6

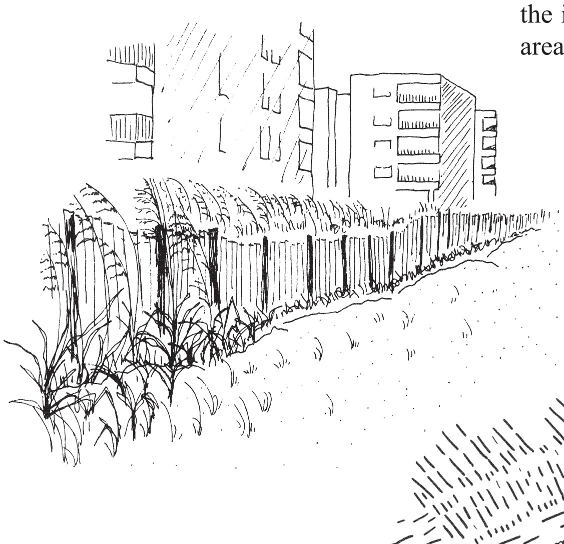
Practice Standards and Specifications

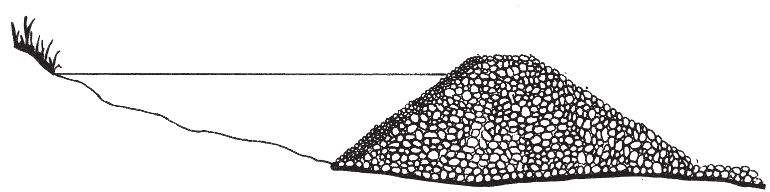
6

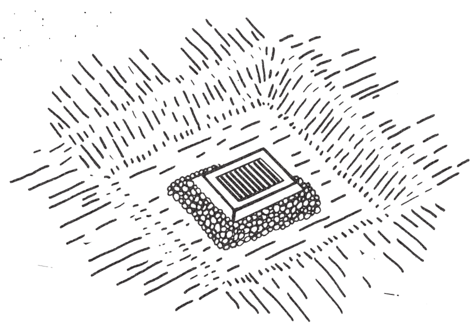
Practice Standards and Specifications

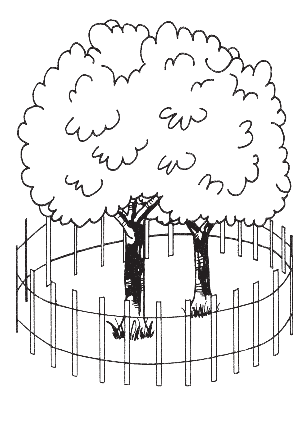
Chapter 6 contains Standards and Specifications for structural and vegetative erosion and sediment control practices. **Specifications given in this section are guidelines, and are intended to minimize the time required to design practices for use under typical site conditions. Unusual conditions may dictate that specifications be modified and practices specially designed. Exceptions to these guidelines may be made based on best professional judgement.** Additional guidelines on the design and use of practices are contained in the appendices.

The vegetative and structural measures described in this chapter are not intended to stand alone. Rather, they should be employed as a system, sequenced and sited to control erosion and sedimentation during development, and to stabilize disturbed land as development is completed. On most sites successful erosion and sedimentation control requires combining structural and vegetative practices into a comprehensive plan. Design professionals should consider the changing requirements of their site when determining the sequence in which practices are to be implemented and should recognize the importance of vegetative and other groundcover for stabilizing disturbed areas.









6

6

Practice Standards and Specifications

INDEX

INDEX

SITE PREPARATION

6.01

CONSTRUCTION SEQUENCE SCHEDULE

Definition

A specified work schedule that coordinates the timing of land-disturbing activities and the installation of erosion and sedimentation control measures.

Purpose

To reduce on-site erosion and off-site sedimentation by performing land-disturbing activities, and installing erosion and sedimentation control practices in accordance with a planned schedule.

Conditions Where Practice Applies

All land-development projects that will disturb more than one contiguous acre.

Planning Considerations

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

Scheduling considerations are summarized in Table 6.01a. The generalized construction activities shown in the table do not usually occur in a specified linear sequence, and schedules will vary due to weather and other unpredictable factors. However, the proposed construction sequence should be indicated clearly in the erosion and sedimentation control plan.

Construction access is normally the first land-disturbing activity. Exercise care not to damage valuable trees or disturb designated buffer zones.

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

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

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

Normally, install stream stabilization, including necessary stream crossings, independently and ahead of other construction activities. It is usually best to schedule this work as soon as weather conditions permit. Site clearing and

Table 6.01a
Considerations for Construction Scheduling

Construction Activity[1]	Schedule Consideration
Construction access. Construction entrance, construction routes, equipment parking areas.	First land-disturbing activity—Stabilize bare areas immediately with gravel and temporary vegetation as construction takes place.
Sediment traps and barriers. Basin traps, sediment fences, and outlet protection.	Install principal basins after construction site is accessed. Install additional traps and barriers as needed during grading.
Runoff control. Diversions, perimeter dikes, water bars, and outlet protection.	Install key practices after principal sediment traps and before land grading. Install additional runoff-control measures during grading.
Runoff conveyance system. Stabilize streambanks, storm drains, channels, inlet and outlet protection, and slope drains.	Where necessary, stabilize streambanks as early as possible. Install principal runoff conveyance system with runoff-control measures. Install remainder of system after grading.
Landing clearing and grading. Site preparation—cutting, filling and grading, sediment traps, barriers, diversions, drains, and surface roughening.	Begin major clearing and grading **after** principal sediment and key runoff-control measures are installed. Clear borrow and disposal areas only as needed. Install additional control measures as grading progresses. Mark trees and buffer areas for preservation.
Surface stabilization. Temporary and permanent seeding, mulching, sodding, and riprap.	Apply temporary or permanent stabilization measures immediately on all disturbed areas where work is delayed or complete.
Building construction. Buildings, utilities, and paving.	Install necessary erosion and sedimentation control practices as work takes place.
Landscaping and final stabilization. Topsoiling, trees and shrubs, permanent seeding, mulching, sodding, and riprap.	Last construction phase—Stabilize all open areas, including borrow and spoil areas. Remove and stabilize all temporary control areas.

1 Maintenance, (1) maintenance inspections should be performed weekly, and (2) after periods of rainfall, maintenance repairs should be made immediately.

project construction increases storm runoff, often making streambank stabilization work more difficult and costly.

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

Runoff control is essential during the grading operation. Temporary diversions, slope drains, and inlet and outlet protection installed in a timely manner can be very effective in controlling erosion during this critical period of development.

Immediately after land clearing and grading, apply **surface stabilization** on graded areas, channels, dikes, and other disturbed areas. Stabilize any graded slopes and fills where active construction will not take place for 21 calendar days by temporary seeding and/or mulching or by other suitable means. Install permanent stabilization measures immediately after final grading, in accordance with the vegetative plan. Temporary seeding and/or mulching may be necessary during extreme weather conditions with permanent measures delayed for a more suitable time.

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

Landscaping and final stabilization is the last major construction phase, but the topsoil stockpiling, tree preservation, undisturbed buffer area, and well-planned road locations established earlier in the project may determine the ease or difficulty of this activity. All disturbed areas should have permanent stabilization practices applied. Unstable sediment should be removed from sediment basing and traps. All temporary structures should be removed after the area above has been properly stabilized. Borrow and disposal areas should be permanently vegetated or otherwise stabilized.

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

A construction sequence schedule is shown as part of the sample erosion plan (*Chapter 7, Sample Erosion and Sedimentation Control Plan*).

Design Criteria

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

- The erosion and sedimentation control practices to be installed,
- Principal development activities,
- What measures should be in place before other activities are begun, and
- Compatibility with the general construction schedule of the contract.

Construction Specifications

Many timely construction techniques can reduce the erosion potential of a site, such as (1) shaping earthen fills daily to prevent overflows and (2) constructing temporary diversions ahead of anticipated storms. These types of activities cannot be put on the construction sequence schedule, but should be used whenever possible.

Following a planned construction sequence schedule to control erosion should help keep field personnel aware of the possibilities of erosion prevention through construction management.

Maintenance

Follow the construction sequence throughout the project development. When changes in construction activities are needed, amend the sequence schedule in advance to maintain management control.

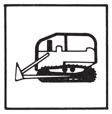
Orderly modification assures coordination of construction and erosion control practices to minimize erosion and sedimentation problems. When major changes are necessary, send a copy of the modified schedule to the local sediment control agency.

References

Chapter 4, Preparing the Erosion and Sedimentation Control Plan
Chapter 7, Sample Erosion and Sedimentation Control Plan

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

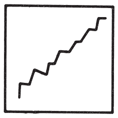
Periodically, check all graded areas and the supporting erosion and sedimentation control practices, especially after heavy rainfalls. Promptly remove all sediment from diversions and other water-disposal practices. If washouts or breaks occur, repair them immediately. Prompt maintenance of small eroded 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

6.03

SURFACE ROUGHENING



Definition

Roughening a bare soil surface with horizontal grooves running across the slope, stair stepping, or tracking with construction equipment.

Purpose

To aid the establishment of vegetative cover from seed, to reduce runoff velocity and increase infiltration, and to reduce erosion and provide for sediment trapping.

Conditions Where Practice Applies

All construction slopes require surface roughening to facilitate stabilization with vegetation, particularly slopes steeper than 3:1.

Planning Considerations

Rough slope surfaces are preferred because they aid the establishment of vegetation, improve water infiltration, and decrease runoff velocity. Graded areas with smooth, hard surfaces may be initially attractive, but such surfaces increase the potential for erosion. A rough, loose soil surface gives a mulching effect that protects lime, fertilizer, and seed. Nicks in the surface are cooler and provide more favorable moisture conditions than hard, smooth surfaces; this aids seed germination.

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include stair-step grading, grooving (Figure 6.03a), and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

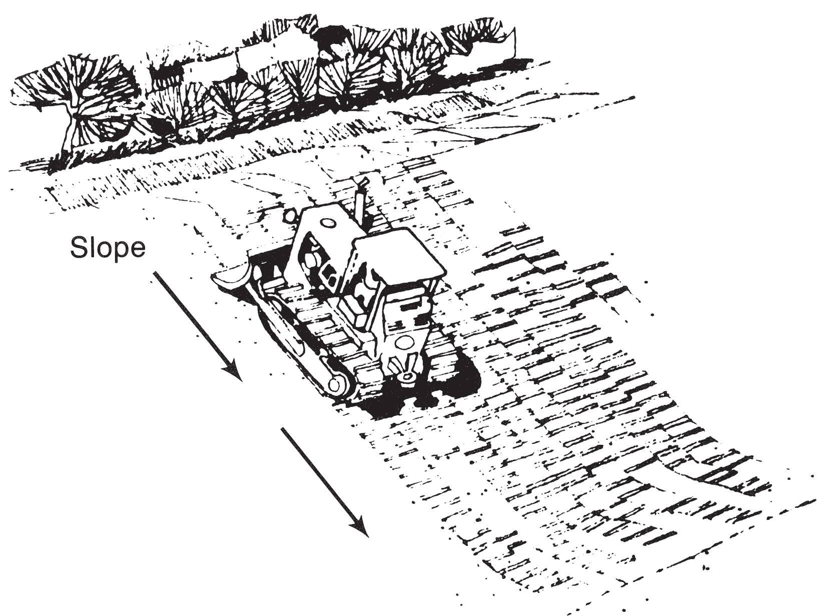


Figure 6.03a Bulldozer treads create grooves perpendicular to the slope. The slope face should not be back-bladed during the final grading operation (source: Va SWCC).

Design Criteria

No formal design is required.

Construction Specifications

CUT SLOPE ROUGHENING FOR AREAS NOT TO BE MOWED
Stair-step grade or groove cut slopes with a gradient steeper than 3:1 (Figures 6.03b and 6.03c).

Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading.

Make the vertical cut distance less than the horizontal distance, and slightly slope the horizontal position of the "step" in toward the vertical wall.

Do not make individual vertical cuts more than 2 feet in soft materials or more than 3 feet in rocky materials.

Grooving uses machinery to create a series of ridges and depressions that run across the slope (on the contour).

Groove using any appropriate implement that can be safely operated on the slope, such as disks, tillers, spring harrows, or the teeth on a front-end loader bucket. Do not make such grooves less than 3 inches deep nor more than 15 inches apart.

FILL SLOPE ROUGHENING FOR AREAS NOT TO BE MOWED
Place fill slopes with a gradient steeper than 3:1 in lifts not to exceed 9 inches, and make sure each lift is properly compacted. Ensure that the face of the slope consists of loose, uncompacted fill 4 to 6 inches deep. Use grooving, as described above, to roughen the face of the slopes, if necessary.

Do not blade or scrape the final slope face.

CUTS, FILLS, AND GRADED AREAS THAT WILL BE MOWED
Make mowed slopes **no steeper than 3:1**.

Roughen these areas to shallow grooves by normal tilling, disking, harrowing, or use of cultipacker-seeder. Make the final pass of any such tillage implement on the contour.

Make grooves, formed by such implements, close together (less than 10 inches) and not less than 1 inch deep.

Excessive roughness is undesirable where mowing is planned.

ROUGHENING WITH TRACKED MACHINERY
Limit roughening with tracked machinery to sandy soils to avoid undue compaction of the soil surface. Tracking is generally not as effective as the other roughening methods described.

Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. Do not back-blade during the final grading operation.

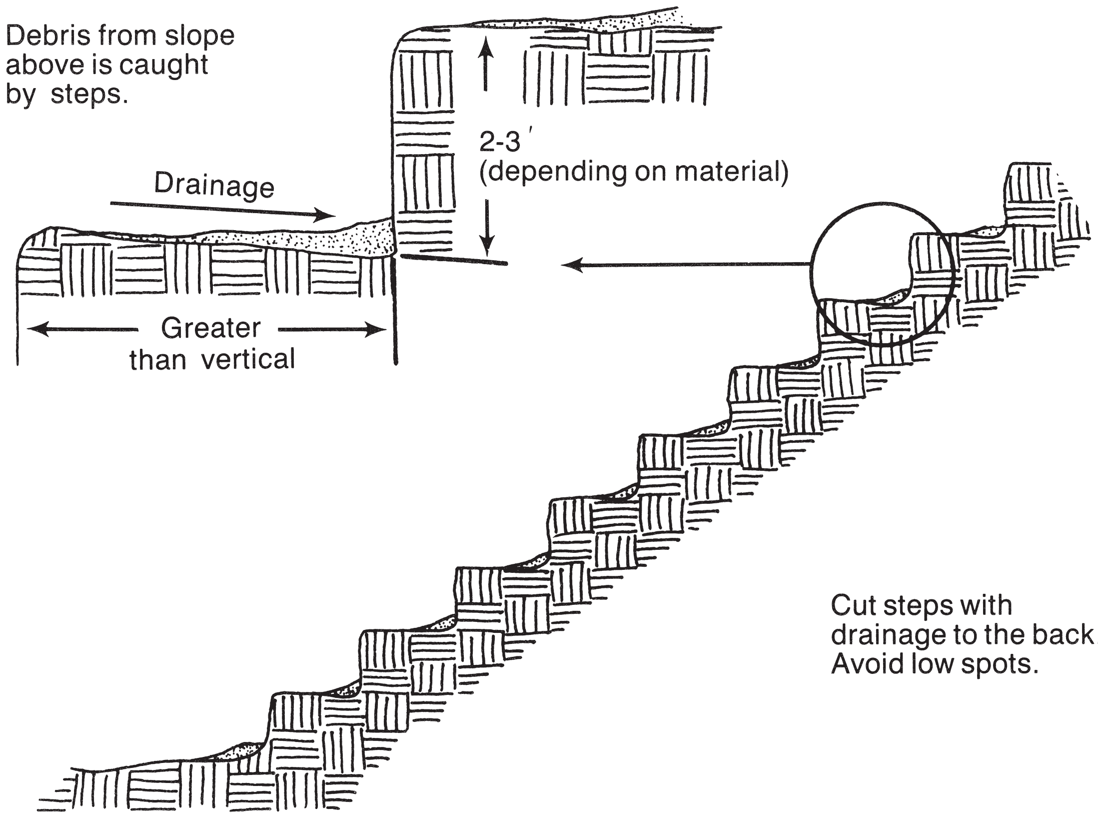


Figure 6.03b Stair stepping cut slopes (modified from Va SWCC).

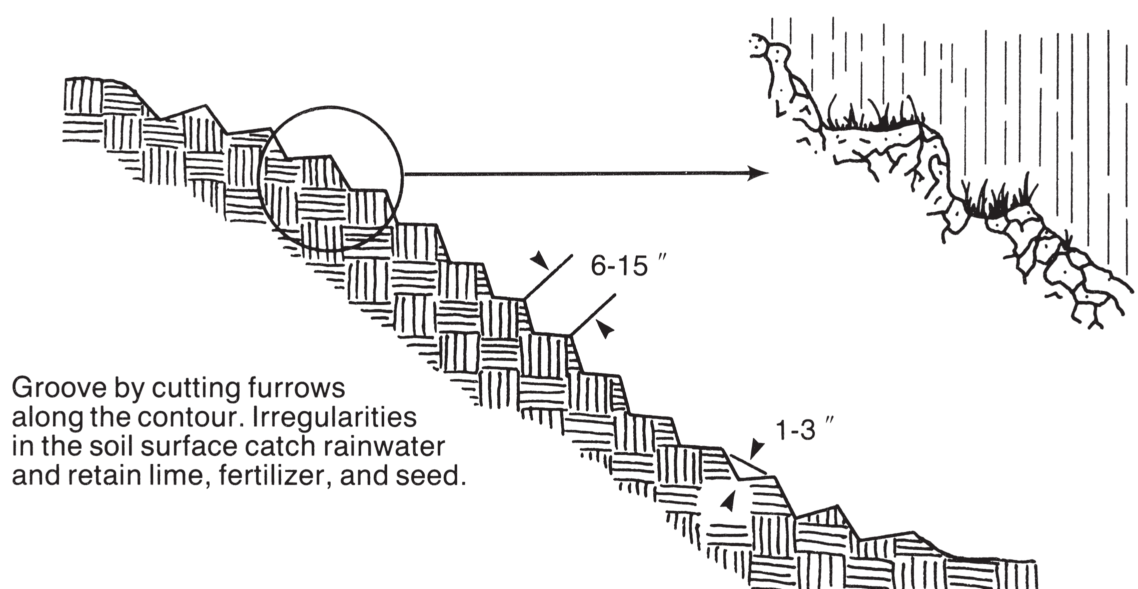


Figure 6.03c Grooving slopes (modified from Va SWCC).

Seeding—Immediately seed and mulch roughened areas to obtain optimum seed germination and growth.

Maintenance

Periodically check the seeded slopes for rills and washes. Fill these areas slightly above the original grade, then reseed and mulch as soon as possible.

References

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

Chapter 3, Vegetative Considerations

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*

6.05

TREE PROTECTION

Definition

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

Purpose

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

Figure 6.05a Tree protection zone. A protected zone preserves roots and soil and keeps branches clear of contact with construction equipment and materials.

Conditions Where Practice Applies

On development sites containing trees or stands of trees.

Planning Considerations

Conserving the right trees can reap rewards for developers, homeowners, and communities. Healthy trees enhance property values and community development by providing shade, wildlife habitat, and beauty. Sickly, stressed trees reduce property values, discourage potential buyers and detract from a community. Post-construction maintenance and removal of trees is difficult and expensive. Replacing trees after construction can also be costly and time consuming.

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

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

Trees should be considered for preservation for the following benefits:

- They stabilize the soil and prevent erosion.
- They reduce stormwater runoff by intercepting rainfall, promote infiltration, and lower the water table through transpiration.
- They moderate temperature changes, promote shade, and reduce the force of wind.
- They provide buffers and screens against noise and visual disturbance, providing a degree of privacy.
- They filter pollutants from the air, remove carbon dioxide from the air, and produce oxygen.
- They provide a habitat for animals and birds.
- **They increase property values and improve site aesthetics**.

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

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

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

Tree species—Preserve those species that are most suitable for site conditions and landscape design. Trees that are short-lived or brittle or are susceptible to attack by insects and disease may be poor choices for preservation.

