PUERTO RICO EROSION AND SEDIMENT CONTROL HANDBOOK FOR DEVELOPING AREAS

Puerto Rico Environmental Quality Board

and

USDA – Natural Resources Conservation Service

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SECTION 1: INTRODUCTION

The Puerto Rico Erosion and Sediment Control Handbook for Developing Areas is intended for use as a technical reference by developers, planners, engineers, government officials, and others involved in land use planning, building site development, and natural resource conservation in rural and urban communities and developing areas.

The handbook is not intended to be a comprehensive site planning and practice design manual because there are many good existing handbooks and references.

The standards and associated materials describe best management practices (BMPs) for controlling nonpoint source pollution impacts that affect ecosystems in existing communities and developing areas. Agricultural activities are not included. Includes an array of BMPs to accomplish three basic elements to prevent the sedimentation. These are: soil stabilization, runoff control, and erosion control.

This handbook was prepared by the United States Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS), Caribbean Area. Initially released in 2004, the handbook is being revised by a committee composed of NRCS, Puerto Rico Environmental Quality Board, Environmental Protection Agency (CEPD), Puerto Rico Planning Board, “Asociación de Contratistas,” and the College of Engineers and Surveyors.

This handbook sets no policy, rules, regulations or restrictions. However, it is anticipated that various units of government and local, state, or federal agencies would use these technical materials to guide development of policy, ordinances, restrictions, or regulations. If adopted by reference in a regulatory program, such as in Soil Erosion and Sediment Control Regulations adopted by a local jurisdiction, the contents of the handbook will have the force of law.

No individual section of this handbook will contain all the guidance or material necessary to fully assist users to develop or implement site specific plans. Other references or sections of other manuals or handbooks that supplement this publication should be utilized as appropriate.

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SECTION 2: PLANNING PRINCIPLES FOR EROSION AND SEDIMENT CONTROL

2.1 Introduction

This handbook describes BMPs to accomplish three basic elements of erosion and sediment control. These are soil stabilization, runoff control, and sediment control.

The most important and most often neglected task is to provide effective soil stabilization throughout the duration of a construction project. Soil stabilization is based on a simple premise: If water cannot detach the soil, it cannot be transported (i.e., erosion does not occur). The easiest, most economical, and environmentally sound way to prevent detachment is by keeping a good vegetative cover in place. It can also be accomplished by other techniques such as mulching or use of erosion blankets.

Runoff control measures are needed to deal with concentrated runoff. Concentrated runoff is a common occurrence on large sites containing existing drainage ways and is made more severe by grading activities that remove water absorbent topsoil and compact underlying soils. If concentrated runoff occurs, it will further erode the soil and carry it into streams, lakes, or road ditches. The basic principles behind runoff control measures are to provide stabilized channels for runoff water and to divert concentrated runoff from exposed, erodible soils. Once the soil is detached, flowing water transports the soil to downslope positions.

Sediment control measures are needed to filter, trap, or otherwise remove eroded sediment before they can leave the construction site. In implementing the erosion and sediment control BMPs described in this handbook, it is important to understand them in the context of an overall construction site plan.

The purpose of erosion control and sediment prevention planning is to clearly establish the control measures, which are intended to prevent erosion and offsite sedimentation during construction. The Erosion Control and Sediment Prevention Plan (ECSPP) serves as a blueprint for the location, installation, and maintenance of practices to control erosion and prevent sediment from leaving the site during construction. It should also be understood that plans are only a blueprint and will require modification throughout the life of the project.

2.2 Erosion Prevention

The driving consideration in creating and implementing an effective Erosion Control and Sediment Prevention Plan (ECSPP) is to provide erosion prevention measures rather than sediment control. Although every ECSPP will have elements of both, it is often far more cost effective and practical to emphasize erosion prevention. Erosion prevention measures are designed to prevent exposed soil particles from becoming dislodged by rain or wind. Such measures include temporary ground covers (mulch, temporary seeding, straw mulch, etc.), matting, and numerous other products designed to provide mechanical or physical protection to exposed soil. Sediment control involves techniques to re-capture transported sediment from runoff. Sediment control measures include sediment traps and basins, sediment fences, and sediment barriers among others.

The benefit of erosion prevention is that it seeks to prevent the problem before it starts. It is also often impractical to recover large amounts of sediment after it becomes dislodged and suspended in runoff. On projects where the predominant soil particle size is very small (fine silts and clays), the amount of time required to allow for settling of solids can reach days or even weeks. It is also generally true that erosion prevention measures are more reliable, whereas sediment control measures require continual and costly maintenance. Because successful erosion control requires minimizing disturbed areas, the ECSPP should emphasize scheduling and phasing. Project scheduling and phasing is often driven by factors other than erosion control, therefore, contingency planning is essential. Most importantly, the ECSPP should be designed and implemented as a living, dynamic plan that can be adapted to address changes in the project as work progresses.

2.3 Basic Rules

Erosion control measures are required for construction areas where the ground surface will be disturbed by clearing, demolition, storage, grading, fills, excavations and other construction and related activities. When developing an effective ECSPP, there are several important concepts to consider:

Timing - schedule work to minimize overall impacts

Stage work - identify and process critical areas first

Minimize disturbance - create buffers and reduce mass grading

Pre-construction - during preliminary design and prior onsite grading activities

Pictures/Video - documentation throughout life of project

The long-term benefits of an effective erosion control and sediment prevention plan are enormous. There is less chance of soil washing off the site and clogging streets, drainage systems, and entering adjacent properties. The number and size of erosion control measures required will be minimized. The cost of maintaining erosion control facilities is minimized. As much top soil as possible is retained on the site making revegetation and landscaping easier to establish.

It is equally important to note that approval of an erosion control and sediment prevention plan by the local jurisdiction does not relieve the applicant's responsibility to ensure that erosion control measures are constructed and maintained to prevent sediment from leaving the construction site. These requirements are upheld throughout the life of the construction site.

2.4 Responsibilities

A qualified designer, as defined in the existing regulation ("Reglamento para el Control de la Erosión y Prevención de la Sedimentación"), prepares the Erosion Control and Sediment Prevention Plan based upon information provided from resources obtained from local and regional agencies, and **a detailed field site visit**. The designer must identify potential erosion and sediment problems, develop design objectives, formulate and evaluate alternatives, select best erosion prevention measures, and develop a plan. A determination is made about what best management practices are appropriate. A variety of BMPs should be included on the plan in order to provide adequate tools in the field.

The designated person, whether contractor or owner has a defined responsibility to prevent pollution from leaving the site. The person must follow a plan and insure that the site is stable. Even though the ECSPP may be followed in detail and appear to have addressed all issues, there will inevitably be obstacles along the way that will change those plans. Therefore, the best scenario includes a good plan, open lines of communication, and defined responsibilities.

2.5 Elements of the Erosion Control and Sediment Prevention Plan

The Erosion Control and Sediment Prevention Plan submitted to the Environmental Quality Board with the project application should contain all the pertinent information for review and implementation. The following elements should be present and are required:

<u>Narrative</u>

The narrative is a brief description of the overall strategy for erosion and sediment control. It should summarize the aspects of the project that are important for erosion control and should include but is not limited to:

> A brief description of the proposed land-disturbing activities, existing site conditions, and adjacent areas (such as creeks and buildings) that might be affected by the land disturbance.

A description of critical areas on the site - areas that have potential for serious erosion problems such as severe grades, highly erodible soils, and areas near wetlands or water bodies.

A work schedule that includes the date grading will begin and the expected date of stabilization.

A brief description of the measures that will be used to minimize erosion and control sediment on the site, when they will be installed, and where they will be located.

A maintenance program; including frequency of inspection, provisions for repair of damaged structures, and routine maintenance of erosion and sediment control practices.

Map/Site plan

The map is the key item in an Erosion Control and Sediment Prevention Plan. It should show at least:

Existing and final elevation contours at an interval and scale sufficient for distinguishing runoff patterns before and after disturbance.

Critical areas within or near the project area, such as streams, lakes, wetlands, highly erodible soils, public streets, and residences.

Existing vegetation.

Limits of clearing and grading.

Locations and names of erosion and sediment control measures, with dimensions.

It is strongly recommended that standard symbols be used on the map to denote erosion and sediment control measures. Use of standardized symbols will speed up plan review time and make it easier for site contractors and inspectors to understand plans quickly.

Construction Details, Specifications, and Notes

Construction details, often in large-scale, detailed drawings, provide key dimensions and spatial information that will not fit on the map. Other important information should also be provided; examples are seeding and mulching specifications; equivalent opening size and strength requirements for filter fabric; specifications for wire mesh, fence posts, and staples; installation procedures for control measures; and maintenance instructions.

Calculations

Include the calculations used to size the control measures, particularly the data for the design storm (recurrence interval, duration and magnitude, and peak intensity for the time of concentration), and the design assumptions for sediment basins and traps (design particle size, trap efficiency, discharge rate, and dewatering time). Also include calculations to support the sizing of storm drain systems when an engineering design was necessary.

2.6 Preparing an Erosion Control and Sediment Prevention Plan

Step 1: Collect Data

The purpose of data collection is to gather the information onsite conditions that will enable you to develop an effective Erosion Control and Sediment Prevention Plan. Most of this data describes the natural environment of the site. Drainage information is particularly important (see Step 2).

It is best to collect all data in map form, if possible, and to plot it on one or more site maps at the same scale. Mapping the data at the same scale greatly facilitates the planning process by enabling you to overlay different maps and read through them on a light table.

- Topography

A good topographic map should form the basis of any kind of land planning, including site development planning and erosion control and sediment prevention planning. From a topographic base map, you can determine drainage patterns, slope lengths and angles, and locations of sensitive features on or adjacent to the site such as water bodies, buildings, and streets. All of these are critical concerns in erosion control.

Prepare a topographic map of the site which shows the existing contours at a suitable interval for determining drainage patterns over small areas. The contour lines must be close enough together to show which way water will flow. On relatively flat sites, a 2-ft (0.6-m) or smaller interval will probably be needed. On a sloping site, a 10-ft (3-m) interval may be acceptable.

- Drainage

The drainage pattern of a site has two components: overland flow and channel flow. Both are important in erosion control. In the data collection stage, it is helpful to clearly mark all existing streams and major conveyances on the topographic base map. Major watercourses are shown as blue lines on U.S. Geological Survey topographic maps, but lesser drainage ways will also be important to show. Delineating drainage ways now will make it easier to determine watershed boundaries in the data analysis stage (Step 2).

- Rainfall

In erosion control, rainfall data is primarily used for sizing large conveyances and sediment basins. Rainfall frequency and intensity are the key types of data. Rainfall intensity determines the ***i*** value used in runoff calculations. Rainfall intensity is also a component of the R factor in the universal soil loss equation. This equation can be used to estimate the sediment storage requirements of sediment basins. Rainfall frequency data is used for determining "a design storm."

On small sites and in small drainage areas it is often unnecessary to size control measures by using rainfall data. Most of the control measures described in this handbook have been designed to handle a major storm in a small drainage area (typically 1 to 5 acres). Since a fairly large margin of error has been incorporated in the standard designs, these structures, if used properly in small watersheds within the specified size limits, should be able to withstand major storms anywhere in Puerto Rico

Project planners should use their knowledge of the yearly pattern of rainfall to schedule construction during the times of year when erosion potential is lowest. In Puerto Rico the high raining season occurs during May and from August to November. Special attention to BMP installation and maintenance must be made when grading or construction must take place during periods of high erosion hazard. Rainfall data can be obtained from the National Weather Service, http://www.srh.noaa.gov/sju/.

- Soils

Soils data is used to locate highly erodible areas on a site, where extra erosion control precautions may be needed. It also shows the distribution of particle sizes in the soil, a critical factor in sizing sediment basins and traps. A high content of clay and fine silt in a soil should suggest a strategy of erosion control by using vegetation and mulch rather than a strategy of sediment control by using straw bales and sediment basins. Soils data can be obtained from soil surveys published by the U.S. Natural Resources Conservation Service (NRCS) at http://www.pr.nrcs.usda.gov and the Soil Survey Geographic (SSURGO) Database at http://www.soils.usda.gov. Appendix A includes the soils information such as the Puerto Rico Major Land Resources Areas (A.1), the Highly Erodible Soils List (A.2), Hydric Soils (A.3), and Hydrologic Soils List (A.4) for Puerto Rico. Also in web site http://www.soils.usda.gov you will find the Official Soil Series Description (OSD).

- Ground Cover

Ground cover primarily refers to existing vegetation, which should be preserved to the greatest extent possible because it is the most effective form of erosion prevention. Many communities also wish to preserve trees and certain vegetation for aesthetic and other reasons. Ground cover, along with other physical characteristics of the watershed, is used to determine the C factor in the rational method for calculating runoff (Section 6). It is also used to calculate the erosion rate in the universal soil loss equation.

- Adjacent Areas

Offsite features, such as streams, lakes, wetlands, buildings, and roads, are particularly sensitive to erosion and sediment damage. Such areas should therefore be noted on the site map. If including the offsite features on the same map would result in an unwieldy document, one of the following options can be chosen:

Describe on the margin of the map the nature and location of the adjacent feature.

Draw a smaller-scale map (vicinity map) showing the site and all the pertinent adjacent features.

Step 2: Analyze Data

The purpose of this step is to interpret the data collected in Step 1 for its significance in erosion and sediment control. This interpretation may require stating the data in a different form (e.g., translating a topographic map into a slope map). The result of this step is a map that highlights areas of importance in erosion and sediment control.

- Drainage Areas

The most important part of Step 2 is to understand the site's surface water flow pattern. You must determine:

Where will concentrated and sheet flows enter the site?

How will runoff, both concentrated and sheet flow, travel across the site?

Where will runoff leave the site and will it be concentrated or sheet flow?

How much water will flow?

Map the drainage boundaries of each of the water courses delineated in Step 1, and then estimate the area of each major watershed. If the site is larger than 5 acres, you may have to subdivide the watershed into smaller units. Bear in mind that many control measures discussed in this handbook have a 5-acre maximum drainage area and that straw bale, silt fences, and most inlet protection structures have a 1-acre limit. Define watersheds that are appropriate for the control measures to be used. If grading will alter natural watershed boundaries, you will later need to map the drainage boundaries that will exist after grading is completed (see Step 4). If grading will not be completed before the rainy season, you may have to have several interim drainage plans.

- Rainfall and Runoff

Examine the rainfall data collected in Step 1 to determine the times of year when erosion potential is at its lowest and highest. Try to schedule grading during times of low erosion potential and take extra precautions during times when heavy, intense rainfalls are likely.

If a project will require permanent waterways and sediment basins draining large areas, rainfall frequency and intensity data will be used to calculate runoff volumes to be expected. Since these calculations must be based on specific watershed areas that drain to each planned facility, the calculations must be done at a later stage of plan development (see Step 4).

- Slope Steepness and Slope Length

Slope steepness and slope length are critical factors in erosion control. The longer and steeper the slope, the greater the erosion potential. If an existing long or steep slope is disturbed or a new one is created by grading, carefully designed and installed erosion control measures will be required. These measures may include ditches at regular intervals, temporary vegetative stabilization, or stabilization using a covering of punched straw or other mulch material.

Erosion potential is closely related to slope steepness. The following slope categories can be used as a rough guide for evaluating erosion potential:

0-7 percent slope	Low to moderate potential
7-15 percent slope	Moderate to high potential
Over 15 percent slope	High to very high potential

It is a good idea to outline on the topographic base map the above slope categories. Slopes that are over 15 percent and 7 to 15 percent slopes that are very long [over 100 ft (30 m)] should be highlighted as critical.

- Soils

The Highly Erodible List (HEL) in Appendix A.2 indicates soil erodibility. The K factor is an estimate of soil erodibility. Highly erodible soils should be left undisturbed. If they must be disturbed, they should be mulched and revegetated as soon as possible after grading is completed.

- Ground Cover

Note any areas of critical vegetation. Vegetation on or above long or steep slopes and on highly erodible soils is particularly important for erosion control.

- Adjacent Areas

Examine areas downslope from the project. Note any watercourses or other sensitive features which receive runoff from the site. Analyze the potential for sediment pollution of these watercourses and the potential for downstream channel erosion due to increased volume, velocity, and peak flow of storm runoff from the site.

<u>Step 3: Develop Site Plan</u>

When a site plan is developed, erosion and sediment control should be considered along with such traditional planning criteria as economics, utility access, and traffic patterns. After analyzing the erosion hazards onsite in Step 2, develop a site plan with erosion control in mind. Consider the following points when preparing a site plan.

- Fit Development to the Terrain

Tailor the locations of building pads and roads to the existing contours of the land as much as possible. Locate them to take advantage of the natural strengths of the site and to minimize disturbance.

- Restrict Construction Activities to the Least Critical Areas

Land disturbance in critically erodible areas, such as steep slopes, will require installation of costly control measures. Keeping construction out of these areas will minimize the costs.

- Cluster Buildings Together

Clustering buildings minimizes land disturbance for roads and utilities and reduces erodible area. Other benefits of clustering are reduced runoff, preservation of open space, and reduced development costs.

- Minimize Impervious Areas

Make paved areas, such as streets, driveways, and parking lots, as small as possible. Preserve trees, grass, and other natural vegetation. Consider paving driveways with gravel or porous paving stones.

- Retain the Natural Storm Water System

Use the natural storm water system to convey runoff from the site wherever possible. If possible, augment the natural system with vegetated swales rather than storm sewers or concrete channels. If impervious surfaces are kept to a minimum and runoff from these surfaces is percolated into the soils onsite, it may be possible, without installing channel protection measures, to use the natural storm water system to drain a development. The cost of using the natural drainage system can be substantially lower than the cost of constructing a conventional storm drain system. Preserving the natural storm water system can also retain a visual amenity that will enhance the value of a development.

If runoff flows will be increased by development, route these augmented flows into a storm water conveyance system and preserve the natural storm water system in its preexisting condition. If the stability of the natural system is upset, it may be very difficult to prevent a long term erosion process from beginning. A constructed storm water conveyance system can be designed to resemble a natural creek.

Step 4: Develop the Erosion Control and Sediment Prevention Plan

- Determine Limits of Clearing and Grading

Start with a topographic base map that shows existing and finished contours and proposed improvements. On this base map, delineate the limits of the disturbed area. This line defines the area that must be protected.

- Reexamine Drainage Areas

Check to see if the drainage boundaries defined in Step 2 have been altered by the development plan. If so, outline the drainage areas that will exist after grading. Since many control measures have a 1-acre or a 5-acre drainage area limit, you may want to break large watersheds into smaller units. Enlarged drainage areas and/or increased impervious surface within a drainage area will produce increased flows. Discharging the increased flows to existing swales and watercourses will cause channel erosion, unless the conveyances are adequately prepared.

As was done in Step 2, determine where concentrated flows will originate on and offsite, how runoff will cross the site, and where runoff will leave the site. Check for and avoid unnaturally concentrated flows in natural swales created by pipes, ditches, berms, etc.

- Apply the Principles of Erosion and Sediment Control

1) Fit development to the terrain.

   This principle is applied in the site development process (see Step 3).

2) Time grading and construction to minimize soil exposure.

   Schedule the project so that grading is done during a time of low erosion potential. On large projects, stage the construction, if possible, so that one area can be stabilized before another is disturbed.

3) Retain existing vegetation wherever possible.

When laying out site improvements, try to site buildings between existing tree clusters and build roads around trees. Route construction traffic to avoid existing or newly planted vegetation. Avoid unnecessary clearing of vegetation around building pads, where construction will not be taking place. Also avoid disturbing vegetation on steep slopes or in other critical areas. Physically mark off the limits of land disturbance on the site with rope, fencing, surveyors' flags, or signs so that workers can clearly see areas to be protected. A bulldozer operator will probably not know to protect a clump of trees that is only noted on a set of plans.

4) Vegetate and mulch denuded areas.

Reestablish vegetation on all denuded areas that will not be covered with buildings or pavement. If graded areas are to be paved or built upon at a later date they must be stabilized temporarily by mulching or establishing a temporary vegetative cover on those areas. It is often cheaper to establish and remove a temporary cover on such an area than to repair the gullying and sediment damage that is likely to occur. Before seeding an area, make sure necessary storm water controls are installed (see the following subsection). Plant establishment will be more successful if graded slopes are roughened or scarified before seeding.

5) Divert runoff away from denuded areas.

Determine how runoff should be conveyed from the top to bottom of each drainage area. Is a diversion or a slope drain required? If so, locate it where it can intercept potentially erosive flows and route them to a well protected outlet such as a storm drain or a lined channel. Do not allow runoff to cross a denuded or newly seeded slope or other critical areas. All conveyances and systems should be fully stabilized before allowing flows into them. If there is a significant drainage area above a cut or fill slope construct a diversion and slope drain at the top of the slope to convey the water to the bottom without causing erosion. Diversions and conveyances also can be used at the base of a disturbed slope to protect downstream areas by diverting sediment-laden runoff to a sediment trap or basin. It is often good strategy to construct a diversion or swale all the way around a disturbed area to prevent clean runoff from entering the area and also to prevent silt-laden runoff from escaping before being desilted.

6) Minimize length and steepness of slopes.

On long or steep disturbed or constructed slopes construct benches, diversions, or swales at regular intervals to intercept runoff. Each bench should be tilted at a gentle grade into the hill to channel the flow along the inner edge of the bench. Route the intercepted runoff to a protected outlet.

7) Keep runoff velocities low.

Keep runoff velocities low by minimizing flow path lengths, constructing channels with gentle gradients, lining channels with rough surfaces, and using check dams in channels.

8) Prepare conveyances and outlets to handle concentrated or increased flows.

Design storm water conveyance channels to withstand the expected flow volume and velocity from a design storm. Compute the expected discharge and velocity for both existing and newly constructed swales and for on and offsite channels which will carry increased flow as a result of the project. By using these calculations, determine whether any drainage channels will require protection. If the computations indicate the runoff flow will be erosive, first determine whether a vegetative lining will be sufficient. If the expected velocity exceeds the limit for grasses, choose between rock, asphalt, or concrete linings. Remember, grass and rock linings are desirable because they keep velocities low, allow runoff to percolate into the soil, and are aesthetically pleasing. Because they resemble natural conveyances, they can enhance the appearance of a development.

Also determine whether outlet protection will be needed. Pay particular attention to transitions from pipes or paved channels to natural or unlined channels. Locate riprap aprons or other energy-dissipating devices at discharge points where erosion is likely.

9) Trap sediment onsite.

Install sediment basins or traps, silt fences, or straw bale barriers below denuded areas so that runoff will be detained long enough for suspended sediment to settle out. Try to locate sediment barriers in relatively level areas or in natural depressions. A flat area at the base of a slope is a good location for a silt fence or straw bale barriers because the runoff can slow down before reaching the barrier and the sediment has a place to settle. Avoid placing sediment barriers where their construction would cause excessive soil disturbance. For example, excavating a sediment trap on a hillside is likely to cause more soil erosion and sedimentation than the device was intended to prevent. Also, locate sediment barriers above sensitive areas such as streams, lakes, public streets, and adjacent properties.

Make sure there will be adequate access in wet weather for maintenance and sediment removal.

Individual lots can be surrounded by dikes to create small sediment traps called lot ponds. Gravel- or fabric-covered driveway aprons can serve as the outlets. If standing water on lots will interfere with construction activities, this type of sediment control should not be used. However, lots are often graded but are not built upon for months or even years. In these situations, lot ponding may be a good approach. It should be realized, however, that lot ponding may necessitate re-compaction of pads prior to building construction. Consult the soils report for the soils engineering recommendation on this issue.

The size of the drainage area determines which type of sediment barrier should be used. Straw bale barriers and silt fences have 1 acre drainage area limit. A sediment trap is generally adequate in drainage areas of less than 5 acres. A sediment basin is needed if the drainage area exceeds 5 acres. Unless the basin is designed as a permanent pond, its maximum drainage area should be less than 100 acres. Drainage areas larger than 100 acres can be subdivided into smaller subcatchments by creating barriers to trap runoff in stages, perhaps in a group of basins. Basins must drain in parallel, not in series. When a watershed is subdivided into smaller drainage areas, each with its own sediment basin, the degree of risk is likely to be substantially lower. That is, the damage which could be caused by the failure of a small basin in a small watershed is minor compared to the damage potential of the failure of a large basin in a large watershed.

Dividing a watershed into smaller drainage areas also can save money. Sediment basins are more costly than simple sediment traps to construct. In addition, sediment basins require an engineering design, whereas sediment traps are typically based on standard designs.

Sediment basins and traps are commonly located below large disturbed areas, at the lowest point in a watershed, and in swales and small conveyances. Do not locate a sediment basin in a major stream, such as one designated with a blue line on a U.S. Geological Survey topographic map or in a wetland. It is unnecessary, costly, and dangerous to impound runoff from large, undisturbed areas. Trap the sediment-laden runoff before it enters a stream.

10) Inspect and maintain control measures.

Develop a maintenance schedule and instructions for maintaining control measures. The instructions should specify where sediment dredge spoils should be placed, what spare materials (such as extra filter fabric, straw bales, stakes, and gravel) are needed, and where they should be stockpiled.

It is the responsibility of the contractor to make sure that all workers understand the major provisions of the Erosion Control and Sediment Prevention Plan. If they understand the plan, they are less likely to disturb drainage patterns and control measures, as by running over a dike with a truck. A routine end-of-day maintenance check is strongly advised, while inspections are required after any storm with a half inch or more of rainfall.

In particular, the contractor should look for breaches in dikes and for erosion or sedimentation near wetlands, water bodies, discharge points, or roads. All maintenance procedures and the maintenance schedule should be specified on the plans. The plans should also remind the contractor of his or her responsibility to inform construction site workers about the erosion and sediment control features on the site.

2.7 Evaluating an Erosion Control and Sediment Prevention Plan

The following section is written from the perspective of the Environmental Quality Board plan reviewer. It describes what to look for when evaluating an Erosion Control and Sediment Prevention Plan. A checklist is helpful, however, over reliance on checklists can give a false feeling of completeness. See checklist example in Section 2.9.

Responsibility

It is not the responsibility of the plan reviewer to see that the plan is the best possible one. The reviewer can only ensure that the plan meets the minimum standards set by the reviewing agency and its authorizing regulations.

Communications

Encourage informal communications between the plan reviewer and the plan preparer. This will enable the reviewer to make informal suggestions that may save the developer money and the preparer time, and it may result in a better, more effective plan. It will also enable the preparer to explain and justify the plan. Pre-application conferences are strongly encouraged.

Required Information

Make sure all the required information has been submitted. Checklists can be used by both plan reviewers and plan preparers. However, checklists can encourage laziness. Having everything checked off does not necessarily mean that everything is in order.

Incomplete Plans

Do not review seriously incomplete plans. Send them back with a request for the missing information.

First Review

The first review should be a complete review. In subsequent reviews, deal only with items identified in the first review. It is unfair to the developer to keep injecting new requirements in subsequent reviews.

Plan Concept

The concept should be examined first, starting with the general and moving to the specific. Does the plan make sense?

Schedule

Examine the construction schedule. Will grading be completed before the rainy season? When will storm water management facilities, paving, and utilities be installed in reference to the rainy season? If grading will take place during months when there is a high probability of heavy rains, what extra precautions will be taken to protect against erosion, sedimentation, and changing drainage patterns?

Site Storm Water

Make sure you understand where all runoff, including roof-top runoff, comes from on and above the site, where it goes, and how it traverses the site. For large sites, require or prepare a drainage area map. If runoff patterns are unclear, ask for clarification.

Sediment Basins and Traps

Locate all sediment basins and traps, and define their contributing areas.

Erosion Control

Check the method used to prevent erosion. Hydraulic seeding and mulching may adequately stabilize some areas, but other areas, because of their proximity to sensitive features such as watercourses or their steepness or lack of backup protection such as sediment basins, may need far more intensive revegetation efforts. On critical slopes, a reliable backup system for hydraulic seeding, such as punched straw, is strongly recommended. Even better, these areas should be sodded.

Channels and Outlets

Examine all conveyances where concentrated flows will occur. Be sure adequate erosion protection is provided both along channels and at channel and pipe outlets. Check the sources of runoff to be sure that all the runoff comes from undisturbed or stabilized areas or has been desilted by sediment basins or other sediment retention devices.

Miscellaneous

Look for haul roads, stockpile areas, and borrow areas. They are often overlooked and can have a substantial effect on drainage patterns. Look at all points of vehicle access to the site and be sure mud and dirt will not be tracked onto paved streets and that sediment-laden runoff will not escape from the site at these points. Pay particular attention to watercourses and their protection.

Plan Details

Once the plan concept has been shown to be sound, check the details to be sure the concept is adequately executed in the plans.

Structural Details

Be sure that sufficiently detailed drawings of each structure (sediment basin, dike, swale, silt fence, etc.) are included so there is no doubt about locations, dimensions, or method of construction.

Calculations

See if calculations have been submitted to support the capacity and structural integrity of all structures. Were the calculations made correctly?

Vegetation

Look at seed, fertilizer, and mulch specifications. Check quantities and methods of application to be sure they are appropriate and consistent with local guidelines.

Maintenance

Be sure that general maintenance requirements and specific maintenance criteria, such as the frequency of sediment basin cleaning, are included. Are there stockpiles of spare materials (filter fabric, straw bales, stakes, gravel, etc.) to repair damaged control measures? Routine maintenance inspections should be part of the plans.

Contingencies

The plan must provide for unforeseen field conditions, scheduling delays, and other situations that may affect the assumed conditions.

Technical Review

The Erosion Control and Sediment Prevention Plan should be reviewed by the soils or geotechnical consultant for the project, if there is one.

Signature

They should be signed by a qualified design professional.

2.8 Implementing the Plan

Installation of an Erosion Control and Sediment Prevention Plan will be discussed from the standpoint of the contractor.

Study the plan and the site.

The contractor must be thoroughly familiar with both the Erosion Control and Sediment Prevention Plan and the construction site. Note all of the critical areas indicated in the plan and then actually identify their location and extent on the ground. These should include stream channels and associated flood plain areas, drainage ways, and outlets into streams, points where land-disturbing activities are adjacent to or must cross streams and drainage ways, steep slopes and highly erodible soils, and runoff entering the site from adjacent areas. Note what practices are specified to protect these areas. Also, be aware of critical areas not specifically treated in the plan; and discuss these with the inspector at the pre-construction conference.

Determine the locations of all control measures and determine their "fit" on the land. Note any needed adjustments, and plan to discuss these at the pre-construction conference.

Check the schedule for the installation of erosion control and sediment prevention practices, the schedule for all earth-disturbing activities, and the relationship between the sequence and timing of BMP installation and the earth-disturbing activities. The timing and sequence of installation are important elements of an Erosion Control and Sediment Prevention Plan. The site must be ready for rain before the earth-disturbing activities are started. For this reason, certain practices must be in place and ready to provide protection before other areas are exposed. The staging of major earth-disturbing activities to limit the size of bare area exposed at any time is another important element of the plan which should be noted. Section 3.3 presents more details regarding construction sequence.

The pre-construction conference.

The next step is a pre-construction conference and site review with the erosion and sediment control inspector. It should be called for by the contractor and should be held on the construction site. The conference may also include the design professional, the owner, and inspectors from other agencies. The site review will help all parties in meeting their responsibilities. All aspects of the plan should be discussed to ensure that the contractor and the inspector are in agreement in interpreting the plan, scheduling, procedures, and practices which are to be used. They should agree particularly on the critical problem areas and on the perimeter practices specified to prevent damage to adjacent properties.

The location of all measures should be discussed. If the study of the plan indicates that adjustments in location are needed; these should be discussed with the permitting agency and the inspector. The inspector may authorize minor adjustments such as moving a diversion from a property line to a grading limit, or shifting an outlet to match a natural depression in the land. Major adjustments will require formal revision of the plan and should be approved by the permitting agency.

The sequence of installation of practices and earth-disturbing activities should also be discussed. The guidelines for erosion and sediment control planning require that sediment basins and other appropriate erosion and sediment control measures be installed prior to or as a first phase of land grading. Other appropriate measures include construction entrances, diversion dikes, interceptor dikes, perimeter dikes, gravel outlet structures, level spreaders, swales, protected outlets, and grade stabilization structures. The contractor and the inspector must be firm about establishment of these practices before grading begins.

Site preparation.

One of the first things to do in preparing the site is to lay out all traffic circulation routes and storage areas. Route locations should be chosen to pose the least threat to the critical areas which have been identified. Well-vegetated areas should be damaged as little as possible. Soil stockpiles should be located a safe distance from waterways and streams. Barriers may be required to keep traffic within the delineated areas or at least out of the critical areas. If needed, barriers should be installed before opening the site to general construction traffic. Required sediment trapping practices should be installed. Note that compacting, seeding, and mulching are required to stabilize these practices. Next, waterways and outlets should be installed with the vegetation or lining material called for in the plan. The work force should be instructed about the location of critical areas and sediment control practices and the need to protect these areas from damage.

Inspection and maintenance of erosion control measures.

Maintenance differs from the other activities. It must begin as soon as the first practice is installed and must continue through all the succeeding activities until the permanent erosion control measures are established and functioning. The features of a maintenance program are described in the narrative part of the plan. All structural measures should be checked at the end of each work day and, particularly, at the end of the work week. Also, they must be checked before and after each rainstorm of one quarter inch or more. Diversion berms should be checked to see that they have not been breached by equipment. The condition of level spreader areas, waterways, and other outlets should also be checked. Traffic should be moving within the established access routes. Channels should be checked for sediment deposits or other impeding material. Repairs should be made promptly when damages are discovered. When repairing swales or other channels, the new lining material should be at least as erosion resistant as the original material. Vegetative practices and vegetative cover on structural practices require maintenance fertilizer and, perhaps, mowing. All sediment traps should be checked and cleaned out after each storm. Sediment basins should be cleaned out when the deposited material reaches the level designated in the plan or standards and specifications.

Grading and utility construction.

If stockpiling of fill or topsoil is planned, a pre-selected, relatively safe stockpile area should be used. To minimize the hazard of erosion, the slopes of the stockpile should be flattened at the end of each working period. The stockpile should be mulched and seeded as soon as it is completed.

Disturbed areas which can be brought to final grade at this stage during a satisfactory season for seeding should be seeded, sodded, or otherwise stabilized with the permanent material and techniques indicated in the plan. If they cannot be seeded, they should be stabilized with anchored mulch. Areas, which are to remain at rough grade for more than 14 days before permanent stabilization, must be mulched and seeded with temporary cover immediately following rough grading.

Utilities such as storm sewers, sanitary sewers, electrical conduits, water mains, and gas mains are usually installed at this time. To minimize the amount of area disturbed, the work should be organized and the trenches sized to take several utilities in one trench. The installation should be carefully coordinated to reduce the time that the trenches must stay open. Excavated materials should be placed on the side of the trench away from streams and conveyances. If sediment-laden water must be pumped from utility trenches, it should be conveyed safely to a sediment trap or basin. As soon as possible, trenches should be filled, compacted, mulched, and seeded to temporary or permanent vegetation.

As soon as the storm sewers are installed, inlet sediment traps should be installed to prevent sediment from entering the system. If called for, storm drain outlet protection should be installed.

Building construction.

Two major hazards are common during this step. The first major hazard is that additional equipment and work force bring added risks to areas which should be protected. Efforts to control traffic must be increased during this period. All types of traffic should be made to stay on the established travel routes.

The second major hazard is from the excavated material. This phase usually results in high volumes of soil for disposal and stockpiling. Stockpiles should be located where they will not wash into drainage ways or onto previously stabilized areas. The slopes on these areas should be flattened and they should be protected by anchored mulch and temporary seeding. Excavations should be backfilled as soon as possible, and appropriate surface protection should be provided.

Runoff from rooftops should be directed to stabilize areas upon completion of the structure. Whenever possible the runoff should be treated or infiltrated in swales or retention facilities. Rooftop runoff should never be tied into sanitary sewers.

Permanent stabilization.

As mentioned earlier, this need not and should not be delayed until the entire development is completed. A significant reduction in erosion damage repair costs and regrading costs can be made if smaller areas are stabilized with permanent vegetation as soon as they are ready.

Most sediment basins, dikes, sediment traps, and other control structures should be removed, regraded, mulched, and seeded before leaving the site. However, the inspector should be consulted before removing them - they should not be removed until the surrounding area is stabilized and they are no longer needed.

In some cases, sediment basins, diversions, and swales are to remain as part of the permanent runoff management system. In such cases, sediment basins should be cleaned out to provide the required capacity and stabilized with suitable permanent vegetation. Diversions and swales should be checked, repaired if needed, and left in good condition.

When final grading is completed, all bare areas should be stabilized with permanent vegetation. The standards and specifications for permanent vegetative practices are in Section 3.4 of this handbook.

2.9 Checklist - Example

The checklist is an excellent tool for organizing yourself for an inspection or plan review.

> Like any other tool, the checklist can and will hurt you if not used properly!
>
> It is only a tool, not a substitute for the human mind.
>
> The checklist can lull you into a false sense of completeness and security.
>
> After using a checklist, ask yourself:
> ☑ Is there anything else?
> ☑ Is there anything which is not covered in the checklist?
>
> Periodically examine your checklists to make sure that they cover the issues which you encounter and that they stay current with any changing regulations or other conditions.

PLAN FOR EROSION CONTROL AND SEDIMENT PREVENTION CHECKLIST

DESIGNER: ________________________ PHONE #:_____________

PROJECT: ____

REVIEW DATE: _______________________

LOCATION INFORMATION

____ Vicinity Map
  a. Project location
  b. Roads, streets
  c. North arrow

____ Legend, scale, north arrow for plan view
____ Property lines
____ Existing contours
____ Proposed contours
____ Limit and acreage of disturbed area
____ Planned existing buildings location and elevations
____ Planned and existing roads location and elevation
____ Lot and/or building numbers
____ Land use of surrounding areas
____ Rock outcrops
____ Seeps or springs
____ Wetland limits
____ Easements
____ Streams, lakes, ponds, drainage ways, dams
____ Stockpiled topsoil or subsoil location
____ Street profiles
____ Boundaries of the total tract
____ Sequence operation

SITE DRAINAGE FEATURES

____ Existing and planned drainage patterns (include offsite areas that drain through project).
____ Size of area (acreage).
____ Size and location of culverts and sewers.
____ Soils information (type, special characteristics).
____ Design calculation and construction details for culverts and storm sewers.
____ Design calculations cross sections, and method of stabilization of existing and planned channels (include temporary linings).
____ Design calculations for peak discharges of runoff (including the construction phase and final runoff coefficients of the site).
____ Name of receiving watercourse or name of municipal operator (only where storm water discharges are to occur).

____ Design calculations and construction details of energy dissipaters below culverts and storm sewer outlets (for riprap aprons, include stone sizes and apron dimensions).
____ Design calculations and construction details to control groundwater, i.e. seeps, high water table, etc.

EROSION CONTROL MEASURES

____ Legend
____ Location of temporary and permanent measures
____ Construction drawings and details for temporary and permanent measure.
____ Design calculations for sediment basins and other measures.
____ Maintenance requirements during construction.
____ Person responsible for maintenance during construction.
____ Maintenance requirements and responsible person(s) of permanent measures.

VEGETATIVE STABILIZATION

____ Areas and acreage to be vegetatively stabilized.
____ Planned vegetation with details of plants, seed, mulch, fertilizer.
____ Specifications for permanent and temporary vegetation.
____ Method of soil preparation.

NOTE: Should include provisions for ground cover on exposed slopes within 30 working days following completion of any phase of grading, permanent ground cover for all disturbed areas within 30 working days or 120 calendar days (whichever is shorter) following completion of construction or development.

WATERSHED PROTECTION

____ Project location
____ Built upon area (include all existing and proposed buildings and other structures. For non-residential developments include location and size of all built-upon areas including parking and loading facilities).
____ Percent of project to be covered with impervious surface.
____ Proposed number of dwelling units.
____ Names of adjoining property owners Legal description of areas storm water control structure (deeded area shall include sufficient area to perform inspection, maintenance, repairs and reconstruction).
____ Impoundment design and calculations as per Standard Specifications.

OTHER INFORMATION

____ Construction sequence related to sedimentation and erosion control (include installation of critical measures prior to initiation of the land-disturbing activity and removal of measures after they have been permanently stabilized.

SECTION 3: EROSION AND SEDIMENT BEST MANAGEMENT PRACTICES

3.1 Introduction

Erosion and sediment control practices can be categorized several ways. The primary practices are those that keep the soil in place and protect it from the erosive forces of precipitation and runoff. The secondary or backup practices are those that attempt to control the sediment that has already been eroded and mobilized from its original location and to keep it from being transported off site. Non-structural practices include management alternatives that can influence soil erosion and sediment control, such as planning, construction sequence and seasonal timing. Another categorization of practices is by type of problem area.

Problem areas for soil erosion and sediment control can be grouped as follows:

Slopes

Receiving waters (streams, lakes, and waterways)

Open drainage ways

Culverts and outfalls

Adjacent private and public properties and facilities (roads, utilities, etc.)

A general description of each problem area and appropriate strategy for erosion control for each follows.

Erosion on slopes takes place when one or more conditions exist. These could be that the slope length is long, the slope is steep, the soil is highly erodible, or that the soil cover (vegetation) has been removed and will take some time to be reestablished.

Slope erosion can occur on cuts, fills, stockpiles, or cleared but ungraded surfaces. Measures applied to these situations could include some combination of: vegetative and structural protective covers (temporary seeding, permanent seeding, groundcover, mulch, sodding, erosion control matting, and topsoiling); water conveyance (temporary or permanent diversions and slope drains); and temporary construction road stabilization.

Receiving waters need to be protected from increased runoff quantities, flow rates, and sediment loads from the construction site. Any increased runoff could lead to increased stream bank erosion and downstream flooding. Measures applied to these situations could include some combination of: basic sediment barriers (straw or hay bale barriers, silt/geotextile fence, brush barrier); water conveyance (outlet protection); sediment detention ponds and basins (temporary sediment trap or sediment basin); and stream and stream bank protection (temporary stream crossing, temporary stream diversion and riprap).

Open drainage ways can become significant sources of sediment if they are improperly designed, constructed, or maintained. These drainage ways need to be designed, constructed, or maintained. These drainage ways need to be designed so that they are not overtopped and do not transport the runoff at velocities that will erode the bottom or sides of the drainage way. Preventive measures applied to these situations could include some combination of: vegetative and structural protective cover (mulch, sodding, and erosion control matting); water conveyance (check dams, inlet protection, and outlet protection); and stream and stream bank protection (riprap).

Culverts and outfalls also need specific measures to ensure that their entrances are not blocked, that they do not become filled with sediment, and that their outlets do not erode down slope or downstream areas. Erosion control measures with application to culverts and outfalls include water conveyance (temporary slope drains, inlet protection, and outlet protection).

Adjacent properties need to be protected from increased quantity and flow of runoff and sediment load. Additionally, slopes within the construction site need to be protected from runoff from adjacent properties. Erosion control measures with application to adjacent properties include some combination of: basic sediment barriers (straw or hay bale barriers, silt fence, and brush barriers); water conveyance (temporary and permanent diversions); and sediment detention ponds and basins (temporary sediment traps and sediment basins).

3.2 Minimum Erosion and Sediment Control Best Management Practices for Construction Sites

Guidelines of minimum requirements that will help keep your site in compliance are provided below.

- Minimize the amount of existing vegetation that you must disturb for construction. Keep out of sensitive areas and their buffers.
- Before construction activities begin adjacent to sensitive areas, more conservative Best Management Practices (BMPs) must be evaluated and installed (e.g. stream banks and shorelines; wetlands and water bodies; forest, Karst areas).
- Perimeter protection to filter sediment for sheet erosion shall be located downslope of all disturbed areas and properly installed prior to upslope grading.
- One hundred linear feet of silt fence per 0.25 acre and the necessary stakes to hold the fence in place shall be stockpiled onsite.
- Stabilized construction entrances will be installed as the first step of clearing and grading.

- Roads and parking areas will be stabilized immediately after the initial grading. Unsurfaced driveway entrances, access roads and parking areas used by construction traffic will be stabilized to minimize erosion and prevent tracking mud.
- The paved areas shall not be cleaned by washing/flushing streets.
- Dirty equipment, especially concrete trucks, **should not** be cleaned in or near waterways.
- Sediment retention facilities will be installed before grading.
- If sediment retention facilities need to be removed for grading, additional ponds/traps/systems to accommodate storage capacity need to be installed onsite. This will be **prior** to removal of existing facility.
- Dust is to be controlled on construction sites.
- Water truck is used to control dust on dirty/grades areas only.
- Water truck will only drop enough water to control the dust or reach the optimum moisture content of the soil for compaction. No runoff is to be generated.

Maintenance requirements

- Erosion and sediment measures will be inspected a minimum of once a week and within 24 hours of significant storms (0.5 inches/24-hour, or where runoff is generated).

- A 24-hour phone number for the Erosion Sediment and Control Designated Inspector will be posted in clearly visible location on the project site.

3.3 Construction Sequence

Following a specified work schedule that coordinates the timing and land disturbing activities and the installation of control measures is perhaps the most cost-effective way of controlling erosion during construction. The removal of ground cover leaves a site vulnerable to accelerated erosion. Construction procedures that limit land clearing provide the timely installation of erosion control and sedimentation controls, and restore protective cover quickly can significantly reduce the erosion potential of a site.

