APPENDIX 3

EXCEPTS FROM
NORTH CAROLINA EROSION AND SEDIMENT CONTROL PLANNING & DESIGN MANUAL

6.02

LAND GRADING

Definition

Reshaping the ground surface to planned grades as determined by engineering survey evaluation and layout.

Purpose

To provide more suitable topography for buildings, facilities, and other land uses, to control surface runoff, and to minimize soil erosion and sedimentation both during and after construction.

Conditions Where Practice Applies

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.

Planning Considerations

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 sedimentation control measures. It may also result in a more desirable and less costly development.

Before grading begins, decisions must be made on the steepness of cut-and-fill slopes, how they will be protected from runoff, how they will be stabilized, and how they will be maintained. The grading plan establishes drainage areas, directs drainage patterns, and affects runoff velocities.

The grading plan forms the basis of the erosion and sedimentation control plan. Key considerations that affect erosion and sedimentation include deciding which slopes are to be graded, when the work will start and stop, the degree and length of finished slopes, where and how excess material will be wasted, and where borrow is needed.

Leaving undisturbed temporary and permanent buffer zones in the grading operation may provide an effective and low-cost erosion control measure that will help reduce runoff velocity and volume and off-site sedimentation. In developing the grading plan, always consider how to take advantage of undisturbed water disposal outlets before storm drains or other constructed outlets are installed.

Design Criteria

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, and surface and subsurface drains. The practices may be temporary or permanent, depending upon the need after construction is completed.

In the grading plan consider the following as a minimum:

Make a provision to intercept and conduct all surface runoff to storm drains, protected outlets, or to stable watercourses to minimize erosion on newly graded slopes.

Use slope breaks, such as diversions or benches, as appropriate, to reduce the length of cut-and-fill slope to limit sheet and rill erosion and prevent gullying. A spacing guide is shown in Table 6.02a.

Table 6.02a
Spacing Guide for Slope Breaks

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

Stabilize all graded areas with vegetation, crushed stone, riprap, or other ground cover as soon as grading is completed, or when work is interrupted for 30 working days or more. Use mulch to stabilize areas temporarily where final grading must be delayed. The finished cut-and-fill slopes, which are to be vegetated with grass and legumes, should not be steeper than 2:1. Slopes to be maintained by tractor or other equipment should not be steeper than 3:1. Slopes in excess of 2:1 may warrant vines, special vegetation, or retaining walls. Roughen the surface of all slopes during the construction operation to retain water, increase filtration, and facilitate vegetation. (Practice 6.03, *Surface Roughening*.)

Do not place cuts or fill so close to property lines as to endanger adjoining property without adequately protecting such properties from erosion, sedimentation, slippage, subsidence, or other damages.

Provide subsurface drainage to intercept seepage in areas with high water tables that would affect slope stability, bearing strength, or create undesirable wetness.

Do not place fill adjacent to a channel bank where it can create bank failure or result in deposition of sediment downstream.

Show all borrow and disposal areas in the grading plan, and ensure they are adequately drained and stabilized.

Provide stable channels and floodways to convey all runoff from the developed area to an adequate outlet without causing increased erosion or off-site sedimentation.

Construction Specifications

1. Construct and maintain all erosion and sedimentation control practices and measures in accordance with the approved sedimentation control plan and construction schedule.

2. Remove good topsoil from areas to be graded and filled, and preserve it for use in finishing the grading of all critical areas.

3. Scarify areas to be topsoiled to a minimum depth of 2 inches before placing topsoil (Practice 6.04, *Topsoiling*).

4. Clear and grub areas to be filled by removing trees, vegetation, roots, or other objectionable material that would affect the planned stability of the fill.

5. Ensure that fill material is free of brush, rubbish, rocks, logs, stumps, building debris, and other materials inappropriate for constructing stable fills.

6. Place all fill in layers not to exceed 9 inches in thickness, and compact the layers as required to reduce erosion, slippage, settlement, or other related problems.

7. Do not incorporate frozen, soft, mucky, or highly compressible materials into fill slopes.

8. Do not place fill on a frozen foundation, due to possible subsidence and slippage.

9. Keep diversions and other water conveyance measures free of sediment during all phases of development.

10. Handle seeps or springs encountered during construction in accordance with approved methods (Practice 6.81, *Subsurface Drain*).

11. Permanently stabilize all graded areas immediately after final grading is completed on each area in the grading plan. Apply temporary stabilization measures on all graded areas when work is to be interrupted or delayed for 30 working days or longer.

12. Show topsoil stockpiles, borrow areas, and spoil areas on the plans, and make sure they are adequately protected from erosion. Include final stabilization of these areas in the plan.

Maintenance

Periodically, check all graded areas and the supporting erosion and sedimentation control practices, especially after heavy rainfalls. Promptly remove all sediment from diversions and other water-disposal practices. If washouts or breaks occur, repair them immediately. Prompt maintenance of small eroded areas before they become significant gullies is an essential part of an effective erosion and sedimentation control plan.

References

Chapter 3, Vegetative Considerations
Chapter 5, Overview of Erosion and Sedimentation Control Practices

6.04

TOPSOILING

Definition

Preserving and using topsoil to enhance final site stabilization with vegetation.

Purpose

To provide a suitable growth medium for vegetation.

Conditions Where Practice Applies

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, and
- The soil contains substances toxic to the desired vegetation.

Where high-quality turf or ornamental plants are desired.

Where slopes are 2:1 or flatter.

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 content usually increases in the subsoil. In North Carolina, were subsoils are often high in clay, the topsoil layer may be significantly coarser in texture. 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 emergence 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 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 subsoils 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, and
- location 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, nor 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.

Construction Specifications

MATERIALS

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

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

Organic matter content—(sometimes referred to as "humic matter") should be greater than 1.5% by weight.

Acidity—pH should be greater than 3.6 before liming, and liming is required if it is less than 6.0.

Soluble salts—should be less than 500 ppm.

Sodium—sodium adsorption ratio should be less than 12.

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 extremely light weight when dry.

STRIPPING

Strip topsoil only from those areas that will be disturbed by excavation, filling, roadbuilding, 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 the slope. Put sediment basins, diversions, and other controls into place before stripping.

STOCKPILING

Select stockpile location to avoid slopes, natural drainageways, and 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 21 calendar days after the formation of the stockpile (Practice 6.10, *Temporary Seeding*).

Permanent vegetation—If stockpiles will not be used within 90 days they must be stabilized with permanent vegetation to control erosion and weed growth (Practice 6.11, *Permanent Seeding*).

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 and do not alter them by adding topsoil.

Limit 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 (Practice 6.11, *Permanent Seeding*). 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 Table 6.04a. Do not spread topsoil while it is frozen or muddy or when the subgrade is wet or frozen. 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.

Table 6.04a Cubic Yards of Topsoil Required for Application to Various Depths

Depth (Inches)	Per 1,000 Sq. ft.	Per Acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	536
5	15.5	670
6	18.6	804

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 seedbed preparation, taking care to avoid excessive mixing of topsoil into the subsoil.

References

Site Preparation
6.03, Surface Roughening

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding

Chapter 3, *Vegetative Considerations*

6.06

TEMPORARY GRAVEL CONSTRUCTION ENTRANCE/EXIT

Definition

A graveled area or pad located at points where vehicles enter and leave a construction site.

Purpose

To provide a buffer area where vehicles can drop their mud and sediment to avoid transporting it onto public roads, to control erosion from surface runoff, and to help control dust.

Conditions Where Practice Applies

Wherever traffic will be leaving a construction site and moving directly onto a public road or other paved off-site area. Construction plans should limit traffic to properly constructed entrances.

Design Criteria

Aggregate Size—Use 2-3 inch washed stone.

Dimensions of gravel pad—

Thickness: 6 inches minimum

Width: 12-feet minimum or full width at all points of the vehicular entrance and exit area, whichever is greater

Length: 50-feet minimum

Location—Locate construction entrances and exits to limit sediment from leaving the site and to provide for maximum utility by all construction vehicles (Figure 6.06a). Avoid steep grades, and entrances at curves in public roads.

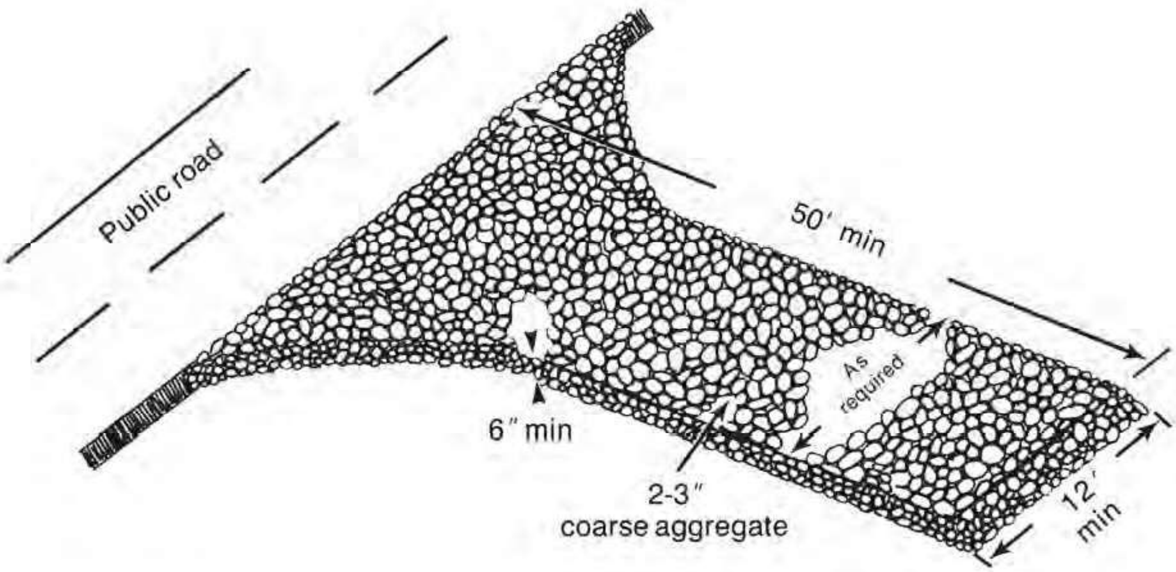


Figure 6.06a Gravel entrance/exit keeps sediment from leaving the construction site (modified from Va SWCC).

Washing—If conditions at the site are such that most of the mud and sediment are not removed by vehicles traveling over the gravel, the tires should be washed. Washing should be done on an area stabilized with crushed stone that drains into a sediment trap or other suitable disposal area. A wash rack may also be used to make washing more convenient and effective.

Construction Specifications

1. Clear the entrance and exit area of all vegetation, roots, and other objectionable material and properly grade it.

2. Place the gravel to the specific grade and dimensions shown on the plans, and smooth it.

3. Provide drainage to carry water to a sediment trap or other suitable outlet.

4. Use geotextile fabrics because they improve stability of the foundation in locations subject to seepage or high water table.

Maintenance

Maintain the gravel pad in a condition to prevent mud or sediment from leaving the construction site. This may require periodic topdressing with 2-inch stone. After each rainfall, inspect any structure used to trap sediment and clean it out as necessary. Immediately remove all objectionable materials spilled, washed, or tracked onto public roadways.

References

Runoff Conveyance Measures
6.30, Grass-lined Channels

Sediment Traps and Barriers
6.60, Temporary Sediment Trap

6.10

TEMPORARY SEEDING

TS

Definition

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

Purpose

To temporarily stabilize denuded areas that will not be brought to final grade for a period of more than 21 calendar days.

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.

Conditions Where Practice Applies

On any cleared, unvegetated, or sparsely vegetated soil surface where vegetative cover is needed for less than 1 year. Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.

Planning Considerations

Annual plants, which sprout and grow rapidly and survive for only one season, are suitable for establishing initial or temporary vegetative cover. Temporary seeding preserves the integrity of earthen sediment control structures such as dikes, diversions, and the banks of dams 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 Practice 6.11, *Permanent Seeding*. 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.

Specifications

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 the 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.

Fertilizer—Base application rates on soil tests. When these are not possible, apply a 10-10-10 grade fertilizer at 700-1,000 lb/acre. Both fertilizer and lime 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.

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 (Practice 6.03, *Surface Roughening*).

PLANT SELECTION

Select an appropriate species or species mixture from Table 6.10a for seeding in late winter and early spring, Table 6.10b for summer, and Table 6.10c for fall.

In the Mountains, December and January seedings have poor chances of success. When it is necessary to plant at these times, use recommendations for fall and a securely tacked mulch.

SEEDING

Evenly apply seed using a cyclone seeder (broadcast), drill, cultipacker seeder, or hydroseeder. Use seeding rates given in Tables 6.10a-6.10c. 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.

Small grains should be planted no more than 1 inch deep, and grasses and legumes no more than 1/2 inch. Broadcast seed must be covered by raking or chain dragging, and then lightly firmed with a roller or cultipacker. Hydroseeded mixtures should include a wood fiber (cellulose) mulch.

MULCHING

The use of an appropriate mulch will help ensure establishment under normal conditions, and is essential to seeding success under harsh site conditions (Practice 6.14, *Mulching*). Harsh site conditions include:

- seeding in fall for winter cover (wood fiber mulches are not considered adequate for this use),
- slopes steeper than 3:1,
- excessively hot or dry weather,
- adverse soils (shallow, rocky, or high in clay or sand), and
- areas receiving concentrated flow.

If the area to be mulched is subject to concentrated waterflow, as in channels, anchor mulch with netting (Practice 6.14, *Mulching*).

Maintenance

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

References

Site Preparation
6.03, Surface Roughening
6.04, Topsoiling

Surface Stabilization
6.11, Permanent Seeding
6.14, Mulching

Appendix
8.02, Vegetation Tables

Table 6.10a Temporary Seeding Recommendations for Late Winter and Early Spring

Seeding mixture

Species	Rate (lb/acre)
Rye (grain)	120
Annual lespedeza (Kobe in Piedmont and Coastal Plain, Korean in Mountains)	50

Omit annual lespedeza when duration of temporary cover is not to extend beyond June.

Seeding dates

Mountains—Above 2500 feet: Feb. 15 - May 15
Below 2500 feet: Feb. 1- May 1
Piedmont—Jan. 1 - May 1
Coastal Plain—Dec. 1 - Apr. 15

Soil amendments

Follow recommendations of soil tests or apply 2,000 lb/acre ground agricultural limestone and 750 lb/acre 10-10-10 fertilizer.

Mulch

Apply 4,000 lb/acre straw. Anchor straw by tacking with asphalt, netting, or a mulch anchoring tool. A disk with blades set nearly straight can be used as a mulch anchoring tool.

Maintenance

Refertilize if growth is not fully adequate. Reseed, refertilize and mulch immediately following erosion or other damage.

Table 6.10b Temporary Seeding Recommendations for Summer

Seeding mixture

Species	Rate (lb/acre)
German millet	40

In the Piedmont and Mountains, a small-stemmed Sudangrass may be substituted at a rate of 50 lb/acre.

Seeding dates

Mountains—May 15 - Aug. 15
Piedmont—May 1 - Aug. 15
Coastal Plain—Apr. 15 - Aug. 15

Soil amendments

Follow recommendations of soil tests or apply 2,000 lb/acre ground agricultural limestone and 750 lb/acre 10-10-10 fertilizer.

Mulch

Apply 4,000 lb/acre straw. Anchor straw by tacking with asphalt, netting, or a mulch anchoring tool. A disk with blades set nearly straight can be used as a mulch anchoring tool.

Maintenance

Refertilize if growth is not fully adequate. Reseed, refertilize and mulch immediately following erosion or other damage.

Table 6.10c Temporary Seeding Recommendations for Fall

Seeding mixture

Species	Rate (lb/acre)
Rye (grain)	120

Seeding dates
Mountains—Aug. 15 - Dec. 15
Coastal Plain and Piedmont—Aug. 15 - Dec. 30

Soil amendments
Follow soil tests or apply 2,000 lb/acre ground agricultural limestone and 1,000 lb/acre 10-10-10 fertilizer.

Mulch
Apply 4,000 lb/acre straw. Anchor straw by tacking with asphalt, netting, or a mulch anchoring tool. A disk with blades set nearly straight can be used as a mulch anchoring tool.

Maintenance
Repair and refertilize damaged areas immediately. Topdress with 50 lb/acre of nitrogen in March. If it is necessary to extent temporary cover beyond June 15, overseed with 50 lb/acre Kobe (Piedmont and Coastal Plain) or Korean (Mountains) lespedeza in late February or early March.

6.11

PERMANENT SEEDING

PS

Definition

Controlling runoff and erosion on disturbed areas by establishing perennial vegetative cover with seed.

Purpose

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

Conditions Where Practice Applies

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

Areas to be stabilized with permanent vegetation must be seeded or planted within 15 working days or 90 calendar days after final grade is reached, unless temporary stabilization is applied.

Introduction

During the initial phase of all land disturbing projects, the protective layer, either natural or man-made, is removed from the earth's surface. As the protective layer is removed, the resulting bare areas are exposed to the natural forces of rainfall, freezing, thawing, and wind. The result is soil erosion that leads to sediment pollution of North Carolina streams, rivers, lakes, and estuaries.

This design manual presents many alternative strategies for preventing erosion and reducing sediment loss during the construction process. Establishment of protective vegetative cover during the construction project, however, is the crucial step in achieving soil stabilization, controlling soil erosion, and preventing sedimentation of waterways. Without a sufficient amount of root mat and leaf cover to protect and hold the soil in place, large volumes of soil will be lost and waterways will be degraded long after projects are considered complete.

Sections of this practice standard address many of these various situations and set forth selection criteria for the appropriate cover based on purpose and adaptability. Some sediment and erosion control practices recommended in earlier editions of the manual may no longer be applicable. For example, many popular and commonly used seed and plant varieties have been identified as invasive. Invasive plants are defined as species that aggressively compete with, and displace, locally adapted native plant communities. In select cases where no practical alternative is available, these plants may be considered on a limited basis for soil stabilization, understanding that the goal is to eliminate the use of all invasive plants in favor of non-invasive native and/or introduced species that will provide an equally acceptable vegetative cover. Where there is no alternative to the use of invasive species, measures need to be incorporated in the installation and maintenance of these plants to limit their impacts.

It is imperative that disturbed soils be totally protected from erosion and sediment loss during construction and before a project is considered complete and acceptable. Installing appropriate vegetation in an immediate and timely fashion is the optimal means of achieving this stabilization. Vegetative specifications for most exposed soil conditions across North Carolina are provided in this section of the manual. It should be noted however, that no two sites in the State are exactly alike; therefore the protective vegetative cover for individual sites should be carefully selected. Each requires its own investigation, analysis, design and vegetative prescription as set forth in this section of the manual.

This practice standard describes three stages of vegetative cover; immediate, primary and long term. Effective and acceptable stabilization can be provided only when the optimum combination of immediate, primary, and long term vegetative practices are applied.

The vegetative measures presented in this chapter include application of seed, sod and sprigs. Use of field and container grown plants are not addressed in this manual. Planting of these types of vegetation is typically at spacing and intervals that will not provide the required protective cover. However, the design professional is encouraged to utilize these larger plants to compliment the required protective cover, particularly where these types of plants will provide seed for continued long term cover and wildlife habitat.

PLANNING CONSIDERATIONS

SOILS

Test and analyze the type(s) and quality of the existing soils on a site, their pH ranges, and their nutrient levels. Taking soil samples from the different areas of the project site and having them tested at a state or independent lab will provide a baseline for determining the pH modifiers and additional nutrients required for the selected plant varieties.

Disturbed conditions on a site may produce a variety of soil communities. Nutrient and pH levels in deeply cut soils will be quite different from those soils found on the original surface. When sites are highly disturbed through mechanical means such as grading, the soils become mixed together in many different ratios. These areas should be identified and tested.

Results from soil tests will usually include recommended application rates of soil modifiers such as lime and fertilizer for the selected plant species in the particular soils. Application rates will be itemized in the report.

The texture of the soil on a site, which is the proportion of sand, silt, and clay in the soil, is an important physical indicator of the site's ability to support vegetation. In heavy clay soils amendments may be necessary to provide an adequately drained planting medium. Conversely, in extremely sandy soils, amendments may be required to provide for moisture and nutrient retention.

Soil tests will indicate the texture of the given soil but will not provide recommendations for amendments that will improve the soil texture. Generally, the addition of organic materials will improve the porosity of heavy clay soils and improve the water holding capacity of extremely sandy soils. On sites where these different soil conditions exist, it is recommended that a design professional with experience in soil modification be employed to recommend the proper amendments.

For more information visit the NCDA Agronomic Services Soil Testing web page http://www.agr.state.nc.us/agronomic/sthome.htm

SOIL PREPARATION

Proper soil preparation is necessary for successful seed germination and root establishment. It is also necessary for establishment of rooted sprigs, sod and woody plants. Heavily compacted soils prevent air, nutrients and moisture from reaching roots thereby retarding or preventing plant growth. The success of site stabilization and reduction of future maintenance are dependent on an adequately prepared soil bed. Following are the requirements for preparation of areas to be vegetated by grassing, sprigging, sodding, and/or planting of woody plants:

General Requirements:

- Preparation for primary/permanent stabilization shall not begin until all construction and utility work within the preparation area is complete. However, it may be necessary to prepare for nurse crops prior to completion of construction and installation of utilities.

- A North Carolina Department of Agriculture Soils Test (or equal) shall be obtained for all areas to be seeded, sprigged, sodded or planted. Recommended fertilizer and pH adjusting products shall be incorporated into the prepared areas and backfill material per the test.

- All areas to be seeded or planted shall be tilled or ripped to a depth specified on the approved plans, construction sequence and/or construction bid list. Ripping consists of creating fissures in a criss-cross pattern over the entire surface area, utilizing an implement that will not glaze the side walls of the fissures. Site preparation that does not comply with these documents shall not be acceptable. The depth of soil preparation may be established as a range based on the approval of the reviewing state or local agency. Once tilled or ripped according to the approved plan, all areas are to be returned to the approved final grade. pH modifiers and/or other soil amendments specified in the soil tests can be added during the soil preparation procedure or as described below.

- All stones larger than three (3) inches on any side, sticks, roots, and other extraneous materials that surface during the bed preparation shall be removed.

Areas to be Seeded:

- Till or disc the prepared areas to be seeded to a minimum depth of four (4) inches. Remove stones larger than three (3) inches on any side, sticks, roots and other extraneous materials that surface. If not incorporated during the soil preparation process, add pH modifier and fertilizers at the rate specified in the soil test report.

- Re-compact the area utilizing a cultipacker roller. The finished grade shall be a smooth even soil surface with a loose, uniformly fine texture. All ridges and depressions shall be removed and filled to provide the approved surface drainage. Seeding of graded areas is to be done immediately after finished grades are obtained and seedbed preparation is completed.

Areas to be Sprigged, Sodded, and/or Planted:

- At the time of planting till or disc the prepared areas to a depth of four (4) to six (6) inches below the approved finished grade. Remove all stones larger than three (3) inches on any side, sticks, roots and other extraneous materials that surface. If not incorporated in the ripping process, add pH modifier, fertilizer, and other recommended soil amendments.

- Re-compact the area utilizing a cultipacker roller and prepare final grades as described above. Install sprigs, sod and plants as directed immediately after fine grading is complete. Mulch, mat and/or tack as specified.

VEGETATION

Availability of seed and plant materials is an important consideration of any construction stabilization effort. Throughout North Carolina, climate, economics, construction schedule delays and accelerations, and other factors present difficult challenges in specifying the different vegetation needed for site stabilization. To help resolve this issue, vegetative stabilization requires consideration in three categories:

- Immediate Stabilization – nurse crop varieties (Note: temporary mulching may be utilized for immediate stabilization if outlined on the approved plans and construction sequence.)

- Primary Stabilization – plant varieties providing cover up to 3 years with a specified maintenance program

- Long Term Stabilization – plant varieties providing protective cover with maintenance levels selected by the owner

An adequate job in one of these areas does not guarantee success in the later phases. Horticultural maintenance must be included in the plans.

Immediate vegetative cover will always require additional fertilization, soil amendments, soil tests, overseeding and/or other horticultural maintenance until primary vegetative cover is established.

Where provisions are made for regular maintenance, primary vegetative cover may be the end result. An example of primary vegetative cover being acceptable as an end use would be lawns in residential and commercial developments that are established, monitored and complimented with regular and approved horticultural maintenance practices. (See Example 6.11.a.)

In projects where continual maintenance will not be provided or scheduled following the primary stabilization of a project, long-term stabilization will be necessary. Maintenance of initial and long-term stabilization can cease only after the long-term cover has established and hardened to local climatic conditions. Maintenance of long-term vegetation must be included in the project construction sequence and on the approved plans. Examples of areas suitable for long term vegetation include roadsides, reforestation areas, restored flood plains, restored riparian areas, phased closing of landfills, and mining reclamations.

Complete stabilization requires using at least two, and most times, all three vegetative phases. The design professional must clearly communicate this point in their specifications, construction sequence, and in direct communications to owners and installers. The charts in tables 6.11.a through 6.11.d provide information to assist the design professional in this task. The tables are not inclusive and are presented only as alternatives. The professional is expected and required to provide design and specifications that combine the information in the manual with knowledge of the particular sites and their constraints.

pH AND NUTRIENT AMENDMENTS

Determining the nutrients that enable seed and container plants to grow, flourish, and become established after planting are critical elements of the design and stabilization process. The soils tests previously described will provide a recipe for amendments based on particular plants and particular soils. The test results will recommend the amounts of base elements (nitrogen, phosphorous, potassium), pH modifiers and other trace elements that should to be added to the soil for selected species of seeds and plants.

The acid/base characteristic of the soil is a primary component of soil fertility. If the soil acidity is not in the proper range, other nutrients will be ineffective, resulting in less productive plant growth. Most plants grow best in a pH range of 6.5 – 7.0 (slightly acidic to neutral). The soil tests will recommend the specific amendments and application rates required to achieve this range. These amendments must be incorporated into the soil (not applied on the surface) to be effective. (See the General Requirements for soil preparation specifications and timing for incorporation of soil amendments.)

The base elements are easily found in bulk quantities. Lime can also be obtained in large quantities. They all must be thoroughly incorporated into the soil through appropriate mechanical means. Ground surface applications without proper soil mixing will result in poor results.

In addition to the base fertilizers, other trace elements are needed to produce healthy and vigorous growth. These include but may not be limited to sulfur, manganese, zinc, boron, chlorine and molybdenum. If not already included with bulk mixes of the base elements, they can be obtained from commercial suppliers.

Provisions for soils test during and/or after initial grading is complete shall be included on the approved plan, in the approved construction sequence, and on the bid item list utilized for the project. *If you did not obtain a soil test:* Follow these recommendations for all grasses except centipedegrass.

1. Apply 75 pounds of ground limestone per 1,000 sq. ft.
2. Apply a starter type fertilizer (one that is high in phosphorus) based on the type of grass and planting method. Fertilizer bags have a three-number system indicating the primary nutrients, such as 8-8-8 or 5-10-10. These numbers denote the N-P-K ratio—the percentage of each nutrient in a fertilizer. The percentages are always noted in the following order:
N Nitrogen for green color and growth.
P_2O_5 Phosphorus for good establishment and rooting.
K_2O Potassium to enhance pest and environmental stress tolerance.

Some common examples of starter type fertilizers required for a 1,000 sq. ft. area include 40 pounds of 5-10-10, 20 pounds of 10-20-20, or 16 pounds of 18-24-6. For sandy soils, typical to coastal plain and sandhills of North Carolina, fertilizer rates should be increased by 20 percent.

Where available, it is recommended that the design professional specify organic compounds that meet the fertilization requirements, pH and other element requirements. Initial studies have indicated that these compounds have a more positive effect on the environment than some of the synthetic compounds used to manufacture inorganic fertilizers. These materials are readily available in the commercial trade as well as found in recycled yard waste debris, sewerage sludge, lime-stabilized sludge and animal manures. Materials proposed for use must be industry certified and/or privately tested and certified to be acceptable for proposed areas of use and application prior to approval.

MULCHES AND TACKING AGENTS

Mulches and tacking agents may be required or necessary to protect a seedbed's disturbed surface until the seed can germinate and provide the required protection from erosion. Selection of the materials used in this application should be based on their ability to hold moisture in the soil, as well as protect exposed soil from rainfall, storm water runoff, and wind. The availability of the selected material and the means to apply it are critical factors to consider when planning for the stabilization of any disturbed area. The mulch must cover a minimum of eighty (80) percent of the soil surface and must be secured by a tacking agent, crimping, or protective biodegradable netting. Netting that incorporates plastic mesh and/or plastic twine should not be used in wetlands, riparian buffers or floodplains due to the potential of small animal mortality. See Section 6.14 for detailed specifications and product applications.

SOIL BLANKETS

Soil blankets can be an acceptable and effective method of temporary sediment and erosion control in lieu of nurse crops. See Section 6.17 of the manual for descriptions of this product and how it can be used in conjunction with this section. In absence of mulches and tracking agents other means of protection may be necessary and required.

PROTECTIVE MATTING

Protective matting consists of an impervious cover secured to the soil surface in lieu of vegetative cover. It is used to protect and stabilize the surface where the process of seeding or planting forms of vegetation may cause more erosion and off-site sedimentation than application of the mat. It is also used where a disturbed area is intended to lay fallow for a period of time before additional construction or land disturbance takes place. If a pervious matting is selected, a combination of vegetation and matting is required. Seeds can be applied prior to installation of the matting only after proper seedbed preparation has been provided. Also, live stakes, dormant sprigs, and other vegetation forms can be inserted in the pervious matting once it has been installed. Pre-seeded pervious matting may be used for quicker root establishment and stabilization only if certified dating and germination guarantees are provided. The reviewing agency must approve all pre-seeded matting on site prior to installation. Matting that incorporates plastic mesh and/or plastic twine should not be used in wetlands, riparian buffers or floodplains due to the potential of small animal mortality. See Section 6.17 for detailed specifications and recommended product applications.