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

Wildlife benefits—Choose trees that are preferred by wildlife for food, cover, or nesting. A mixture of evergreens and hardwoods may be beneficial. Evergreen trees are important for cover during the winter months, whereas hardwoods are more valuable for food.

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

Design Criteria

1. Take stock of trees on the site. Hire a professional arborist or urban forester to inventory existing trees. An inventory records the variety, location, size, and health of each tree. A proper tree inventory creates the foundation for a successful tree protection plan. A professional can identify valuable trees and those that need attention or removal. Identify any stressed trees that need removal. Stressed, unhealthy trees have wilting leaves, dying limbs, thinning crowns or other signs of declining health. Always remove insect-, disease-, or storm-damaged trees prior to construction. This is fast, efficient, and saves resources.

2. Draw a base map. Include all the important site features such as existing vegetation, property lines, utility connections, slopes, and required setback distances before drawing in the proposed building(s):

• Map grading and drainage.

• Identify priority trees for protection. Mark their locations on the base map and sketch in approximate tree protection zones where temporary fences should be located around priority trees.

• Locate the building footprints: the areas where structures and their amenities will affect the landscape. Draw in the driveways, parking areas, and decks.

• Mark trees that need to be removed or pruned to make room for future structures and construction equipment.

3. Prepare a tree protection plan. A tree protection plan designates the valuable trees that must be protected during the construction process. Assemble a team to write a tree protection plan before ground is broken. The team should include the site managers as well as professionals who can provide tree protection advice (Table 1). Do not leave anyone out who should be involved. By working together, the team can identify potential conflicts between construction needs and tree protection, and identify compromise solutions.

Planning takes time, but it pays off during and after construction. Using the base map, the team can plan for tree protection, foresee problems, and solve them. Early planning helps to keep construction on schedule, reduce costs, and avoid conflicts:

• Locate construction activities after considering the priority trees and the development requirements.

• Look for potential conflicts, and explore alternate solutions.

• Consider grading and stormwater drainage. Remember that cutting or filling around roots will weaken and eventually kill valuable trees. Weigh alternatives such as retaining walls to protect priority trees.

• Designate **tree protection zones (TPZs).** The protection plan should specify the location of temporary tree protection fences to protect trees and their root zones during construction. TPZ fences identify "exclusion zones" where construction and equipment use is prohibited. Effective TPZs maintain a radius of at least 1.25 feet of protected area for each inch of trunk diameter (Table 6.05a).

Table 6.05a Mature Tree Protection Zone Guidelines

Mature Tree Protection Zone Radius			
Trunk Diameter	**Good Protection**	**Better Protection**	**Best Protection**
8 inches	10 feet	12 feet	20 feet
12 inches	15 feet	18 feet	30 feet
16 inches	20 feet	24 feet	40 feet
20 inches	25 feet	30 feet	50 feet

• Identify techniques that will protect valuable trees. A tree professional can develop a schedule of tree maintenance activities, including watering, mulching, and fertilization. Stay committed to this plan throughout the project.

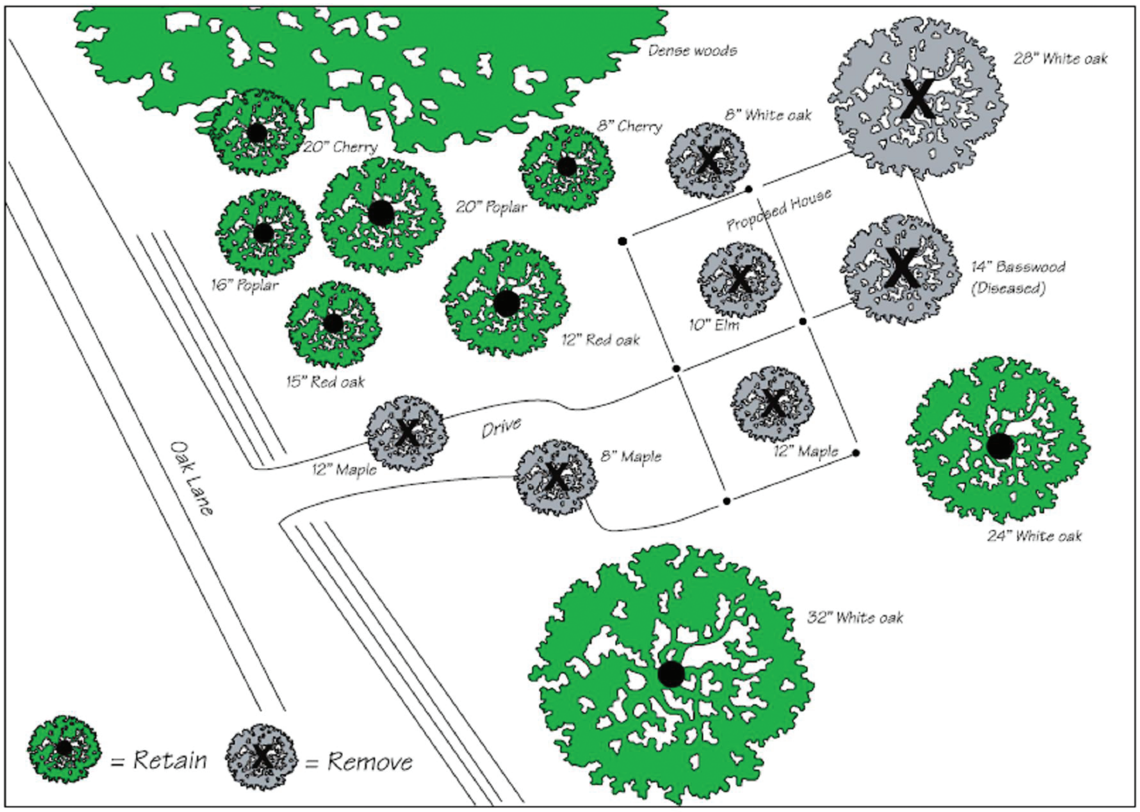


Figure 6.05b Simple tree protection plan. A plan identifies the size and species of existing trees, designates trees that must be protected, and marks trees to be removed. It also indicates planned structures, vehicle access, and excavation areas.

Design Criteria

The following general criteria should be considered when developing sites in wooded areas:

- Leave critical areas (such as flood plains, steep slopes and wetlands) with desirable trees in their natural condition or only partially cleared.
- Locate roadways, storage areas, and parking pads away from valuable tree stands. Follow natural contours, where feasible, to minimize cutting and filling in the vicinity of trees.
- Select trees to be preserved before siting roads, buildings, or other structures.
- Minimize trenching in areas with trees. Place several utilities in the same trench.
- Designate groups of trees and individual trees to be saved on the erosion and sedimentation control plan.
- **Do not excavate, traverse, or fill closer than the drip line, or perimeter of the canopy, of trees to be saved**.

Construction Specifications

1. Erect TPZ fences. Restrict access to TPZs, with tall, bright, protective fencing. Most fencing is inexpensive and durable enough to last throughout most construction projects. Temporary tree protection fencing should be erected before clearing, deliveries and other construction activities begin on the site.

2. Prohibit or restrict access to TPZs. All on-site workers should be aware of the TPZs and the restrictions on activities within the zones. Use these TPZ guidelines for the best effect:

• Post “keep out” signs on all sides of fencing. Do not store construction equipment or materials in TPZs.

• Prohibit construction activities near the most valuable trees, and restrict activities around others.

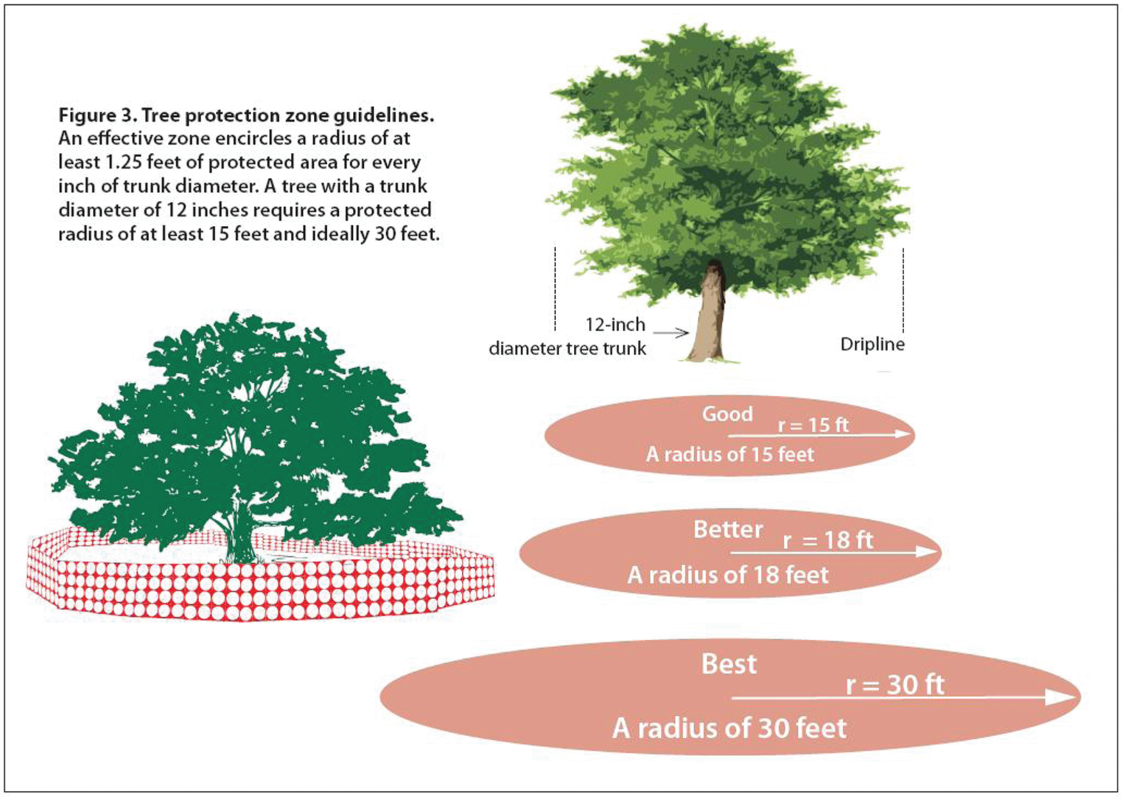
• Assess crew and contractor penalties, if necessary, to keep the TPZs intact.

3. Monitor trees. Vigilance is required to protect trees on construction sites. Use a tree professional or train your staff to monitor tree health during and after construction on a regular, frequent basis. Watch for signs of tree stress, such as dieback, leaf loss, or general decline in tree health or appearance.

4. Monitor TPZ fences. Assign a crewmember the weekly responsibility of checking the integrity of TPZ fences. Repair and replace TPZ fencing as needed.

5. Optimize tree health. Assign a trained crewmember or hire a professional to complete regular tree maintenance tasks, including watering, fertilization, and mulching to protect tree roots. Consult a tree professional for advice on these practices if needed. Survival of protected trees will increase if these practices continue during construction. Healthy trees require undisturbed healthy soils. Do not cause injuries to trees and roots. Do not change the soil, grade, drainage, or aeration without protecting priority trees

Figure 6.05c Tree protection zone guidelines.



Maintenance

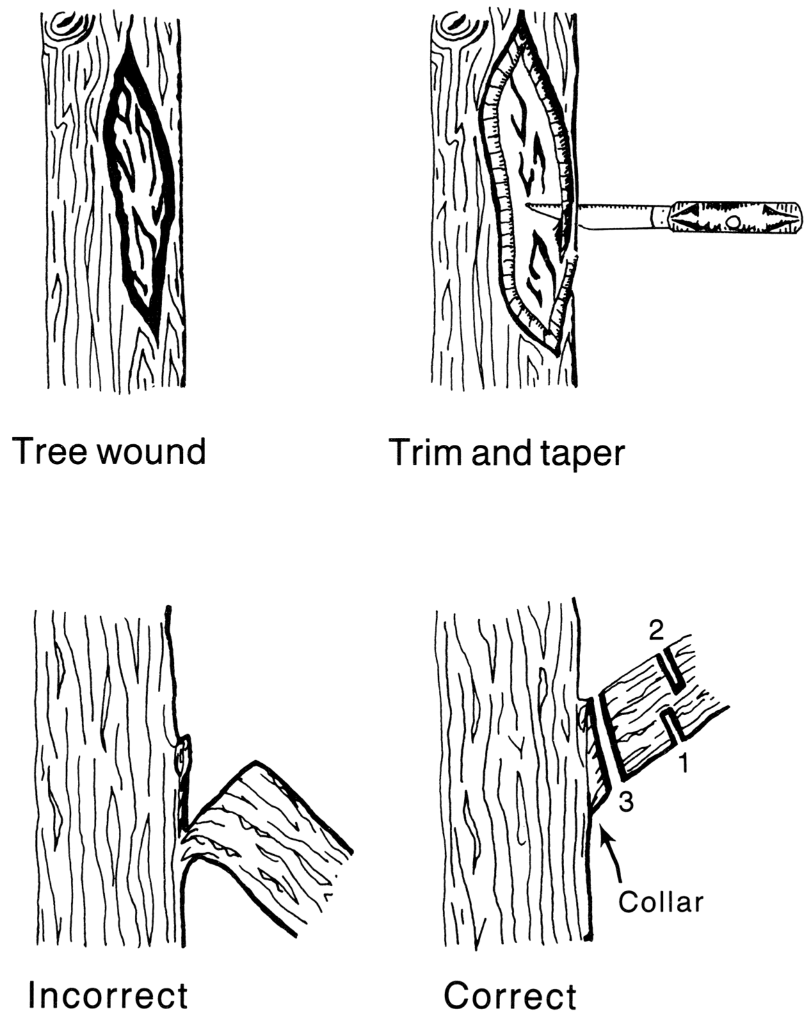
Continue to care for the site until the new owner takes possession. Take these steps after all materials and equipment have been removed from the site:

- Remove tree protection zone fences.
- Prune any damaged trees. In spite of precautions, some damage to protected trees may occur. In such cases, repair any damage to the crown, trunk, or root system immediately.
  - Repair roots by cutting off the damaged areas and painting them with tree paint. Spread peat moss or moist topsoil over exposed roots.
  - Repair damage to bark by trimming around the damaged area as shown in Figure 6.05d, taper the cut to provide drainage, and paint with tree paint.
  - Cut off all damaged tree limbs above the tree collar at the trunk or main branch. Use three separate cuts as shown in Figure 6.05d to avoid peeling bark from healthy areas of the tree.
- Continue maintenance care. Pay special attention to any stressed, diseased, or insect-infested trees. Reduce tree stress caused by unintended construction damage by optimizing plant care with water, mulch, and fertilizer where appropriate. Consult your tree expert if needed.
- Inform the property owner about the measures employed during construction, why those measures were taken, and how the effort can be continued.

Figure 6.05d Wound repair and pruning of damaged trees.

Trim bark wounds with a tapered cut, then apply tree paint.

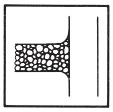
Prune damaged branches with three cuts to avoid peeling bark from the trunk when limb falls.



References

Construction and Tree Protection, AG-685 (Revised) North Carolina Cooperative Extension Service

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.

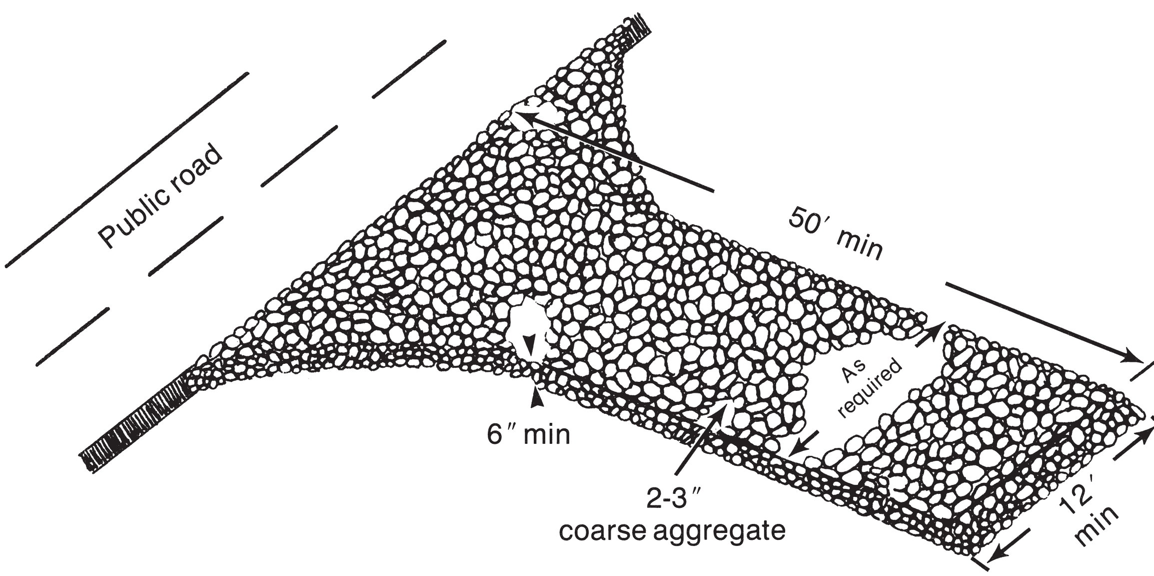


Figure 6.06a Gravel entrance/exit keeps sediment from leaving the construction site (modified from Va SWCC).

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

INDEX

SURFACE STABILIZATION

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.

Table 6.11.a

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)

Table 6.11.b

NON-NATIVE SPECIES

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 seeding 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	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
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 y ear 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

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.

6.12

SODDING

S

Definition

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

Purpose

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

- to provide immediate vegetative cover of critical areas,
- to stabilize disturbed areas with a suitable plant material that cannot be established by seed, or
- to stabilize drainageways, channels, and other areas of concentrated flow where flow velocities will not exceed that specified for a grass lining (*Appendix 8.05*).

Conditions Where Practice Applies

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

- waterways and channels carrying intermittent flow at acceptable velocities (*Appendix 6.05*),
- areas around drop inlets, when the drainage area has been stabilized (Practice 6.53, *Sod Drop Inlet Protection*),
- residential or commercial lawns and golf courses where prompt use and aesthetics are important, and
- steep critical areas.

Planning Considerations

Quality turf can be established with either seed or sod; site preparation for the two methods is similar. The practice of sodding for soil stabilization eliminates both the seeding and mulching operations, and is a much more reliable method of producing adequate cover and sediment control. However, compared to seed, sod is more difficult to obtain, transport, and store.

Advantages of properly installed sod include:

- immediate erosion and dust control,
- nearly year-round establishment capability,
- less chance of failure than with seedings,
- freedom from weeds, and
- rapid stabilization of surfaces for traffic areas, channel linings, or critical areas.

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

In waterways and channels that carry concentrated flow, properly pegged sod is preferable to seed because it provides immediate protection. Drop inlets placed in areas to be grassed can be protected from sediment by placing permanent sod strips around the inlet (Practice 6.53, *Sod Drop Inlet Protection*). Sod also maintains the necessary grade around the inlet.

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

Specifications

Choosing appropriate types of sod—The type of sod selected should be composed of plants adapted to both the site and the intended purpose. In North Carolina these are limited to Kentucky bluegrass, tall fescue, bluegrass-tall fescue blends, fine-turf (hybrid) Bermudagrass, St. Augustinegrass, centipedegrass, and zoysiagrass. Species selection is primarily determined by region, availability, and intended use (Table 6.12a). Availability varies across the state and from year to year. New varieties are continually being developed and tested. A complete and current listing of sod recommendations can be obtained from suppliers or the State Agricultural Extension office. Sod composed of a mixture of varieties may be preferred becuase of its broader range of adaptability.

Table 6.12a
Types of sod Available in North Carolina

	Varieties	Region of Adaptation
Cool Season Grasses:		
Kentucky blugrass blend[1]		Mountains
Tall fescue blend	Adventure, Brookston, Falcon, Finelawn, Galway, Houndog, Jaguar, Olympic, Rebel	Mountains and Piedmont
Tall fescue/Kentucky bluegrass		Mountains and Piedmont
Warm Season Grasses:		
Hybrid Bermudagrass	Vamont, Tifway, Tifway II & Tifgreen	Piedmont and Coastal Plain
Zoysiagrass	Emerald, Meyer	Piedmont and Coastal Plain
Centipedegrass	No improved varieties	Piedmont and Coastal Plain
St. Augustinegrass	Raleigh	Piedmont and Coastal Plain

[1]A large number of varieties exist—consult suppliers and your local Agricultural Extension office for recommendations.