Construction projects should be sequenced to reduce the amount and duration of soil exposure to erosion by wind, rain, runoff, and vehicle tracking. The con-struction schedule is an orderly listing of all major land disturbing activities together with the necessary erosion and sedimentation control measures planned for a project. This type of schedule guides the contractor on work sequencing so that serious erosion and sedimentation problems can be avoided. The ECSPP should indicate in each of the scheduled work, how the proposed erosion/sediment control measures will divert flows, limit runoff from exposed areas, stabilize exposed soil and filter sediment. The following activities should be included in the schedule, if applicable.

- Identify and label protection areas (e.g., riparian buffer zones, filter strips, trees).
- Construction accesses - Construction entrance, construction routes, equipment parking areas (necessary perimeter controls).
- Sediment traps and barriers - Sediment fences, straw bale barriers, and outlet protection.
- Runoff control - Diversions, and outlet protection.
- Runoff conveyance system - Stabilize stream banks, storm drains, channels, inlet and outlet protection, slope drains.
- Land clearing and grading - Site preparation - cutting, filling and grading, sediment basins, barriers, diversions, drains, surface roughening.
- Surface stabilization - Temporary and permanent seeding, mulching, sodding.
- Building construction - Buildings, utilities, paving.
- Landscaping and final stabilization - Topsoiling, trees and shrubs, permanent seeding, mulching, sodding, riprap.

Note that the construction activities listed above do not usually occur in a specified linear sequence, and schedules will vary due to weather and other unpredictable factors. Schedules for temporary and permanent erosion control work required in construction activity, should be submitted for review by the agency. Plans for erosion control on haul roads and borrow pits and plans for disposal of waste materials should also be submitted. The contractor may submit the ECSPP from the project plans if it is correct for the proposed stage of construction, or prepare a modified version, proposing methods, materials, and procedures, to be used for the weather and site conditions at the time of construction, if applicable.

The following practice consists of scheduling specified work sequence that coordinates the timing of land disturbing activities and the installation of control measures to minimize the impact of the activity on the environment. It is perhaps the most cost effective method to control erosion and pollution during construction.

3.3.1 Construction Sequence

Definition

A work schedule that coordinates the sequence of land-disturbing activities with the installation of erosion and sedimentation control practices.

A construction sequence schedule is a specified work schedule that coordinates the timing of land-disturbing activities and the installation of erosion protection and sediment control measures.

Purpose

To reduce onsite erosion and offsite sedimentation by performing land disturbing activities and installing erosion protection and sedimentation control practices in accordance with planned schedule.

Where Construction Sequence is Used

All land-development projects.

Planning Considerations

In planning construction work, it may be helpful to outline all land-disturbing activities necessary to complete the proposed project. Then list all practices needed to control erosion and sedimentation on the site. These two lists can then be combined in logical order to provide a practical and effective construction sequence schedule.

The removal of existing surface ground cover leaves a site vulnerable to accelerated erosion. Good planning will reduce land clearing, provide necessary controls, and restore protective cover in an efficient and effective manner. Appropriate sequencing of construction activities can be a cost-effective way to help accomplish this goal.

Scheduling considerations are summarized in Table A. The generalized construction activities shown in the table do not usually occur in a specified linear sequence, and schedules will vary due to weather and other unpredictable factors. However, the proposed construction schedule should be indicated clearly in the erosion and sedimentation control plan.

- Construction access is normally the first land-disturbing activity. Exercise care not to damage valuable trees or disturb designated buffer zones as well as established initial areas on site for preservation. The preserved areas should be shown on all property maps and should be clearly marked during clearing and construction activities.

- Next, install principal sediment basins and traps before any major site grading takes place and additional sediment traps and sediment fences as grading takes place to keep sediment contained onsite at appropriate locations.

- Locate key runoff-control measures in conjunction with sediment traps to divert water from planned undisturbed areas out of the traps and sediment-laden water into the traps. Install diversions above areas to be disturbed prior to grading. Place necessary perimeter dikes with stable outlets before opening major areas for development. Install additional needed runoff-control measures as grading takes place.

- Install the main runoff conveyance system with inlet and outlet protection devices early, and use it to convey storm runoff through the development site without creating gullies and washes. Install inlet protection for storm drains as soon as the drain is functional to trap sediment onsite in shallow pools and to allow flood flows to safely enter the storm drainage system. Install outlet protection at the same time as the conveyance system to prevent damage to the receiving stream.

- Normally, install stream stabilization, including necessary stream crossings, independently and ahead of other construction activities. It is usually best to schedule this work as soon as weather conditions permit. Site clearing and project construction increases storm runoff, often making stream bank stabilization work more difficult and costly.

- Begin land clearing and grading as soon as key erosion and sediment control measures are in place. Once a scheduled development area is cleared, grading should follow immediately so that protective ground cover can be reestablished quickly. Do not leave any area bare and exposed for extended periods. Leave adjoining areas planned for development, or to be used for borrow and disposal, undisturbed as long as possible to serve as natural buffer zones.

- Runoff control is essential during the grading operation. Diversions, slope drains, and outlet protection installed in a timely manner can be very effective in controlling erosion during this critical period of development. Immediately after land clearing and grading, apply surface stabilization on graded areas, channels, dikes, and other disturbed areas. Stabilize any disturbed area where active construction will not take place for 30 working days by temporary seeding and/or mulching or by other suitable means. Install permanent stabilization measures immediately after final grading, in accordance with the vegetative plan. Temporary seeding and/or mulching may be necessary during extreme weather conditions with permanent measures delayed for a more suitable time.

- Coordinate building construction with other development activities so that all work can take place in an orderly manner and on schedule. Experience shows that careful project scheduling improves efficiency, reduces cost, and lowers the potential for erosion and sedimentation problems.

- Landscaping and final stabilization is the last major construction phase, but the topsoil stockpiling, tree preservation, undisturbed buffer area, and well-planned road locations established earlier in the project may determine the ease or difficulty of this activity.

- All disturbed areas should have permanent stabilization practices applied.

- Unstable sediment should be removed from sediment basins and traps.

- All temporary structures should be removed after the area above has been properly stabilized.

- Borrow and disposal areas should be permanently vegetated or otherwise stabilized.

Design Criteria

As a minimum, the construction schedule should show the following:

The erosion and sedimentation control practices to be installed.

Principal development activities.

What measures should be in place before other activities are begun.

Schedule of operations for construction performance time.

Construction Specifications

Many timely construction techniques can reduce the erosion potential of a site. These are:

Shaping earthen fills to prevent overflows.
Constructing additional temporary practices ahead of anticipated storms.

These types of activities cannot be put on the construction sequence schedule but should be used whenever possible. Following a planned construction schedule to control erosion should help keep field personnel aware of the possibilities of erosion prevention through construction management.

Operation and Maintenance

Follow the construction sequence throughout project development. When changes in construction activities are needed, amend the sequence schedule in advance to maintain management control. Orderly modification assures coordination of construction and erosion control practices to minimize erosion and sedimentation problems. When major changes are necessary, send a copy of the amended schedule to the appropriate agency.

Table A.

Construction Activity	**Schedule Consideration**
1. Identify and label protection areas (e.g., riparian buffer zones, filter strips, trees).	Site delineation should be completed before construction begins.
2. Construction accesses. Construction entrance, construction routes, equipment parking areas (necessary perimeter controls).	First land-disturbing activity – Stabilize bare areas immediately with gravel and temporary vegetation as construction takes place.
3. Sediment traps and barriers. Sediment fences, straw bale barriers, and outlet protection.	Install principal basins after construction site is accessed. Install additional traps and barriers as needed during grading.
4. Runoff control. Diversions and outlet protection.	Install key practices after principal sediment traps and before land grading. Install additional runoff-control measures during grading.
4. Runoff control. Diversions and outlet protection.	Install key practices after principal sediment traps and before land grading. Install additional runoff-control measures during grading.
5. Runoff conveyance system. Stabilize stream banks, storm drains, channels, inlet and outlet protection, slope drains.	Where necessary, stabilize stream banks as early as possible. Install principal runoff conveyance system with runoff-control measures. Install remainder of system after grading.
6. Land clearing and grading. Site preparation - cutting, filling and grading, sediment basins, barriers, diversions, drains, surface roughening.	Begin major clearing and grading after principal sediment and key runoff-control measures are installed. Clear borrow and disposal areas only as needed. Install additional control measures as grading progresses. Mark trees and buffer areas for preservation.
7. Surface stabilization. Temporary and permanent seeding, mulching, sodding, riprap.	Apply temporary or permanent stabilization measures immediately on all disturbed areas where work is delayed or completed.
8. Building construction. Buildings, utilities, paving.	Install necessary erosion and sedimentation control practices as work takes place.
9. Landscaping and final stabilization. Topsoiling, trees and shrubs, permanent seeding, mulching, sodding, riprap.	Last construction phase-stabilize all open areas, including borrows and spoil areas. Remove and stabilize all temporary control measures.
10. Maintenance	Maintenance inspections should be performed weekly, and maintenance repair should be made immediately after period of rainfall.

3.4 Vegetative Practices

There are two kinds of erosion and sediment control measures – structural and vegetative. For best results, these measures should complement each other. Establishing vegetation on recently disturbed or bare areas depends on several basic considerations. First, excess water which falls on the area and flowing from land above must be disposed of properly. This includes properly located and designed diversions, grassed waterways, subsurface drains, and stabilized outlets of different types.

Once the water has been disposed of, a second consideration is seeding and/or planting. This includes selection of plant species having characteristics enabling them to grow and hold the soil on a particular area. They fulfill a variety of other uses in addition to stabilization. Included in seeding and planting is consideration of the chemical nature (ability to supply plant nutrients) of the soil. Chemical tests will guide intelligent application of lime and fertilizer.

Third, when the water is controlled on a site and the area has been prepared and seeded, it must be protected from heavy use until plants can provide the needed soil protection for the planned uses. In some cases future use may always be so intensive that the only stabilization is a paved surface. For less intensive uses, protection may be provided in different ways such as fencing, or netting until vegetation is established. The primary objective of vegetative growth is stabilization on the area so that erosion is controlled and sediment losses are reduced to a minimum. Both permanent and temporary vegetative measures should be considered.

The types of protective vegetative cover should be included as part of the project plan. Planning for the erosion hazard, seeding needs, and implementation during construction will eliminate serious problems later.

For best results, the following elements are essential: proper planning, frequent follow-up during project installation, prompt establishment of vegetative measures, and proper maintenance. This handbook includes the following vegetative practices:

- Tree Preservation and Protection
- Topsoiling
- Mulching
- Erosion Control Matting
- Temporary Seeding
- Permanent Seeding and Planting
- Sodding
- Filter Strip
- Vegetative Barrier
- Riparian Forest Buffer

3.4.1 Tree Preservation and Protection

Definition

Practices to preserve and protect desirable trees from mechanical and other injury damage during project development.

Purpose

To preserve and protect trees that have present or future value for their use in protection from erosion, for their landscape and aesthetic value, or for other environmental benefits such as endangered or threatened species.

Where Tree Preservation and Protection is Used

On development of a site containing trees or stands of trees.

Planning Considerations

Preserving and protecting trees and other natural plant groups often results in a more stable and aesthetically pleasing development. During site evaluation, note where valuable trees and other natural landscape features should be preserved, then consider these trees and plants when determining the location of roads, buildings, or other structures.

Trees that are near construction zones should be either protected or removed, because damage during construction activities may cause the death of the tree at a later time.

Trees should be considered for preservation for the following benefits:

- Stabilize the soil and prevent erosion.
- Reduce storm water runoff by intercepting rainfall, promote infiltration, and lower the water table through transpiration.
- Moderate temperature changes, promote shade, and reduce the force of wind.
- Provide buffers and screens against noise and visual disturbance, providing a degree of privacy.
- Filter pollutants from the air, remove carbon dioxide from the air, and produce oxygen.
- Provide a habitat for animals and birds.

- Increase property values and improve site aesthetics.

- Is classified as endangered or threatened.

Tree Selection Criteria

Consider the following characteristics when selecting trees to be protected and saved:

Tree vigor.
Preserve healthy trees. A tree of low vigor is susceptible to damage by environmental changes that occur during site development. Healthy trees are less susceptible to insects and disease. Indications of poor vigor may include dead tips of branches, small annual twig growth, stunted leaf size, sparse foliage, and pale foliage color. Hollow or rotten trees, cracked, split, or leaning trees or trees with broken tips have less chance for survival.

Tree age.
Old, picturesque trees may be more aesthetically valuable than smaller, younger trees, but they may require more extensive protection.

Tree species.
Preserve those species that are most suitable for site conditions and landscape design. Trees that are short-lived or brittle or are susceptible to attack by insects and disease may be poor choices for preservation. Take in consideration species included in the endangered and threatened list.

Tree aesthetics.
Choose trees that are aesthetically pleasing, shapely, large, or colorful. Avoid trees that are leaning or in danger of falling. Occasionally, an odd-shaped tree or one of unusual form may add interest to the landscape if strategically located. However, be sure the tree is healthy.

Wildlife benefits.
Choose trees that are preferred by wildlife for food, cover, or nesting. A mixture of species may be beneficial. Evergreen trees are important for cover.

Construction activities can significantly injure or kill trees unless protective measures are taken. Although direct contact by equipment is an obvious means of damaging trees, most serious damage is caused by root zone stress from compacting, filling, or excavating too close to the tree. Clearly mark boundaries to maintain sufficient undisturbed area around the trees.

Design General Criteria

The following general criteria should be considered:

- Leave critical areas (such as water body banks, swales and wetlands buffers) with desirable trees in their natural condition or only partially cleared.

- Locate roadways, storage areas, and parking pads away from valuable tree stands. Follow natural contours, where feasible, to minimize cutting and filling in the vicinity of trees.

- Select trees to be preserved before sitting, roads, buildings, or other structures.

- Minimize trenching in areas with trees. Place several utilities in the same trench.

- Designate groups of trees and individual trees to be saved on the erosion and sedimentation control plan.

- Do not excavate, traverse, or fill closer than the drip line, or perimeter of the canopy, of trees to be saved.

Basic design and criteria for protecting trees[1]

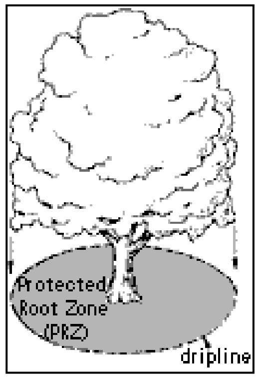
These steps will help you create a successful landscape protection plan:

- Mark construction zone boundaries. Obtain a complete set of site development plans, including the proposed location of buildings, driveways, sidewalks, and utility lines. Ask the builder or architect to mark areas where heavy equipment will be used, where soil will be permanently added or removed and to what depth, and where fill and building materials will be temporarily stockpiled. Use a measuring tape, stakes, and string to temporarily mark the boundaries of construction activities on the site.

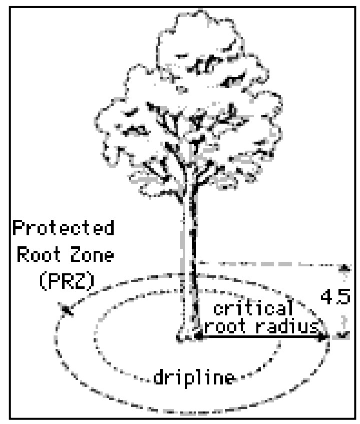
- Inventory trees on the site. Record the location, size, and health of each tree. Wilted leaves, broken or dead limbs, trunk rot, and thin tops are all symptoms of stress.

- Select the trees to be saved. Examine the site carefully and note how each tree fits into the future landscape. Keep in mind that the builder may be able to shift the location of a building, utility line, or driveway. If considerable damage to the tree's root system within the Protected Root Zone (PRZ) is inevitable, you should seriously consider changing the original design, adding protection measures, or removing the tree before construction begins.

[1] Taken in part from Publication Protecting Trees from Construction Damage: A Homeowner's Guide, Gary R. Johnson, University of Minnesota.



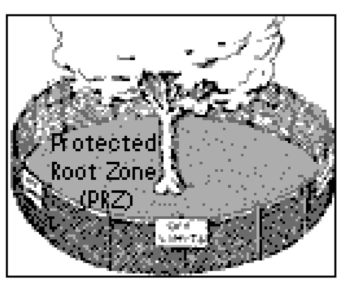
One common method used to identify the tree's Protected Root Zone (PRZ) is to consider it to be the part of the roots that lie directly below its branches within an area known as the "drip line".



For endangered or threatened tree species calculate the PRZ using the Critical Root Radius Method. To calculate critical root radius, begin by measuring the diameter at breast height (dbh). This is done by measuring the tree's trunk diameter (thickness) at a point 4.5 feet above the ground. The measurement should be done in inches. For each inch of dbh, allow for 1.5 feet of critical root radius for sensitive trees, or 1.0 feet for tolerant trees. For example, if a tree's dbh is 10 inches, then its critical root radius is 15 feet (10 x 1.5 = 15). The PRZ is an area around the tree with a diameter of 30 feet (2 x radius), and is the area in which a critical amount of the tree's roots may be found. Whenever possible, isolate this area from construction disturbance

- Protect the trees you plan to save. Develop a map with the builder or architect showing the location of trees to be protected and the safest route for access to the building zone. Then install bright orange polypropylene fencing and post "Off Limits" signs at the PRZ of the trees you plan to save.

  Your primary objective is to protect delicate root systems, so provide your trees with as much space as possible.



Put up fences and signs around trees you want to save.

Make sure all construction workers know that nothing inside this area is to be raked, cut, stored, or otherwise disturbed. A landscape protection contract signed by the builder and all contractors will help ensure compliance. You may take several photographs of the site before construction begins to document the protection methods used and the condition of individual trees.

- Prepare the trees for construction disturbance. You will boost your trees chance for survival if you make sure they are as healthy as possible before construction begins. Prune branches that are dead, diseased, hazardous, or detrimental to the plant's natural form. Irrigate and fertilize according to soil test if needed.

- Protect and preserve the soil for future trees planting. Apply a layer of wood chips at least six inches thick over areas that will be used for traffic or materials storage during construction. If these areas become part of the new landscape, the mulch will prevent the soil from becoming too compacted. Soil compaction is the largest killer of urban trees.

- Monitor the construction process. Visit the site periodically and inspect the trees. Your presence alerts workers of your concern for the careful treatment of the trees. Should damage occur, begin repairs as soon as possible. Insist that protective fences remain in place until all construction workers have left the site.

- Make a final inspection of the site. After construction has been completed, evaluate the condition of the remaining trees. Look for indications of damage or stress. It may take several years for severe problems to appear.

Operation and Maintenance

In spite of precautions, some damage to protected trees may occur. In such cases, repair any damage immediately.

Commit to long-term maintenance. Trees will not recover from construction damage in one or two years. Mulch as much of the PRZ as you can tolerate and plant understory shrubs and perennials within the mulched areas. Irrigate the PRZ regularly for several years - never let the trees become water-stressed.

Plans and Specifications

Plans for tree preservation and protection shall be in keeping with this management practice and shall describe the requirements for applying the practice to achieve the intended purpose. Plans shall identify the location of all trees to be preserved.

Specifications for tree preservation and protection shall use or be in conformance with the following. Any variation from these specifications shall be approved by an engineer and submitted to EQB.

- Place barriers to prevent the approach of equipment within the drip line of trees to be retained.
- Do not nail boards to trees during building operations.
- Do not cut tree roots inside the tree drip line.
- Do not place equipment, construction materials, topsoil, or fill dirt within the limit of the drip line of trees to be saved.
- If a tree marked for preservation is damaged, examine the damage to determine if repair is possible to preserve the tree. If the tree is damaged beyond repair, remove it and replace it with tree of the same or similar species (2-inch diameter or larger) from balled and burlaped nursery stock when activity in the area is complete.
- During final site cleanup, remove barriers around trees.

3.4.2 Topsoiling *

Definition

Methods of preserving and using the surface layer of undisturbed soil often enriched in organic matter, in order to obtain a more desirable planting and growth medium.

Purpose

To provide a suitable growth medium for final site stabilization with vegetation.

Where Topsoiling is Used

Where a sufficient supply of quality topsoil is available. Where the subsoil or areas of existing surface soil present the following problems:

> The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation.
>
> The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation.
>
> The soil contains substance toxic to the desired vegetation.

Where high-quality grass or ornamental plants are desired.

Only on slopes that are **2:1 or flatter** unless other measures are taken to prevent erosion and sloughing.

Planning Considerations

Topsoil is the surface layer of the soil profile, generally characterized as darker than the subsoil due to enrichment with organic matter. It is the major zone of root development and biological activity. Microorganisms that enhance plant growth thrive in this layer. Topsoil can usually be differentiated from subsoil by texture as well as color. Clay contents usually increases in the subsoil. Where subsoils are often high in clay, the topsoil layer may be significantly coarser in texture.

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* Topsoiling has been included in this section because it is an integral component of preparing permanent cover to those areas where there is an unsuitable soil surface for plant growth.

The depth of topsoil may be quite variable. On severely eroded sites it may be gone entirely. Advantages of topsoil include its high organic-matter content and friable consistence (soil aggregates can be crushed with only moderate pressure), and its available water holding capacity and nutrient content. Most often it is superior to subsoil in these characteristics. The texture and friability of topsoil are usually much more conducive to seedling emergency and root growth.

In addition to being a better growth medium, topsoil is often less erodible than subsoils, and the coarser texture of topsoil increases infiltration capacity and reduces runoff. Although topsoil may provide an improved growth medium, there may be disadvantages, too. Stripping, stockpiling, hauling, and spreading topsoil, or importing topsoil, may not be cost-effective. Handling may be difficult if large amounts of branches or rocks are present or if the terrain is too rough. Most topsoil contains weed seeds, which compete with desirable species.

In site planning, compare the options of topsoiling with preparing a seedbed in the available subsoil. The clay content of many types of subsoil retains moisture. When properly limed and fertilized, subsoils may provide a satisfactory growth medium, which is generally free of weed seeds.

Topsoiling is normally recommended where ornamental plants or high maintenance turf will be grown. It may also be required to establish vegetation on shallow soils, soils containing potentially toxic materials, stony soils, and soils of critically low pH (high acidity).

If topsoiling is to be used, consider the following:

Quality and amount of topsoil available and needed.

Locations for a stabilized stockpile that will not erode, block drainage, or interfere with work on the site.

Bonding - if topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly, and it will be difficult to establish vegetation.

Do not apply topsoil to slopes steeper than 2:1 to avoid slippage, or to a subsoil of highly contrasting texture. Sandy topsoil over clay subsoil is a particularly poor combination especially on steep slopes. Water may creep along the junction between the soil layers and cause the topsoil to slough.

<u>Plans and Specifications</u>

Plans for installing land grading shall be in keeping with this measure and shall describe the requirements for applying the practice to achieve the intended purpose.

Specifications for salvaging, storing, and using topsoil shall use or be in conformance with the following:

- Materials. Determine whether the quality and quantity of available topsoil justifies selective handling. Quality topsoil has the following characteristics:

    1) Texture--loam, sandy loam, and silt loam are best; sandy clay loam, silty clay loam, clay loam, and loamy sand are fair. Do not use heavy clay and organic soils such as peat or muck as topsoil.

    2) Organic matter content--(sometimes referred to as "humic matter") should be greater than 1.0 percent by weight.

    3) pH nearly 5.5-7.0.

The depth of material meeting the above qualifications should be at least 2 inches. Soil factors such as rock fragments, slope, depth to water table, and layer thickness affect the ease of excavation and spreading of topsoil.

Generally, the upper part of the soil, which is richest in organic matter, is most desirable; however, material excavated from deeper layers may be worth storing if it meets the other criteria listed above. Organic soils such as mucks and peats do not make good topsoil. They can be identified by their extreme lightness when dry.

- Stripping.
  Strip topsoil only from those areas that will be disturbed by excavation, filling, road building, or compaction by equipment. A 4-6-inch stripping depth is common, but depth varies depending on the site. Determine depth of stripping by taking soil cores at several locations within each area to be stripped. Topsoil depth generally varies along a gradient from hilltop to toe of slope. Put sediment basins, diversions, and other controls into place before stripping.

- Stockpiling.
  Select stockpile location to avoid slopes and natural drainage ways, avoiding traffic routes. On large sites, respreading is easier and more economical when topsoil is stockpiled in small piles located near areas where they will be used.

Sediment barriers - Use sediment fences or other barriers where necessary to retain sediment.

Temporary seeding - Protect topsoil stockpiles by temporarily seeding as soon as possible, no more than 30 days after the formation of the stockpile.

Permanent vegetation - If stockpiles will not be used within 12 months they must be stabilized with permanent vegetation to control erosion and weed growth.

- Site Preparation.
  Before spreading topsoil, establish erosion and sedimentation control practices such as diversions, berms, dikes, waterways, and sediment basins.

Grading - Maintain grades on the areas to be topsoiled according to the approved plan. Adjust grades and elevations for receipt of topsoil.

Liming of subsoil - Where the pH of the existing subsoil is 6.0 or less, or the soil is composed of heavy clays, incorporate agricultural limestone in amounts recommended by soil tests or specified for the seeding mixture to be used (see Permanent Seeding BMP). Incorporate lime to a depth of at least 2 inches by disking.

Roughening - Immediately prior to spreading the topsoil, loosen the subgrade by disking or scarifying to a depth of at least 4 inches, to ensure bonding of the topsoil and subsoil. If no amendments have been incorporated, loosen the soil to a depth of at least 6 inches before spreading topsoil.

- Spreading Topsoil.
  Uniformly distribute topsoil to a minimum compacted depth of 2 inches on 3:1 slopes and 4 inches on flatter slopes. To determine the volume of topsoil required for application to various depths, use the following table:

Volume of Topsoil Requires for Application to Various Depths

Depth		Volume		Volume	
Inches	Millimeters	Cu. Yards per 1,000 Sq.Ft	Cu. Meters per 100 Sq. Meters	Cu. Yards per Acre	Cu. Meters per Hectare
1	25	3.1	2.5	134	253
2	51	6.2	5.1	268	506
3	76	9.3	7.6	403	761
4	102	12.4	10.1	536	1013
5	127	15.5	12.7	670	1266
6	152	18.6	15.2	804	1519

Do not spread topsoil while it is muddy or when the subgrade is wet. Correct any irregularities in the surface that result from topsoiling or other operations to prevent the formation of depressions or water pockets.

Compact the topsoil enough to ensure good contact with the underlying soil, but avoid excessive compaction, as it increases runoff and inhibits seed germination. Light packing with a roller is recommended where high-maintenance turf is to be established.

On slopes and areas that will not be mowed, the surface may be left rough after spreading topsoil. A disk may be used to promote bonding at the interface between the topsoil and subsoil.

After topsoil application, follow procedures for temporary or permanent seeding, taking care to avoid excessive mixing of topsoil into the subsoil.

Common Trouble Points

Topsoil washes away; erosion control practices were not provided.

Uncertainty on quality of topsoil; if doubts exist, take a sample for examination.

Operation and Maintenance ·

Cover piles with clear plastic covering until needed.

3.4.3 Mulching

Definition

Applying plant residues or other suitable materials produced offsite, to the land surface.

Purpose

To protect the soil surface from the forces of raindrop impact and overland flow. Mulch fosters the growth of vegetation, reduces evaporation, insulates the soil, moderates soil temperature, conserves soil moisture, suppresses weed growth, improves soil condition, and increases soil fertility.

Where Mulching is Used

This practice applies to all lands where mulches are needed. This practice may be used alone or in combination with other practices to:

Establish temporary or permanent grass vegetation for disturbed soils after a construction project or land use reclamation project.

Temporary stabilization of freshly seeded and planted areas, or during periods unsuitable for growing permanent vegetation.

Permanent stabilization around established plants, such as trees or shrubs, in order to prevent the growth of weeds and to maintain soil moisture conditions.

On poor or marginal soils, to add organic matter and retain moisture and fertilizer, as a strategy to speed establishment of permanent vegetative cover.

As a short-term ground cover on steep slopes to reduce rainfall impact, decrease the velocity of sheet flow, and settle out sediment.

Criteria

- General Criteria Applicable to all Purposes

The choice of mulch should be based on the size of the area, site slopes amount of sunlight or shade, proximity to drainage features and natural streams, soil hardness and moisture, weed potential, and availability of mulch materials. Organic materials may also decompose and aid the soil in providing nutrients for vegetation. Inorganic materials such as inert black plastic or manufactured landscaping fabric can also be used to prevent weeds and retain moisture, but are not considered as mulch.

Newspaper is also commonly used to control weeds, but is subject to leaching of ink and chemicals. The use of newspaper within soil for weed control is discouraged.

The grass hay mulch is often selected due to the ease of application and good results. Alternatively, hydroseeding (including hydraulic application of mulch) is often performed, especially on steep slopes and locations, which require quick establishment of grass.

Mulching is generally performed after grading, soil surface preparation and seeding and plantings are complete. Soil surface shall be prepared in order to achieve the desired purpose.

The mulch material shall be evenly applied and anchored to the soil. Tackifiers, emulsions, pinning, netting, crimping or other acceptable of anchoring will be used if needed to hold the mulch in place for specified periods.

Manufactured mulches shall be applied according to the manufacturer's specifications.

Mulching operations shall comply with federal, state and/or local laws and regulations during the installation, operation and maintenance of this practice.

Mulch material shall be relatively free of disease, noxious weed seeds, and other pests and pathogens.

- Additional Criteria to Conserve Soil Moisture

Mulch materials applied to the soil surface shall provide at least 60 percent cover to reduce potential evaporation.

Mulch material shall be applied prior to moisture loss. Prior to mulching, ensure soil under shallow rooted crops is moist, as these crops require a constant supply of moisture.

- Additional Criteria to Moderate Soil Temperature

Mulch materials shall be selected and applied to obtain 100 percent coverage over the area treated. The material shall be of a significant thickness to persist for the period required for the temperature modification.

- Additional Criteria to Provide Erosion Control

When mulching with straw or grass hay, apply in sufficient amounts to provide 70 percent ground cover. Mulch rate shall be determined using current erosion prediction technology to reach the soil erosion objective.

When mulching with wood products such as wood chips, bark, or shavings or other wood materials, apply to a 2-inch thickness if the soil is not well drained and to a 3- to 4-inch thickness if drainage is good. More finely textured mulches, which allow less oxygen penetration than coarser materials, should be no thicker than 1 or 2 inches. The mulch material shall provide no greater than 80 percent ground cover in order to ensure adequate air drainage.

- Additional Criteria to Suppress Weed Growth

The thickness of mulch will be determined by the size of the plant being mulched. Small plants must not be smothered. Mulches shall be kept clear of the stems of plants where disease is likely to occur. Mulches applied around growing plants or prior to weed seeding development shall have 100 percent ground cover. Thickness of the mulch shall be adequate to prevent emergence of targeted weeds. Plastic mulches may be used.

- Additional Criteria to Establish Vegetative Cover

Mulch shall be applied at a rate that achieves 50 percent ground cover to provide protection from erosion and runoff and yet allow adequate light and air penetration to the seedbed to ensure proper germination, emergence, and disease suppression.

- Additional Criteria to Improve Soil Condition and Increase Soil Fertility

To increase soil fertility, apply mulch materials with a carbon to nitrogen ratio (C:N) less than 30 to 1 such as animal manure, bio-solids, food processing wastes, or similar materials. Apply other practices such as contouring, filter strips or riparian forest buffers to assure that runoff from the mulched areas will not transport mulching materials to sensitive water bodies. Do not apply mulch with C:N less than 20:1 to the area of designed flow in watercourses.

<u>Considerations</u>

Consider the effects of mulching on evaporation, infiltration and runoff. Mulch material may affect microbial activity in the soil surface, increase infiltration, and decrease runoff, erosion and evaporation. Increased infiltration may increase nutrient and chemical transport below the root zone. The temperature of the surface runoff may also be lowered.

Mulched soil retains moisture, requires less watering and reduces the chance of water stress on plant materials. Mulch also minimizes evaporation from the soil surface and hence reduces losses from bare soil areas.

Mulch materials high in organic matter with a high water holding capacity and high impermeability to water droplets may adversely affect the water needs of plants.

Clear and infrared transmissible (IRT) plastics have the greatest warming potential. They are transparent to incoming radiation and trap the longer wave lengths radiating from the soil. Black mulches are limited to warming soils by conduction only and are less effective.

Clear mulches allow profuse weed growth and may negate the benefits of soil warming. Black mulches provide effective weed control. Wave length selective (IRT) blends the soil warming characteristics of clear mulch with the weed control ability of black mulch.

Consider potential toxic allopathic effects that mulch material may have on other organisms. Animal and plant pest species may be incompatible with the site.

Consider the potential for increased pathogenic activity within the applied mulch material.

Keep mulches 3 to 6 inches away from plant stems and crowns to prevent disease and pest problems.

Deep mulch provides nesting habitat for ground-burrowing rodents that can chew extensively on bark on tree trunk and/or tree roots.

Plans and Specifications

Specifications shall be prepared for each site and purpose and recorded using approved specification sheets, technical notes, and narrative statements in the Erosion Control and Sediment Prevention Plan, or other acceptable documentation. Documentation shall include:

- Type of mulch material used
- Percent cover and/or thickness of mulch material
- Timing of application
- Site preparation
- Listing of netting, tackifiers, or method of anchoring
- Operation and maintenance

Common Trouble Points

The potential of introduction of weed-seed and unwanted plant material.

Punching of “straw” does not work in sandy soils.

Can be easily blown or washed away by runoff if not secured.

Operation and Maintenance

Inspect all mulches periodically, and after rainstorms to check for rill erosion, dislocation, or failure. Where erosion is observed, apply additional mulch. If washout occurs, repair the slope grade, reseed, and reinstall mulch.

Continue inspections until vegetation if firmly established.

Operation of equipment near and on the site shall not compromise the intended purpose of the mulch.

Properly collect and dispose of artificial mulch material after intended use.

Monitor and control undesirable weeds in mulched areas.

3.4.4 Erosion Control Matting

Definition

The placing and securing of either jute mesh, excelsior matting, erosion control fabric, or other approved matting is used to prevent erosion on previously shaped and seeded drainage channels, slopes, or other critical areas.

Purpose

The basic objective of erosion control matting is to provide a stable seedbed for one or more growing seasons (though some may be designed to last longer in extreme conditions), then to biodegrade as vegetal matter builds up to produce a healthy cover crop.

Where Erosion Control Matting is Used

Can be used in any area subjected to erosive actions such as newly graded slopes, detention structures, and stream banks where moving water is likely to wash out new vegetative plantings.

Erosion control mattings are quite effective in controlling erosion on steep slopes and in ditches where design flow may exceed 3.5 feet per second. Mattings are especially advantageous where the soil erosion potential is high.

Criteria

- Site Preparation

  The areas to receive the erosion control matting should have been previously shaped, fertilized, and seeded as shown on the plans or as specified by the engineer. A smooth surface free of depressions and eroded areas that would allow water to collect or flow under the matting should be required. Unless otherwise specified, the soil should be left with a loose surface after seeding.

- Materials

  Staples - Staples should be No. 11 gauge new steel wire formed into a "U" shape, or as specified by the engineer. Staples should be 6 to 10 inches long, with the longer staples used on loose, unstable soils.

  Erosion Control Matting - Fabric mattings should meet the material requirements as stated in by the State, as stated on the plans, or as directed by the engineer.

- <u>Installation</u>

Numerous variations of erosion control mattings currently exist. Basic application of a few most commonly used erosion control mattings are listed below. Erosion control products should always be installed in accordance with the manufacturer's instructions.

1) Erosion Control Fabrics

Erosion control fabrics, such as nettings, are especially useful when applied over mulch, over sod, and/or in low volume and velocity ditches. Erosion control fabrics may be applied perpendicular or horizontal to the contour lines depending upon the slope characteristics, but should be placed in the direction of the water flow in ditch installation.

Fabric should be placed approximately horizontal on slopes that are less than 2:1 and less than 20 feet long or in situations where one width of the fabric will cover the entire length.

Fabric should be placed approximately perpendicular on slopes greater than 2:1, if the length of the slope exceeds the width to be covered, or on slopes with excessive runoff from adjacent areas regardless of the degree or length of the slope.

Prior to netting placement, a 4-inch anchor trench should be dug at the top and toe of the slope with the top trench placed 1 foot back from the crown, or a berm over which the fabric can be carried should be used.

For perpendicular application the erosion control fabric should be tucked into the top trench, stapled, and covered with topsoil. The material is then unrolled and stapled as the work proceeds. The vertical strips should have a 4-inch overlap. The material should be in the trench at the bottom of the slope.

For horizontal application, work must proceed from the bottom toward the top of the slope with a 4-inch overlap. After cutting, the material should be folded under 3 to 4 inches at the end, stapled, and covered with topsoil.

The netting should not be stretched, but allowed to lay smoothly and loosely on the surface.

Staples should be placed 9 to 12 inches apart in the trenches and along horizontal lap joints. For perpendicular applications, a 3-foot interval is sufficient along the laps. Staples should be placed in three alternating rows at approximately 3-foot intervals along the length of the inner portions of the material. Extra staples on 9 to 12-inch centers should be used around the mouths of culverts and flumes.

Where extremely erodible soil is anticipated, an erosion stop should be placed at the midpoint of the slope. The material should be stapled every 9 to 12 inches along the center of the erosion stop, filled with topsoil, and tamped thoroughly.

2) Excelsior Matting

Matting should be unrolled in the direction of flow with edges and ends butted snugly against each other. Anchor ditches should be required on the upgrade side of the fabric when directed by the engineer. When unrolled, the netting should be on top and the fibers should be in contact with the soil.

Staples should be driven vertically into the ground, anchoring the mat firmly to the soil, and driven flush with the surface of the mat. Slopes flatter than 4:1 should be stapled no more than 5 feet apart on all edges and 1 foot apart at all joints and ends. On all slopes steeper than 4:1 and in all ditches, three staggered rows of staples should be spaced 2.5 to 3 feet apart. Additionally, all joints and ends should be spaced not more than 6 inches apart. The spacing of staples may be modified to fit the conditions as directed by the engineer.

3) Jute Mesh

When jute mesh is to be used, the upslope end should be in a trench at least 6 inches deep with the soil firmly tamped against it and unrolled in the direction of the water flow. Areas exposed to more than normal flow of water should be anchored around the edges as well. The matting should not be stretched but should be spread evenly and smoothly so that it is in close contact with the ground at all points.

Successive strips of matting should overlap at least 6 inches at the ends, with the upgrade strip on top. Parallel strips of matting should overlap at least 4 inches.

Check slots should be spaced not more than 50 feet from an end slot or another check slot. Check slots should be placed with a tight fold of matting anchored at least 6 inches vertically into the ground and tamped firmly.

Staples should be No. 11 gauge new steel wire formed into a "U" shape and should be driven vertically into the ground to tightly hold the matting flush to the ground. Staples should be spaced no more than 4 feet apart in three rows for each strip, with one row along each edge and one row alternately spaced in the center. On overlapping edges of parallel strips, staples should be spaced no more than 2 feet apart. All anchor, junction, and check slots staples should be spaced no more than 6 inches apart. After the matting is stapled into place, it should then be pressed into the ground with a light lawn roller or by other means approved by the engineer.

4) Other Forms of Erosion Control Matting

   Other forms of erosion control matting should be installed as specified on the plans, as directed by the manufacturer, or as specified by the engineer.

Common Trouble Points

Inadequate coverage; inadequate coverage results in erosion, washout, and poor plant establishment.

Appropriate staple spacing not applied, or applied in insufficient amount; seed, topsoil, and mulch is lost to wind and runoff.

Channel grade and liner not appropriate for amount of runoff; this may result in erosion of the channel bottom. Modification may be necessary.

If the fabric is not properly selected, designed, or installed the effectiveness may be reduced drastically.

Operation and Maintenance

Inspect erosion control mattings after rainstorms to check for movement of topsoil, movement of the mulch, or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, resod, remulch and/or replace topsoil, and install new netting. Continue inspections until vegetation is firmly established.

3.4.5 Temporary Seeding

Definition

Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas.

Purpose

To provide temporary soil stabilization by planting grasses and legumes to areas that would remain bare for more than 7 days where permanent cover is not necessary or appropriate. Temporary seeding controls runoff and erosion until permanent vegetation or other erosion control measures can be established. In addition, it provides residue for soil protection and seedbed preparation and reduces problems of mud and dust production from bare soil surfaces during construction.

Where Temporary Seeding is Used

On any cleared, unvegetated, or sparsely vegetated soil surface where:

- Permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.
- Areas which will not be subjected to heavy wear by construction traffic.
- Areas sloping up to 10% for 100 feet or less (where temporary seeding is the only management practice used).
- Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.

Planning Considerations

Temporary seeding preserves the integrity of earthen sediment control structures such as dikes, diversions, and sediment basins. It can also reduce the amount of maintenance associated with these devices. For example, the frequency of sediment basin cleanouts will be reduced if watershed areas, outside the active construction zone, are stabilized.

Proper seedbed preparation, selection of appropriate species, and use of quality seed are as important in this practice as in the Permanent Seeding Practice. Failure to follow established guidelines and recommendations carefully may result in an inadequate or short-lived stand of vegetation that will not control erosion.

Temporary seeding provides protection for no more than 1 year, during which time permanent stabilization should be initiated.

<u>Plans and Specifications</u>

Plans for installing temporary seeding shall be in keeping with this practice and shall describe the requirements for applying the practice to achieve the intended purpose.

Specifications for applying and installing temporary seeding shall use or be in conformance with the following. Any variation from these specifications shall be approved by an engineer.

General.
Complete grading before preparing seedbeds and install all necessary erosion control practices, such as dikes, waterways and basins. Minimize steep slopes because they make seedbed preparation difficult and increase the erosion hazard. If soils become compacted during grading, loosen them to a depth of 6-8 inches using a ripper, harrow, or chisel plow.

Seedbed Preparation.
Good seedbed preparation is essential to successful plant establishment. A good seedbed is well-pulverized, loose, and uniform. Where hydroseeding methods are used, the surface may be left with a more irregular surface of large clods and stones.

- Liming--Apply lime according to soil test recommendations. If pH (acidity) of the soil is not known, an application of ground agricultural limestone at the rate of 1 to 1 1/2 tons/acre on coarse-textured soils and 2-3 tons/acre on fine textured soils is usually sufficient. Apply limestone uniformly and incorporate into the top 4-6 inches of soil. Soils with a pH of 6 or higher need not be limed. Never mix $CaCo_2$ with the fertilizer.

- Fertilizer--Base application rates on soil tests. Limit the application of fertilizers to the minimum area and the minimum recommended amount. Fertilizer should be incorporated into the top 4-6 inches of soil. If a hydraulic seeder is used, do not mix seed and fertilizer more than 30 minutes before application. Over-fertilization can cause pollution of storm water runoff, other practices such as MULCHING alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems.

- Surface roughening--If recent tillage operations have resulted in a loose surface, additional roughening may not be required except to break up large clods. If rainfall causes the surface to become sealed or crusted, loosen it just prior to seeding by disking, raking, harrowing, or other suitable methods. Groove or furrow slopes steeper than 3:1 on the contour before seeding.

➢ Plant Selection. Select an appropriate species or species mixture from Table 1.

Table 1. Recommended Species for Temporary Seeding

Species	Seeding Rate		Planting Depth (in)
	lbs/acres	lbs/1000 sq.ft.	
Grasses			
Ryegrass* *Lolium perenne*	40	1	¼
Brown Top Millet* *Urochloa ramosa*	40	1	¼
Legumes			
Habichuela de terciopelo Velvet bean *Mucuna pruriens*	20	0.5	¼
Neonotonia wightii	5 [(a)]	0.12	¼

* Commercially available grasses which have been proven to perform well under prevailing conditions in Puerto Rico.
(a) deep in water 24 hrs before planting

Seeding.
Evenly apply seed uniformly on a firm, moist soil. Use seeding rates and planting method given in Table 1. Broadcast seeding and hydroseeding are appropriate for steep slopes where equipment cannot be driven. Hand broadcasting is not recommended because of the difficulty in achieving a uniform distribution.

Grasses and legumes should not be planted more than ¼ inch deep. Broadcast seed must be covered by raking or chain dragging, and then lightly firmed with a roller or cultipacker. Hydroseeded mixtures should include wood fiber (cellulose) or paper fiber mulch.

Mulching.
The use of appropriate mulch will help ensure establishment under normal conditions and is essential to seeding success under harsh site conditions. Harsh site conditions include:

➢ Seeding during the rainy season.

➢ Slopes steeper than 3:1.

➢ Adverse soils (shallow, rocky, or high in clay or sandy).

➢ Areas receiving concentrated flow.

- High concentration of predators.

- Semiarid regions where climate prevents fast plant growth.

If the area to be mulched is subject to concentrated water flow, as in channels, anchor mulch with netting.

Common Trouble Points

Seed not broadcasted evenly or application too low; either problems result in patchy growth and erosion.

Improper calculation of seeding rate, based on seed purity and germination information.

Operation and Maintenance

Re-seed and mulch areas as soon as possible where seedling emergence is poor, or where erosion occurs. Do not mow. Protect from traffic as much as possible.