STABILIZATION IN WETLANDS, RIPARIAN BUFFERS, AND FLOODPLAINS

Land disturbing activity involving streams, wetlands or other waterbodies may also require permitting by the U.S. Army Corps of Engineers or the N.C. Division of Water Quality. Approval of an erosion and sedimentation control plan is conditioned upon the applicant's compliance with federal and State water quality laws, regulations, and rules. Additionally, a draft plan should be disapproved if implementation of the plan would result in a violation of rules adopted by the Environmental Management Commission to protect riparian buffers along surface waters. Care should be taken in selecting vegetative stabilization of wetlands and riparian buffers to comply with permitting requirements of other agencies, as well as provide adequate ground cover.

Planning Considerations for Land Disturbing Activities Within Wetland, Riparian, and Floodplain Areas

Wetlands, riparian areas, floodplains, and/or terrestrial areas between streams and uplands, serve to buffer surface water and provide habitat for aquatic and terrestrial flora and fauna. When cleared and disturbed, these sensitive areas are difficult to protect. Because of their proximity to water courses, relatively high ground water tables, and flooding potential, detailed analysis and design is necessary to determine the appropriate erosion control measures during construction. Determining the appropriate and most expeditious means of permanent vegetative stabilization in these areas requires equally detailed analysis and design. The following considerations for erosion control and stabilization should be taken into account during the design phase of the land disturbing project where sensitive areas are involved:

- Obtain soil tests to determine the soil type, pH, texture and available nutrients.
- Based on the soil tests provide a schedule of nutrients and other soil amendments that will be required.

- Select a seeding mix of non-invasive species that will provide immediate stabilization (a short-term environment that will support and compliment permanent vegetative stabilization) and include a selective native species mix that will eventually provide a permanent cover (a long-term environment that, with minimal maintenance, will provide adequate root and leaf cover).
- Invasive species are to be avoided. If native species and introduced non-invasive seed sources are not available, protective matting that will hold and foster the development of native cover from adjacent seed sources should be used. Continuous maintenance must be employed until the selected species have matured and are no longer susceptible to competition from invasive plants. If no alternative to the use of invasive seeds and plants is available, invasives approved on the plans may be utilized only with strict containment measures outlined in detail on the plans, in the construction sequence and in the maintenance specifications.
- A quickly germinating nurse crop of non-invasive, non-competitive annual grass species can be used along with native seeding and/or matting. These temporary systems should be planted at minimal density so that they do not inhibit the growth and establishment of the permanent, native species. (See the plant chart in Table 6.11.a for recommended native and nurse crop species.)
- Seed bed preparation is key to successful establishment of seeds. Particular care should be taken, however, when working in wetlands, riparian areas, or floodplains due to their sensitive nature. Careful consideration should be given to the types and placement of large equipment working in these areas. This process must be outlined in detail on the plan's construction sequence.
- Installation techniques vary and should be planned for accordingly.
- A maintenance plan must be established for optimal plant establishment, submitted with the plans and included in the bid list for the project.

Like all construction sites, wetlands, riparian areas, and floodplains will vary widely in physical makeup across North Carolina. Different conditions will dictate specific treatment, design and plant selection within the Mountains, Piedmont, and Coastal Plain regions. Soil tests, seedbed preparation, mulching, matting, and maintenance will be critical for successful vegetative establishment and long-term protection of these environmentally sensitive areas. Unavoidable impacts to these areas during land disturbing activities need to be addressed in detail on the plan sheets and construction sequence.

Native Seed and Plant Selection for Stabilization of Wetlands, Riparian Areas, and Floodplains

Upon the completion of the land disturbing activity, vegetative cover must be established on all areas not stabilized by other means. If work in these areas stops for more than 15 working days, temporary vegetative cover and/or matting must be applied to all disturbed areas. The goal is to protect these areas from erosion and to prevent sedimentation of adjacent streams, wetlands, lakes, and other water bodies.

Planning considerations for wetlands, riparian areas and floodplains will require additional research, detail and specifications. Native grasses are usually required as a condition of a 401 Water Quality Certification or a trout buffer variance.

Native vegetative species are plant species that naturally occur in the region in which they evolved. These plants are adapted to local soil types and climatic variations. Because most native species do not germinate and establish as readily as some introduced species, it is necessary to provide a non-native nurse crop or matting to stabilize the soil until the native crop can become established as the dominant cover. Once established, the native plants will produce an extensive root structure that, if properly maintained, will stabilize soils and reduce erosive forces of rainfall and overland stormwater flow. Many of these plants also possess characteristics that, when established, allow them not only to survive, but also to thrive under local conditions.

Seeding a mixture of perennial native grasses, rushes, and sedges is a way to establish permanent ground cover within wetlands, riparian areas and floodplains. The use of propagated plants is another method of reestablishing natives in these environments. Selecting a seed mixture and/or propagated plants of different species with complimentary characteristics will provide vegetation to fill select niches on sites with varying physical conditions. The design professional should note that because most native species do not germinate and establish as readily as some introduced species, it is necessary to provide a non-native nurse crop or matting to stabilize the soil until the native crop can become established as the dominant cover. For additional information about acceptable nurse crop varieties, consult the planting list in Appendix 8.02, local seed and plant suppliers, the North Carolina Cooperative Extension Service or a qualified design professional to assure the proper selection and plant mix.

Permanent native seed species within the seed mixture should be selected based on natural occurrence of each species in the project site area. Climate, soils, topography, and aspect are major factors affecting the suitability of plants for a particular site and these factors vary widely across North Carolina, with the most significant contrasts occurring among the three major physiographic regions of the state – Mountains, Piedmont, and Coastal Plain. Sub-regions of the state should also be considered. For example, the Triassic Basin in the Piedmont region may have characteristics that call for special soil treatment, limited plant selection, and special maintenance. Even within the riparian area, there may be need for different species depending on site conditions (i.e., dry sandy alluvial floodplains with wet pockets). Therefore, thoughtful planning is required when selecting species for individual sites in order to maximize successful vegetation establishment.

Native seed and plant species are included on the plant list in Appendix 8.02 of this manual.

The design professional should note that regardless of the benefits and advantages of native seeds and plants, there are potential issues if proper planning, installation and maintenance do not occur. These may include:

- Potential for erosion or washout during the establishment stage;
- Seasonal limitation on suitable seeding dates and availability of seed and plants;
- Adaptability of species at specific sites;
- Availability of water and appropriate temperatures during germination and early growth; and
- Lack of maintenance to control invasive plants and undesirable competition.

PLANTING

- **Seed –** Prepare the seed bed as described above in soil preparation. Apply seed at rates specified on the plans, and/or as recommended in Tables 6.11a-c of this manual, with a cyclone seeder, prop type spreader, drill, or hydroseeder on and/or into the prepared bed. Incorporate the seed into the seed bed as specified. Provide finished grades as specified on the approved plan and carefully culti-pack the seedbed as terrain allows. If terrain does not allow for the use of a cultipacker, the approved plans and construction sequence must provide an alternative method of lightly compacting the soil. Mulch immediately.

- **Sprigs and Sod –** Install onto the prepared seed bed per the most current guidance in Carolina Lawns, NCSU Extension Bulletin AG-69, or Practice 6.12 *Sodding*.

- **Woody plants (liners, container, B&B) –** These materials are typically used to complement an herbaceous protective cover. They eventually are major components of long-term, permanent stabilization and should be chosen and planned in conjunction with immediate and long-term maintenance. The plants should be selected and specified by the design professional for each individual project. See Practice 6.13 *Trees, Shrubs, Vines, and Ground Covers.*

MAINTENANCE

The absence of or an incomplete landscape management specification and/or complete maintenance schedule shall constitute grounds for disapproval of the plans. Proper maintenance is critical for the continued stabilization once vegetative cover is established. Although maintenance strategies for different sites may be similar, no two construction sites in North Carolina have been or will be able to be controlled or protected in identical ways. Variations in climate, topography, soils, available moisture, size and many other conditions will dictate the maintenance methodology to be used. A detailed schedule of maintenance will be required on the plans. This schedule will illustrate how the initial planting will be maintained to assure immediate, short term and permanent protection. The schedule will address topics such as appropriate irrigation of plants during the early establishment phase, drought conditions, excessive rainfall, mulch replacement, supplemental seeding, supplemental soils tests, application of nutrients and amendments, control of competitive and invasive species, disease and insect control, and corrective maintenance, measures to address failure of vegetation to become established. Contractual responsibility for maintenance after initial establishment of vegetative cover will be provided on the plans, in the construction sequence and on the bid list for the project. Maintenance bonds and/or warranty guarantee may be required of the responsible party, especially for areas in or adjacent to environmentally sensitive sites such as wetlands, riparian buffers, floodplains, and waters of the State. See Example 6.11a for a sample maintenance specification and a minimum maintenance check list that shall be provided on all plans.

RECOMMENDED BID LIST

(These items should be itemized on documents utilized to obtain pricing for planting pertaining to vegetative stabilization of land disturbing projects in North Carolina.)

- Soil test prior to grading (price per each test).
- Soil test during grading operations (price per each test).
- Soil test at completion of grading and/or prior to seeding, sprigging, sodding and application of fertilizer, lime, and other soil amendments (price per each test).
- Ripping/subsoiling to a depth of six (6) inches. (Provide an alternate for ripping to a depth greater than six (6) inches.) (price per acre)
- Tilling/discing ripped area to a depth of four (4) inches and re-compacting with a cultipacker roller (include in seeding price).

- Seeding (price per square foot).
- Mulching (price per square foot).
- Repair seeding (price per square foot).
- Repair mulching (price per square foot).
- Matting (price per square yard).
- Watering (price per thousand gallons).
- Mowing (price per square foot).

SEEDING RECOMMENDATIONS

The following tables list herbaceous plants recommended for use as nurse crops for immediate stabilization and primary crops for initial and long-term stabilization. Nurse crops are expected to develop in two to five weeks and, with adequate maintenance, be an effective method of soil stabilization for a period of six months to one year. Nurse crops are not effective as primary long-term cover, however if properly maintained they can be an adequate cover and protection for the development of primary crops.

The goal for a primary crop is for it to develop over a three-week to one-year period and be effective up to three years with a well-defined maintenance program. The long-term goal for a primary crop is the initial step toward a sustainable protective cover without the need of maintenance. Where the primary crop is intended for a managed lawn and landscape aesthetics, the effective period can be extended by a more intense maintenance program. Where native species are utilized and become established during the planned maintenance program, a permanent cover that will support future succession species should exist and require little or no additional maintenance or management.

In uses of both nurse and primary crops, the development periods listed on the tables are optimal based on normal climatic conditions for the planting dates listed. The sediment and erosion control maintenance program must recognize that optimum temperatures and rainfall are the exception rather than the rule. The design professional needs to provide flexibility in the stabilization plan to address the potential ranges of temperature and moisture conditions we experience in North Carolina.

Information is provided for seeding rates, optimum planting dates in the state's three regions, sun and shade tolerance, invasive characteristics, compatibility in wetlands and riparian buffers, and installation maintenance considerations. By going through the lists the design professional can select the nurse and primary seed varieties and maintenance characteristics they feel are best suited for their site conditions, vegetation management expertise and maintenance capabilities.

To use the information in the seeding charts the plan preparer must:

- Determine what nurse crop best fits their site, soil conditions, and permanent seed mix.
- Obtain soil tests for all areas to be seeded.
- Know the site's region: mountains, piedmont, or coastal plain.
- Know if the areas to be seeded are sunny, part shade, or full shade.
- Know if the areas are well or poorly drained.
- Know if wetlands or riparian buffers are included in the areas to be seeded.
- Know if a chosen crop is invasive and if so, what potential impacts it will have on the site and adjacent properties.

With this knowledge the plan preparation may proceed utilizing the charts provided to provide the several seed mixes that will be applicable to the different areas requiring stabilization.

HERBACEOUS PLANTS-Seeding recommendations for immediate stabilization/nurse crops

(2 to 5 weeks for development; effectiveness goal: 6 months to 1 year stabilization)

NURSE CROP SPECIES

Common Name	Botanical Name	Native / Introduced	Seeding Rates lbs/acre	Fertilization/ limestone lbs/acre	Optimal Planting Dates: Mountains	Optimal Planting Dates: Piedmont	Optimal Planting Dates: Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Rye Grain	*Secale cereale*	I	40 lbs	By soil test	11/1 - 4/30	8/15 - 4/15	8/15 - 4/15	Sun	Yes	Yes	No	Must be mown to reduce competitiveness with permanent or long term vegetation	
Wheat	*Triticum aestivum*	I	30 lbs	By soil test	11/1 - 4/30	8/15 - 5/15	8/15 - 4/15	Sun	Yes	Yes	No	Must be mown to reduce competitiveness with permanent or long term vegetation	Not water tolerant. May be used in wetlands that are not continuously saturated.
German Millet	*Setaria italica*	I	10 lbs	By soil test	5/11 - 9/30	5/15 - 8/15	4/15 - 8/15	Sun	Yes	Yes	No	Crop should be cut / disc prior to planting primary or long term vegetation	Not water tolerant. May be used in wetlands that are not continuously saturated.
Browntop Millet	*Urochloa ramosa*	I	10 lbs	By soil test	5/11 - 9/30	5/15 - 8/15	4/15 - 8/15	Sun	Yes	Yes	No	Crop should be cut / disc prior to planting primary or long term vegetation	Not water tolerant. May be used in wetlands that are not continuously saturated.
Sudangrass (hybrids)	*Sorghum saccharatum* *S. bicolor ssp.Drummondi*	I	15 lbs	By soil test	NR	NR	4/15 - 8/15	Sun	No	No	Yes	Crop should be cut / disc prior to planting primary or long term vegetation	Use only where plants and seed can be contained and controlled.
Kobe Lespedeza	*Kummerowia striata v. kobe*	I	10 lbs	By soil test	5/1 - 9/1	5/1 - 9/1	5/1 - 9/1	Sun	No	No	No	Consult qualified horticulturalist or extension agent for over-seeding with primary cover	Use in Coastal Plain
Korean Lespedeza	*Kummerowia stipulacea*	I	10 lbs	By soil test	5/1 - 9/1	5/1 - 9/1	5/1 - 9/1	Sun	No	No	No	Consult qualified horticulturalist or extension agent for over-seeding with primary cover	Use in Piedmont and Mountains. May become invasive

NOTES:

1. Seeding rates are for hulled seed unless otherwise noted.
2. Fertilizer & Limestone - rates to be applied in absense of soils tests. Recommended application rate assumes significantly disturbed site soils with little or no residual value.
3. NR means Species not recommended for this region or application area.
4. Invasive designation as determined by the N.C. Exotic Pest Pant Council and N.C. Native Plant Society .
5. Sprigging is not recommended for immediate stabilization unless terrain is flat heavy mulch is applied and no other immediate stabilization method is practical.

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successful development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

NON-NATIVE SPECIES

Table 6.11.b

Common Name	Botanical Name / Cultivar	Native / Introduced	Broadcast Seeding Rates lbs/acre	Fertilization/ limestone lbs/acre	Optimal Planting Dates: Mountains	Optimal Planting Dates: Piedmont	Optimal Planting Dates: Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Sericea Lespedeza	*Lespedeza cuneata Dumont'*	I	15 lbs	By soil test	9/1 - 6/1	9/1 - 5/1	10/1 - 4/1	Sun	NR	NR	Yes	Responds well to controlled burns	Severe Threat Invasive species
Crown Vetch	*Securigera varia (Coronilla varia)*	I	15 lbs	By soil test	3/15-4/30	NR	NR	Sun	NR	NR	Yes	Highly competitive, not recommended unless an acceptable alternative is not available.	Prefers neutral soils
Centipede Grass	*Eremochloa ophiuroi*	I	5 lbs 10 lbs. for road shoulders	By soil test	NR	Eastern only	9/1 - 5/1	Sun	NR	NR	No	Significant maintenance may be required to obtain desired cover	Does not tolerate high traffic. Acceptable for sodding
KY 31 Tall Fescue	*Schedonorus phoeni (Festuca arundinacea)*	I	100 lbs	By soil test	8/15-5/1	9/1-4/15	9/30 - 3/15	Sun / mod. Shade	NR	NR	Yes	If utilized, it is imperative that maintenance includes a containment plan	Acceptable for sodding
KY Blue Grass	*Poa pratensis*	I	15 lbs	By soil test	8/15-5/1	NR	NR	Sun	NR	NR	Yes	If utilized, it is imperative that maintenance includes a containment plan	Prefers neutral soils, highly competitive, not recommended unless an acceptable alternative is not available. Acceptable for sodding
Hard Fescue	*Festuca brevipila (Festuca longifolia)*	I	15 lbs	By soil test	8/1 - 6/1	NR	NR	Shade	NR	NR	No	Not recommended for slopes greater than 5%	Low growing, bunch grass
Bermuda Grass	*Cynodon dactylon*	I	25 lbs	By soil test	NR	4/15-6/30	4/15-6/30	Sun	NR	NR	Yes	If utilized, it is imperative that maintenance includes a containment plan	Extremely aggressive, not recommended and should be avoided unless an acceptable alternative is not available. May be sodded or sprigged

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c

NATIVE SPECIES

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	NR	NR	Sun	NR	Well drained	No	Responds well to	
	Cave-in-Rock									only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*		A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to	
	Blackwell	N								only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to	
	Shelter									only		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	Yes	Yes	No	Responds well to	
	Carthage											controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	No	Poorly	No	Responds well to	
	Kanlow									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Switchgrass	*Panicum virgatum /*	N	A	By soil test	NR	12/1 - 5/1	1/1 - 5/1	Sun	No	Poorly	No	Responds well to	
	Alamo									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well	No	Responds well to	Western coastal plain only
	Rumsey									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	
Indiangrass	*Sorghastrum nutans /*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well	No	Responds well to	Western coastal plain only
	Osage									drained		controlled burns. Mix with	
												3 to 5 other seed varieties	
												that have similar soil	
												drainage adaptations.	

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c (con't)

NATIVE SPECIES

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Indiangrass	*Sorghastrum nutans / Cheyenne*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Western coastal plain only
Indiangrass	*Sorghastrum nutans / Lomenta*	N	B	By soil test	NR	12/1 - 5/1	1/1 -5/1	Sun	NR	Well drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Only Indiangrass adaptable to Eastern coastal plain (Zone 8)
Deertongue	*Dichanthelium clandestinum / Tioga*	N	C	By soil test	5/1-4/15	5/1 - 4/1	NR	Sun & Shade	Yes	Poorly drained to drought	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	
Big Bluestem	*Andropogon gerardii / Rountree*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Big Bluestem	*Andropogon gerardii / Kaw*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Big Bluestem	*Andropogon gerardii / Earl*	N	D	By soil test	12/1-4/15	12/1 - 4/1	12/1-5/1	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Little Bluestem	*Schizachyrium scoparium / Aldous*	N	E	By soil test	12/1-4/15	NR	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Little Bluestem	*Schizachyrium scoparium / Cimmaron*	N	E	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

Successfull development depends on planting date (effectiveness goal: 6 mo. - 3 yrs. without an ongoing maintenance program)

Table 6.11.c (con't)

NATIVE SPECIES

Common Name	Botanical Name / Cultivar	Native / Introduced	See Table 6.11.d for variety seedling rates	Fertilization/ limestone lbs/acre	Optimal Planting Dates: Mountains	Piedmont	Coastal Plains	Sun/Shade tolerant	Wetlands	Riparian Buffers	Invasive Yes or No	Installation / Maintenance Considerations	Other information, commentary
Little Bluestem	*Schizachyrium scoparium / Common*	N	E	By soil test	NR	NR	12/1-4/1	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Sweet Woodreed	*Cinna arundinacea*	N	F	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun & mod. Shade	Yes	Poorly to well drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	Warm season grass
Rice Cutgrass	*Leersia oryzoides*	N	G	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	Yes	Poorly drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	Warm season grass
Indian Woodoats	*Chasmanthium latifolium*	N	H	By soil test	3/1 - 5/15 7/15-8/15	2/15 - 4/1 8/15 - 10/15	2/15-3/20 9/1 - 11/1	Sun & mod. Shade	NR	Well drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	Cool season grass
Virginia Wild Rye	*Elymus virginicus*	N	I	By soil test	3/1 - 5/15 7/15-8/15	2/15 - 4/1 8/15 - 10/15	2/15-3/20 9/1 - 11/1	Sun & mod. Shade	NR	Well drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	Cool season grass
Eastern Bottlebrush Grass	*Elymus hystrix*	N	J	By soil test	3/1 - 5/15 7/15-8/15	2/15 - 4/1 8/15 - 10/15	NR	Sun & mod. Shade	NR	Well drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	Cool season grass
Soft Rush	*Juncus effusus*	N	K	By soil test	12/1 - 5/15 8/15-10/15	12/1 - 5/1 9/1 - 11/1	12/1-4/15	Sun	Yes	Poorly drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	
Shallow Sedge	*Carex lurida*	N	L	By soil test	12/1 - 5/15 8/15-10/15	12/1 - 5/1 9/1 - 11/1	12/1-4/15	Sun	Yes	Poorly drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	
Fox Sedge	*Carex vulpinoidea*	N	L	By soil test	12/1 - 5/15 8/15-10/15	12/1 - 5/1 9/1 - 11/1	12/1-4/15	Sun	Yes	Poorly drained	No	Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations	

NOTE:

1. Seeding rates are for hulled seed unless otherwise noted.
2. Fertilizer & Limestone - rates to be applied in absense of soils tests. Recommended application rate assumes significantly disturbed site soils with little or no residual value.
3. NR means Species not recommended for this region or application area.
4. Native, warm season grasses require six or more months to germinate under optimum conditions. If they are planted in the summer, then a whole year will have to pass before they germinate.
5. Invasive designation as determined by the N.C. Exotic Pest Pant Council and N.C. Native Plant Society .
6. Sprigging is not recommended for immediate stabilization unless terrain is flat, heavymulch is applied and no other immediate stabilization method is practical.
7. Sodding for immediate stabilization - see primary stabilization charts (other information column) and Section 6.12.
8. Long term stabilization can only be accomplished with an adequate, immediate, and primary stabilization program. To achieve long term protective cover with the species listed in this chart, the approved plan, construction sequence and maintenance schedule must include sufficient detail to assure vegetation will be established and maintained. To assure the long term protective cover will be established, the reviewing and approving governing body may require a performance/maintenance bond.

Table 6.11.d

Seed Mixes for Native Species (lbs/ac)
When Mixed with 3, 4, or 5 Other Native Species
(See Table 6.11.a for nurse crop species to be added to these mixes)

	3 Other (total 4 species)	**4 Other (total 5 species)**	**5 Other (total 6 species)**
Switch Grasses (A)	3.5 lbs.	3.0 lbs.	2.5 lbs.
Indian Grasses (B)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Deertongue (C)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Big Bluestem (D)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Little Bluestem (E)	7.0 lbs.	6.0 lbs.	5.0 lbs.
Sweet Woodreed (F)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Rice Cutgrass (G)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Indian Woodoats (H)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Virginia Wild Rye (I)	6.0 lbs.	5.0 lbs.	4.0 lbs.
Eastern Bottlebrush Grass (J)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Soft Rush (K)	2.5 lbs.	2.0 lbs.	1.5 lbs.
Sedges (L)	2.5 lbs.	2.0 lbs.	1.5 lbs.

NOTE:
With the native varieties, the seed mix should be in the range of 15 pounds per acre. Depending on availability of native seeds adaptable to North Carolina, the percentage of a particular variety used may be reduced or increased accordingly. Although diversity is desirable, it is imperative that the primary crop develop and become an effective protective cover. In addition to the native species mix, additional nurse crop species must be included to provide immediate stabilization and an adequate ground cover.

Example 6.11.a GUIDELINES FOR WRITING MINIMUM LANDSCAPE MANAGEMENT SPECIFICATIONS

Following is an outline that demonstrates what should be included in specifications that will insure the long term stabilization of disturbed sites in North Carolina. As noted before in this manual, each construction site in the state is unique and has features that will require special provisions for revegetation and stabilization. The outline provided below cannot address these individual sites. It is the responsibility of the design professional and the financially responsible party to see that the specifications are edited to fit their site and to assure that permanent stabilization is achieved.

General Provisions

A. Intent:

1. These specifications are prepared with the intent of promoting outstanding performance in long-term stabilization. They are to be used as guidelines in establishing sediment control and vegetative standards for the sites. Final technical decisions such as herbicides, fertilizer ratios, times of application and schedules are to be determined by the Contractor, who has the responsibility to obtain soil test and to manage the vegetation to achieve the desired results. The maintenance specifications must address maintenance for sediment and erosion control vegetation during construction and for permanent/long-term stabilization.

B. Description of Work:

1. Perform all work necessary and required for the (insert period of contract) maintenance of the project as indicated on the drawings, in the project manual, and specified herein.

2. Licensing:

a) Contractor shall provide verification of current, applicable pesticide applicator licensing for each applicator that will handle pesticides on the contracted sites.

3. Contract Administration

a) Staffing: The Contractor shall provide adequate staffing, with the appropriate expertise, to perform all required work.

b) Monthly Site Review meetings will be held. Attendees will include the Contractor's Project Manager and Site Foreman and the property manager or other representative designated by the financially responsible party. Result of site reviews will be documented and circulated to the attendees and the owner by the contractor.

c) The Contractor will communicate with the proper person on a monthly basis to summarize work performed and immediately notify the project manager of any failure of the site to remain stabilized.

II. Materials

A. Soil Additives: Additives are to be applied per soils test taken prior to, during and after construction. **(Use this section to provide the types and quantities of fertilizers, lime, and other soil amendments called for in the soils report. Include all soils test reports in the specifications document. This narrative or list should include quantities, rates, mixes, organic information, manufacturer, sources, and other information suggested in the soils test.)**

A. Pesticides:

1. Establish an Integrated Pest Management (IPM) program for the site that relies on targeted insect and disease control coupled with sound stabilization management and water management practices.

2. These specifications do not include pesticide treatments for infestations of Southern Pine Beetle, Gypsy Moth, or Fire Ants. The contractor shall notify the Owner if these pests are observed on site.

3. All pesticides shall be applied by a North Carolina licensed applicator in accordance with all State and Federal regulations and per manufacturer's recommendations.

B. Mulches: Mulch for areas not subject to erosion and over wash by storm water should be called out in this section addressing its maintenance, replacement, removal and conversion to other uses. Those subject to erosion and over wash by storm water must be addressed on the plans and in the calculations.

III. Execution

A. General:

1. Good long term stabilization is based on the proper maintenance, management and balance of nutrients, soil moisture and general cultural practices. It is recognized that fewer fungicide and pesticide treatments as well as lower fertility rates are required with a well managed, balanced landscape. The following section is meant to promote this balance and therefore do not highlight specific quantitative standards. **(Quantitative standards should be addressed as site specific by the design professional in conjunction with the owner and contractor.)** Calendar references are general and are to be used only as a guide. Weather and soil conditions that are most appropriate for a given process, procedure and/or area of the state shall be the determining factor in scheduling work.

B. Soil Tests:

1. After the soil test prior to stabilization, tests shall be made yearly in the fall to determine the required soil additives for all stabilized areas. If known nitrogen requirements are not specified by previous test, they need to be determined by the subsequent soils test and the proper applications made. Fertilizer ratios may be determined through analysis of the soil tests coupled with the contractor's experience and knowledge of the site.

C. Mowing

1. Mowing for maintained turf/lawns

a. Mow areas intended for "groomed appearance" on a schedule during the growing season and as required throughout the year to provide the desired appearance. **(Establish a mowing frequency here that addresses the specific plant species used and their growing habits.)** This frequency will be a minimum standard. Particular properties and their peculiar characteristics as well as individual plant species may require mowing more often than the stated minimum may be required. This should be noted in this section.

b. The range of turf species suggested for lawns in the three growing regions of North Carolina vary as to optimum maintained height. The selected species should be maintained at a height recommended by the seed producer. Do not cut too short and do not allow the turf to attain a height that will cause the crop to decline or die. Consult individual seed producers and/or packaging for recommended mowing heights.

c. Mow with a mulching mower to limit the amount of clippings removed, or mow and blow in such a manner that clippings are not evident and not to adversely effect the growing capacity and/or health of the existing vegetation turf. It is important clippings are allowed to remain spread throughout the lawn area, to the extent possible, so that they might aid in building a more productive soil profile and root zone.

2. Mowing other stabilized areas to promote continued growth. Include mowing specification here for other stabilized areas which require maintenance but not a "groomed" appearance. Also include specifications for mowing areas where it is desirable for woody native volunteer vegetation to become established. This should include attention to mowing stakes or other way of protecting the desired woody natives from the mowing operation.

D. Watering

1. Irrigation System Maintenance and Monitoring: If stabilized areas are to be irrigated the design professional should include specifications for the system, its maintenance and its operation in this section.

2. In the absence of an automatic or manual irrigation system, provisions for providing adequate water to stabilized areas should be addressed in this section.

3. **(Provisions should be made in this section for adjustments to application rates of water during times of regulated droughts and/or periods of excessive rainfall.)**

E. CONTROL OF INVASIVES: Competition from invasive species can be detrimental to the establishment of the permanent vegetative cover. Left unchecked, these invasives can undermine a revegetation process in a short period of time and eventually lead to unprotected soil and sediment damage. Make site observations monthly to check for the presence of such species and, if found, treat them immediately with the appropriate cultural practices and/or by the use of seasonally-appropriate and site appropriate herbicides.

F. Maintenance items including fertilization, mowing, continued soils testing, repair, mulching, matting and soil preparation are to be addressed in the approved construction sequence and on the project bid list.

6.13

TREES, SHRUBS, VINES, AND GROUND COVERS

GC

Definition

Stabilizing disturbed areas by establishing a vegetative cover of trees, shrubs, vines, or ground covers.

Purpose

To stabilize the soil with vegetation other than grasses or legumes, to provide food and shelter for wildlife, and to provide windbreaks or screens.

Conditions Where Practice Applies

Trees, shrubs, vines, and ground covers may be used on steep or rocky slopes where mowing is not feasible; as ornamentals for landscaping purposes; or in shaded areas where grass establishment is difficult.

Planning Considerations

Woody plants and ground covers provide alternatives to grasses and legumes as low-maintenance, long-term erosion control. However, they are normally planted only for special, high-value applications, or for aesthetic reasons because there is additional cost and labor associated with their use.