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

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

Soil preparation—Test soil to determine the exact requirements for lime and fertilizer. Soil tests may be conducted by the State soil testing lab or a reputable commercial laboratory. Information on free soil testing is available from the Agronomic Division of the North Carolina Department of Agriculture or the Agricultural Extension Service. Where sodding must be planned without soil tests the following soil amendments may be sufficient:

- **Pulverized agricultural limestone** at a rate of 2 tons/acre (100 lb/1,000 ft^2)
- **Fertilizer** at a rate of 1,000 lb/acre (25 lb/1,000 ft^2) of 10-10-10 in fall or 5-10-10 in spring.

Equivalent nutrients may be applied with other fertilizer formulations. These amendments should be spread evenly over the area, and incorporated into the top 4-8 inches of soil by disking, harrowing, or other effective means. If topsoil is applied, follow specifications given in Practice 6.04, *Topsoiling*.

Prior to laying sod, clear the soil surface of trash, debris, roots, branches, stones, and clods larger than 2 inches in diameter. Fill or level low spots in order to avoid standing water. Rake or harrow the site to achieve a smooth and level final grade.

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

Sod installation—A step-by-step procedure for installing sod is illustrated in Figure 6.12a and described below.

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

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

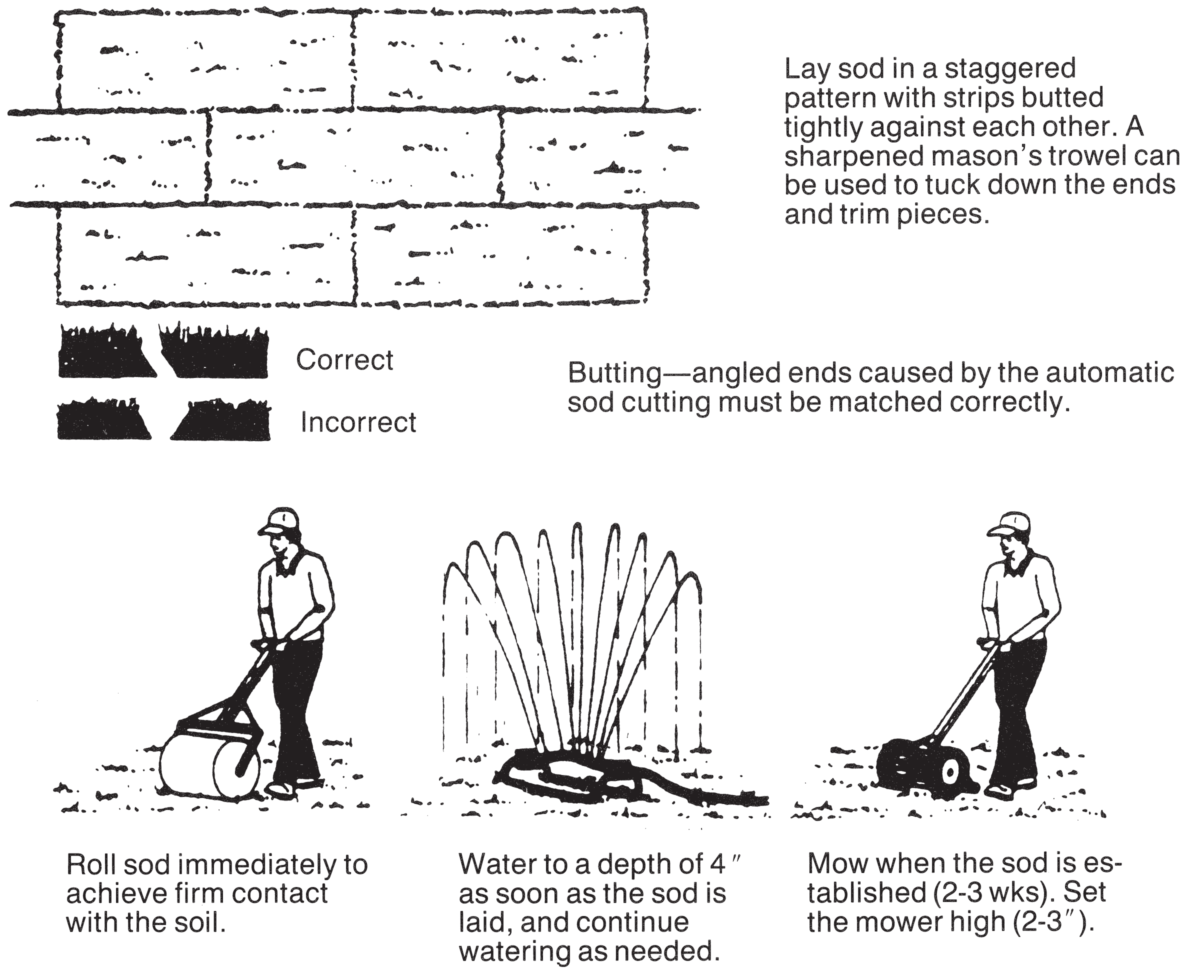


Figure 6.12a Proper installation of grass sod (modified from Va SWCC).

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

4. Lay the first row of sod in a straight line with subsequent rows placed paralled to and butting tightly against each other. Stagger strips in a brick-like pattern. Be sure that the sod is not streached or overlapped and that all joints are butted tightly to prevent voids. Use a knife or sharp spade to trim and fit irregularly shaped areas.

5. Install strips of sod with their longest dimension perpendicular to the slope. On slopes 3:1 or greater, or wherever erosion may be a problem, secure sod with pegs or staples.

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

7. After rolling, irrigate until the soil is wet 4 inches below the sod.

8. Keep sodded areas moist to a depth of 4 inches until the grass takes root. This can be determined by gently tugging on the sod—resistance indicates that rooting has occurred.

9. Mowing should not be attempted until the sod is firmly rooted, usually 2-3 weeks.

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

1. Prepare the soil as described in Practice 6.30, *Grass-lined Channels*. The sod type must be able to withstand the velocity of flow specified in the channel design (*Appendix 8.05*).

2. Lay sod strips perpendicular to the direction of flow, with the lateral joints staggered in a brick-like pattern. Edges should butt tightly together (Figure 6.12b).

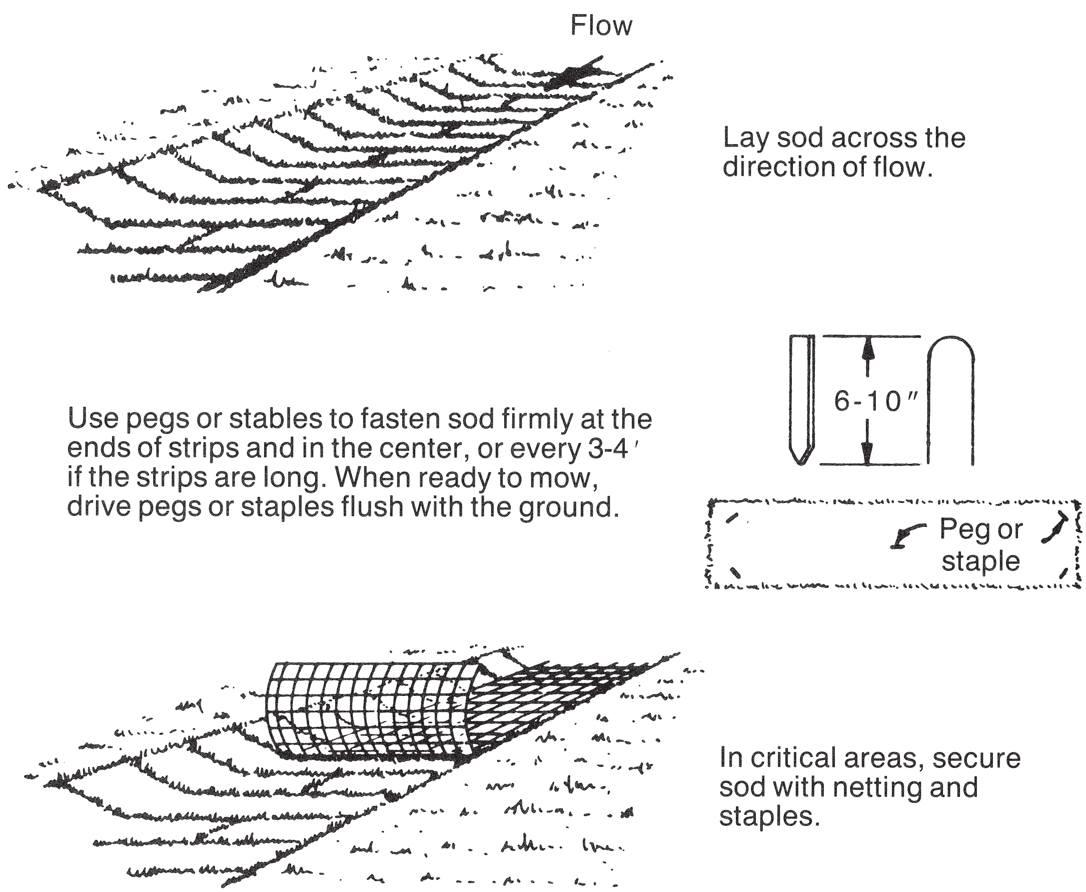


Figure 6.12b Installation of sod in waterways (modified from Va SWCC).

Table 6.12b
Characteristics of the Principal Lawn Grasses Grown as Sod in North Carolina

Species or Mixture	Adaptation					Maintenance		
	Shade	Heat	Cold	Drought	Wear	Annual Fertilizer (lb N/1000 ft^2)	Mowing Height (in.)	Mowing Frequency
Kentucky bluegrass	good	fair	good	good	good	2.5-4	2	med.
Kentucky bluegrass/ Tall fescue	good	good	good	good	good	2.5-3	3	high
Tall fescue	good	good	good	good	good	2.5-3.5	3	high
Hybrid Bermudagrass	poor	good	poor	excel.	excel.	5-6	1	high
Centipedegrass	fair	good	poor	good	poor	0.5	1	low
St. Augustinegrass	good	good	poor	good	poor	2.5	2-3	med.
Zoysiagrass	fair	good	fair	excel.	good	1.5	1	high

Adapted from *Carolina Lawns*, NCAES Bulletin no. AG-69.

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

Maintenance

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

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

After the first growing season, established sod requires fertilization, and may also require lime. Follow soil test recommendations when possible, or use the rates in Table 6.12b.

References

Site Preparation
6.04, Topsoiling

Surface Stabilization
6.11, Permanent Seeding

Runoff Conveyance Measures
6.30, Grass-lined Channels

Inlet Protection
6.53, Sod Drop Inlet Protection

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

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

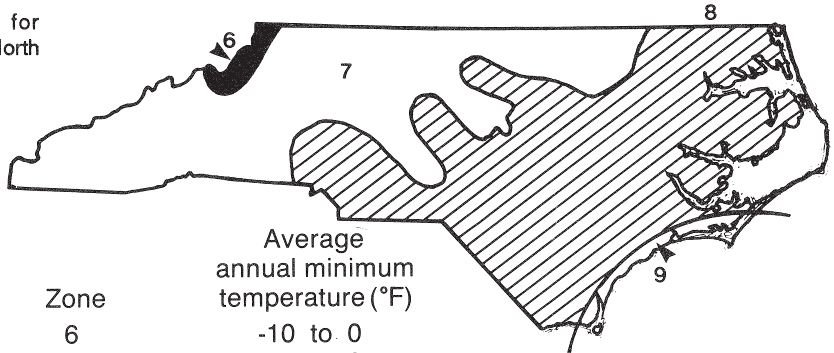
Zones of climatic adaptation of landscape plants are referred to as "Plant Hardiness Zones" (Figure 6.13a). North Carolina encompasses portions of zones 6, 7, 8, and 9, but most of the State falls into zones 7 and 8. Most of the plants listed in Table 8.02b (*Appendix 8.02*) are climatically adapted 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.



Zone	Average annual minimum temperature (°F)
6	-10 to 0
7	0 to 10
8	10 to 20
9	20 to 30

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.

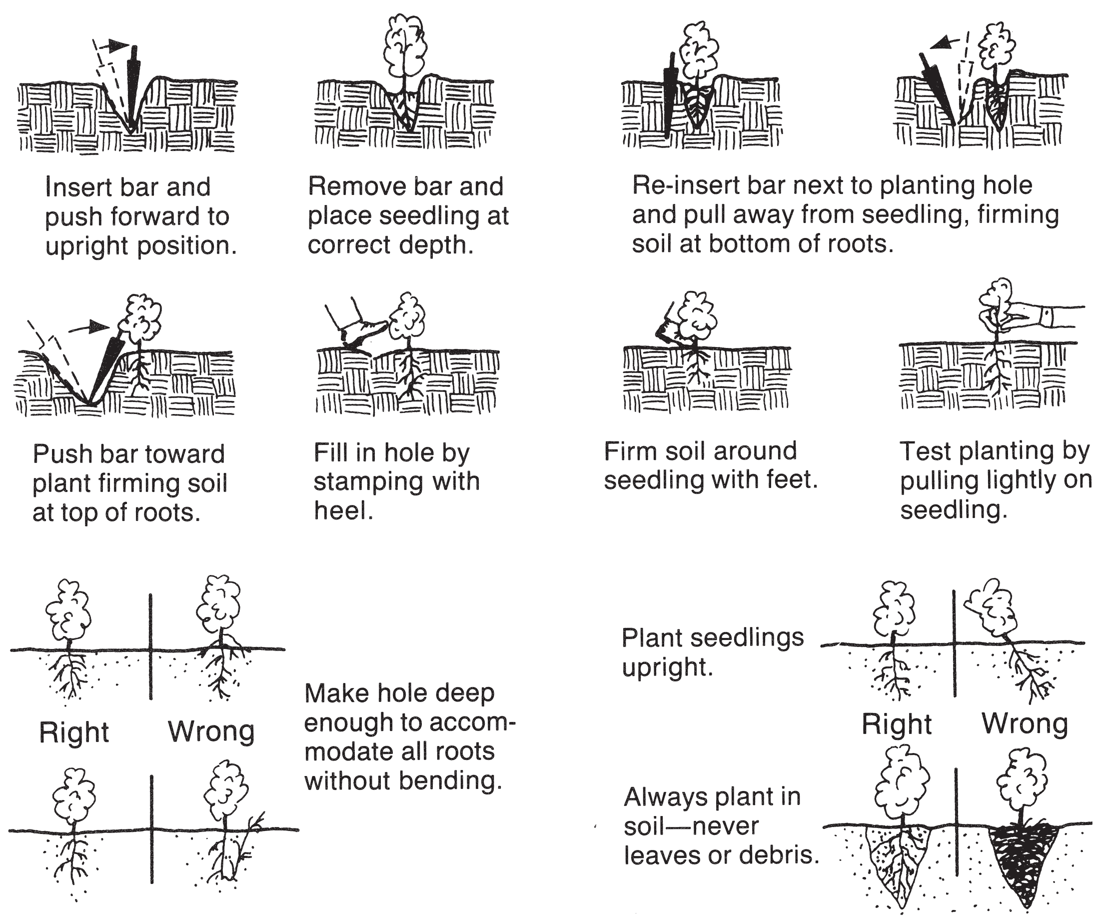


Figure 6.13b Planting bare-root seedlings (modified from Va. Div. of Forestry).

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.

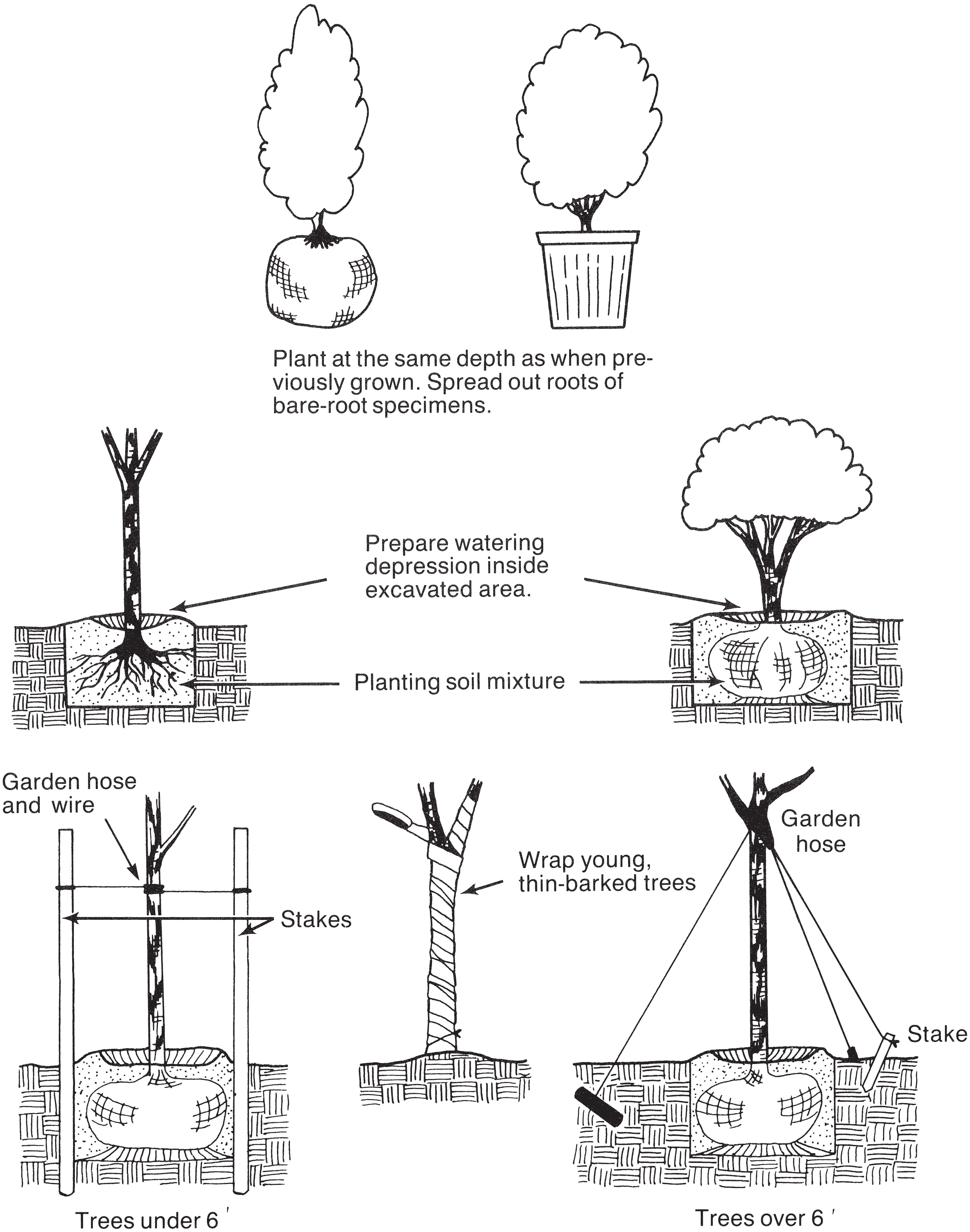


Figure 6.13c Planting balled-and-burlapped and container-grown trees (modified from Va. Div. of Forestry).

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.