Seeding should be supplied with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.

Re-seeding - Areas which fail to establish vegetative cover adequate to prevent erosion shall be re-seeded as soon as such areas are identified.

All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practice is no longer needed. Trapped sediment must be removed or stabilized on site. Disturbed soil areas resulting from removal should be permanently stabilized.

3.4.6 Permanent Seeding and Planting

Definition

The establishment of perennial vegetative covers on disturbed areas.

Purpose

To reduce erosion and decrease sediment yield from disturbed areas, and to permanently stabilize such areas in a manner that is economical, adapts to site conditions, and allows selection of the most appropriate plant materials.

Where Permanent Seeding and Planting is Used

In fine-graded areas on which permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. Permanent seeding may also be used on rough-graded areas.

Areas to be stabilized with permanent vegetation must be seeded or planted within 30 days after final grade is reached, on a segment of the construction site, unless temporary stabilization is applied.

Graded, final graded or cleared areas where permanent vegetative cover is needed to stabilize the soil.

Areas that will not be brought to final grade for a year or more.

Vegetation-lined channels.

Retention or detention ponds as required.

Planning Considerations

Vegetation controls erosion by protecting bare soil surfaces from raindrop impact and by reducing the velocity and volume of overland flow.

The most common and economical means of stabilizing disturbed soils is by seeding grasses and legumes. The advantages of seeding over other means of establishing plants include the smaller initial cost, lower labor input, and greater flexibility of method.

The probability of successful plant establishment can be maximized through good planning, knowledge of the soil characteristics, selection of suitable plant material for the site, good seedbed preparation, adequate liming and fertilization, and timely planting and maintenance.

Selecting Plant Materials.
Plant selection is made early in the development of a site so that the seedbed can be prepared to fit requirements of the plants. A large number of plant species and varieties can be grown in Puerto Rico and many have been used for soil stabilization (See Table 1). The plants emphasized in this handbook were chosen for their wide adaptation and high degree of erosion control reliability. Others may be preferable for special applications.

<u>Plans and Specifications</u>

Plans for installing permanent seeding shall be in keeping with this practice and shall describe the requirements for applying the practice to achieve the intended purpose.

Specifications for applying and installing permanent seeding shall use or be in conformance with the following. Any variation from these specifications shall be approved by an engineer.

- Seedbed

  The operation of equipment is restricted on slopes steeper than 3:1, severely limiting the quality of the seedbed that can be prepared. The soil on such slopes cannot be sufficiently worked, and amendments cannot be thoroughly incorporated.

  Provisions for establishment of vegetation on steep slopes can be made during final grading. In construction of fill slopes, for example, the last 4-6 inches might be left uncompacted. A loose, rough seedbed is essential. Large clods and stones provide irregularities that hold seeds and fertilizer. Cut slopes should be roughened.

  Where sternness prohibits the use of farm machinery, seeding methods are limited to broadcast or hydroseeding, with hydroseeding giving the most dependable results. Vegetation chosen for these slopes must not require mowing or other intensive maintenance. Using a hydraulic seeder, seed, fertilizer, wood fiber mulch, and a tacking agent can be applied in one operation.

  Good mulching practices are critical to protect against erosion on steep slopes. When using straw, anchor with netting or asphalt. On slopes steeper than 2:1, jute, excelsior, or synthetic matting may be required to protect the slope.

  Seedbed Requirements.
  Establishment of vegetation should not be tempted on sites that are unsuitable due to poor drainage, concentrated overland flow, or steepness of slope until measures are taken to correct these problems. To maintain a

good stand of vegetation, the soil must meet certain minimum requirements as a growth medium. The existing soil should meet the following conditions:

1) Enough fine-grained (silt and clay) material to maintain adequate moisture and nutrient supply.

2) Sufficient pore space to permit root penetration.

3) Sufficient depth of soil to provide an adequate root zone. The depth to rock or impermeable layers such as hardpans should be 12 inches or more, except on slopes steeper than 2:1 where the addition of soil is not feasible.

4) A favorable pH range for plant growth, usually 6.0-6.5.

5) Freedom from large roots, branches, stones, large clods of earth, or trash of any kind. Clods and stones may be left on slopes steeper than 3:1 if the slopes are to be hydroseeded.

Seedbed Preparation.
Good seedbed preparation is essential to successful plant establishment. A good seedbed is well pulverized, loose, and uniform. Where hydroseeding methods are used, the surface may be left with a more irregular surface of large clods and stones.

1) Liming--Apply lime according to soil test recommendations. If acidity of the soil is not known, an application of ground agricultural limestone at the rate of 1 to 1 1/2 tons/acre on coarse-textured soils and 2-3 tons/acre on fine textured soils is usually sufficient. Apply limestone uniformly and incorporate into the top 4-6 inches of soil. Soils with a pH of 6 or higher need not be limed. Never mix $CaCo_2$ with the fertilizer.

2) Fertilizer--Base application rates on soil tests. Fertilizer should be incorporated into the top 4-6 inches of soil. If a hydraulic seeder is used, do not mix seed and fertilizer more than 30 minutes before application. Over-fertilization can cause pollution of storm water runoff; other practices such as mulching (3.4.3) alone may be more appropriate. Developments adjacent to water bodies must use non-phosphorus fertilizer. The potential for over-fertilization is an even worse problem in or near aquatic systems. Limit the application of fertilizers to the minimum area and the minimum recommended amount.

3) Surface roughening--If recent tillage operations have resulted in a loose surface, additional roughening may not be required except to break up large clods. If rainfall causes the surface to become sealed or crusted, loosen it just prior to seeding by disking, raking, harrowing, or other suitable methods. Groove or furrow slopes steeper than 3:1 on the contour before seeding.

- Soil Conditioners

In order to improve the structure or drainage characteristics of a soil, the following materials may be added. These amendments should only be necessary where soils have limitations that make them poor for plant growth or are needed for fine turf establishment.

1) Peat - Appropriate types are sphagnum moss peat, hypnum moss peat, reed-sedge peat, or peat humus, all from fresh-water sources. Peat should be shredded and conditioned in storage piles for at least 6 months after excavation.

2) Sand - clean and free of toxic materials.

3) Vermiculite - horticultural grade and free of toxic substances.

- Vegetation

Select an appropriate species or species mixture from Table 1.

- Seeding

Should be taken into account when scheduling land-disturbing activities.

Use certified seed. Each bag of seed must be labeled with a bag tag showing percent pure seed, percent germination (including hard seed), and percent weed seed. The information on the bag tag shall be from a seed test made within six (6) months prior to the date of planting.

Apply seed uniformly with a cyclone seeder, drop-type spreader, drill, cultipacker seeder, or hydroseeder on a firm, friable seedbed.

When using a drill or cultipacker seeder, plant small grains no more than 1-inch deep, grasses and legumes no more than ¼ inch. Equipment should be calibrated in the field for the desired seeding rate.

When using broadcast-seeding methods, subdivide the area into workable sections and determine the amount of seed needed for each section. Apply one-half the seed while moving back and forth across the area, making a uniform pattern; then apply the second half in the same way, but moving at right angles to the first pass.

Cover broadcast seed by raking or chain dragging; then firm the surface with a roller or cultipacker to provide good seed contact.

Mulch all plantings immediately after seeding (see MULCHING practice).

- Hydroseeding

  Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage for lime, fertilizer, and seed. The surface should not be compacted or smooth. Fine seedbed preparation is not necessary for hydroseeding operations; large clods, stones, and irregularities provide cavities in which seeds can lodge.

- Sprigging

  Some hybrid grasses cannot be grown from seed and must be planted vegetatively. Vegetative methods of establishing these include sodding, plugging and sprigging. Sprigs are fragments of horizontal stems, which include at least one node (joint).

  Furrows should be 4-6 inches deep and 2 feet apart. Place sprigs about 2 feet apart in the row with one end at or above ground level.

  Broadcast sprigs at the specified rate. Press into the top 1/2-2 inches of soil with a cultipacker or with a disk set nearly straight so that the sprigs are not brought back to the surface.

- Irrigation

  Moisture is essential for seed germination and seedling establishment. Supplemental irrigation can be very helpful in assuring adequate stands in dry seasons or to speed development of full cover. It is a requirement for the fine turf establishment and should be used elsewhere when feasible.

  However, irrigation is rarely critical for low-maintenance vegetation planted at the appropriate time of the year. Water application rates must be carefully controlled to prevent runoff. Inadequate or excessive amounts of water can be more harmful than no supplemental water.

<u>Common Trouble Points</u>

Inadequate seedbed preparation.

Unsuitable choice of plant materials.

<u>Operation and Maintenance</u>

Generally, a stand of vegetation cannot be determined to be fully established until soil cover has been maintained for one full year from planting. Inspect seeded areas for failure and make necessary repairs and re-seedings.

If vegetation fails to grow, soil must be tested to determine if acidity or nutrient imbalance is responsible.

If a stand has less than 40% cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following seedbed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results.

Table 1. Recommended Species for Permanent Seeding

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Bermudagrass*	60	1.5
Ryegrass	40	1
Bermudagrass	60	1.5
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Ciempiés*	20	0.5
Ryegrass	40	1
Ciempiés	20	0.5
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Bahiagrass*	40	1
Ryegrass	40	1
Bahiagrass	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Carpetgrass*	40	1
Ryegrass	40	1
Carpetgrass	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Zoyzia*	40	1
Ryegrass	40	1
Zoyzia	40	1
Brown Top Millet	60	1.5

Seeding Mixtures	Seeding Rate lbs/acres	Seeding Rate lbs/1000 sq.ft.
Dallis*	20	0.5
Ryegrass	40	1
Dallis	20	0.5
Brown Top Millet	60	1.5

* Springgs planting rate 1,500 lb/acre

Maximum seeding depth should be 1/4 inch on clay soils and 1/2 inch on sandy soils.

Brown Top Millet and Ryegrass are annual grasses (commercially available) that will create favorable conditions for establishment of the perennial grasses.

Name		
English	Spanish	Scientific
Bahia grass	Yerba Bahía	*Paspalum notatum*
Bermuda grass	Yerba Bermuda	*Cynodon dactylon*
Browntop millet		*Urochloa ramosa*
Carpet grass	Grama colorada	*Axonopus compressus*
Centipede grass	Ciempiés	*Eremochloa ophiuroides*
Dallis grass	Yerba Dalis	*Paspalum dilatatum*
Ryegrass		*Lolium perenne*
Zoyzia	Zoisia	*Zoysia* spp.

3.4.7 Sodding

Definition

Permanently stabilizing areas by laying a continuous cover of grass sod.

Purpose

To prevent erosion and damage from sediment and runoff by stabilizing the soil surface with permanent vegetation where specific goals might be to:

Provide immediate vegetative cover of critical areas.

Stabilize disturbed areas with a suitable plant material that cannot be established by seed.

Stabilize drainage ways and channels and other areas of concentrated flow where flow velocities will not exceed that specified for a grass lining.

Where Sodding is Used

Disturbed areas which require immediate and permanent vegetative cover, or where sodding is preferred to other means of grass establishment. Locations particularly suited to stabilization with sod are:

Waterways and channels carrying intermittent flow at acceptable velocities.

Areas around drop inlets, when the drainage area has been stabilized.

Residential or commercial lawns and golf courses where prompt use and aesthetics are important.

Steep critical areas.

Planning Considerations

The practice of sodding for soil stabilization eliminates both the seeding and mulching operations and is a much more reliable method of producing adequate cover and sediment control.

Advantages of properly installed sod include:

Immediate erosion and dust control.

Nearly year-round establishment capability.

Less chance of failure than with seedings.

More freedom from weeds.

Rapid stabilization of surfaces for traffic areas, channel linings, or critical areas.

Improve aesthetics.

Sod can be laid during times of the year when seeded grasses may fail, provided there is adequate water available for irrigation in the early weeks. Irrigation is essential at all times of the year to install sod. It is initially more costly to install sod than to plant seed. However, the higher cost may be justified for specific applications where sod performs better than seed.

In waterways and channels that carry concentrated flow, properly pegged sod is preferable to seed because it provides immediate protection. Drop inlets placed in areas to be grassed can be protected from sediment by placing permanent sod strips around the inlet (Storm Drain Inlet Protection). Sod also maintains the necessary grade around the inlet.

Because sod is composed of living plants that must receive adequate care, final grading and soil preparation should be completed before sod is delivered. If left rolled or stacked, heat can build up inside the sod, causing severe damage and loss of costly plant material.

Plans and Specifications

Plans for installing sodding shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve the intended purpose.

Specifications for applying and installing sodding shall use or be in conformance with the following. Any variation from these specifications shall be approved by an engineer.

- Choosing appropriate types of sod.
  The type of sod selected should be composed of plants adapted to both the site and the intended purpose. In Puerto Rico, these are limited to Bermuda grass, St. Augustine grass, Centipede grass, Bahía grass, Carpet grass and Zoyzia grass.

Table 1. Vegetation for Sodding

Name			Soil Permeability			Tolerant				
Spanish	English	Technical	Well	Mod	Fair	Acid	Salinity	Shade	Drought	Wear
San Agustín	St. Agustine grass	*Stenotaphrum secundatum*	x	x		No	Light	Good	Fair	Good
Ciempiés	Centipede grass	*Eremochloa ophiuroides*	x	x		Yes	No	Fair to Poor	Fair	Fair
Grama zoisia	Zoyzia grass	*Zoysia sp.*	x	x		Yes	Yes	Good to Fair	Good	Good
Yerba bahía	Bahia grass	*Paspalum notatum*	x	x		Yes	Fair	Good to Fair	Good	Good
Bermuda	Common bermuda	*Cynodon datylon*	x	x		Yes	Yes	Poor	Good	Good
Grama colorada	Carpet grass	*Axonopus compressus*		x	x	Yes	No	Good	Very Poor	Fair

Quality of sod -Use only high-quality sod of known genetic origin, free of noxious weeds, disease, and insect problems. It should appear healthy and vigorous, and conform to the following specifications:

1) Sod should be machine cut at a uniform depth of 1/2 - 2 inches (excluding shoot growth and thatch).
2) Sod should not have been cut in excessively wet or dry weather.
3) Sections of sod should be standard and uniform.
4) Sections of sod should be strong enough to support their own weight and retain their size and shape when lifted by one end.
5) Harvest, delivery, and installation of sod should take place within a period of 36 hours.

- Soil preparation.
  Test soil to determine the exact requirements for lime and fertilizer. Do not apply fertilizer and lime mixed. Fertilizer should be spread evenly over the area and incorporated into the top 4-8 inches of soil by disking, harrowing, or other effective means. If topsoil is applied, follow specifications given in the Topsoiling 3.4.2. Prior to laying sod, clear the soil surface of trash, debris, roots, branches, stones, and clods larger than 2 inches in diameter.

  Fill or level low spots in order to avoid standing water. Rake or harrow the site to achieve a smooth and level final grade.

  Complete soil preparation by rolling or cultipacking to firm the soil. Avoid using heavy equipment on the area, particularly when the soil is wet, as this may cause excessive compaction and make it difficult for the sod to take root.

- Sod installation.
  A step-by-step procedure for installing sod is described below.

  1) Moistening the sod after it is unrolled helps maintain its viability. Store it in the shade during installation.

2) Rake the soil surface to break the crust just before laying sod. During the summer, lightly irrigate the soil immediately before laying the sod to fresh the soil and reduce root burning and dieback.

3) Do not sod on gravel or soils that have been treated recently with sterilants or herbicides.

4) Lay the first row of sod in a straight line with subsequent rows placed parallel to and butting tightly against each other. Lateral joints shall be staggered to promote more uniform growth and strength. Stagger strips in a brick-like pattern. Be sure that the sod is not stretched or overlapped and that all joints are butted tightly to prevent voids. Use a knife or sharp spade to trim and fit irregularly shaped areas.

5) Install strips of sod with their longest dimension perpendicular to the slope. On slopes 3:1 or greater, or wherever erosion may be a problem, sod shall be laid with long edges parallel to contour and with staggered joints. Secure sod with pegs or staples or other approved method.

6) As sodding of clearly defined areas is completed, roll sod to provide firm contact between roots and soil.

7) Sod shall be watered immediately after rolling or tamping until the underside, of the new sod pad and soil surface below the sod are thoroughly wet.

8) Keep sodded areas moist until the grass takes root. This can be determined by gently tugging on the sod-resistance indicates that rooting has occurred.

9) Mowing should not be attempted until the sod is firmly rooted, usually 2-3 weeks, when good climate conditions prevail.

- Sodded waterways.

Sod provides a resilient channel lining, providing immediate protection from concentrated runoff and eliminating the need for installing mats or mulch. The following points apply to the use of sod in waterways:

1) Properly prepare the soil. The sod type must be able to withstand the velocity of flow specified in the channel design.

2) Lay sod strips perpendicular to the direction of flow, with the lateral joints staggered in a brick-like pattern. Edges should butt tightly together.

3) After rolling or tamping to create a firm contact, peg or staple individual sod strips to resist washout during establishment. Jute or other netting material may be pegged over the sod for extra protection on critical areas.

Common Trouble Points

Sod laid on poorly prepared soil or unsuitable surface; grass dies because it is unable to root.

Sod not adequately irrigated after installation; lack of water may cause root dieback or grass may not root properly because of dry conditions.

Sod not anchored properly; unanchored sod may be loosened by runoff.

Equipment allowed traveling over sodded area or materials are stored on sod; the sod may become damaged or destroyed.

Operation and Maintenance

Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.

After the first week, water as necessary to maintain adequate moisture in the root zone and prevent dormancy of the sod.

Do not remove more than one-third of the shoot in any mowing. Grass height should be maintained between 2 and 3 inches unless otherwise specified.

3.4.8 Filter Strip

Definition

Created or preserved vegetated strip located down slopes of disturbed areas and designed to remove sediment, other pollutants and to enhance the infiltration of surface water runoff.

Purpose

The principal purpose of this practice is to remove sediment and other pollutants from runoff water by filtration, deposition, infiltration, absorption, and vegetative uptake, see Figure 1. Another purpose is to reduce runoff quantities from impervious surfaces by infiltrating it into the ground.

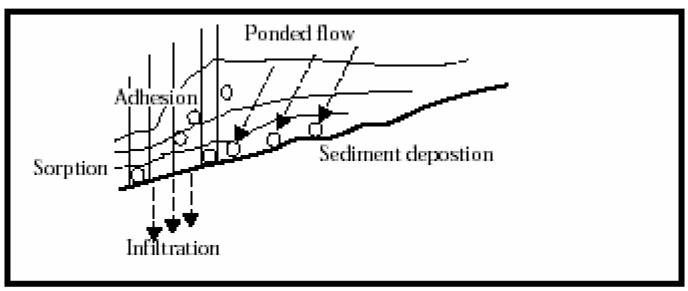


Figure 1. Trapping Mechanisms of Contaminants in Filter Strip

Where Filter Strip is Used

This practice may be applied in a variety of urban land uses where surface water runoff is discharged as overland sheet flow; **not** concentrated flows. Filter strip, when implemented as treatment control measure alone, requires significant land area. Some typical locations of vegetated filter strips include:

On construction sites and land undergoing development to filter sediment from overland sheet flow.

Adjacent to roadways, parking lots, and other impervious surfaces to filter and convey runoff before it is discharged to swales, storm sewers, or surface water bodies.

Lawns where roof downspouts are discharged to disperse and infiltrate runoff.

Adjacent to wetlands, streams, ponds or lakes, or conservation practices to provide the runoff mitigation benefits described above and to serve as a wildlife habitat buffer.

The soils are important parameter in judging filter effectiveness. Filter strip located on hydrologic soil groups C and D are less effective in treating runoff than filter areas on A and B soils. See Appendix A.4 for Puerto Rico Hydrologic Soil Groups.

Hydrologic Soil Group (NRCS)	Filter Strip Effective
"A"	Good
"B"	Good
"C"	Poor
"D"	Poor

Criteria

Drainage area.
The maximum contributing upland drainage area to a filter strip shall be 5 acres.

Slope.
Should not be used on slopes greater than 15%.

Width.
Filter strip should be sized according to the individual characteristics of the site, taking into account the size of the area to be drained and the slope of the land that they are located on.

Width is measured in the direction of flow (see Figure 2). Since filter strips are placed along the contour, as much as possible, their dimension at the narrow point is called *width*. The flow of water moves parallel with the width. The *length* of a filter strip is the longitudinal distance across the landscape that the strip occupies perpendicular to the direction of flow. Other terms, such as flow length, may be used to depict the direction of flow.

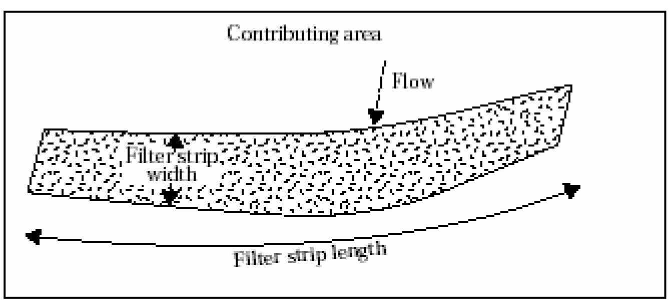


Figure 2. Width and Length in Filter Strip

For areas not adjacent to permanent water body, filter strip of 15 ft. (4.5m) for slope less than 10% will be maintained on perimeter of construction sites. Add additional 4 feet for each percent of slope at site up to 15%.

Activities adjacent to permanent water body represent the most stringent requirement that applies to filter strips. For this case width greater than the minimum or buffer zones must be considered. The following table provides guidance.

Suggested Filter Strip width based on percent of slope for areas adjacent to permanent water body*	
Land slope, %	Strip width, Feet
0-4	20
5-6	30
6-9	40
10-13	50
14-15	60
*Width is for grass and legume species only and not intended for shrub and trees species. Adapted from USDA-NRCS, Indiana	

Length.
Same as the contributing area (see Figure 2).

Flow.
Maintaining sheet flow is critical to the proper operation of filter strip. To ensure that concentrated flow is eliminated before runoff enters the filter strip, a level spreader must be constructed at the top of the filter strip. These devices disperse flows over a wide area, dissipating the energy of the runoff and creating sheet flow.

The maximum flow velocity through the filter strip shall be calculated for the 10-year frequency, 24-hour duration storm event and shall not exceed the maximum permissible velocities as described in GRASSED WATERWAY practice.

Vegetation.
Should be fully established before construction site preparation (cutting, filling and grading) and its runoff directed onto the filter strip. Where this is not possible, the filter strip shall be vegetated with sod.

Filter strip only provide effective erosion control once the vegetation is densely established. The minimum stem densities required for filter strip are:

Stem diameter (inches)	Number of stems (stems per square foot)
0.10	50
0.25	25
0.50	12
0.75	8
1.0	5

Vegetation shall follow the requirements of practice standard PERMANENT SEEDING (3.4.6) and be protected with an erosion control blanket meeting the requirements of the practice standard. Mulch meeting the requirements of practice standard MULCHING 3.4.3. In place of permanent seeding, the filter strip may be vegetated with sod following the requirements of practice standard SODDING. For species selections see Table 1.

Considerations

Ideally, filter strips function best on slopes 15% or less. However, on slopes 1% or less, vegetation used should be tolerant of saturated soil conditions.

It is critical that appropriate soil stabilization materials be applied immediately after seeding on all vegetative filter strips to minimize rill development during cover establishment. Due to the added runoff volumes coming from the impervious surfaces, an erosion control blanket will be necessary in most installations. Mulch may be adequate on relatively flat slopes where the contributing drainage area is small. In addition to stabilizing soils, these materials should significantly aid seed germination and early plant establishment.

Native or naturalized vegetation should be used if possible. Native or naturalized vegetation has distinct advantages over turf grass, including denser, deeper root structure to enhance infiltration; reduce maintenance needs (particularly less need for herbicides and fertilizer); and enhance wildlife habitat.

Protect the filter strips from heavy foot and vehicular traffic during construction to prevent compaction and loss of infiltration capacity.

Table 1. Recommended Plants for Establishing Filter Strip

Name		Soil Permeability			Tolerant		Planting method minimum rate		
Spanish/English	Scientific	Well	Mod	Poor	Acid	Salinity	Stolon (lbs/ac)	Seeds (lbs/ac)	Seeds (lbs/1000 p^2)
Grama colorada/ Carpet grass [(a)]	*Axonopus compressus*		*x*	x	Yes	No	1,500	40	1
Malojilla/Carib grass	*Eriochloa polystachya*		*x*	x	Yes	No	1,500	--	--
Malojillo/Para grass	*Urochloa mutica*		*x*	x	Yes	Fair	1,500	5	0.12
Matojo de playa/Saltgrass	*Sporobolus virginicus*	x			No	Yes	1,500	--	--
Pajón/Railroad-track grass	*Dichanthium annulatum*	x	x		No	Fair	--	20	0.5
Rhodes grass	*Chloris gayana*	x	x		No	Fair	1,500	9	0.2
Signal/Signal grass	*Urochloa brizantha*	x	x		Yes	No	1,500	6	0.14
Táner/Tanner grass	*Urochloa arrecta*		x	x	Fair	No	1,500	--	--
Yerba Bahía/Bahia Grass [(a)]	*Paspalum notatum*	x	x		Yes	Fair	1,500	40	1
Yerba Bermuda/Common Bermuda [(a)]	*Cynodon dactylon*	x	x		Yes	Yes	1,500	60	1.5
Yerba Buffel/Buffel grass [(b)]	*Pennisetum ciliare*	x			No	Fair	--	6	0.14
Yerba Dalis/Dallis grass	*Paspalum dilatatum*	x	x		Yes	No	1,500	20	0.5
Yerba Estrella/Star grass	*Cynodon nlemfuensis*	x	x		Fair	Fair	1,500	--	--
Yerba Huracán/Hurricane grass [(b)]	*Bothriochloa pertusa*	x	x		Fair	Fair	--	6	0.14
Yerba Pangola/Pangola grass	*Digitaria eriantha*	x	x		Yes	No	1500	--	--

(a) Sod
(b) By clump division

The filter strip area should be cleared of trees, stumps, brush, rocks, and similar materials if they are likely to interfere with installation of the filter strip (e.g., cause short-circuiting or concentrations of flow).

Ideally, uniform, well-vegetated strips of natural/native vegetation should be preserved as filter strips since their infiltration capacities are likely to be greater if grading is avoided.

On construction sites and other areas with bare soil where the filter strip is being used as a temporary sediment control technique, it is critical that temporary stabilization be applied to exposed soils and that concentrated flow through the filter strip be avoided. If the potential for concentrated flow exists, consideration should be given to construction of other sediment control practices above the filter strip. These practices shall meet the requirements of practice standards found in this Handbook such as TEMPORARY SEDIMENT TRAP and SILT FENCES.

Plans and Specifications

Plans and specifications for installing filter strips shall be in keeping with the above criteria and shall describe the requirements for applying the practice to achieve its intended purpose. At a minimum include the following items:

- Location of the practice.
- Length and width of the filter strip.
- Slope of the filter strip.
- Required appurtenant practices such as level spreaders or temporary sediment basins.
- Grading requirements, topsoil stockpiling and utilization requirements.
- Soil preparation, seeding and temporary soil stabilization (i.e., erosion control blanket or mulching) requirements.

All plans shall include installation, inspection, and maintenance schedules with the responsible party identified.

Common Trouble Points

Improper planting distance or strips have poor vegetative cover.

Inadequate irrigation.

Lack of remedial measures for repair and maintenance.

Design slope has exceeded the recommended fifteen percent.

Design width of slopes has been to narrow to adequately service the contributing area.

Operation and Maintenance

On active construction sites, the filter strip shall be inspected at least once every 7 days and within 24 hours of a rainfall of 0.5 inches or more.

After construction, filter strips should be inspected during and after major storm events, particularly during the first one or two years.

After the first one or two years, the filter strip may be inspected after major storm events.

Filter strips should be inspected for proper distribution of flows and signs of erosion.

The filter strips should be kept free of litter.

Irrigation needs should be minimal except during extended dry periods.

If erosion is discovered, the eroded areas should be filled, reseeded, and mulched. Then the causes for the erosion should be determined and prevented from recurring.

Maintain the vegetation dense stand.

Caution should be used when applying herbicides to filter strips or adjacent areas to minimize pollution to the water resources being protected.

Filter strips vegetated with native or naturalized species should be managed through mowing once every two to three years, after the vegetation is established.

Mowing should only be performed during dry periods using lightweight equipment to prevent soil compaction and damage to vegetation.

Filter strips that have accumulated so much sediment that they are higher than adjacent areas should be disked or graded as necessary to reestablish shallow sheet flow conditions, and be reseeded.

3.4.9 Vegetative Barriers

Definition

Herbaceous vegetation established in strips or rows at determined intervals across the slope.

Purposes

Reduce erosion by water.

Slow runoff flow.

Entrap sediment.

Produce forage and other vegetative materials.

Increase water infiltration.

Where Vegetative Barriers are Used

On land subject to water erosion or where movement of soil constitutes a resource concern.

Criteria

The following criteria, unless noted, applies to all purposes of this practice.

- Criteria for the placement of the vegetative row barriers:

  1) Maximum slope to be established with vegetative row barriers is 50%.

  2) The spacing along the horizontal distance (see Figure 1) of the slope shall be as follows:

Ave. Field Grade (Percent)	Maximum Spacing (Feet)
11 or less	40
12 - 24	35
24 - 40	25
41 - 50	20

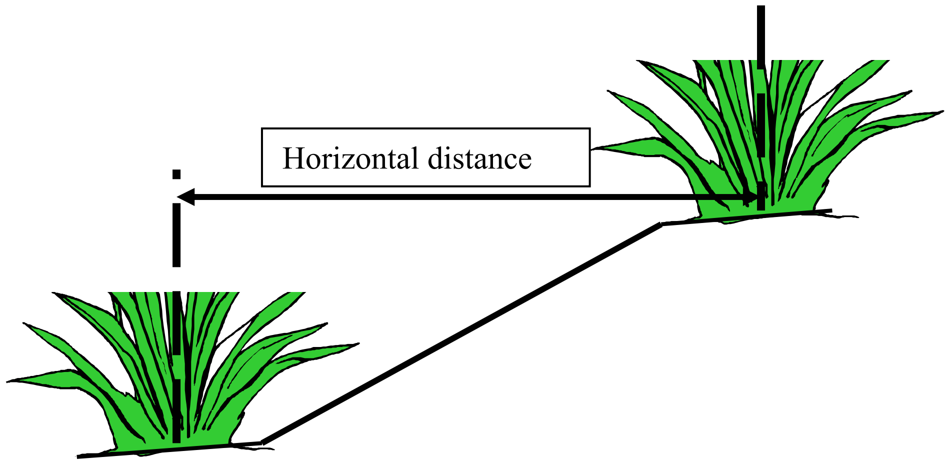


Figure 1. Horizontal Distance

3) Barriers will be established at intervals across the slope as nearly as possible to the contour.

4) Drainage ways will be left undisturbed except for elimination of undesirable plant species.

- Criteria for establishment of vegetative barriers:

  1) Land preparation for planting vegetative barriers will be done when adequate soil moisture is available to remove brush and weed vegetation with minimum soil disturbance.

  2) Vegetation must be established before months of May and September to October when the erosive rainfall occurs.

  3) Fertility of the soil must be amended if needed to meet the nutritional requirements of the vegetative barrier species. Follow guidance of soil test recommendation.

  4) Species must be adaptive to the site. Select species from table below. Other species may be considered if they possess the desired vegetative barrier traits.

  5) Planting rate, density and method shall conform to the following table.

Table 1. Planting Method to Establish Vegetative Barriers

	Name: Spanish/English	Name: Scientific	Acid Soil Tolerant	Salinity Soil Tolerant	Habit growth	Planting Method and Minimum Rate (ac)	Type of Planting	Row spacing (inches)	Within row spacing (inches)	Minimum Size of Planting Stock
Grass	Bambú/Bamboo	*Bambusa spp*	Yes	Fair	Bunch	Clump division. [a]	Continuos row	6	3-6	2 nodes/steam
	Caña de azúcar	*Saccharum officinarum*	No	Fair	Bunch	Stem cutting, 2000 lbs	Double stem within row, alternated nodes	6	6	2 nodes/steam
	Caña guajana	*Arundo donax*	Fair	Fair	Bunch	Stem cutting, 2000 lbs	Double stem within row, alternated nodes	6	6	2 nodes/steam
	Elefante/Elephant grass [b]	*Pennisetum purpureum*	Fair	No	Bunch	Stem cutting, 2000 lbs	Double stem within row, alternated nodes	6	6	2 nodes/steam
	Guinea/ Guinea grass	*Urochloa maxima*	Fair [c]	No	Bunch	Seed 25 lbs or clump division [d]	Continuos single row	6	6	8 inches or 2 nodes/steam
	Limoncillo/Lemon grass	*Cymbopogon citratus*	Fair	No	Bunch	Clump division	Continuos row	6	6	8 inches or 2 nodes/steam
	Pacholí/Vetiver grass	*Vetiveria zizanioides*	Yes	Low	Bunch	Clump division	Continuos row	N/A	2-4	8 inches
Forb	Aloe	*Aloe vera*	No	Yes	Clump	Single plant	Continuos row	N/A	3	N/A
	Lengua de suegra, Chucho	*Sansevieria spp.*	Yes	Fair	Clump	Clump division	Continuos row	N/A	3	8 inches or 2 nodes/steam

(a) Rate varies per species
(b) All varieties including Mott dwarf elephant grass
(c) Variety gramalota is high acid soil tolerant
(d) Depending on variety

Table 2. Recommendations for Vegetative Barrier Maintenance

Name		Barrier Height (in)	Number of stems (Ln.ft)	Minimum Stubble Height (in)	Cutting Frequency (day)
Spanish/English	Scientific				
Bambú/Bamboo	*Bambusa spp*	Varies per species		>12	(a)
Caña de azúcar	*Saccharum officinarum*	24	12	18	50
Caña guajana	*Arundo donax*	24	12	18	50
Elefante/Elephant grass* (b)	*Pennisetum purpureum*	24	12	18	50
Guinea/ Guinea grass (b)	*Urochloa maxima*	24	12-24	10	30
Limoncillo/Lemon grass	*Cymbopogon citratus*	24	12-24	10	30
Pacholí/Vetiver grass	*Vetiveria zizanioides*	24	12-24	18	90
Aloe (c)	*Aloe vera*	>12	>5	10	N/A
Lengua de suegra, Chucho	*Sansevieria spp.*	>12	>5	10	N/A

(a) As needed. Includes prunning, fertilizer and liming.
(b) Use carefully-high potential to invade.
(c) For very dry areas/ No other options are suitable
* All varieties included Mott dwarf elefant grass

Common Trouble Points

Improper planting distance.

Inadequate irrigation.

Lack of remedial measures for repair and maintenance.

Operation and Maintenance

Criteria for operating and maintaining the vegetative barrier:

Follow the recommendations in the table below for Barrier Height, Density, Minimum Stubble Height and Cutting Frequency.

Delay cutting of vegetative barrier if density of the specific species has been attained. This material could be deposited as mulch at the upper edge of the barrier.

Frequency of vegetation cutting shall be determined by onsite needs.

The formation of seeds on the barrier vegetation is to be discouraged. Vegetation will be cut on a maintenance schedule to prevent seed formation.

Vegetative growth will be contained within the barrier row. Tillage or other mechanical or chemical control will be used to control vegetative growth outside the barrier row.

Maintenance of barrier after damage will be performed (excess sediment removal, repair of gullies, planting replacements) as needed.

Planning and Considerations

Evaluate slope, soil, esthetic landscape, growth, development characteristics, and fire hazard before designing the vegetative barrier.

Select species for runoff and sediment control.

Establish companion strip of vegetation, and/or mulch, during establishment of vegetative barrier to provide protection against sediment and concentrated flow.

Plans and Specifications

Plans and specifications to establish the vegetative barrier shall be keeping with the above criteria and shall describe the requirements for applying the practice to achieve its intended purpose. At a minimum the following items are to be included:

Location

Slope of the vegetative barrier

Selected species

Planting spacing

Planting method

Fertility needs

Row grade

Site preparation

Planting date

Maintenance requirements and any other important factor

3.4.10 Riparian Forest Buffer

Definition

An undisturbed area or strip of natural vegetation or an established suitable planting, which will provide a living filter to reduce soil erosion and runoff velocities.

Purpose

Provide critical habitat adjacent to streams and wetlands, as well as assist in controlling erosion, especially on unstable steep slopes.

Act as a visibility and noise screen.

Reduce or deter the effects of nutrients, sediment, organic materials, pesticides or other detrimental substance prior to entry into surface waters and ground water recharge areas.

Increase potential for stream bank stabilization. (See Appendix B, Streambank and Shoreline Protection, National Engineering Handbook, Part 650 – Engineering Field Handbook, Chapter 16).

Where Riparian Forest Buffer is Used

This practice applies on areas adjacent to permanent or intermittent streams, at the margins of lakes, at the margins of ponds, where:

Water quality is impaired and adjacent land use contributes to the degradation.

Wildlife habitat enhancement is desired.

Good water quality exists and protection against future impairment is desired.

Stream banks erosion is a concern.

Improvement in stream banks temperature (shading) or woody structure is desired for aquatic production.

General Planning Considerations

Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.

Leave all unstable steep slopes in natural vegetation.

Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.

Keep all excavations outside the dripline of trees and shrubs.

Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.

Criteria

Riparian forest buffers will be designed to encourage sheet flow and infiltration and impede concentrated flow. The location, layout and density will accomplish the intended purpose and function. Depending upon purpose, riparian forest buffers will consist of three zones.

- Zone 1 will begin at the normal water line, or at the top of a bank, and extend for all purposes a minimum of 15 feet measured horizontally on a line perpendicular to water body.

  Dominant vegetation will consist of existing or planted trees, shrubs and grass species and such plantings as necessary for stream bank stabilization during establishment period. Indigenous species are preferred but other species can be used. Nitrogen fixing species should be discouraged where nitrogen removal or buffering is desired. (See Table on page 87).

- Zone 2 consists of an additional strip of land beginning at the outer edge of Zone 1. For all purposes, Zone 2 will occupy a minimum width of 20 feet measured horizontally on a line perpendicular to the water body or as specified. The width must be increased in areas with high production of sediment or nutrients.

  Pre-dominant vegetation will be composed of existing or planted riparian trees and shrubs suitable to the ecosystem (See Table on page 88). Indigenous multipurpose tree species are preferred but other species can be used. Nitrogen fixing species should be discouraged where nitrogen removal or buffering is desired.

- Zone 3 will begin at the outer edge of Zone 2 and have a minimum width of 20 feet measured horizontally on a line perpendicular to the water body. This Zone may not be needed for all purposes. It is requirement when: a) there is an area where high erosion is evident or potential to occur and, b) where ephemeral concentrated flows need to be converted back to sheet flows.

  Zone widths (stream side zones) may vary depending mainly on slope of land between disturbed area and stream or other body, but not less than the minimum distances for each zone.

  Vegetation will be composed mainly of dense grasses and forbs. Mow or harvest as necessary to recycle sequestered nutrients, promote vigorous sod and control weed growth.

Buffer widths (stream side zones), may vary depending mainly on slope of land between disturbed area and stream or other water body, but not less than the minimum distances for each zone.

Minimum Spacing Criteria for Riparian Forest Buffer Zones[a/]

Slope %	Recommended Width/Zone (feet) 1	2	3	Total
0-15	15	20	20	55
20	19	23	23	65
25	21	27	27	75
30	23	31	31	85
35	25	35	35	95
40	29	38	38	105
45	33	41	41	115
50	35	45	45	125
55	37	49	49	135
60+	41	52	52	145

[a/] For intermittent channels use minimum width.

To maintain biodiversity within the ecosystem, use Zone 1 and Zone 2. Concentrated or pipe flows needing treatment must be converted to sheet flow or subsurface flows. Outflow from subsurface drains needing treatment must not be allowed to pass through the riparian forest in pipes or tile thus circumventing the treatment process.

Plans and Specifications

Plans and specifications shall be in keeping with this management practice and shall describe the specific requirements for properly establishing, managing and maintaining the Riparian Forest Buffer. Use narrative statements in the plan, or other acceptable documentation. For recommended species for each zone, see attached tables. Bioengineering vegetative measures are encouraged. See Appendix B, Soil Bioengineering for Upland Slope Protection and Erosion Reduction, National Engineering Handbook, Part 650 – Engineering Field Handbook, Chapter 18.

Consider the type and quantity of potential pollutants that will be derived from the drainage area.

Select preferably indigenous species adapted to the soils and site factors and their ability to achieve multiple benefits. Preservation of native streamside vegetation community is important for stream bank protection.

Do not select species that can create a hazard for endangered species in the site like shelter and fodder for predators.

Vegetation should remain undisturbed except for removal of trees that represent a hazard to stream bank stability, or individual trees of high value.

Consider provisions for mowing and removing vegetation.

Deposit removed material a sufficient distance from the stream so that it will not be redeposited by high water into the stream.

The use of this practice without other conservation practices can result in adverse impacts on buffer vegetation and hydraulics. The expected adverse impacts could be high maintenance costs, periodic need for reestablishment of vegetation, and the delivery of excess nutrients, sediment and other potential pollutants through the buffer by concentrated flows.

Consideration must be given to the sequence of practice application needed to protect the riparian forest buffer where erosion or pollutant rates might prohibit the buffers successful establishment.

The location, layout and density of the buffer should compliment natural features.

<u>Common Trouble Points</u>

Inadequate plant selection.

Lack of remedial measures for repair and maintenance.

<u>Operation and Maintenance</u>

Riparian forest buffers must be inspected periodically and protected to maintain the intended purpose from adverse impacts such as: severe storm, excessive vehicular or pedestrian traffic, pest infestation, dumping, pesticide and fertilizer used on adjacent land, and damage.

Replacement of dead trees and shrubs, and control of undesirable vegetation will be continued until the buffer is, or will progress to, a fully functional condition.

The removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives must be avoided.