Very few of these plants can be dependably planted from seed, and none of them are capable of providing the rapid cover possible with grasses. Trees and shrubs in particular require a long time to produce cover adequate to control erosion. Consequently, efforts must first focus on short-term stabilization using densely-growing herbaceous species or a dependable mulch.

There are many different species of woody plants and ground covers from which to choose. Most are not as broadly adapted as herbaceous species, and care must be taken in their selection. It is essential to select planting material suited to both the intended use and site. Specific characteristics and requirements of recommended species are given in *Appendix 8.02* as an aid to their selection.

The large selection of available plant material makes it impractical to give planting specifications for even the most common species. Instead, general planting guidelines are given here.

ZONES OF ADAPTATION

Zones of climatic adaptation of landscape plants are referred to as "Plant Hardiness Zones" (Figure 6.13a). North Carolina encompasses portions of zones 6, 7, 8, and 9, but most of the State falls into zones 7 and 8. Most of the plants listed in Table 8.02b (*Appendix 8.02*) are climatically adapted throughout the state. Plant selection is most limited for high elevations in the Mountains and the extreme northwest corner of the state (zone 6).

TREES

Although trees are among the best soil stabilizers, years are required for the development of forest cover adequate to meet sedimentation control objectives. Efforts must first focus on establishing densely-growing species to stabilize the site and protect the area between immature trees.

For areas in which tree or shrub plantings are planned, initial seedings of grasses and legumes may need to be altered somewhat to reduce competition with the woody species. Unless the site is highly erodible, seeding rates may

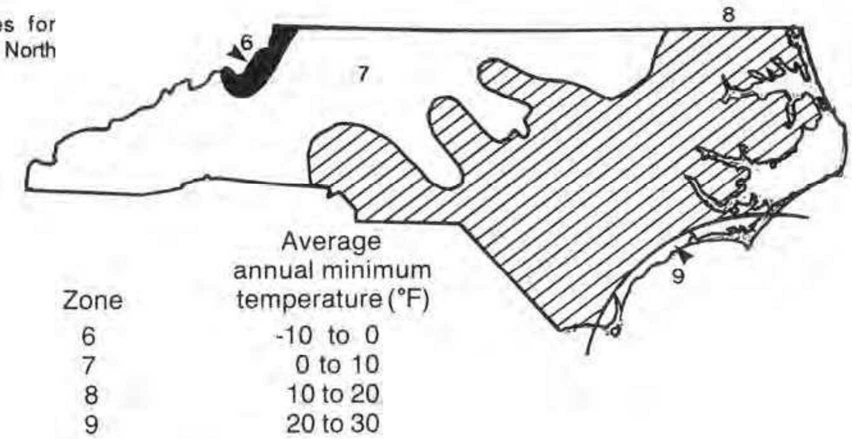


Figure 6.13a Plant hardiness zones for woody plants and ground covers in North Carolina.

be reduced, or competitive species may be omitted. Species such as tall fescue, which produce vigorous early growth, are highly competitive. Annual lespedezas, which start growing relatively late in the spring, are much less competitive with tree seedlings. On highly erodible sites the addition of a low seeding rate of weeping lovegrass may be effective.

Two alternative approaches to establishing tree cover on disturbed sites are: (1) planting seedlings of the desired species, usually at the earliest suitable date, or (2) allowing natural invasion by native species. Most unmowed sites in North Carolina will be colonized, usually within a few years, by pine species dominant in the locality.

Planting speeds tree establishment, ensures adequate stands, and allows selection of species composition. Where forest production is the objective, planting is preferable to natural invasion. Where invasion is acceptable, tree planting is not necessary if there is a seed source near the site.

Black locust is the only tree useful for conservation and revegetation that is readily established by adding seeds to the initial seeding mixture (Practice 6.11, *Permanent Seeding*, Table 6.11i). It is only adapted to the Mountain region where it is recommended for particularly erodible sites.

Black locust grows rapidly, and is tolerant of shallow, dry, infertile soils. Being a legume, it contributes nitrogen and nutrient-rich litter to the soil, thereby preparing the way for succession by more valuable hardwoods. It has other characteristics that also foster successional development; it is fairly short-lived, intolerant of shade, and unable to regenerate under its own or other tree canopies.

Seeded stands of black locust can be almost impenetrable for 6-8 years. The trees are thorny, and can be hazardous to people and equipment. At the same time they provide effective protection from traffic—a highly beneficial function on fragile sites.

SHRUBS

Shrubs vary in form from small trees to sprawling, woody ground covers. They differ from most trees in that several small trunks arise from a common base.

As a supplement to herbaceous, plantings shrubs can be used to:

- increase the aesthetic value of plantings,
- provide screening,
- enhance windbreaks,
- provide food and cover for wildlife,
- accelerate the transition to a diverse landscape, and
- provide post-construction landscaping.

GROUND COVERS

As used by landscapers, “ground cover” refers to low-growing, herbaceous or woody plants that spread vegetatively to produce a dense, continuous cover. They are used in landscape plantings, or as an alternative to turf. Typically only a few ornamental grasses are included in this category. Many ground covers, such as English ivy, are vines that spread along the ground but also climb on buildings, fences, or other vegetation.

Ground covers differ in growth form, growth rate, and shade tolerance. They may be evergreen or deciduous. Some are suitable only as part of a high-maintenance landscape; others can be used to stabilize large areas with little maintenance.

In addition to stabilizing disturbed soil, vines and ground covers perform the following functions:

- They maintain cover in heavily shaded areas where turf will not thrive.
- They provide attractive cover that does not need mowing.
- They restrict pedestrian traffic (people are likely to avoid walking through a thick bed of ivy or a planting of juniper).

Specifications

Areas planted to shrubs or trees must also be covered with a suitable mulch, or seeded to permanent vegetation, to protect the site until the woody plants become established. Refer to Practices 6.11, *Permanent Seeding*, and 6.14, *Mulching*, to select methods for stabilizing these areas. Do not use plants that will shade-out the woody seedlings. A circle of mulch around seedlings helps them compete with herbaceous plants.

TREES

Sources—Trees can be dug on-site with a tree spade, or purchased from a nursery. Large trees come with their roots and the attached soil wrapped in burlap, and small trees and shrubs are sold in plastic containers or as bare-root stock. The soil ball of containerized and burlapped trees should be 12 inches in diameter for each inch of trunk diameter.

Black locust is a tree that can be readily established by seed. It is an excellent tree for stabilization purposes, but is only adapted to the Mountain region. Seeds can be included in the initial seeding mixture (Practice 6.11, *Permanent Seeding*, Table 6.11i).

Planting bare-root tree seedlings—Bare-root seedlings should be handled only while dormant in late winter, early spring, or after leaf fall in autumn. Availability of stock usually limits planting to winter or spring. Store packages of seedlings in a shaded location out of the wind. If it is necessary to store moss-packed seedlings for more than two weeks, add one pint of water per package. Do not add water to clay-treated seedlings.

Do not allow roots to dry out during planting by carrying seedlings exposed to air and sun. Keep moss-packed seedlings in a container packed with wet moss or filled with thick muddy water. Cover clay-treated seedlings with wet burlap.

A method for hand planting bare-root seedlings is illustrated in Figure 6.13b. With a tree planting bar or spade, make a notch deep enough to accommodate the roots. Place the roots in the notch to the same depth as in the nursery, then firm soil around roots by pressing the notch closed. Water immediately and mulch the area within 2 ft of the plant. Several weeks after planting, broadcast a handful of 10-10-10 fertilizer around each plant, at least 1 ft from the base.

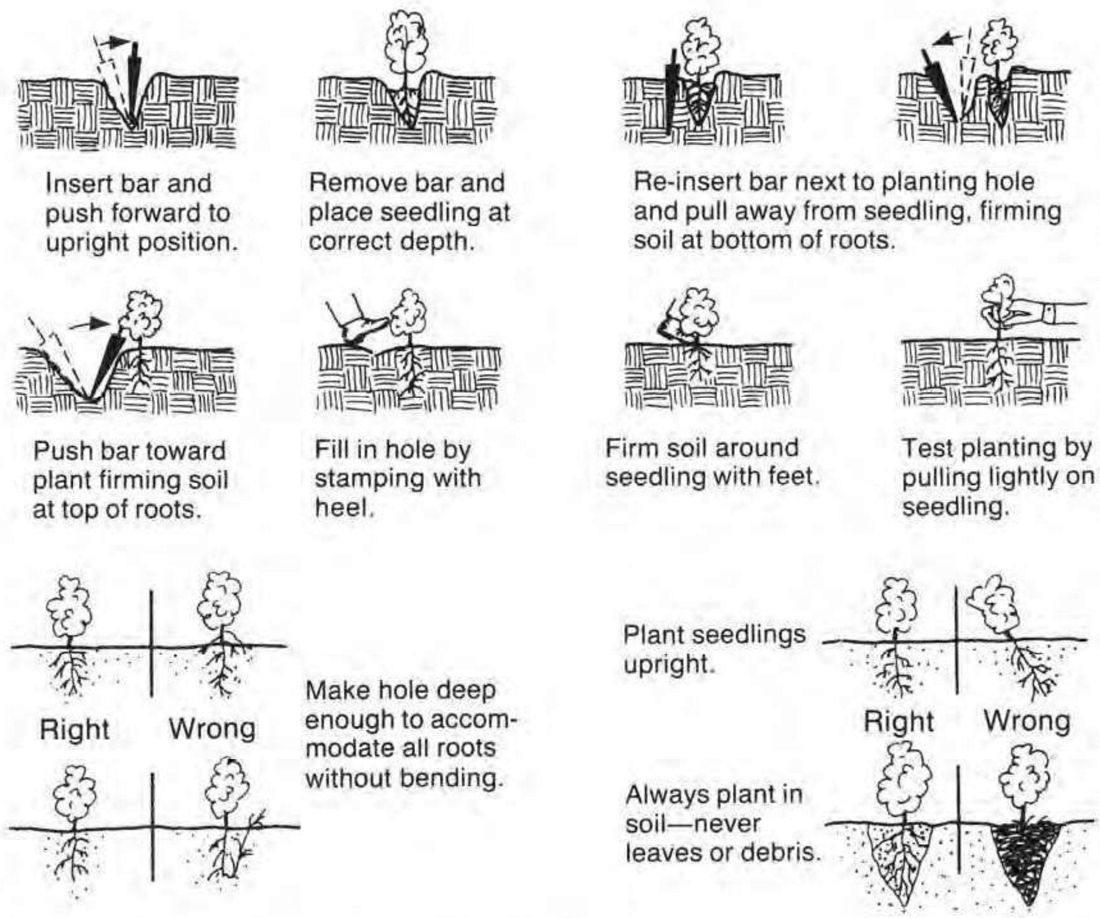


Figure 6.13b Planting bare-root seedlings (modified from Va. Div. of Forestry).

On large sites where slopes are not prohibitive, bare-root seedlings can be efficiently planted in furrows using a tractor-drawn vegetable transplanter.

Planting balled-and-burlapped or container-grown trees—(Figure 6.13c). Late fall (Nov. - Dec.) is the preferred planting time for deciduous trees and evergreens, although they may be planted year-round. Avoid summer planting.

Keep the soil around the roots moist until planting. Branches should be bound with soft rope to prevent damage during transport.

Each planting hole must be deep and wide enough to allow proper placement of the root ball. Ideally, the hole should be twice the size of the root ball. When digging the hole, keep topsoil separate from subsoil. If the subsoil is high in clay, allow extra room (one-half again the height of the root ball). Backfill the hole with enough topsoil or peat moss to position the base of the tree at the same level as in the nursery.

If the plant is in a container, carefully remove it, taking the soil surrounding the roots with it. This may require cutting the container. Loosen the twine and burlap at the top of balled-and-burlapped plants, and check to make sure that no other wrapping is present before planting.

Before replacing subsoil, mix it with one-third peat moss or well-rotted manure. Backfill the hole, firming the soil as it is replaced, and leave a depression around the trunk within the excavated area to hold water. Cover the base of the trunk to the same level as before it was removed (Figure 6.13c). Water thoroughly, and rewater as necessary to keep the roots moist.

Stake small trees with vertical stakes driven into the ground, just beyond the root ball (Figure 6.13c). Secure large trees with guy wires. Cushion wire, where it contacts the tree, with rubber hose. Wrap the trunks of young trees to protect them from sunburn and pests.

Fertilize trees in late fall or early spring, **before leaves emerge**. Using a punchbar, crowbar, or auger, make holes 18 inches deep and about 2 ft apart around the drip line of each tree. Distribute the fertilizer evenly among the holes to bring it in contact with tree roots, and close.

SHRUBS

Selecting shrubs—The best shrubs for erosion control have characteristics such as fast growth, ease of establishment, large lateral spread or prostrate growth, year-round foliage (evergreens), disease and insect resistance, ability of the roots to fix nitrogen, and adaptation to a broad range of soil conditions. Selections should be based on a specific site and purpose.

Many different species and varieties of shrubs are available that grow well in North Carolina. Those described in Table 8.02b (*Appendix 8.02*) are generally available, and are useful for stabilization and erosion control. In most situations it will not be necessary to look further than this listing. For very specific uses consult local nurserymen or the State Extension Horticulturist.

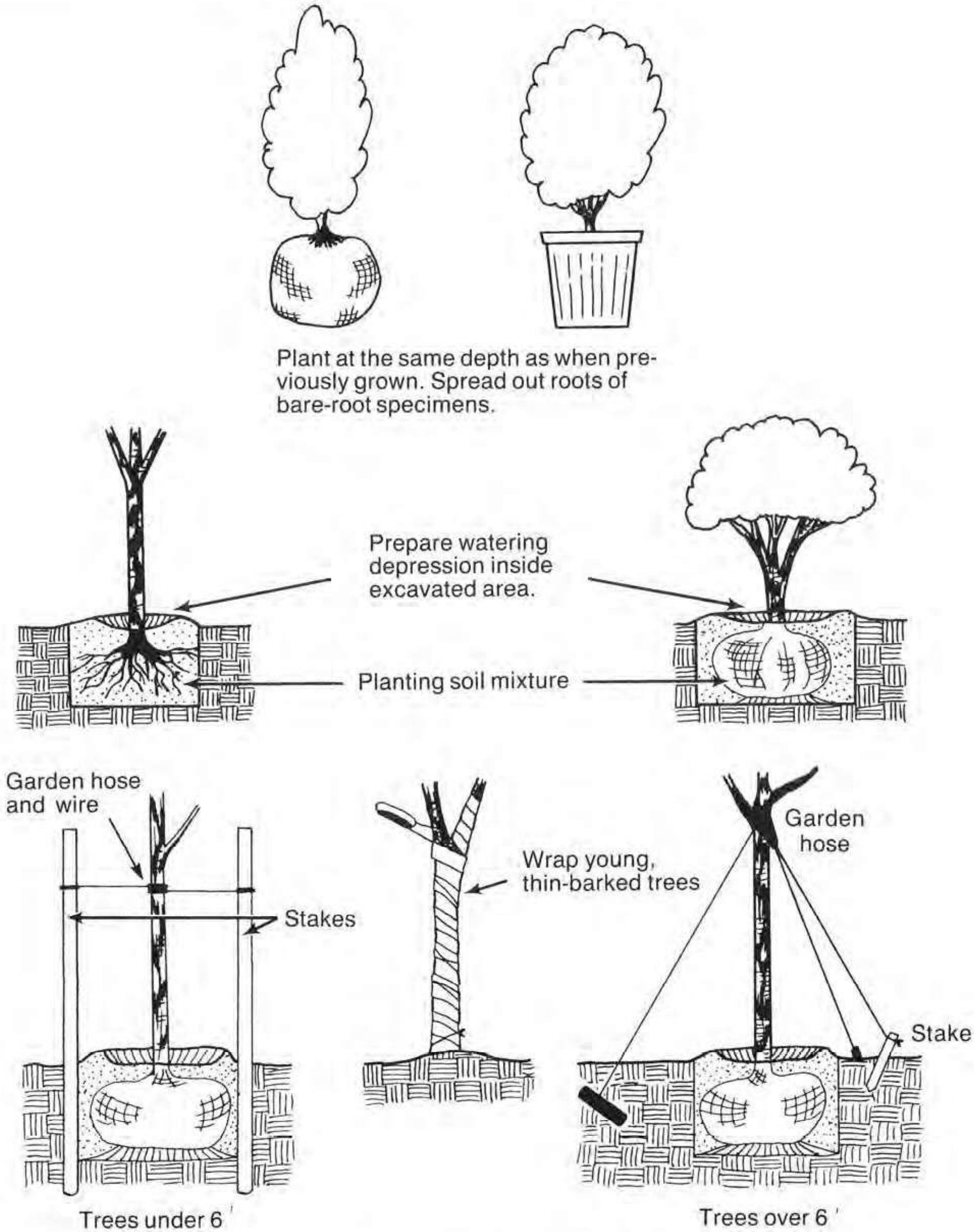


Figure 6.13c Planting balled-and-burlapped and container-grown trees (modified from Va. Div. of Forestry).

Obtaining shrubs—Shrubs are normally planted as bare-root stock or container-grown plants. Container-grown seedlings, 1 year old, are usually recommended for their ease of planting and cost.

Planting is best done in early fall or early spring. Follow the general procedures for tree care and planting (Figures 6.13b and c).

Maintenance requirements depend on the particular shrub. In all cases watering is important in getting plants established. Once established, fertilizing every 3 years is generally sufficient. A heavy layer of mulch around the base of each plant reduces weeds and retains moisture. Mulch may consist of woodchips, sawdust pine needles, or straw.

VINES AND GROUND COVERS

Selecting plants—For most stabilization purposes, fast-growing, evergreen, low-maintenance ground covers are preferable. Some pertinent characteristics that should help in selecting appropriate ground covers are given in Table 8.02b *(Appendix 8.02)*.

When to plant—Ground covers are best planted in early fall or early spring. Spring planting is preferred in the mountains.

Site preparation—Good soil is important in establishing ground covers because their dense growth requires large amounts of nutrients and water. Well-drained soils high in organic matter work best. When possible, apply organic matter in the form of peat, sawdust, or well-rotted manure, and incorporate to 4-6 inches.

Add lime and fertilizer according to soil tests, or add 100 lb/1,000 ft^2 ground agricultural limestone, and 50 lb/1,000 ft^2 of 10-10-10 fertilizer and incorporate into the top 4-6 inches of soil. Add organic matter in an amount up to one-third the total soil volume, either over the whole area (layer 2 inches deep mixed into the top 6 inches) or in each planting hole if the area is large.

On steep slopes, till the soil in contour rows, or dig single holes for each plant. Blend the needed lime, fertilizer, and organic material with the soil removed from each hole or furrow. Mix fertilizer thoroughly with the soil before planting, and use it sparingly to avoid burning roots.

To eliminate harmful competition from weeds, a pre-emergent herbicide may be useful if weeding is not practical.

Planting—Most ground covers are planted from container-grown nursery stock. Planting density determines how quickly full cover is achieved; a 1-foot spacing is often suggested for rapid cover. Large plants such as junipers can be spaced on 3-feet centers.

Transplanting to the prepared seedbed can be done using a small trowel or a spade. Make a hole large enough to accommodate the roots and soil. Backfill and firm the soil around the plant, water immediately, and keep well watered until established.

Mulching—Competition from volunteer plants inhibits development and maintenance of the ground cover. A thick durable mulch such as shredded bark or wood chips should prevent erosion and reduce weeds. Mulch the entire planting area.

On steep slopes (3:1) or highly erodible soils, install netting or matting prior to planting, and tuck plants into the soil through slits in the net. Plant in a staggered pattern.

Maintenance—Most ground covers need yearly trimming to promote growth. Trim back from trees, flower beds, fences, and buildings. Add mulch where needed and fertilize, as described above, every 3-4 years.

References

Site Preparation
6.04, Topsoiling

Surface Stabilization
6.11, Permanent Seeding
6.14, Mulching

Appendix
8.02, Vegetation Tables

6.14

MULCHING

M

Definition

Application of a protective blanket of straw or other plant residue, gravel, or synthetic material to the soil 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, and suppresses weed growth. Mulch is frequently used to accent landscape plantings.

Conditions Where Practice Applies

Mulch temporary or permanent seedings immediately. Areas that cannot be seeded because of the season should be mulched to provide temporary protection of the soil surface. Use an organic mulch in this case (but not wood fiber), and seed the area as soon as possible. Mulch around plantings of trees, shrubs, or ground covers to stabilize the soil between plants.

Planning Considerations

A surface mulch is the most effective, practical means of controlling runoff and erosion on disturbed land prior to vegetation establishment. Mulch reduces soil moisture loss by evaporation, prevents crusting and sealing of the soil surface, moderates soil temperatures, provides a suitable microclimate for seed germination, and may increase the infiltration rate of the soil.

Organic mulches such as straw, wood chips, and shredded bark have been found to be the most effective. Do not use materials which may be sources of competing weed and grass seeds. Decomposition of some wood products can tie up significant amounts of soil nitrogen, making it necessary to modify fertilization rates, or add fertilizer with the mulch (Table 6.14a).

A variety of mats and fabrics have been developed in recent years for use as mulch, particularly in critical areas such as waterways and channels. Various types of netting materials are also available to anchor organic mulches.

Chemical soil stabilizers or soil binders, when used alone, are less effective than other types of mulches. These products are primarily useful for tacking wood fiber mulches.

The choice of materials for mulching should be based on soil conditions, season, type of vegetation, and size of the area. A properly applied and tacked mulch is always beneficial. It is especially important when conditions for germination are not optimum, such as midsummer and early winter, and on difficult areas such as cut slopes and slopes with southern exposures.

ORGANIC MULCHES

Straw is the mulch most commonly used in conjunction with seeding. The straw should come from wheat or oats ("small grains"), and may be spread by hand or with a mulch blower. Straw may be lost to wind, and must be tacked down.

Wood chips are suitable for areas that will not be closely mowed, and around ornamental plantings. Chips do not require tacking. Because they decompose slowly, they must be treated with 12 pounds of nitrogen per ton to prevent

Table 6.14a
Mulching Materials and Application Rates

Material	Rate Per Acre	Quality	Notes
Organic Mulches			
Straw	1-2 tons	Dry, unchopped, unweathered; avoid weeds.	Should come from wheat or oats; spread by hand or machine; must be tacked down.
Wood chips	5-6 tons	Air dry	Treat with 12 lbs nitrogen/ton. Apply with mulch blower, chip handler, or by hand. Not for use in fine turf.
Wood fiber	0.5-1 tons		Also referred to as wood cellulose. May be hydroseeded. Do not use in hot, dry weather.
Bark	35 cubic yards	Air dry, shredded or hammer-milled, or chips.	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.
Corn stalks	4-6 tons	Cut or shredded in 4-6 in. lengths.	Apply with mulch blower or by hand. Not for use in fine turf.
Sericea lespedeza seed-bearing stems	1-3 tons	Green or dry; should contain mature seed.	
Nets and Mats[1]			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn.	Withstands waterflow. Best when used with organic mulch.
Fiberglass net	Cover area		Withstands waterflow. Best when used with organic mulch.
Excelsior (wood fiber) mat	Cover area		Withstands waterflow.
Fiberglass roving	0.5-1 tons	Continuous fibers of drawn glass bound together with a non-toxic agent.	Apply with a compressed air ejector. Tack with emulsified asphalt at a rate of 25-35 gal/1,000 sq ft.
Chemical Stabilizers[2]			
Aquatain Aerospray Curasol AK Petroset SB Terra Tack Crust 500 Genaqua 743 M-145	follow manufacturer's specifications		Not beneficial to plant growth.

[1]Refer to Practice No. 6.30, *Grass Lined Channels.*

[2]Use of trade names does not imply endorsement of product.

nutrient deficiency in plants. This can be an inexpensive mulch if chips are obtained from trees cleared on the site.

Bark chips and shredded bark are by-products of timber processing often used in landscape plantings. Bark is also a suitable mulch for areas planted to grasses and not closely mowed. It may be applied by hand or with a mulch blower. Unlike wood chips, the use of bark does not require additional nitrogen fertilizer.

Wood fiber refers to short cellulose fibers applied as a slurry in hydroseeding operations. Wood fiber does not require tacking, although tacking agents or soil binders can easily be added to the slurry. Wood fiber hydroseeder slurries may be used to tack straw mulch on steep slopes, critical areas, and where harsh climatic conditions exist. **Wood fiber mulch does not provide sufficient erosion protection to be used alone**.

There are other organic materials that make excellent mulches, but may only be available locally or seasonally, for example: dried sewage sludge, corn stalks, animal manure, pine boughs, cotton burs, peanut hulls, and hay. Creative use of these materials can reduce costs.

CHEMICAL MULCHES AND SOIL BINDERS

A wide range of synthetic mulching compounds is available to stabilize and protect the soil surface. These include emulsions or dispersions of vinyl compounds, asphalt, or rubber mixed with water. They may be used alone, or may be used to tack wood fiber hydromulches.

When used alone, chemical mulches do not insulate the soil or retain moisture, and therefore do little to aid seedling establishment. They are easily damaged by traffic, are usually more expensive than organic mulches, and they decompose in 60-90 days.

Check labels on chemical mulches and binders for environmental concerns. Take precautions to avoid damage to fish, wildlife, and water resources.

NETS, MATS, AND ROVING

Netting is very effective in holding mulch in place on waterways and slopes before grasses become established.

Mats promote seedling growth in the same way as organic mulches. They are very useful in establishing grass in channels and waterways. A wide variety of synthetic and organic materials are available. “Excelsior” is a wood fiber mat, and should not be confused with wood fiber slurry.

When installing nets and mats, it is critical to obtain a firm, continuous contact between the material and the soil. Without such contact, the material is useless, and erosion will occur underneath.

Fiberglass roving consists of continuous strands of fiberglass which, when blown onto the soil surface from a special compressed air ejector, form a mat of glass fibers. This mat must then be tacked down with asphalt.

Construction Specifications

Select a material based on site and practice requirements, availability of material, labor, and equipment. Table 6.14a lists commonly used mulches and some alternatives.

Before mulching, complete the required grading, install sediment control practices, and prepare the seedbed. Apply seed before mulching **except** in the following cases:

- Seed is applied as part of a hydroseeder slurry containing wood fiber mulch.
- A hydroseeder slurry is applied over straw.

APPLICATION OF ORGANIC MULCH

Organic mulches are effective where they can be tacked securely to the surface. Material and specifications are given in Table 6.14a.

Spread mulch uniformly by hand, or with a mulch blower. When spreading straw mulch by hand, divide the area to be mulched into sections of approximately 1,000 ft^2, and place 70-90 lb of straw (1 1/2 to 2 bales) in each section to facilitate uniform distribution. After spreading mulch, no more than 25% of the ground surface should be visible. In hydroseeding operations a green dye, added to the slurry, assures a uniform application.

ANCHORING ORGANIC MULCH

Straw mulch must be anchored immediately after spreading. The following methods of anchoring mulch may be used:

Mulch anchoring tool—A tractor-drawn implement designed to punch mulch into the soil, a mulch anchoring tool provides maximum erosion control with straw. A regular farm disk, weighted and set nearly straight, may substitute, but will not do a job comparable to the mulch anchoring tool. The disk should not be sharp enough to cut the straw. These methods are limited to slopes no steeper than 3:1, where equipment can operate safely. Operate machinery on the contour.

Liquid mulch binders—Application of liquid mulch binders and tackifiers should be heaviest at the edges of areas and at crests of ridges and banks, to resist wind. Binder should be applied uniformly to the rest of the area. Binders may be applied after mulch is spread, or may be sprayed into the mulch as it is being blown onto the soil. Applying straw and binder together is the most effective method. Liquid binders include asphalt and an array of commercially available synthetic binders.

Emulsified asphalt is the most commonly used mulch binder. Any type thin enough to be blown from spray equipment is satisfactory. Asphalt is classified according to the time it takes to cure. Rapid setting (RS or CRS designation) is formulated for curing in less than 24 hours, even during periods of high humidity; it is best used in spring and fall. Medium setting (MS or CMS) is formulated for curing within 24 to 48 hours, and slow setting (SS or CSS) is formulated for use during hot, dry weather, requiring 48 hours or more curing time.

Apply asphalt at 0.10 gallons per square yard (10 gal/1,000 ft^2). Heavier applications cause straw to "perch" over rills.

In traffic areas, uncured asphalt can be picked up on shoes and cause damage to rugs, clothing etc. Use types RS or CRS to minimize such problems.

Synthetic binders such as Petroset, Terratack, and Aerospray may be used, as recommended by the manufacturer, to anchor mulch. These are expensive, and therefore usually used in small areas or in residential areas where asphalt may be a problem (Use of trade names does not constitute an endorsement).

Mulch nettings—Lightweight plastic, cotton, jute, wire, or paper nets may be stapled over the mulch according to the manufacturer's recommendations (see "Nets and Mats" below).

Peg and twine—Because it is labor-intensive, this method is feasible only in small areas where other methods cannot be used. Drive 8-10 inch wooden pegs to within 3 inches of the soil surface, every 4 feet in all directions. Stakes may be driven before or after straw is spread. Secure mulch by stretching twine between pegs in a criss-cross-within-a-square pattern. Turn twine two or more times around each peg. Twine may be tightened over the mulch by driving pegs further into the ground.

Vegetation—Rye (grain) may be used to anchor mulch in fall plantings, and German millet in spring. Broadcast at 15 lb/acre before applying mulch.

CHEMICAL MULCHES

Chemical mulches may be effective for soil stabilization if used between May 1 and June 15, or Sept. 15 and Oct. 15, provided that they are used on slopes **no steeper** than 4:1, and that proper seedbed preparation has been accomplished, including surface roughening where required.

Chemical mulches may be used to bind other mulches, or with wood fiber in a hydroseeded slurry at any time. Follow the manufacturer's recommendations for application.

FIBERGLASS ROVING

Fiberglass roving ("roving") is wound into a cylindrical package so that it can be continuously withdrawn from the center using a compressed air ejector. Roving expands into a mat of glass fibers as it contacts the soil surface. It is often used over a straw mulch, but must still be tacked with asphalt.