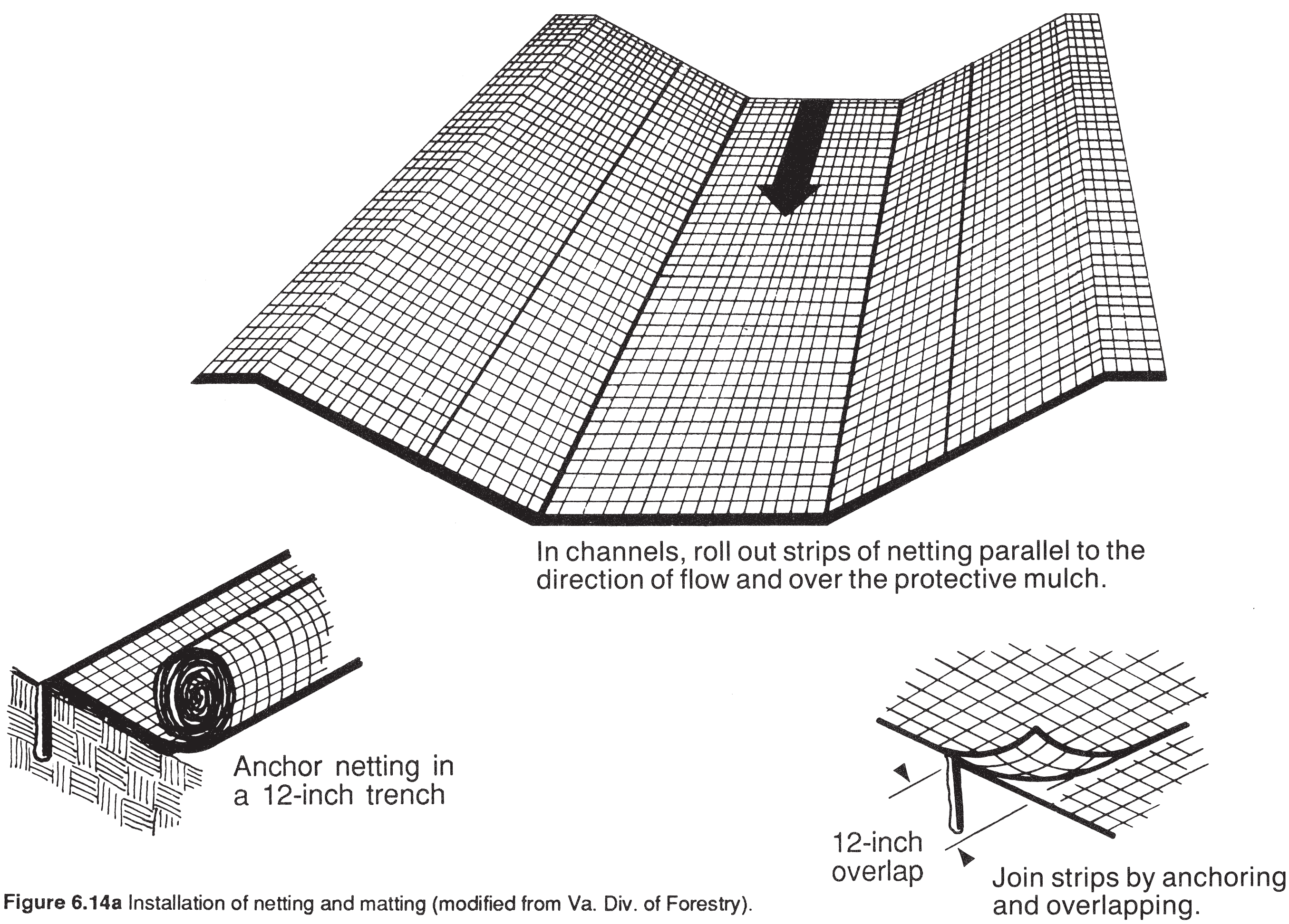


Figure 6.14a Installation of netting and matting (modified from Va. Div. of Forestry).

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.

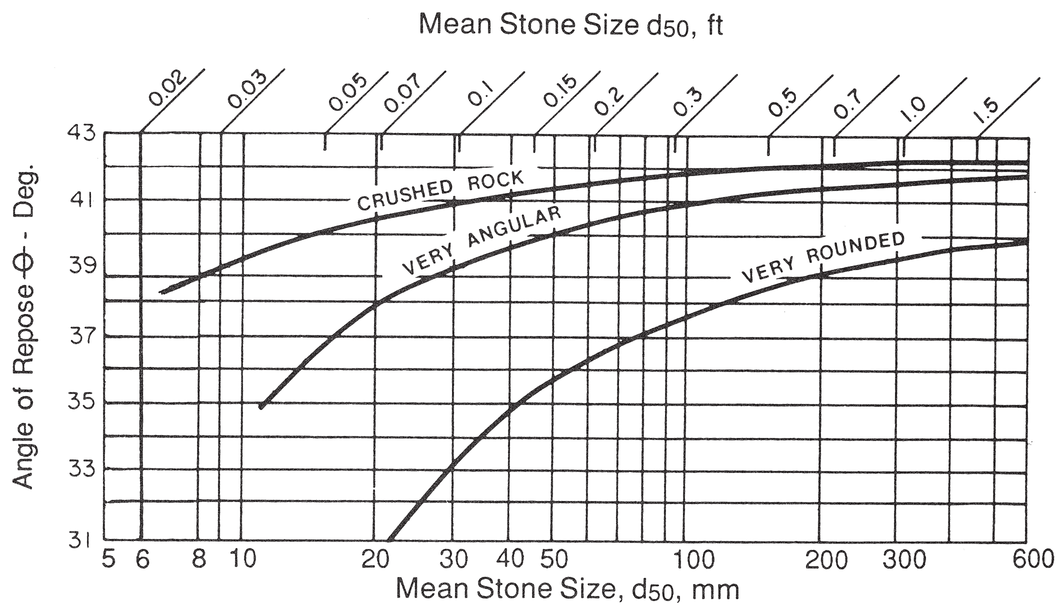


Figure 6.15a Angle of repose for different rock shapes and sizes.
Adapted from: FHWA, HEC-15, pg. 49 - April 1988

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.

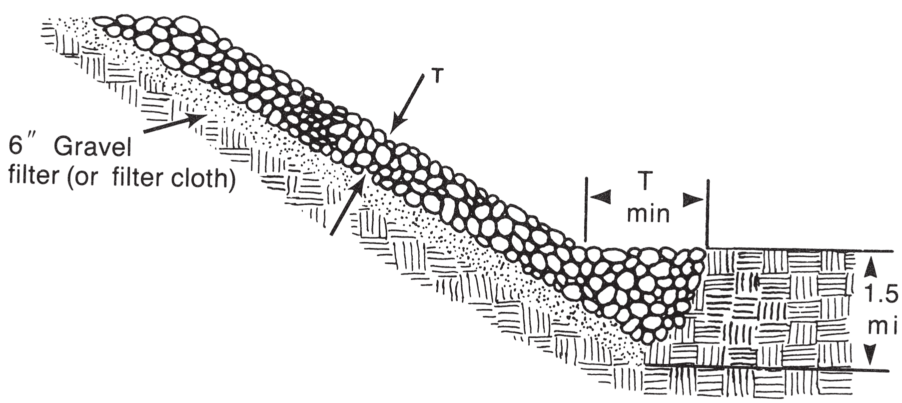
Where large stones are used or machine placement is difficult, a 4-inch layer of fine gravel or sand may be needed to protect the filter cloth.

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

6.16

VEGETATIVE DUNE STABILIZATION

DS

Definition

Use of adapted vegetation and mechanical means to catch and hold sand, and build or repair dunes.

Purpose

To maintain a barrier dune system that protects low-lying backshore areas during storms of short duration; to stabilize sandy areas disturbed by construction activities; and to protect roads, buildings, and valued areas from encroachment by blowing sand. Dunes act as barriers to waves, as energy dissipators, and as reservoirs of sand that reduce foreshore recession during storms. Dunes are not effective against persistent, continuous beach recession when shoreline changes are occurring.

Conditions Where Practice Applies

On coastal foredunes or in areas on barrier islands, away from the foredune area, where stabilization of sand is necessary.

Planning Considerations

There are only a few plant species that are tolerant of the stresses of the beach environment. Plants must be able to survive burial by blowing sand, sand blasting, salt spray, saltwater flooding, drought, heat, and low nutrient supply. Perennial grasses are the primary stabilizers of frontal dunes. The North Carolina coast is a transition zone between the northern-dominant American beachgrass and the southern-dominant sea oats. Bitter panicum is also an important perennial grass on foredunes in North Carolina.

American beachgrass is the most practical vegetation to plant for initial coastal dune stabilization. It is easy to propagate, harvest, store, and transplant; it establishes and grows rapidly, trapping sand effectively by the middle of the first growing season. The vigorous rhizome system of American beachgrass makes it effective for filling sparse stands.

The main disadvantages of American beachgrass are that it is susceptible to heat and drought in North Carolina, and that stands begin to die out when the supply of sand and nutrients is cut off. Consequently, it persists for only a few years behind the crest of the frontal dune. It is also susceptible to disease and insect pests. To overcome these problems, a small amount of sea oats and bitter panicum can be included in beachgrass plantings. Replace dead beachgrass patches with sea oats, bitter panicum or seashore elder.

Sea oats is a warm-season dune grass ranging from southeastern Virginia to Mexico. It is vigorous, drought and heat tolerant, and is relatively free of pests. Sea oats is more tolerant of reduced sand and nutrient supply than American beachgrass and persists in backdune areas. The disadvantages of sea oats are that it is more difficult to propagate in field nurseries than American beachgrass, and commercial availability is limited. Potted plants can easily be grown from seed, but this method of production makes costs higher than for American beachgrass.

Bitter panicum—Commercial sources of bitter panicum are also limited. It grows and multiplies well in field nurseries, but it is more difficult to dig, store, and transport than American beachgrass. There is a wide range of types of bitter panicum ranging from slender to large stemmed and from low-growing and decumbent to tall and erect.

Specifications

Plant selection—American beachgrass is the most practical species for large-scale dune plantings in North Carolina, due to its commercial availability, low cost, ease of transplanting, and quick establishment. Use cultivars adapted to North Carolina such as Hatteras and Bogue. Cape is a northern strain, not recommended for North Carolina because it declines rapidly after the first growing season.

Include sea oats and/or bitter panicum (10% is adequate) in dune plantings of American beachgrass to fill bare spots created as the beachgrass dies out.

Site preparation—Low areas benefit from installation of wind fences to accumulate blowing sand, raising the elevation and decreasing the chance of flooding by salt water. Tillage or liming are not required for planting on beach sand.

Planting—Plant small areas and steep slopes by hand. Place single plants into separate holes made with a shovel or dibble bar. Firm the sand around plants. Complete planting specifications are given in Table 6.16a.

Large, flat sites can be planted more economically using a tractor-drawn transplanter with planting shoes extended to make furrows 8-10 inches deep.

Bitter panicum roots at every node on its stem. Place runners in a trench and cover, leaving 6-8 inches sticking out of the sand.

Fertilizer—A good supply of nutrients promotes rapid establishment of transplants, increases growth and sand-trapping capacity, and improves chances of survival. Therefore fertilizer is usually required for establishment and maintenance, particularly in areas that are heavily used, because dune sand is low in plant nutrients. Periodic maintenance fertilization may also be necessary to maintain stands in areas not receiving a fresh sand supply. Grasses on the front of foredunes, receiving blowing sand, have adequate plant nutrients, and do not respond to fertilization.

Do not apply fertilizer to dune vegetation until it is certain that root growth has begun. If fertilizer is applied before or at planting, there is a risk of losing nitrogen to leaching before plant uptake occurs. During the first growing season, apply 15 lb/1,000 ft^2 or 10-10-10 fertilizer in April followed by 1.3 lb of nitrogen in June, and again around the first of September. Maintenance fertilization should be continued through the third growing season (Table 6.16b).

Maintenance

Replant areas lost to erosion. Fertilize twice during the second growing season and once a year thereafter if needed (Table 6.16b). Replace American beachgrass that dies out with sea oats, bitter panicum, or seashore elder.

Table 6.16a
Planting Specifications for: Coastal Sands Exposed to Salt Spray and/or Wind Erosion

Planting mixture

Species	Rate
Hatteras American beachgrass	1 healthy stem/hill

Interplant 5-10% sea oats and/or bitter panicum if possible.

Planting dates
American beachgrass: November - March
Sea oats and bitter panicum: March - June

Planting depth
American beachgrass and sea oats: 8-10 inches
Bitter panicum: 6 inches

Spacing
To repair or maintain existing dunes plant at a spacing of 1.5 ft x 1.5 ft. To build dunes by trapping sand, a graduated spacing pattern should be used that allows sand to penetrate to the center of the planting, creating a wide, flat dune; spacing should be as follows.

Number of Rows	Row Spacing (ft)
4	3
4	2
4*	1.5
4	2
4	3

* - center of dune

Fertilization
Refer to Table 6.16b for suggested dates and rates of dune fertilization.

Mulch
Do not mulch.

Maintenance
Do not mow. Fertilize as needed; fill in dead areas of American beachgrass by transplanting sea oats, bitter panicum, or seashore elder.

Table 6.16b Dune Fertilization Schedule for Maintenance (Rates are pounds per 1,000 Square Feet)

Date	First year	Second Year	Subsequent Years (if needed)
American Beachgrass			
March 15	---	10 lbs 10-10-10	10 lbs 10-10-10
April 15	15 lbs 10-10-10	---	---
June 15	4 lbs ammonium nitrate	---	---
Sept. 1	4 lbs ammonium nitrate	3 lbs ammonium nitrate	---
Sea Oats and Bitter Panicum			
April 15	---	10 lbs 10-10-10	10 lbs 10-10-10
May 1	15 lbs 10-10-10	---	---
June 15	4 lbs ammonium nitrate	---	---
July 1	---	3 lbs ammonium nitrate	---
August 1	4 lbs ammonium nitrate	---	---

Souce: *Building and Stabilizing Dunes with Vegatation.* UNC Sea Grant Publication 82-05, S. W. Broome et al., 1982

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

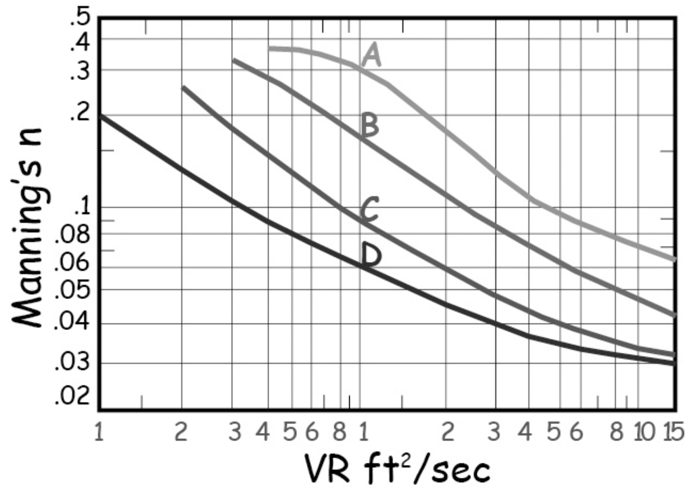


Figure 6.17b Limiting values for bare and TRM protected soils

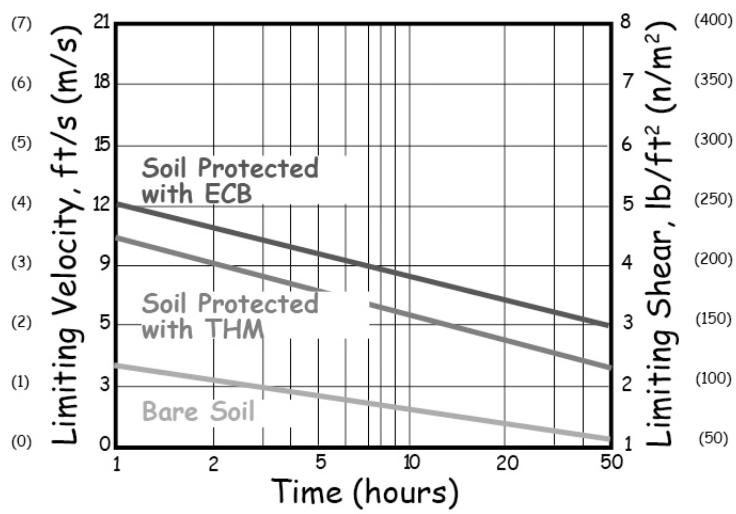
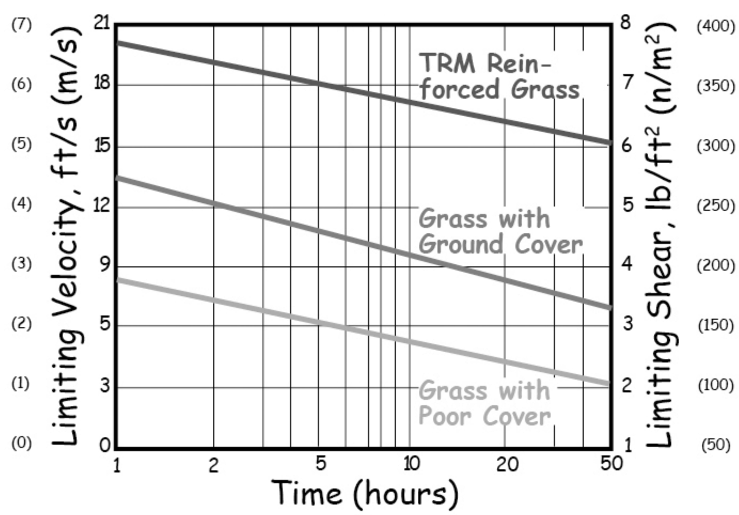


Figure 6.17c Limiting values for plain and TRM reinforced grass



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:
$V_{estimate}$ = 7.1ft/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 $\tau = YDS$
$= (62.4)\,(1.0)\,(0.05)$
$= 3.12$ 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.

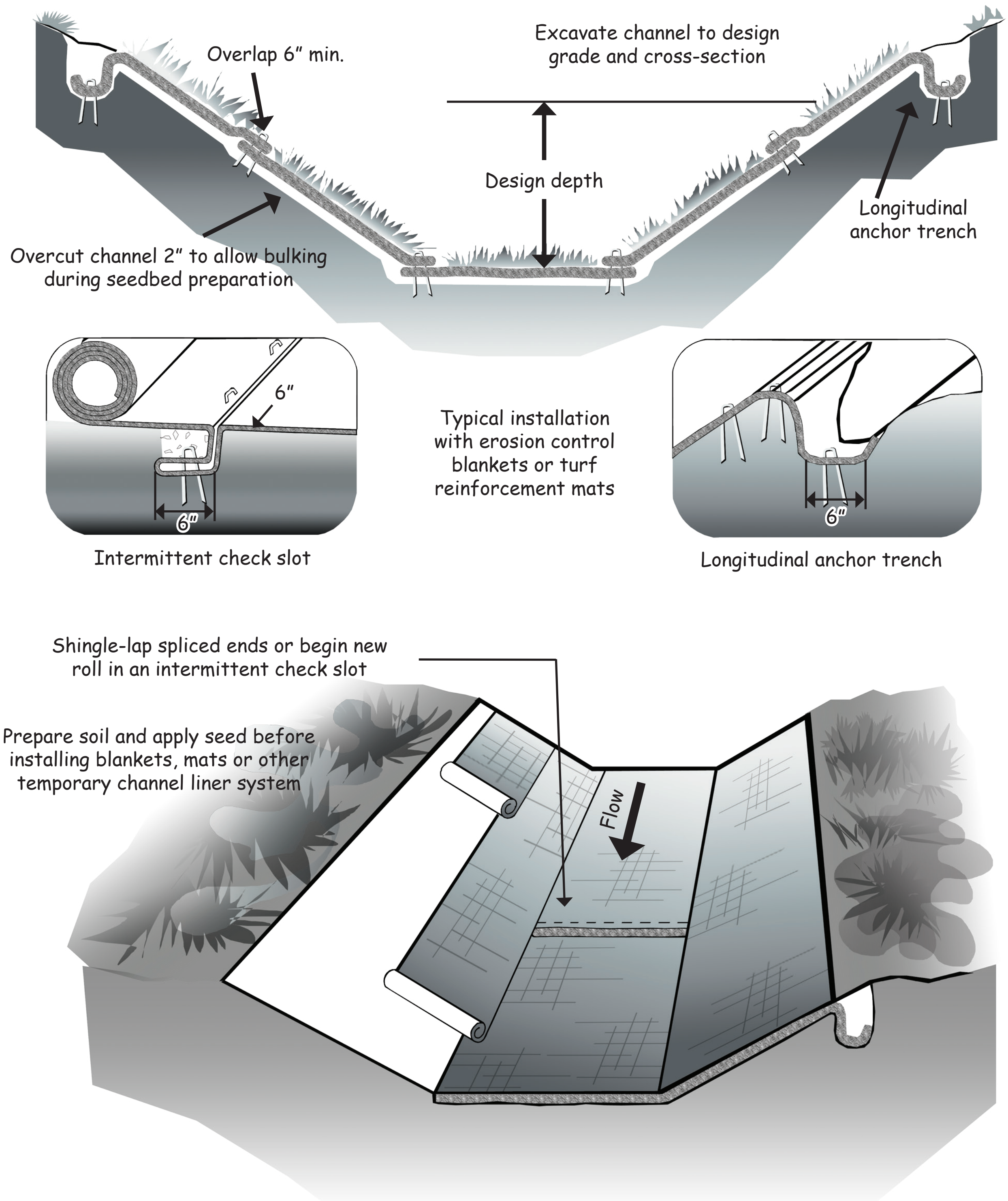
Then pin the RECP (two layers) to the bottom of the trench, backfill, and compact. Continue up the channel (wrapping over the top of the intermittent trench) repeating this step at other intermittent trenches, until reaching the upper terminal trench.