Zone 1 Recommended Species for Riparian Forest Buffers

	Name			Suitable	
	Spanish	English	Scientific	Dry	Humid
GRASS	Arrocillo	Gulf cockspur grass	*Echinochloa crusgalli*		x
	Bambú	Bamboo	*Bambusa vulgaris*	x	x
	Caña brava	Wildcane	*Gynerium sagittatum*		x
	Malojilla	Caribgrass	*Eriochloa polystachya*		x
	Malojillo	Paragrass	*Urochloa mutica*		x
	Redecilla	Seashore papalum	*Paspalum vaginatum*		x
	Yerba acuática	American cupscale	*Sacciolepis striata*		x
	Yerba acuática	Aquatic grass	*Panicum aquaticum*		x
	Yerba de pantano	Water panicum	*Paspalidium geminatum*		x
	Yerba de río	Creeping river grass	*Echinochloa polystachya*		x
	Yerba trompetilla	West Indian marsh grass	*Hymenachne amplexicaulis*		x
FORB	Alpinia	Red ginger	*Alpinia spp.*		x
	Cohitre	Climbing day flower	*Commelina diffusa*		x
	Gengibre antorcha	Grand turmeric	*Etlingera elatior*		x
	Malanga	Coco yam	*Colocasia esculenta*		x
	Yerba cangá	Mexican primrosewillow	*Ludwigia octovalvis*		x
SHRUB	Corazón cimarrón	Pond apple	*Annona glabra**		x
	Higuillo		*Piper aduncum*		x
	Mangle blanco	White mangrove	*Laguncularia racemosa*		x
	Mangle rojo	American mangrove	*Rhizophora mangle*		x
	Uva playera	Sea grape	*Coccoloba uvifera*	x	x
	Uvilla		*Coccoloba costata*	x	x
TREE	Arrayán	Dwarf bayberry	*Myrica cerifera*		x
	Ausubo	Bulletwood	*Manilkara bidentata*		x
	Bucayo	Mountain immortelle	*Erythrina poeppigiana*		x
	Bucayo enano	Erythrina	*Erythrina berteroana*		x
	Cacaillo	Sloanea	*Sloanea berteriana*		x
	Camasey		*Miconia prasina*	x	
	Capa blanco	Bastard stopper	*Petitia domingensis*	x	
	Cobana negra		*Stahlia monosperma*	x	x
	Emajagua	Sea hibiscus	*Hibiscus pernanbucensis*		x
	Emajaguilla	Portia tree	*Thespesia populnea*	x	x
	Guaraguao	American musk wood	*Guarea guidonia*	x	
	Guava	River koko	*Inga vera*	x	
	Mangle botón	Button mangrove	*Conocarpus erectus*		x
	Mangle negro	Black mangrove	*Avicennia germinans*		x
	María	Antilles calophyllum	*Calophyllum calaba*		x
	Moca	Cabbagebark	*Andira inermis*	x	x
	Palma de sierra	Sierran palm	*Prestoea montana*		x
	Palma real	Puerto Rico royal palm	*Roystonea borinqueña*		x
	Palo colorado	Swamp titi	*Cyrilla racemiflora*		x
	Palo de pollo	Dragon's blood tree	*Pterocarpus officinalis*		x
	Pomarrosa	Melabar plum	*Syzygium jambos*		x
	Pterocarpus	Pterocarpus	*Pterocarpus indicus*		x
	Ucar	Black olive	*Bucida buceras*	x	
	Yagrumo hembra	Pumpwood	*Cecropia peltata*		x
	Yagrumo macho	Matchwood	*Didymopanax morototoni*		x
	Yuquilla		*Didymopanax gleasonii*		x

Plants of dry areas are adapted to humid or wet places of those sites such as: ravines and creeks.
*Growth habit (Shrub or tree)

Zone 2 Recommended Species for Riparian Forest Buffers

	Name			Suitable	
	Spanish	English	Scientific	Dry	Humid
GRASS	Bambú	Bamboo	*Bambusa vulgaris*	x	x
	Limoncillo	Lemon grass	*Cymbopogon citratus*		x
	Malojilla	Caribgrass	*Eriochloa polystachya*		x
	Malojillo	Paragrass	*Urochloa mutica*		x
FORB	Alpinia	Red ginger	*Alpinia spp.*		x
	Anturio	Laceleaf	*Anthurium* spp.		x
	Cohitre	Climbing day flower	*Commelina diffusa*		x
	Culantro	Coriander	*Coriandrum sativum*		x
	Llantén	Common plantain	*Plantago major*		x
	Mejorana	False thyme	*Lippia micromera*	x	x
	Parcha	Golden bellapple	*Passiflora laurifolia*	x	x
	Perejil	Parsley	*Petroselinum crispum*		x
	Plátano de Indio	Lobsterclaw	*Heliconia spp.*		x
	Romero	Rosemary	*Rosmarinus officinalis*		x
	Zamia	Coontie	*Zamia* spp.		x
SHRUB	Achiote	Lipsticktree	*Bixa orellana*	x	
	Albahaca	Sweet basil	*Ocimum basilicum*		x
	Anón	Sugar apple	*Annona squamosa**	x	x
	Canela	Pepper cinnamon	*Canella winteriana*	x	
	Cítricas	Citrus	*Citrus spp.**		x
	Guanábana	Soursop	*Annona muricata**	x	x
	Mabí	Soldier wood	*Colubrina elliptica*	x	
	Yerba buena	Hairy mint	*Mentha nemorosa*		x
	Higuillo		*Piper aduncum*		x
	Uva playera	Sea grape	*Coccoloba uvifera*	x	x
TREE	Achiotillo		*Alchornea latifolia*		x
	Aguacate	Avocado	*Persea americana*	x	x
	Algarroba	Strikingtoe	*Hymenaea courbaril*	x	
	Almácigo	Turpentine tree	*Bursera simaruba*	x	
	Almendro	Indian almond	*Terminalia catappa*		x
	Ausubo	Bulletwood	*Manilkara bidentata*		x
	Bucayo	Mountain immortelle	*Erythrina poeppigiana*		x
	Bucayo enano	Erythrina	*Erythrina berteroana*		x
	Cabo de hacha	Broomstick	*Trichilia hirta*	x	
	Cacaillo	Sloanea	*Sloanea berteriana*		x
	Camasey		*Miconia prasina*		
	Caoba dominicana	West Indian mahogany	*Swietenia mahagoni*	x	x
	Caoba hondureña	Honduras mahogany	*Swietenia macrophylla*	x	x
	Capa blanco	Bastard stopper	*Petitia domingensis*	x	
	Capa prieto	Spanish elm	*Cordia alliodora*		x

Zone 2 Recommended Species for Riparian Forest Buffers

*	Name: Local	English	Scientific	Suitable: Dry	Humid
T R E E	Cedro hembra	Spanish cedar	*Cedrela odorata*		x
	Cobana negra		*Stahlia monosperma*	x	x
	Corazón	Custard apple	*Annona reticulata*	x	x
	Cupey	Scotch attorney	*Clusia rosea*		x
	Emajaguilla	Portia tree	*Thespesia populnea*	x	x
	Espino rubial	Yellow prickle	*Zanthoxylum monophyllum*		x
	Eucalipto limón	Lemon scented gum	*Eucalyptus citriodora*		x
	Guama	Sacky sac bean	*Inga laurina*	x	x
	Guano	West Indian balsa	*Ochroma pyramidale*	x	x
	Guaraguao	American musk wood	*Guarea guidonia*	x	
	Guayacán	Common lignumvitae	*Guajacum officinale*	x	
	Guayacán blanco	Holywood lignumvitae	*Guajacum sanctum*	x	
	Higuero	Calabash	*Crescentia cujete*	x	x
	Jacaranda	Black poui	*Jacaranda mimosifolia*		x
	Jobillo	Purple mombin	*Spondias purpurea*		x
	Maga	Maga	*Thespesia grandiflora*	x	x
	Malagueta	Bayrum tree	*Pimenta racemosa*	x	x
	Mamey	Mamme apple	*Mammea americana*		x
	Mangle negro	Black mangrove	*Avicennia germinans*		x
	Mangó	Mango	*Mangifera indica*	x	x
	María	Antilles calophyllum	*Calophyllum calaba*		x
	Moca	Cabbagebark	*Andira inermis*	x	x
	Nemoca		*Ocotea spathulata*		x
	Níspero		*Manilkara zapota*		x
	Palma de sierra	Sierran palm	*Prestoea montana*		x
	Palma real	Puerto Rico royal palm	*Roystonea borinqueña*		x
	Panapén	Breadfruit	*Artocarpus altilis*		x
	Pendula	Florida fiddlewood	*Citharexylum fruticosum*	x	
	Pino Hondureño	Honduras pine	*Pinus caribaea*		x
	Pomarrosa	Melabar plum	*Syzygium jambos*		x
	Pomarrosa malaya	Malaysian apple	*Syzygium malaccense*		x
	Pterocarpus	Pterocarpus	*Pterocarpus indicus*		x
	Quenepa	Spanish lime	*Melicoccus bijugatus*	x	x
	Roble nativo	White cedar	*Tabebuia heterophylla*	x	x
	Tabonuco	Candle tree	*Dacryodes excelsa*		x
	Tachuelo	Fustic	*Pictetia aculeata*	x	
	Teca	Teak	*Tectona grandis*	x	x
	Ucar	Black olive	*Bucida buceras*	x	
	Violetas	Violet tree	*Polygala cowellii*	x	
	Yagrumo hembra	Pumpwood	*Cecropia peltata*		x
	Yagrumo macho	Matchwood	*Didymopanax morototoni*		x

* Growth habit (shrub or tree)

Plants of dry areas are adapted to humid or wet places of those sites such as: ravines and creeks.

Zone 3 Recommended Species for Riparian Forest Buffers

	Name			Suitable	
	Spanish	English	Scientific	Dry	Humid
GRASS	Malojilla	Caribgrass	*Eriochloa polystachya*		x
	Malojillo	Paragrass	*Urochloa mutica*		x
	Signal	Palisade signalgrass	*Urochloa brizantha*		x
	Signal	African signalgrass	*Urochloa arrecta*		x
	Yerba bahía	Bahia grass	*Paspalum notatum*	x	x
	Yerba bermuda	Bermuda grass	*Cynodon dactylon*	x	x
	Yerba buffel	Buffel grass	*Pennisetum ciliare*	x	
	Yerba colorada	Carpet grass	*Axonopus compressus*		x
	Yerba estrella	Star grass	*Cynodon nlemfuensis*		x
	Yerba huracán	Hurricane grass	*Bothriochloa pertusa*	x	
	Yerba melao	Molassesgrass	*Melinis minutiflora*		x
	Yerba pacholí	Vetiver grass	*Vetiveria zizanioides*	x	x
	Yerba pajón	Kleberg's bluestem	*Dichanthium annulatum*	x	
	Yerba pangola	Pangola grass	*Digitaria eriantha*		x
	Yerba San Agustín	St. Augustine grass	*Stenotaphrum secundatum*		x
	Yerba torcida	Tanglehead	*Heteropogon contortus*	x	

Plants of dry areas are adapted to humid or wet places of those sites such as: ravines and creeks.

3.5 Structural Practices

Structural measures are used where vegetative measures are not adequate to prevent erosion, or where control of runoff is required to protect a facility or area of use. Structural measures are engineering practices which require careful planning, design, and installation to function as intended and be effective soil erosion control structures. Designs are based on many factors, including expected storm runoff, hazard to life and property should the structure fail, expected sediment accumulation, future land use, and maximum allowable water velocity. General information, design criteria and aids, and construction specifications are included in the following in the following discussion of each practice.

This Handbook includes the following structural practices:

- Stabilized Construction Entrance
- Temporary Sediment Trap
- Sediment Basin
- Silt Fences
- Straw Bale Barrier
- Land Grading
- Dust Control
- Construction Road Stabilization

3.5.1 Stabilized Construction Entrance

Definition

A stabilized pad of aggregate underlain with filter fabric located at any point where traffic will be entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk, or parking area.

Purpose

Construction entrances are stabilized to reduce the amount of sediment (mud, dirt, rocks, etc.) transported onto paved roads by vehicles or equipment.

Where Stabilized Construction Entrances are Used

Construction entrances shall be stabilized at all points of construction ingress and egress to paved roads or other paved areas.

On large commercial, highway, and road projects, the designer should include enough extra materials in the contract to allow for additional stabilized entrances not shown in the initial Construction Plans. It is difficult to determine exactly where access to these projects will take place; additional materials will enable the contractor to install them where needed.

Basic Design and Construction Criteria

Improperly planned and maintained construction entrances can become a continual erosion problem. The tracking of mud from active building sites onto paved roads by construction vehicles can be greatly reduced, and in some cases eliminated, by the use of a stabilized construction entrance. These entrances provide an area where mud can be removed from construction vehicle tires before they enter a public road.

If the action of the vehicles tires traveling over the stone is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road. When washing is required it shall be done on an area stabilized with aggregate, or using a wash rack underlain with gravel. The washing station should be located to provide for maximum utility by all construction vehicles. All sediment shall be prevented from entering storm drains, ditches, watercourses, or surface waters including wetlands. Provisions shall be made to intercept the wash water and trap the sediment before it is carried offsite.

Construction entrances should be used in conjunction with the stabilization of construction roads, and other exposed areas, to reduce the amount of mud picked up by construction vehicles.

All surface water flowing or diverted toward construction entrances shall be piped across the entrance. If piping is impractical, a mountable berm with 5:1 slopes will be permitted.

The graveled access shall be installed as soon as practical after the start of site disturbance.

Consider early installation of the first lift of asphalt in areas that will be paved; this can be used as a stabilized entrance. Also consider the installation of excess concrete as a stabilized entrance. During large concrete pours, excess concrete is often available for this purpose.

Fencing shall be installed as necessary to restrict traffic to the construction entrance.

Whenever possible, the entrance shall be constructed on a firm, compacted subgrade. This can substantially increase the effectiveness of the pad and reduce the need for maintenance.

The area of the entrance should be cleared of all vegetation, roots, and other objectionable material. The aggregates shall be placed to the specified dimensions.

Design Criteria.
Stabilized construction entrance shall meet the following requirements.

- Aggregate size – Place coarse aggregate 2 to 4 inches in size.
- Thickness - 6 inches or more.
- Width - 12 feet minimum but not less than the full width of ingress or egress points.
- Length - As required, but not less than 50 feet.
- A separation geotextile shall be used under the aggregate to minimize the migration of stone into the underlying soil by heavy vehicle loads. The geotextile shall meet the requirements of Materials Specification GEOTEXTILE Table 1 or 2, class I, II, or IV.

<u>Common Trouble Point</u>

Not providing required periodic top dressing with additional stones.

<u>Operation and Maintenance</u>

The entrance shall be maintained in a condition that will prevent tracking of sediment onto public rights-of-way or streets. This may require periodic top dressing with additional aggregate. All sediment spilled, dropped, or washed onto public rights-of-way must be removed immediately. Periodic inspection and needed maintenance shall be provided after each rain event and/or heavy traffic. Immediately remove sediment or any other materials tracked onto public road way.

If vehicles are entering or exiting the site at points other than the construction entrance(s), fencing shall be installed to control traffic. Expand stabilized area as required to accommodate traffic and prevent erosion at driveways.

Removal.
The entrance shall remain in place and be maintained until the disturbed area is stabilized by permanent best management practices. Upon project completion and site stabilization, all construction accesses intended as permanent access for maintenance shall be permanently stabilized.

MATERIAL SPECIFICATION

GEOTEXTILE

Scope

This specification covers the quality of geotextiles.

General Requirements

Fibers (threads and yarns) used in the manufacture of geotextile shall consist of synthetic polymers composed of at least 85 percent by weight polypropylenes, polyesters, polyamides, polyethylene, polyolefins, or polyvinylidene-chlorides. They shall be formed into a stable network of filaments or yarns retaining dimensional stability relative to each other. The geotextile shall be free of defects and conform to the physical requirements contained in Tables 1 and 2. The geotextile shall be free of any chemical treatment or coating that significantly reduces its porosity. Fibers shall contain stabilizers and/or inhibitors to enhance resistance to ultraviolet light.

Thread used for factory or field sewing shall be of contrasting color to the fabric and made of high strength polypropylene, polyester, or polyamide thread. Thread shall be as resistant to ultraviolet light as the geotextile being sewn.

Classification

Geotextiles shall be classified based on the method used to place the threads or yarns forming the fabric. The geotextiles will be grouped into the types described below.

Woven.
Fabrics formed by the uniform and regular interweaving of the threads or yarns in two directions.

Woven fabrics shall be manufactured from monofilament yarn formed into a uniform pattern with distinct and measurable openings, retaining their position relative to each other.

The edges of fabric shall be selvedged or otherwise finished to prevent the outer yarn from unraveling.

Nonwoven.
Fabrics formed by a random placement of threads in a mat and bonded by heat-bonding, resin-bonding, or needle punching.

Nonwoven fabrics shall be manufactured from individual fibers formed into a random pattern with distinct but variable small openings, retaining their position relative to each other when bonded by needle punching, heat, or resin bonding. The use of nonwovens, other than the needle punched geotextiles, is some what restricted (see Note 3 on Table 2).

Sampling and Testing

The geotextile shall meet the specified requirements (Table 1 or 2) for the product style shown on the label. Product properties as listed in the "Specifiers Guide" (Dec. 1990 or Dec. 1991 after that date), Geotechnical Fabrics Report, Industrial Fabrics Association International, 345 Cedar Bldg., Suite 450, St. Paul, Minnesota 55101; and that represents minimum average roll values, will be acceptable documentation that the product style meets the requirements of these specifications.

For products that do not appear in the above directory, or do not have minimum average roll values listed, typical test data from the identified production run of the geotextile will be required for each of the specified tests (Table 1 or 2) as covered under clause AGAR 452.236-76.

Shipping and Storage

The geotextile shall be shipped in rolls wrapped with a cover for protection against moisture, dust, dirt, debris, and ultraviolet light. The cover shall be kept in place to the maximum extent possible prior to placement.

Each roll of geotextile shall be labeled or tagged to clearly identify the brand, class and the individual production run in accordance with ASTM D4873.

Table 1. Requirements for Woven Geotextiles

Property	Test Method	Class I	Class II & III	Class IV
Tensile Strength (lb.) 1/	ASTM D 4632 Grab Test	200 min. in any principal dir.	120 min. in any principal dir.	180 min. in any principal dir.
Bursting Strength (psi) 1/	ASTM D 3786 Diameter Tester	400 min.	300 min.	NA
Elongation at (percent) 1/	ASTM D 4632 Grab Test	<50	<50	<50
Punture (lb.) 1/	ASTM D 4833	90 min.	60 min.	60 min.
Ultraviolet Light (percent residual tensile strength)	ASTM D 4355 150 hours exposure	70 min.	70 min.	70 min.
Apparent Opening Size – OAS	ASTM D 4751	As specified or a min. #100 2/	As specified or a min. #100 2/	As specified or a min. #100 2/
Percent Open Area (percent)	CWO-02215-86	4.0 min.	4.0 min.	1.0 min.
Permitivity (1/second)	ASTM D 4491	0.10 min.	0.10 min.	0.10 min.

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.

Table 2. Requirements for Nowoven Geotextiles

Property	Test Method	Class I	Class II	Class III	Class IV 3/
Tensile Strength (lb.) 1/	ASTM D 4632 Grab Test	180 min.	120 min.	90 min.	115 min.
Bursting Strength (psi) 1/	ASTM D 3786 Diameter tester	320 min.	210 min.	180 min.	NA
Elongation at Failure (percent) 1/	ASTM D 4632 Grab Test	>50	>50	>50	>50
Punture (lb.) 1/	ASTM D 4833	80 min.	60 min.	40 min.	40 min.
Ultraviolet Light (percent residual tensile strength)	ASTM D 4355 150 hours exposure	70 min.	70 min.	70 min.	70 min.
Apparent Opening Size – OAS	ASTM D 4751	As specified, max. # 40 2/	As specified, max. # 40 2/	As specified, max. # 40 2/	As specified, max. # 40 2/
Permittivity (1/second)	ASTM D 4491	0.70 min.	0.70 min.	0.70 min.	0.10 min.

1/ Minimum average roll value (weakest principal direction).

2/ U.S. standard sieve size.

3/ Heat-bonded or resin bonded geotextile may be used for Class IV only, and are particularly well suited for this use. Needle punched geotextiles are required for all other classes.

3.5.2 Temporary Sediment Trap

Definition

A temporary sediment trap is a control device used to intercept sediment-laden runoff and to trap sediment to prevent/reduce offsite sedimentation. A temporary sediment trap can be formed by excavation and/or embankments constructed at designated locations accessible for cleanout.

Sediment traps work by creating a ponding effect. This provides detention to allow the larger soil particles to settle down. Another effect of the ponded water is to slow the velocity of the runoff flow. Traps are simple to construct, relatively inexpensive and easily moved as construction proceeds.

Purpose

Temporary sediment traps are used to collect and store sediment from sites cleared and/or graded during construction. It is intended for use on relatively small building areas, with no unusual drainage features. It should help in reducing silt-laden runoff. This silt-laden runoff clogs offsite conveyance systems and destroys habitat, particularly in streams. The trap is a temporary measure and is to be maintained until the site area is permanently protected against erosion by vegetation and/or structures.

Where Temporary Sediment Traps are Used

A temporary sediment trap may be located in a drainage way, at a storm drain inlet, or at other points of discharge from a disturbed area. They may be constructed independently or in conjunction with diversions. Sediment traps are used in association with sediment fences and/or diversion drains and banks to trap suspended sediment onsite. They may be used in most drainage situations to prevent excessive siltation of pipe structures.

Basic Design and Construction Criteria

Sediment trap design and frequency of use will depend upon site topography, catchment area and the volume of sediment and water intercepted. Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the traps should be selected. Traps are not meant to control concentrated flows and store large volumes of sediment. Sediment basins perform this function.

Traps should be installed before construction commences, be located away from construction activity, maximize the storage potential on the site, and allow easy access for the sediment removal.

Sediment traps are formed by excavating an area or by placing an earthen embankment across a low area or drainage swale (see Figure 1).

A sediment trap should be designed to maximize surface area for infiltration and sediment settling. This will increase the effectiveness of the trap and decrease the likelihood of backup during and after periods of high runoff intensity. Although site conditions will dictate specific design criteria, the approximate storage capacity of each trap should be at least 1,800 ft^3 per acre of the drainage area contributing storm water to the trap.

The temporary sediment trap volume can be found by computing the detention volume required for the 2-year, 24-hour design storm. Side slopes should not exceed 2:1. After determining the necessary volume, size the trap by adding an additional 1½ feet for sediment accumulation to the volume computed using the 2-year, 24-hour design storm.

Care should be taken in the sitting and design phase to situate sediment traps for easy access by maintenance crews. This will allow for proper inspection and maintenance on a periodic basis (see Figure 2).

All sediment structures should be at least twice as long as they are wide. A 3:1 aspect ratio between the trap length and width of the trap is desirable.

A temporary sediment trap should not be located within 20 feet of a building foundation if the trap is to function during building construction.

- Limitations

  Sediment traps should not be used for drainage areas greater than 5 acres. The effective life span of these temporary structures is usually limited to 24 months.

  Although sediment traps allow for settling of eroded soils, because of their short detention periods for storm water they typically do not remove fine particles such as silts and clays.

- Construction Specifications

  When excavating an area for sediment trap implementation, side slopes should not be steeper than 2:1 and embankment height should not exceed 5 feet from the original ground surface.

  The area under the embankment shall be cleared, grubbed, and stripped of any vegetation and root mat. Fill material for the embankment shall be free of roots or other woody vegetation, organic material, large stones, and other objectionable material. The embankment should be compacted in 8-inch layers by traversing with construction equipment. All embankments should be machine compacted to ensure stability. The earthen embankment shall be seeded with temporary or permanent vegetation immediately after installation.

  To reduce flow rate from the trap, the outlet should be lined with well-graded stone. The spillway weir for each temporary sediment trap should be at least

4 feet wide for a 1-acre drainage area and increase by 2 feet for each additional drainage acre added, up to a maximum drainage area of 5 acres. The minimum depth of the spillway is 1 feet.

Sediment traps must outlet onto stabilized (preferable undisturbed) ground, or into a stabilized channel, drainage, or storm drain system.

Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.

Common Trouble Points

Serves only limited areas.

Inadequate spillway size; this result in overtopping of dam, poor trap efficiency, and possible failure of the structure.

Omission or improper installation of filter fabric (under riprap outlets); this results in washout under sides or bottom of the stone outlet section (piping).

Low point in embankment caused by inadequate compaction and settling; this can result in overtopping and possible failure.

Stone size too small or backslope too steep; this may result in stone displacement.

Inadequate vegetative protection; this can result in erosion of embankment.

Inadequate storage capacity; the sediment is not removed from basin frequently enough.

Contact slope between stone spillway and earth embankment too steep; piping failure is likely.

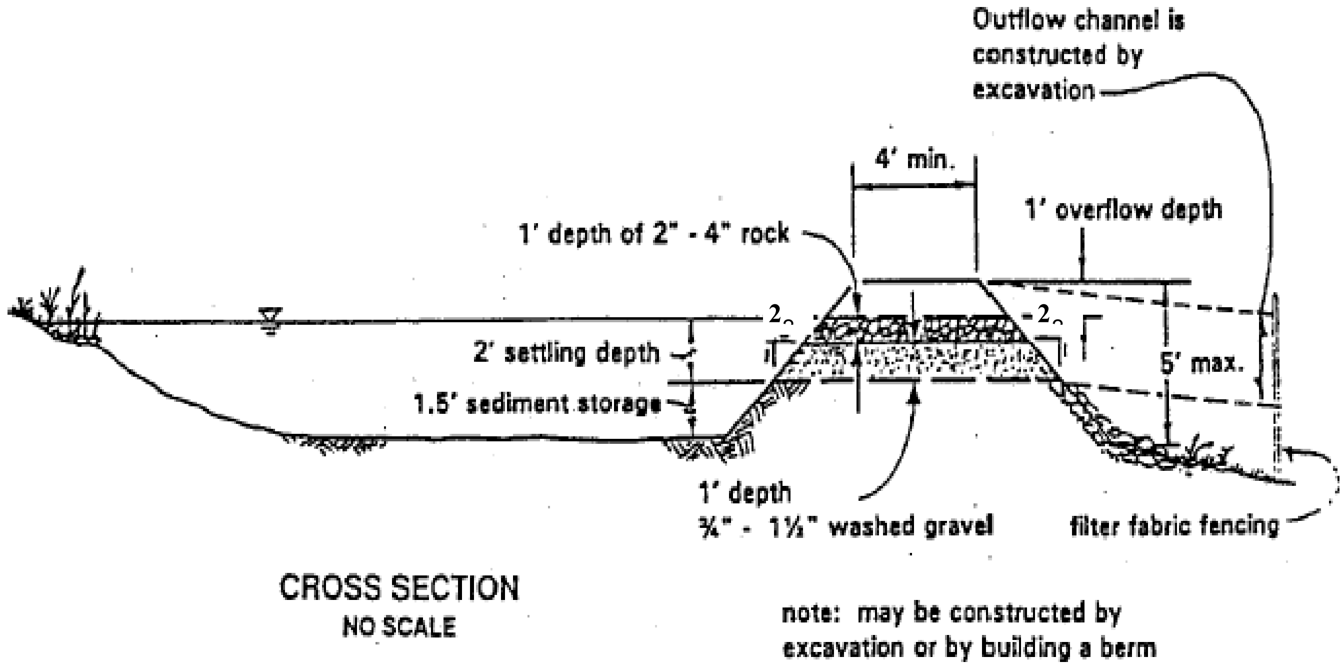
Operation and Maintenance

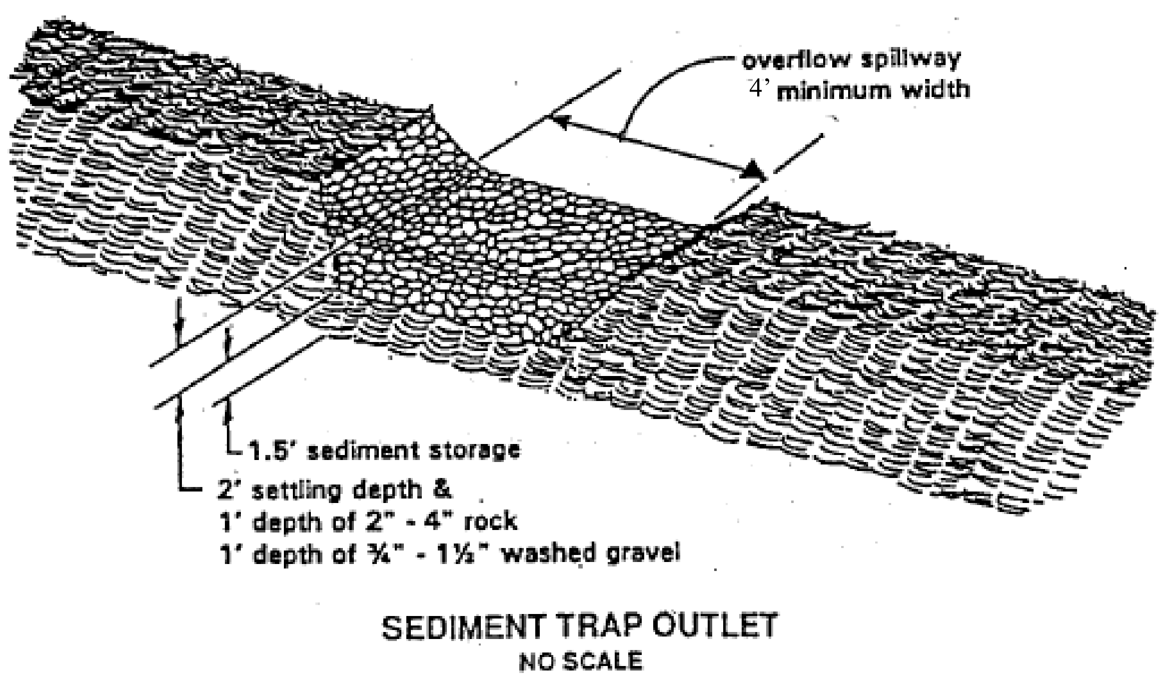
Inspect temporary sediment traps following each significant rainfall event and repair immediately any damage to the trap caused by undercutting, bypassing, scouring or overtopping. Trap should be cleaned out when sediment reaches 1/3 the design depth; a stake set at the cleanout level is helpful. Sediment removal from the basin shall be deposited in a suitable area and in such a manner that will not erode and cause sedimentation problems. Gravel facing should be cleaned or replaced if clogged. Check spillway depth periodically to ensure minimum 1-foot depth.

Removal.

Do not remove the sediment trap until all sediment producing areas have been permanently stabilized. The accumulated sediment in the trap should be removed, and all excavation should be backfilled and properly compacted. Smooth the site to blend with the terrain or as specified on plans.

TEMPORARY SEDIMENT TRAP INSTALLATION





Figue 1. Temporary Sediment Trap

PLACEMENT

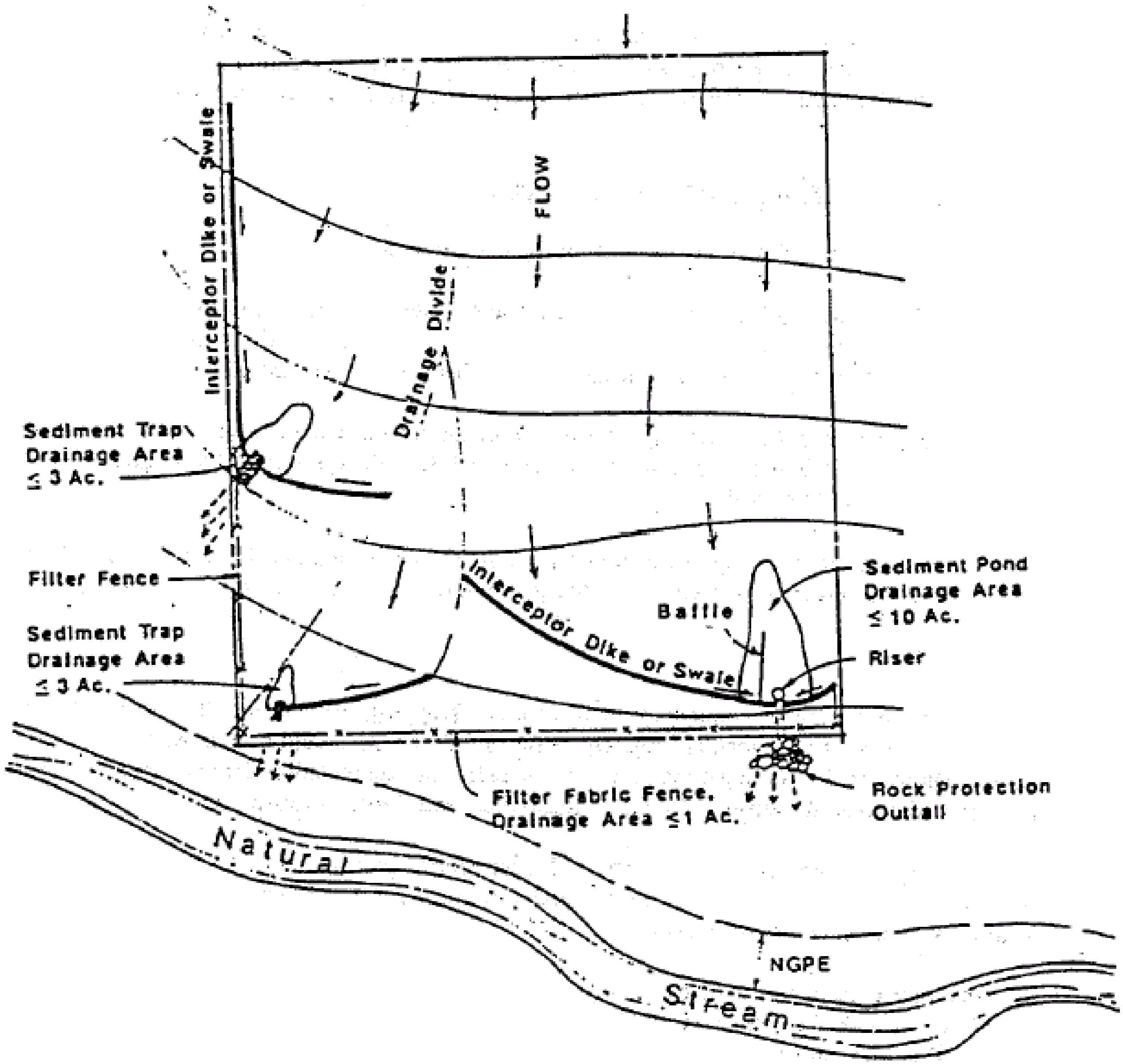


Figure 2. Temporary Sediment Trap Placement

3.5.3 Sediment Basin

Definition

A sediment basin is a storm water detention structure formed by constructing a dam across drainage way or at other suitable locations and using it to intercept sediment-laden runoff. Consist of a settling pond with a controlled storm water release structure used to collect and store sediment produced by construction activities. Sediment basins are generally larger and more effective in retaining sediment than temporary sediment traps.

Purpose

Sediment basin is used to intercept sediment-laden runoff and reduce the amount of sediment leaving the disturbed area in order to protect drainage ways, properties, and rights-of-way below the sediment basin from sedimentation.

Where Sediment Basins are Used

Sediment basins are usually designed for disturbed areas larger than 5 acres. It may be used below construction operations which expose critical areas to soil erosion. A sediment basin should be installed before clearing and grading is undertaken. Sediment basins should be used at sites where there is sufficient space and appropriate topography. When used in combination with other control practices such as seeding or mulching it is especially effective in removing sediment.

Sediment basins should be located and designed such that failure of the structure would not result in loss of life, in damage to homes, commercial buildings, highways, and streets, or in interruption of the use of services or public utilities.

Regions that require post-development flow to be less than or equal to pre-development flow may employ the designed detention facilities as a temporary sediment basin during construction.

Basic Design and Construction Criteria

- Planning.
  Sediment basins are at best only 70-80% effective in trapping sediment that flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc., to reduce the amount of sediment flowing into the basin.

  Sediment basin design and frequency of use will depend upon site topography, catchment area and the volume of sediment and water intercepted. Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the basin should be selected. Sediment basins can control concentrated flows and store large volumes of sediment.

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally low areas below disturbed areas. The use of diversion dikes and ditches can improve drainage into the basin. The basin must not be located in a stream but should be located to trap sediment-laden runoff before it enters the stream.

Sediment basin should be installed before construction commences, be located away from construction activity, maximize the storage potential on the site, and allow easy access for the sediment removal.

- Design.
  A sediment basin should be designed to maximize surface area for infiltration and sediment settling. This will increase the effectiveness of the basin and decrease the likelihood of backup during and after periods of high runoff intensity.

  The capacity of the sediment basin shall equal the volume of sediment expected to be trapped at the site during the planned useful life of the basin. The sediment storage volume may be determined by using the Revised Universal Soil Loss Equation (RUSLE) and gully erosion rates with an appropriate delivery ratio or by using other accepted sediment predictive procedures.

  Where it is determined that periodic removal of debris will be practicable, the capacity may be proportionally reduced. The design sediment yield to the basin shall be at least that required by the applicable Puerto Rico and federal laws, rules or regulations. Although site conditions will dictate specific design criteria, the approximate storage capacity of a sediment basin should be at least 1,800 ft^3 per acre of the drainage area contributing storm water to the basin.

EPA BASELINE GENERAL PERMIT REQUIREMENTS

Sediment Basin Requirements
Part IV.D.2.a(2).(a).

For common drainage locations that serve an area with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. The 3,600 cubic feet of storage area per acre drained does not apply to flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around the sediment basin. For drainage locations which serve 10 or more disturbed acres at one time and where a temporary sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent controls is not attainable, sediment traps, silt fences, or equivalent sediment controls are required for all sideslope and downslope boundaries of the construction area.

Source: Storm Water Management for Construction Activities Manual, EPA 832-R-92-005, September 1992.

Dams that can store at least 30 acre-feet of runoff or are 20 feet or more in height must be designed as permanent ponds. The design of dams, spillways, and drainage facilities shall be according to NRCS conservation practice standard Pond, Code 378 or according to the requirements in NRCS Technical Release (TR)-60, Earth Dams and Reservoirs, as appropriate for the class and kind of structure being considered. Other criteria may be acceptable but their acceptance shall be verified with the Environmental Quality Board prior to use.

Temporary basins having drainage areas of 5 acres or less and a total embankment height of 5 feet or less may be designed with less conservative criteria if conditions warrant. The embankment shall have a minimum top width of 4 feet and side slopes of 2 horizontal to 1 vertical (2:1) or flatter. An outlet shall be provided of earth, pipe, stone, or other devices adequate to keep the sediment in the trap and to handle the 10-year frequency discharge without failure or significant erosion.

Basic design for a sediment basin is illustrated in Figure 1. Embankment side slopes should be 2:1 or flatter with a minimum top width of 8 feet for dams less than 10 feet in height. Dams greater than 10 feet in height should have 2.5:1 or flatter slopes with a minimum top width of 10 feet. Embankments should be keyed in with a 2-foot x 2-foot trench. Embankment height should include a 10% settlement allowance and include a minimum 1-foot freeboard between the maximum water level and top of the dam. The height of a dam is measured from the top to the lowest point at the downstream toe.

All sediment structures should be at least twice as long as they are wide. A 3:1 aspect ratio between the basin length and width of the basin is desirable.

Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as storm water detention ponds. Wherever these structures are to become permanent, or if they exceed the size limitations of the design criteria, they must be designed as permanent. Design and construction shall comply with all federal and Puerto Rico laws, ordinances, rules and regulations.

Limitations.

- The drainage area for a sediment basin should not exceed 100 acres.
- The basin is to be removed within 36 months after the beginning of construction of the basin.
- The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

Principal Spillway.
The purpose of a principal spillway is to provide a flow outlet for minor storm events. Principal spillways may appear in several forms and designs. The minimum capacity of the principal spillway will be sufficient to discharge the temporary water storage in 72 hours or less.

The following discusses the basic design considerations for some of the most common designs.

- Usually a vertical pipe or box-type riser is jointed to a conduit (commonly called the barrel) that extends through the embankment to an outlet beyond the downstream toe of the fill (see Figure 1). The upper half of the riser will be perforated, with 1/2" diameter holes spaced 8 inches vertically and 10–12 inches horizontally, to provide for a gradual drawdown after each storm event.

- Material must be able to withstand the maximum external loading without yielding, buckling, or cracking. Pipe conduits must withstand the internal hydrostatic pressure without leakage while subject to full external load and settlement. Material guidance and minimum strength requirements are governed by the appropriate ASTM specification.

- Structural spillways other than pipe should have structural designs based on sound engineering data with acceptable soil and hydrostatic loading as determined on an individual site basis.

- The minimum flow rate should be 0.2 cubic feet per second per acre (ft^3/ sec/ acre) of drainage area.

- The minimum barrel diameter should be 8 inches and the riser cross sectional area should be at least 1.5 x barrel area. The principal spillway shall be a straight alignment. The minimum slope of the conduit shall be 1 percent.

- The crest elevation of the riser should be a minimum of 1 foot below the emergency spillway crest.

- An anti-vortex device and trash rack should be securely installed on the top of the riser.

- Anti-seep collars should be watertight and should project at least 15 inches around the barrel. A minimum of one anti-seep collar should be installed at approximately midpoint of the fill; dams greater than 15 feet in height should receive at least two collars, with the second collar located at the intersection of the water surface with the fill slope.

- Anti-flotation blocks should anchor the barrel to hold the riser in place and should have a buoyant weight greater than 1.1 times the weight of water displaced by the riser and any exposed portion of barrel.

- An outlet shall be provided including a means of conveying the discharge in an erosion-free manner to an existing stable stream. Protection against scour at the discharge end of the pipe spillway shall be provided.

Emergency Spillway.
The purpose of an emergency spillway is to provide adequate flood flow capacity without overtopping the dam. An emergency spillway should be used on a sediment basin serving a drainage area greater than 5 acres. They usually consist of open channels excavated in earth or rock. The emergency spillway should be constructed in undisturbed soil (not fill). Shall be capable of withstanding a 10-year, 24-hr. peak flow with no flow out of the emergency spillway. Effective cross sections can be saddle-shaped or trapezoidal with side slopes of 3:1 or flatter. The control section should be flat for at least 20 feet. The minimum freeboard required above the emergency spillway outflow is one foot. An example emergency spillway is illustrated in Figure 2.

Entrance of runoff into the basin.
Points of entrance of surface runoff into excavated sediment basins shall be protected to prevent erosion. Diversion, grade stabilization structures or other water control devices shall be installed as necessary to insure direction of runoff and protect points of entry into the basin.

Disposal.
The sediment basin plans shall indicate the method(s) of disposing of the sediment removed from the basin. The sediment shall be placed in such a manner that it will not erode from the site. The sediment shall not be deposited downstream from the basin or in or adjacent to a stream or floodplain.

The sediment basin plans shall also show the method of disposing of the sediment basin after the drainage area is stabilized, and shall include the stabilizing of the sediment basin site.

Safety.
Sediment basins are attractive to children and can be very dangerous. They shall be fenced or otherwise made inaccessible to persons or animals.

- Construction Specifications

Site Preparation.
The area under the embankment shall be cleared, grubbed, and stripped of any vegetation and root mat. Fill material for the embankment shall be free of roots or other woody vegetation, organic material, large stones, and other objectionable material. The pool area will be cleared of all brushes and trees.

Embankment.
The fill material shall be taken from approved borrow areas. It shall be clean soil free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Areas on which fill is to be placed shall be scarified prior to placement of fill. The fill material shall contain sufficient moisture so that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction. The embankment should be compacted in 6-inch layers by traversing with construction equipment. All embankments should be machine compacted to ensure stability. Compaction shall be obtained by routing the hauling equipment over the fill so that the entire surface of each layer of the fill is traversed by at least one wheel or tread track of the equipment or by the use of a compactor. The earthen embankment shall be seeded with temporary or permanent vegetation immediately after installation.

Sediment basin must outlet onto stabilized (preferable undisturbed) ground, or into a stabilized channel, drainage, or storm drain system.

Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.

Common Trouble Points

Piping failure along conduit, this can be caused by a lack of proper compaction, omission of an anti-seep collar, or leaking pipe joints.

Erosion of spillway or embankment slopes; this can be caused by inadequate vegetation, improper grading and sloping, or improper slope protection.

Slumping and/or settling of embankment; slumping can be caused by inadequate compaction and/or use of poor-quality fill material.

Slumping failure; this is caused by having overly steep side slopes.

Erosion and caving below pipe; this is caused by inadequate outlet protection.

Basin not located properly for access; this makes maintenance difficult and costly.

Sediment not properly removed; this leaves inadequate storage capacity.

Lack of trash rack; the barrel and riser may become blocked with debris.

Sediment disposal area not designated on plans; this results in improper disposal of accumulated sediment.

Operation and Maintenance

Inspect sediment basins following each significant rainfall event, repairing embankment, spillway, and outlet erosion damage. Remove trash and other debris from riser, spillway, and pool area. Look for signs of piping, settlement, seepage, or slumping on the embankment and repair these problems immediately.

The cleanout elevation should be located at 50% of the design volume; a stake placed at this elevation can be helpful. Deposit removed sediment in designated locations.

Removal.
After the drainage area has been permanently stabilized, the basin may be drained, the sediment deposited in designated areas, and the site smoothed to blend with terrain or as indicated on plans.

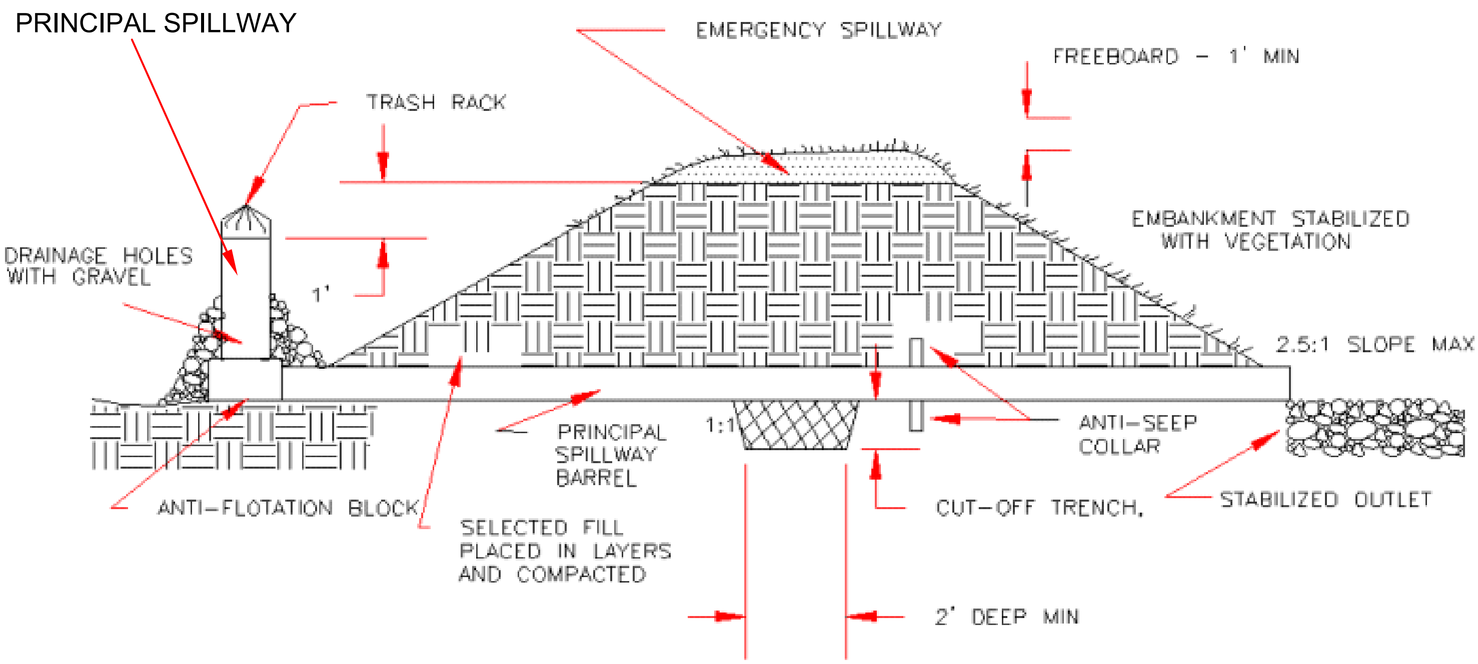
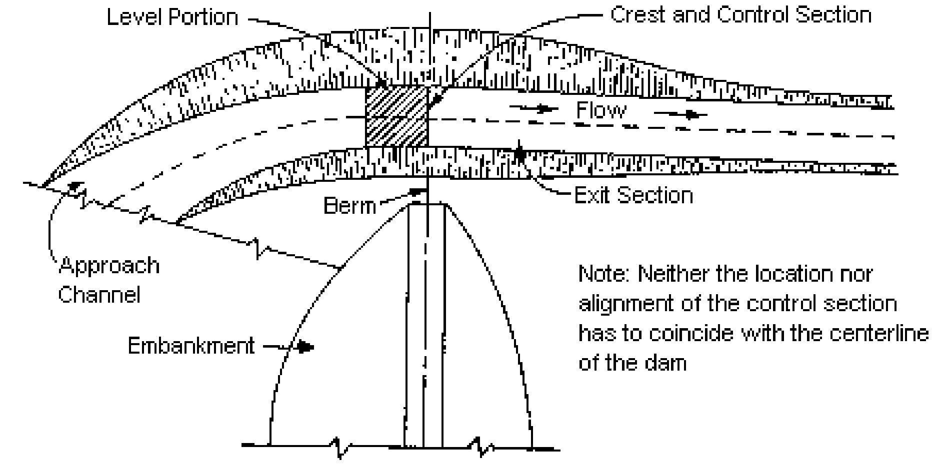
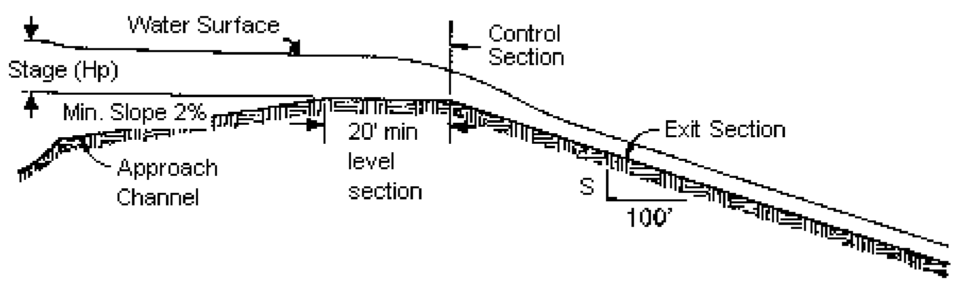


Figure 1. Sediment Basin



Plan View



Approach Along the Centerline of the Spillway

Cross Section at the Control Section

Figure 2. Emergency Spillway

3.5.4 Silt Fences

Definition

A silt fence is a temporary barrier of geotextile fabric (filter cloth), entrenched into the soil and attached to supporting posts, used to intercept sediment-laden runoff from small drainage areas. They are installed below small disturbed areas or at the toe of a slope at a construction site or new development. The expected life span is normally six months or less and is dependent on ultraviolet stability and type of fabric.