Spread roving uniformly over the area at a rate of 0.25 to 0.35 lb/yd^2. Anchor with asphalt immediately after application, at a rate of 0.25 to 0.35 gal/yd^2.

As a channel lining, and at other sites of concentrated flow, the roving mat must be further anchored to prevent undermining. It may be secured with stakes placed at intervals no greater than 10 feet along the drainageway, and randomly throughout its width, but not more than 10 feet apart. As an option to staking, the roving can be buried to a depth of 5 inches at the upgrade end and at intervals of 50 feet along the length of the channel.

NETS AND MATS

Nets alone generally provide little moisture conservation benefits and only limited erosion protection. Therefore, they are usually used in conjunction with an organic mulch such as straw.

Except when wood fiber slurry is used, netting should always be installed **over** the mulch. Wood fiber may be sprayed on top of an installed net.

Mats, including "excelsior" (wood fiber) blankets, are considered protective mulches and may be used alone, on erodible soils, and during all times of the year. Place the matting in firm contact with the soil, and staple securely.

INSTALLATION OF NETTING AND MATTING

Products designed to control erosion should be installed in accordance with manufacturer's instructions. Any mat or blanket-type product used as a protective mulch should provide cover of at least 30% of the surface where it is applied. Installation is illustrated in Figure 6.14a.

1. Apply lime, fertilizer, and seed **before** laying the net or mat.

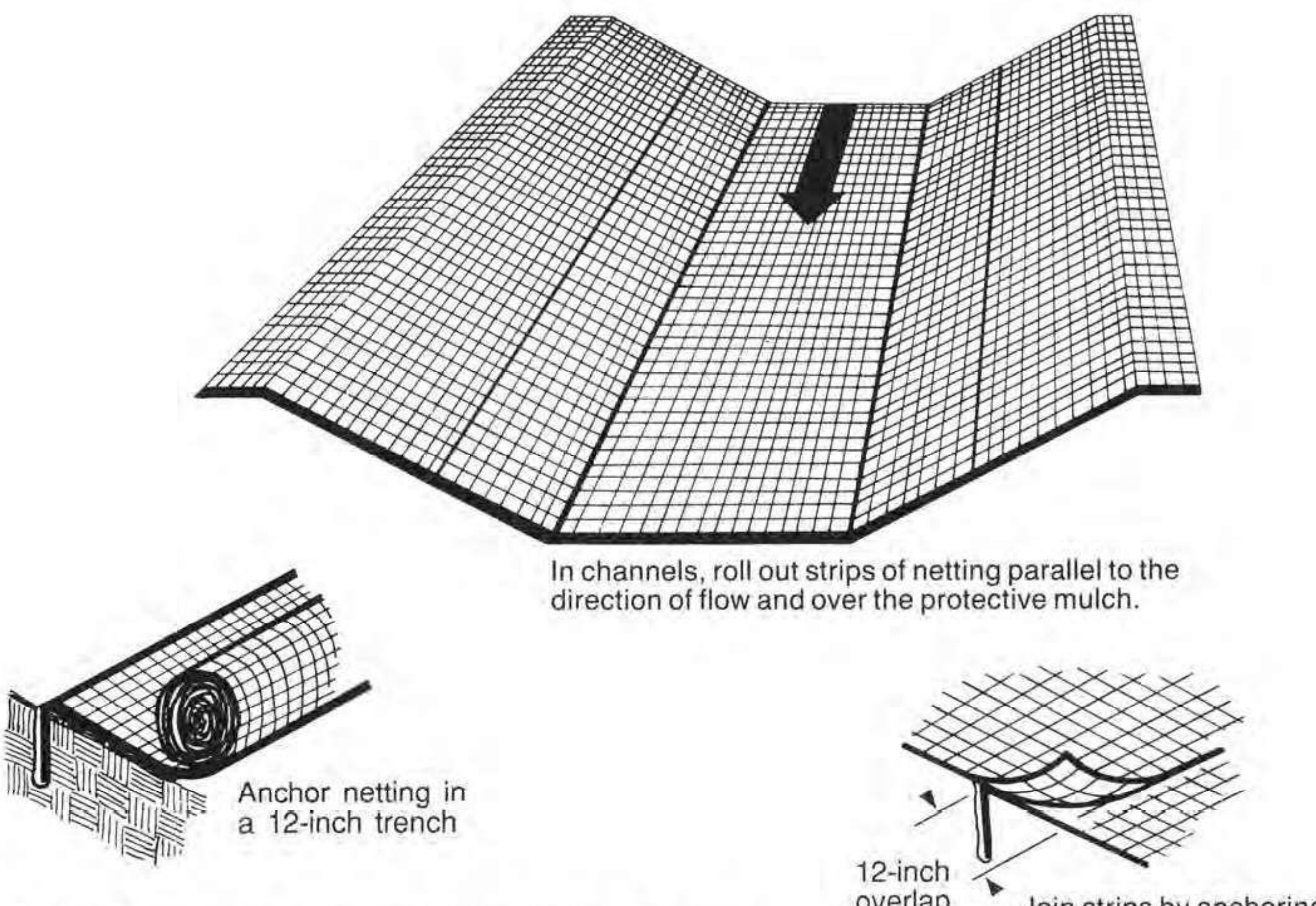


Figure 6.14a Installation of netting and matting (modified from Va. Div. of Forestry).

2. Start laying the net from the top of the channel or slope, and unroll it down the grade. **Allow netting to lay loosely on the soil or mulch cover but without wrinkles—do not stretch**.

3. To secure the net, bury the upslope end in a slot or trench no less than 6 inches deep, cover with soil, and tamp firmly as shown in Figure 6.14a. Staple the net every 12 inches across the top end and every 3 ft around the edges and bottom. Where 2 strips of net are laid side by side, the adjacent edges should be overlapped 3 inches and stapled together. Each strip of netting should also be stapled down the center, every 3 ft. **Do not stretch the net when applying staples**.

4. To join two strips, cut a trench to anchor the end of the new net. Overlap the end of the previous roll 18 inches, as shown in Figure 6.14a, and staple every 12 inches just below the anchor slot.

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 is firmly established.

References

Surface Stabilization
6.11, Permanent Seeding

Appendix
8.02, Vegetation Tables

6.15

RIPRAP

RR

Definition

A layer of stone designed to protect and stabilize areas subject to erosion.

Purpose

To protect the soil surface from erosive forces and/or improve stability of soil slopes that are subject to seepage or have poor soil structure.

Conditions Where Practice Applies

Riprap is used for the following applications:

- cut-and-fill slopes subject to seepage or weathering, particularly where conditions prohibit establishment of vegetation,
- channel side slopes and bottoms,
- inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains
- streambank and stream grades,
- shorelines subject to wave action.

Planning Considerations

Riprap is a versatile, highly erosion-resistant material that can be used effectively in many locations and in a variety of ways to control erosion on construction sites.

GRADED VERSUS UNIFORM RIPRAP

Riprap is classed as either graded or uniform. Graded riprap includes a wide mixture of stone sizes. Uniform riprap consists of stones nearly all the same size.

Graded riprap is preferred to uniform riprap in most applications because it forms a dense, flexible cover. Uniform riprap is more open, and cannot adjust as effectively to movement of the stones. Graded riprap is also cheaper to install requiring less hand work for installation than uniform riprap, which must be placed in a uniform pattern. Uniform riprap may give a more pleasing appearance.

Riprap sizes are designated by either the mean diameter or the weight of the stones. The diameter specification is often misleading since the stones are usually angular. However, common practice is to specify stone size by the diameter of an equivalent size of spherical stone. Table 6.15a lists some typical stones by weight, spherical diameter, and the corresponding rectangular dimensions. These stone sizes are based upon an assumed specific weight of 165 lb/ft^3.

A method commonly used for specifying the range of stone sizes in graded riprap is to designate a diameter for which some percentage, by weight, will be smaller. For example, "d_{85}" specifies a mixture of stones in which 85% of the stone by weight would be smaller than the diameter specified. Most designs are based on "d_{50}", or median size stones.

Riprap and gravel are often designated by N.C. Department of Transportation specifications (Table 6.15b).

Table 6.15a
Size or Riprap Stones

Weight (lb)	Mean Spherical Diameter (ft)	Length (ft)	Rectangular Shape Width/Height (ft)
50	0.8	1.4	0.5
100	1.1	1.8	0.6
150	1.3	2.0	0.7
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.3
1500	2.6	4.7	1.5
2000	2.8	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3

source: Va SWCC

When considering riprap for surface stabilization, it is important to anticipate visual impacts, including weed control, hazards from snakes and other animals, danger of slides and hazards to areas below steep riprap slopes, damage and possible slides from children moving stones, and general safety.

Proper slope selection and surface preparation are essential for successful long-term functioning of riprap. Adequate compaction of fill areas and proper use of filter blankets are necessary.

Sequence of construction—Schedule disturbance of areas that require riprap protection so that the placement of riprap can follow immediately after grading. When riprap is used for outlet protection, place the riprap before or in conjunction with the installation of the structure so that it is in place before the first runoff event.

Design Criteria

Gradation—Riprap should be a well-graded mixture with 50% by weight larger than the specified design size. The diameter of the largest stone size in such a mixture should be 1.5 times the d_{50} size with smaller sizes grading down to 1 inch.

The designer should determine the riprap size that will be stable for design conditions. Having determined the design stone size, the designer should select the size or sizes that equal or exceed that minimum size based on riprap gradations commercially available in the area.

Thickness—Construction techniques, dimensions of the area to be protected, size and gradation of the riprap, the frequency and duration of flow, difficulty and cost of maintenance, and consequences of failure should be considered when determining the thickness of riprap linings. The minimum thickness should be 1.5 times the maximum stone diameter, but in no case less than 6 inches.

Quality of stone—Stone for riprap may consist of field stone or quarry stone. The stone should be hard, angular, of such quality that it will not break down

Table 6.15b
Sizes for Riprap and Erosion Control Stone Specified by the N.C. Department of Transportation

Riprap		Erosion Control	
Class 1	**Class 2**	**Class A**	**Class B**
5 to 200 lb	25 to 250 lb	2” to 6”	5” to 15”
30% shall weigh a minimum of 60 lbs each	60% shall weigh a minimum of 100 lb each		
No more than 10% shall weigh less than 15 lb each	No more than 5% shall weigh less than 50 lb each	10% tolerance top and bottom sizes	
		Equally distributed, no gradation specified	Equally distributed, no gradation specified

source: North Carolina Aggregates Association

on exposure to water or weathering, and suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

Size of stone—The sizes of stones used for riprap protection are determined by purpose and specific site conditions.

- **Slope stabilization—**Riprap stone for slope stabilization, not subject to flowing water or wave action, should be sized for stability for the proposed grade. The gradient of the slope to be stabilized should be less than the natural angle of repose of the stone selected. Angle of repose of riprap stones may be estimated from Figure 6.15a.

  Riprap used for surface stabilization of slopes does not add significant resistance to sliding or slope failure, and should not be considered a retaining wall. The inherent stability of the soil must be satisfactory before riprap is used for surface stabilization. Slopes approaching 1.5:1 may require special stability analysis.

- **Outlet protection—**Design criteria for sizing stone, and determining the dimensions of riprap pads at channel or conduit outlets are presented in Practice 6.41, *Outlet Stabilization Structure*.

- **Channel stabilization and streambank protection—**Design criteria for sizing stone for stability of channels are contained in *Appendix 8.05*.

Filter blanket—A filter blanket is a layer of material placed between the riprap and the underlying soil to prevent soil movement into or through the riprap.

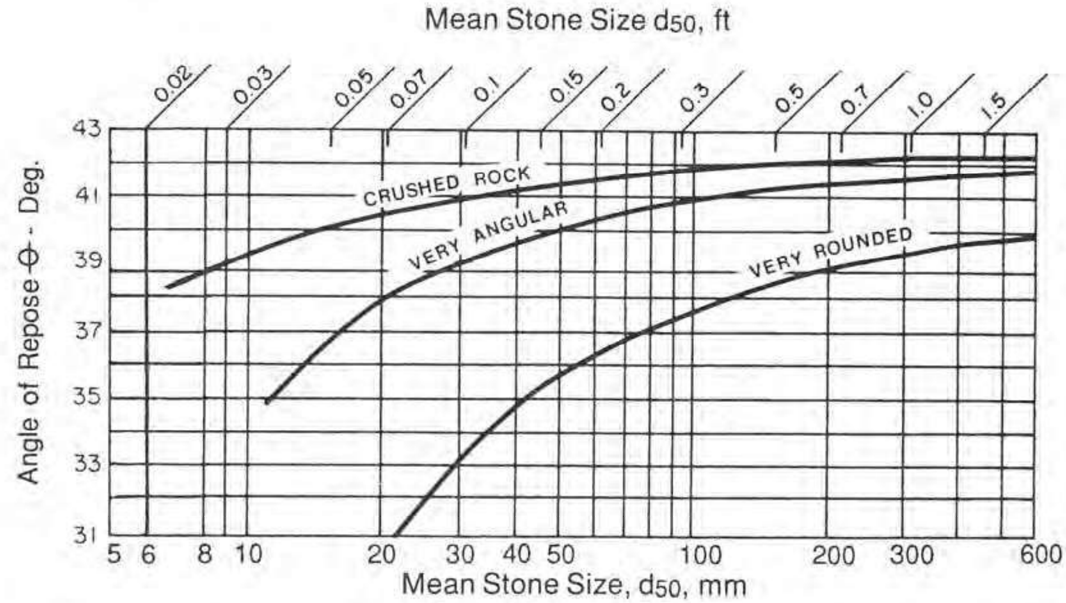


Figure 6.15a Angle of repose for different rock shapes and sizes.
Adapted from: FHWA, HEC-15, pg. 49 - April 1988

A suitable filter may consist of a well-graded gravel or sand-gravel layer or a synthetic filter fabric manufactured for this express purpose. The design of a gravel filter blanket is based on the ratio of particle size in the overlying filter material to that of the base material in accordance with the criteria below. The designed gravel filter blanket may consist of several layers of increasingly large particles from sand to erosion control stone.

A gravel filter blanket should have the following relationship for a stable design:

$$\frac{d_{15}\text{ filter}}{d_{85}\text{ base}} \leq 5$$

$$5 \leq \frac{d_{15}\text{ filter}}{d_{15}\text{ base}} \leq 40$$

$$\frac{d_{50}\text{ filter}}{d_{50}\text{ base}} \leq 40$$

In these relationships, filter refers to the overlying material, and base refers to the underlying material. These relationships must hold between the filter material and the base material (soil foundation), and between the riprap and the filter. More than one layer of filter material may be needed. Each layer of filter material should be at least 6 inches thick.

A synthetic filter fabric may be used with or in place of gravel filters. The following particle size relationships should exist:

- Filter fabric covering a base with granular particles containing 50% or less (by weight) of fine particles (less than U.S. Standard Sieve no. 200 [0.074mm]):

  a.
  $$\frac{d_{85} \text{ base (mm)}}{\text{EOS* filter fabric (mm)}} > 1$$

  b. total open area of filter should not exceed 36%.

- Filter fabric covering other soils:

  a. EOS is no larger than U.S. Standard Sieve no. 70 (0.21mm),

  b. total open area of filter should not exceed 10%.

  **EOS - Equivalent opening size compared to a U.S. standard sieve size.*

No filter fabric should have less than 4% open area, or an EOS less than U.S. Standard Sieve No. 100 (0.15mm). The permeability of the fabric must be greater than that of the soil. The fabric may be made of woven or nonwoven monofilament yarns, and should meet the following minimum requirements:

- thickness 20 - 60 mils,
- grab strength 90 - 120 lb, and
- conform to ASTM D-1682 or ASTM D-177.

Filter blankets should always be provided where seepage is significant, or where flow velocity and duration of flow or turbulence may cause the underlying soil particles to move through the riprap.

Construction Specifications

Subgrade preparation—Prepare the subgrade for riprap and filter to the required lines and grades shown on the plans. Compact any fill required in the subgrade to a density approximating that of the surrounding undisturbed material or overfill depressions with riprap. Remove brush, trees, stumps, and other objectionable material. Cut the subgrade sufficiently deep that the finished grade of the riprap will be at the elevation of the surrounding area. Channels should be excavated sufficiently to allow placement of the riprap in a manner such that the finished inside dimensions and grade of the riprap meet design specifications.

Sand and gravel filter blanket—Place the filter blanket immediately after the ground foundation is prepared. For gravel, spread filter stone in a uniform layer to the specified depth. Where more than one layer of filter material is used, spread the layers with minimal mixing.

Synthetic filter fabric—Place the cloth filter directly on the prepared foundation. Overlap the edges by at least 12 inches, and space anchor pins every 3 ft along the overlap. Bury the upstream end of the cloth a minimum of 12 inches below ground and where necessary, bury the lower end of the cloth or over lap with the next section as required. See Figure 6.14a Page 6.14.6.

Take care not to damage the cloth when placing riprap. If damage occurs remove the riprap, and repair the sheet by adding another layer of filter material with a minimum overlap of 12 inches around the damaged area. If extensive damage is suspected, remove and replace the entire sheet.

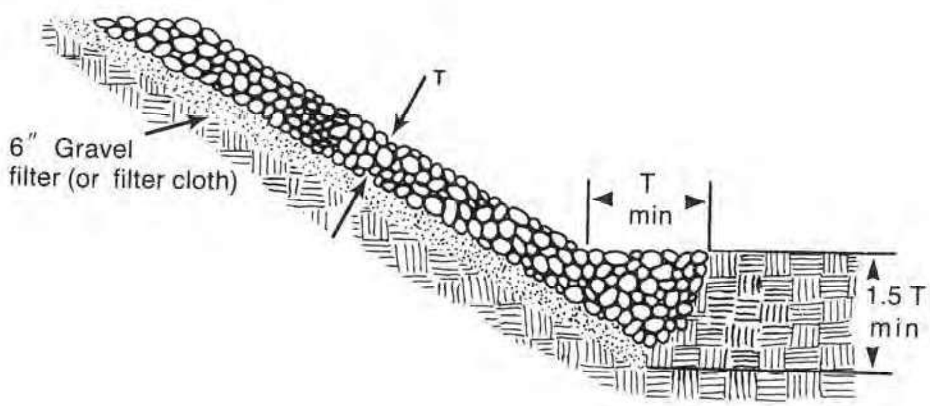
Where large stones are used or machine placement is difficult, a 4-inch layer of fine gravel or sand may be needed to protect the filter cloth.

Stone placement—Placement of riprap should follow immediately after placement of the filter. Place riprap so that it forms 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, and controlled dumping during final placement. Place riprap to its full thickness in one operation. Do not place riprap by dumping through chutes or other methods that cause segregation of stone sizes. Take care not to dislodge the underlying base or filter when placing the stones.

The toe of the riprap slope should be keyed to a stable foundation at its base as shown in Figure 6.15b. The toe should be excavated to a depth about 1.5 times the design thickness of the riprap, and should extend horizontally from the slope.

The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the proper distribution of stone sizes to produce a relatively smooth, uniform surface. The finished grade of the riprap should blend with the surrounding area. No overfall or protrusion of riprap should be apparent.

Figure 6.15b Riprap slope protection (modified from VDH&T).



Maintenance

In general, once a riprap installation has been properly designed and installed it requires very little maintenance. Riprap should be inspected periodically for scour or dislodged stones. Control of weed and brush growth may be needed in some locations.

References

Runoff Conveyance Measures
6.31, Riprap-lined and Paved Channels

Outlet Protection
6.41, Outlet Stabilization Structure

Appendices
8.05, Design of Stable Channels and Diversions
8.06, Design of Riprap Outlet Protection

6.17

RECP

ROLLED EROSION CONTROL PRODUCTS

Definition

Rolled erosion control products are manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation. Examples of RECP's are blankets, nets, and matting.

Purpose

Erosion control mats and blankets are intended to protect soil and hold seed and mulch in place on slopes and in channels so that vegetation can become well established. Turf reinforcement mats can be used to permanently reinforce grass in drainage ways during high flows. Nets are made of high tensile material woven into an open net which overlays mulch materials. Blankets are made of interlocking fibers, typically held together by a biodegradable or photodegradable netting (for example, excelsior or straw blankets). They generally have lower tensile strength than nets, but cover the ground more completely. Coir (coconut fiber) fabric comes as both nets and blankets.

Conditions Where Practice Applies

Rolled Erosion Control Products (RECP's) should be used to aid permanent vegetated stabilization of slopes 2:1 or greater and with more than 10 feet of vertical relief. RECP's should also be used when mulch cannot be adequately tacked and where immediate ground cover is required to prevent erosion damage.

RECP's should be used to aid in permanent stabilization of vegetated channels when runoff velocity will exceed 2 ft/sec on bare earth during the 2-year rainfall event that produces peak runoff. The product selected must have a permissible shear stress that exceeds the shear stress of the design runoff event.

Planning Considerations

- Good ground contact is critical to the effectiveness of these products. If good ground contact is not achieved, runoff can concentrate under the product, resulting in significant erosion.

- Nets must be used in conjunction with mulch. Excelsior, woven straw blankets and coir (coconut fiber) blankets may be installed without mulch. There are many other types of erosion control nets and blankets on the market that may be appropriate in certain circumstances. In general, most nets (e.g. jute matting) require mulch in order to prevent erosion because they have a fairly open structure. Blankets typically do not require mulch because they usually provide complete protection of the surface.

- Most netting used with blankets is photodegradable, meaning they break down under sunlight (not UV stabilized). However, this process can take months or years even under bright sun. Once vegetation is established, sunlight does not reach the mesh. It is not uncommon to find non-degraded netting still in place several years after the installation. This can be a problem if maintenance requires the use of mowers or ditch cleaning equipment. In addition, birds and small animals can become trapped in the netting.

- Biodegradable blankets are available for use in sensitive areas. These organic blankets are usually held together with a fiber mesh and stitching which may last up to a year.

Design Criteria

The following discussion and examples of design are adapted from *"Green Engineering, Design Principles and Applications Using Rolled Erosion Control Products"* by C. Joel Sprague.

Slope Protection: **Reducing raindrop and overland flow erosion.** The Revised Universal Soil Loss Equation (RUSLE), as shown below, is commonly used to estimate erosion due to rainfall and sheet runoff.

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

where:

A = soil loss in tons/acre/year
R = rain factor
K = soil erodibility
LS = topographic factor
C = cover factor
P = practice factor

The United States Department of Agriculture's handbook, "Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), 1997," provides agriculture-oriented values for all of these variables. Yet, when the equation is used to estimate construction-related erosion, the following unique C- and P-factors developed specifically for these applications should be used.

The C-Factor—C-factors are equal to the reduction in soil loss when using a specific erosion control system when compared to the comparable bare soil (control) condition. The designer will require C-factors representing various conditions from unvegetated to fully vegetated, including vegetation, which has been mulched or, alternatively, protected by an RECP, in order to determine an appropriate factor to be used to represent the design condition. (See Table 6.17a for a range of C-factors.)

Table 6.17a C-Factor for Various Slope Treatments

Treatment	Dry Mulch Rate		C-Factor for Growing Period*			
	kg/m^3	Slope %	<6 Weeks	1.5-6 Months	6-12 Months	Annualized**
No mulching or seeding	—	all	1.00	1.00	1.00	1.00
Seeded grass	none	all	0.70	0.10	0.05	0.15
	0.22	<10	0.20	0.07	0.03	0.07
	0.34	<10	0.12	0.05	0.02	0.05
	0.45	<10	0.06	0.05	0.02	0.04
	0.45	11 - 15	0.07	0.05	0.02	0.04
	0.45	16 - 20	0.11	0.05	0.02	0.04
	0.45	21 - 25	0.14	0.05	0.02	0.05
	0.45	26 - 33	0.17	0.05	0.02	0.05
	0.45	34 - 50	0.20	0.05	0.02	0.05
Second-year grass	—	all	0.01	0.01	0.01	0.01
Organic and Synthetic Blankets	—	all	0.07	0.01	0.005	0.02
Composite Mats	—	all	0.07	0.01	0.005	0.02
Synthetic Mats	—	all	0.14	0.02	0.005	0.03
Fully Vegetated Mats	—	all	0.005	0.005	0.005	0.005

* Approximate time periods for humid climates: Conversion: kg/m^3 x 4.45 = tons/acre.

** Annualized C-Factor = (<6 weeks value x 6/52) + (1.5-6 months value x 20/52) + (6-12 months value x 26/52).

Table 6.17b Permissible Shear Stress, τ_P, of Various RECP's

Category	Product Type	Max. Permissible Shear Stress (lb/ft^2)	Slopes* Up To
Degradable RECP's (Unvegetated)	Nets and Mulch	0.1 - 0.2	20:1
	Coir Mesh	0.4 - 3.0	3:1
	Blanket - Single Net	1.55 - 2.0	2:1
	Blanket - Double Net	1.65 - 3.0	1:1
Nondegradable RECP's	Unvegetated TRM**	2 - 4	1:1
	Partially Vegetated TRM	4 - 6	>1:1
	Fully Vegetated	5 - 10	>1:1

* Steeper slope limits may apply. For further information, contact the manufacturer.

** Turf Reinforcement Mat.

The P-Factor—when examining erosion by itself, is commonly taken as 1.0, since this assumes that no special "practices" (i.e. terracing, contouring, etc.) will be used. Yet, the use of silt fences or other storm water management/sediment control practices may be integrated into the RUSLE using a P-factor that is less than 1.0, which reflects the effectiveness of the sediment control practice in removing sediment from runoff.

Sample Problem 6.17a

A steep slope is to be protected from erosion using RECP. The 3H:1V slope is 100 feet long and comprised of silty loam. The RUSLE will be used to evaluate the effectiveness of RECP in limiting annual soil loss. Following are the inputs to the RUSLE equation from the U.S. Department of Agriculture:

R = 250
K = 0.33
LS = 6.2
P = 1.0 (assuming no sediment control)

From Table 6.17a:

$C_{unprotected}$ = 1.00
$C_{protected}$, year 1 = 0.03
$C_{protected}$, year 2+ = 0.005

$A_{unprotected}$ = 250 x 0.33 x 6.2 x 1.0 x 1.0 = 511 tons/acre/year
$A_{protected}$, year 1 = 250 x 0.33 x 6.2 x 0.03 x 1.0 = 15 tons/acre/year
$A_{protected}$, year 2+ = 250 x 0.33 x 6.2 x 0.005 x 1.0 = 3 tons/acre/year

This example shows that vegetation, protected by an RECP, is 97 percent effective in reducing erosion in the first year and 99.5 percent effective in the longer-term.

Table 6.17b aids in selecting an appropriate type of RECP for the project-specific slope.

Drainage Channels Concepts—Permissible shear design is commonly used to determine if a channel liner is stable. This method requires the input of an appropriate expected flow rate (discharge) as well as the determination of flow depth. A broader presentation of channel design is located in Appendix 8.05, *Design of Stable Channels and Diversions.*

The design flow rate will be based on local storm frequency design standards and flow depth is calculated - commonly using Manning's equation. With these inputs the designer can then perform a permissible shear design, which compares the permissible shear of the prospective liner materials to the expected flow-induced shear as calculated using the equation below.

$$\tau_c = Y\ D\ S$$

where:

Y = unit weight of water (62.4lb/ft^3)
D = depth of flow (ft)
S = channel slope (ft/ft)

If the permissible shear stress, τ_p, is greater than the computed shear, τ_c, the lining is considered acceptable. Values for permissible shear stress, τ_p, for linings are based on research conducted at laboratory facilities and in the field. Typical values are given in Table 6.17b. The permissible shear stress, τ_p, indicates the force per unit area resulting from flowing water required to create instability of the lining material and/or adjacent soil.

Manning's Equation and Roughness Coefficient, n—The condition of uniform, steady flow in a channel at a known discharge is computed using the Manning's Equation below. Numerous computer programs are available to facilitate the use of this equation since a trial-and-error solution relating channel width, B, and depth, D, is required.

$$Q = (1.49/n)\,(A)\,(R)^{2/3}\,(S)^{1/2}$$

Manning's equation for determining velocity:

$$V = (1.49/n)\,(R)^{2/3}\,(S)^{1/2}$$

where:

Q = discharge (cfs)
V = average velocity in cross section (ft/s)
n = Manning's roughness coefficient
A = cross-sectional area (ft^2)
R = hydraulic radius = A/P (ft)
P = wetted perimeter (ft)
S = energy gradient (commonly taken as equivalent to the channel bed slope, ft/ft)

The appropriate Manning's "n" to use when designing with RECP's depends on whether one is designing for bare soil retention and vegetation establishment (short-term) or for fully grassed conditions (long term), or both. The "n" values for RECP's can vary significantly with material type and flow depth, but they typically range from 0.02 to 0.04 and are usually provided by the manufacturer.

In lieu of product-specific information, the following values can be used as approximations.