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.

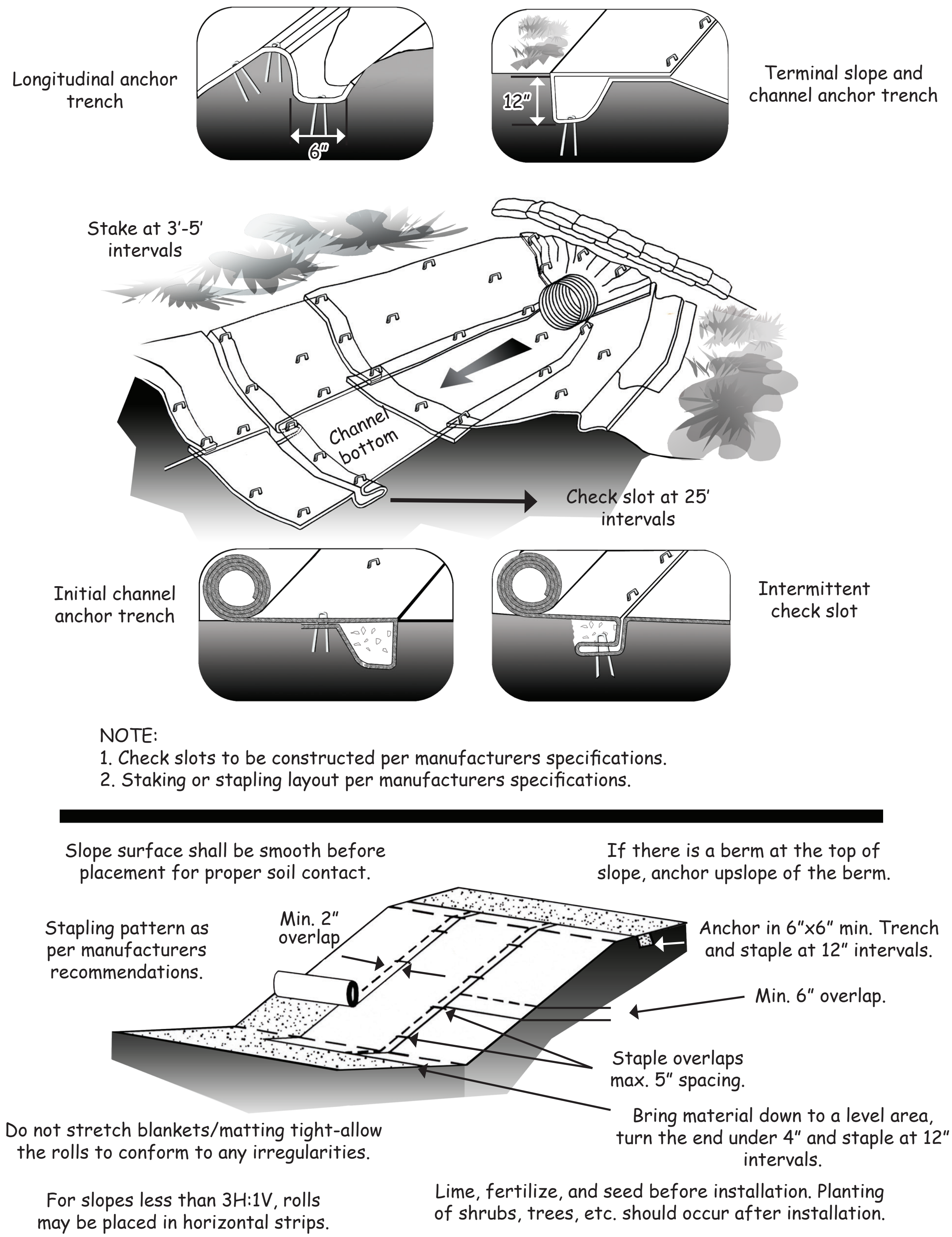
Drive staples or pins so that the top of the staple or pin is flush with the ground surface. Anchor each RECP every 3 feet along its center. Longitudinal overlaps must be sufficient to accommodate a row of anchors and uniform along the entire length of overlap and anchored every 3 feet along the overlap 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

6.18

C
BLK

COMPOST BLANKETS

Definition

Compost is the organic product resulting from the controlled biological decomposition of organic material, occurring under aerobic conditions that has been sanitized through the generation of heat and stabilized to the point that it is appropriate for its particular application. Active composting is characterized by a high-temperature phase that sanitizes the product and allows a high rate of decomposition. This is followed by a lower-temperature phase that allows the compost to stabilize while it continues to decompose at a slower rate. Compost should possess no objectionable odors. It shall not contain substances toxic to plants, and shall not resemble the raw material from which it was derived. Compost is not a fertilizer.

It is recommended that compost utilized on construction sites in North Carolina meet the minimum rules and regulations for proper thermophilic composting set forth by NCDENR, defined by USEPA, described in 40 Code of Federal Regulations Part 503, Appendix B, and as described in Table 6.18a.

Most compost contains a wood based fraction (e.g., bark, ground brush, wood chips, etc.) which is typically removed before the compost is used as a soil amendment. However, this coarser, woody fraction of the compost plays an important role in erosion and sediment control. For certain compost applications it may be advantageous to add fresh, ground bark or composted, properly sized wood based material to a compost product to improve its efficacy in a particular application.

Compost materials may be considered fill material when placed in wetlands or riparian buffers. Prior to installation in these areas consult with the U.S. Army Corp of Engineers, and the NCDENR Division of Water Quality for permitting requirements.

Compost Blankets

A compost blanket is a slope stabilization, erosion control, and vegetation establishment practice used on construction sites to stabilize bare, disturbed, or erodible soils. Compost blankets may be used for temporary erosion control and in the process of providing permanent vegetative cover.

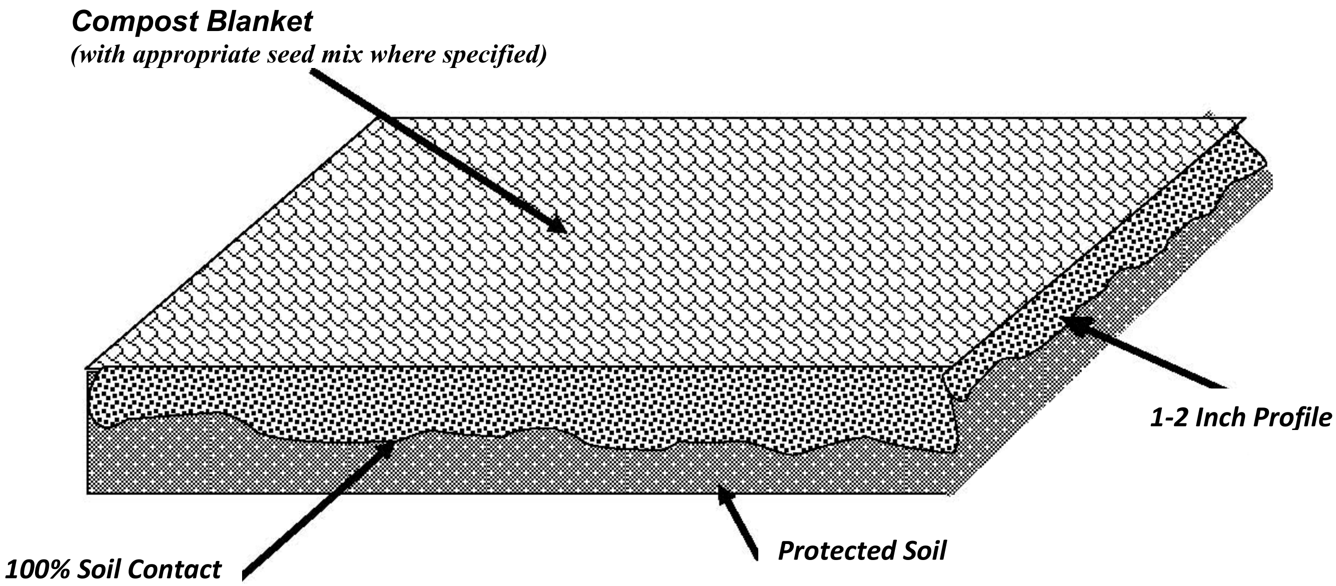


Figure 6.18a Compost Blanket Installation

Conditions Where Practice Applies

Compost blankets should be considered when soil is poor. Compost blankets can be placed on rocky slopes and shallow or infertile soils to improve the growth medium for grasses. Care should be taken not to apply compost where it can raise the nutrient level of streams. When the blanket is specified for permanent stabilization, vegetative cover shall be incorporated with the compost at rates shown in the seeding specification on the approved plan and maintained until the permanent cover is established. Where specified for temporary stabilization the blanket must be installed and maintained as specified in the construction sequence on the approved plan. A temporary vegetative cover or nurse crop should be considered for incorporation with temporary compost blankets.

Planning Considerations

Compost blankets have a mulch function and cover 100% of the soil surface, and therefore provide the beneficial effects characteristic to mulches, including: reduced raindrop impact and splash erosion, reduced runoff energy and sheet erosion, buffered soil temperature for plants, decreased moisture evaporation, increased moisture holding capacity at the soil surface, reduced runoff volume and velocity, and increased infiltration. Where planned and applied correctly to a properly prepared subgrade, compost blankets can aid in amending the soil. This can provide benefits to the soil's structure; increased aggregation, aeration, infiltration and percolation, moisture holding capacity, activity of beneficial microbes, availability of nutrients; decreased runoff volume and velocity, and decreased erosion; increased plant health; and long-term site sustainability.

A compost blanket may be considered appropriate for erosion and sediment control in conjunction with other methodologies, during the construction process. Compost blankets should only be used to control sheet flow from rainfall. Blankets may not be utilized in areas of concentrated runoff. Blankets may not be utilized in areas subject to vehicular traffic and use by heavy equipment. Very coarse compost should be avoided, if the slope is to be landscaped or seeded, as it will make planting and crop establishment more difficult.

When planning the use of compost blankets, it is recommended to use products that are certified by the US Composting Council's Seal of Testing (STA) Program (**www.compostingcouncil.org**). This practice will allow for the acquisition of products that are analyzed on a routine basis, using the specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products. Compost use for compost blankets should be considered mature as defined by USCC-STA Biological Assays Seedling Emergence and Relative Growth test.

Design Criteria

Compost blankets may be used for temporary erosion/sediment control applications. This application is appropriate for slopes up to a 2:1 grade (horizontal distance: vertical distance), and only be used in areas that have sheet flow drainage patterns (not areas that receive concentrated flows). Slopes steeper than 2:1 may require special installation techniques (consult compost supplier for recommendations). The chemical, physical and biological parameters of compost blankets approved for use in this application are described in Table 6.18a. Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limit standards pertaining to the source materials from which it is derived.

Table 6.18a – Compost Blanket Parameters

Parameters[1,4]	Reported as (units of measure)	Surface Mulch to be Vegetated	Surface Mulch to be left Un-vegetated	Test Method	Test Method Name
pH[2]	pH units	5.0 - 8.5	N/A	TMECC 04.11-A	Electrometric pH Determinations for Compost. 1:5 Slurry Method
Soluble Salt Concentration[2] (electrical conductivity)	dS/m (mmhos/cm)	Maximum 5	Maximum 5	TMECC 04.10-A	Electrical Conductivity for Compost. 1:5 Slurry Method (Mass Basis)
Moisture Content	%, wet weight basis	30 – 60	30 – 60	TMECC 03.09-A	Total Solids and Moisture at 70±5°C
Organic Matter Content	%, dry weight basis	25 – 65	25-100	TMECC 05.07-A	Matter Method. Loss On Ignition Organic Matter Method
Particle Size	% passing a selected mesh size, dry weight basis	• 3" (75 mm), 100% passing • 1" (25mm), 90- 100% passing • 3/4" (19mm), 65-100% passing • 1/4" (6.4 mm),	• 3" (75 mm), 99% passing • 1" (25mm), 90-100% passing • 3/4" (19mm), 65-100% passing • 1/2" (12.5 mm),	TMECC 02.12-B	Laboratory Sample Preparation. Sample Sieving for Aggregate Size Classification

		0-75% passing • Maximum particle length of 6" (152mm)	0-30% passing • Maximum particle length of 6" (152mm)		
Stability[3] Carbon Dioxide Evolution Rate	mg CO_2-C per g OM per day	< 8	N/A	TMECC 05.08-B	Respirometry. Carbon Dioxide Evolution Rate
Maturity (Bioassay) Percent Emergence Relative Seedling Vigor	% (average) % (average)	100% 100%	90-100% 90-100%	TMECC 05.05-A	
Physical Contaminants (man-made inerts)	%, dry weight basis	< 1	< 1		Biological Assays. Seedling Emergence and Relative Growth

1 Recommended test methodologies are provided in Test Methods for the Examination of Composting and Compost (TMECC, The US Composting Council)

2 Each specific plant species requires a specific pH range. Each plant also has a salinity tolerance rating, and maximum tolerable quantities are known. When specifying the establishment of any plant or turf species, it is important to understand their pH and soluble salt requirements, and how they relate to the compost in use.

3 Stability/Maturity rating is an area of compost science that is still evolving, and as such, other various test methods could be considered. Also, never base compost quality conclusions on the result of a single stability/maturity test.

4 Landscape architects and project (field) engineers may modify the allowable compost specification ranges based on specific field conditions and plant requirements.

Construction Specifications

The following steps shall be taken for the installation of compost blankets for erosion/sediment control. The information shall also be included in the construction sequence on the approved erosion and sediment control plan.
Prepare the soil by removing large clods, rocks, stumps, roots as described in Chapter 6 of this manual.

Apply the compost blanket to 100% of the area as required on the approved plan.

1. The blanket shall cover 100% of the bare or disturbed soil area, whereas, no native soil shall be visible in or through the compost blanket. It shall be applied at the application rates, as specified in Table 6.18b. Seed shall be thoroughly mixed with the compost prior to application or surface applied to the compost blanket at time of application at the appropriate rates as prescribed by the approved plan.

2. Compost blankets shall be installed at least 10 ft over and beyond the shoulder of the slope and/or into the edge of existing vegetation to ensure runoff does not undercut the blanket. When installing into the edge of existing vegetation, care must be taken not to disturb the existing root mat.

3. Compost blanket application rates should be designed and specified based on specific site (e.g., soil characteristics, existing vegetation) and climatic conditions, as well as particular project related requirements and calculated storm water runoff.

4. Compost blankets installed on slopes greater than or equal to 4:1 shall be tracked. Blankets on 3:1 slopes shall be tracked and secured with an adequate rolled erosion control product. (See Practice Standard 6.17 *Rolled Erosion Control Products* (RECP) for installation procedure.) Where high winds and wind erosion are expected, RECPs shall be installed over the compost blanket, regardless of slope. All other installation procedures and specifications will be as shown on the approved plan and described in the approved construction sequence. Compost shall be uniformly applied as described in the approved construction sequence with the appropriate equipment. If required, thorough watering may be used to improve settling of the blanket.

Table 6.18b– Compost Blanket Application Rates

Annual Rainfall/Flow Rate	**Total Precipitation & Rainfall Erosivity Index**	**Application Rate For Vegetated* Compost Surface Mulch**	**Application Rate For Unvegetated Compost Surface Mulch**
Low	1”-25”, 20-90	1”–1 ½” (25 mm – 37.5mm)	1”–1 ½” (25 mm – 37.5mm)
Average	26”-50”, 91-200	1”–1 ½” (25 mm – 37.5mm)	1 ½”–2” (37 mm – 50 mm)
High	51” and above, 201 and above	1”-2” (25 mm - 50 mm)	2”-4” (50mm – 100mm)

*these lower application rates should only be used in conjunction with seeding, and for compost blankets applied during the prescribed planting season for the particular region.

Maintenance

Inspect compost blankets weekly and within 24 hours of a rainfall event of ½ inch or greater. If failure or damage to the blanket occurs or if vegetation does not establish within the expected germination time of the selected seed type, reapply compost and seed to the affected area to return it to the original condition. Take additional measures as necessary to establish permanent ground cover. Compost blankets shall be inspected until permanent vegetation is established. RECP placed over the compost blanket should be repaired if it has been moved or damaged by wind or storm runoff and/or if part of or the whole blanket is not in contact with the soil surface.

Compost Sampling And Characterization Of Compost

Sampling procedures to be used for purposes of this specification (and the Seal of Testing Assurance program) are as provided in 02.01 Field Sampling of Compost Materials, 02.01-B Selection of Sampling Locations for Windrows and Piles of the Test Methods for the Examination of Compost and Composting (TMECC), Chapter 2, Section One, Sample Collection and Laboratory Preparation, jointly published by the USDA and USCC (2002 publishing as a part of the USDA National Resource Conservation Technical Bulletin Series). The sample collection section is available online at http://compostingcouncil.org/tmecc/.

Test Methods to be used for purposes of this specification are as provided in The Test Methods for the Examination of Compost and Composting (TMECC), Jointly published by the USDA and USCC (2002 publishing as a part of the USDA National Resource Conservation Technical Bulletin Series). A list of such methods is provided online at http://compostingcouncil.org/tmecc/

References

Chapter 3 Vegetative Considerations
Chapter 6 Surface Stabilization
6.03, Surface Roughing
6.10, Temporary Seeding
6.11, Permanent Seeding
6.17, Rolled Erosion Control Products

Test Methods for the Examination of Compost and Composting TMECC), jointly published by the USDA and US Composting Council (2002 publishing as a part of the USDA National Resource Conservation Technical Bulletin Series). http://compostingcouncil.org/tmecc/

ECTC. 2004. Erosion Control Technology Council Standard Specification for Rolled Erosion Control Products. Rev. 4904. www.ectc.org

Faucette, L.B., C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman, and L.T. West. 2005. Evaluation of storm water from compost and conventional erosion control practices in construction activities. Journal of Soil and Water Conservation. 60:6:288-297.

Fifield, J. 2001. Designing for Effective Sediment and Erosion Control on Construction Sites. Forester Press, Santa Barbara, CA.

GA Soil and Water Conservation Commission, 2000. Georgia Erosion and Sediment Control Manual, 2000, 5th Ed..

Tyler, R., A. Marks, B. Faucette. 2010. The Sustainable Site: Design Manual for Green Infrastructure and Low Impact Development Forester Press, Santa Barbara, CA.

6

INDEX

RUNOFF CONTROL MEASURES

6

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

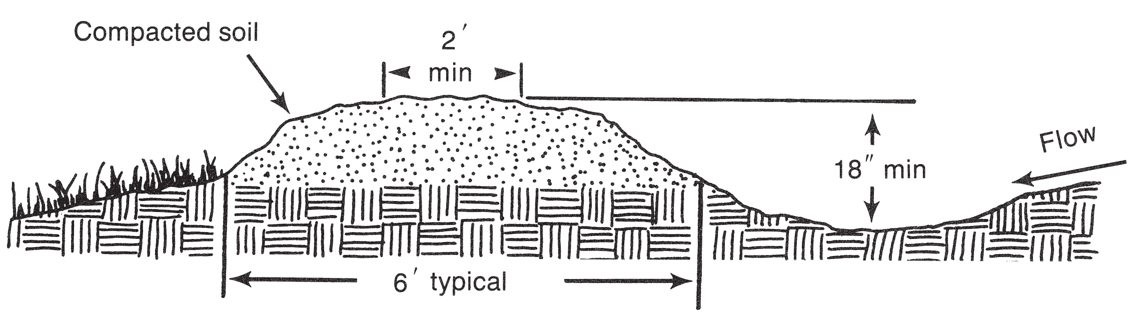


Figure 6.20a Temporary earthen diversion dike.

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).