Silt fences are very effective in sheet flow conditions and usually ineffective with concentrated flows. Woven and nonwoven synthetic fabrics are available. Woven fabric is generally stronger than nonwoven fabric and usually does not require the additional support of a wire mesh.

Purpose

Silt fence is a sediment control practice. The purpose of a silt fence is to intercept and retain sediment from small, unprotected drainage areas. It is not intended to be an erosion control practice. A silt fence can be used to promote sheet flow, to reduce runoff velocity, and to help retain transported sediment on the site, thus reducing erosion and improving water quality. They are inexpensive, relatively easy to construct, and effective.

Where Silt Fences are Used

- Slope Protection

  There is no concentration of water in a channel or other drainage way above the barrier.

  Erosion will occur in the form of sheet and rill erosion.

  Protection of adjacent property or areas beyond the limits of grading is needed (perimeter control).

  Contributing drainage area is no more than .25 acre per 100 linear feet of silt fence and the maximum flow path length above the barrier is 100 feet. The slope should be 50% or less.

Maximum allowable slope lengths contributing runoff to a silt fence are listed in the table below:

Slope Steepness	Maximum Slope Length (Feet)
2:1	20
3:1	40
4:1	60
5:1	80
Flatter than 5:1	100

A silt fence may be used around or downslope of soil stockpiles and along the sides of streams and ponds.

- Channel Application

  Filter fences may be used in minor swales or ditch lines where the maximum contributing drainage area is no greater than 1 acre. They are not for use in perennial channels.

  Filter fences should be used only where the volume of runoff water is not expected to exceed 0.5 cubic feet per second.

  Use burlap filter fabric or equivalent.

<u>Basic Design and Construction Criteria</u>:

- Materials

  Fence Posts – Posts should be at least 36 inches long. Wood posts should be of hardwood with a minimum cross-section area of 3 inches. Steel posts should be standard "T" or "U" section and should weigh no less than 1 pound per linear foot. Steel posts can be recycled and used repeatedly.

  Wire – Wire fence should be at least 14-gauge with openings no larger than 6 inches by 6 inches.

  Geotextile Fabric – The fabric should have the following minimum material properties:

Fabric Properties	Minimum Acceptable	Value Test Method
Grab Tensile Strength (lbs)	100	ASTM D4632
Elongation at Failure (%)	50	ASTM D4632
Mullen Burst Strength (PSI)	190	ASTM D3786
Puncture Strength (lbs.)	60	ASTM D4833
Apparent Opening Size	#30 - #70	ASTM D4751
Ultraviolet Radiation Stability (%)	80	ASTM D4355

Fabricated Units - Shall comply with same material requirements and install as per manufacturer's instructions.

- Silt Fence Installation (See Figure1)

  Silt fence is a system where all the parts must function, or the system is worthless.

  Silt fences should be continuous and transverse to the flow. The silt fence should follow the contours of the site as closely as possible. Place the fence such that the water cannot run off around the end of the fence. The ends of the fence should be turned uphill.

  Silt fence ditch checks should be placed perpendicular to the flow line of the ditch. Silt fence should extend far enough so that the ground level at the ends of the fence is higher than the top of the low point of the fence. This prevents water from flowing around the check.

  The minimum height above ground for the silt fence shall be 2.5 ft. Minimum embedment depth shall be 0.5 ft (6 inches). The height of a silt fence shall not exceed 3 ft. Storage height and ponding height shall not exceed 0.5 ft. (18 inches).

  Wood, steel, or synthetic support posts having a minimum length of 3.3-ft (1 meter) plus the burial depth may be used. They shall be of sufficient strength to resist damage during installation and to the support applied loads due to material build up behind the silt fence.

  Soil type can play a role in the placement and quantity requirements; sandy soils might require more silt fence per area to contain the volume of potential sediment than clay soils, although the volume of water might be greater because clay soils allow less rainfall infiltration.

- Construction

  The chronological installation order is important to silt fence effectiveness.

  1) Excavate the trench. A trench shall be excavated at least 4 inches wide and 6 inches deep along the length of the planned barrier and upslope from the barrier. Slope barriers should be placed along contours to avoid concentration of flow. Place the soil on the upslope side of the trench for later use.

  2) Clean the bottom. Prior to fabric burial, clean debris and clods from the bottom of the trench to achieve a smooth surface.

  3) Insert fabric. Roll out a continuous length of silt fence fabric on the down-slope side of the trench. Insert the geotextile so the bottom is buried in a "J" configuration to a minimum depth of 6 in. and 6 in. horizontally in the

trench so that no flow can pass under the silt fence. When joints are necessary, splice the geotextile together by overlapping at a support post, but not in an area where water concentration will probably occur. Minimum overlap should be 6 inches.

4) Over-backfill the trench. Overfill the trench with clean backfill 2-3 inches above undisturbed ground.

5) Compact the soil. Backfill is compacted by wheels rolling with small equipment. Compact the soil immediately next to the silt fence geotextile. Compact the upstream side first and then the downstream side. Note: *Hard clays may require more than two passes to achieve low permeability of the soil. Research has shown a direct correlation to greater soil density and silt fence effectiveness.*

6) Insert posts on downslope side. Place the posts at spacing as shown on the project plans. Post spacing shall not exceed 6 feet. Wire mesh support is required with a maximum post spacing of 10 feet. Drive posts or place a minimum of 1.5 ft into the ground. Increase depth to 2 ft if fence is placed on a slope of 30% or greater. If depth cannot be achieved with wood posts, use steel posts.

7) Attach fabric. Fasten the support fence securely to the upslope side of the fence post. The support fence shall extend from the ground surface to the top of the geotextile. Gather fabric at posts if necessary. With steel posts place nipples away from the fabric. Attach the fabric to each post with three ties, all spaced within the top 1 in. of the fabric. Attach each tie diagonally 45 degrees through the fabric with each puncture at least 1 in. vertically apart. Also, each tie should be positioned to hang on a post nipple, when tightened, to prevent sagging. With wood posts, gather the fabric at each post if needed. Use a small lathe to overlay the fabric and secure to the post with several staples in the top 8-in. of the fabric. Do not attach filter fabric to existing trees.

8) Compaction – Compact the backfill soil immediately next to the silt fence geotextile. Compact the upstream side first and then the downstream side. Compaction is commonly accomplished with the front wheel of a tractor, skid steer, roller or other device, as well as with manual tamping or other manual means.

Common Trouble Points

Drainage area too large; break up into smaller areas.

Slope barriers should be placed along contours to avoid concentration of flow. When the flow concentrates, it overtops the barrier, and the silt fence slope barrier quickly deteriorates (see Figure 2).

Too much sediment accumulation allowed before clean out; too much sediment accumulation may cause barrier to fail. Requires frequent inspection and maintenance to ensure effectiveness.

Upstream slope too steep or too long; break up length with additional rows of barriers.

Fence not adequately supported; this may result in failure.

Fence located across a drainage way; flows may be in excess of the silt fence's capability.

Undercutting occurs; fence was not buried at least 6 inches or the trench was not backfilled and compacted properly. A silt fence will fail if it is not anchored and trenched into the ground.

Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation; reshape ends to elevation above the pool level.

Do not place silt fence barriers in areas with shallow soils underlain by rock. If the barrier is not anchored sufficiently, it will wash out.

Operation and Maintenance

Silt fence slope barrier should be inspected every 7 days for damage (such as tearing by equipment, undercutting, bulge, excessive sag, fabric detached from the posts) and repair or replacement shall be made promptly as needed. An inspection should be made within 24 hours of each significant rainfall (0.5 inches or more) or daily during periods of prolonged rainfall.

Sediment should be removed when they reach 1/3 to ½ the height of the barrier (18 inches maximum). Sediment deposits shall be removed when heavy rain is anticipated. The removed sediment shall be placed in an area where there is little erosion and shall conform to the existing grade and be vegetated or otherwise stabilized. *Hint: When removing sediment from behind a silt fence slope barrier or working around with a bulldozer or backhoe, take care not to undermine the entrenched silt fence.*

Removal.
Silt fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized and any sediment stored behind the silt fence has been removed. Smooth the site to blend with the terrain or as specified on plans. Generally, the fabric is cut at ground level and posts are removed, then the sediment is spread, seeded, and protected immediately.

Removed silt fence may be used at other locations provided the geotextile and other material requirements continue to be met to the satisfaction of the engineer.

SILT FENCE BARRIER INSTALLATION

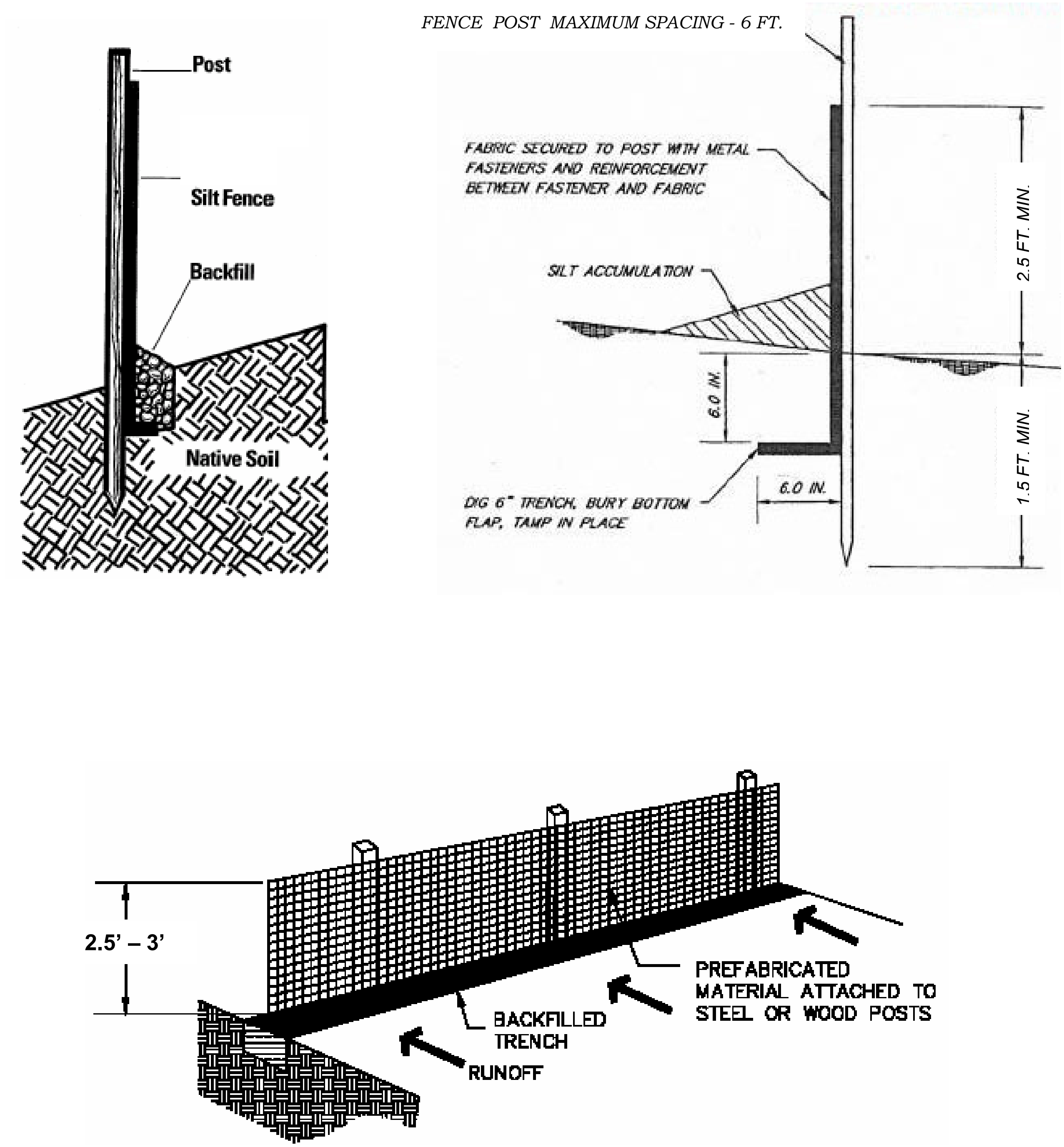
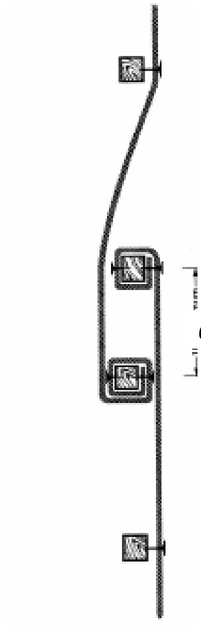
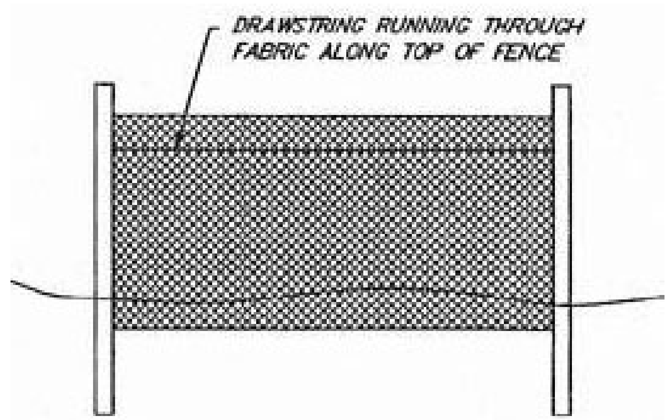


Figure 1. Silt Fence Installation and Reinforcement Details

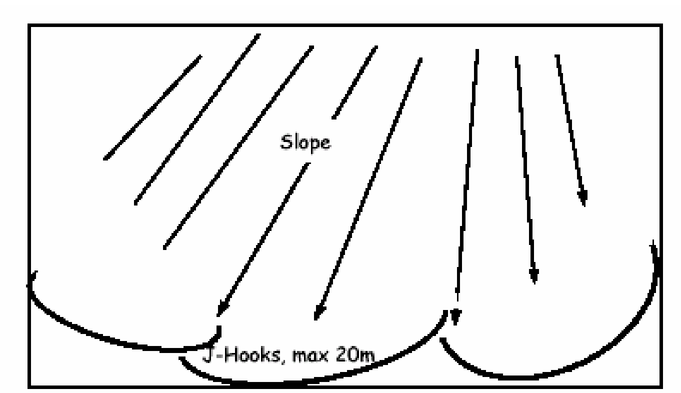




Reinforcement Along Top of the Fence

Joint Detail

PLACEMENT



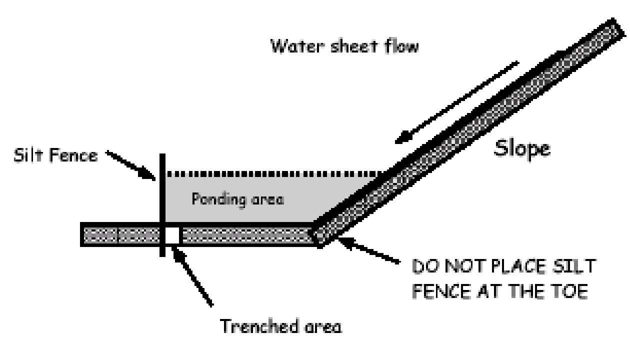


Figure 2. Silt Fence Placement and Reinforcement Details

3.5.5 Straw Bale Barrier

Definition

A temporary entrenched and anchored barrier installed across or at the toe of a slope of a construction site or new development. The expected life span is normally three months or less.

Purpose

Straw bales are used to intercept and retain sediment from small unprotected drainage areas. A straw bale barrier can be used to promote sheet flow and to reduce runoff velocity, thus reducing erosion and improving water quality.

Where Straw Bale Barriers are Used

- Slope Protection

  1) There is no concentration of water in a channel or other drainage way above the barrier.

  2) Erosion will occur in the form of sheet and rill erosion.

  3) Contributing drainage area is less than ½ acre and the length of slope of the contributing area is less than 200 feet. The slope should be 15% or less.

  The maximum length of slope behind the barrier is 100 feet; and the maximum slope length for given slopes is as follows:

Slope	Slope Length
<2%	100 ft
>2% to 5%	75 ft
>5% to 10%	50 ft
>10% to 15%	25 ft

  Straw bale barriers should be used around or downslope of soil stockpiles.

- Channel Application

  1) Straw bale barriers may be used for areas draining 1 acre or less.

  2) Straw bale barriers may be used where runoff water velocities are not expected to exceed 2 feet per second.

Basic Design and Construction Criteria (See Figure 1)

An average straw bale should be 30 inches in length, weight at least 50 pounds, and contain 5 cubic feet or more of material.

All bales shall be placed on the contour and should be tied with either wire or nylon strings if available. These types of ties will not deteriorate rapidly and insure a longer life. If ordinary baler twine is used, the bales should be placed so that the twine is not in contact with the ground. Bales shall be placed in a row with ends tightly abutting the adjacent bales.

A 4- to 6-inch deep trench should be excavated to the length of the barrier and the width of the bale. Make sure that the trench is excavated along a single contour to avoid concentration of flow. Excavated material is to be placed on the upstream side of the trench for later use. Place the bales in the trench, making sure that they are butted tightly.

Bales shall be securely anchored in place by two 2 x 2 wooden stakes or rebar steel pickets driven through the bales into the underlying soil at a slight upstream angle to help prevent the bale from overturning. Stakes should be driven at least 18 inches into the ground. The first stake in each bale shall be driven toward previously laid bale to force bales together. Spacing between the bales should be tightly chinked with loose straw.

Once all the bales have been installed and anchored, place the excavated soil against the upslope side and compact it.

When using straw bale check dams in swales or ditches (see Figures 2 and 3), the barrier is to be placed perpendicular to the contour. The same installation procedure is followed with the barrier extended up the sides of the ditch until the tops of the end bales are higher than the top of the lowest middle bale. This will prevent scour due to flow around the ends of the barrier.

Common Trouble Points

Drainage area too large; break up into smaller areas.

Too much sediment accumulation allowed before clean out; too much sediment accumulation may cause barrier to fail.

Upstream slope too steep or too long; break up length with additional rows of barriers.

Undercutting occurs; bales were not trenched at least 4 inches or compacted properly.

Loose spots or spacing not tightly chinked with loose hay; this may result in insufficient trap efficiency.

Bales located across a drainage way; flow may be in excess of bale's capacity.

Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation; reshape ends to elevation above the pool level.

Do not place bale slope barriers in areas with shallow soils underlain by rock. If the barrier is not anchored sufficiently, it will wash out.

Bale slope barriers must be dug into the ground. Bales at ground level do not work because they allow water to flow under the barrier.

Operation and Maintenance

Inspection shall be frequent (at least every week) and repair or replacement shall be made promptly as needed. An inspection should be made immediately after each rainfall or daily during periods of prolonged rainfall. Sediment should be removed when it reaches ½ the height of the barrier. *Hint: When removing sediment from behind a bale slope barrier with a bulldozer or backhoe, take care not to undermine the entrenched bales.*

Do not use any chemical substance on the bales to prevent being eaten by animals.

Removal.
After all sediment producing areas have been permanently stabilized and all sediment accumulation at the barrier trap should be removed, bales shall be removed so as no to block or impede storm flow or drainage. All excavation should be backfilled and properly compacted. Smooth the site to blend with the terrain or as specified on plans.

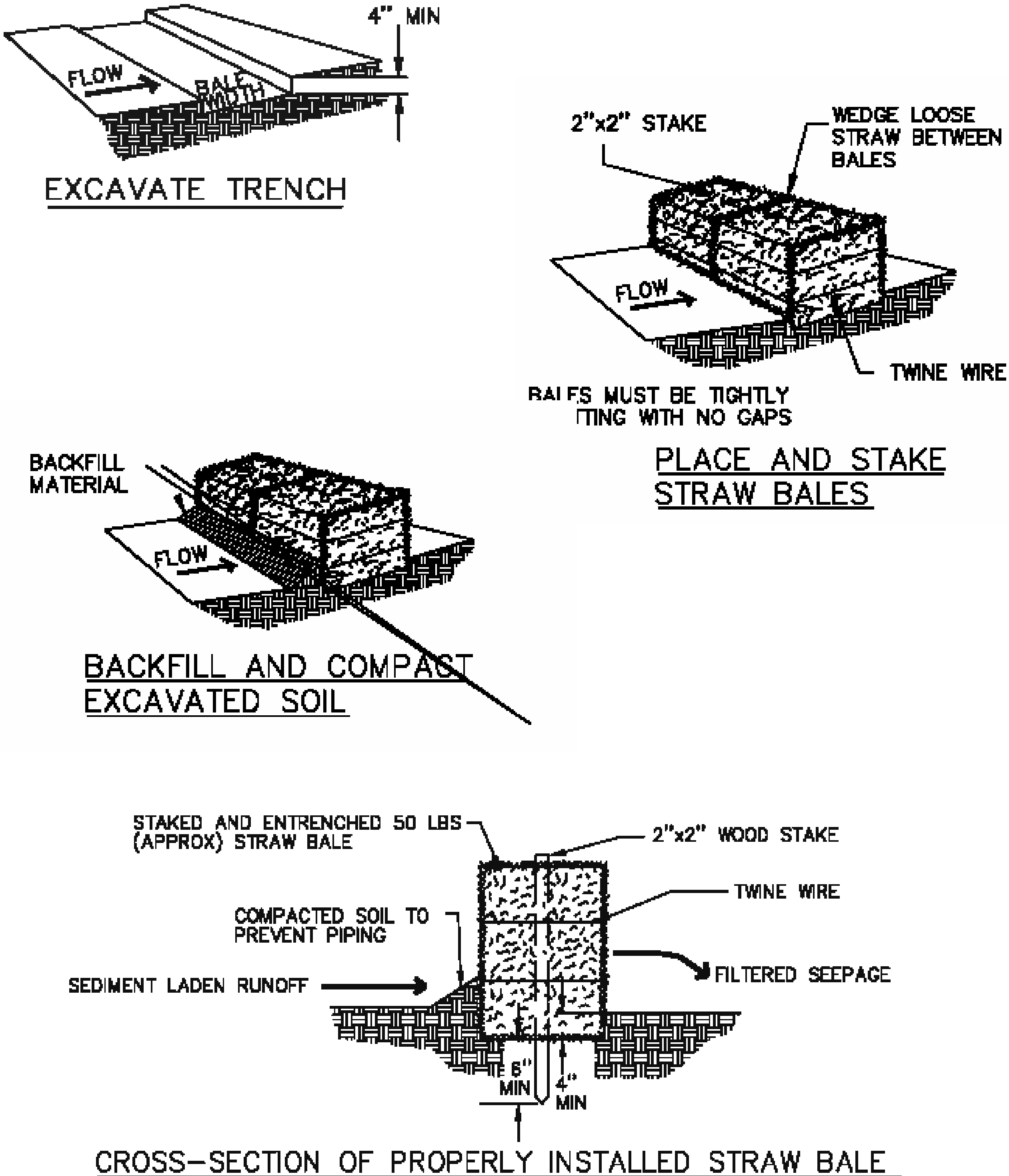
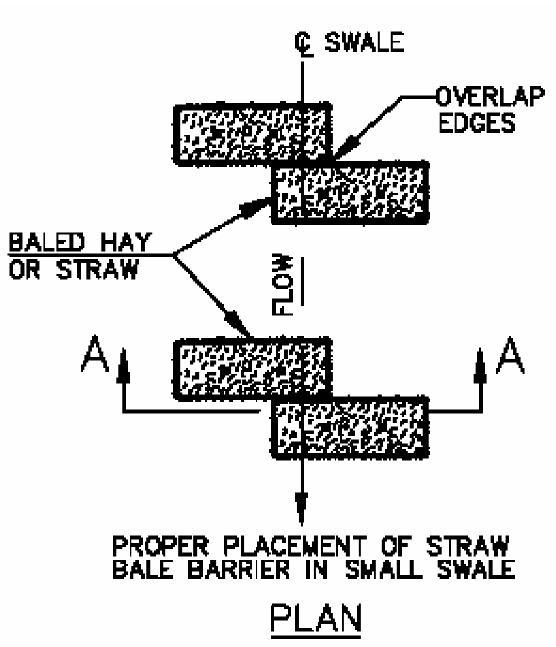
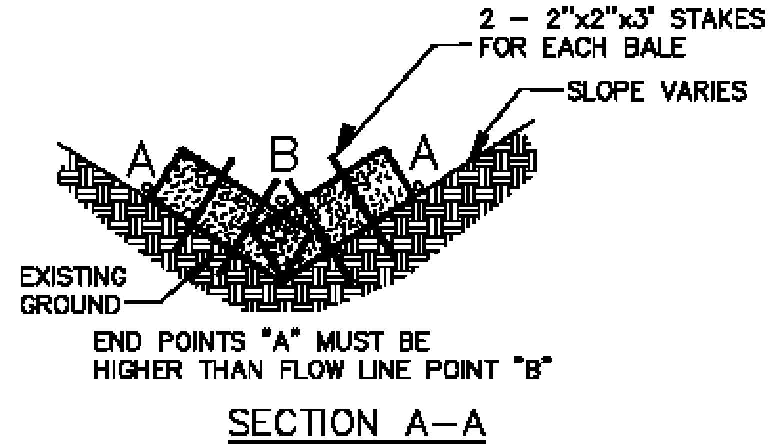
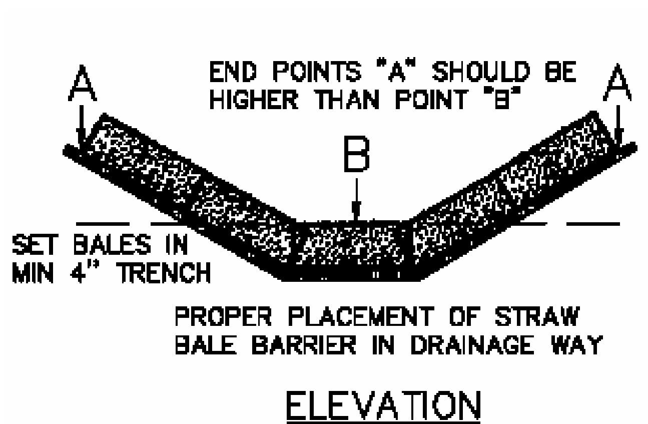


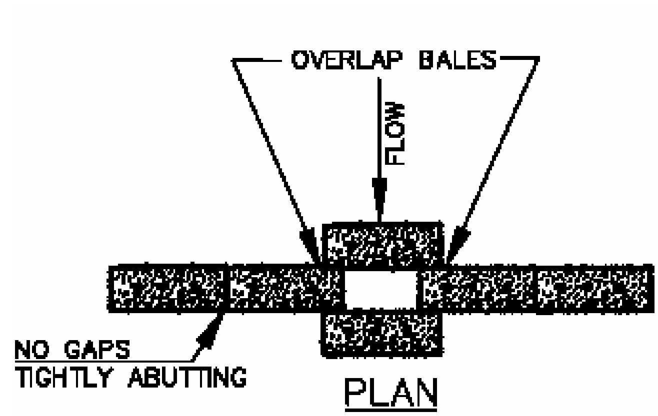
Figure 1. Straw Bale Barriers Installation





SMALL SWALE





DRAINAGE WAY

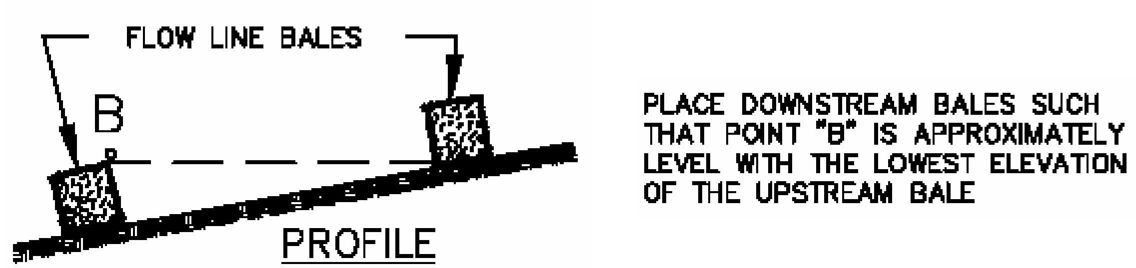


Figure 2. Straw Bale Check Dams Installation

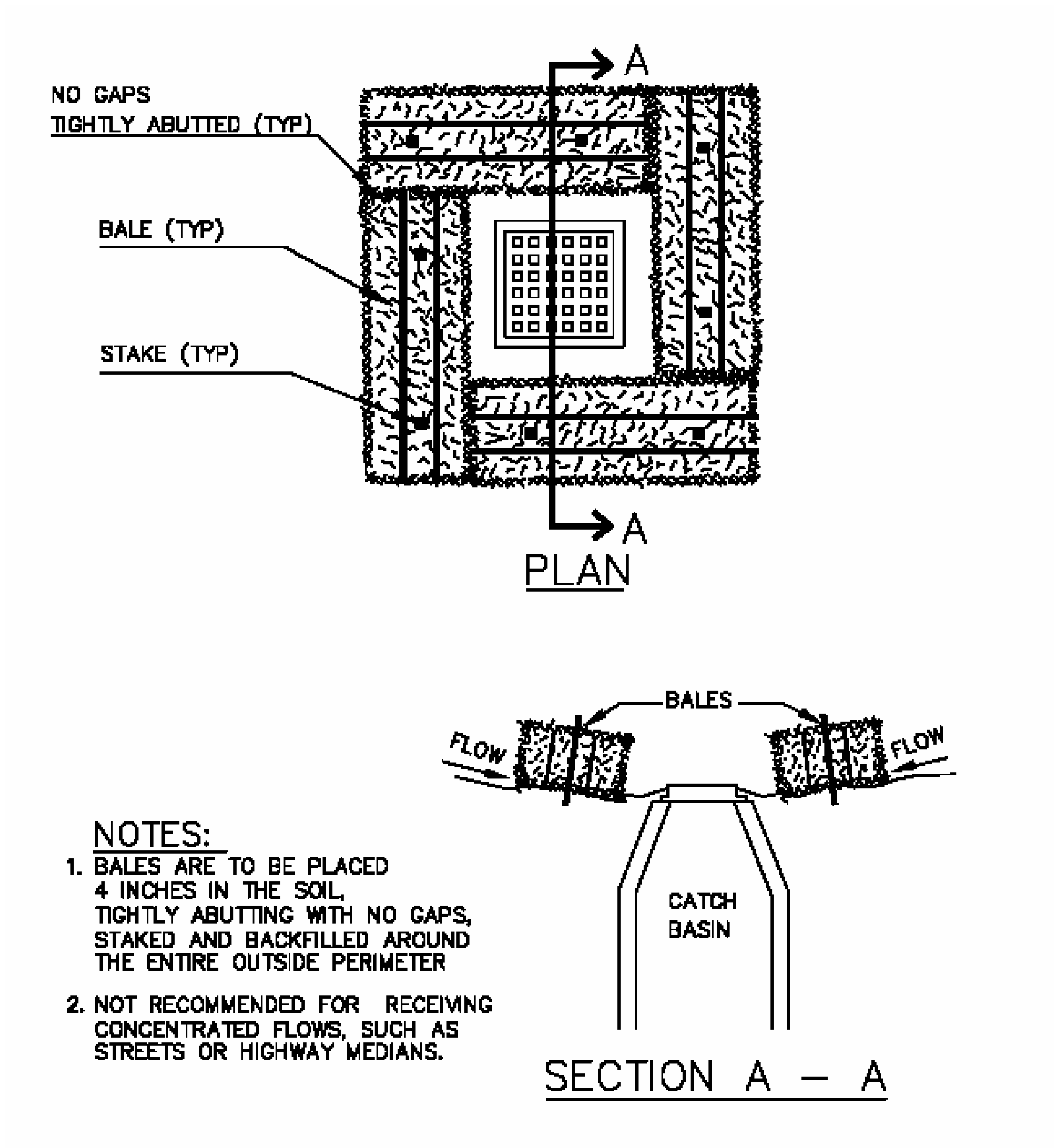


Figure 3. Straw Bale Sediment Control at Catch Basins

3.5.6 Land Grading

Definition

Land grading is reshaping the ground surface to planned grades as determined by an engineering survey, evaluation, and layout. Grading of lots within sub-divisions so that the runoff from each one is directed to a stable outlet rather than to an adjacent lot.

Purpose

Land grading provides more suitable topography for buildings, facilities, and other land uses and helps to control surface runoff, soil erosion, and sedimentation during and after construction. The plan should define areas that must not be disrupted by grading and filling, including staking, marking and fencing required to prevent damage to these areas.

Where Land Grading is Used

Land grading is applicable to sites with uneven or steep topography or easily erodible soils, because it stabilizes slopes and decreases runoff velocity. Grading activities should maintain existing drainage patterns as much as possible. This practice is applicable where grading to a planned elevation is necessary and practical for the proposed development of a site and for proper operation of sedimentation control practices.

Lot benching is grading of lots within subdivisions so that the runoff from each lot is directed to a stable outlet rather than to an adjacent lot. This practice is more applicable in subdivisions developments on hilly or rolling topography. Lot benching will reduce the slope and length of slope of disturbed areas, thereby reducing the erosion potential. This practice also establishes drainage patterns on individual lots within a subdivision at the time of rough grading. This prevents drainage problems later during structures construction.

Basic Design and Construction Criteria

Fitting a proposed development to the natural configurations of an existing landscape reduces the erosion potential of the site and the cost of installing erosion and sediment control measures. It may also result in a more desirable and less costly development. Before grading activities begin, decisions must be made regarding the steepness of cut-and-fill slopes and how the slopes will be protected from runoff, stabilized, and maintained.

A grading plan should be prepared that establishes:

Which areas of the site will be graded.

How drainage patterns will be directed.

How runoff velocities will affect receiving waters.

When earthwork will start and stop.

Establishes the degree and length of finished slopes.

Dictates where and how excess material will be disposed of (or where borrow materials will be obtained if needed).

Berms, diversions, and other storm water practices that require excavation and filling also should be incorporated into the grading plan. The grading plan forms the basis of the Erosion Control and Sediment Prevention Plan.

A low-impact development BMP that can be incorporated into a grading plan is "site fingerprinting", which involves clearing and grading only those areas necessary for building activities and equipment traffic. Maintaining undisturbed temporary or permanent buffer zones in the grading operation provides a low-cost sediment control measure that will help reduce runoff and offsite sedimentation. The lowest elevation of the site should remain undisturbed to provide a protected storm water outlet before storm drains or other construction outlets are installed.

- Design
  Base the grading plan and installation upon adequate surveys and soil investigations. In the plan, show disturbed areas, cuts, fills, and finished elevations of the surface to be graded. Include in the plan all practices necessary for controlling erosion on the graded site and minimizing sedimentation downstream. Such practices may include, but are not limited to:

  Sediment basins
  Diversions
  Mulching
  Vegetation, vegetated and lined waterways
  Grade-stabilization structures
  Surface and subsurface drains

The practices may be temporary or permanent depending upon the need after construction is completed.

Guidelines for slope breaks on site:

Slope	Spacing (ft)
50% (2:1)	20
33% (3:1)	35
25% (4:1)	45
15-25%	50
10-15%	80
6-10%	125
3-6%	200
<3%	300

Borrow or stockpile areas should be considered a part of the erosion control plan and should be stabilized on any cleared, graded or filled areas of a construction site.

Side slopes on stockpiles should be kept to 2:1 or 1.5:1 slopes with silt fence installed around the perimeter. Show all borrow and disposal areas within the project limits in the grading plan, and ensure that they are adequately identified and protected.

Use slope breaks, such as diversions or benches, as appropriate to reduce the length of cut-and-fill slopes to limit sheet and rill erosion and prevent gullying.

Show environmentally sensitive areas on the grading plan and ensure that they are adequately identified and protected.

Provide stable channels and floodways to convey all runoff from the development area to an adequate outlet without causing increased erosion or offsite sedimentation.

- Effectiveness
  Land grading is an effective means of reducing steep slopes and stabilizing highly erodible soils when properly implemented with storm water management and erosion and sediment control practices. Land grading is not effective when drainage patterns are altered or when areas on the perimeter of the site vegetated are destroyed.

- Cost Considerations
  Land grading is practiced at virtually all construction sites. Additional site planning to incorporate storm water and erosion and sediment controls in the grading plan can require several hours of planning by a certified engineer or landscape architect. Extra time might be required to excavate diversions and construct berms, and fill materials might be needed to build up low-lying areas or fill depressions.

Common Trouble Points

High cost, if extensive amounts of grading are required to properly grade site.

Improper grading practices that disrupt natural storm water patterns might lead to poor drainage, high runoff velocities, and increased peak flows during storm events.

Clearing and grading of the entire site without vegetated buffers promotes offsite transport of sediment and other pollutants.

Operation and Maintenance

All graded areas and supporting erosion and sediment control practices should be periodically checked, especially after heavy rainfalls. All sediment should be removed from diversions or other storm water conveyances promptly. If washouts or breaks occur, they should be repaired immediately. Prompt maintenance of small-scale eroded areas is essential to prevent these areas from becoming significant gullies.

3.5.7 Dust Control

Definition

Reducing surface and air movement of dust during construction activities. Dust is generated when vegetation is removed and soil is exposed to wind. Light winds can pick up and transport silty soils, fine sands and clays. Course sands can also become erodible when winds are strong.

Dust control measures should be implemented to prevent the soil and attached pollutants from leaving the site. Acceptable dust control practices include watering, using mulch, establishing vegetation, and using spray-on adhesives.

Purpose

Prevent surface and air movement of dust from exposed and disturbed soil surfaces onto roadways, drainage ways and surface waters. Reduced the presence of airborne substances, which may be harmful or injurious to human health, welfare, or safety, or to animal or plant life.

Where Dust Control is Used

In areas (including roadways) subject to surface and air movement of dust where onsite and offsite damage is likely to occur if preventive measures are not taken. Dust control measures should be applied any time dust is generated on a construction site or road.

Basic Design and Construction Criteria

Construction activities inevitably result in the exposure and disturbance of soil. Dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activities) and as a result of wind erosion over exposed earth surfaces. Large quantities of dust are typically generated in "heavy" construction activities, such as road and street construction and subdivision, commercial or industrial development, which involve disturbance of significant areas of soil surface. Earth-moving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control the amount of soil exposed at any one time should be kept to an absolute minimum.

- Phasing a project and utilizing temporary stabilization practices upon the completion of grading can significantly reduce dust emissions.

- Vegetate or mulch areas that will not receive vehicle traffic. In areas where planting, mulching, or paving is impractical, apply gravel or landscaping rock. On large areas, consider planting trees and shrubs as wind breakers.

- Limit dust generation by clearing only those areas where immediate activity will take place, leaving the remaining area(s) in the original condition, if stable. Maintain the original ground cover as long as practical.

- Construct natural or artificial windbreaks or windscreens. These may be designed as enclosures for small dust sources.

- Sprinkle the site with water until surface is wet. Repeat as needed. Irrigation water can be used for dust control. Irrigation systems should be installed as a first step on sites where dust control is a concern. Watering should be done at a rate, which prevents dust but does not cause soil erosion.

- Spray exposed soil areas with a dust palliative, following the manufacturer's instructions and cautions regarding handling and application. Used oil is prohibited from use as a dust suppressant.

- Special attention needs to be given to dust control during the drought months when the ground is dry.

Techniques that can be used for unpaved roads and lots include:

Lower speed limits. High vehicle speed increases the amount of dust stirred up from unpaved roads and lots.

Upgrade the road surface strength by improving particle size, shape, and mineral types that make up the surface and base materials.

Add surface gravel to reduce the source of dust emission. Limit the amount of fine particles (those smaller than .075 mm) to 10 to 20 percent.

Use geotextile fabrics to increase the strength of new roads or roads undergoing reconstruction.

Encourage the use of alternate, paved routes, if available.

Restrict use by tracked vehicles and heavy trucks to prevent damage to road surface and base.

Apply chemical dust suppressants using the admix method, blending the product with the top few inches of surface material. Suppressants may also be applied as surface treatments.

Pave unpaved permanent roads and other trafficked areas.

Use vacuum street sweepers.

Remove mud and other dirt promptly so it does not dry and then turn into dust.

Limit dust-causing work on windy days.

- Temporary Dust Control Measures

  Mulching – See MULCHING practice.

  Vegetative covers – See TEMPORARY SEEDING practice.

  Watering - Site is sprinkled with water until the surface is wet. Repeat as needed.

  Barriers – Solid board fences, burlap fences, crate walls, bales of hay and similar material can be used to control air currents and soil blowing. Barriers placed at right angles to prevailing currents at intervals of about 10 times the barrier height are effective in controlling wind erosion.

- Permanent Dust Control Measures

  Permanent vegetation – See PERMANENT SEEDING practice. Existing trees and large shrubs may afford valuable protection if left in place.

  Topsoiling – See TOPSOILING practice.

  Stone – Cover surface with crushed stone or coarse gravel.

Common Trouble Point

Use of water onsite to control dust emissions, particularly in areas where the soil is already compacted, can cause a runoff problem where there was not one.

Operation and Maintenance

To prevent dust from becoming a public nuisance and causing offsite damages, dust control should be ongoing during earth change activities. Proceed to re-spray the area as necessary to keep dust to a minimum.

3.5.8 Construction Road Stabilization

Definition

Construction road stabilization is the temporary stabilization with stone of access roads, subdivision roads, parking areas, and other onsite vehicle transportation routes immediately after grading.

The temporary stabilization of an area subjected to construction traffic is used to reduce sediment leaving a site via construction vehicles and to reduce erosion of the road face.

Purpose

To reduce erosion of temporary roadbeds by construction traffic during wet weather.

To reduce erosion and therefore regrading of permanent road beds between the time of initial grading and final stabilization.

Where Construction Road Stabilization is Used

Road stabilization is used at any location where traffic will be leaving or entering a construction site. Temporary construction entrances can help keep sediment transported by construction equipment onsite. This practice is also desirable to prevent erosion of temporary roads until they are permanently stabilized.

Basic Design and Construction Criteria

- Planning.
  Areas that are graded for construction vehicle transport and parking purposes are especially susceptible to erosion because they become compacted and collect and convey runoff along their surfaces. Rills, gullies and troublesome muddy areas form unless the road is stabilized. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. During wet weather, they often become muddy and unstable generating significant quantities of sediment that may pollute nearby streams or are transported offsite on the wheels of construction vehicles. Unstabilized dirt roads may become so muddy they are virtually unusable causing work interruption.