$n_{unvegetated}$ = 0.02
$n_{vegetated}$ = refer to Table 6.17c and Figure 6.17a
n_{lined} = refer to Table 8.05e

Table 6.17c Grass Retardance Categories

Average Grass Length	Retardance
>24 in.	A
10 in. to 24 in.	B
6 in. to 10 in.	C
2 in. to 6 in.	D
Less than 2 in.	E

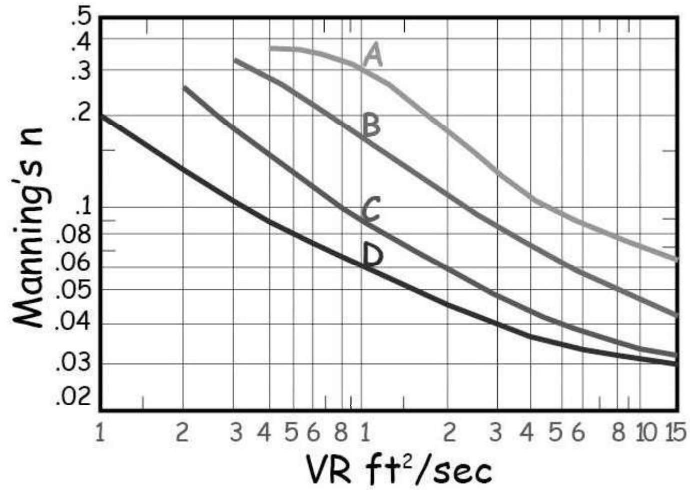


Figure 6.17a Hydraulic roughness of grass

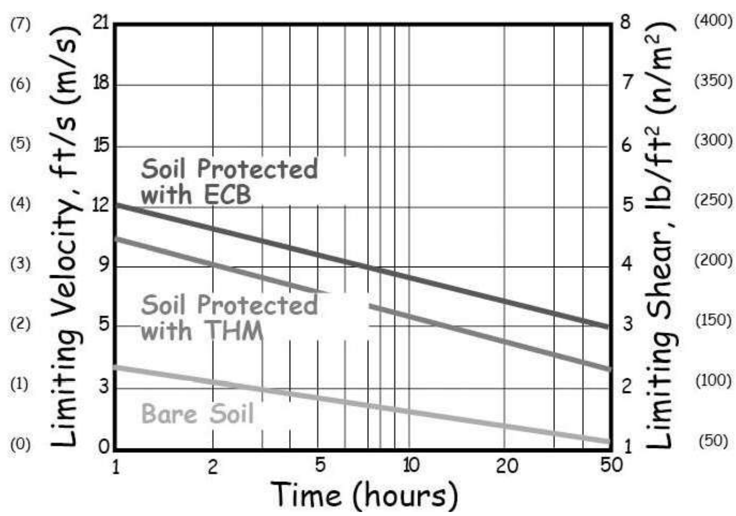


Figure 6.17b Limiting values for bare and TRM protected soils

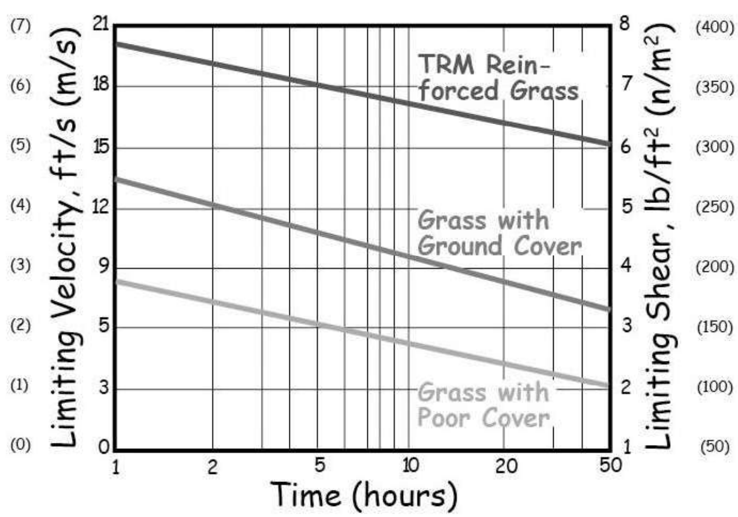


Figure 6.17c Limiting values for plain and TRM reinforced grass

Sample Problem 6.17b

Determine if an RECP-lined drainage channel will be stable for a long-term peak flow (10-year design storm) of 70 cfs down a 20:1 slope (S=0.05) with a 4 foot bottom width and 1:1 side slopes. The duration of flow is 50 hours for long-term and one hour for short-term design. The grass cover is expected to be in retardance group D. Short-term stability can be checked using the two-year design storm, which produces a short-term peak flow of 45 cfs.

Long-term design = vegetated channel stability

- Use $Q_{peak} = Q_{10\text{-}year} = 70$ cfs
- From Figure 6.17c: Limiting shear = 6 lb/ft^2
- Assume $n_{vegetated} = 0.05$

Solve for the depth of flow using iterations of Manning's equation. An Excel spreadsheet located on the internet at http://www.dlr.enr.state.nc.us/pages/sedimenttecassist.html or commercially available channel software is recommended.

For trapezoidal channels:

$$(bd + zd^2)\left[\frac{(bd + zd^2)}{b + 2d\,(z^2 + 1)^{1/2}}\right]^{2/3} = \frac{Qn}{1.49S^{1/2}}$$

From trial-and-error, d = 1.7ft

Determine area of flow A, from $A = (bd + zd^2)$
$= 9.8ft^2$

Since slope < 1:10, calculate VR using:
$V_{estimate} = 7.1$ft/s;
VR= (7.1ft/s) (1.11) = 7.88ft/s
From Figure 6.17a: Use n = 0.032. Recalculate d = 1.34ft
$A = 7.14ft^2$

Check shear stress $\tau_C = YDS$
= (62.4) (1.34) (0.05)
= 4.18 lb/ft^2
4.18 < 6 lb/ft^2, therefore acceptable

Sample Problem 6.17b con't.

Short-term design = bare soil channel stability

- Use $Q_{peak} = Q_{2\text{-}year}$ = 45 cfs
- From Figure 6.17b: Limiting shear = 4.5 lb/ft^2
- For mat on bare soil, n = 0.03

Determine depth of flow via trail-and-error using Manning's Equation:

For trapezoidal channels: $(bd + zd^2)$

$$(bd + zd^2)\left[\frac{(bd + zd^2)}{b + 2d\,(z^2 + 1)^{1/2}}\right]^{2/3} = \frac{Qn}{1.49S^{1/2}}$$

From trial-and-error, d = 1.0ft

Check shear stress τ = YDS
= (62.4) (1.0) (0.05)
= 3.12 lb/ft^2
3.12 < 4.5 lb/ft^2, therefore acceptable

Construction Specifications

Construction
Even if properly designed, if not properly installed, RECP's will probably not function as desired. Proper installation is imperative. Even if properly installed, if not properly timed and nourished, vegetation will probably not grow as desired. Proper seed/vegetation selection is also imperative.

Grade the surface of installation areas so that the ground is smooth and loose. When seeding prior to installation, follow the steps for seed bed preparation, soil amendments, and seeding in *Surface Stabilization*, 6.1. All gullies, rills, and any other disturbed areas must be fine graded prior to installation. Spread seed before RECP installation. (**Important**: Remove all large rocks, dirt clods, stumps, roots, grass clumps, trash, and other obstructions from the soil surface to allow for direct contact between the soil surface and the RECP.)

Terminal anchor trenches are required at RECP ends and intermittent trenches must be constructed across channels at 25-foot intervals. Terminal anchor trenches should be a minimum of 12 inches in depth and 6 inches in width, while intermittent trenches need be only 6 inches deep and 6 inches wide.

Installation for Slopes— Place the RECP 2-3 feet over the top of the slope and into an excavated end trench measuring approximately 12 inches deep by 6 inches wide. Pin the RECP at 1 foot intervals along the bottom of the trench, backfill, and compact. Unroll the RECP down (or along) the slope maintaining direct contact between the soil and the RECP. Overlap adjacent rolls a minimum of 3 inches. Pin the RECP to the ground using staples or pins in a 3 foot center-to-center pattern. Less frequent stapling/pinning is acceptable on moderate slopes.

Installation in Channels— Excavate terminal trenches (12 inches deep and 6 inches wide) across the channel at the upper and lower end of the lined channel sections. At 25-foot intervals along the channel, anchor the RECP across the channel either in 6 inch by 6 inch trenches or by installing two closely spaced rows of anchors. Excavate longitudinal trenches 6 inches deep and wide along channel edges (above water line) in which to bury the outside RECP edges. Place the first RECP at the downstream end of the channel. Place the end of the first RECP in the terminal trench and pin it at 1 foot intervals along the bottom of the trench.

Note: The RECP should be placed upside down in the trench with the roll on the downstream side of the bench.

Once pinned and backfilled, the RECP is deployed by wrapping over the top of the trench and unrolling upstream. If the channel is wider than the provided rolls, place ends of adjacent rolls in the terminal trench, overlapping the adjacent rolls a minimum of 3 inches. Pin at 1 foot intervals, backfill, and compact. Unroll the RECP in the upstream direction until reaching the first intermittent trench. Fold the RECP back over itself, positioning the roll on the downstream side of the trench, and allowing the mat to conform to the trench.

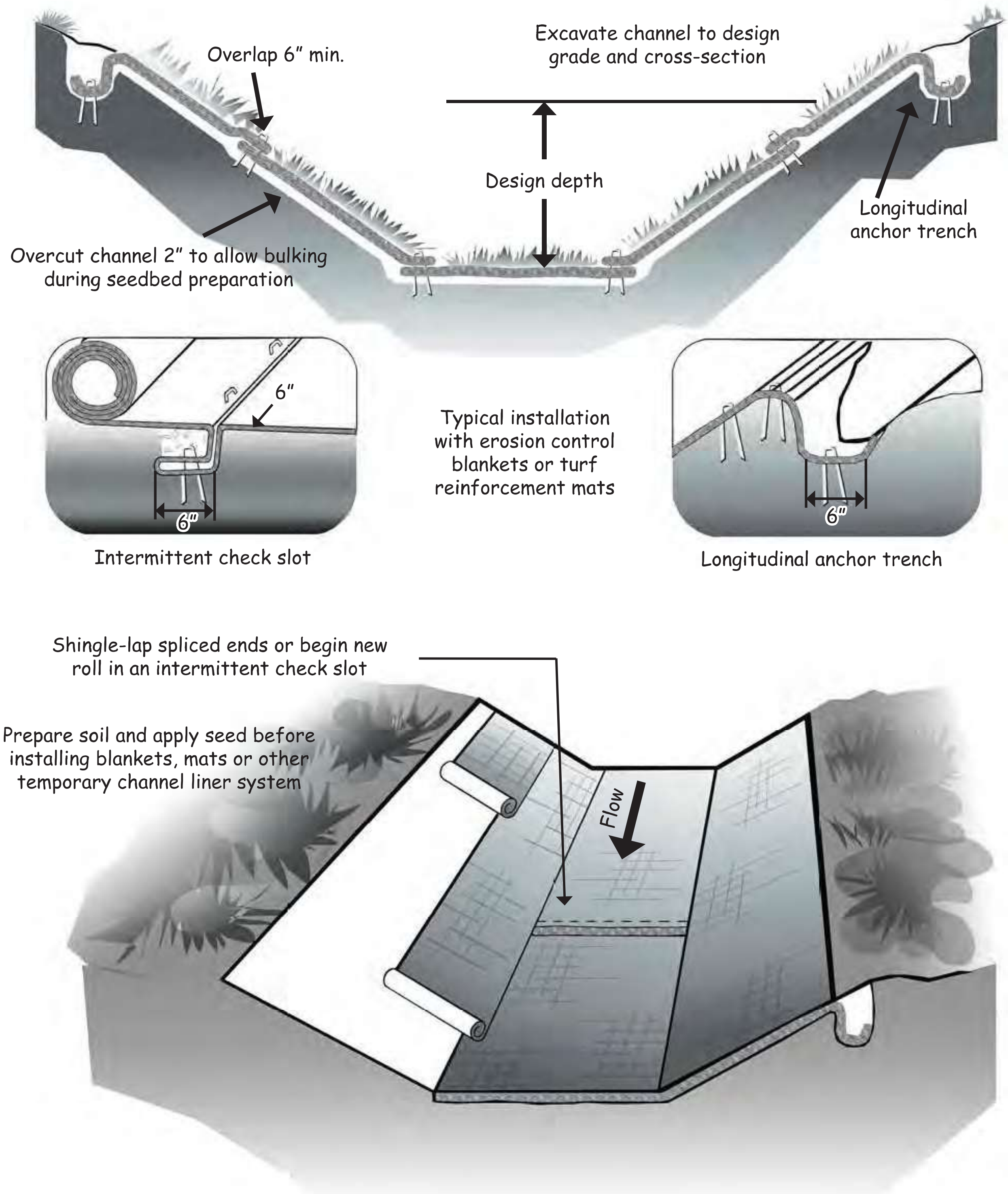
Then pin the RECP (two layers) to the bottom of the trench, backfill, and compact. Continue up the channel (wrapping over the top of the intermittent trench) repeating this step at other intermittent trenches, until reaching the upper terminal trench.

At the upper terminal trench, allow the RECP to conform to the trench, secure with pins or staples, backfill, compact and then bring the mat back over the top of the trench and onto the existing mat (2 to 3 feet overlap in the downstream direction), and pin at 1 foot intervals across the RECP. When starting installation of a new roll, begin in a trench or shingle-lap ends of rolls a minimum of 1 foot with upstream RECP on top to prevent uplifting. Place the outside edges of the RECP(s) in longitudinal trenches, pin, backfill, and compact.

Anchoring Devices—11 gauge, at least 6 inches length by 1 inch width staples or 12 inch minimum length wooden stakes are recommended for anchoring the RECP to the ground.

Drive staples or pins so that the top of the staple or pin is flush with the ground surface. Anchor each RECP every 3 feet along its center. Longitudinal overlaps must be sufficient to accommodate a row of anchors and uniform along the entire length of overlap and anchored every 3 feet along the overlap length. Roll ends may be spliced by overlapping 1 foot (in the direction of water flow), with the upstream/upslope mat placed on top of the downstream/downslope RECP. This overlap should be anchored at 1 foot spacing across the RECP. When installing multiple width mats heat seamed in the factory, all factory seams and field overlaps should be similarly anchored.

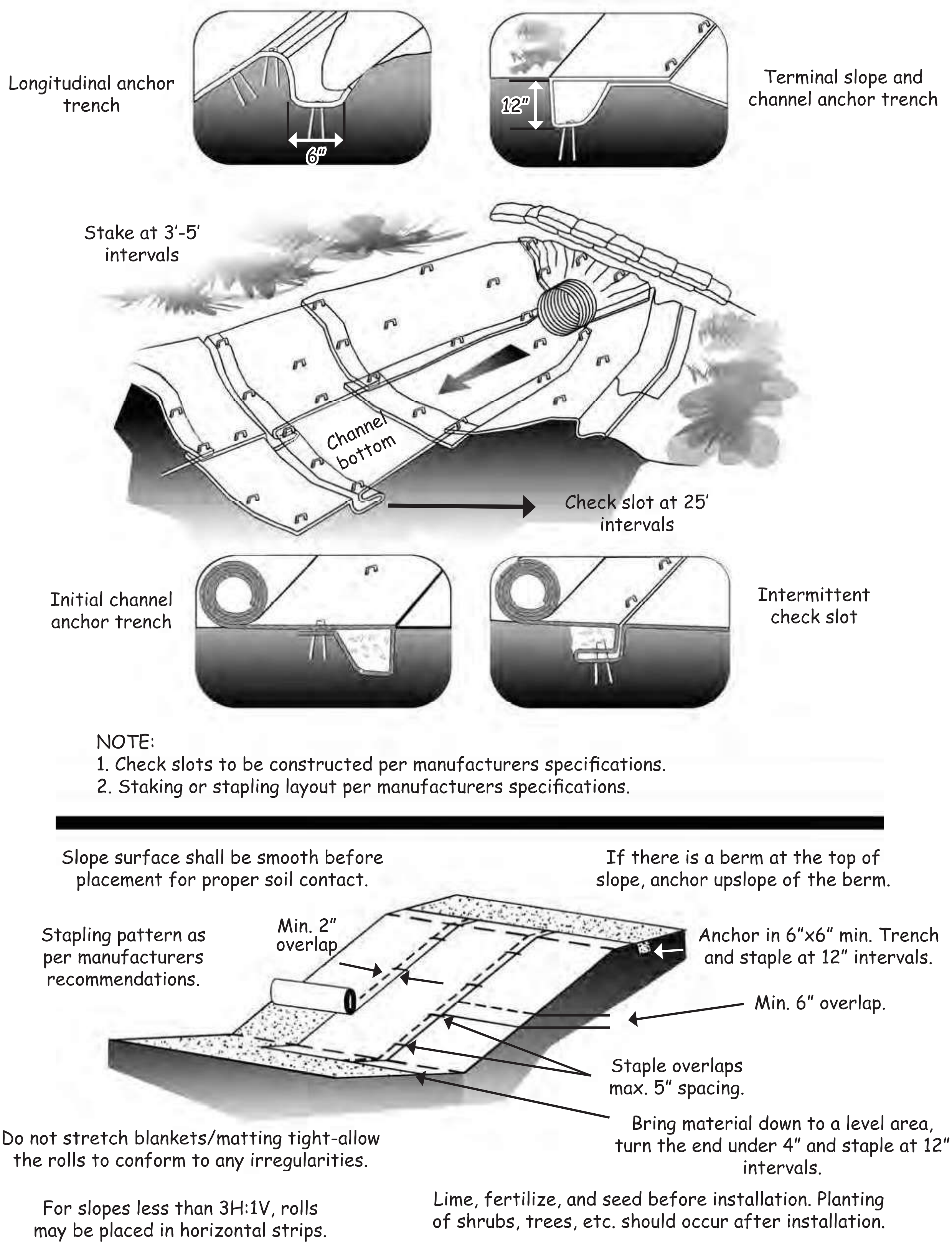
Figure 6.17d Temporary Channel Liners; Washington State Department of Ecology



NOTES:

1. Design velocities exceeding 2 ft/sec require temporary blankets, mats or similar liners to protect seed and soil until vegetation becomes established.
2. Grass-lined channels with design velocities exceeding 6 ft/sec should include turf reinforcement mats

Figure 6.17e Channel Installation and Slope Installation; Washington State Ecology Department



Maintenance

1. Inspect Rolled Erosion Control Products at least weekly and after each significant (1/2 inch or greater) rain fall event repair immediately.

2. Good contact with the ground must be maintained, and erosion must not occur beneath the RECP.

3. Any areas of the RECP that are damaged or not in close contact with the ground shall be repaired and stapled.

4. If erosion occurs due to poorly controlled drainage, the problem shall be fixed and the eroded area protected.

5. Monitor and repair the RECP as necessary until ground cover is established.

References

Sprague, C. Joel. TRI/ Environmental, Inc. “Green Engineering, Design principles and applications using rolled erosion control products”

Storm Water Management Manual for Western Washington, Washington State Department of Ecology, Water Quality Program http://www.ecy.wa.gov/programs/wq/stormwater/index.html

Erosion Control Technology Council, http://www.ectc.org

6.20

→ TD →

TEMPORARY DIVERSIONS

Definition

A temporary ridge or excavated channel or combination ridge and channel constructed across sloping land on a predetermined grade.

Purpose

To protect work areas from upslope runoff, and to divert sediment-laden water to appropriate traps or stable outlets.

Conditions Where Practice Applies

This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include:

- above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope;
- across unprotected slopes, as slope breaks, to reduce slope length;
- below slopes to divert excess runoff to stabilized outlets;
- where needed to divert sediment-laden water to sediment traps;
- at or near the perimeter of the construction area to keep sediment from leaving the site; and
- above disturbed areas before stabilization to prevent erosion, and maintain acceptable working conditions.
- Temporary diversions may also serve as sediment traps when the site has been overexcavated on a flat grade; they may also be used in conjunction with a sediment fence.

Planning Considerations

It is important that diversions are properly designed, constructed and maintained since they concentrate water flow and increase erosion potential (Figure 6.20a). Particular care must be taken in planning diversion grades. Too much slope can result in erosive velocity in the diversion channel or at the outlet. A change of slope from steeper grade to flatter may cause deposition to occur. The deposition reduces carrying capacity, and may cause overtopping and failure. Frequent inspection and timely maintenance are essential to the proper functioning of diversions.

Sufficient area must be available to construct and properly maintain diversions. It is usually less costly to excavate a channel and form a ridge or dike on the

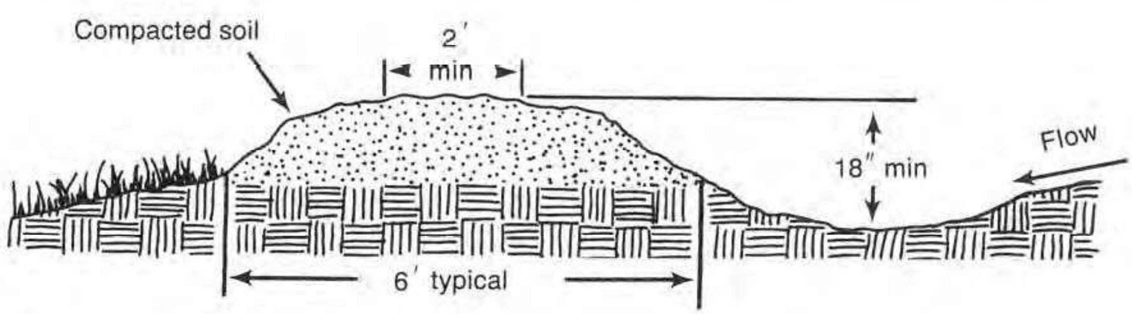


Figure 6.20a Temporary earthen diversion dike.

downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the ridge by hauling in diking material, or using a silt fence to divert the flow. Use gravel to form the diversion dike when vehicles must cross frequently (Figure 6.20b).

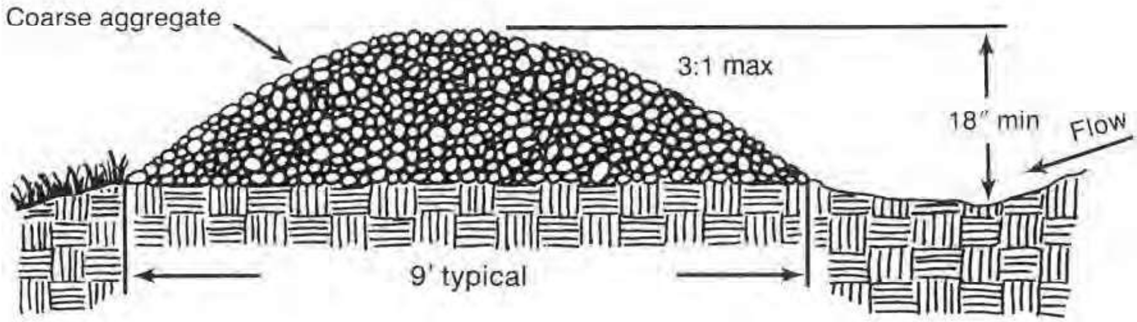


Figure 6.20b Temporary gravel diversion dike for vehicle crossing (modified from Va SWCC).

Plan temporary diversions to function 1 year or more, or they may be constructed anew at the end of each day's grading operation to protect new fill. Diversions that are to serve longer than 30 working days should be seeded and mulched as soon as they are constructed to preserve dike height and reduce maintenance.

Where design velocities exceed 2 ft/sec, a channel liner is usually necessary to prevent erosion (Table 8.05a, *Appendix 8.05*).

Temporary diversions may serve as in-place sediment traps if overexcavated 1 to 2 feet and placed on a nearly flat grade. The dike serves to divert water as the stage increases. A combination silt fence and channel in which fill from the channel is used to stabilize the fence can trap sediment and divert runoff simultaneously.

Wherever feasible, build and stabilize diversions and outlets before initiating other land-disturbing activities.

Design Criteria

Drainage area—5 acres or less.

Capacity—peak runoff from 10-year storm.

Velocity—See Table 8.05a, Permissible Velocities for Erosion Protection, Appendix 8.05.

Ridge design—	side slope:	2:1 or flatter
		3:1 or flatter at points where cross
	top width:	2 ft minimum
	freeboard:	0.3 ft minimum
	settlement:	10% of total fill height minimum

Channel design— shape: parabolic, trapezoidal, or V-shaped
side slope: 2:1 or flatter
3:1 or flatter where vehicles cross

Grades— Either a uniform or a gradually increasing grade is preferred. Sudden decreases in grade accumulate sediment and should be expected to cause overtopping. A large increase in grade may erode.

Outlet—Design the outlet to accept flow from the diversion plus any other contributing areas. Divert sediment-laden runoff and release through a sediment-trapping device (Practice 6.60, *Temporary Sediment Trap* and Practice 6.61, *Sediment Basin*). Flow from undisturbed areas can be dispersed by a level spreader (Practice 6.40, *Level Spreader*).

Small diversions—Where the diversion channel grade is between 0.2 and 3%, a permanent vegetative cover is required. A parabolic channel and ridge 1.5 feet deep and 12 feet wide may be used for diversions with flows up to 5 cfs. This depth does not include freeboard or settlement. Side slopes should be 3:1 or flatter, and the top of the dike must be at least 2 feet wide.

Construction Specifications

1. Remove and properly dispose of all trees, brush, stumps, and other objectionable material.

2. Ensure that the minimum constructed cross section meets all design requirements.

3. Ensure that the top of the dike is not lower at any point than the design elevation plus the specified settlement.

4. Provide sufficient room around diversions to permit machine regrading and cleanout.

5. Vegetate the ridge immediately after construction, unless it will remain in place less than 30 working days.

Maintenance

Inspect temporary diversions once a week and after every rainfall. Immediately remove sediment from the flow area and repair the diversion ridge. Carefully check outlets and make timely repairs as needed. When the area protected is permanently stabilized, remove the ridge and the channel to blend with the natural ground level and appropriately stabilize it.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.14, Mulching

Outlet Protection
6.40, Level Spreader
6.41, Outlet Stabilization Structure

Sediment Traps and Barriers
6.60, Temporary Sediment Trap
6.61, Sediment Basin

Appendices
8.03, Estimating Runoff
8.05, Design of Stable Channels and Diversions

6.21

→ D →

PERMANENT DIVERSIONS

Definition

A permanent ridge or channel or a combination ridge and channel constructed on a designed grade across sloping land.

Purpose

To divert water from areas where it is in excess to locations where it can be used or released without erosion or flood damage.

Conditions Where Practice Applies

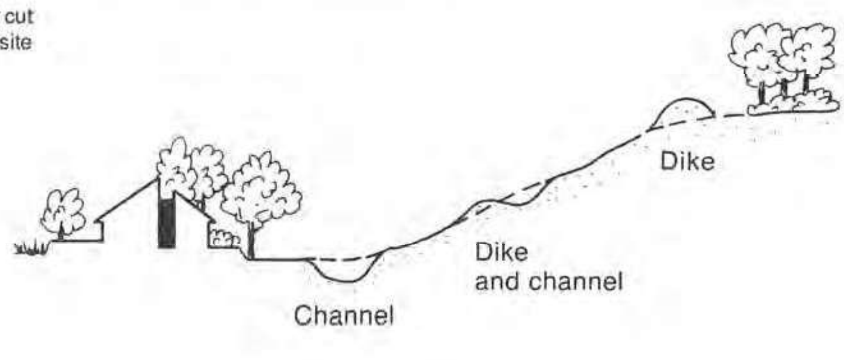
This permanent site development practice applies to construction areas where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sedimentation damage. Specific locations and conditions include:

- above steep slopes to limit surface runoff onto the slope;
- across long slopes to reduce slope length to prevent gully erosion;
- below steep grades where flooding, seepage problems, or sediment deposition may occur;
- around buildings or areas that are subject to damage from runoff.

Planning Considerations

Permanent diversions should be planned as a part of initial site development. They are principally runoff control measures that subdivide the site into specific drainage areas (Figure 6.21a). Permanent diversions can be installed as temporary diversions until the site is stabilized then completed as a permanent measure, or they can be installed in final form during the initial construction operation (Practice 6.20, *Temporary Diversions*). The amount of sediment anticipated and the maintenance required as a result of construction operations will determine which approach should be used. Stabilize permanent diversions with vegetation or materials such as riprap, paving stone, or concrete as soon as possible after installation. Base the location, type of stabilization, and diversion configuration on final site conditions. Evaluate function, need, velocity control, outlet stability, and site aesthetics. When properly located, land forms such as landscape islands, swales or ridges can be used effectively as permanent diversions. Base the capacity of a diversion on the runoff characteristics of the site and the potential damage after development. Consider designing an emergency overflow section or bypass area to limit damage from storms that exceed the design storm. The overflow section may be designed as a weir with riprap protection.

Figure 6.21a Use of diversions to protect cut or fill slopes, protect structures or off-site property, or break long slopes.



Design Criteria

Location—Determine diversion locations by topography, development layout, soil conditions, outlet conditions, length of slope, seepage planes, and need for water and sediment storage.

Capacity—Ensure that permanent diversions have sufficient capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved, as shown in Table 6.21a.

Velocity—See Table 8.05a, *Appendix 8.05*.

Ridge design—

	side slope:	2:1 or flatter 3:1 or flatter when maintained by mowing
	top width:	2 feet minimum
	freeboard:	0.5 feet minimum
	settlement:	10% of total fill height minimum

Channel design—

	material:	to meet velocity requirements and site aesthetics
	shape:	to fit site conditions
	side slope:	2:1 or flatter 3:1 or flatter when maintained by mowing

Grades—Either a uniform or a gradually increasing grade is preferred.

Outlet—Design the outlet stable enough to accept flow from the diversions plus any other contributing runoff. Divert sediment-laden runoff and release it through a sediment-trapping device (Practice 6.60, *Temporary Sediment Trap*, or Practice 6.61, *Sediment Basin*).

Stabilization—Unless the area is otherwise stabilized, provide vegetative stabilization after installation of the diversion. Seed and mulch disturbed areas draining into the diversion within 21 calender days of completing any phase of grading.

Table 6.21a
Minimum Design Storm for Degrees of Hazard

Level of Protection	Area to Be Protected	Minimum Design Storm
Low	All erosion control facilities. Open areas, parking lots, minor recreation areas.	10 year
Medium	Recreation development, low-capacity roads and minor structures.	25 year, 24 hour 50 year, 24 hour
High	Major structures, homes, main school buildings, high-capacity roads.	100 year, 24 hour

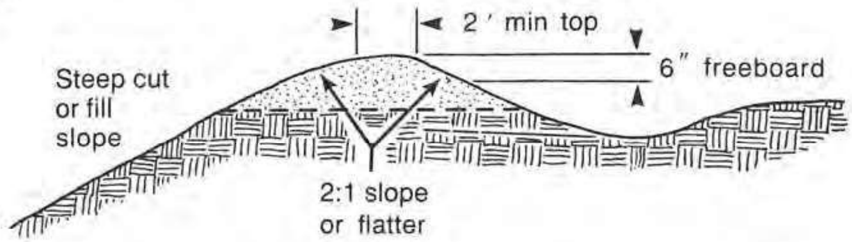
Construction Specifications

1. Remove and properly dispose of all trees, brush, stumps, or other objectionable material. Fill and compact all ditches, swales, or gullies that will be crossed to natural ground level or above.