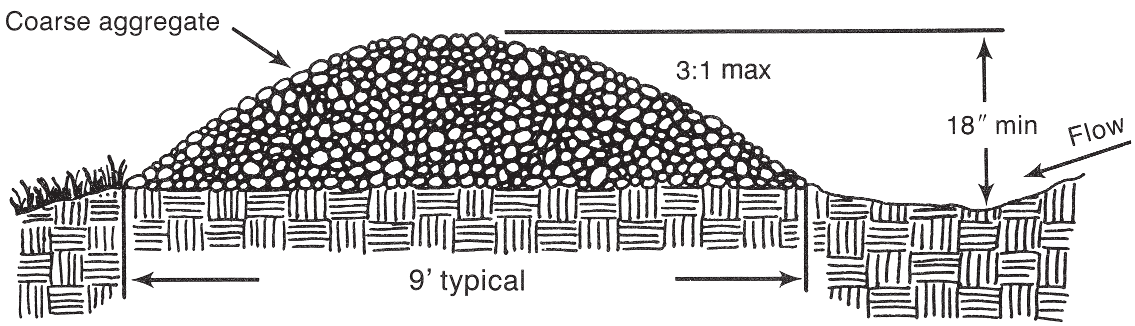


Figure 6.20b Temporary gravel diversion dike for vehicle crossing (modified from Va SWCC).

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

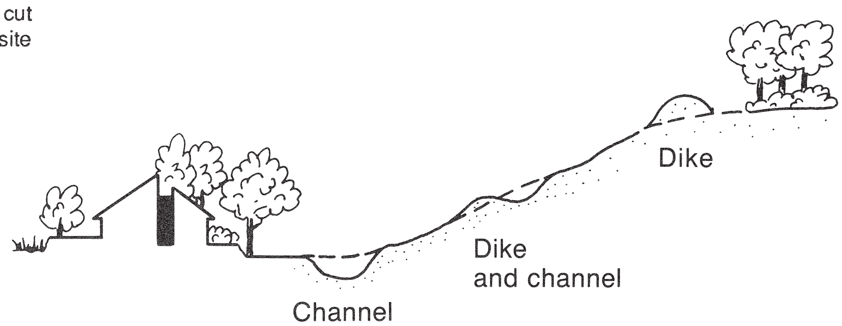
This permanent site development practice applies to construction areas where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sedimentation damage. Specific locations and conditions include:

- 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

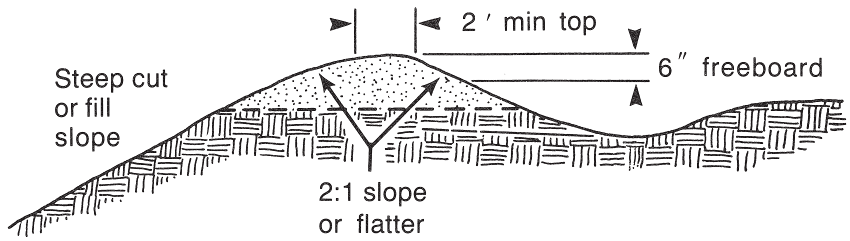
Construction Specifications

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

6.22

→ PD →

DIVERSION DIKE (Perimeter Protection)

Definition

A dike or dike and channel constructed along the perimeter of a disturbed construction area.

Purpose

To prevent storm runoff from entering the work area, or to prevent sediment-laden runoff from leaving the construction site.

Conditions Where Practice Applies

Diversion dikes may be located at the upslope side of a construction site to prevent surface runoff from entering the disturbed area or at the downslope side of the work area to divert sediment-laden runoff to on-site sediment traps or basins. Diversion dikes do not usually encircle the entire area.

The upslope dike can improve working conditions at the construction site and prevent erosion. The downslope dike assures that sediment-laden runoff will not leave the site without treatment.

Planning Considerations

A diversion dike is a special application of a temporary or permanent diversion. It differs from other diversions in that the location and grade are usually fixed, and the cross section and stabilization requirements are based on the existing grade of the work boundary. Hence, the design cross section may vary significantly throughout the length. Give special care to avoid erosive velocities in steep areas. Identify areas where sedimentation will occur since they are often subject to overtopping.

Immediately vegetate diversion dikes after construction, but make sure channel flow area is stabilized during construction. Exercise caution in diverting flow to be certain that the diverted water is released through a stable outlet and that the flow will not cause flood damage. Diversion dikes may be either temporary or permanent depending on site conditions (Figure 6.22a).

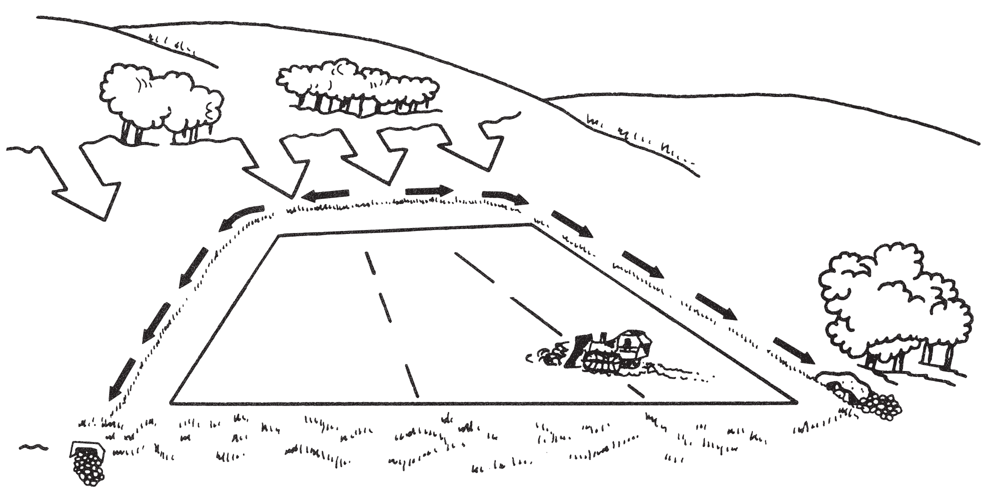


Figure 6.22a Perimeter dikes prevent surface runoff from entering construction sites.

Design Criteria

Drainage area—5 acres or less.

Capacity—consistent with the hazard involved and design life and with a 10 year peak runoff minimum.

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

Dike design—	side slope:	2:1 or flatter
		3:1 or flatter where vehicles must cross
	width:	2.0 feet minimum top width
	height:	1.5 feet minimum
	freeboard:	0.5 feet 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 must cross
	stabilization:	based on velocity by reaches

Grade—Dependent on site topography. Channel should have positive grade.

Outlet—Divert sediment-laden water into a temporary sediment trap or sediment basin. Runoff from undisturbed areas should empty into an outlet protection device such as a level spreader or riprap outlet structure unless well stabilized natural outlets exist.

Construction Specifications

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

2. Disk the base of the dike before placing fill.

3. Ensure that the constructed cross section meets all design requirements.

4. Compact the dike by tracking with construction equipment.

5. Ensure that the top of the dike is not lower at any point than the design elevation plus the specified settlement after it has been compacted.

6. Leave sufficient area along the dike to permit machine re-grading and cleanout.

7. Immediately seed and mulch the dike after its construction, and stabilize the flow portion in accordance with design requirements.

Maintenance

Inspect diversion dikes once a week and after every rainfall. Immediately remove sediment from the flow area and repair the dike.

Check outlets, and make timely repairs as needed to avoid gully formation. When the area above the temporary diversion dike is permanently stabilized, remove the dike, and fill and stabilize the channel to blend with the natural surface.

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

Appendix
8.05, Design of Stable Channels and Diversions

6.23

→ WB →

RIGHT-OF-WAY DIVERSIONS (Water Bars)

Definition

A ridge or ridge and channel constructed diagonally across a sloping road or utility right-of-way that is subject to erosion.

Purpose

To limit the accumulation of erosive volumes of water by diverting surface runoff at predesigned intervals.

Conditions Where Practice Applies

Where runoff protection is needed to prevent erosion on sloping access rights-of-way or other long, narrow sloping areas generally less than 100 feet in width.

Planning Considerations

Construction of access roads, power lines, pipelines, and other similar installations often requires clearing long narrow rights-of-way over sloping terrain (Figure 6.23a). Disturbance and compaction promotes gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to undisturbed areas by using small predesigned diversions. Give special consideration to each individual outlet area, as well as to the cumulative effect of added diversions. Use gravel to stabilize the diversion where significant vehicular traffic is anticipated.

Design Criteria

Height—18-inch minimum measured from the channel bottom to the ridge top.

Side slope—2:1 or flatter

3:1 or flatter where vehicles cross

Base width of ridge—6 feet minimum (Figure 6.23b).

Spacing of water bars is shown in Table 6.23a:

Table 6.23a Spacing of Water Bars on Right-of-Way Less than 100 ft Wide

Slope (%)	Spacing (Ft)
<5	125
5 to 10	100
10 to 20	75
20 to 35	50
>35	25

Grade and angle—A crossing angle should be selected to provide a positive grade not to exceed 2%

Outlet—Diversions should have stable outlets, either natural or constructed. Site spacing may need to be adjusted for field conditions to use the most suitable areas for water disposal.

Construction Specifications

1. Install the diversion as soon as the right-of-way has been cleared and graded.

2. Disk the base for the constructed ridge before placing fill.

Figure 6.23a Water bars to protect utility right-of-way.

3. Track the ridge to compact it to the design cross section.

4. Locate the outlet on an undisturbed area. Adjust field spacing of the diversion to use the most stable outlet areas. When natural areas are not deemed satisfactory, provide outlet protection (Practices 6.40, *Level Spreader*, and 6.41, *Outlet Stabilization Structure*).

5. Immediately seed and mulch the portions of the diversions not subject to construction traffic. Stabilize with gravel areas to be crossed by vehicles.

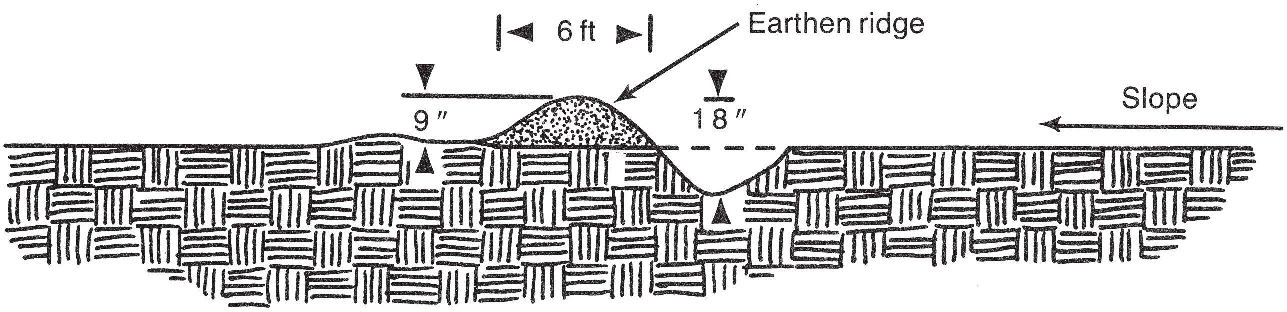


Figure 6.23b Section view of a water bar.

Maintenance

Periodically inspect right-of-way diversions for wear and after every heavy rainfall for erosion damage. Immediately remove sediment from the flow area, and repair the dike. Check outlet areas, and make timely repairs as needed. When permanent road drainage is established and the area above the temporary right-of-way diversions is permanently stabilized, remove the dike, and fill the channel to blend with the natural ground, and appropriately stabilize the disturbed area.

References

Outlet Protection
6.40, Level Spreader
6.41, Outlet Stabilization Structure

Appendix
8.03, Estimating Runoff

6.24 RIPARIAN AREA SEEDING

Definition

Controlling runoff and erosion in riparian areas by establishing temporary annual and perennial native vegetative cover.

Purpose

To protect riparian areas from erosion and decrease sediment yield in adjacent streams using temporary annual vegetation as an immediate cover and establish perennial native herbaceous vegetation.

Conditions Where Practice Applies

Disturbed riparian areas between streams and uplands where permanent herbaceous vegetation is needed to stabilize the soil and provide long-term protection.

Planning Considerations

Native vegetation species are defined as plant species that naturally occur in the region in which they evolved. These plants are adapted to local soil types and climatic variations and generally require little to no maintenance. Many of the species have evolved deep, extensive root structures that help stabilize soils and reduce erosive forces of rainfall and overland stream flow. Native species possess certain characteristics that allow them not only to survive, but also to thrive under local conditions. Further, naturally occurring plant communities provide optimal habitat for terrestrial and aquatic fauna. Other agency permits (i.e., ACOE 404 and DWQ 401) may specify further conditions for establishment of native woody vegetation and limits on use of mechanical equipment.

Seeding a mixture of perennial native grasses, rushes, and sedges is a common way to establish permanent ground cover within riparian areas. Both labor and material costs are lower than installation of propagated plants, though some sites may require installation of established vegetation due to site limitations. Selecting a seed mixture with different species having complementary characteristics will allow vegetation to fill select niches within the varying riparian area and respond to different environmental conditions.

Despite the advantages, several disadvantages of seeding riparian areas with native seed may include:

- Potential for erosion or washout during the establishment stage;
- Longer time for germination and establishment;
- Seasonal limitation on suitable seeding dates;
- Specificity of species at each site;
- Need for water and appropriate temperatures during germination and early growth; and
- Need for invasive plant/competition control.

A temporary, non-invasive, and non-competitive annual grass species should be incorporated with the native seeding. This will provide an immediate cover over the site that serves to:

- Prevent bare soil exposure and hold soil in place; and
- Provide a nurse crop for native seeds while they become established.

Temporary annual species should be planted at a low density so they do not suppress growth of permanent species.

Successful plant establishment can be maximized through good planning, knowledge of soil characteristics, selections of suitable plant species for each site, proper seedbed preparation, and timely planting and maintenance.

Selecting Plant Materials

Permanent seed species within the seed mixture should be selected based on natural occurrence of each species in the project site area. Climate, soils, and topography 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. 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.

Seeds adapted to North Carolina should be purchased from a reputable seed grower and should be certified. Do not accept seed containing “prohibited” noxious weed seed. For successful broadcast seeding, seeds should be cleaned. If warm season grasses with “fluffy” seeds are used, a specialized warm season grass drill should be employed. Cultivars should be selected based on adaptation to site region. Stratification, either naturally or artificially, is required for most native seed species to ensure proper germination.

Table 6.24a provides suitable temporary seed species with recommended application rates and optimal planting dates. Temporary annual seed selection should be based on season of project installation. A single species selection for temporary cover is acceptable. In some cases where seasons overlap, a mixture of two or more temporary species may be necessary; however, application rates should not exceed the total recommended rate per acre. Temporary seed should be mixed and applied simultaneously with the permanent seed mix if optimal planting dates allow.

Table 6.24a Temporary Seeding Recommendations

Common Name	**Scientific Name**	**Rate per Acre**	**Optimal Planting Dates**		
			Mountains	*Piedmont*	*Coastal Plain*
Rye grain	Secale cereale	30 lbs	Aug. 15 - May 15	Aug. 15 - May 1	Aug. 15 - Apr. 15
Wheat	Triticum aestivum	30 lbs	Aug. 15 - May 15	Aug. 15 - May 1	Aug. 15 - Apr. 15
German millet	Setaria italica	10 lbs	May 15 - Aug. 15	May 1 - Aug. 15	Apr. 15 - Aug. 15
Browntop millet	Urochloa ramosa	10 lbs	May 15 - Aug. 15	May 1 - Aug. 15	Apr. 15 - Aug. 15

Tables 6.24b-6.24d provide selections of native permanent seeds based on physiographic regions. Included in these tables are species, cultivars, appropriate percentage rates of mixture, and optimal planting times. **No specific seeding rate is given in order to allow for custom seed mixes based on site characteristics and season. However, permanent seed inclusion in the**

mixture should total 15 pounds of pure live seed (PLS) per acre drilled or 15 to 20 pounds PLS per acre broadcast applied. At least four species should be selected for the mixture, including one species from each type (warm season, cold season, wetland); selection of more than four species is recommended for increasing chances of successful vegetation establishment. If other species such as wildflowers are added to the mix, they should not be counted in the minimum seeding rate for grasses.

Seedbed Preparation

Disturbed soils within riparian areas must be amended to provide an optimum environment for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. The pH of the soil must be such that it is not toxic and nutrients are available. Riparian areas are generally considered rich in nutrients due to flooding and deposition, however, these areas can be highly variable (i.e., narrow steep corridors in the mountains, artificial fill material on top of alluvial floodplains in the Piedmont). Soil analysis should be performed to determine nutrient and lime needs of each site. Appropriate levels of phosphorus and potassium are critical for permanent seed establishment. Appropriate pH levels are between 5.5 and 7. Riparian buffers regulated for nutrient management may be limited to a single application of fertilizer.

Construction activities within the riparian area can greatly compact soils. Suitable mechanical means such as disking, raking, or harrowing must be employed to loosen the compacted soil prior to seeding.

Planting

Seeding rates of native herbaceous species are given in pounds of pure live seed due to the variability in the germination and purity of native seed. Reputable seed growers and dealers will buy and sell native seed by the pure live seed pound. When the seed is sown, the amount of pure live seed must be converted to pounds of bulk (actual) seed to sow the proper amount of seed. The amount of bulk (actual) seed is calculated by dividing the amount of pure live seed by the germination and purity as decimals. For example, a ten pound pure live seed per acre seeding rate with seed with 50 percent germination and 50 percent purity will require 40 pounds of bulk (actual) seed (40-10/0.5*0.5).

Planting dates given in the seeding mixture specifications (Tables 6.24b – 6.24d) are designated as “optimal”. Seeds properly sown within the “optimal” dates have a high probability of success. It is also possible to have satisfactory establishment when seeding outside these dates. However, as you deviate from them, the probability of failure increases rapidly. Always take this into account when scheduling land-disturbing activities. Many perennial native species require a cold, wet treatment (stratification) before they will germinate at the rate noted on the seed tag. Seeding before the local date of last frost usually provides enough exposure to cold moist conditions to meet these requirements. Seeding before that date also insures early germination that will decrease the chance that seedlings will be affected by summer droughts. Seed sown late may not germinate until the next year after it has laid in the ground through a winter.

Apply seed uniformly with a cyclone seeder, drop-type spreader, drill, or hydroseeder on a firm, friable seedbed. When using a drill, equipment should be calibrated in the field for the desired seeding rate. In fine soils, seeds should be drilled ¼ to ½ inch. In coarse sandy soils, seeds should be planted no deeper than ¾ inch. Cover broadcast seed by lightly raking or chain dragging; then firm the surface with a roller or cultipacker to provide good seed contact.

Mulch all plantings immediately after seeding (Practice 6.14, Mulching). If planting on stream banks steeper than 10 percent or areas subject to flooding, a biodegradable RECP (Practice 6.17, Rolled Erosion Control Products) is recommended to hold seed and soil in place.