  Improperly planned and maintained roads can become a continual erosion problem. Excess runoff from roads cause erosion in adjacent areas, and an unstabilized road may become a dust problem.

  Proper grading and stabilization of construction routes often saves money for the contractor by improving the overall efficiency of the construction operation while reducing the erosion problem. Low-grade asphalt or asphalt grindings may be used to facilitate maintenance and remove tracked earth.

Permanent roads and parking areas should be designed and constructed according to criteria established by the local authority.

- Design Criteria

1) Location.
Temporary roads should be located to serve the purpose intended, facilitate the control and disposal of water, control or reduce erosion, and make best use of topographic features. Temporary roads should follow the contour of the natural terrain to minimize disturbance of drainage patterns. Locate parking areas on naturally flat areas if they are available to minimize grading.

2) Grade and Alignment.
The gradient and vertical and horizontal alignment should be adapted to the intensity of use, mode of travel and level of development. Grades for temporary roads should not exceed 10%. Frequent grade changes generally cause fewer erosion problems than long continuous gradients. Grades for temporary parking areas should be sufficient to provide drainage but not more than 4%.

3) Width.
Construction roads shall be at least 12 feet wide for one-way traffic and 20 feet wide for two-way traffic. Two-way traffic widths shall be increased a minimum of 4 feet for trailer traffic. Where turnouts are used, road width should be increased to a minimum of 20 feet for a distance of 30 feet. The type of vehicle or equipment, speed, loads, climatic and other conditions under which vehicles and equipment are expected to operate need to be considered and the minimum widths increased accordingly.

4) Stabilization.
A 6-inch course of 2 to 4-inch crushed rock, gravel base, or crushed surfacing base course shall be applied immediately after grading or the completion of utility installation within the right-of-way. In areas experiencing heavy traffic, stone should be placed at an 8 to 10 inch depth to avoid excessive dissipation or maintenance needs. A 4-inch course of asphalt treated base (ATB) may be used in lieu of the crushed rock, or as advised by the local government.

Geotextile should be used under the coarse aggregate to provide a stable foundation and to facilitate removal of the stone. The geotextile used to minimize the migration of stone into the underlying soil by heavy vehicle loads shall meet the requirements of material specification GEOTEXTILE, Table 1 or 2, Class I, II or IV. (See STABILIZED CONSTRUCTION ENTRANCE specification).

Where seepage areas or seasonally wet areas must be crossed, install subsurface drains and geotextile filter fabric. All roadside ditches, cuts, fills and disturbed areas adjacent to parking areas and roads should be stabilized with appropriate temporary or permanent vegetation.

5) Side Slopes.
All cut and fill slopes should have side slopes designed to be stable for the particular site conditions and soil materials involved. All cut and fill slopes shall be 2:1 (horizontal to vertical) or flatter.

6) Drainage.
The type of drainage structure used will depend on the type of activity and runoff conditions. The capacity and design should be consistent with sound engineering principles and should be adequate for the class of vehicle, type of road, development, or use.

Roadside ditches shall be provided as needed. Ditches should be designed to be on stable grades and/or protected with structures or linings for stability.

Plans and Specifications

Plans and specifications for installing construction road stabilization shall at a minimum include the following:

Location where the practice will be installed
Dimensions of the practice - length, width and thickness
Alignment and grade of the practice
Type of materials

All plans shall include installation, inspection, and maintenance schedules with the responsible party identified.

- Construction Specifications

The roadbed or parking surface shall be cleared of all vegetation, roots and other objectionable material. Trees, stumps, brush, roots, weeds, and other objectionable materials should be removed from the work area.

Grading, subgrade preparation, and compaction should be done as needed. Fill material should be deposited in layers not to exceed 9 inches and compacted with the controlled movement of compacting and earth moving equipment.

Roads should be planned and laid out with storm water flow paths in mind.

Leave surfaces smooth and sloped for drainage. Divert runoff and drainage from the stone pad to a designated sediment trap/basin.

Place geotextile fabric on graded foundation to improve stability, especially where wet conditions are anticipated. Pipe may be installed to help maintain proper drainage.

Where feasible, alternative routes should be made for construction traffic, one for use in dry conditions, the other for wet conditions.

Areas adjacent to culvert crossings and steep slopes should be seeded and mulched and/or covered.

Dust control should be used when necessary.

Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Common Trouble Points

Temporary gravel entrance becomes muddy; stone is pressed into soil due to pad being too thin, the stone applied was too small, and/or the geotextile fabric was not used. Reconstruct temporary entrance.

Sediment is tracked onto road by construction equipment, extend the pad beyond the minimum 50 feet length until condition is corrected.

Pad not flared sufficiently at road entrance, this may result in mud being tracked onto road and possible damage to road edge.

For unstable foundation, use geotextile fabric under pad and/or improve foundation drainage.

Measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area.

Application of aggregate to construction roads may need to be made more than once during a construction period.

Operation and Maintenance

Inspection of erosion control measures should be made before anticipated storm events, after the end of a storm event of 0.5 inches or greater, and at least once every 14 calendar days.

Maintain entrance conditions to prevent tracking or flowing of sediment onto public roads. This may require periodic top dressing with additional stone to maintain a gravel depth of 6 inches or additional length as condition demands

and repairs and/or cleanout of any methods used to trap sediment. Remove mud and sediment tracked or washed onto public roads immediately.
Inspect seeded areas adjacent to the roads and parking areas to ensure that a vigorous stand of vegetation is maintained and inspect roadside ditches and other drainage structures to ensure that they do not become clogged with silt or other debris.

Removal.
All temporary erosion and sediment control measures shall be removed after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

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SECTION 4: STORM AND RUNOFF PRACTICES

Storm water management practices are designed to perform one or more of the following functions: decrease the erosive potential of increased runoff volumes and velocities caused by land development; remove suspended solids and associated pollutants in storm water runoff that result from activities that occur during and after development; preserve drainage patterns and other hydrological conditions so that they closely resemble conditions previous to development; and preserve natural systems. Storm water control practices rely on three different processes to treat runoff: infiltration, filtration, and detention.

These practices are:

- Storm Water Retention Basin
- Storm Water Detention Basin
- Storm Water Conveyance Channel
- Diversion
- Check Dams
- Outlet Protection
- Inlet Protection
- Riprap
- Grassed Waterway
- Level Spreader

4.1 Storm Water Retention Basins

Definition

A surface area used to store runoff for a selected design storm or specified treatment volume. Storm water is retained on site, with the storage volume recovered when the runoff percolates into the soil or evapotranspires. Such facilities are practical whenever soil permeability is sufficient to allow rapid percolation between storms. If soil permeability is insufficient, an underdrain or storm water filtration system may need to be incorporated.

These systems may also be used for groundwater recharge. Potential groundwater contamination may be a problem associated with these systems and must always be considered in their design.

Purpose

To reduce storm water volume, peak discharge rate, and pollutants; and to recharge ground water and base flow.

Where Storm Water Retention Basins are Used

Applicability of this practice is primarily dependent upon the ability of the soils to percolate runoff, and the availability of adequate land area for a retention area or for modifications of an existing system. Geologic, topographic and soils conditions must be considered in determining site suitability. Besides soil infiltration rates, the single most significant limiting factor in many cases is the availability of sufficient land area to provide the necessary storage volume. This is particularly true in densely urbanized areas where land is scarce and property values are high.

The soil and water table conditions must also be such that the system can, in a maximum of 72 hours following a storm water event, provide for a new volume of storage through percolation and/or evapotranspiration. When retention systems are vegetated as recommended, the runoff needs to percolate within 24 to 36 hours to assure viability of the vegetation. Retention systems do not release stored waters for surface discharge.

Typically retention basins are used to treat parking lot and rooftop runoff.

Retention Basin

Basic Design and Construction Criteria

Initial basin excavation should be carried to within 1 ft. (0.3m) of the final elevation of the basin floor. Interior side slopes should be sodded immediately to prevent erosion and the introduction of additional sediment. Final excavation shall be deferred until all contributing areas of the watershed have been stabilized. Light equipment should be used to remove accumulated sediment and achieve final grade without compacting the basin floor. After final grading, the basin floor should be scarified with rotary tillers or disc harrows to promote infiltration and grass establishment.

Structural elements, such as embankments, inlets, flumes, and emergency spillways, shall be designed by a registered professional engineer.

These elements shall be constructed in accordance with NRCS Conservation Practice Standard, Pond, Code 378 or, according to the requirements of NRCS Technical Release (TR-60), Earth Dams and Reservoirs, as appropriate for the class and kind of structure being considered or in accordance with other acceptable engineering criteria.

Do not allow sediment laden runoff to enter a finished basin. Do not over excavate in order to provide additional sediment capacity unless the intent is to remove all sediment and backfill with a more pervious soil type.

Laws and Regulations.
These projects must conform to all federal, state, and local laws and regulations. Laws and regulations of particular concern include involving water rights, dam construction, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.

Embankment Cross Section.
For portion of the basin controlling only flowing water 3 feet or less deep, embankment slopes must be two horizontal to one vertical (2:1), or flatter. For all other portions of the basin, the sum of the upstream and downstream slopes must be 5:1 or flatter with a maximum of 2:1 in either slope.

Earth Embankment.
Minimum effective top widths are given in Table 1. Constructed embankment height must be at least 5% greater than design height to allow for settlement. The maximum settled height of the embankment must be 15 feet or less measured from natural ground at centerline of the embankment.

Table 1. Minimum Top Width of Embankments

Fill Height (feet)	Effective Top Width (feet)
0 - 5	3
5 - 10	6
10 - 15	8

Capacity.
Basins must have capacity to prevent overtopping by runoff from a 10-year frequency, 24-hour duration storm. Larger design storms may be used where needed for flood control or other purposes. In addition to the above storage, basins must have capacity to store at least the anticipated 10-year sediment accumulation, or periodic sediment removal must be provided to maintain the required capacity. Basin ends must be closed to an elevation that will contain design capacity. Freeboard may be added to design height to provide for safe operation of auxiliary spillways. Auxiliary spillways must not contribute runoff to a lower basin (or pond) except where the lower basin (or pond) is designed to control the flow.

Outlets.
Water control basins must have spillways, underground outlets or soil infiltration outlets, grassed waterway, and diversion channel as appropriate.

Vegetation.
Disturbed areas must be established to appropriate vegetation or otherwise protected from erosion using gravel mulch or other measures. Selection of vegetation species must consider environmental quantity and quality, endangered species needs, and wildlife food and habitat needs.

Operation and Maintenance

A site specific O&M plan must be prepared for and reviewed with the landowner or operator. The plan shall contain guidance to maintain the embankment, design capacity, vegetative cover and outlet.

All plans shall include a provision that after each large storm, basins must be inspected and needed maintenance performed. When sediment storage is full, accumulated sediment must be removed or the basin must be redesigned and modified to restore capacity. Where designs include underground outlets, O&M plans should include checking for clogging and/or pipe damage.

4.2 Storm Water Detention Basins

Definition

Onsite detention refers to the temporary storage of excess runoff on the site prior to its gradual release after the peak of the storm inflow has passed. Runoff is held for a short period of time and is slowly released to a natural or constructed water course, usually at a rate no greater than the pre-development peak discharge rate.

Purpose

The objective of a detention facility is to regulate the runoff from a given rainfall event and to control discharge rates to reduce the impact on downstream storm water systems, either natural or manmade. Generally, detention facilities will not reduce the total volume of runoff, but will redistribute the rate of runoff over a period of time by providing temporary "live" storage of a certain amount of storm water. The volume of temporary "live" storage provided is the volume indicated by the area between the inflow and outflow hydrographs as shown in Figure 1.

A major benefit derived from properly designed and operated detention facilities is the reduction in downstream flooding problems. Other benefits include reduced costs of downstream storm water conveyance facilities, reduction in pollution of receiving streams and enhancement of aesthetics within a development area by providing a core of "blue-green" areas for parks and recreation.

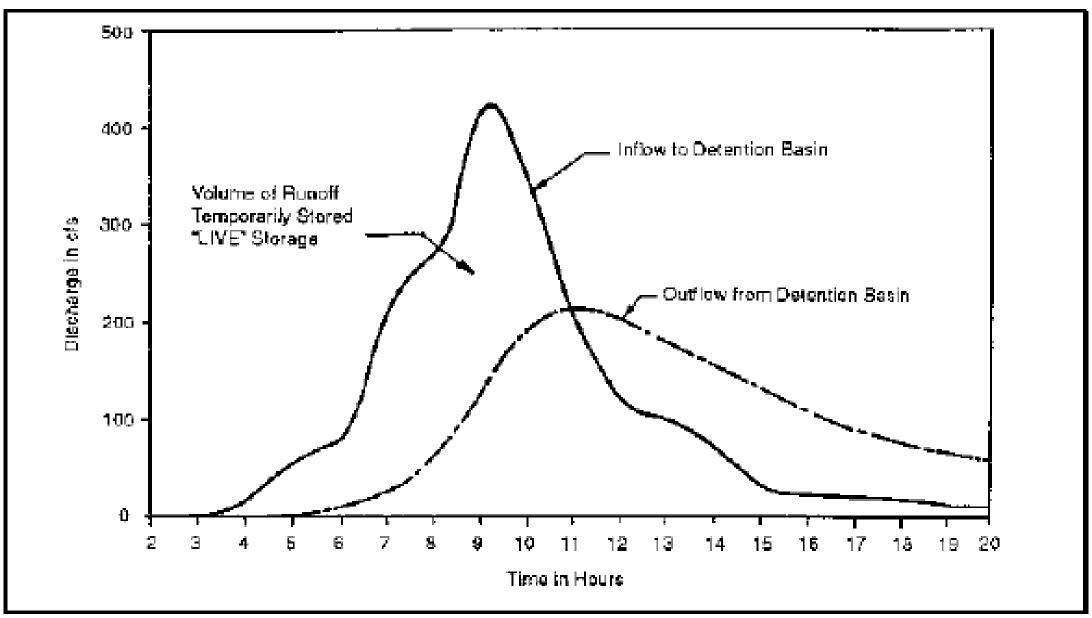

Figure 1. Typical Detention Basin Hydrographic, Source NRCS

Where Storm Water Detention Basins are Used

A detention basin is an impoundment or excavated basin for the short term detention of storm water runoff from a completed development area.

Detention basins are strategically located near the outlet of a project site to detain runoff reducing downstream peak flows.

Basic Design and Construction Criteria

Initial basin construction should be carried to within 1 ft. (0.3m) of the elevation of the basin floor. Interior side slopes should be sodded immediately to prevent erosion and the introduction of additional sediment. Final excavation shall be deferred until all contributing areas of the watershed have been stabilized.

Structural elements, such as embankments, inlets, flumes, and emergency spillways, shall be designed by a registered professional engineer. These elements shall be constructed in accordance with NRCS Conservation Practice Standard, Pond, Code 378 or, according to the requirements of NRCS Technical Release (TR-60), Earth Dams and Reservoirs, as appropriate for the class and kind of structure being considered or, in accordance with other acceptable engineering criteria.

Laws and Regulations.
These projects must conform to all federal, state, and local laws and regulations. Laws and regulations of particular concern include involving water rights, dam construction, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.

Embankment Cross Section.
For portion of the basin controlling only flowing water 3 feet or less deep, embankment slopes must be two horizontal to one vertical (2:1), or flatter. For all other portions of the basin, the sum of the upstream and downstream slopes must be 5:1 or flatter with a maximum of 2:1 in either slope.

Earth Embankment.
Minimum effective top widths are given in Table 1. Constructed embankment height must be at least 5% greater than design height to allow for settlement. The maximum settled height of the embankment must be 15 feet or less measured from natural ground at centerline of the embankment.

Table 1. Minimum Top Width of Embankments

Fill Height (feet)	Effective Top Width (feet)
0 – 5	3
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Capacity.
Basins must have capacity to prevent overtopping by runoff from a 10-year frequency, 24-hour duration storm. Larger design storms may be used where needed for flood control or other purposes. In addition to the above storage, basins must have capacity to store at least the anticipated 10-year sediment accumulation, or periodic sediment removal must be provided to maintain the required capacity. Basin ends must be closed to an elevation that will contain design capacity. Freeboard may be added to design height to provide for safe operation of auxiliary spillways. Auxiliary spillways must not contribute runoff to a lower basin (or pond) except where the lower basin (or pond) is designed to control the flow.

Outlets.
Water control basins must have spillways, underground outlets or soil infiltration outlets, grassed waterway, and diversion channel as appropriate.

Vegetation.
Disturbed areas must be established to appropriate vegetation or otherwise protected from erosion using gravel mulch or other measures. Selection of vegetation species must consider environmental quantity and quality, endangered species needs, and wildlife food and habitat needs.

Operation and Maintenance

A site specific O&M plan must be prepared for and reviewed with the landowner or operator. The plan shall contain guidance to maintain the embankment, design capacity, vegetative cover and outlet.

All plans shall include a provision that after each large storm, basins must be inspected and needed maintenance performed. When sediment storage is full, accumulated sediment must be removed or the basin must be redesigned and modified to restore capacity. Where designs include underground outlets, O&M plans should include checking for clogging and/or pipe damage.

4.3 Storm Water Conveyance Channel

Definition

A permanent, designed waterway shaped and lined with appropriate vegetation or structural material to safely convey excess storm water runoff away from a developing area.

Purpose

To provide for the conveyance of concentrated surface runoff water without damage from erosion.

Where Storm Water Conveyance Channels are Used

Generally applicable to man-made-channels, including roadside ditches, and intermittent natural channels that are modified to accommodate increased flows generated by land development. This practice is not applicable to major, continuous flowing natural streams.

Basic Design and Construction Criteria

The design of a channel is based primarily on the volume and velocity of flow expected in the channel. The intent is to design the waterway so that it has adequate capacity and sufficient erosion resistance.

The design of storm water conveyance channels should be done by a registered professional engineer.

- General Criteria

Shape.
There are two types of channels to choose from: parabolic and trapezoidal (see Figure 1). Parabolic channels are more similar to the shape of natural channels and are often used where space is available for a wide, shallow channel to allow low velocities. Trapezoidal channels are normally used where deeper channels are needed to carry large flows. Trapezoidal design works well with riprap or other structural linings, and tends to revert to a parabolic shape over time.

Side Slopes.
Vegetated slopes in urban areas should be 4:1 or flatter for maintenance reasons. Slopes can be steeper for structurally lined channels as long as they are within the capability of the soil and structural lining. For trapezoidal channels with a bottom width greater than 15 feet, the center should be lowered 0.5 foot to prevent meandering during low flows.

Capacity.
Unless local storm water requirements indicate otherwise, all storm water channels should be designed to contain at least the peak flow from a 10-year frequency storm. In areas where flooding of the channel will cause damage to property owners, the channel capacity should be increased. The capacity of the channel should not exceed the capacity of the outlet area. Property damage or safety hazards may result if channel capacity is exceeded. Extra capacity may be needed for areas where sediment is expected to accumulate. An extra 0.3 to 0.5 foot of depth is recommended.

Velocity.
Channels should be designed so that the velocity of flow expected from the design storm does not exceed the permissible velocity for the type of lining used. Design velocities should be appropriate for the type of liner selected. See "Channel Linings," below.

Depth.
The design water surface elevation of a channel receiving water from other tributary channels should be equal to or less than the design water surface elevation of the other tributary channel at the point of intersection.

Cross Sections.
The top width of parabolic and grass-lined channels should not exceed 30 feet, and the bottom width of trapezoidal, grass-lined channels should not exceed 15 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering of low flows.

Freeboard.
Where good vegetative cover cannot be grown adjacent to the lined side slopes, a minimum freeboard of 1 foot above design flow depth should be incorporated into the lined waterway.

Channel Linings.
If flows are expected to be 6 cfs or less, consider using Grassed Waterways. If flows are expected to be over 6 cfs, consider using Riprap. If flows or slopes are such that riprap cannot be used, consider using gabions. If it is necessary, use concrete but this is not the preferred material for storm water conveyance.

It is important to follow the design and installation procedures for the type of liner selected.

Outlet.
All channels should discharge through a protected outlet. The outlet should be designed so that it will handle the expected runoff velocities and volumes from the channel without resulting in scouring. An energy dissipator may be needed if it is determined that flow velocities exceed the allowable velocity of the receiving channel.

Upstream Areas.
If the channel is below a high sediment-producing area, sediment should be trapped before it enters the channel (see SEDIMENT BASIN practice) or the area stabilized with vegetation.

- Grass-lined channels

Grass shall be established in accordance with GRASSED WATERWAY practice.

- Riprap-lined channels

Riprap shall be installed in accordance with RIPRAP practice.

- Gabion–lined channels

Gabion baskets and gabion mattresses shall be installed in accordance with manufacturer's recommendations and in compliance with federal and state regulations.

- Concrete-lined channels

Concrete-lined channels must be constructed in accordance with all applicable specifications. Following is a summary of some specifications provided as a guide only:

1. The subgrade should be moist at the time the concrete is poured.

2. Traverse joints for crack control should be provided at approximately 20-feet (6 m) intervals and when more than 45 minutes elapses between the times of consecutive concrete placements. All sections should be at least 6 feet (1.8 m) long. Crack control joints may be formed by using a 1/8-inch (3 mm) thick removable template, by scoring or sawing to a depth of at least 3/4 inch (19 mm) or by an approved "leave in" type insert.

3. Expansion joints shall be installed every 100 feet (30 m).

- Construction Considerations

All trees, brush, stumps, roots, obstructions and other unsuitable materials shall be removed and properly disposed of.

The channel shall be excavated or shaped to the proper grade and cross-section, taking into account the type of channel lining.

All fills shall be well compacted to prevent unequal settlement.

Any excess soil shall be removed and properly disposed of.

Install the channel liner based on the specification of appropriate standard.

<u>Operation and Maintenance</u>

Provisions must be made for timely maintenance to insure lined channels function properly. Items that should be considered are suggested below. These are not the only items that may need to be considered. Each plan must be site specific.

Inspect periodically, at least after every design frequency storm. Particular attention should be paid to the outlet of the channel. If erosion is occurring at the outlet, appropriate energy dissipation measures should be taken.

Repair blowouts, slumps, and eroded areas.

Regrade and reseed bare areas above the lining.

Replace riprap to design grade if settling or washing has occurred.

Inspect concrete for cracks, spalls, or damage needing repair.

Remove debris from channel.

Repair flagstones or hand-laid rock.

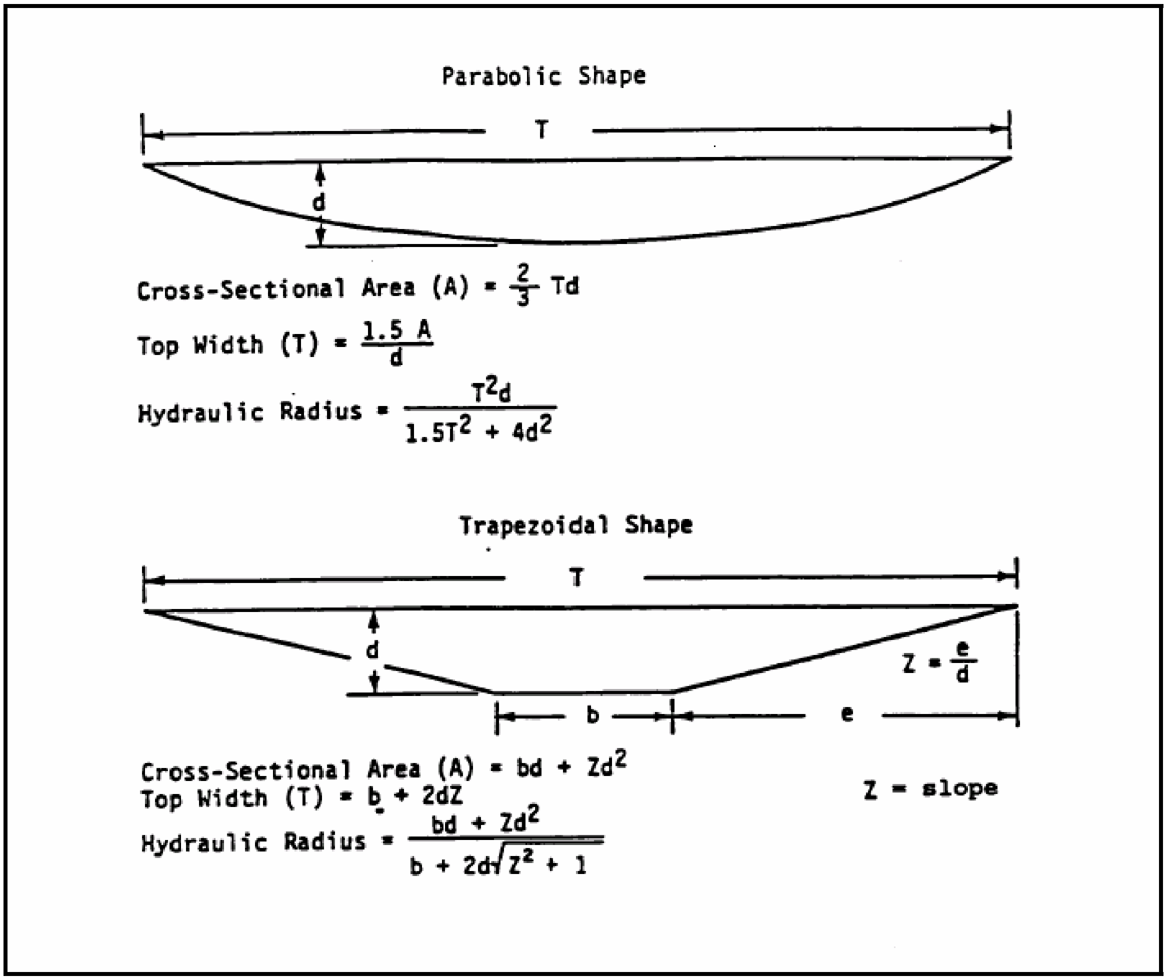


Figure 1. Channel Geometry
Source: USDA, Natural Resources Conservation Service.

4.4 Diversion

Definition

A channel constructed across a slope with a supporting ridge on the lower side.

Purpose

To reduce slope length and to intercept and divert storm water runoff to stabilized outlets at non-erosive velocities

Where Diversion Channels are Used

Where runoff from higher areas may damage property, cause erosion, or interfere with the establishment of vegetation on lower areas.

Where surface and/or shallow subsurface flow is damaging upland slopes.

Where the slope length needs to be reduced to minimize soil loss.

Diversions are applicable only below stabilized or protected areas. They should not be used below high sediment producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions.

Diversions should not be placed on slopes greater than fifteen percent.

Planning Considerations

Diversions can be useful tools for managing surface water flows and preventing erosion. On moderately sloping areas, they may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion. They may be placed at the top of cut or fill slopes to keep runoff from upland drainage areas off the slope. They can also be used to protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversions are preferable to other types of constructed storm water conveyance systems because they more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum. When properly coordinated into the landscape design of a site, diversions can be visually pleasing as well as functional.

As with any earthen structure, it is very important to establish adequate vegetation as soon as possible after installation. It is equally important to stabilize the drainage area above the diversion so that sediment will not enter and accumulate in the diversion channel.

Diversions should be constructed before clearing and grading operations begin. If used to protect a flat, exposed area, a diversion might be constructed as a dike or berm. Berms that are made of gravel or stone can be crossed by construction equipment.

Design Criteria

- Location.
  Diversion location shall be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage planes (where seepage is a problem), and the development layout.

- Capacity.
  Diversions designed to protect areas such as urban areas, homes, schools, industrial buildings, roads, parking lots, and comparable high-risk areas, and those designed to function in connection with other structures, shall have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved but not less than a 25-year frequency, 24-hour duration storm with a freeboard of at least 0.3 foot (10 cm).

- Channel Design.
  The diversion channel may be parabolic, trapezoidal, or V-shaped (See Figure 1). The diversion shall be designed to have stable side slopes.

- Ridge Design.
  The supporting ridge cross-section shall meet the following criteria:
  1) The side slopes shall be no steeper than 2:1 and shall be flat enough to insure ease of maintenance of the structure and its protective vegetative cover.
  2) The width at the design water elevation shall be a minimum of 4 feet.
  3) The minimum freeboard shall be 0.3 foot (10 cm).
  4) The design shall include a 10 percent settlement factor. The top of the constructed ridge at any point shall not be lower than the design depth plus the specified overfill for settlement.

- Outlet.
  Diversions shall have stabilized outlets, with adequate capacity, which will convey concentrated runoff without erosion. Acceptable outlets include Storm Water Conveyance Channels, Outlet Protection and Level Spreaders. Outlets shall be constructed and stabilized prior to the operation of the diversion.

- Stabilization.
  Unless otherwise stabilized, the ridge and channel shall be seeded and mulched within 15 days of installation in accordance with PERMANENT SEEDING practice.

  Disturbed areas draining into the diversion shall be seeded and mulched prior to, or at the time the diversion is constructed.

Permanent diversions should include a filter strip of close growing grass maintain above the channel. The width of the filter strip, measured from the center of the channel, shall be one-half the channel width plus 15 feet (4.5 m).

Construction Specifications

- All trees, brush, stumps, debris, and other obstructions shall be removed and disposed of so as not to interfere with the proper functioning of the diversion.

- The diversion shall be excavated or shaped to line, grade, and cross-section as required to meet the criteria specified herein, free of irregularities, which will impede flow.

- Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the complete diversion.

- All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the diversion.

- Permanent stabilization of disturbed areas shall be done in accordance with the applicable standard and specification contained in this handbook. Permanent stabilization techniques include permanent seeding and sodding.

Common Trouble Points

Frequent inspection and maintenance required.

If constructed improperly, can cause erosion and sediment transport since flows are concentrated.

Operation and Maintenance

A maintenance program shall be established to maintain diversion capacity, storage, ridge height, and the outlets. As a minimum, the diversion must be inspected and repaired as necessary after every storm event that causes flow in the diversion. Any hazards must be brought to the attention of the responsible person.

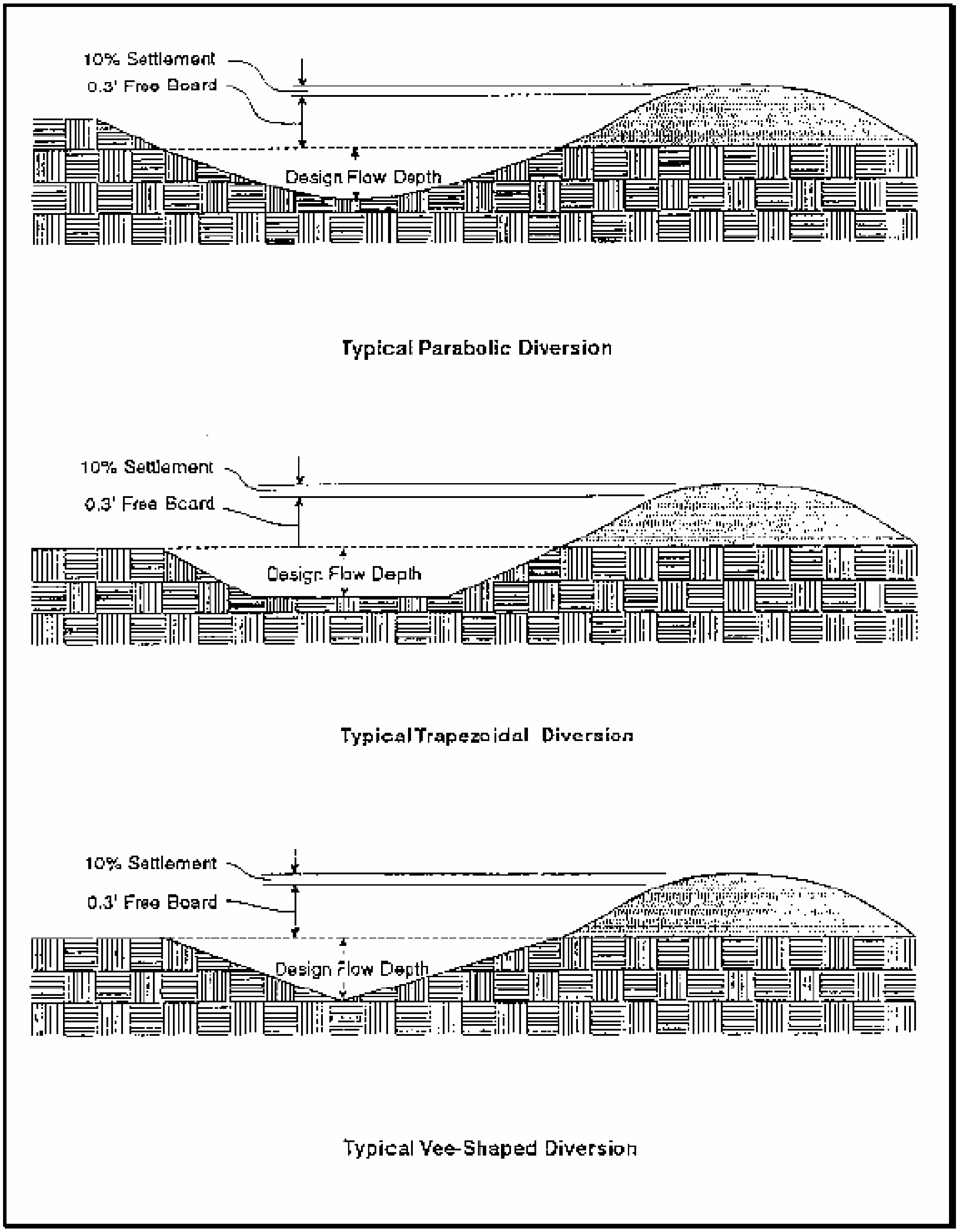


Figure 1. Diversions Shape

4.5 Check Dams

Definition

Small dams constructed across a swale or other storm water conveyance.

Purpose

To reduce the velocity of concentrated storm water flows, thereby reducing erosion of the swale or channel. This practice also traps small amounts of sediment generated in the conveyance itself. However, this is not a sediment trapping practice and should not be used as such.

Where Check Dams are Used

This practice is limited to use in small open channels, which drain small areas. Check dams should be used in channels, which will not be overtopped by flow, once the dams are constructed. They should not be used in a live stream. They are especially applicable to sloping sites where the gradient of waterways is close to the maximum for a grass lining. Some specific applications include:

- Temporary ditches or swales which, because of their short length of service, cannot receive a non-erodible lining but still need protection to reduce erosion.
- Either temporary or permanent ditches or swales, which need protection during the establishment of grass linings.
- An aid in the sediment trapping strategy for a construction site. This practice is not a substitute for mayor perimeter trapping measures such as a Sediment Trap or a Sediment Basin

Basic Design and Construction Criteria

No formal design is required for check dams. They can be used as temporary or permanent structures. Check dams may be designed by an engineer or may be installed by the contractor on an "as required" basis.

In any case, the following criteria should be adhered to when constructing check dams.

- The drainage area of the ditch or swale being protected shall not exceed 2 acres when coarse aggregate is used alone and shall not exceed 10 acres when a combination of Class I Riprap (added for stability) and coarse aggregate is used (see Figure 1). An effort should be made to extend the stone to the top of channel banks.

- Stone check dams should be constructed of coarse aggregate 2 to 15-inch stone.

- The riprap shall be composed of a well-graded mixture down to the 1-inch size particle such that 50% of the mixture by weight shall be larger than the d_{50} size as determined from the design procedure (for Riprap Class I, d_{50} = 1.1 ft.). A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d_{50} size.

- Extend the stone 18 inches beyond the banks and keep the side slopes 2:1 or flatter.

- The maximum height of the dam shall be 3 feet.

- The center of the check dam must be at least 6 inches lower than the outer edges (see Figure 1).

- Stone should be placed according to the configuration in Figure 1. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to insure that the center of the dam is lower than the edges.

- For added stability, the base of the check dam can be keyed into the soil approximately 6 inches.

- Filter cloth may be used under the stone to provide a stable foundation and to facilitate the removal of the stone.

- Excavating a sump immediately upstream from the check dam improves its effectiveness.

- Provide outlet stabilization below the lowest check dam where the risk of erosion is greatest.

- The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam (see Figure 3).

The cross-sections of the dams should be as shown in Figures 1 and 2, respectively, for logs and stone.

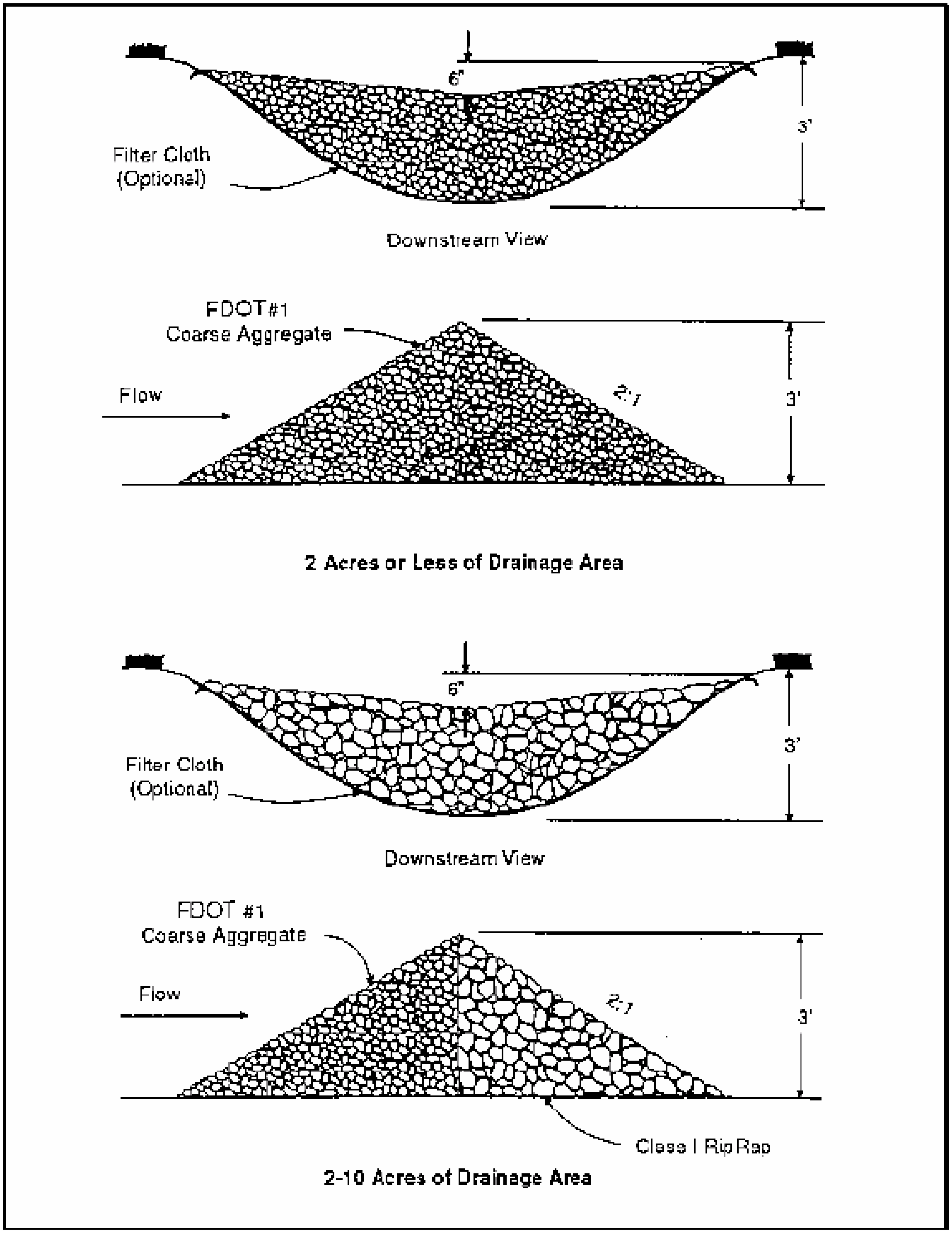


Figure 1. Rock Check Dam
Source: Virginia SWCC

Log check dams should be constructed of 6 to 8 inch logs salvaged from clearing operation site, if possible. The logs should be embedded into the soil at least 18 inches (45 cm). The 6-inch (15 cm) lower height required at the center can be achieved either by careful placement of the logs or by cutting the logs after they are in place. Logs and/or brush should be placed on the downstream side of the dam to prevent scour during high flows.

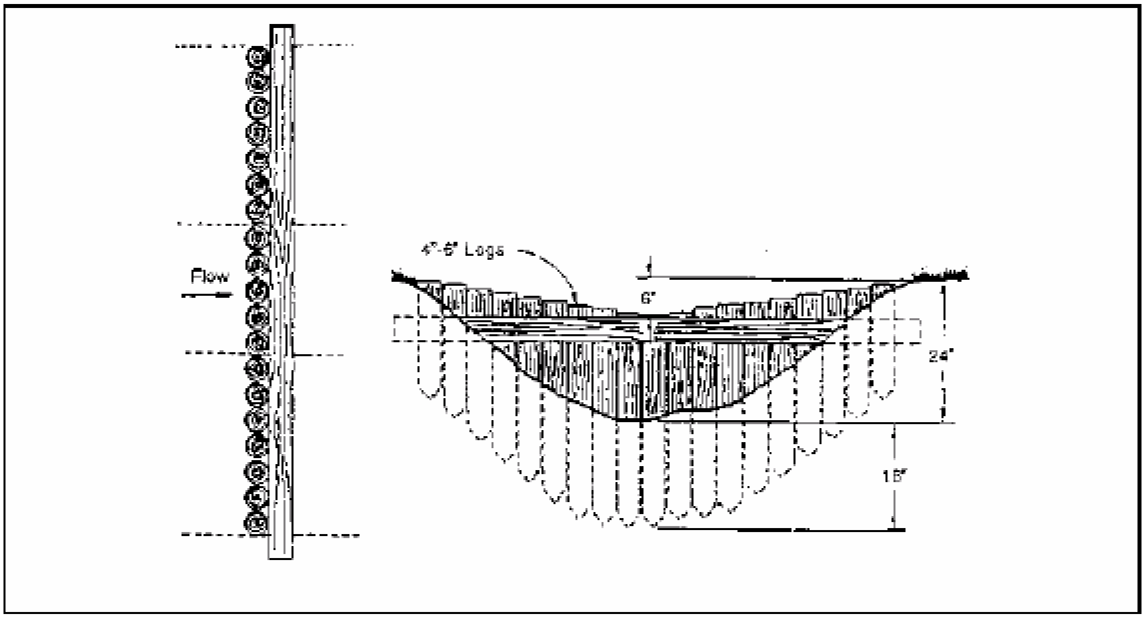


Figure 2. Log Check Dam
Source: Virginia SWCC

Operation and Maintenance

Check dams should be checked for sediment accumulation after each significant rainfall. Sediment should be removed when it reaches one half of the original height or before. All accumulated material removed from the dam shall be properly disposed.

Regular inspections should be made to insure that the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam should be corrected immediately. Replace stone as necessary for the dams to maintain their correct height.

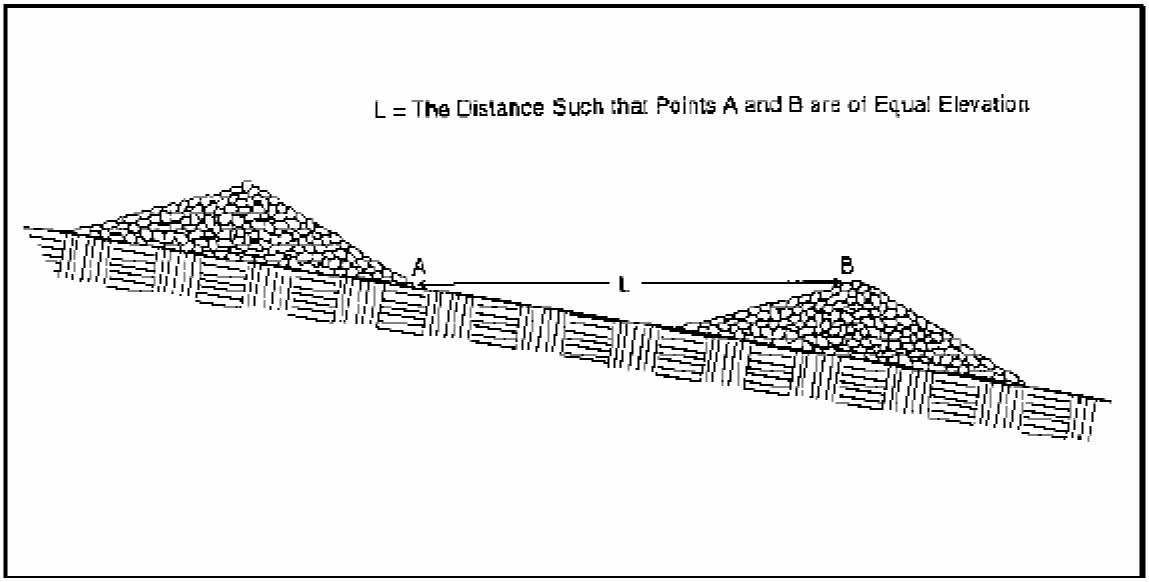


Figure 3. Spacing between Check Dams
Source: Virginia DSWC

4.6 Outlet Protection

Definition

Structurally lined aprons or other acceptable energy dissipating devices install below a storm drain outlet. The most common types are stone or riprap and concrete aprons with energy dissipator blocks or walls.