2. Just before placement of fill, the base of the ridge should be disked by machinery.

3. Excavate, shape, and stabilize the diversion to line, grade, and cross section, as required in the design plan (Figure 6.21b).

Figure 6.21b Permanent diversion located above a slope.



4. Compact the ridge to prevent unequal settlement, and to provide stability against seepage.

5. Vegetatively stabilize the diversion after its installation.

Maintenance

Inspect permanent diversions after every rainfall during the construction operation. Immediately remove any obstructions from the flow area, and repair the diversion ridge. Check outlets, and make timely repairs as needed. Maintain the vegetation in a vigorous, healthy condition at all times.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.14, Mulching

Runoff Control Measures
6.20, Temporary Diversions

Outlet Protection
6.40, Level Spreader
6.41, Outlet Stabilization Structure

Sediment Traps and Barriers
6.60, Temporary Sediment Trap
6.61, Sediment Basin

Appendices
8.03, Estimating Runoff
8.05, Design of Stable Channels and Diversions

6.30

GL

GRASS-LINED CHANNELS

Definition

A channel with vegetative lining constructed to design cross section and grade for conveyance of runoff.

Purpose

To convey and dispose of concentrated surface runoff without damage from erosion, deposition, or flooding.

Conditions Where Practice Applies

This practice applies to construction sites where:

- concentrated runoff will cause damage from erosion or flooding;
- a vegetative lining can provide sufficient stability for the channel cross section and grade;
- slopes are generally less than 5%; and
- space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, outlets for diversions, and other channels and drainage of low areas.

Planning Considerations

LOCATION

Generally, channels should be located to conform with and use the natural drainage system. Channels may also be needed along development boundaries, roadways, and backlot lines. Avoid channels crossing watershed boundaries or ridges.

Plan the course of the channel to avoid sharp changes in direction or grade. Site development should conform to natural features of the land and use natural drainageways rather than drastically reshape the land surface. Major reconfiguration of the drainage system often entails increased maintenance and risk of failure.

Grass-lined channels must not be subject to sedimentation from disturbed areas.

An established grass-lined channel resembles natural drainage systems and, therefore, is usually preferred if design velocities are below 5 ft/sec. Velocities up to 6 ft/sec can be safely used under certain conditions (Table 8.05a, *Appendix 8.05*).

Establishment of a dense, resistant vegetation is essential. Construct and vegetate grass-lined channels early in the construction schedule before grading and paving increase the rate of runoff.

Geotextile fabrics or special mulch protection such as fiberglass roving or straw and netting provide stability until the vegetation is fully established. These protective liners must be used whenever design velocities exceed 2 ft/sec for bare soil conditions. It may also be necessary to divert water from the channel until vegetation is established, or to line the channel with sod. Sediment traps may be needed at channel inlets and outlets.

V-shaped grass channels generally apply where the quantity of water is small, such as in short reaches along roadsides. The V-shaped cross section is least desirable because it is difficult to stabilize the bottom where velocities may be high.

Parabolic grass channels are often used where larger flows are expected and space is available. The swale-like shape is pleasing and may best fit site conditions.

Trapezoidal grass channels are used where runoff volumes are large and slope is low so that velocities are nonerosive to vegetated linings.

Subsurface drainage, or riprap channel bottoms, may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or high water tables (Practice 6.81, *Subsurface Drain* and Practice 6.31, *Riprap-lined and Paved Channels*).

OUTLETS
Outlets must be stable. Where channel improvement ends, the exit velocity for the design flow must be nonerosive for the existing field conditions. Stability conditions beyond the property boundary should always be considered (Practice 6.41, *Outlet Stabilization Structure*).

AREA
Where urban drainage area exceeds 10 acres, it is recommended that grass-lined channels be designed by an engineer experienced in channel design.

Design Criteria

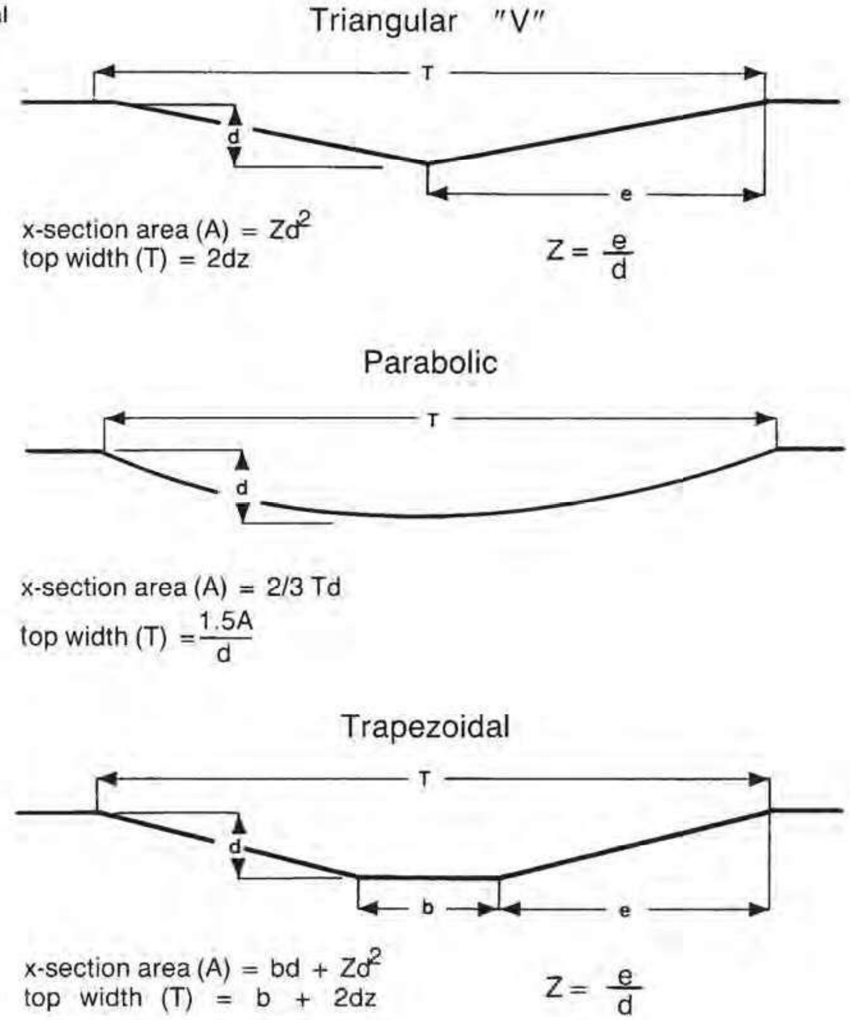
Capacity—At a minimum, grass-lined channels should carry peak runoff from the 10-year storm without eroding. Where flood hazard exists, increase the capacity according to the potential damage. Channel dimensions may be determined by using design tables with appropriate retardance factors or by Manning's formula using an appropriate "n" value. When retardance factors are used, the capacity is usually based on retardance "C" and stability on retardance "D" (*References: Appendix, 8.05*).

Velocity—The allowable design velocity for grass-lined channels is based on soil conditions, type of vegetation, and method of establishment (Table 8.05a, *Appendix 8.05*).

If design velocity of a channel to be vegetated by seeding exceeds 2 ft/sec, a temporary channel liner is required. The design of the liner may be based on peak flow from a 2-year storm. If vegetation is established by sodding, the permissible velocity for established vegetation shown in Table 8.05a may be used and no temporary liner is needed. Whether a temporary lining is required or not permanent channel linings must be stable for the 10-year storm. A design approach based on erosion resistance of various liner materials developed by the Federal Highway Administration is presented in *Appendix 8.05*.

Cross section—The channel shape may be parabolic, trapezoidal, or V-shaped, depending on need and site conditions (Figure 6.30a).

Figure 6.30a Cross section geometry of triangular, parabolic, and trapezoidal channels.



Hydraulic grade line—Examine the design water surface if the channel system becomes complex.

Side slopes—Grassed channel side slopes generally are constructed 3:1 or flatter to aid in the establishment of vegetation and for maintenance. Side slopes of V-shaped channels are usually constructed 6:1 or flatter along roadways for safety.

Depth and width—The channel depth and width are proportioned to meet the needs of drainage, soil conditions, erosion control, carrying capacity, and site conditions. Construct channels a minimum of 0.2 foot larger around the periphery to allow for soil bulking during seedbed preparations and sod buildup.

Grade—Either a uniform or gradually increasing grade is preferred to avoid sedimentation. Where the grade is excessive, grade stabilization structures may be required or channel linings of riprap or paving should be considered (Practice 6.82, *Grade Stabilization Structure*).

Drainage—Install subsurface drains in locations with high water tables or seepage problems that would inhibit establishment of vegetation in the channel. Stone channel bottom lining may be needed where prolonged low flow is anticipated.

Outlets—Evaluate the outlets of all channels for carrying capacity and stability, and protect them from erosion by limiting the exit velocity (Practice 6.41, *Outlet Stabilization Structure*).

Sedimentation protection—Protect permanent grass channels from sediment produced in the watershed, especially during the construction period. This can be accomplished by the effective use of diversions, sediment traps, protected side inlets, and vegetative filter strips along the channel.

Construction Specifications

1. Remove all trees, brush, stumps, and other objectionable material from the foundation area, and dispose of properly.

2. Excavate the channel, and shape it to neat lines and dimensions shown on the plans plus a 0.2-foot overcut around the channel perimeter to allow for bulking during seedbed preparations and sod buildup.

3. Remove and properly dispose of all excess soil so that surface water may enter the channel freely.

4. The procedure used to establish grass in the channel will depend upon the severity of the conditions and selection of species. Protect the channel with mulch or a temporary liner sufficient to withstand anticipated velocities during the establishment period (*Appendix 8.05*).

Maintenance

During the establishment period, check grass-lined channels after every rainfall. After grass is established, periodically check the channel; check it after every heavy rainfall event. Immediately make repairs. It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes. Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel (Practice 6.11, *Permanent Seeding*).

References

Surface Stabilization
6.11, Permanent Seeding
6.12, Sodding
6.14, Mulching

Outlet Protection
6.41, Outlet Stabilization Structure

Other Related Practices
6.81, Subsurface Drain
6.82, Grade Stabilization Structure

Appendices
8.02, Vegetation Tables
8.03, Estimating Runoff
8.05, Design of Stable Channels and Diversions

6.41

OUTLET STABILIZATION STRUCTURE

Definition

A structure designed to control erosion at the outlet of a channel or conduit.

Purpose

To prevent erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating energy.

Conditions Where Practice Applies

This practice applies where the discharge velocity of a pipe, box culvert, diversion, open channel, or other water conveyance structure exceeds the permissible velocity of the receiving channel or disposal area.

Planning Considerations

The outlets of channels, conduits, and other structures are points of high erosion potential because they frequently carry flows at velocities that exceed the allowable limit for the area downstream. To prevent scour and undermining, an outlet stabilization structure is needed to absorb the impact of the flow and reduce the velocity to non-erosive levels. A riprap-lined apron is the most commonly used practice for this purpose because of its relatively low cost and ease of installation. The riprap apron should be extended downstream until stable conditions are reached even though this may exceed the length calculated for design velocity control.

Riprap-stilling basins or plunge pools reduce flow velocity rapidly. They should be considered in lieu of aprons where pipe outlets are cantilevered or where high flows would require excessive apron length (Figure 6.41a). Consider other energy dissipaters such as concrete impact basins or paved outlet structures where site conditions warrant.

Alternative methods of energy dissipation can be found in Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular No. 14, U.S. Department of Transportation, Federal Highway Administration.

The installation of a culvert in a stream is subject to the conditions of a U.S. Army Corps of Engineers 404 Permit and a N.C. Division of Water Quality 401 Certification. These permit conditions may not allow the use of a riprap apron, and may require that the bottom of the culvert be buried below the natural stream bed elevation. A pre-formed scour pool or plunge pool should be considered in these situations. Plunge pool designs in streams should not use a cantilevered outlet because it would pose a barrier to migration of aquatic life through the culvert. Reducing the outlet velocity may require a combination of techniques, including a culvert with a flat bottom, a downstream cross vane to create tail-water at the pipe outlet, and/or a preformed scour pool.

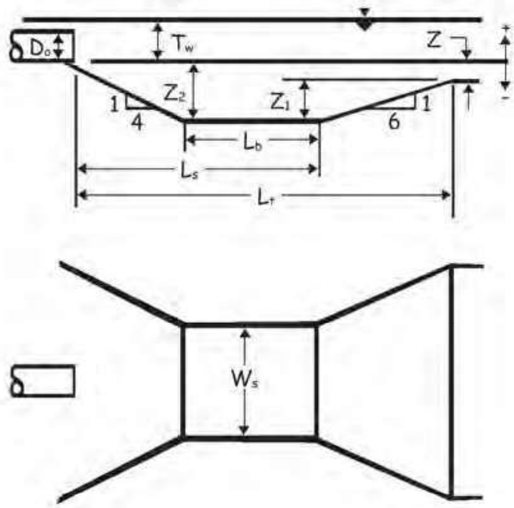
Design Criteria

Capacity—10-year, peak runoff or the design discharge of the water conveyance structure, whichever is greater.

Tail-water depth—Determine the tail-water depth immediately below the culvert or pipe outlet based on the design discharge. The ratio of tail-water depth to pipe diameter must be determined in order to select the appropriate riprap apron or plunge pool design method.

Plunge Pools—Two plunge pool methods are presented in Appendix 8.06, the USDA Plunge Pool Design at Submerged Pipe Spillway Outlets, and the USDA Riprap Lined Plunge Pool for Cantilevered Outlet. Software from the Federal Highway Administration can be downloaded at http://www.fhwa.dot.gov/engineering/hydraulics/software.cfm. Excel spreadsheets for the USDA methods are available through the Land Quality web-site at http://www.dlr.enr.state.nc.us/pages/links.htm.

Figure 6.41a Typical plunge pool design showing variable dimensions.



Riprap Aprons size—The apron length and width can be determined according to the tail-water condition. If the water conveyance structure discharges directly into a well-defined channel, extend the apron across the channel bottom and up the channel banks to an elevation of 0.5 foot above the maximum tail-water depth or to the top of the bank, whichever is less (Figure 6.41c).

Determine the maximum allowable velocity for the receiving stream, and design the riprap apron to reduce flow to this velocity before flow leaves the apron. Calculate the apron length for velocity control or use the length required to meet stable conditions downstream, whichever is greater.

Grade—Ensure that the apron has zero grade. There should be no overfall at the end of the apron; that is, the elevation of the top of the riprap at the downstream end should be the same as the elevation of the bottom of the receiving channel or the adjacent ground if there is no channel.

Alignment—The apron should be straight throughout its entire length, but if a curve is necessary to align the apron with the receiving stream, locate the curve in the upstream section of riprap.

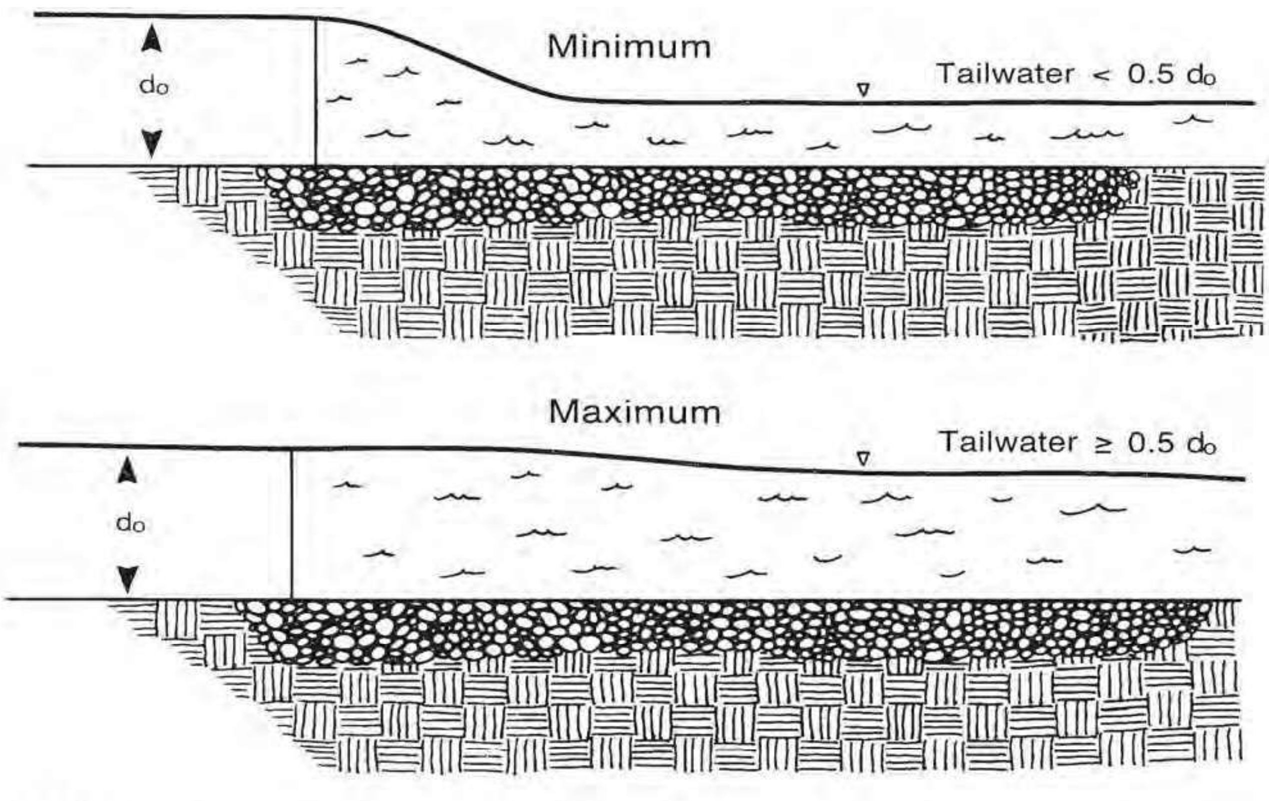


Figure 6.41b Stage showing maximum and minimum tailwater condition.

Materials—Ensure that riprap consists of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be no greater than 1.5 times the d_{50} size.

Thickness—Make the minimum thickness of riprap 1.5 times the maximum stone diameter.

Stone quality—Select stone for riprap from field stone or quarry stone. The stone should be hard, angular, and highly weather-resistant. The specific gravity of the individual stones should be at least 2.5.

Filter—Install a filter to prevent soil movement through the openings in the riprap. The filter should consist of a graded gravel layer or a synthetic filter cloth. Design filter blankets by the method described in Practice 6.15, *Riprap*.

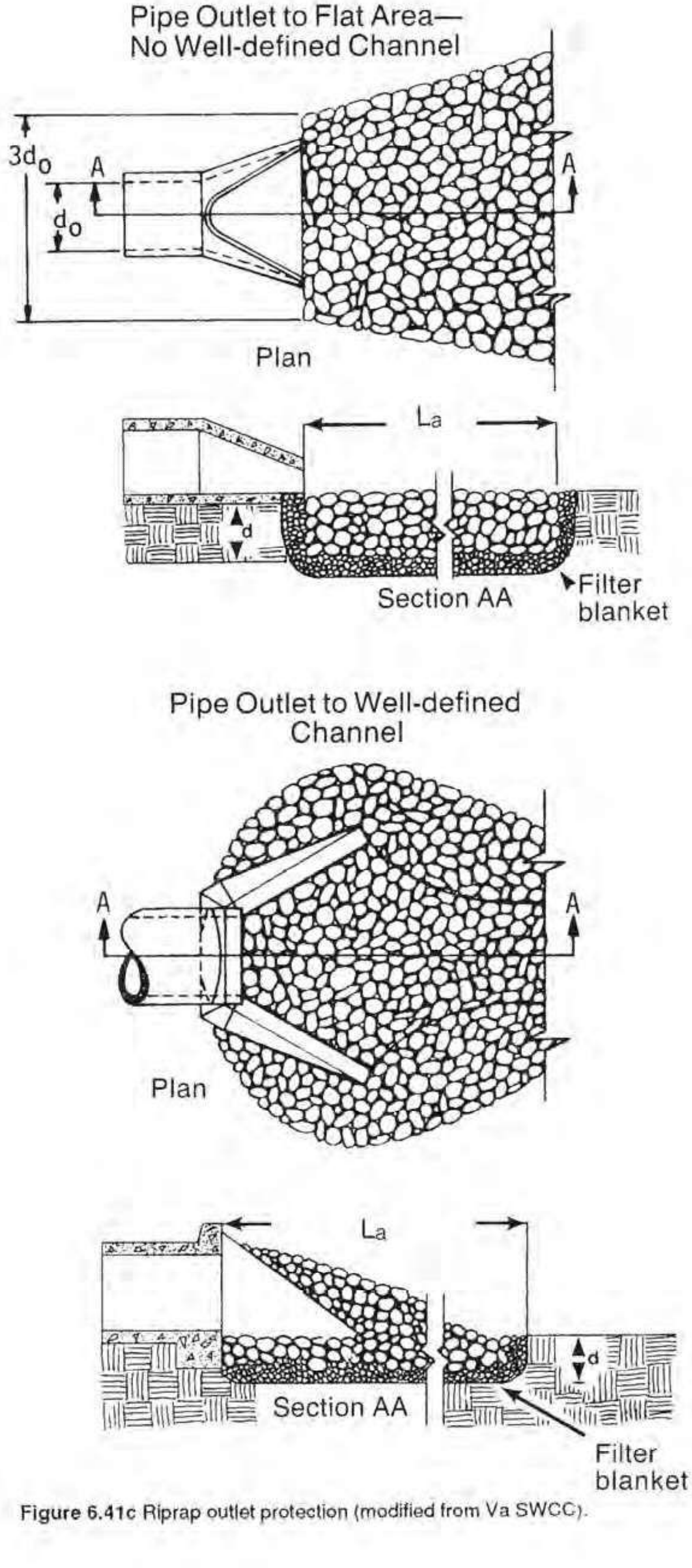


Figure 6.41c Riprap outlet protection (modified from Va SWCC).

Notes

1. L_a is the length of the riprap apron.
2. d = 1.5 times the maximum stone diameter but not less than 6″.
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6″ above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.

Construction Specifications

1. Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Compact any fill required in the subgrade to the density of the surrounding undisturbed material. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.

2. The riprap and gravel filter must conform to the specified grading limits shown on the plans.

3. Filter cloth, when used, must meet design requirements and be properly protected from punching or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap so the top layer is above the downstream layer a minimum of 1 foot. If the damage is extensive, replace the entire filter cloth.

4. Riprap may be placed by equipment, but take care to avoid damaging the filter.

5. The minimum thickness of the riprap should be 1.5 times the maximum stone diameter.

6. Riprap may be field stone or rough quarry stone. It should be hard, angular, highly weather-resistant and well graded.

7. Construct the apron on zero grade with no overfill at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.

8. Ensure that the apron is properly aligned with the receiving stream and preferably straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron.

9. Immediately after construction, stabilize all disturbed areas with vegetation (Practices 6.10, *Temporary Seeding*, and 6.11, *Permanent Seeding*).

Maintenance

Inspect riprap outlet structures weekly and after significant (1/2 inch or greater) rainfall events to see if any erosion around or below the riprap has taken place, or if stones have been dislodged. Immediately make all needed repairs to prevent further damage.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.15, Riprap

Appendix
8.06, Design of Riprap Outlet Protection

Rice, C.E., Kadavy, K.C "Riprap Design for Pipe Spillways at $-1 \leq TW/D \leq 0.7$" Presented at the December 13, 1994 International Winter Meeting, American Society of Agricultural Engineers, Paper Number 942541.

Rice, C.E. and K.C. Kadavy. 1994, Plunge Pool Design at Submerged Pipe Spillway Outlets. Transactions of the ASAE 37(4):1167-1173.

FHWA. 1983. Hydralic Design of Energy Dissipaters for Culverts and Channels. Hydraulic Engineering Circular Number 14.

6.55

ROCK PIPE INLET PROTECTION

Definition

A horseshoe shaped rock dam structure at a pipe inlet with a sediment storage area around the outside perimeter of the structure.

Purpose

To prevent sediment from entering, accumulating in and being transferred by a culvert or storm drainage system prior to stabilization of the disturbed drainage area. This practice allows early use of the storm drainage system.

Conditions Where Practice Applies

Rock pipe inlet protection may be used at pipes with a maximum diameter of 36 inches. This inlet protection may be used to supplement additional sediment traps or basins at the pipe outlet, or used in combination with an excavated sediment storage area to serve as a temporary sediment trap. Pipe inlet protection should be provided to protect the storm drainage system and downstream areas from sedimentation until permanent stabilization of the disturbed drainage area.

Do not install this measure in an intermittent or perennial stream.

Planning Considerations

When construction on a project reaches a stage where culverts and other storm drainage structures are installed and many areas are brought to the desired grade, there is a need to protect the points where runoff can leave the site through culverts or storm drains. Similar to drop and curb inlets, culverts receiving runoff from disturbed areas can convey large amounts of sediment to lakes or streams. Even if the pipe discharges into a sediment trap or basin, the pipe or pipe system itself may clog with sediment.

Design Criteria

When used in combination with an excavated sediment storage area to serve as a temporary sediment trap, the design criteria for temporary sediment traps must be satisfied. The maximum drainage area should be 5 acres, and 3600 cubic feet of sediment storage per acre of disturbed drainage area should be provided.

The minimum stone height should be 2 feet, with side slopes no steeper than 2:1. The stone “horseshoe” around the pipe inlet should be constructed of Class B or Class I riprap, with a minimum crest width of 3 feet. The outside face of the riprap should be coved with a 12-inch thick layer of #5 or #57 washed stone.

In preparing plans for rock pipe inlet protection, it is important to protect the embankment over the pipe from overtopping. The top of the stone should be a minimum of 1 foot below the top of the fill over the pipe. The stone should tie into the fill on both sides of the pipe. The inside toe of the stone should be no closer than 2 feet from the culvert opening to allow passage of high flows.

The sediment storage area should be excavated upstream of the rock pipe inlet protection, with a minimum depth of 18 inches below grade.

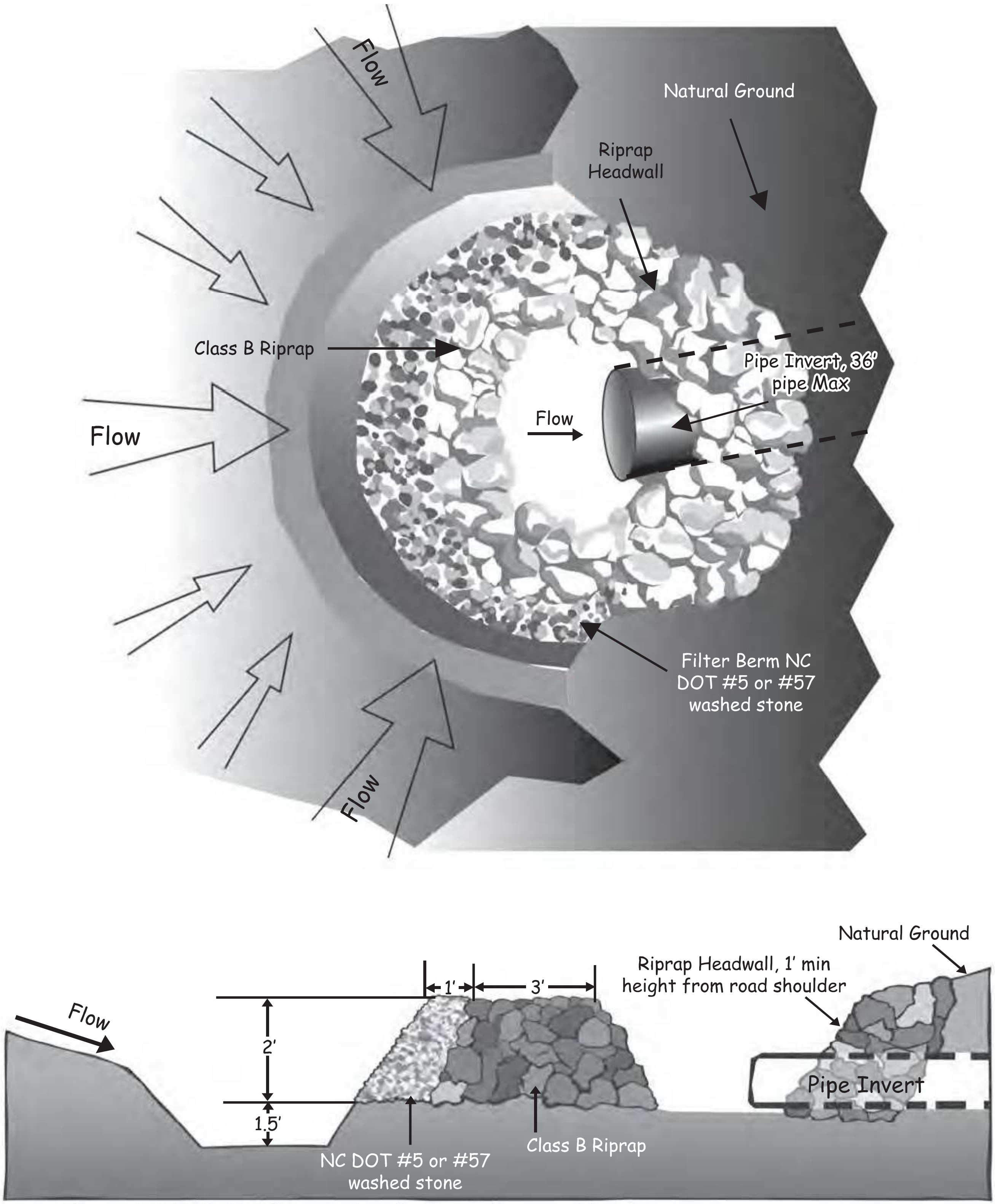


Figure 6.55a Rock pipe inlet protection plan view and cross-section view

Construction Specifications

1. Clear the area of all debris that might hinder excavation and disposal of spoil.

2. Install the Class B or Class I riprap in a semi-circle around the pipe inlet. The stone should be built up higher on each end where it ties into the embankment. The minimum crest width of the riprap should be 3 feet, with a minimum bottom width of 11 feet. The minimum height should be 2 feet, but also 1 foot lower than the shoulder of the embankment or diversions.