Table 6.24b Permanent Seeding Recommendations -- Mountain Region

Common Name	Scientific Name	Cultivars	Type*	Percentage of Mix	Optimal Planting Dates	Soil Drainage Adaptation	Shade Tolerance	Height
Switchgrass	Panicum virgatum	**Cave-in-rock --** well drained **Blackwell --** well drained **Shelter --** well drained **Kanlow --** poorly drained **Carthage --** well drained	Warm Season	10-15%	Dec. 1 - Apr. 15	Cultivar Dependent	Poor	6
Indiangrass	Sorghastrum nutans	**Rumsey, Osage, Cheyenne**	Warm Season	10-30%	Dec. 1 - Apr. 15	Well-drained to Droughty	Poor	6
Deertongue	Dichanthelium clandestinum	**Tioga**	Warm Season	5-25%	Dec. 1 - Apr. 15	Poorly-drained to Droughty	Moderate	6
Big Bluestem	Andropogon gerardii	**Roundtree, Kaw, Earl**	Warm Season	10-30%	Dec. 1 - Apr. 15	Well-drained to Droughty	Poor	6
Little Bluestem	Schizachyrium scoparium	**Aldous, Cimarron**	Warm Season	10-30%	Dec. 1 - Apr. 15	Well-drained to Droughty	Poor	4
Sweet Woodreed	Cinna arundinacea		Warm Season	1-10%	Dec. 1 - Apr. 15	Poorly-drained to Well-drained	Moderate	5
Rice Cutgrass	Leersia oryzoides		Warm Season	5-25%	Dec. 1 - Apr. 15	Poorly-drained	Poor	5
Redtop Panicgrass	Panicum rigidulum		Warm Season	10-20%	Dec. 1 - Apr. 15	Well-drained	Poor	3.5
Eastern Gammagrass	Tripsacum dactyloides		Warm Season	10-20%	Dec. 1 - Apr. 15	Well-drained to Poorly-drained	Poor	4.5
Purple top	Tridens flavus		Warm Season	5-10%	Dec. 1 - Apr. 15	Well-drained to Droughty	Poor	2.5
Indian Woodoats	Chasmanthium latifolium		Cold Season	1-10%	Mar. 1 - May 15, July 15 - Aug. 15	Well-drained to Droughty	Moderate	4
Virginia Wildrye	Elymus virginicus		Cold Season	5-25%	Mar. 1 - May 15, July 15 - Aug. 15	Well-drained to Droughty	Moderate	3
Eastern Bottle-brush Grass	Elymus hystrix		Cold Season	5-10%	Mar. 1 - May 15, July 15 - Aug. 15	Well-drained to Droughty	Moderate	3
Winter Bentgrass	Agrostis hyemalis		Cold Season	10-20%	Mar. 1 - May 15, July 15 - Aug. 15	Well-drained	Moderate	3.5
Rough Bentgrass	Agostis scabra		Cold Season	10-20%	Mar. 1 - May 15, July 15 - Aug. 15	Poorly-drained	Poor	2.5
Soft Rush	Juncus effusus		Wetland	1-10%	Dec. 1 - May 15, Aug. 15 - Oct.. 15	Poorly-drained	Poor	4
Shallow Sedge	Carex lurida		Wetland	1-10%	Dec. 1 - May 15, Aug. 15 - Oct.. 15	Poorly-drained	Poor	3
Fox Sedge	Carex vulpinoidea		Wetland	1-10%	Dec. 1 - May 15, Aug. 15 - Oct.. 15	Poorly-drained	Poor	3
Leathery Rush	Juncus coriaceus		Wetland	2-5%	Dec. 1 - May 15, Aug. 15 - Oct.. 15	Poorly-drained	Poor	2

*Pick at least four species, including one from each type.

Table 6.24c Permanent Seeding Recommendations -- Piedmont Region

Common Name	Scientific Name	Cultivars	Type*	Percentage of Mix	Optimal Planting Dates	Soil Drainage Adaptation	Shade Tolerance	Height
Switchgrass	Panicum virgatum	**Blackwell --** well drained **Shelter --** well drained **Kanlow --** poorly drained **Carthage --** well drained	Warm Season	10-15%	Dec. 1 - Apr. 1	Cultivar Dependent	Poor	6
Switchgrass	Panicum virgatum	**Alamo --** poorly-drained	Warm Season	10-15%	Dec. 1 - May 1	Cultivar Dependent	Poor	6
Indiangrass	Sorghastrum nutans	**Rumsey, Osage, Cheyenne**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	6
Indiangrass	Sorghastrum nutans	**Lometa**	Warm Season	10-30%	Dec. 1 - May 1	Well-drained to Droughty	Poor	6
Deertongue	Dichanthelium clandestinum	**Tioga**	Warm Season	5-25%	Dec. 1 - Apr. 1	Poorly-drained to Droughty	Moderate	2
Big Bluestem	Andropogon gerardii	**Roundtree, Kaw, Earl**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	6
Little Bluestem	Schizachyrium scoparium	**Cimarron**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	4
Sweet Woodreed	Cinna arundinacea		Warm Season	1-10%	Dec. 1 - Apr. 1	Poorly-drained to Well-drained	Moderate	5
Rice Cutgrass	Leersia oryzoides		Warm Season	5-25%	Dec. 1 - Apr. 1	Poorly-drained	Poor	5
Redtop Panicgrass	Panicum rigidulum		Warm Season	10-20%	Dec. 1 - Apr. 1	Well-drained	Poor	3.5
Beaked Panicgrass	Panicum anceps		Warm Season	10-20%	Dec. 1 - Apr. 1	Poorly-drained	Moderate	3.5
Purple top	Tridens flavus		Warm Season	5-10%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	2.5
Eastern Gammagrass	Tripsacum dactyloides		Warm Season	5-10%	Dec. 1 - Apr. 1	Well-drained to Poorly-drained	Poor	4.5
Indian Woodoats	Chasmanthium latifolium		Cold Season	1-10%	Feb. 15 - Apr. 1, Aug. 15 - Oct. 15	Well-drained to Droughty	Moderate	4
Virginia Wildrye	Elymus virginicus		Cold Season	5-25%	Feb. 15 - Apr. 1, Aug. 15 - Oct. 15	Well-drained to Droughty	Moderate	3
Eastern Bottle-brush Grass	Elymus hystrix		Cold Season	5-10%	Feb. 15 - Apr. 1, Aug. 15 - Oct. 15	Well-drained to Droughty	Moderate	3
Rough Bentgrass	Agrostis scabra		Cold Season	10-20%	Feb. 15 - Apr. 1, Aug. 15 - Oct. 15	Poorly-drained	Poor	2.5
Winter Bentgrass	Agrostis hyemalis		Cold Season	2-5%	Feb. 15 - Apr. 1, Aug. 15 - Oct. 15	Well-drained	Moderate	3.5
Soft Rush	Juncus effusus		Wetland	1-10%	Dec. 1 - May 1, Sep. 1 - Nov. 1	Poorly-drained	Poor	4
Shallow Sedge	Carex lurida		Wetland	1-10%	Dec. 1 - May 1, Sep. 1 - Nov. 1	Poorly-drained	Poor	3
Fox Sedge	Carex vulpinoidea		Wetland	1-10%	Dec. 1 - May 1, Sep. 1 - Nov. 1	Poorly-drained	Poor	3
Leathery Rush	Juncus coriaceus		Wetland	2-5%	Dec. 1 - May 1, Sep. 1 - Nov. 1	Poorly-drained	Poor	2

* Pick at least four species, including one from each type.

Table 6.24d Permanent Seeding Recommendations -- Coastal Plain Region

Common Name	Scientific Name	Cultivars	Type*	Percentage of Mix	Optimal Planting Dates	Soil Drainage Adaptation	Shade Tolerance	Height
Switchgrass	Panicum virgatum	**Blackwell --** well drained **Shelter --** well drained **Kanlow --** poorly drained **Carthage --** well drained	Warm Season	10-15%	Dec. 1 - Apr. 1	Cultivar Dependent	Poor	6
Switchgrass	Panicum virgatum	**Alamo --** poorly-drained	Warm Season	10-15%	Dec. 1 - May 1	Cultivar Dependent	Poor	6
Indiangrass*	Sorghastrum nutans*	**Rumsey, Osage, Cheyenne**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	6
Indiangrass*	Sorghastrum nutans*	**Lometa**	Warm Season	10-30%	Dec. 1 - May 1	Well-drained to Droughty	Poor	6
Big Bluestem	Andropogon gerardii	**Earl**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	6
Little Bluestem	Schizachyrium scoparium	**Cimarron**	Warm Season	10-30%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	4
Sweet Woodreed	Cinna arundinacea		Warm Season	1-10%	Dec. 1 - Apr. 1	Poorly-drained to Well-drained	Moderate	5
Rice Cutgrass	Leersia oryzoides		Warm Season	5-25%	Dec. 1 - Apr. 1	Poorly-drained	Poor	5
Redtop Panicgrass	Panicum rigidulum		Warm Season	10-20%	Dec. 1 - Apr. 1	Well-drained	Poor	3.5
Beaked Panicgrass	Panicum anceps		Warm Season	10-20%	Dec. 1 - Apr. 1	Poorly--drained	Moderate	3.5
Eastern Gammagrass	Tripsacum datyoides		Warm Season	5-10%	Dec. 1 - Apr. 1	Well-drained to Poorly-drained	Poor	4.5
Purple top	Tridens flavus		Warm Season	5-10%	Dec. 1 - Apr. 1	Well-drained to Droughty	Poor	2.5
Indian Woodoats	Chasmanthium latifolium		Cold Season	1-10%	Feb. 15 - Mar. 20, Sep. 1 - Nov. 1	Well-drained to Droughty	Moderate	4
Virginia Wildrye	Elymus virginicus		Cold Season	5-25%	Feb. 15 - Mar. 20, Sep. 1 - Nov. 1	Well-drained to Droughty	Moderate	3
Rough Bentgrass	Agrostis scabra		Cold Season	10-20%	Feb. 15 - Mar. 20, Sep. 1 - Nov. 1	Poorly-drained	Poor	2.5
Soft Rush	Juncus effusus		Wetland	1-10%	Dec. 1 - Apr. 15	Poorly-drained	Poor	4
Shallow Sedge	Carex lurida		Wetland	1-10%	Dec. 1 - Apr. 15	Poorly-drained	Poor	3
Fox Sedge	Carex vulpinoidea		Wetland	1-10%	Dec. 1 - Apr. 15	Poorly-drained	Poor	3
Leathery Rush	Juncus coriaceus		Wetland	2-5%	Dec. 1 - Apr. 15	Poorly-drained	Poor	2

* Only Lometa in eastern coastal plain (Plant Hardiness Zone 8).

* Pick at least four species, including one from each type.

Maintenance

Many of the recommended permanent grass species may require two years for establishment, depending on site conditions. Inspect seeded areas for failure and make necessary repairs, soil amendments, and reseedings. If weedy exotic species have overtaken the area after the first growing season, the invading species must be eradicated to allow native species to grow. Native vegetations are difficult to manage and take longer to establish. Monitor the site until long term stability has been established.

INDEX

RUNOFF CONVEYANCE MEASURES

6

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

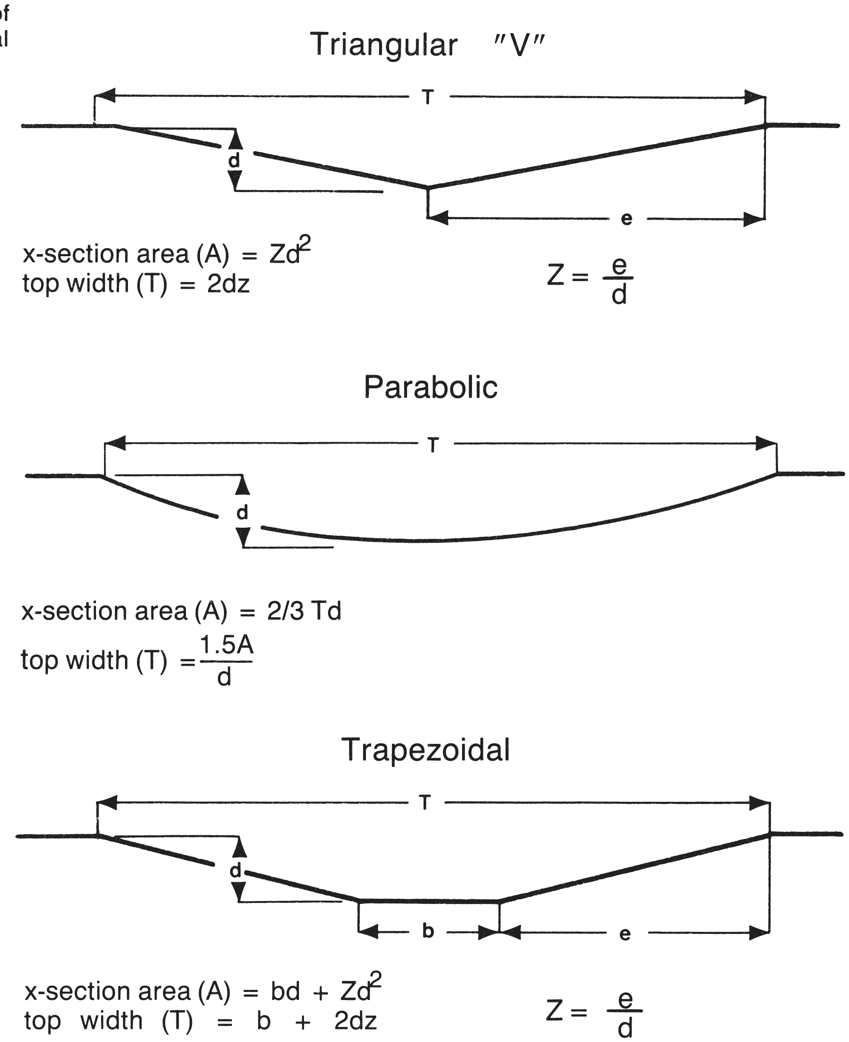
Capacity—At a minimum, grass-lined channels should carry peak runoff from the 10-year storm without eroding. Where flood hazard exists, increase the capacity according to the potential damage. Channel dimensions may be determined by using design tables with appropriate retardance factors or by Manning's 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

6.31

RR

P

RIPRAP AND PAVED CHANNELS

Definition

Channels with erosion-resistant linings of riprap, paving, or other structural material designed for the conveyance and safe disposal of excess water.

Purpose

To convey concentrated surface runoff without erosion.

Conditions Where Practice Applies

This practice applies where design flow velocity exceeds 2 ft/sec so that a channel lining is required, but conditions are unsuitable for grass-lined channels. Specific conditions include:

- Channels where slopes over 5% predominate; continuous or prolonged flows occur; potential for damage from traffic (people or vehicles) exists; or soils are erodible, and soil properties are not suitable for vegetative protection.
- Design velocity exceeds that allowable for a grass-lined channel.
- Property value justifies the cost to contain the design runoff in a limited space.
- Channel setting warrants the use of special paving materials.

Planning Considerations

Riprap or paving materials are generally employed as channel liners when design flow velocities exceed the tolerance of grass or where grass lining is inappropriate (Practice 6.30, *Grass-lined Channels*).

Flexible liners are preferred to rigid liners, and riprap is the flexible liner of choice. Riprap is preferred primarily on the basis of cost, but it has several additional advantages such as:

- Riprap liners can be designed to withstand most flow velocities by choosing stable stone size.
- Riprap adjusts to unstable foundation conditions without failure.
- Failure of a riprap liner is not as expensive to repair as a rigid liner would be.
- The roughness of riprap reduces outlet velocity, and tends to reduce flow volume by allowing infiltration.

Rigid liners such as concrete or flagstone can carry large volumes of water without eroding. However, they are more expensive to design and construct, are less forgiving of foundation conditions, and introduce high energies that must be controlled and dissipated to avoid damage to channel outlets and receiving streams.

Channels combining grassed side slopes and riprap or paved bottoms may be used where velocities are within allowable limits for grass lining along the channel sides, but long-duration flows, seepage, or a high velocity flow would damage vegetation in the channel bottom.

Paving blocks and gabions have some of the same characteristics as riprap, and are often used instead of riprap to fit certain site conditions.

Channels with smooth liners, such as concrete or flagstone, usually are not limited by velocity, take up less land area, and can be constructed to fit limited site conditions. In addition, they provide a more formal appearance and usually require less maintenance. Exercise care to see that foundation soils are stable, and proper foundation drainage is installed. Appropriate measures are needed to reduce the exit velocity of the paved channel to protect the receiving channel or outlet.

Where urban drainage area exceeds 10 acres it is recommended that riprap and paved channels be designed by an engineer experienced in channel design.

Design Criteria

Capacity—Design channels to contain the peak runoff from the 10-year storm as a minimum. Where flood damage potential is high, expand the capacity to the extent of the value or hazard involved.

Velocity—Compute velocity using Manning's equation with an appropriate *n* value for the selected lining. Values for Manning's *n* are shown in Table 6.31a.

Table 6.31a
Guide for Selecting Manning *n* Values

Lining Material	*n*
Concrete:	
Trowel finish	0.012-0.014
Float finish	0.013-0.017
Gunite	0.016-0.022
Flagstone	0.020-0.025
Paving blocks	0.025
Riprap	Determine from Table 8.05f
Gabion	0.025-0.030

Channel gradient—When the Froude Number is between 0.7 and 1.3, channel flows may become unstable and the designer should consider modifying the channel slope. Reaches designed for supercritical flow should be straight unless special design procedures are used.

$$FR = \frac{\sqrt{Q^2B}}{gA^3}$$

where:
- FR = Froude Number, dimensionless
- Q = Discharge, ft^3/sec
- B = Water surface width, ft
- g = 32.2 ft/sec^2
- A = Cross-sectional area, ft^2

Cross section—The cross section may be triangular, parabolic, or trapezoidal. Reinforced concrete or gabions may be rectangular (Figure 6.31a).

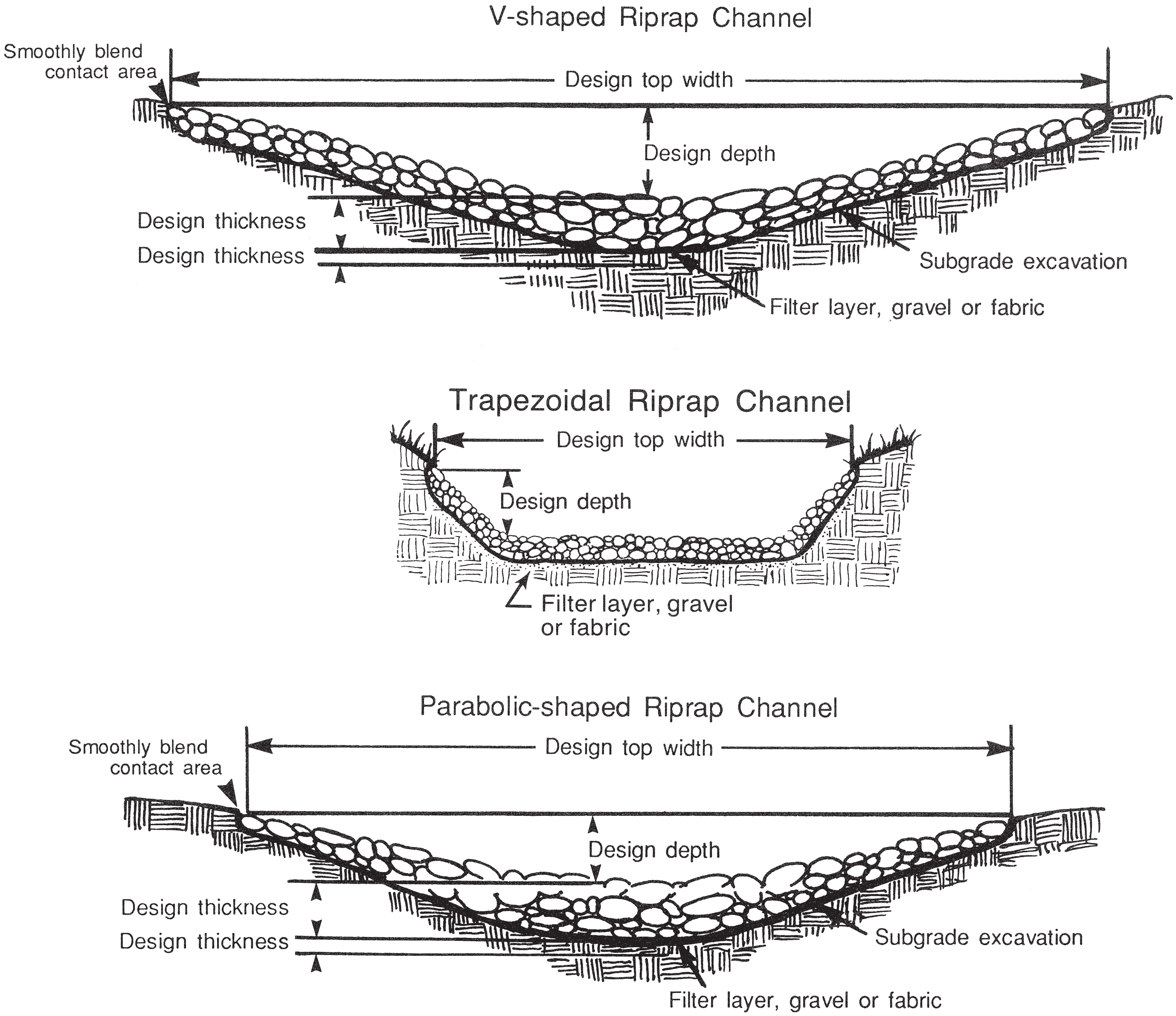


Figure 6.31a Construction detail of riprap channel cross sections.