Purpose

Outlet protection reduces the speed of concentrated storm water flows and therefore it reduces erosion or scouring at storm water outlets and paved channel sections. In addition, outlet protection lowers the potential for downstream erosion.

Where Outlet Protection is Used

Outlet protection should be installed at all pipe, interceptor dike, swale, or channel section where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel.

The maximum allowable velocity at the outlet should be determined using the Table 1 below. When the velocity at the outlet exceeds the allowable velocity given in Table 1, outlet protection should be used to dissipate energy.

Table 1

Maximum Allowable Velocities for Various Soils

Soil Texture	Maximum Allowable Velocity (ft/sec)
Sand and sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel, graded loam to gravel	5.0
Cobbles	5.5
Shale	6.0

Source: Connecticut Guidelines for Soil Erosion and Sediment Control, Connecticut Council for Soil and Water Conservation, 1985.

Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools.

Basic Design and Construction Criteria

As with most channel design projects, depth of flow, roughness, gradient, side slopes, discharge rate, and velocity should be considered in the outlet design. Compliance to local and state regulations should also be considered while working in environmentally sensitive streambeds.

The exit velocity of the runoff as it leaves the outlet protection structure should be reduced to levels that minimize erosion.

General recommendations for rock size and length of outlet protection mat are shown in Table 2 and should be considered minimums.

The apron length and rock size gradation are determined using a combination of the discharge pipe diameter and estimate discharge rate. Select the longest apron length and largest rock size suggested by the pipe size and discharge rate. Where flows are conveyed in open channels such as ditches and swales, use the estimated discharge rate for selecting the apron length and rock size. The structure should be designed to handle the peak storm flow from the 25-year, 24-hour frequency storm, or the design discharge of the water conveyance structure, whichever is greater.

- There are many types of energy dissipaters, with rock being the one that is represented in Figure 1.

- Rock should consist of clean, angular stone that is resistant to weathering. Recycled concrete may also be used provided it has a density of at least 150 pounds per square inch and is clear of any steel or reinforcing agents, and that it is broken into blocky pieces such that the largest dimensions of each piece is no more than 3 times the smallest dimension.

- Rock outlet protection is usually less expensive and easier to install than concrete aprons or energy dissipaters. It also serves to trap sediment and reduce flow velocities.

- In all cases a geotextile (filter fabric) shall be placed between the apron and the underlying soil to prevent soil movement into and through the rocks. Underlying geotextile shall be anchor trenched in at least 6 to 9 inches and backfilled.

- Carefully place stones to avoid damaging the filter fabric.
    1) Stones 4 to 6 inches may be carefully dumped onto filter fabric from a height not to exceed 12 inches.
    2) Stones 8 to 12 inches must be hand placed onto filter fabric, or the filter fabric may be covered with 4 inches of gravel and the 8 to 12 inches rock may be dumped from a height not to exceed 16 inches.
    3) Stones greater than 12 inches shall only be dumped onto filter fabric protected with a layer of gravel with a thickness equal to one half the D50 rock size, and the dump height limited to twice the depth of the gravel protection layer thickness.

- Install riprap, grouted riprap, or concrete apron at selected outlet. Riprap aprons are best suited for temporary use during construction. Grouted or wired tied rock riprap can minimize maintenance requirements.

Riprap outlet protection aprons shall be installed in accordance with the RIPRAP practice and the RIPRAP OUTLET PROTECTION SPECIFICATIONS at the end of this standard.

Gabion mattresses can also be used. When a gabion mattress is used it shall be made of double twisted steel wire. The mats shall be a minimum of 12 inches thick.

Concrete or paved outlet protection is a permanent form of structure and, therefore, should be designed by qualified engineer. The design and installation of such a structure should follow plan specifications.

Align apron with receiving stream and keep straight throughout its length. If a curve is needed to fit site conditions, place it in upper section of apron.

Outlets on slopes steeper than 10 percent should have additional protection.

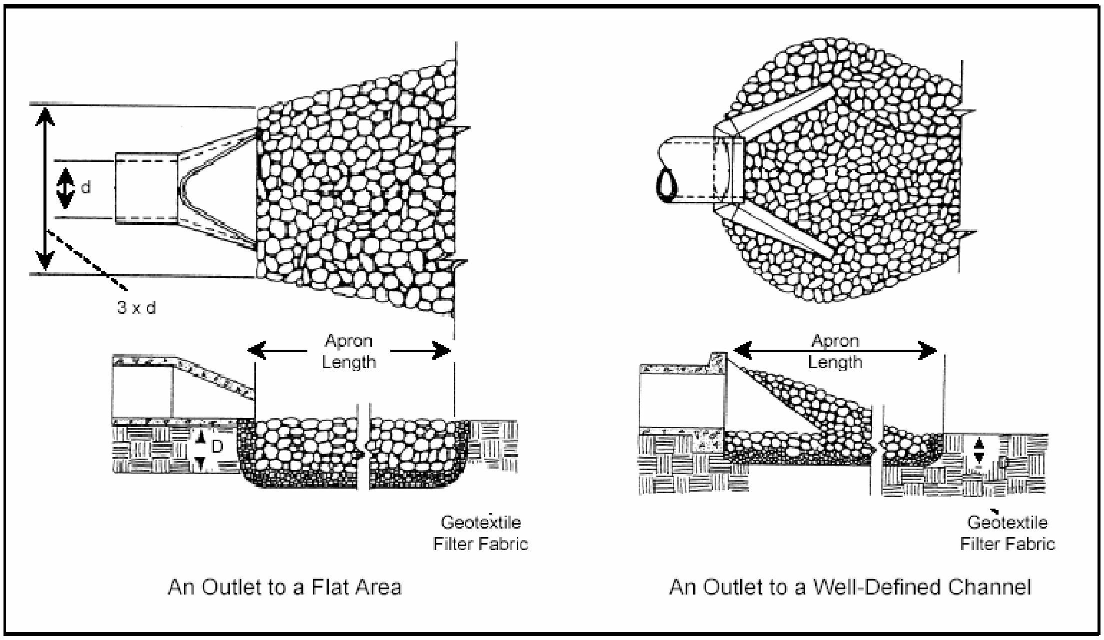
Operation and Maintenance

Outlet structures do not require much maintenance when properly installed, but should be checked, after all storm events, at sides and ends of the apron and for stone displacement. Repair damage immediately using appropriate stone sizes. Replace stones that have been washed away. If rocks continue to wash away, consider using larger material.

Inspect apron for any damage to the underlying fabric and repair immediately. Inspect for scour beneath the riprap and around the outlet. Repair damage to slopes or underlying filter fabric immediately.

Accumulated sediment should be removed periodically.

Temporary devices should be completely removed as soon as the surrounding drainage area has been stabilized or at the completion of construction.



Source: Adapted from the Georgia Stormwater Management Manual

Figure 1: Rock Outlet Protection

Table 2: General Recommendations for Rock Size and Length of Outlet Protection

Pipe Diameter inches	Discharge ft^3/s	Apron Length, La ft	Rip Rap D_{50} Diameter Min inches
12	5	10	4
	10	13	6
18	10	10	6
	20	16	8
	30	23	12
	40	26	16
24	30	16	8
	40	26	8
	50	26	12
	60	30	16

For larger or higher flows consult a Registered Civil Engineer
Source: USDA - SCS

Riprap Outlet Protection Specifications

This table is intended to select two parameters for the design of riprap outlet protection, based upon outlet velocities that correspond with circular culverts flowing full. Flow values less than the lowest value for the culvert size usually indicate a full-flow velocity less than 5 feet per second, for which riprap is usually not necessary. Flow values more than the highest value for the culvert size usually indicates that concrete stilling basin or energy dissipater structure is necessary.

Adjust values upward if the circular culvert is not flowing full based upon outlet conditions.

Riprap Aprons for Low Tailwater (downstream flow depth < 0.5 x pipe diameter)

Culvert Diameter	Lowest value			Intermediate values to interpolate from									Highest value		
	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}
	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In
12"	4	7	2.5	6	10	3.5	9	131	6	12	16	7	14	17	8.5
15"	6.5	8	3	10	12	5	15	16	7	20	18	10	25	20	12
18"	10	9	3.5	15	14	5.5	20	17	7	30	22	11	40	25	14
21"	15	11	4	25	18	7	35	22	10	45	26	13	60	29	18
24"	21	13	5	35	20	8.5	50	26	12	65	30	16	80	33	19
27"	27	14	5.5	50	24	9.5	70	29	14	90	34	18	110	37	22
30"	36	16	6	60	25	9.5	90	33	15.5	120	38	20	140	41	24
36"	56	20	7	100	32	13	140	40	18	180	45	23	220	50	28
42"	82	22	8.5	120	32	12	160	39	17	200	45	20	260	52	26
48"	120	26	10	170	37	14	220	46	19	270	54	23	320	64	37

Riprap Aprons for High Tailwater (downstream flow depth > 0.5 x pipe diameter)

Culvert Diameter	Lowest value			Intermediate values to interpolate from									Highest value		
	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}
	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In
12"	4	8	2	6	18	2.5	9	28	4.5	12	36	7	14	40	8
15"	7	8	2	10	20	2.5	15	34	5	20	42	7.5	25	50	10
18"	10	8	2	15	22	3	20	34	5	30	50	9	40	60	11
21"	15	8	2	25	32	4.5	35	48	7	45	58	11	60	72	14
24"	20	8	2	35	36	5	50	55	8.5	65	68	12	80	80	15
27"	27	10	2	50	41	6	70	58	10	90	70	14	110	82	17
30"	36	11	2	60	42	6	90	64	11	120	80	15	140	90	18
36"	56	13	2.5	100	60	7	140	85	13	180	104	18	220	120	23
42"	82	15	2.5	120	50	6	160	75	10	200	96	14	260	120	19
48"	120	20	2.5	170	58	7	220	85	12	270	105	16	320	120	20

4.7 Inlet Protection

Definition

A storm drain inlet protection is a sediment filter installed around any inlet or drain to trap sediment.

Purpose

The purpose of storm drain inlet protection is to prevent sediment from entering a storm drainage system prior to permanent stabilization of the disturbed area.

Where Inlet Protection is Used

Storm drains made operational before their drainage area is stabilized can convey large amounts of sediment to storm sewer systems or natural drainage ways and, in extreme cases, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

The following concerns shall be taken into consideration:

- This practice applies mainly to enclosed drainage systems.
- If these systems outlet to a stream, water quality must be protected.
- This practice contains several types of inlet filters and traps which have different applications dependent upon site conditions and the type of inlet. Other innovative techniques for accomplishing the same purpose are encouraged, but they should be installed only after careful study of their effectiveness.
- Note that these various inlet protection devices are for drainage areas of less than one acre. Runoff from large disturbed areas should be routed through a sediment trap or sediment basin.
- The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source.

Basic Design and Construction Criteria

Storm drain inlet protection is not meant for use in drainage areas exceeding 1 acre or for large concentrated storm water flows.

Installation of this measure should take place before any soil disturbance in the drainage area.

The inlet protection device shall be constructed in a manner that will facilitate clean-out and disposal of trapped sediment and minimize interference with construction activities.

Any resultant ponding of storm water must not cause excessive inconvenience or damage to adjacent areas or structures.

The type of material used will depend on site conditions and the size of the drainage area.

Inlet protection should be used in combination with other measures, such as small impoundments or sediment traps, to provide more effective sediment removal.

- Hay Bale Drop Inlet Structure

  Hay bales shall be string-tied with the bindings oriented around the sides rather than over and under the bales.

  Bales shall be placed lengthwise in a single row surrounding the inlet, with the ends of adjacent bales pressed together.

  The filter barrier shall be entrenched and backfilled. A trench shall be excavated around the inlet, the width of a bale, to a minimum depth of 4 inches. After the bales are staked, the excavated soil shall be backfilled and compacted against the filter barrier.

  Each bale shall be securely anchored and held in place by at least two stakes or steel bars driven through the bale.

  Loose straw shall be wedged between bales to prevent water from entering between bales.

- Silt Fence Drop Inlet Sediment Filter

  Silt fence inlet protection is appropriate for drainage areas fairly flat with slopes of 5% or less and the area immediately surrounding the inlet should not exceed a slope of 1%.

  Overland flow to the inlet should not be greater than 0.5 cubic feet per second (cfs).

  This type of inlet protection is not appropriate for use in paved areas because the filter fabric requires staking.

  Silt fence shall be as specified in the SILT FENCES practice and shall be cut from a continuous roll to avoid joints.

  Stakes shall be spaced around the perimeter of the inlet a maximum of 3 feet apart and securely driven into the ground (minimum of 18 inches).

A trench shall be excavated approximately 6 inches wide and 8 to 12 inches deep around the outside perimeter of the stakes and 12 to 18 inches of the fabric shall be extended into the trench.

The height of the filter barrier shall be a minimum of 15 inches and shall not exceed 18 inches.

The trench shall be backfilled and the soil compacted over the fabric.

See Figure 1 for general information on the proper installation of silt fence sediment barrier.

- Block and Gravel Drop Inlet Sediment Barrier

  Block and gravel inlet protection is appropriate for drainage areas fairly flat with slopes of 5% or less and the area immediately surrounding the inlet should not exceed a slope of 1%.

  May be used with most types of inlets where overflow capability is needed and in areas of heavy flows 0.5 cubic feet per second (cfs) or greater.

  To achieve maximum trapping efficiency the longest dimension of the basin should be oriented toward the longest inflow area.

  See Figure 2 for general information on the proper installation of this structure.

Operation and Maintenance

The structure shall be inspected before and after each rain event and repaired as needed.

Sediment shall be removed and the storm drain sediment barrier restored to its original dimensions when the sediment has accumulated to ½ the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.

Structures shall be removed and the area stabilized when the remaining drainage area has been properly stabilized. All catch basins and storm drains inlet must be cleaned at the end of construction and after the site has been fully stabilized.

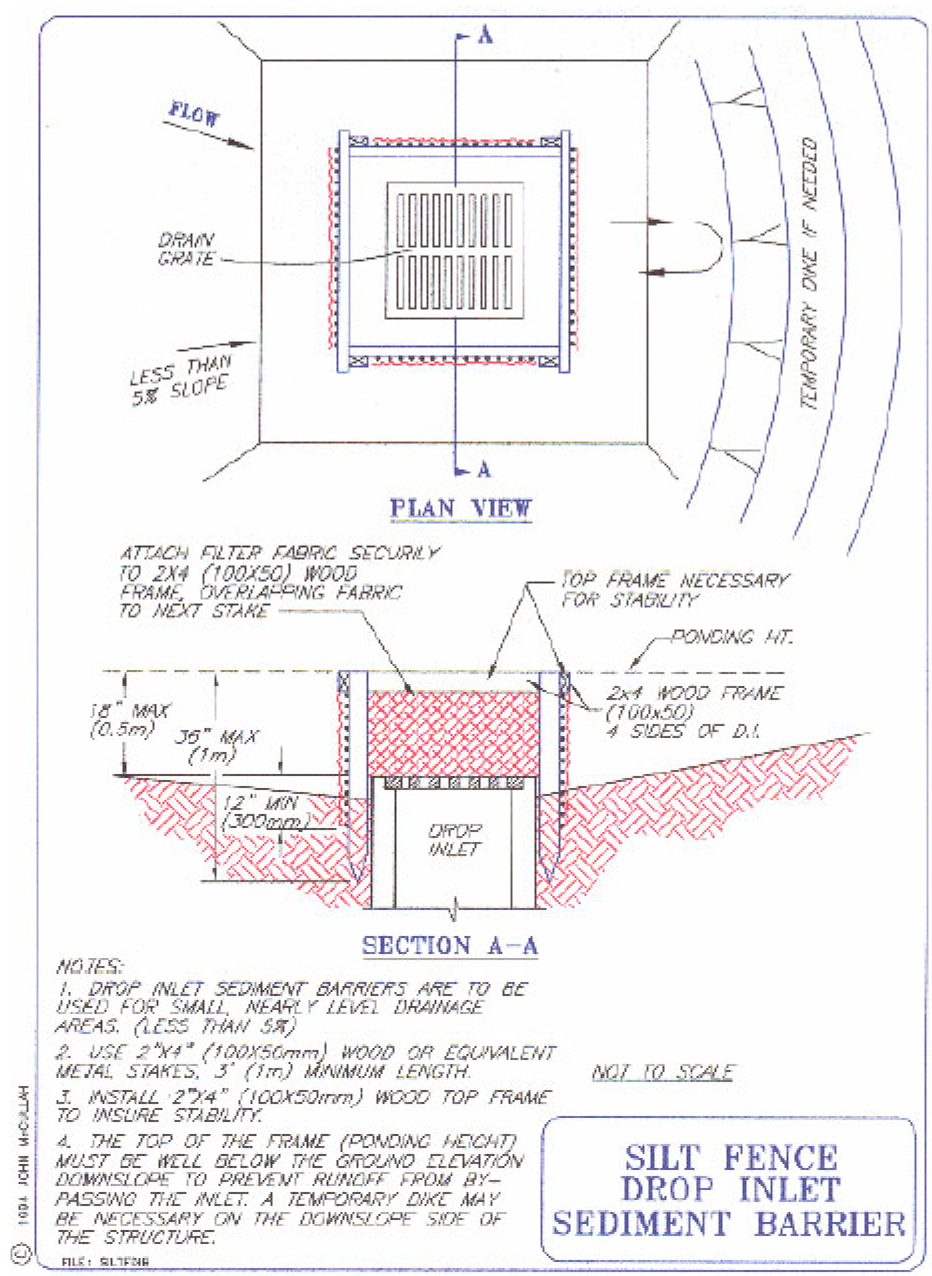


Figure 1: Silt Fence Drop Inlet

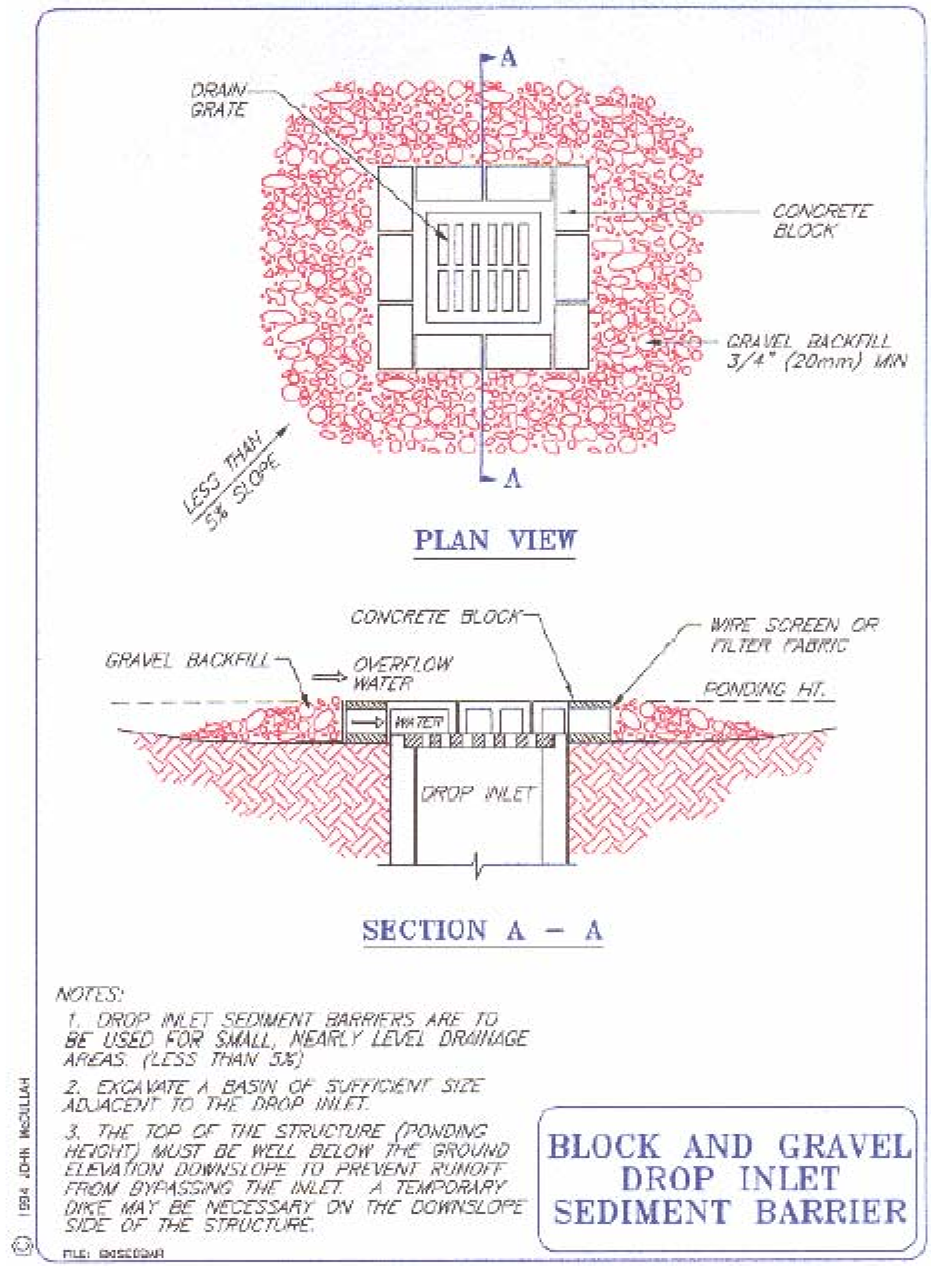


Figure 2: Block and Gravel Drop Inlet

4.8 Riprap

Definition

A permanent erosion-resistant ground cover of large, loose, angular stone.

Purposes

- To protect the soil surface from the erosive forces of concentrated runoff.
- To slow the velocity of concentrated runoff while enhancing the potential for infiltration.
- To stabilize slopes with seepage problems and/or non-cohesive soils.

Where Riprap Protection is Used

To soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toe of slopes, etc. (See Figures 1, 2, and 3)

For slopes steeper than 2:1, consider using materials other than riprap for erosion protection.

Basic Design and Construction Criteria

Riprap protection is a permanent form of structure and, therefore, should be designed by a qualified engineer. The design and installation of such a structure should follow plans and specifications.

- Subgrade Preparation.
  The subgrade for the riprap or filter blanket shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material. Brush, trees, stumps and other objectionable material shall be removed.

- Filter Blanket.
  Placement of the filter blanket should be done immediately after slope preparation. For granular filters the stone should be spread in a uniform layer to the specified depth. Where more than one layer of filter material is used, the layers should be spread so that there is minimal mixing of the layers.

  For plastic filter cloths, the cloth should be placed directly on the prepared slope. The edges of the sheets should overlap by at least 12 inches. Anchor pins, 15 inches long, should be spaced every 3 feet along the overlap. The upper and lower ends of the cloth should be buried a minimum of 12 inches deep. Care should be taken not to damage the cloth when placing the riprap. If damage occurs, that sheet should be removed and replaced. For large stone (12 inches or greater), a 4-inch (10 cm) layer of gravel may be necessary to prevent damage to the cloth.

- Stone Placement.
  Placement of riprap should follow immediately after placement of the filter. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods. The riprap should be placed to its full thickness in one operation, not placed in layers. Stones should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones.

  The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus ¼ of the specified thickness.

Operation and Maintenance

When properly placed, riprap lining requires little or no maintenance.

Check after a major storm event for slumping or displacement of the rocks and check to see if scour has occurred under the riprap. If the riprap has been damaged, repairs should be made promptly to prevent a progressive failure.

If repairs are needed repeatedly at one location, the site should be evaluated to determine if the original conditions have changed.

Riprap should be checked at least twice a year for potential brush growth. Brush should be cleared before costly removal becomes necessary.

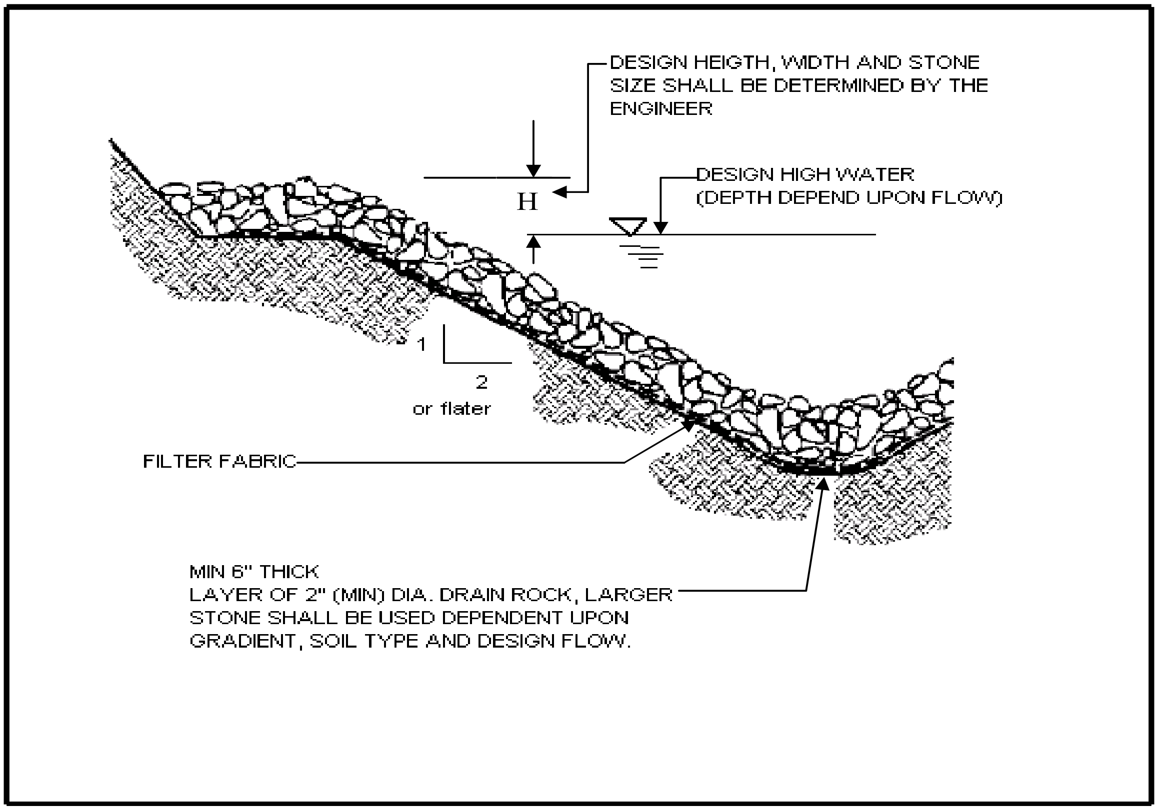


Figure 1: Riprap Protection at Channel Bank

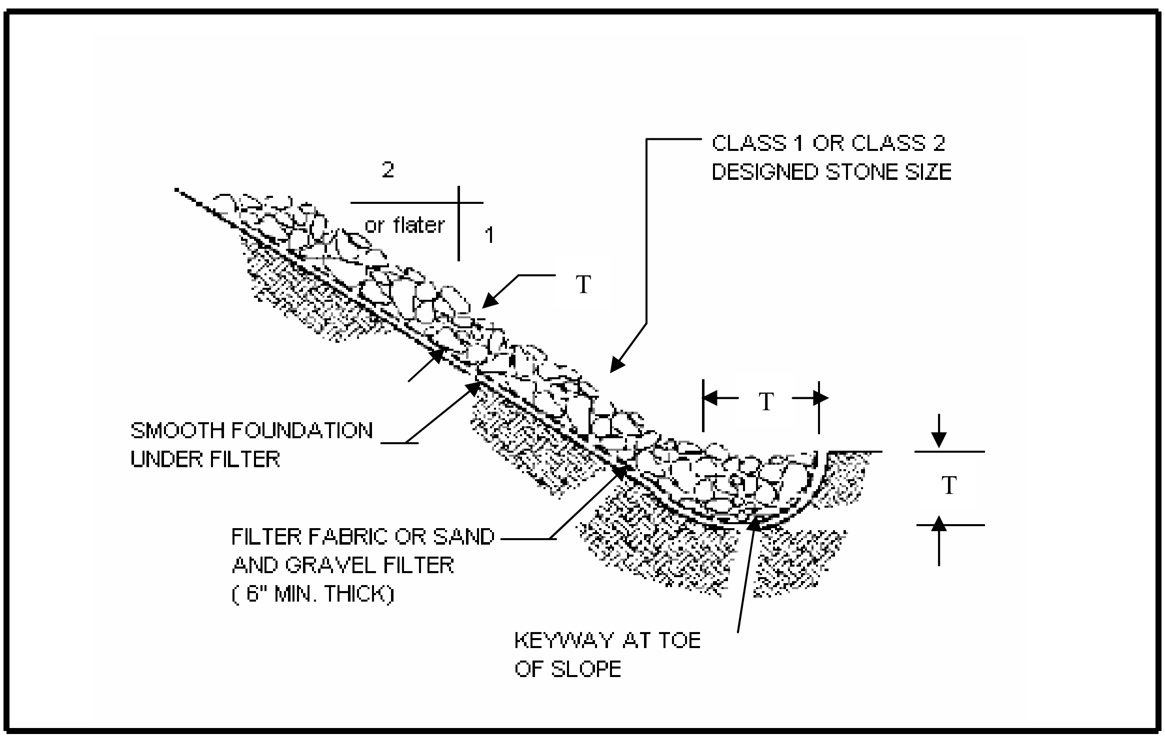


Figure 2: Riprap Protection at Slope

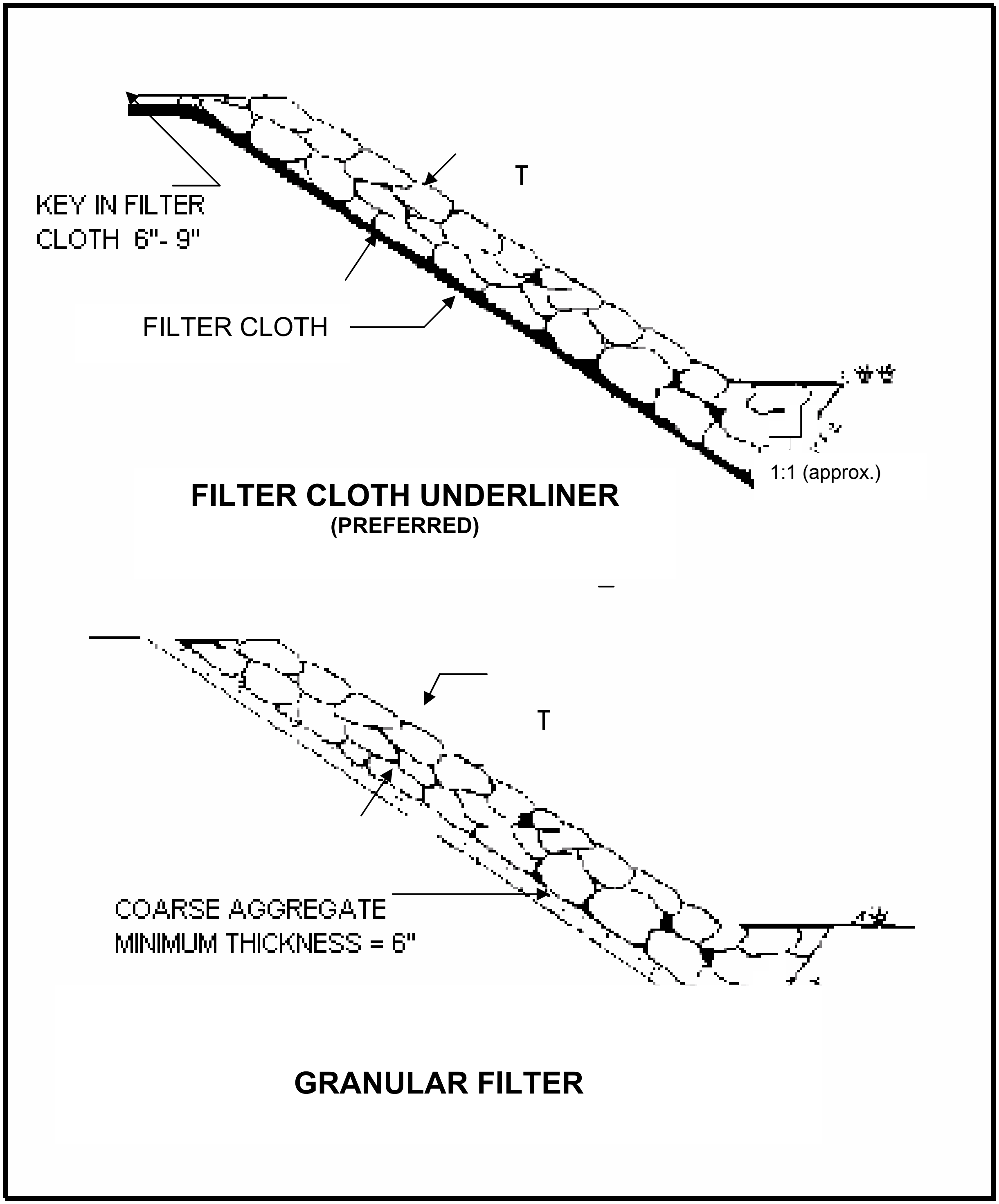


Figure 3: Riprap Protection at Toe of Slope

4.9 Grassed Waterway

Definition

A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation to carry surface water at a non-erosive velocity to a stable outlet.

Purpose

The primary purposes of a grassed waterway are:

- To convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding.
- To reduce gully erosion.
- To protect/improve water quality.

Where Grassed Waterways are Used

In areas where added water conveyance capacity and vegetative protection are needed to control erosion resulting from concentrated runoff and where such control can be achieved by using this practice alone or combined with other conservation practices.

Basic Design and Construction Criteria

- General Criteria Applicable to All Purposes

  Grassed waterways shall be planned, designed, and constructed to comply with all federal, state, and local laws and regulations.

  Capacity.
  The minimum capacity shall be that required to convey the peak runoff expected from a storm of 10-year frequency, 24-hour duration. When the waterway slope is less than 1 percent, out-of-bank flow may be permitted if such flow will not cause excessive erosion. The minimum in such cases shall be the capacity required removing the water before crops are damaged.

  Velocity.
  Design velocities shall not exceed those obtained by using the procedures, "n" values, and recommendations in the NRCS Engineering Field Handbook (EFH) Part 650, Chapter 7, or Agricultural Research Service (ARS) Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

  Width.
  The bottom width of trapezoidal waterways shall not exceed 100 feet unless multiple or divided waterways or other means are provided to control meandering of low flows.

Side slopes.
Side slopes shall not be steeper than a ratio of two horizontals to one vertical. They shall be designed to accommodate the equipment anticipated to be used for maintenance and tillage/harvesting equipment that will cross the waterway.

Depth.
The minimum depth of a waterway that receives water from terraces, diversions, or other tributary channels shall be that required to keep the design water surface elevation at, or below the design water surface elevation in the tributary channel, at their junction when both are flowing at design depth. Freeboard above the designed depth shall be provided when flow must be contained to prevent damage. Freeboard shall be provided above the designed depth when the vegetation has the maximum expected retardant.

Drainage.
Designs for sites having prolonged flows, a high water table, or seepage problems shall include suitable measures to avoid saturated conditions.

Outlets.
All grassed waterways shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. The outlet can be another vegetated channel, an earthen ditch, a grade-stabilization structure, filter strip or other suitable outlet.

Vegetative Establishment.
For species selections see Table 1. Seedbed preparation, time of seeding, mixture rate, stabilizing crop, mulching, or mechanical means of stabilizing, fertilizer, and lime requirements shall be specified for each applicable area. Establish vegetation as soon as conditions permit. Use mulch anchoring, nurse crop, rock, straw or hay bale dikes, filter fences, or runoff diversion to protect the vegetation until it is established.

- Considerations

Important wildlife habitat, such as woody cover or wetlands, should be avoided or protected if possible when sitting the grassed waterway. If trees and shrubs are incorporated, they should be retained or planted in the periphery of grassed waterways so they do not interfere with hydraulic functions. Mid- or tall bunch grasses and perennial forbs may also be planted along waterway margins to improve wildlife habitat. Waterways with these wildlife features are more beneficial when connecting other habitat types; e.g., riparian areas, wooded tracts and wetlands. Water-tolerant vegetation may be an alternative on some wet sites.

Use irrigation in dry regions or supplemental irrigation as necessary to promote germination and vegetation establishment. Provide livestock and vehicular crossings as necessary to prevent damage to the waterway and its vegetation.

Establish filter strips on each side of the waterway to improve water quality. Add width of appropriate vegetation to the sides of the waterway for wildlife habitat.

- Design Steps

For the design of a grassed waterway follow the 10 steps recommended by NRCS's Engineering Field Handbook (EFH), Part 650, Chapter 7, Grassed Waterways and Outlets (http://www.info.usda.gov/CED/Ftp/EFH-Ch07.pdf).

1) Plan the location of the waterway centerline that minimizes impact. An onsite inventory is conducted and the centerline located.

2) Select design points along the waterway where grades change or drainage areas and type of lining change significantly. This step requires the evaluation of the chosen alignment in terms of the site's topography and where major side drainage enters the waterway.

3) Determine the watershed area for the points in step 2 and for the outlet. This step involves delineating the boundaries of the watershed contributing to the waterway on a map and then measuring this delineated area with a planimeter or similar tool.

4) Find the peak runoff produced by the design storm. The procedures given in EFH, Part 650, Chapter 2, Estimating Runoff and Peak Discharges, or the technical release, Hydrology for Urban Watersheds (TR-55), may be used for making this determination. See example of the worksheet for determination of time of concentration and peak discharge, included (Figure 1).

5) Determine the slope of the waterway from the topographic map, profiles, or cross sections. This step is self-explanatory.

6) Select the appropriate waterway cross section and type of waterway protection to be used — bare, vegetated, or lined. Typically the shapes of grassed waterways are parabolic, trapezoidal, or triangular.

7) Design the waterway for stability by selecting the maximum permissible velocity. The maximum permissible velocity is based on the erosivity of the soil and the type of vegetative lining. For plant selection see the following tables:

   Recommended Species for Grassed Waterway (Table 1)
   Classification of Vegetation Cover as to Degree of Retardance (Table 2)
   Permissible Velocity for Diversion (Table 3)

Vegetation in a grassed waterway tends to bend and oscillate under the influence of flow velocity and depth. Retardance to flow varies as these factors change. The approach in designing a grassed waterway is to design for stability using a retardance factor for when the vegetation has the least retardance to flow and to design for capacity using a retardance factor for when the vegetation has the most retardance to flow. This approach assures that regardless of what stage the vegetation is in, the flow velocity does not exceed the maximum permissible velocity nor will the waterway overtop during the design storm.

8) Design the waterway for adequate capacity using Manning's formula.

9) Design a system to adequately dispose of base flow and to keep the waterway or lining well drained. The concern in this step is dealing with a continual flow in the waterway or saturation resulting from a high water table that if allowed, would drown out the vegetation depriving the waterway of the protection of the vegetative lining. Several alternatives provide this system. The alternatives include stone centers, subsurface drainage, and underground outlets.

10) Select depth of waterway from National Engineering Handbook (NEH), Part 650, Engineering Field Handbook (EFH), Chapter 7. This information can also be found at:

(http://www.info.usda.gov/CED/Ftp/EFH-Ch07.pdf)

Plans and Specifications

Plans and specifications for grassed waterways shall be in keeping with the above criteria and shall describe the requirements for applying the practice to achieve its intended purpose(s).

Operation and Maintenance

An operation and maintenance plan shall be provided to and reviewed with the landowner. The plan shall include the following items and others as appropriate. A maintenance program shall be established to maintain waterway capacity, vegetative cover, and outlet stability. Vegetation damaged by machinery, herbicides, or erosion must be repaired promptly.

Seeding shall be protected from concentrated flow and grazing until vegetation is established.

Minimize damage to vegetation by excluding livestock whenever possible, especially during wet periods.

Inspect grassed waterways regularly, especially following heavy rains. Damaged areas will be filled, compacted, and seeded immediately. Remove sediment deposits to maintain capacity of grassed waterway.

Landowners should be advised to avoid areas where forbs have been established when applying herbicides. Avoid using waterways as turn-rows during tillage and cultivation operations. Prescribed burning and mowing may be appropriate to enhance wildlife values, but must be conducted to avoid peak nesting seasons and reduced winter cover.

Mow or periodically graze vegetation to maintain capacity and reduce sediment deposition.

Control noxious weeds.

Do not use as a field road. Avoid crossing with heavy equipment when wet.

Worksheet 2
Time of concentration and peak discharge

Client ___A. B. Smith___ By ___DEW___ Date ___6-6-99___

County ___Adams___ State ___MD___ Checked ___TAS___ Date ___6-7-99___

Practice ___Grassed waterway___

Estimating time of concentraton

1. Data:

   Rainfall distribution type.......................... = ___II___ (I, IA, II, III)

   Drainage area..........................A = ___90___ ac

   Runoff curve number..........................CN = ___78___ (Worksheet 1)

   Watershed slope..........................Y = ___1___ %

   Flow length..........................ℓ = ___3,400___ ft

2. T_c using ℓ, Y, CN, and EFH figure 2-27 or using EFH equation 2-5

$$T_c = \frac{\ell^{0.8}\,(1{,}000/CN-9)^{0.7}}{1{,}140\,Y^{0.5}} = \frac{(3{,}400)^{0.8}\,(1{,}000/78-9)^{0.7}}{1{,}140\;1^{0.5}} = 1.5 \text{ hr}$$

Estimation peak discharge	Storm number 1	Storm number 2	Storm number 3
1. Frequency.......................... yr	10		
2. Rainfall, P (24 hour).......................... in	5.5		
3. Initial abstraction (use CN with EFH table 2-4).... in	0.564		
4. Compute I_a/P ratio	0.10		
5. Unit peak discharge qu .... $ft^3/s/ac/in$ (Use T_c and I_a/P with EFH exhibit 2- ______)	0.43		
6. Runoff, Q .... in (Use P and CN with EFH figure 2-6 or table 2-2)	3.1		
7. Peak discharge q_p .... ft^3/s (Where $q_p = q_u AQ$)	120		

1 Engineering Field Handbook, chapter 2

Core4 Conservation Practices, August 1999

Figure 1. Worksheet Example

Table 1. Recommended Species and Planting Method for Grassed Waterway

Name		Soil Permeability			Acid Tolerant	Salinity Tolerant	Planting mehtod minimum rate		
Spanish/English	Scientific	Well	Mod	Fair			Stolon (lbs/ac)	Seeds (lbs/ac)	Seeds (lbs/1000p^2)
Ciempiés/Centipede grass	Eremochloa ophiuroides	x	x		Yes	No		20 [(a)]	
Grama colorada/ Carpet grass [(a)]	Axonopus compressus		x	x	Yes	No	1,500	40	1
Mallojilla/Carib grass	Eriochloa polystachya		x	x	Yes	No	1,500	--	--
Malojillo/Para grass	Urochloa mutica		x	x	Yes	Fair	1,500	5	0.12
Pajón/Railroad-track grass	Dichanthium annulatum	x	x		No	Fair	--	20 [(b)]	0.5
Rhodes grass	Chloris gayana	x	x		No	Fair	1,500	9	0.2
San Agustín/San Agustin grass	Stenotaphrum secundatum	x	x		No	Fair	(a)	(a)	(a)
Signal/Signal grass	Urochloa brizantha	x	x		Yes	No	1,500	6	0.14
Yerba Bahía/Bahia Grass [(a)]	Paspalum notatum	x	x		Yes	Fair	1,500	40	1
Yerba Bermuda/Common Bermuda [(a)]	Cynodon dactylon	x	x		Yes	Yes	1,500	60	1.5
Yerba Buffel/Buffel grass	Pennisetum ciliare	x			No	Fair	--	6 [(b)]	0.14
Yerba Dalis/Dallis grass	Paspalum dilatatum	x	x		Yes	No	1,500	20	0.5
Yerba Estrella/Star grass	Cynodon nlemfuensis	x	x		Fair	Fair	1,500	--	--
Yerba Huracán/Hurricane grass	Bothriochloa pertusa	x	x		Fair	Fair	--	6 [(b)]	0.14
Yerba Pangola/Pangola grass	Digitaria eriantha	x	x		Yes	No	1500	--	--
Zoysia	Zoyzia spp	x	x		Yes	Yes	(a)	(a)	(a)

(a) Sod
(b) By clump division

Table 2. Classification of Vegetative Cover as to Degree of Retardance

Name		Degree of Retardance	Percent of cover (%)			Average height (inches)
Spanish/English	Scientific		100-95	94-86	85-80	
Ciempiés/Centipede grass	Eremochloa ophiuroides	C		x		6
		D		x		2-6
		E			x	2
Grama colorada/Carpet grass	Axonopus compressus	D		x		2-6
		E		x		2
Mallojilla/Carib grass	Eriochloa polystachya	C		x		>20
Malojillo/Para grass	Urochloa mutica	C		x		11-24
Pajón/Railroad-track grass	Dichanthium annulatum	B		x		>20
		C			x	>20
Rhodes grass	Chloris gayana	B			x	>20
San Agustín/San Agustin grass	Stenotaphrum secundatum	C		x		6-10
		D			x	6-10
Signal/Signal grass	Urochloa brizantha	C			x	>20
Yerba Bahía/Bahia Grass	Paspalum notatum	B		x		>10
		C		x		6-10
		D			x	6-10
Yerba Bermuda/Common Bermuda	Cynodon dactylon	C		x		6-10
		D			x	2-6
		E			x	2
Yerba Buffel/Buffel grass	Pennisetum ciliare	B		x		11-24
		C		x		10-12
Yerba Dalis/Dallis grass	Paspalum dilatatum	C		x		6-12
Yerba Estrella/Star grass	Cynodon nlemfuensis	A	x			>30
		B		x		>30
		C			x	30
Yerba Huracán/Hurricane grass	Bothriochloa pertusa	B		x		>20
		C			x	>20
Yerba Pangola/Pangola grass	Digitaria eriantha	A	x			>30
		B		x		>30
		C			x	>30
Zoysia	Zoyzia spp	C		x		6
		E		x		2

Table 3. Permissible Velocity for Diversions

Soil texture	Bare Channel ft/s	Retardance (1)	Channel Vegetation Condition Poor ft/s	Fair	Good
Sand, silt, sandy loam, & silty loam	1.5	B	2.0	3.0	4.0
		C	1.5	2.5	3.5
		D	1.5	2.0	3.0
Silty clay loam & sandy clay loam	2.0	B	3.0	4.0	5.0
		C	2.5	3.5	4.5
		D	2.0	3.0	4.0
Clay	2.5	B	3.5	5.0	6.0
		C	3.0	4.5	5.5
		D	2.5	4.0	5.0
Coarse gravel	5.0	B, C, or D	5.0	6.0	7.0
Cobbles & shale	6.0	B, C, or D	6.0	7.0	8.0

(1) See Table Classification of Vegetation Cover as to Degree of Retardance
Source: National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 9

4.10 Level Spreader

Definition

Level spreader is an outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope without causing erosion. An outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope. Level spreaders then release the storm water flow onto level areas stabilized by vegetation to reduce speed and increase infiltration.