3. A 1 foot thick layer of NC DOT #5 or #57 stone should be placed on the outside slope of the riprap.

4. The sediment storage area should be excavated around the outside of the stone horseshoe 18 inches below natural grade.

5. When the contributing drainage area has been stabilized, fill depression and establish final grading elevations, compact area properly, and stabilize with ground cover.

Maintenance

Inspect rock pipe inlet protection at least weekly and after each significant (½ inch or greater) rainfall event and repair immediately. Remove sediment and restore the sediment storage area to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Place the sediment that is removed in the designated disposal area and replace the contaminated part of the gravel facing.

Check the structure for damage. Any riprap displaced from the stone horseshoe must be replaced immediately.

After all the sediment-producing areas have been permanently stabilized, remove the structure and all the unstable sediment. Smooth the area to blend with the adjoining areas and provide permanent ground cover (*Surface Stabilization*).

References

Inlet protection
6.52, Block and Gravel Inlet Protection (Temporary)

Sediment Trap and Barriers
6.60, Temporary Sediment Trap

Surface Stabilization
6.15, Riprap

North Carolina Department of Transportation
Erosion & Sedimentation Guidelines for Division Maintenance Operation, 1993.

Virginia Erosion and Sediment Control Handbook. 1992. STD & SPEC 3.08, Culvert Inlet Protection. pages III-46 - III-51 (Culvert Inlets Sediment Trap).

6.61 **SEDIMENT BASIN**

Definition

An earthen embankment suitably located to capture sediment with a primary spillway system consisting of a riser and barrel pipe.

Purpose

To retain sediment on the construction site, and prevent sedimentation in off-site streams, lakes, and drainageways.

Conditions Where Practice Applies

Special limitation – This practice applies only to the design and installation of sediment basins where failure of the structure would not result in the loss of life, damage to homes or buildings, or interrupt the use of public roads or utilities. All high hazard potential dams and structures taller than 25 feet, and that also have a maximum storage capacity of 50 acre-feet or more are subject to the N.C. Dam Safety Law of 1967.

Sediment basins are needed where drainage areas exceed design criteria of other measures. Specific criteria for installation of a sediment basin are as follows:

- Keep the drainage area less than 100 acres;
- Ensure that basin location provides a convenient concentration point for sediment-laden flows from the area served;
- Ensure that basin location allows access for sediment removal and proper disposal under all weather conditions; and
- Keep the basin life limited to 3 years, unless it is designed as a permanent structure;

Do not locate sediment basins in intermittent or perennial streams.

Planning Considerations

Select key locations for sediment basins during initial site evaluation. Install basins before any land-disturbance takes place within the drainage area.

Select basin sites to capture sediment from all areas that are not treated adequately by other sediment controls. Always consider access for cleanout and disposal of the trapped sediment. Locations where a pond can be formed by constructing a low dam across a natural swale are generally preferred to sites that require excavation. Where practical, divert sediment-free runoff away from the basin.

Sediment trapping efficiency is primarily a function of sediment particle size and the ratio of basin surface area to inflow rate. Therefore, design the basin to have a large surface area for its volume. Figure 6.61a shows the relationship between the ratio of surface area to peak inflow rate and trap efficiency observed by Barfield and Clar (1986).

Sediment basins with an expected life greater than 3 years should be designed as permanent structures. Often sediment basins are converted to stormwater ponds. In these cases, the structure should be designed by a qualified professional engineer experienced in the design of dams. Permanent ponds and artificial lakes are beyond the scope of this practice standard. USDA Soil Conservation Services Practice Standard Ponds Code No. 378 provides criteria for design of permanent ponds.

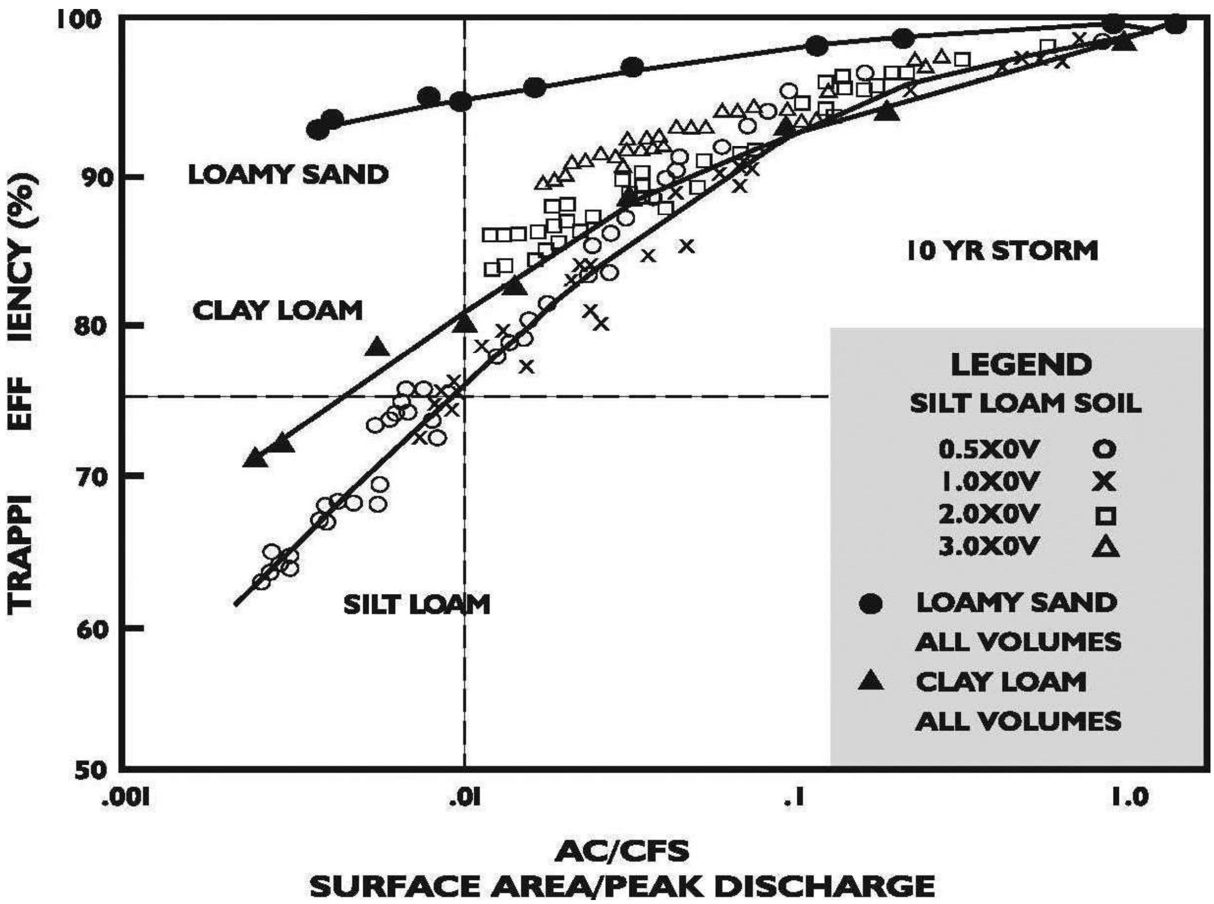


Figure 6.61a Relationship between the ratio of surface area to peak inflow rate and trap efficiency.

Design Criteria

Summary:	**Temporary Sediment Basin:**
Primary Spillway:	Riser/Barrel Pipe
Maximum Drainage Area:	100 acres
Minimum Sediment Storage Volume:	1800 cubic feet per acre of disturbed area
Minimum Surface Area:	435 square feet per cfs of Q_{10} peak inflow
Minimum L/W Ratio:	2:1
Maximum L/W Ratio:	6:1
Minimum Depth:	2 feet
Dewatering Mechanism:	Skimmer(s) attached at bottom of riser pipe or flashboard riser
Minimum Dewatering Time:	48 hours
Baffles Required:	3 baffles*

(*Note: Basins less than 20 feet in length may use 2 baffles.)

Drainage areas- Limit drainage areas to 100 acres.

Design basin life- Ensure a design basin life of 3 years or less.

Dam height- Limit dam height to 15 feet. Height of a dam is measured from the top of the dam to the lowest point at the downstream toe. Volume is measured from the top of the dam when determining if the dam impounds enough water to be regulated by the Dam Safety Law.

Basin locations- Select areas that:

- Provide capacity for sediment storage from as much of the planned disturbed area as practical;
- Exclude runoff from undisturbed areas where practical;
- Provide access for sediment removal throughout the life of the project and;
- Interfere minimally with construction activities.

Basin shape- Ensure that the flow length to basin width ratio is at least 2:1 to improve trapping efficiency. This basin shape may be attained by site selection or excavation. Length is measured at the elevation of the principal spillway.

Storage volume- Ensure that the sediment storage volume of the basin, as measured to the elevation of the crest of the principal spillway, is at least 1,800 ft^3/acre for the disturbed area draining into the basin (1,800 ft^3 is equivalent to a ½ inch of sediment per acre of basin drainage area).

Remove sediment from the basin when approximately one-half of the storage volume has been filled.

Spillway capacity- The spillway system must carry the peak runoff from the 10-year storm with a minimum 1 foot freeboard in the emergency spillway.
Base runoff computations on the disturbed soil cover conditions expected during the effective life of the structure.

Principal spillway- Construct the principal spillway with a vertical riser connected to a horizontal barrel that extends through the embankment and outlets beyond the downstream toe of the dam, or an equivalent design.

- Capacity- The primary spillway system must carry the peak runoff from the 2-year storm, with the water surface at the emergency spillway crest elevation.

Sediment cleanout elevation- Show the distance from the top of the riser to the pool level when the basin is 50 percent full. This elevation should also be marked in the field with a permanent stake set at this ground elevation (not the top of the stake).

Crest elevation- Keep the crest elevation of the riser a minimum of 1 foot below the crest elevation of the emergency spillway.

Riser and Barrel- Keep the minimum barrel size at 15 inches for corrugated metal pipe or 12 inches for smooth wall pipe to facilitate installation and reduce potential for failure from blockage. Ensure that the pipe is capable of withstanding the maximum external loading without yielding, buckling or cracking. To improve the efficiency of the principal spillway system, make the cross-sectional area of the riser at least 1.5 times that of the barrel. The riser should be sized to minimize the range of stages when orifice flow will occur.

Pipe Connections- Ensure that all conduit connections are watertight. Rod and lug type connector bands with gaskets are preferred for corrugated metal pipe to assure watertightness under maximum loading and internal pressure. Do not use dimple (universal) connectors under any circumstances.

- **Trash guard-** It is important that a suitable trash guard be installed to prevent the riser and barrel pipes from becoming clogged. Install a trash guard on the top of the riser to prevent trash and other debris from clogging the conduit. A combination anti-vortex device and trash guard improves the efficiency of the principal spillway and protects against trash intake.

- **Protection against piping-** Install at least one watertight anti-seep collar with a minimum projection of 1.5 feet around the barrel of principal spillway conduits, 8 inches or larger in diameter. Locate the anti-seep collar slightly downstream from the dam center line. A properly designed drainage diaphragm installed around the barrel may be used instead of an anti-seep collar when it is appropriate.
- **Protection against flotation-** Secure the riser by an anchor with buoyant weight greater than 1.1 times the water displaced by the riser.
- **Outlet-** Protect the outlet of barrel against erosion.

Discharge velocities must be within allowable limits for the receiving stream (*References: Outlet Protection*).

Basin dewatering- The basin should be provided with a mechanism to dewater the basin from the water surface. Previously sediment basins were dewatered with a perforated riser. These were designed to dewater relatively quickly and draw water from the entire water column. Dewatering from the surface provides greater trapping efficiency. Two common methods are a skimmer and flashboard riser.

- Skimmer- A floating skimmer should be attached to the base of the riser. The orifice in the skimmer will control the rate of dewatering. The skimmer should be sized to dewater the basin in 2-5 days. A chart to determine the appropriate skimmer and orifice size is included on page 6.64.3. See Practice 6.64, *Skimmer Basins* for details on the installation of skimmers.

Figure 6.61b Sediment basin with skimmer attached to riser for dewatering.
Photo Credit: Town of Apex

- Flashboard Riser**-** A different approach is to use a flashboard riser, which forces the basin to fill to a given level before the water tops the riser. In this way it is similar to a solid riser, but with the option of being able to lower the water level in the basin when accumulated sediment must be removed. Flashboard risers are usually fabricated as a box or as a riser pipe cut in half. The open face has slots on each side into which boards or "stop logs" are placed, forcing the water up and over them. This device should be sized the same way as a typical riser.

  Forcing the water to exit the sediment basin from the top of the water column has the same advantages in sediment capture as the skimmer. A flashboard riser basin will have an adjustable, permanent pool which also improves basin efficiency. This method is a disadvantage when the sediment needs to be removed because the operator may need to remove the boards down to the sediment level to drain the basin. Flashboard risers are a good option for stilling basins for pump discharges, or when sandy soil conditions will allow dewatering of the basin through infiltration. They should not be selected when the basin will have to be cleaned frequently, or when located in clay soils.

Figure 6.61c Flashboard Riser installation example.
Photo credit: NC State University

Emergency spillway- Construct the entire flow area of the emergency spillway in undisturbed soil (not fill). Make the cross section trapezoidal with side slopes of 3:1 or flatter. Make the control section of the spillway straight and at least 20 feet long. The inlet portion of the spillway may be curved to improve alignment, but ensure that the outlet section is straight due to supercritical flow in this portion.

- Capacity- The minimum design capacity of the emergency spillway must be the peak rate of runoff from the 10-year storm, less any reduction due to flow in the principal spillway. In no case should freeboard of the emergency spillway be less than 1 foot above the design depth of flow.
- Velocity- Ensure that the velocity of flow discharged from the basin is non-erosive for the existing conditions. When velocities exceed that allowable for the receiving areas, provide outlet protection (*References: Outlet Protection*).

Embankment-

- Cut-off trench- Excavate a trench at the center line of the embankment. Ensure that the trench is in undisturbed soil and extends through the length of the embankment to the elevation of the riser crest at each end. A minimum of depth of 2 feet is recommended.
- Top width- The minimum top width of the dam is shown in Table 6.61a.
- Freeboard- Ensure that the minimum difference between the design water elevation in the emergency spillway and the top of the settled embankment is 1 foot.
- Side slopes- Make the side slopes of the impoundment structure 2.5:1 or flatter (Figure 6.61d).
- Allowance for settlement- Increase the constructed height of the fill at least 10 percent above the design height to allow for settlement.
- Erosion protection- Stabilize all areas disturbed by construction (except the lower ½ of the sediment pool) by suitable means immediately after completing the basin (*References: Surface Stabilization*).

Design information included in the Appendices may be used to develop final plans for sediment basins (*References: Appendices*).

Trap efficiency- Improve sediment basin trapping efficiency by employing the following considerations in the basin design:

- Surface area- In the design of the settling pond, allow the largest surface area possible. Studies of Barfield and Clar (1986) indicate that surface area (in acres) should be larger than 0.01 times the peak inflow rate in cfs, or 435 sq. ft. per cfs of peak flow.
- Length- The length to width ratio should be between 2:1 to 6:1.

Table 6.61a
Acceptable Dimensions for Basin Embankment

Fill Height	Minimum Top Width
less than 10 ft	8.0 ft
10 ft to 15 ft	10.0 ft

- Baffles- Provides a minimum of three porous baffles to evenly distribute flow across the basin and reduces turbulence. Basins less than 20 feet in length may use 2 baffles .
- Inlets- Locate the sediment inlets to the basin the greatest distance from the principal spillway.
- Dewatering- Allow the maximum reasonable detention period before the basin is completely dewatered-at least 48 hours.
- Inflow rate- Reduce the inflow velocity and divert all sediment-free runoff.

Construction Specifications

1. Site preparations- Clear, grub, and strip topsoil from areas under the embankment to remove trees, vegetation, roots, and other objectionable material. Delay clearing the pool area until the dam is complete and then remove brush, trees, and other objectionable materials to facilitate sediment cleanout. Stockpile all topsoil or soil containing organic matter for use on the outer shell of the embankment to facilitate vegetative establishment. Place temporary sediment control measures below the basin as needed.

2. Cut-off trench- Excavate a cut-off trench along the center line of the earth fill embankment. Cut the trench to stable soil material, but in no case make it less than 2 feet deep. The cut-off trench must extend into both abutments to at least the elevation of the riser crest. Make the minimum bottom width wide enough to permit operation of excavation and compaction equipment, but in no case less than 2 feet. Make side slopes of the trench no steeper than 1:1. Compaction requirements are the same as those for the embankment. Keep the trench dry during backfilling and compaction operations.

3. Embankment- Take fill material from the approved areas shown on the plans. It should be clean mineral soil, free of roots, woody vegetation, rocks, and other objectionable material. Scarify areas on which fill is to be placed before placing fill. The fill material must contain sufficient moisture so 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. Place fill material in 6 to 8 inch continuous layers over the entire length of the fill area and compact it. Compaction may be obtained by routing the construction hauling equipment over the fill so that the entire surface of each layer is traversed by at least one wheel or tread track of heavy equipment, or a compactor may be used. Construct the embankment to an elevation 10 percent higher than the design height to allow for settling.

4. Conduit spillways- Securely attach the riser to the barrel or barrel stub to make a watertight structural connection. Secure all connections between barrel sections by approved watertight assemblies. Place the barrel and riser on a firm, smooth foundation of impervious soil. Do not use pervious material such as sand, gravel, or crushed stone as backfill around the pipe or anti-seep collars. Place the fill material around the pipe spillway in 4-inch layers, and compact it under and around the pipe to at least the same density as the adjacent embankment. **Care must be taken not to raise the pipe from firm contact with its foundation when compacting under the pipe haunches.**

Place a minimum depth of 2 feet of compacted backfill over the pipe spillway before crossing it with construction equipment. Anchor the riser in place by concrete or other satisfactory means to prevent flotation. In no case should the pipe conduit be installed by cutting a trench through the dam after the embankment is complete.

5. Emergency spillway**-** Install the emergency spillway in undisturbed soil. The achievement of planned elevations, grade, design width, and entrance and exit channel slopes are critical to the successful operation of the emergency spillway.

6. Inlets**-** Discharge water into the basin in a manner to prevent erosion. Use diversions with outlet protection to divert sediment-laden water to the upper end of the pool area to improve basin trap efficiency (*References: Runoff Control Measures and Outlet Protection*).

7. Erosion control**-** Construct the structure so that the disturbed area is minimized. Divert surface water away from bare areas. Complete the embankment before the area is cleared. Stabilize the emergency spillway embankment and all other disturbed areas above the crest of the principal spillway immediately after construction (*References: Surface Stabilization*).

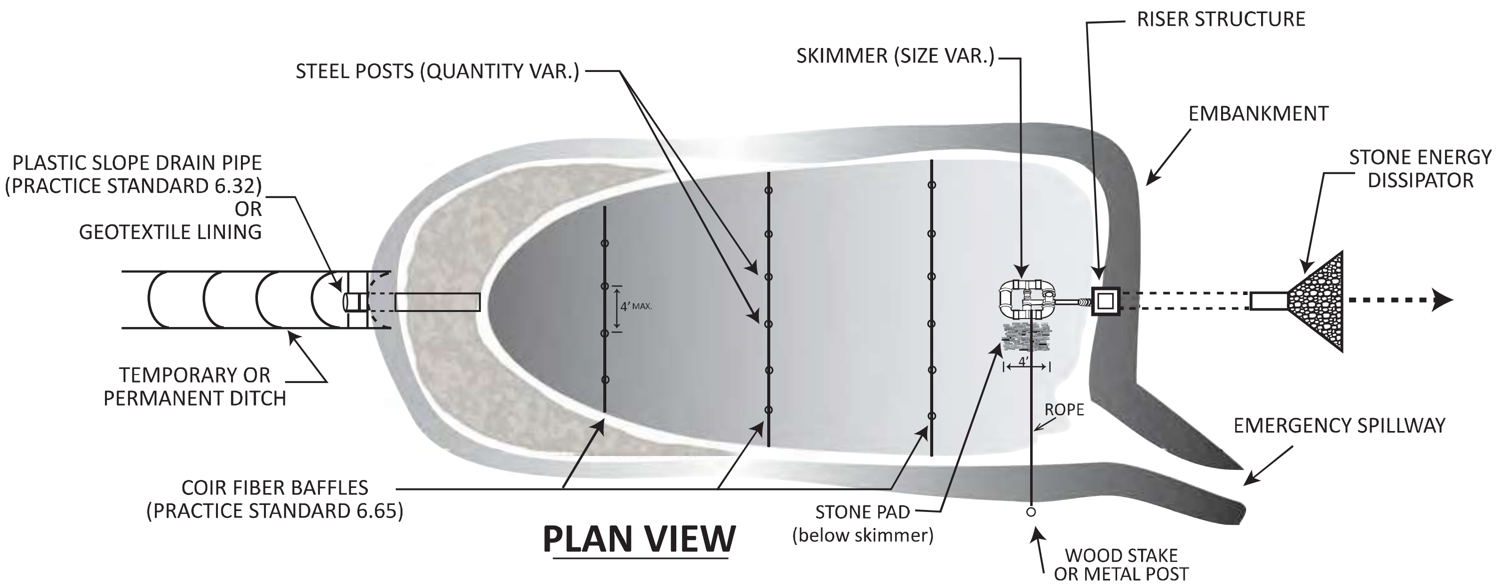
8. Install porous baffles as specified in Practice 6.65, Porous Baffles.

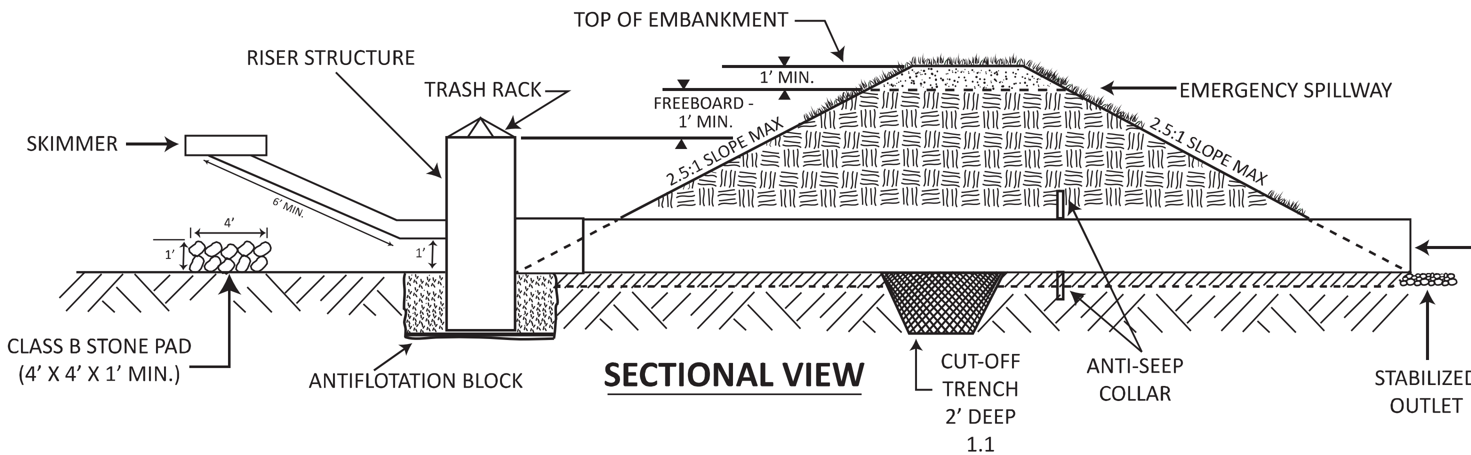
9. Safety**-** Sediment basins may attract children and can be dangerous. Avoid steep side slopes, and fence and mark basins with warning signs if trespassing is likely. **Follow all state and local requirements.**

Maintenance

Inspect temporary sediment basins at least weekly and after each significant (1/2 inch or greater) rainfall event and repair immediately. Remove sediment and restore the basin to its original dimensions when it accumulates to one-half the design depth. Place removed sediment in an area with sediment controls.

Check the embankment, spillways, and outlet for erosion damage, and inspect the embankment for piping and settlement. Make all necessary repairs immediately. Remove all trash and other debris from the riser and pool area.





NOTES

1. SEED AND PLACE MATTING FOR EROSION CONTROL ON INTERIOR AND EXTERIOR SIDESLOPES.
2. INSTALL A MINIMUM OF 3 COIR FIBER BAFFLES IN ACCORDANCE WITH PRACTICE STANDARD 6.65.
3. INSTALL SKIMMER AND COUPLING TO RISER STRUCTURE OR DIRECTLY INTO EMBANKMENT 1 FT. FROM BOTTOM OF BASIN.
4. THE ARM PIPE SHALL HAVE A MINIMUM LENGTH OF 6 FT. BETWEEN THE SKIMMER AND COUPLING.

NOT TO SCALE

Figure 6.61d Sediment Basin (with Riser Barrel Pipe)

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.12, Sodding
6.13, Trees, Shrubs, Vines, and Ground Covers

Runoff Control Measures
6.20, Temporary Diversions
6.21, Permanent Diversions
6.22, Perimeter Dike

Outlet Protection
6.40, Level Spreader
6.41, Outlet Stabilization Structure

Sediment Traps and Barriers
6.64, Skimmer Sediment Basin
6.65, Porous Baffles

Appendices
8.01, Soil Information
8.02, Vegetation Tables
8.03, Estimating Runoff
8.04, Estimating Roughness Coefficients
8.05, Design of Stable Channels and Diversions
8.06, Design of Riprap Outlet Protection
8.07, Sediment Basin Design
8.08, The Sediment Control Law

Barfield, B.J. and M.L. Clar. Erosion and Sediment Control Practices. Report to the Sediment and Stormwater Division – Maryland Water Resources Administration, 1986.

6.62

SEDIMENT FENCE

Definition

A temporary sediment control measure consisting of fabric buried at the bottom, stretched, and supported by posts.

Purpose

To retain sediment from small disturbed areas by reducing the velocity of sheet flows to allow sediment deposition.

Conditions Where Practice Applies

Below small-disturbed areas that are less then ¼ acre per 100 feet of fence.

Where runoff can be stored behind the sediment fence without damaging the fence or the submerged area behind the fence.

Do not install sediment fences across streams, ditches, or waterways, or other areas of concentrated flow.

Sediment fence should be placed along topographic elevation contours, where it can intercept stormwater runoff that is in dispersed sheet flow. Sediment fence should not be used alone below graded slopes greater than 10 feet in height.

Planning Considerations

A sediment fence is a system to retain sediment on the construction site. The fence retains sediment primarily by retarding flow and promoting deposition. In operation, generally the fence becomes clogged with fine particles, which reduce the flow rate. This causes a pond to develop behind the fence. The designer should anticipate ponding and provide sufficient storage areas and overflow outlets to prevent flows from overtopping the fence. Since sediment fences are not designed to withstand high water levels, locate them so that only shallow pools can form. Tie the ends of a sediment fence into higher ground to prevent flow around the end of the fence before the pool reaches design level. Curling each end of the fence uphill in a "J" pattern may be appropriate to prevent end flow. Provide stabilized outlets to protect the fence system and release storm flows that exceed the design storm.

Deposition occurs as the storage pool forms behind the fence. The designer can direct flows to specified deposition areas through appropriate positioning of the fence or by providing an excavated area behind the fence. Plan deposition areas at accessible points to promote routine cleanout and maintenance. Show deposition areas in the erosion and sedimentation control plan. A sediment fence acts as a diversion if placed slightly off the contour. A maximum slope of 2 percent is recommended. This technique may be used to control shallow, uniform flows from small disturbed areas and to deliver sediment-laden water to deposition areas. The anchoring of the toe of the fence should be reinforced with 12 inches of NC DOT #5 or #57 washed stone when flow will run parallel to the toe of the fence.

Sediment fences serve no function along ridges or near drainage divides where there is little movement of water. Confining or diverting runoff unnecessarily with a sediment fence may create erosion and sedimentation problems that would not otherwise occur.

Straw barriers have only a 0-20% trapping efficiency and are inadequate. Straw bales may not be used in place of sediment fence. Prefabricated sediment fence with the fabric already stapled to thin wooden posts does not meet minimum standards specified later in this section.

Anchoring of sediment fence is critical. The toe of the fabric must be anchored in a trench backfilled with compacted earth. Mechanical compaction must be provided in order for the fence to effectively pond runoff.

Design Criteria

Ensure that drainage area is no greater than ¼ acre per 100 feet of fence. This is the maximum drainage area when the slope is less than 2 percent. Where all runoff is to be stored behind the fence, ensure that the maximum slope length behind a sediment fence does not exceed the specifications shown in Table 6.62a. The shorter slope length allowed for steeper slopes will greatly reduce the maximum drainage area. For example, a 10–20 % slope may have a maximum slope length of 25 feet. For a 100-foot length of sediment fence, the drainage area would be 25ft X 100ft = 2500sq.ft., or 0.06 acres.

Table 6.62a Maximum Slope Length and Slope for which Sediment Fence is Applicable

Slope	Slope Length (ft)	Maximum Area (ft^2)
<2%	100	10,000
2 to 5%	75	7,500
5 to 10%	50	5,000
10 to 20%	25	2,500
>20%	15	1,500

Make the fence stable for the 10-year peak storm runoff.

Ensure that the depth of impounded water does not exceed 1.5 feet at any point along the fence.

If non-erosive outlets are provided, slope length may be increased beyond that shown in Table 6.62a, but runoff from the area should be determined and bypass capacity and erosion potential along the fence must be checked. The velocity of the flow at the outlet or along the fence should be in keeping with Table 8.05d, Appendix 8.05.

Provide a riprap splash pad or other outlet protection device for any point where flow may overtop the sediment fence, such as natural depressions or swales. Ensure that the maximum height of the fence at a protected, reinforced outlet does not exceed 2 feet and that support post spacing does not exceed 4 feet.

The design life of a synthetic sediment fence should be 6 months.

Construction Specifications

MATERIALS

1. Use a synthetic filter fabric of at least 95% by weight of polyolefins or polyester, which is certified by the manufacturer or supplier as conforming to the requirements in ASTM D 6461, which is shown in part in Table 6.62b.