Purpose

To convert concentrated runoff to sheet flow and release it uniformly onto areas stabilized by existing vegetation. This structure is particularly well-suited for returning natural sheet flows to exiting drainage that has been altered by development, especially for returning sheet flows to receiving ecosystems such as wetlands where dispersed flow may be important for maintain pre-existing hydrologic regimes.

Where Level Spreading is Used

Where there is a need to divert storm water away from disturbed areas to avoid overstressing erosion control measures; where sediment-free storm runoff can be released in sheet flow down a stabilized slope without causing erosion. This practice applies only in those situations where the spreader can be constructed on undisturbed soil and the area below the level lip is uniform with a slope of 10% or less and is stabilized by natural vegetation. The runoff water should not be allowed to re-concentrate after release unless it occurs during interception by another measure (such as a permanent pond or detention basin) located below the level spreader.

Level spreaders are most often used as an outlet for temporary or permanent storm water conveyances or dikes.

Basic Design and Construction Criteria

Interceptor dikes and swales call for a stable outlet for concentrated storm water flows. The level spreader is a relatively low-cost structure to release small volumes of concentrated flow where site conditions are suitable.

Runoff water containing high sediment loads must be treated before being released to a level spreader in a sediment-trapping device.

- Design Criteria

No formal design is required. The following criteria must be met:

Spreader Dimensions.

Determine the capacity of the spreader by estimating the peak flow expected from a 10-year storm (Q_{10}). Select the appropriate length, width and depth of the spreader from table below.

MINIMIUM DIMENSIONS FOR LEVEL SPREADER

Design Flow Q_{10}		Depth		Width of Lower Side Slope of Spreader		Length	
(m^3/sec)	(cfs)	(mt)	(ft)	(mt)	(ft)	(mt)	(ft)
0 - 0.3	0 - 10	0.15	0.5	1.8	6	3	10
0.3 - 0.6	10 - 20	0.18	0.6	1.8	6	6	20

- For design flows greater than 20 cubic feet per second (0.6 cubic meter per second), the measure should be designed by a qualified engineer.
- A 20-foot transition section should be formed in the diversion channel so that the width of the diversion will smoothly tie in with the width of the spreader to ensure more uniform outflow.
- The depth of the level spreader, as measured from the lip, shall be at least 6 inches and it should be uniform across the entire length.
- The depth may be made greater to increase temporary storage capacity, improve trapping of debris and to enhance settling of any suspended solids.

Grade.

The grade of the channel for the last 20 feet (6 meters) of the dike or diversion entering the level spreader shall be less than or equal to 1%. The grade of the level spreader channel shall be 0% to ensure uniform spreading of storm runoff.

Spreader lip.

The outlet area must be uniform, undisturbed and well vegetated with a maximum slope of 10%. The level lip should be of uniform height and zero grade over the length of the spreader. Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil to avoid formation of an outlet channel and subsequent erosion. Any depressions in the lip will concentrate the flow, resulting in erosion.

The level spreader lip may be stabilized by vegetation or may be of non-erodible material depending on the expected design flow.

Design Flow.

Spreader Lip	(m^3/sec)	(cfs)
Vegetated Rigid	0 - 0.1 0.1 - 0.6	0 - 4 5 - 20

A vegetated level lip must be constructed with an erosion resistant, non-rigid material such as jute or excelsior blankets, to inhibit erosion and allow vegetation to become established.

For higher design flows and permanent installations, a rigid lip of non-erodible material, such as pressure-treated timbers or concrete curbing, should be used to create the desired sheet flow conditions. Erosion-resistant matting of some kind may be necessary across the outlet lip depending on expected flows. Alternative designs to minimize such channeling include hardened structures, stiff grass hedges, and segmenting discharge flows into a number of smaller, adjacent spreaders.

- Construction Specifications

Level spreader shall be installed under direct supervision of the engineer.

Level spreaders must be constructed on undisturbed soil (not fill material).

The entrance to the spreader must be shaped in such a manner as to insure that runoff enters directly onto the 0% channel.

Construct a 20 ft (6 meter) transition section from the diversion channel to blend smoothly to the width and depth of the spreader.

The level lip shall be constructed at 0% grade to insure uniform spreading of storm water runoff.

Protective covering for vegetated lip should be a minimum of 4 feet wide extending 6 inches over the lip and buried 6 inches deep in a vertical trench on the lower edge. The upper edge should butt against smoothly cut sod and be securely held in place with closely spaced heavy-duty wire staples.

Rigid level lip should be entrenched at least 2 inches below existing ground and securely anchored to prevent displacement. An apron of coarse aggregate should be placed to top of level lip and extended down slope at least 3 feet. Place filter fabric under stone and use galvanized wire mesh to hold stone securely in place.

The released runoff must outlet onto undisturbed stabilized areas with slope not exceeding 10%. Slope must be sufficiently smooth to preserve sheet flow and prevent flow from concentrating.

Immediately after its construction, appropriately seed and mulch the entire disturbed area of the spreader.

Common Trouble Points

If the level spreader has any low points, flow tends to concentrate there. This concentrated flow can create channels and cause erosion.

Cannot handle large quantities of sediment-laden storm water.

Operation and Maintenance

The measure shall be inspected after every rainfall and repairs made, if required. Level spreader lip must remain at 0% slope to allow proper function of measure. If ponding or erosion channels develop, the spreader should be regraded.

The contractor should avoid the placement of any material on and prevent construction traffic across the structure. If the measure is damaged by construction traffic, it shall be repaired immediately. Dense vegetation should be maintained and damaged areas reseeded as needed.

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SECTION 5: GUIDELINES FOR THE USE OF THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)

The erosion potential of soils can be readily determined using various models such as the Revised Universal Soil Loss Equation (RUSLE). For a complete copy of the updated guidelines and the public domain RUSLE software, please access the following web site:

http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

"Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE)" is included in Appendix C.

The soil erosion potential of an area, including a construction site, is determined by four interrelated factors. These are: soil characteristics, vegetative cover, topography, and climate.

Collection, analysis, and use of detailed information specific to the construction site for each of these four factors can provide the basis for the construction of effective surface water management systems.

The first three factors, soil characteristics, vegetative cover, and topography are constant with respect to time until altered intentionally by construction. The designer, developer, and construction contractor should have a working knowledge about and control over these factors to provide accurate soil erosion estimates.

The fourth factor, climate, is predictable by season, historical record, and probability of occurrence. While predicting a rainfall event is not possible, many of the impacts of construction surface water runoff can be minimized or avoided by planning appropriate seasonal construction activity and using properly designed BMPs.

5.1 Soil Characteristics

The vulnerability of soil to erode is determined by soil characteristics: particle size, organic content, soil structure, and soil permeability.

- Particle Size.
  Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erodibility of soil decreases as the percentage of clay or organic matter increases; clay acts as a binder and tends to limit erodibility. Most soils with high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, however, clays are easily suspended and settle out very slowly.

- ➢ Organic Content.
  Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the beginning of erosion, and reduces the amount of runoff. The addition of organic matter increases infiltration rates (therefore, reduces surface flows and erodibility), water retention, pollution control, and pore space for oxygen.

- ➢ Soil Structure.
  Organic matter, particle size, and gradation affect soil structure, which is the arrangement, orientation, and organization of particles. When the soil system is protected from compaction, the natural decomposition of plant debris on the surface maintains a healthy soil food web. The soil food web in turn maintains the porosity both on and below the surface.

- ➢ Soil Permeability.
  Soil permeability refers to the ease with which water passes through a given soil. Well-drained and well-graded gravel and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

5.2 Vegetative Cover

Vegetative cover plays an extremely important role in controlling erosion by:

Shielding the soil surface from the impact of falling rain.

Slowing the velocity of runoff, thereby permitting greater infiltration.

Maintaining the soil's capacity to absorb water through root zone uptake and evapotranspiration.

Holding soil particles in place.

Erosion can be significantly reduced by limiting the removal of existing vegetation and by decreasing duration of soil exposure to rainfall events. Give special consideration to the preservation of existing vegetative cover on areas with a high potential for erosion such as erodible soils, steep slopes, drainage ways and banks of streams. When it is necessary to remove vegetation, such as for noxious weed eradication, revegetate these areas immediately.

5.3 Topography

The size, shape, and slope of a construction site influence the amount and rate of surface water runoff. Each site's unique dimensions and characteristics provide both opportunities for and limitations on the use of specific control measures to protect vulnerable areas from high runoff amounts and rates. Slope length, steepness, and surface texture are key elements in determining the volume and velocity of runoff. As slope length and/or steepness increase the rate of runoff and the potential for erosion increases. Slope orientation is also a factor in determining erosion potential. For example, a slope that faces south and contains drought soils may provide such poor growing conditions that vegetative cover will be difficult to re-establish.

5.4 Climate

Seasonal temperatures and the frequency, intensity, and duration of rainfall are fundamental factors in determining amounts of runoff. As the volume and the velocity of runoff increase, the likelihood of erosion increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the period of the year when there is a high erosion risk.

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SECTION 6: HYDROLOGY

6.1 Introduction

The increased amount of erosion occurring with the conversion of rural land to urban areas depends on the amount of runoff that occurs as well as the amount of disturbance to natural vegetation and landforms. This section addresses what influences runoff and how the volume and rate of runoff is determined.

Hydrology is an important part of designing and installing erosion control practices. Selection of acceptable and correct hydrology procedures for determining peak watershed discharge should be carefully considered. A wide variety of procedures have been developed to estimate runoff volume and peak discharge rate. Three commonly used procedures are:

NRCS Estimating Runoff and Peak Discharges - EFH2 Method

This method develops a runoff curve number from watershed conditions (soils, hydrologic condition, and vegetative cover) and provides peak flow (cfs) and total runoff (inches) through relationships to desired 24-hour rainfall frequency, watershed steepness, and drainage area. Copy of the National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 2 is included in Appendix D. It is available as a user friendly computer program. For a copy of the public domain EFH2 software, please access the following web site:

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-efh2.html

The method applies when the following limits and characteristics describe the watershed area:

- Watershed is accurately represented by a single curve number between 40 and 98.
- Watershed area between 1 and 2000 acres.
- Watershed hydraulic length between 200 and 26,000 feet. Flow length is the longest flow path in the watershed from the watershed divide to the outlet.
- Average watershed slope between 0.5 and 64 percent. The slope of the land (not the watercourse slope). Average watershed slope is an average of individual land slope measurements.
- Urban land use within the watershed does not exceed 10%.
- No valley or reservoir routing is required.

NRCS Urban Hydrology for Small Watersheds - TR55 Method

The Technical Release 55 method provides a more detailed peak runoff analysis for urban areas. This method expands procedures used in EFH2 to include options for urban area conditions (lot size, impervious areas, parking lots, etc.) and allows input for accelerated runoff travel time in streets, gutters, paved ditches, etc. Copy of TR-55 manual (June 1986 version) is included in Appendix D and the user is urged to become familiar with the concepts and methods, which it contains. It is also available as a computer program, which automates the manual procedure outlined in the Technical Release. For a copy of the public domain TR55 software, please access the following web site:

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html

TR-55 model has three principal procedures to estimate peak discharge and storage volume for detention basins.

- Graphical Peak Discharge applies where:
  Watershed is accurately represented by a single curve number.
  Time of concentration is from 0.1 to 10 hours.
  Watershed has one main stream, or if more, all have about the same time of concentration.
  No valley or reservoir routing is required.

This method is discussed in Chapter 4 of the TR-55 Manual. Limitations of this theory are also discussed.

- Tabular Hydrograph Method applies where:
  Watershed can be divided into 10 sub areas or less.
  Sub area time of concentration is between 0.1 and 2 hours.
  Travel time from upper most sub area to watershed outlet does not exceed 3 hours.
  All discharges flow at the same velocity in the reach.
  No valley or reservoir routing is required.

This method is discussed in Chapter 4 of the TR-55 Manual.

- Storage volume for detention basins applies where:
  Shortcut flood routing is based on average storage and routing effects.
  The ratio of peak outflow discharge/peak inflow discharge does not approach the unity.
  Errors in basin storage volume of up to 25 percent are acceptable.

The TR-55 model (April 2002 version) has been revised and completely rewritten. The new WIN TR-55 uses the WIN TR-20 program as the driving engine and performs more accurate analysis of the hydrology of the small watershed system being studied.

Copy of the WIN TR-55 User Manual is included in Appendix D. The WIN TR-55 program can be downloaded from the following web site:

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html.

WIN TR-55 uses the WIN TR-20 (NRCS-2002) model for all of the hydrograph procedures: generation, combining hydrographs, channel, storage and structure routing. The minimum and maximum area of the watershed should be 1 acre and 25 square miles respectively; the number of sub areas should be from 1 to 10, and the time of concentration for any sub area: $0.1 \text{ hour} \leq Tc \leq 10 \text{ hours}$.

Rational Method

Rational method is calculated using the equation $Q = CiA$, where Q is in cfs, C is expressed as a dimensionless decimal that represents the ratio of runoff to rainfall, i is the rainfall intensity in inches per hour for desired rainfall frequency, and A is drainage area in acres. Numerous textbooks provide details for application of this procedure and will not be repeated here.

Other methods may be acceptable but their acceptance shall be verified with the Environmental Quality Board prior to use.

The planner and designer must be aware that hydrology determination errors could allow unnecessary flooding and damage for underdesigned conditions or impose extra cost for overdesign situations. The best, onsite judgment and determination should be made and is the responsibility of the designer.

Practices for temporary erosion and sediment control during the construction period shall be designed with a minimum storm capacity of 2-year, 24-hour with the contractor assuming repair/replacement risk for occurrence of a storm larger than that. Permanent erosion and sediment control practices shall be designed for a minimum storm capacity of 10-year, 24-hour unless otherwise noted.

6.2 Factors Affecting Runoff

The following discussion is oriented to NRCS theory of hydrologic models.

Rainfall is the primary source of water that runs off the surface of small rural watersheds. The main factors affecting the volume of rainfall that runs off are the kind of soil, urban development, and type of vegetation in the watershed. Factors that affect the rate at which water runs off are the watershed topography and shape along with any existing conservation practices on a watershed. To estimate runoff from storm rainfall, NRCS uses the curve number (CN) method. Determination of CN depends on the watershed soil and cover conditions.

Rainfall

The peak discharge from a small rural watershed is usually caused by intense rainfall. The intensity of rainfall affects the peak discharge more than it does the volume of runoff. Intense rainfall that produces high peak discharges in small watersheds usually does not extend over a large area. Therefore, the same intense rainfall that causes flooding in a small tributary is not likely to cause major flooding in a main stream that drains 10 to 20 square miles.

For the size of the watershed for which NRCS typically provides assistance; storm duration of 24 hours was chosen for the synthetic rainfall distribution. The 24-hour storm, while longer than that needed to determine peak discharges, is suitable for determining runoff volumes. Thus, a single storm duration and associated synthetic rainfall distribution can be used to estimate peak discharges for a wide range of watershed areas.

The intensity of rainfall varies considerably during the storm period. Storm distributions for duration of 24 hours were developed by NRCS from U.S. National Weather Service data as typical design storms. TR-55 and EFH-2 include four regional rainfall time distributions. All four distributions are for 24-hour periods; see Appendix B of the TR-55 Manual. Type II rainfall time distribution is associated with the climatic regions of Puerto Rico.

Hydrologic soil groups

Soils have been classified into four hydrologic soil groups as shown in Appendix F of the TR-55 Manual and in Appendix A.4 of this handbook. NRCS soil scientists define the four groups as follows:

- Group A.
  Soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of sands and gravels that are deep, well drained to excessively drained, and have a high rate of water transmission (greater than 0.30 in/hr).

- Group B.
  Soils have moderate infiltration rates when thoroughly wetted and consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained, and have moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr).

- Group C.
  Soils have slow infiltration rates when thoroughly wetted and consist chiefly of soils having a layer that impedes downward movement of water and soils of moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 in/hr).

- Group D.
  Soils have high runoff potential. They have very slow infiltration rate when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan 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 (0 to 0.05 in/hr).

Cover type

Cover type affects runoff in several ways. The foliage and its litter maintain the soil's infiltration potential by preventing the impact of the raindrops from sealing the soil surface. Some of the raindrops are retained on the surface of the foliage, increasing their chance of being evaporated back into the atmosphere. Some of the intercepted moisture takes so long to drain from the plant down to the soil that it is withheld from the initial period of runoff. Ground cover also allows soil moisture from previous rains to transpire, leaving a greater void in the soil to be filled. Vegetation, including its ground litter, forms numerous barriers along the path of the water flowing over the surface of the land. This increased surface roughness causes water to flow more slowly, lengthening the time of concentration and reducing the peak discharge.

Urban impervious area modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for urban areas. To estimate runoff from storm rainfall, NRCS uses the runoff curve number CN method. Determination of CN depends on the watershed's soil and cover type, treatment, hydrologic condition, and antecedent runoff condition. Another factor considered in TR-55 is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected).

Treatment

Best Management Practices reduce erosion and runoff and thereby provide greater infiltration opportunities at the soil surface. Detention basins, diversions, vegetation, etc., slow water runoff and increase travel time/distance to an outlet which increases watershed time of concentration. This reduces the runoff, but the effect diminishes rapidly with increases in storm magnitude.

Hydrologic conditions

In most cases, the hydrologic condition of the site affects the volume of runoff more than any other single factor. The hydrologic condition considers the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant cover and residue on the ground surface. Good hydrologic condition indicates that the site usually has a lower runoff potential. Mulch residue incorporated into the soil and the residual root system from grasses remaining in the soil produce a good hydrologic condition.

A grassland cover is good if the vegetation covers 75 percent or more of the ground surface and is lightly compacted. A cover is poor if vegetation covers less than 50 percent of the ground surface or is heavily compacted. Grass cover is evaluated on the basal area of the plant, whereas trees and shrubs are evaluated on the basis of canopy cover.

Topography

The slopes in a watershed have a major effect on the peak discharge at downstream points. Slopes have little effect on how much of the rainfall will run off. As watershed slope increases, velocity increases, time of concentration decreases, and peak discharge increases. An average small watershed is fan shaped. As the watershed becomes elongated or more rectangular, the flow length increases and the peak discharge decreases.

Depressions may trap a small amount of rain, thus reducing the amount of expected runoff. If depressions and marshland areas make up one-third or less of the total watershed and do not intercept the drainage from the remaining two-thirds, they will not significantly change the peak discharge. These areas may be excluded from the drainage area for estimating peak discharge. If depressions constitute more than one-third of the total drainage or if they intercept the drainage, the procedures in the National Engineering Handbook, Part 630-Hydrology should be used to estimate the peak discharge.

6.3 Peak Runoff Calculations

The designer must be aware when urban conditions are present and utilize the appropriate procedure to find the proper peak runoff. Generally, EFH-2 can be used when urban land use within the watershed does not exceed 10 percent, if more than 10 percent urbanization; urban TR-55 adjustments should be used in peak discharge calculations.

Surface runoff is the volume of excess water that runs off a drainage area. Peak discharge is the peak rate of surface runoff from a drainage area for a given rainfall. This section presents procedures for estimating runoff and peak discharge from small rural and/or urban watersheds for use in designing Best Management Practices.

Runoff Curve Numbers

The NRCS runoff equation is:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

Where:

Q = runoff in inches,
P = rainfall in inches,
Ia = initial abstraction in inches, and
S = potential maximum retention after runoff begins in inches

Rainfall (P) - The 24-hour rainfall depths for a desired county can be obtained from the U.S. National Weather Service, Technical Paper 42, Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands. The 24-hour rainfall depths for Puerto Rico are included in Appendix F of the TR-55 Manual.

Initial abstraction **(Ia)** includes all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, and water lost to evaporation and infiltration. **Ia** is highly variable but is generally correlated with soil and cover parameters. Through studies of many small watersheds, **Ia** was found to be approximated by:

$$Ia = 0.2S$$

Removing **Ia** as an independent parameter allows use of a combination of S and P to produce unique runoff volumes. Substituting **Ia** for 0.2S gives:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

The potential maximum retention can range from zero on a smooth, impervious surface to infinity in deep gravel. For greater convenience, the "S-values" were converted to runoff curve numbers (CN's) by the following transformation:

$$CN = \frac{1000}{10+S}$$

According to this equation, the CN is 100 when S is zero and approaches zero as S approaches infinity. Runoff curve numbers can be any value from zero to 100, but for practical applications are limited to a range of 40 to 98.

Estimating runoff - The runoff from a watershed may be expressed as the average depth of water that would cover the entire watershed. The depth is usually expressed in inches. The volume of runoff is computed by converting depth over the drainage area to volume and is usually expressed in acre-feet.

The theory of CN applies to EFH-2 and TR-55 evaluations; the procedure is discussed in Chapter 2 of the TR-55 Manual (June 1986 version). Limitations of this theory are also discussed.

Travel Time and Time of Concentration

- EFH-2:

Time of Concentration (Tc) can be estimated for small rural watersheds using the following empirical relationship:

$$Tc = \frac{(L)^{0.8} \left(\frac{1000}{CN} - 9 \right)^{0.7}}{1140\, y^{0.5}}$$

Where:

Tc = time of concentration in hours
L = flow length in feet
CN = runoff curve number
Y = average watershed slope in percent

This equation is used to compute Tc when a watershed is evaluated using EFH-2. In watersheds with more than 10 percent development, urban (TR-55) adjustments should be used in peak discharge calculations as described in TR-55 Manual (June 1986 version).

- TR 55:

Travel time (Tt) is the time it takes water to travel from one location to another in a watershed. Tt is a component of time of concentration (Tc), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. Tc is computed by summing all the travel times for consecutive components of the drainage conveyance system.

The method used in TR-55 is based on velocities of flow through segments of the watersheds. Tc influences the shape and peak of runoff hydrograph. Urbanization usually decreases Tc, thereby increasing the peak discharge. But Tc can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors affecting travel time and time of concentration:

Surface roughness.
One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development. The flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel shapes and flow patterns.
In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope.
Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when

channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of travel time and time of concentration using TR-55 model:

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Sheet flow.
Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so.

Shallow concentrated flow.
After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow is a function of watercourse slope and type of channel. Land disturbance can affect the direction of shallow 0.5 concentrated flow. Flow may not always be directly down the watershed slope if tillage or construction activity runs across the slope.

Open channels.
Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Manning's n values for open channel flow can be obtained from standard textbooks on hydraulics.

Travel time (Tt) is the ratio of flow length to flow velocity:

$$Tt = \frac{L}{3600\,V}$$

Where:

Tt = travel time (hr)
L = flow length (ft)
V = average velocity (ft/s), and
3600 = conversion factor from seconds to hours.

Time of concentration (Tc) is the sum of Tt values for the various consecutive flow segments:

$$Tc = T_{t1} + T_{t2} + \ldots\ldots T_{tm}$$

This procedure is discussed in Chapter 3 of the TR-55 Manual (June 1986 version). Limitations of this theory are also discussed.

<u>Graphical Peak Discharge Method</u> (TR-55 June 1986 version)

This section presents the Graphical peak discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using Technical Release -20, "Computer Program for Project Formulation Hydrology." The peak discharge equation used is:

$$q_p = q_u A_m Q F_p$$

Where:

q_p = peak discharge (cfs)
q_u = unit peak discharge (csm/in)
A_m = drainage area (mi^2)
Q = runoff (in)
F_p = pond and swamp adjustment factor

The input requirements for the graphical method are: T (hr), drainage area (mi^2), appropriate rainfall distribution (Type II, for PR), 24-hour rainfall (in), and CN. If pond and swamp areas are spread throughout the watershed and are not considered in the Tc computation, an adjustment for pond and swamp areas is also needed.

This procedure is discussed in Chapter 4 of the TR-55 Manual. Limitations of this theory are also discussed.

<u>Tabular Hydrograph Method</u> (TR-55 June 1986 version)

The Tabular Hydrograph method of computing peak discharges from rural and urban areas is discussed in Chapter 5 of the TR-55 Manual. The Tabular method can develop partial composite flood hydrographs at any point in the watershed by dividing the watershed into homogeneous subareas. The watershed must be hydrologically homogeneous, that is, describable by one CN. Land use, soils, and cover are distributed uniformly throughout the watershed. The method is especially applicable for estimating the effects of land use change in a portion of a watershed.

Storage Volume for Detention Basins (TR-55 June 1986 version)

As rural areas become urbanized, the resulting increases in peak discharges can adversely affect down stream flood plains. Local government may decide on some cases to control the type of development and its allowable impacts on the watershed. One of the most common controls requires that post development discharges do not exceed present-condition discharges.

Chapter 6 of the TR-55 Manual discusses ways to manage peak discharges by delaying runoff. Depending on what information is provided, either the required detention basin storage or peak outflow is estimated.

Peak outflow rate is determined from peak inflow rate, volume of storm runoff and basin storage. Basin storage volume is determined from peak inflow rate, volume of storm runoff and desired outflow rate.

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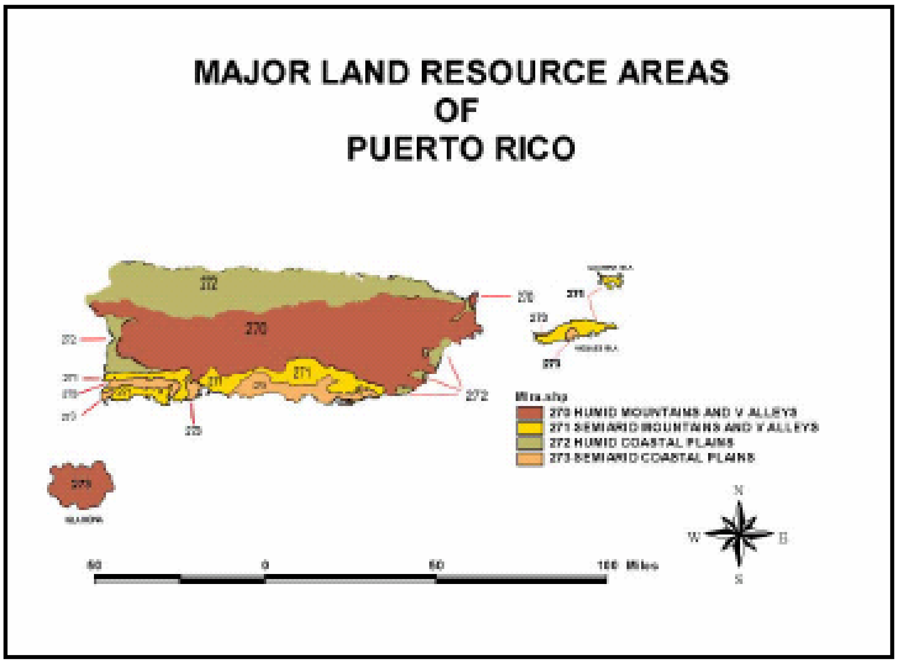
SECTION 8: APPENDIXES

Appendix A.1 - Major Land Resource Areas

Following is a list of the general Major Land Resource Areas of Puerto Rico with a general description of each.



270—Humid Mountains and Valleys
4,910 km² (1,895 mi²)

Elevation and topography: Elevation ranges from 50 to 1,340 m. Three distinct mountain ranges are in the area. The Central Ridge, Cordillera Central as it is known locally, is the highest and largest of the three. It is oriented in a general east-west direction. Cerro de Punta, its highest peak, is 1,338 m above sea level. Los Tres Picachos and Monte Guilarte are about 1,205 m high. Second in extent and elevation is the Sierra de Luquillo in the northeastern part of Puerto Rico.

The three highest peaks are El Toro, 1,074 m above sea level; El Yunque, 1,065 m; and Pico del Este, 1,051 m. The third range is the Sierra de Cayey in the east-central part of Puerto Rico. The Cerro La Santa, 903 m high, and Cerro La Tabla, 890 m high, are the highest peaks of this range.

Climate: Average annual precipitation - 2,075 to 2,150 mm. Maximum precipitations occurs in May and September. Average annual temperature is -

24° C. There is little difference between the temperature in summer and that in winter.

Water: Surface water from precipitation, perennial streams, and lakes are abundant. Ground water is limited to water that seeps into the soil and is stored in the dense and massive underlying volcanic rock.

Soils: Most of the soils are Udepts and Humults, shallow and moderately deep, medium textured Eutrudepts (Caguabo, Múcara, Morado, and Quebrada series) have an isohyperthermic temperature regime and mixed mineralogy. They are on steep side slopes, mainly in the east-central part of Puerto Rico. The Humatas series, a deep, fine textured Haplohumults has an isohyperthermic temperature regime. The Los Guineos series is an Isothermic Humic Hapludox. They are on steep side slopes in the west-central part of Puerto Rico. Soils of minor extent are the deep, extremely weathered Anionic Acrudox (Nipe series) in the western part of Puerto Rico.

271—Semiarid Mountains and Valleys
Puerto Rico—960 km^2 (369 mi^2)

Elevation and topography: Elevation in Puerto Rico ranges from 50 to 400 m. Slopes range from moderately steep to very steep; near-vertical slopes occur in the northernmost part of the area. These semiarid mountains are in the southern slopes of the central mountain chain that runs east and west the length of the island. All streams in the Puerto Rican part of this area flow to the south.

Climate: Average annual precipitation - 1,150 mm. Maximum precipitation is in May and in September. Average annual temperature is - 26° C. The difference between the temperature in summer and that in winter is less than 5° C.

Water: The source of surface water is about 1,143 mm of rainfall a year. Because of high evaporation rates in this area, much of this precipitation is lost in the atmosphere before reaching the small streams and rivers. The few man-made lakes are used for storing water for human consumption and for irrigation. Ground water is scarce because the steep topography and the high evaporation rates prevent sufficient quantities of water from entering the soil and establishing underground deposits.

Soils: Most of the soils are Ustolls. They are shallow and moderately deep and medium textured. They have an isohyperthermic temperature regime and mixed mineralogy on volcanic rocks. The well drained, shallow Typic Haplustolls (Descalabrado series) are dominant throughout the area and are on the steep southern side slopes of the east-west central ridge of mountains. The well-drained, moderately deep Vertic Haplustolls (Jácana series) are on side slopes and foot slopes. Of minor extent are shallow Typic Haplustalfs (Guayama series) on steep side slopes

272—Humid Coastal Plains
2,420 km² (933 mi²)

Elevation and topography: Elevation ranges from sea level to 700 m, rising gradually from the beaches on the Atlantic Ocean to the hilly karst area to the south. This area is divided into two distinct zones - the flat alluvial plains and terraces along the coast and the irregular features of the karst limestone inland. Streams generally flow to the north, but most of the drainage in the karst zone is underground.

Climate: Average annual precipitation - 1,600 mm. Maximum precipitation is in May and August. Average annual temperature is - 25° C. There is little difference between the temperature in summer and that in winter.

Water: Surface and ground water are plentiful. Surface water consists of runoff from rainfall in the humid uplands. Some large manmade lakes are used for hydroelectric power and as a source of water for human consumption. Ground-water supplies are derived from water in the joints and fractures of the underlying volcanic rock and the contiguous limestone aquifers of this humid coastal area.

Soils: There are four distinct geomorphic areas--coastal plains, river flood plains, small lagoon like depressions, and limestone karst areas. All the soils have an isohyperthermic temperature regime. In the coastal plains, the dominant soils are deep, well drained, acid Plintic Hapludox (Almirante series) and Typic Hapludults (Vega Alta series) and Typic Hapludox (Bayamón series) and Typic Eutrustox (Coto series). On the flood plains, the poorly drained Endoaquolls (Bajura series), the somewhat poorly drained Endoaquepts (Coloso series), and the well-drained Hapludolls (Toa series) are the main soils. Poorly drained Haplosaprists (Tiburones and Saladar series), Fluvaquents (Martín Peña series), and swamps and marshes are dominant in small depressions. In the extensive limestone karst, Haprendolls (Colinas and Soller series), Argiudolls (San Sebastián series) and Hapludalfs (Tanamá series) are major soils.

273-Semiarid Coastal Plains
580 km² (223 mi²)

Elevation and topography: Elevation in the Puerto Rican part of this area ranges from sea level to 400 m. Most area is nearly level to gently sloping. Elevation increases gradually from beaches on the Caribbean Sea to the foothills of the semiarid mountains to the north. Limestone hills and ridges are similar to those in the Humid Coastal plains, but they lack the striking karst features. All drainage is superficial and flows in a southerly direction.

Climate: Average annual precipitation - 900 mm. Maximum precipitation is in May and in September. Average annual temperature is - 26° C. The difference between the temperature in summer and that in winter is small.

Water: Surface water is scarce because of limited rainfall and high evaporation rates. Low rainfall and steep topography of the adjacent semiarid mountains to the north provide little additional surface water. Streams and rivers generally are intermittent. Aquifers are affected by saltwater intrusion because of overuse. In places artesian pressure brings saline and sodic groundwater to the surface.

Soils: Aquolls, Ustolls, and Usterts are the dominant soils on flood plains and on high terraces. These soils have an isohyperthermic temperature regime and mixed or smectitic mineralogy. On the flood plains, deep, somewhat poorly drained, fine textured Calciaquolls (Constancia series) and well drained Haplustolls (Jacaguas and San Antón series) are dominant. On the high terraces, deep expansive clayey Typic Haplusterts (Fraternidad series) and sodic Haplusterts and Epiaquerts (Aguirre and Guánica series) are dominant.

Appendix A.2 - Highly Erodible Land

Highly erodible land is defined by the Sodbuster, Conservation Reserve, and Conservation Compliance parts of the Food Security Act of 1985, and the Food, Agriculture, Conservation, and Trade Act of 1990. Determinations for highly erodible land are based on an erodibility index as defined in the National Food Security Act Manual.

Official lists of highly erodible and potential highly erodible soil map units are maintained in the NRCS - Field Office Technical Guide. Policy and procedures for developing and maintaining the lists are given in part 511 of the National Food Security Act Manual.

Highly Erodible Soil Map Units – A soil map unit with an erodibility of 8 or greater is highly erodible land (HEL).

Calculating Erodibility Index – The erodibility index (EI) for a soil map unit is determined by dividing the potential erodibility for the soil map unit by the loss tolerance (T).

Sheet and Rill Equation $\frac{R \times K \times LS}{T} = EI$

Soil Erodibility Factor (K)

Soils vary in their susceptibility to erosion. The soil erodibility factor K is a measure of erodibility for a standard condition. The soil erodibility factor K represents both susceptibility of soil to erosion and the amount and rate of runoff, as measured under the standard unit plot condition. Fine textured soils high in clay have low K values, about 0.02 to 0.15, because they are resistant to detachment. Coarse texture soils, such as sandy soils, have low K values, about 0.05 to 0.2, because of low runoff even though these soils are easily detached. Medium textured soils, such as silt loam soils, have moderate K values, about 0.25 to 0.40, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content are the most erodible of all soils. They are easily detached and they tend to crust and produce large amounts and rates of runoff. Values of K for these soils tend to be greater than 0.4. In the Caribbean Area, K values range from 0.02 to 0.32.

Soil Loss Tolerance (T)

It is defined as the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely. The T factors are integer values from 1 through 5 tons per acre per year. The factor of 1 ton per acre per year is for shallow or otherwise fragile soils and 5 tons per acre per year is for deep soils that are least subject to damage by erosion. The classes of T factors are 1, 2, 3, 4, and 5.

Erosivity Factor (R)

The rainfall-runoff factor, R, can be simply defined as the erosive force of the rainfall. The erosivity of rainfall varies greatly by location. For example, erosivity in the eastern interior zone of the Caribbean Area is much higher than in the south coastal zone of the area. The R factor represents these differences in erosivity among locations. Values for R computed from weather records were used to produce the Caribbean Area data base map.

Slope Gradient Factor (S)

Slope gradient is the difference in elevation between two points and is expressed as a percentage of the distance between those points. For example, a difference in elevation of 1 meter over a horizontal distance of 100 meters is a slope of 1 percent.

Slope gradient influences the retention and movement of water, the potential for soil slippage and accelerated erosion, the ease with which machinery can be used, soil-water states, and the engineering uses of the soil.

Slope gradient is usually measured with a hand level or clinometer. The range is determined by summarizing data from several sightings.

Enter the high, low, and representative values to represent the range of slope gradient as a percentage for the map unit component. Entries for high and low are whole number integers and range from 0 to 999.

Slope Length Factor (L)

Slope length is the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel. Reference: Agriculture Handbook 703.

Slope length has considerable control over runoff and potential accelerated water erosion. Slope length is combined with slope gradient in erosion prediction equations to account for the effect of topography on erosion.

Slope length is measured from the point of origin of overland flow to the point where the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel. Pacing or measuring in the field best determines the slope length.

Enter the high, low, and representative values for the range for each map unit component. Enter a whole number that represents the length in meters from the point of origin of overland flow to the point of deposition or concentrated flow of the slope on which the component lies. The slope length may be fully encompassed within one map unit or it may cross several map units. The minimum value is 0, and the maximum value used in erosion equations is 305 meters.

Source: Caribbean Area FOTG – Section II: Natural Resources Information (12/2002)

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Appendix A.3 - Hydric Soils

Introduction

Hydric soils are developed under sufficiently wet conditions to support the growth and regeneration of hydrophytic vegetation. These lists include phases of soil series that may or may not have been drained. Some series, designated as hydric, have phases that are not hydric depending on water table, flooding, and ponding characteristics.

These lists of hydric soils were created using criteria developed by the National Technical Committee for Hydric Soils. The criteria are selected soil properties that are documented in the Federal Register.

The lists of hydric soils are arranged by soil survey area. Each list consists of two parts:
1) Map units that have named hydric components, and
2) Map units with inclusions of hydric soils or wet miscellaneous areas.

These lists will have a number of agricultural and nonagricultural applications. These include assistance in land-use planning, conservation planning, and assessment of potential wildlife habitat. An area that meets the hydric soil criteria must also meet the hydrophytic vegetation and wetland hydrology criteria in order for it to be classified as a jurisdictional wetland (See the "Corps of Engineers Wetlands Delineation Manual", 1987).

This state listing is a compilation of the individual soil survey area lists, and is recommended for use in making wetland determinations.

Definition of Hydric Soil

A hydric soil is a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Hydric soils along with hydrophytic vegetation and wetland hydrology are used to define wetlands. The following criteria reflect those soils that meet this definition.

Criteria for Hydric Soils

1. All Histels except Folistels and Histosols except Folists.

2. Soils in Aquic suborders, great groups, or subgroups, Albolls suborder, Aquisalids, Historthels, and Histoturbels great groups, and Cumulic or Pachic subgroups that are:

    a. Somewhat poorly drained with a water table equal to 0.0 foot (ft.) from the surface during the growing season, or

b. Poorly drained or very poorly drained and have either:

   (1) Water table equal to 0.0 ft. during the growing season if textures are coarse sand, sand, or fine sand in all layers within 20 inches (in.), or for other soils, or

   (2) Water table at less than or equal to 0.5 ft. from the surface during the growing season if permeability is equal to or greater than 6.0 in/hour (h.) in all layers within 20 in., or

   (3) Water table at less than or equal to 1.0 ft. from the surface during the growing season, if permeability is less than 6.0 in./h. in any layer within 20 in., or

3. Soils that are frequently ponded for long or very long duration during the growing season, or

4. Soils that are frequently flooded for long or very long duration during the growing season.

Glossary of Terms Used in Defining Hydric Soils

Anaerobic: a situation in which molecular oxygen is absent from the environment.

Drained: a condition in which ground or surface water has been removed by artificial means.

Flooded: a condition in which the soil surface is temporarily covered with flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources.

Frequently flooded, ponded, saturated: a frequency class in which flooding, ponding, or saturation is likely to occur often under usual weather conditions (more than 50-percent chance in any year, or more than 50 times in 100 years).

Hydrophytic vegetation: plant life growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excess water content.

Long duration: a duration class in which inundation for a single event ranges from 7 days to 1 month.

Permeability: the quality of the soil that enables water to move downward through the profile, measured as the number of inches per hour that water moves downward through the saturated soil.
Phase, soil: a subdivision of a soil series based on features that affect its use and management (e.g., slope, surface texture, stoniness, and thickness).

Ponded: a condition in which water stands in a closed depression. The water is removed only by percolation, evaporation, or transpiration.

Poorly drained: water is removed from the soil so slowly that the soil is saturated periodically during the growing season or remains wet for long periods.

Saturated: a condition in which all voids (pores) between soil particles are filled with water.

Soil Series: a group of soils having horizons similar in differentiating characteristics and arrangements in the soil profile, except for texture of the surface layer.

Somewhat poorly drained: water is removed slowly enough that the soil is wet for significant periods during the growing season.

Very long duration: a duration class in which inundation for a single event is greater than 1 month.

Very poorly drained: water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season.

Water table: the zone of saturation at the highest average depth during the wettest season. It is at least 6 inches thick and persists in the soil for more than a few weeks.

Literature Cited

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Appendix A.4 - Hydrologic Soil Groups

The Hydrologic Soil Group, designated A, B, C or D, is a group of soils that, when saturated, have the same runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are: depth to seasonally high water table, intake rate, permeability after prolonged wetting, and depth to very slowly permeable layer. The influences of ground cover and slope are treated independently --- not in hydrologic soil groups.

In the definitions of the classes, infiltration rate is the rate at which water enters the soil at the surface and is controlled by surface conditions.

Transmission rate is the rate at which water moves in the soil and is controlled by properties of the soil layers.

Hydrologic Soil Group A - Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission (low runoff potential).

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

Hydrologic Soil Group C - Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water, or (2) soils with moderately fine or fine textures and slow infiltration rate. These soils have a slow rate of water transmission.

Hydrologic Soil Group D - Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clayey soils with high swelling capacity or potential, (2) soils with a high permanent water table, (3) soils with a claypan or clay layer at or near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission (high runoff potential).

Dual Hydrologic Groups.

Dual hydrologic groups, A/D, B/D and C/D, are given for criteria with soils that can be adequately drained. The first letter applies to the drained condition and the second to the undrained condition. Only soils that are rated D in their natural condition are assigned to dual groups.

Source: Caribbean Area FOTG – Section II: Natural Resources Information (6/2002)

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Appendix B.1 – Streambank and Shoreline Protection, NRCS National Engineering Handbook, Part 650 – Engineering Field Handbook, Chapter 16.

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Appendix B.2 – Soil Bioengineering for Upland Slope Protection and Erosion Reduction, NRCS National Engineering Handbook, Part 650 – Engineering Field Handbook, Chapter 18.

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Appendix C.1 – Guidelines for the Use of Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites and Reclaimed Lands.

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Appendix D.1 – Estimating Runoff and Peak Discharges, NRCS Engineering Field Handbook, Chapter 2 (EFH2).

For a copy of the NRCS National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 2, please access the following web site:

http://www.info.usda.gov/CED/ftp/CED/EFH-Ch02.pdf

and the Engineering Field Handbook, Chapter 2, Amendment at:

http://www.info.usda.gov/CED/ftp/CED/EFH-Ch02-amend.pdf

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Appendix D.2 – Urban Hydrology for Small Watershed (TR-55).

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Appendix D.3 – Urban Hydrology for Small Watersheds (WIN-TR-55).

For a copy of the NRCS Urban Hydrology for Small Watersheds (WIN-TR-55), please access the following web site:

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html

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