Synthetic filter fabric should contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months of expected usable construction life at a temperature range of 0 to 120º F.

2. Ensure that posts for sediment fences are 1.25 lb/linear ft minimum steel with a minimum length of 5 feet. Make sure that steel posts have projections to facilitate fastening the fabric.

3. For reinforcement of standard strength filter fabric, use wire fence with a minimum 14 gauge and a maximum mesh spacing of 6 inches.

Table 6.62b Specifications For Sediment Fence Fabric

Temporary Silt Fence Material Property Requirements					
	Test Material	Units	Supported[1] Silt Fence	Un-Supported[1] Silt Fence	Type of Value
Grab Strength	ASTM D 4632	N (lbs)			
Machine Direction			400	550	MARV
			(90)	(90)	
X-Machine Direction			400	450	MARV
			(90)	(90)	
Permittivity[2]	ASTM D 4491	sec-1	0.05	0.05	MARV
Apparent Opening Size[2]	ASTM D 4751	mm	0.60	0.60	Max. ARV[3]
		(US Sieve #)	(30)	(30)	
Ultraviolet Stability	ASTM D 4355	% Retained Strength	70% after 500h of exposure	70% after 500h of exposure	Typical

[1] Silt Fence support shall consist of 14 gage steel wire with a mesh spacing of 150 mm (6 inches), or prefabricated poylmer mesh of equivalent strength.
[2] These default values are based on empirical evidence with a variety of sediment. For environmentally sensitive areas, a review of previous experience and/or site or regionally specific geotextile tests in accordance with Test Method D 5141 should be performed by the agency to confirm suitability of these requirements.
[3] As measured in accordance with Test Method D 4632.

CONSTRUCTION

1. Construct the sediment barrier of standard strength or extra strength synthetic filter fabrics.

2. Ensure that the height of the sediment fence does not exceed 24 inches above the ground surface. (Higher fences may impound volumes of water sufficient to cause failure of the structure.)

3. Construct the filter fabric from a continuous roll cut to the length of the barrier to avoid joints. When joints are necessary, securely fasten the filter cloth only at a support post with 4 feet minimum overlap to the next post.

4. Support standard strength filter fabric by wire mesh fastened securely to the **upslope** side of the posts. Extend the wire mesh support to the bottom of the trench. Fasten the wire reinforcement, then fabric on the upslope side of the fence post. Wire or plastic zip ties should have minimum 50 pound tensile strength.

5. When a wire mesh support fence is used, space posts a maximum of 8 feet apart. Support posts should be driven securely into the ground a minimum of 24 inches.

6. Extra strength filter fabric with 6 feet post spacing does not require wire mesh support fence. Securely fasten the filter fabric directly to posts. Wire or plastic zip ties should have minimum 50 pound tensile strength.

7. Excavate a trench approximately 4 inches wide and 8 inches deep along the proposed line of posts and upslope from the barrier (Figure 6.62a).

8. Place 12 inches of the fabric along the bottom and side of the trench.

9. Backfill the trench with soil placed over the filter fabric and compact. Thorough compaction of the backfill is critical to silt fence performance.

10. Do not attach filter fabric to existing trees.

SEDIMENT FENCE INSTALLATION USING THE SLICING METHOD

Instead of excavating a trench, placing fabric and then backfilling trench, sediment fence may be installed using specially designed equipment that inserts the fabric into a cut sliced in the ground with a disc (Figure 6.62b).

Installation Specifications

1. The base of both end posts should be at least one foot higher than the middle of the fence. Check with a level if necessary.

2. Install posts 4 feet apart in critical areas and 6 feet apart on standard applications.

3. Install posts 2 feet deep on the downstream side of the silt fence, and as close as possible to the fabric, enabling posts to support the fabric from upstream water pressure.

4. Install posts with the nipples facing away from the silt fabric.

5. Attach the fabric to each post with three ties, all spaced within the top 8 inches of the fabric. Attach each tie diagonally 45 degrees through the fabric, with each puncture at least 1 inch vertically apart. Also, each tie should be positioned to hang on a post nipple when tightened to prevent sagging.

6. Wrap approximately 6 inches of fabric around the end posts and secure with 3 ties.

7. No more than 24 inches of a 36 inch fabric is allowed above ground level.

8. The installation should be checked and corrected for any deviations before compaction.

9. Compaction is vitally important for effective results. Compact the soil immediately next to the silt fence fabric with the front wheel of the tractor, skid steer, or roller exerting at least 60 pounds per square inch. Compact the upstream side first, and then each side twice for a total of 4 trips.

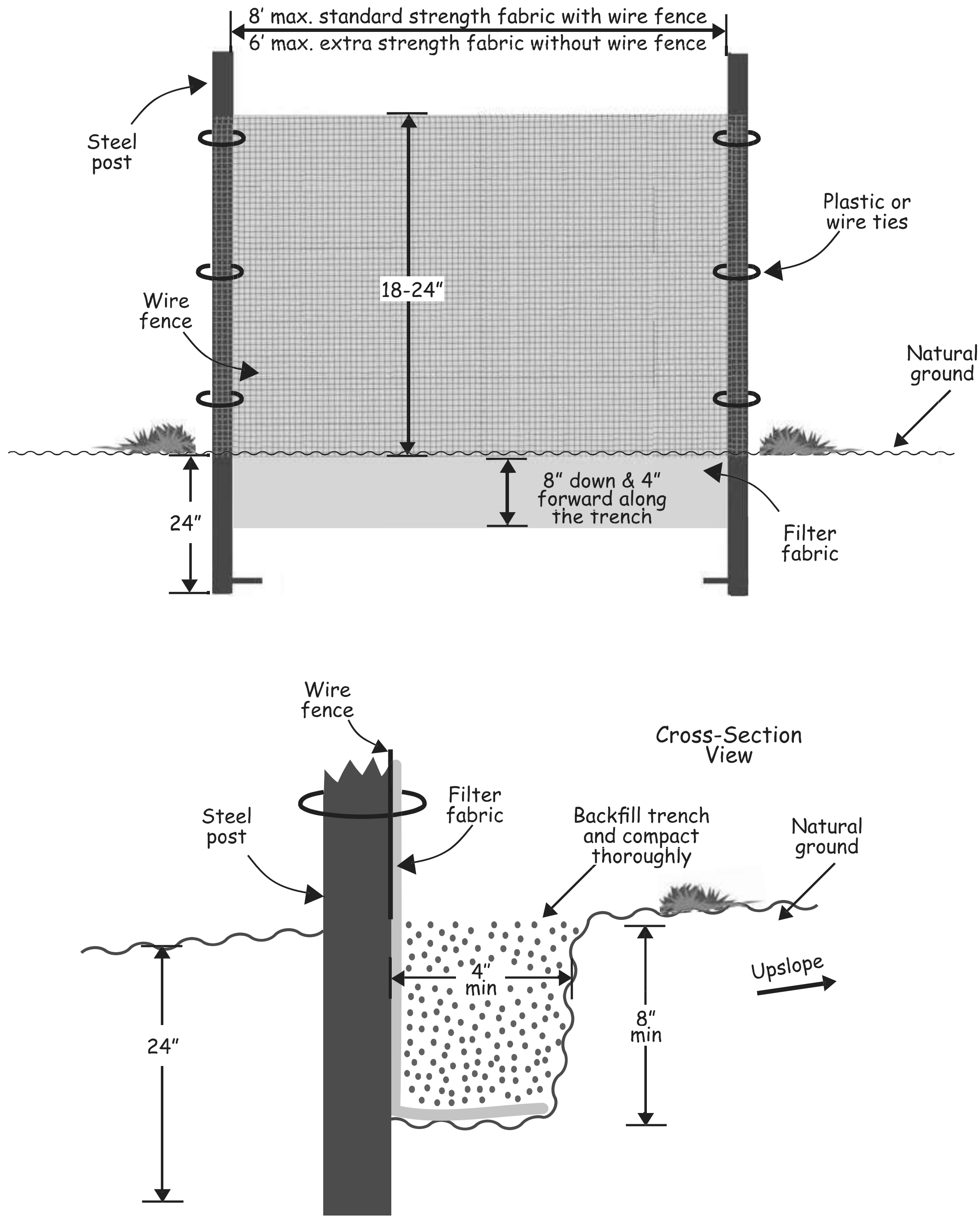


Figure 6.62a Installation detail of a sediment fence.

The Slicing Method

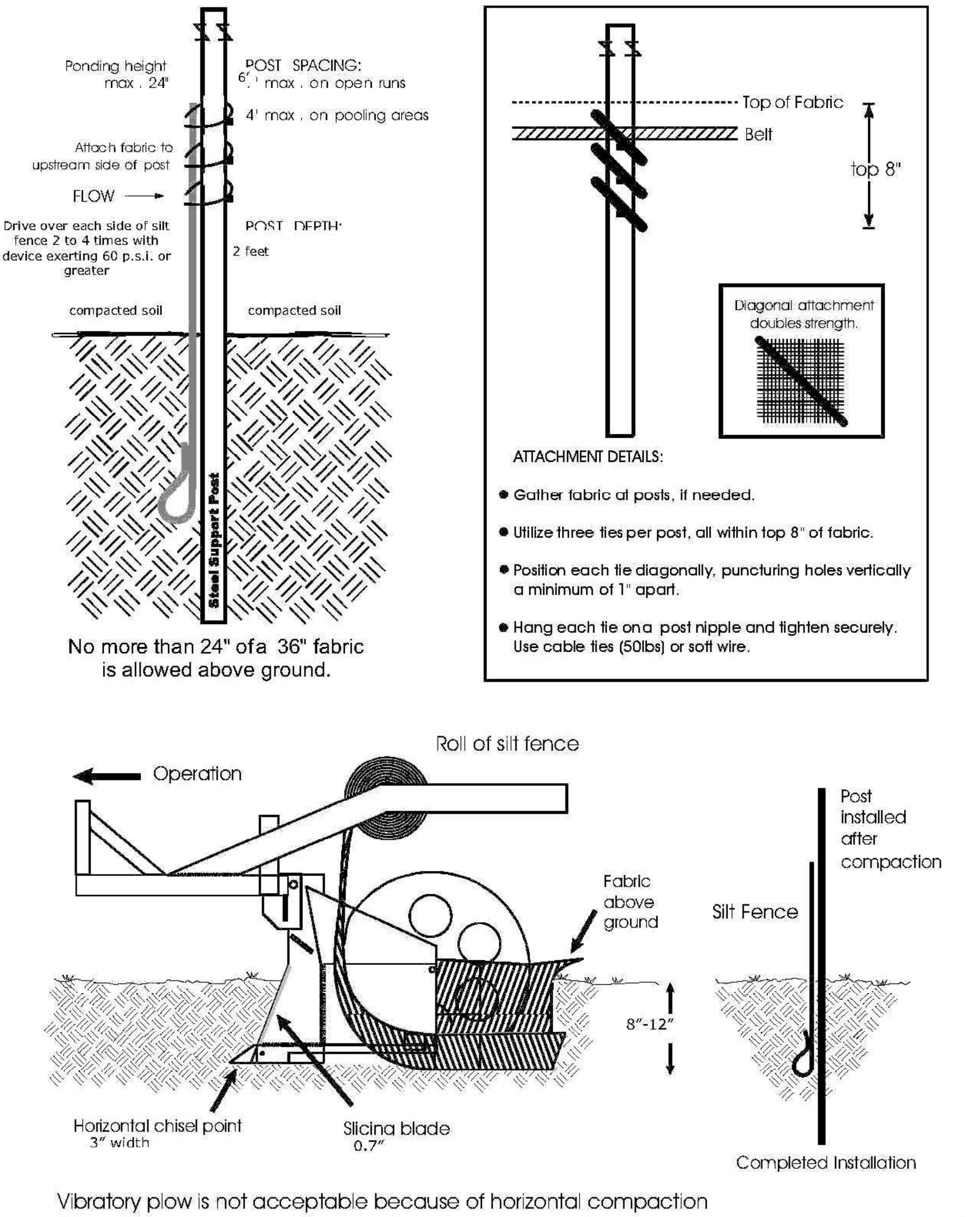


Figure 6.62b Schematics for using the slicing method to install a sediment fence. Adapted from *Silt Fence that Works*

Maintenance

Inspect sediment fences at least once a week and after each rainfall. Make any required repairs immediately.

Should the fabric of a sediment fence collapse, tear, decompose or become ineffective, replace it promptly.

Remove sediment deposits as necessary to provide adequate storage volume for the next rain and to reduce pressure on the fence. Take care to avoid undermining the fence during cleanout.

Remove all fencing materials and unstable sediment deposits and bring the area to grade and stabilize it after the contributing drainage area has been properly stabilized.

References

ASTM D 6461 – 99. "Standard Specification for Silt Fence Materials" ASTM International. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

ASTM D 6462 – 03. "Standard Practice for Silt Fence Installation" ASTM International. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

C. Joel Sprague, PE, Silt Fence Performance Limits and Installation Requirements. Sprague and Sprague Consulting Engineers and TRI/ Environmental, Inc.

Carpenter Erosion Control. http://www.tommy-sfm.com/

Kentucky Erosion Prevention and Sediment Control Field Manual, 2004.

Runoff Control Measures
6.20, Temporary Diversions

Outlet Protection
6.41, Outlet Stabilization Structure

Appendix
8.03, Estimating Runoff

6.65 POROUS BAFFLES

Definition

Porous barriers installed inside a temporary sediment trap, skimmer basin, or sediment basin to reduce the velocity and turbulence of the water flowing through the measure, and to facilitate the settling of sediment from the water before discharge.

Purpose

Sediment traps and basins are designed to temporarily pool runoff water to allow sediment to settle before the water is discharged. Unfortunately, they are usually not very efficient due to high turbulence and "short-circuiting" flows which take runoff quickly to the outlet with little interaction with most of the basin. Porous baffles improve the rate of sediment retention by distributing the flow and reducing turbulence. This process can improve sediment retention.

Conditions Where Practice Applies

This practice should be used in any temporary sediment trap, skimmer basin, or temporary sediment basin.

Planning Considerations

Porous baffles effectively spread the flow across the entire width of a sediment basin or trap. Water flows through the baffle material, but is slowed sufficiently to back up the flow, causing it to spread across the entire width of the baffle (Figure 6.65a).

Spreading the flow in this manner utilizes the full cross section of the basin, which in turn reduces flow rates or velocity as much as possible. In addition, the turbulence is also greatly reduced. This combination increases sediment deposition and retention and also decreases the particle size of sediment captured.

The installation should be similar to a sediment fence (Figure 6.65b). The fabric should be 700 g/m^2 coir erosion blanket (Figure 6.65c) or equal. A support wire across the top will help prevent excessive sagging if the material is attached to it with appropriate ties.

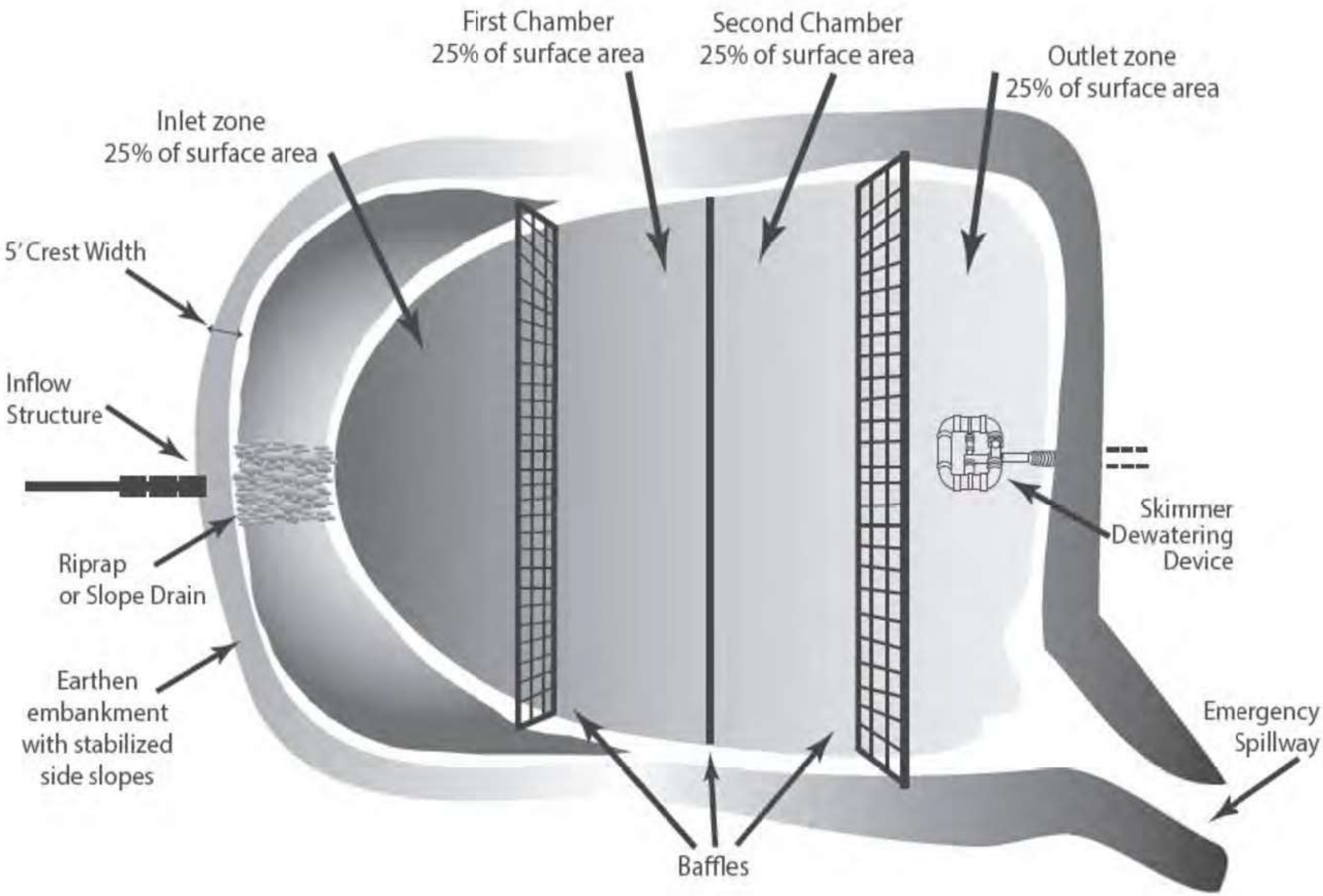
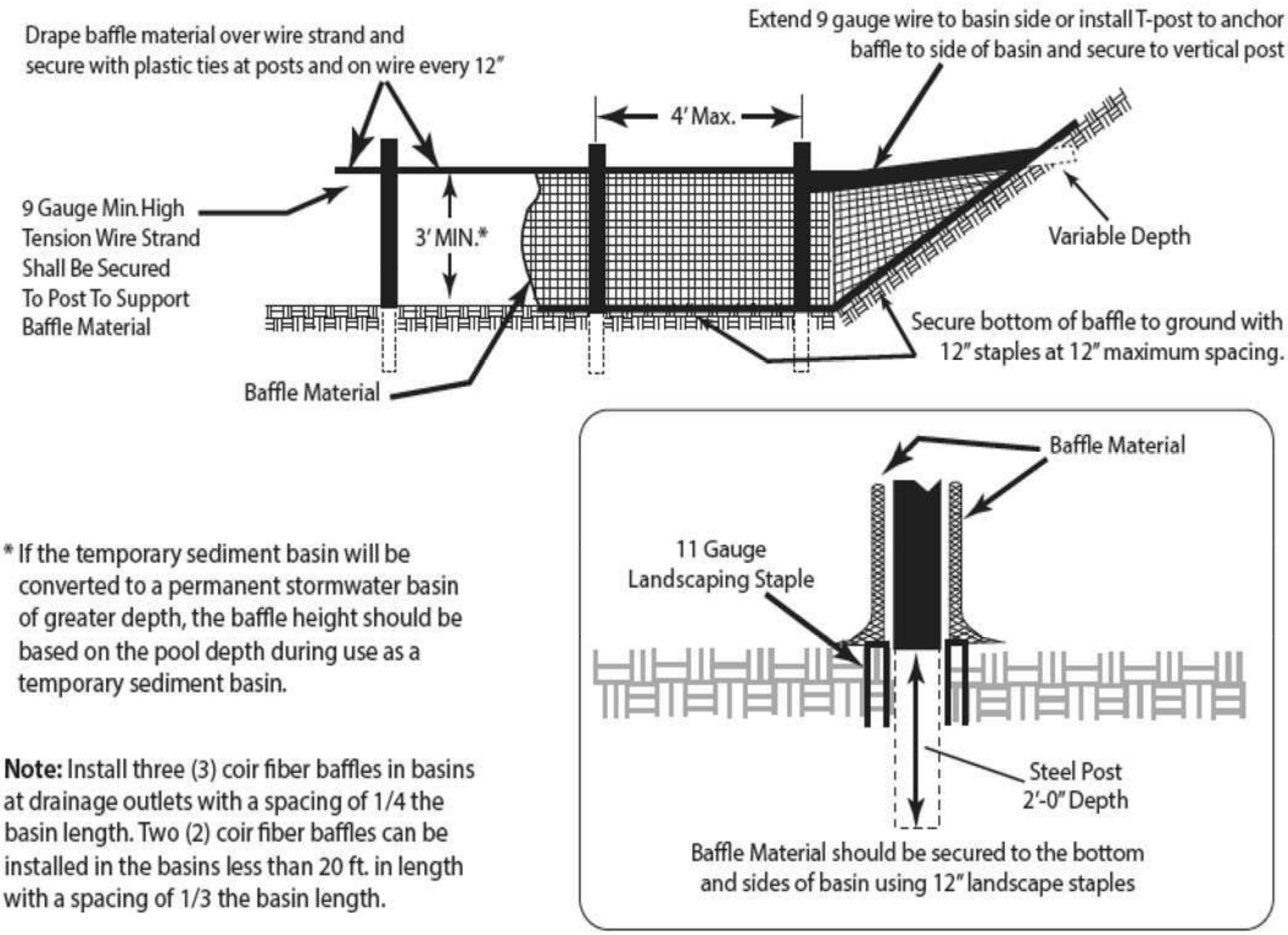


Figure 6.65a Porous baffles in a sediment basin. The flow is distributed evenly across the basin to reduce flow rates and turbulence, resulting in greater sediment retention.

Baffles need to be installed correctly in order to fully provide their benefits. Refer to Figure 6.65b and the following key points:

- The baffle material needs to be secured at the bottom and sides using staples.
- Most of the sediment will accumulate in the first bay, so this should be readily accessible for maintenance.



* If the temporary sediment basin will be converted to a permanent stormwater basin of greater depth, the baffle height should be based on the pool depth during use as a temporary sediment basin.

Note: Install three (3) coir fiber baffles in basins at drainage outlets with a spacing of 1/4 the basin length. Two (2) coir fiber baffles can be installed in the basins less than 20 ft. in length with a spacing of 1/3 the basin length.

Figure 6.65b Coir Fiber Baffle Detail
Cross section of a porous baffle in a sediment basin.

Figure 6.65c Example of porous baffles made of 700 g/m^2 coir erosion blanket as viewed from the outlet.

Figure 6.65d Close-up of a porous baffle.

Design Criteria

The temporary sediment trap or temporary sediment basin should be sized using the appropriate design criteria.

The percent of surface area for each section of the baffle is as follows:

- inlet zone: 25%
- first cell: 25%
- second cell: 25%
- outlet zone: 25%

Baffle spacing in future permanent stormwater basins is beyond forebay.

Be sure to construct baffles up the sides of the trap or basin banks so water does not flow around the structures. Most of the sediment will be captured in the inlet zone. Smaller particle size sediments are captured in the latter cells. Be sure to maintain access to the trap for maintenance and sediment removal.

The design life of the fabric is 6-12 months, but may need to be replaced more often if damaged or clogged.

Construction Specifications

MATERIALS

1. Use matting made of 100% coconut fiber (coir) twine woven into high strength matrix with the properties shown in Table 6.65a.

2. Staples should be made of 0.125 inch diameter new steel wire formed into a 'U' shape not less than 12 inches in length with a throat of 1 inch in width. The staples anchor the porous baffles into the sides and bottom of the basin.

3. Ensure that steel posts for porous baffles are of a sufficient height to support baffles at desired height. Posts should be approximately 1-3/8" wide measured parallel to the fence, and have a minimum weight of 1.25 lb/linear ft. The posts must be equipped with an anchor plate having a minimum area of 14.0 square inches and be of the self-fastener angle steel type to have a means of retaining wire and coir fiber mat in the desired position without displacement.

4. Use 9-gauge high tension wire for support wire.

Table 6.65a Specifications for Porous Baffle Material

Coir Fiber Baffle Material Property Requirements	
Thickness	0.30 in. minimum
Tensile Strength (Wet)	900 x 680 lb/ft minimum
Elongation (Wet)	69% x 34% maximum
Flow Velocity	10-12 ft/sec
Weight	20 oz/SY (680 g/m^2) minimum
Minimum Width	6.5 feet
Open Area	50% maximum

CONSTRUCTION

1. Grade the basin so that the bottom is level front to back and side to side.

2. Install the coir fiber baffles immediately upon excavation of the basins.

3. Install posts across the width of the sediment trap (Practice 6.62, *Sediment Fence*).

4. Steel posts should be driven to a depth of 24 inches and spaced a maximum of 4 feet apart. The top of the fabric should be a minimum of 6 inches higher than the invert of the spillway. Tops of baffles should be a minimum of 2 inches lower than the top of the earthen embankment.

5. Install at least three rows of baffles between the inlet and outlet discharge point. Basins less than 20 feet in length may use 2 baffles.

6. Attach a 9 gauge high tension wire strand to the steel posts at a height of 6 inches above the spillway elevation with plastic ties or wire fasteners to prevent sagging. If the temporary sediment basin will be converted to a permanent stormwater basin of a greater depth, the baffle height should be based on the pool depth during use as a temporary sediment basin.

7. Extend 9 gauge minimum high tension wire strand to side of basin or install steel T-posts to anchor baffle to side of basin and secure to vertical end posts as shown in Figure 6.65b.

8. Drape the coir fiber mat over the wire strand mounted at a height of 6 inches above the spillway elevation. Secure the coir fiber mat to the wire strand with plastic ties or wire fasteners. Anchor the matting to the sides and floor of the basin with 12 inch wire staples, approximately 1 ft apart, along the bottom and side slopes of the basin.

9. Do not splice the fabric, but use a continuous piece across the basin

10. Adjustments may be required in the stapling requirements to fit individual site conditions.

Maintenance

Inspect baffles at least once a week and after each rainfall. Make any required repairs immediately.

Be sure to maintain access to the baffles. Should the fabric of a baffle collapse, tear, decompose, or become ineffective, replace it promptly.

Remove sediment deposits when it reaches half full, to provide adequate storage volume for the next rain and to reduce pressure on the baffles. Take care to avoid damaging the baffles during cleanout, and replace if damaged during cleanout operations. Sediment depth should never exceed half the designed storage depth.

After the contributing drainage area has been properly stabilized, remove all baffle materials and unstable sediment deposits, bring the area to grade, and stabilize it.

References

Sediment Traps and Barriers
6.60, Temporary Sediment Trap
6.61, Sediment Basins
6.62, Sediment Fence
6.64, Skimmer Sediment Basin

McLaughlin, Richard, "Soil Facts: Baffles to Improve Sediment Basins." N.C. State University Cooperative Extension Service Fact Sheet AGW-439-59, 2005.

North Carolina Department of Transportation Erosion and Sedimentation Control Special Provisions

Sullivan, Brian. City of High Point Erosion Control Specifications.

Thaxton, C. S., J. Calantoni, and R. A. McLaughlin. 2004. Hydrodynamic assessment of various types of baffles in a sediment detention pond. Transactions of the ASAE. Vol. 47(3): 741-749.

6.84

DC

DUST CONTROL

Definition

The control of dust resulting from land-disturbing activities.

Purpose

To prevent surface and air movement of dust from disturbed soil surfaces that may cause off-site damage, health hazards, and traffic safety problems.

Conditions Where Practice Applies

On construction routes and other disturbed areas subject to surface dust movement, and dust blowing where off-site damage may occur if dust is not controlled.

Planning Considerations

Construction activities that disturb soil can be a significant source of air pollution. Large quantities of dust can be generated, especially in "heavy" construction activities such as land grading for road construction and commercial, industrial, or subdivision development.

In planning for dust control, it is important to schedule construction operations so that the least area is disturbed at one time.

Leave undisturbed buffer areas between graded areas wherever possible.

The greatest dust problems occur when the probability of rainfall erosion is least. Therefore, do not expose large areas of soil, especially during drought conditions.

Install temporary or permanent surface stabilization measures immediately after completing land grading.

Design Criteria

No formal design procedure is given for dust control. See Construction Specifications below for the most common dust control methods.

Construction Specifications

Vegetative cover—For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control (*References: Surface Stabilization*).

Mulch (including gravel mulch)—When properly applied, mulch offers a fast, effective means of controlling dust.

Spray-on adhesive—Examples of spray-on adhesives for use on mineral soils are presented in Table 6.84a.

Table 6.84a Spray-on Adhesive for Dust Control on Mineral Soil

	Water Dilution	Type of Nozzle	Apply Gallons/Acre
Anionic asphalt emulsion	7:1	Coarse Spray	1,200
Latex emulsion	12.5:1	Fine Spray	235
Resin in water	4:1	Fine Spray	300

Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist, but not so high as to cause water pollution or plant damage.

Sprinkling—The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.

Stone used to stabilize construction roads can also be effective for dust control.

Barriers—A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals about 15 times the barrier height. Where dust is a known problem, preserve windbreak vegetation.

Tillage—Deep plow large open undisturbed areas and bring clods to the surface. This is a temporary emergency measure that can be used as soon as soil blowing starts. Begin plowing on the windward edge of the site.

Maintenance

Maintain dust control measures through dry weather periods until all disturbed areas have been stabilized.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding
6.14, Mulching

Other Related Practices
6.80, Construction Road Stabilization