Side slope—Base side slopes on the materials and placement methods in Table 6.31b.

Hydraulic grade line—Ensure that the design water surface in the channel meets the design flow elevations of tributary channels and diversions. Ensure that it is below safe flood elevations for homes, roads, or other improvements.

Table 6.31b
Guide for Selecting Channel Side Slopes

	Maximum Slope
Nonreinforced Concrete	
Formed Concrete	
Height of lining 1.5 ft or less	vertical
Screeded concrete or flagstone mortared in place	
Height of lining less than 2 ft	1:1
Height of lining more than 2 ft	2:1
Slip form concrete	
Height of lining less than 3 ft	1:1
Riprap and Paving Blocks	2:1

Depth and width—Proportion the channel depth and width to meet the needs of drainage, carrying capacity, foundation limitations, and specific site conditions.

Lining thickness—Minimum lining thickness should be as shown in Table 6.31c.

Filter layer—A sand/gravel filter layer should be used under the channel lining to prevent piping and reduce uplift pressure (*Appendix 8.05*).

Riprap—For the design of riprap channels see *Appendix 8.05*.

Concrete—Concrete for linings should be a dense, durable product sufficiently plastic for thorough consolidation, but stiff enough to stay in place on side slopes. As a minimum, use a mix certified as 3,000 lb/inch^2.

Cutoff—Cutoff walls are needed at the beginning and end of paved or riprapped channel sections to protect against undercutting. Expansion joints and additional cutoff walls may also be needed.

Outlets—Evaluate the capacity and stability of all channel outlets and protect them from erosion by limiting exit velocity (Practices 6.40, *Level Spreader* and 6.41, *Outlet Stabilization Structure*).

Table 6.31c
Channel Lining Thickness

Material	Minimum Thickness
Concrete	4 inches
Rock riprap	1.5 times maximum stone diameter
Flagstone	4 inches including mortar

Construction Specifications

1. Clear the foundation area of trees, stumps, roots, loose rock, and other objectionable material.

2. Excavate the cross section to the lines and grades of the foundation of the liner as shown on the plans. Bring over-excavated areas to grade by increasing the thickness of the liner or by backfilling with moist soil compacted to the density of the surrounding material.

3. Concrete linings:

- Place concrete linings to the thickness shown on the plans and finish them in a workmanlike manner.
- Take adequate precautions to protect freshly placed concrete from extreme temperatures to ensure proper curing.
- Ensure that subgrade is moist when concrete is poured.
- Install foundation drains or weep holes where needed to protect against uplift and piping.
- Provide transverse (contraction) joints to control cracking at approximately 20-feet intervals. These joints may be formed by using a 1/2-inch thick removable template or by sawing to a depth of at least 1 inch.
- Install expansion joints at intervals not to exceed 100 feet.

4. Rock riprap linings: Practice 6.15, *Riprap*.

5. Place filters, beddings, and foundation drains to line and grade in the manner specified. Place filter and bedding materials immediately after slope preparation. For synthetic filter fabrics, overlap the downstream edge by at least 12 inches with the upstream edge which is buried a minimum 12 inches in a trench. See figure 6.14a, page 6.14.6. Space anchor pins every 3 feet along the overlap. Spread granular materials in a uniform layer. When more than one gradation is required, spread the layers so there is minimal mixing. Filter material should consist of at least 3 inches of material on all sides of the drain pipe. The drain pipe conduit should be a minimum of 4 inches in diameter. Acceptable materials include perforated, continuous, closed-joint conduits of clay, concrete, metal, plastic, or other suitable material (Practice 6.81, *Subsurface Drain*).

6. Perform all channel construction to keep erosion and water pollution to a minimum. Immediately upon completion of the channel, vegetate all disturbed areas or otherwise protect them against soil erosion. Where channel construction will take longer than 30 days, stabilize channels by reaches.

Maintenance

Inspect channels at regular intervals as well as after major rains, and make repairs promptly. Give special attention to the outlet and inlet sections and other points where concentrated flow enters. Carefully check stability at road crossings, and look for indications of piping, scour holes, or bank failures. Make repairs immediately. Maintain all vegetation adjacent to the channel in a healthy, vigorous condition to protect the area from erosion and scour during out-of-bank flow.

References

Surface Stabilization
6.11, Permanent Seeding
6.15, Riprap

Runoff Conveyance Measures
6.30, Grass-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

Other Related Practices
6.81, Subsurface Drain

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

6.32

TSD

TEMPORARY SLOPE DRAINS

Definition

A flexible tubing or conduit extending temporarily from the top to the bottom of a cut or fill slope.

Purpose

To convey concentrated runoff down the face of a cut or fill slope without causing erosion.

Conditions Where Practice Applies

This practice applies to construction areas where stormwater runoff above a cut or fill slope will cause erosion if allowed to flow over the slope. Temporary slope drains are generally used in conjunction with diversions to convey runoff down a slope until permanent water disposal measures can be installed.

Planning Considerations

There is often a significant lag between the time a cut or fill slope is graded and the time it is permanently stabilized. During this period, the slope is very vulnerable to erosion, and temporary slope drains together with temporary diversions can provide valuable protection (Practice 6.20, *Temporary Diversions*).

It is very important that these temporary structures be sized, installed, and maintained properly because their failure will usually result in severe erosion of the slope. The entrance section to the drain should be well entrenched and stable so that surface water can enter freely. The drain should extend downslope beyond the toe of the slope to a stable area or appropriately stabilized outlet.

Other points of concern are failure from overtopping from inadequate pipe inlet capacity and lack of maintenance of diversion channel capacity and ridge height.

Design Criteria

Capacity—Peak runoff from the 10-year storm.

Pipe size—Unless they are individually designed, size drains according to Table 6.32a.

Table 6.32a
Size of Slope Drain

Maximum Drainage Area per Pipe (acres)	Pipe Diameter (inches)
0.50	12
0.75	15
1.00	18
>1.00*	as designed

*Inlet design becomes more complex beyond this size.

Conduit—Construct the slope drain from heavy-duty, flexible materials such as nonperforated, corrugated plastic pipe or specially designed flexible tubing (Figure 6.32a). Install reinforced, hold-down grommets or stakes to anchor the conduit at intervals not to exceed 10 ft with the outlet end securely fastened in place. The conduit must extend beyond the toe of the slope.

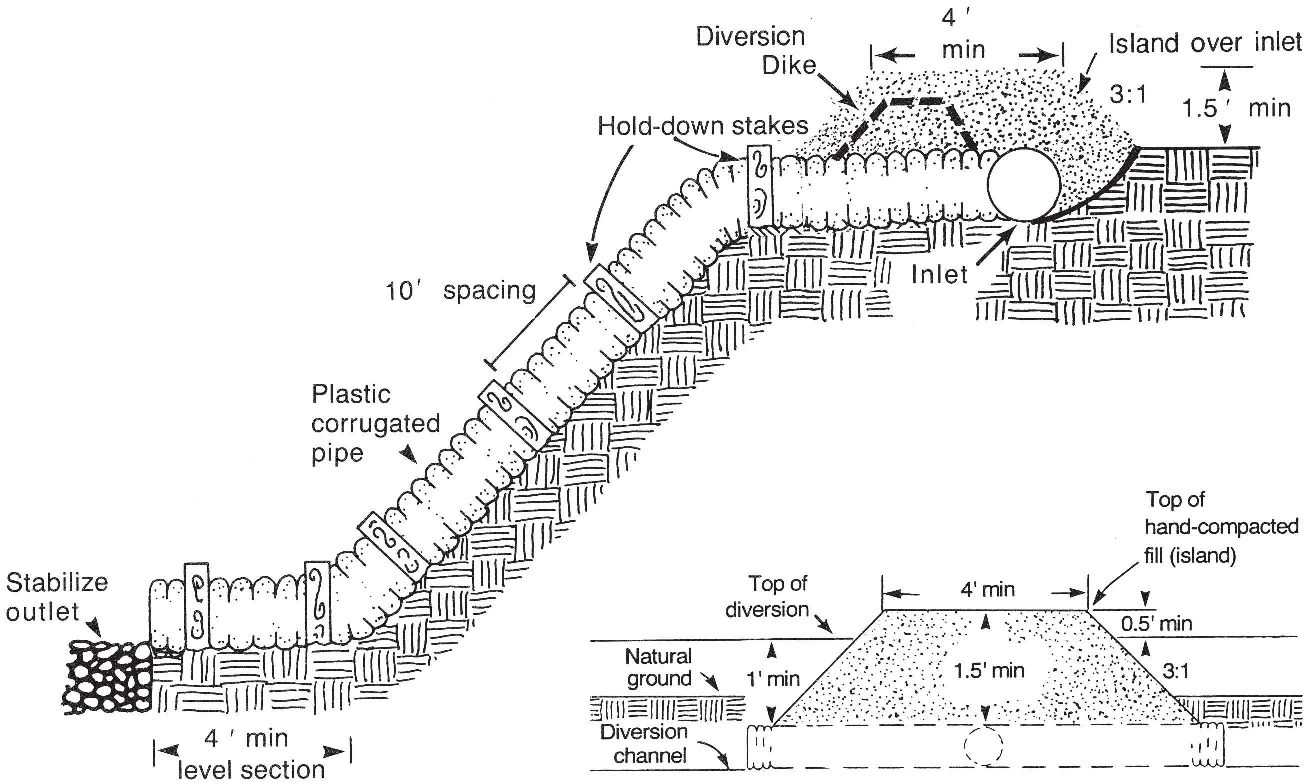


Figure 6.32a Cross section of temporary slope drain.

Entrance—Construct the entrance to the slope drain of a standard flared-end section of pipe with a minimum 6-inch metal toe plate (Figure 6.32a). Make all fittings watertight. A standard T-section fitting may also be used at the inlet.

Temporary diversion—Generally, use an earthen diversion with a dike ridge to direct surface runoff into the temporary slope drain. Make the height of the ridge over the drain conduit a minimum of 1.5 feet and at least 6 inches higher than the adjoining ridge on either side. The lowest point of the diversion ridge should be a minimum of 1 foot above the top of the drain so that design flow can freely enter the pipe.

Outlet protection—Protect the outlet of the slope drain from erosion (Practice 6.41, *Outlet Stabilization Structure*).

Construction Specifications

A common failure of slope drains is caused by water saturating the soil and seeping along the pipe. This creates voids from consolidation and piping and causes washouts. Proper backfilling around and under the pipe "haunches" with stable soil material and hand compacting in 6-inch lifts to achieve firm contact between the pipe and the soil at all points will eliminate this type of failure.

1. Place slope drains on undisturbed soil or well compacted fill at locations and elevations shown on the plan.

2. Slightly slope the section of pipe under the dike toward its outlet.

3. Hand tamp the soil under and around the entrance section in lifts not to exceed 6 inches.

4. Ensure that fill over the drain at the top of the slope has minimum dimensions of 1.5 feet depth, 4 feet top width, and 3:1 side slopes.

5. Ensure that all slope drain connections are watertight.

6. Ensure that all fill material is well-compacted. Securely fasten the exposed section of the drain with grommets or stakes spaced no more than 10 feet apart.

7. Extend the drain beyond the toe of the slope, and adequately protect the outlet from erosion.

8. Make the settled, compacted dike ridge no less than 1 feet above the top of the pipe at every point.

9. Immediately stabilize all disturbed areas following construction.

Maintenance

Inspect the slope drain and supporting diversion after every rainfall, and promptly make necessary repairs. When the protected area has been permanently stabilized, temporary measures may be removed, materials disposed of properly, and all disturbed areas stabilized appropriately.

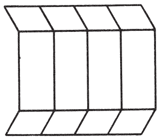
References

Runoff Control Measures
6.20, Temporary Diversions

Outlet Protection
6.41, Outlet Stabilization Structure

6.33

PAVED FLUME (Chutes)



Definition

A small concrete-lined channel to convey water on a relatively steep slope.

Purpose

To conduct concentrated runoff safely down the face of a cut or fill slope without causing erosion.

Conditions Where Practice Applies

Where concentrated storm runoff must be conveyed from the top to the bottom of a cut or fill slope as part of a permanent erosion control system. Paved flumes serve as stable outlets for diversions, drainage channels, or natural drainageways that are located above relatively steep slopes. Restrict paved flumes to slopes of 1.5:1 or flatter.

Planning Considerations

Conveying storm runoff safely down steep slopes is an important consideration when planning permanent erosion control measures for a site (Figure 6.33a). Paved flumes are often selected for this purpose, but other measures such as grassed waterways, riprap channels, and closed storm drains should also be considered. Evaluate the flow volume, velocity and duration of flow, degree of slope, soil and site conditions, visual impacts, construction costs, and maintenance requirements to decide which measure to use.

When planning paved flumes, give special attention to flow entrance conditions, soil stability, outlet energy dissipation, downstream stability, and freeboard or bypass capacity. Setting the flume well into the ground is especially important, particularly on fill slopes.

Paved chutes often have the upper portion of their side slopes grassed. This saves on materials and improves appearance. The paved portion carries the design flow, and the grassed area provides freeboard.

Design Criteria

Capacity—Consider peak runoff from the 10-year storm as a minimum. Provide sufficient freeboard or bypass capacity to safeguard the installation from any peak flow expected during the life of the structure.

Slope—Ensure that the slope of a chute does not exceed 1.5:1 (67%).

Cutoff walls (curtain walls)—Provide cutoff walls at the beginning and end of paved flumes. Make the cutoff wall as wide as the flume, extend it at least 18 inches into the soil below the channel, and keep it a minimum thickness of 6 inches. Reinforce cutoff walls with 3/8-inch reinforcing steel bars placed on 6-inch centers.

Anchor lugs—Space anchor lugs a maximum of 10 feet on the center for the length of the flume. Make anchor lugs as wide as the bottom of the flume, extend them at least 1 foot into the soil below, and keep them a minimum thickness of 6 inches. Reinforce anchor lugs with 3/8-inch steel reinforcing bars placed on 6-inch centers.

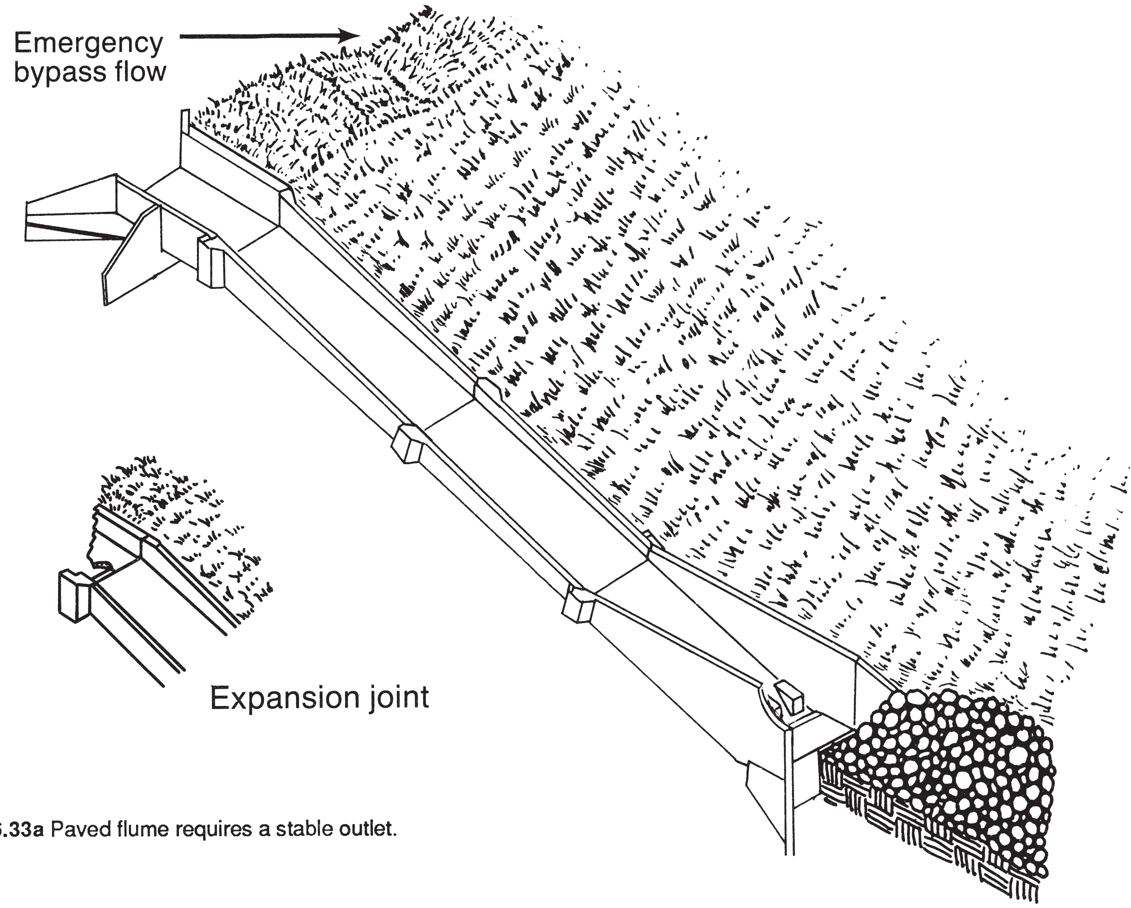


Figure 6.33a Paved flume requires a stable outlet.

Concrete—Keep concrete in the flume channel at least 5 inches thick and reinforce it with 3/8-inch steel bars. Ensure that the concrete used for flumes is a dense, durable product and sufficiently plastic for thorough consolidation but stiff enough to stay in place on steep slopes. As a minimum, use a mix certified as 3,000 lb/inch^2.

Cross section—Ensure that flumes have a minimum depth of 1 foot with 1.5:1 side slopes. Base bottom widths on maximum flow capacity.

Alignment—Keep chute channels straight because they often carry supercritical flow velocities.

Drainage filters—Use a drainage filter to prevent piping and reduce uplift pressure wherever seepage or high water table may occur (*Appendix 8.05*).

Inlet section—Ensure that the inlet to the chute has the following minimum dimensions: side walls 2 feet high, length 6 feet, width equal to the flume channel bottom, and side slope same as flume channel side slopes.

Outlet section—Protect outlets for paved flumes from erosion. Use an energy dissipator to reduce high chute velocities to nonerosive rates. In addition, place riprap at the end of the dissipator to spread the flow evenly over the receiving area. Other measures, such as an impact basin, plunge pool, or rock riprap outlet structure, may also be needed (Practice 6.41, *Outlet Stabilization Structure*).

Table 6.33a
Flume Dimensions

Drainage[1] Area (acres)	Min. Bottom Width (ft)	Min. Inlet Depth (ft)	Min. Channel Depth (ft)	Max. Channel Slope (Ft)	Max. Side Slope (ft)
5	4	2	1.3	1.5:1	1.5:1
10	8	2	1.3	1.5:1	1.5:1

[1]Due to complexity of inlet and outlet design, drainage areas have been limited to 10 acres per flume.

SMALL FLUMES

Where drainage areas are 10 acres or less, the design dimensions for concrete flumes may be selected from Table 6.33a.

Construction Specifications

1. Construct the subgrade to the elevations shown on the plans. Remove all unsuitable material and replace them with stable materials. Compact the subgrade thoroughly and shape it to a smooth, uniform surface. Keep the subgrade moist at the time concrete is poured. On fill slopes, ensure that the soil adjacent to the chute for at least 3 feet is well-compacted.

2. Place concrete for the flume to the thickness shown on the plans and finish it in a workman-like manner.

3. Form, reinforce, and pour together cutoff walls, anchor lugs, and channel linings.

4. Take adequate precautions to protect freshly poured concrete from extreme temperatures to ensure proper curing.

5. Provide transverse (contraction) joints to control cracking at approximately 20-feet intervals. Joints may be formed by using a 1/8-inch thick removable template or by sawing to a depth of at least 1 inch.

6. In very long flumes, install expansion joints at intervals not to exceed 50 feet.

7. Place filters and foundation drains, when required, in the manner specified, and protect them from contamination when pouring the concrete flume.

8. Properly stabilize all disturbed areas immediately after construction.

Maintenance

Inspect flumes after each rainfall until all areas adjoining the flume are permanently stabilized. Repair all damage noted in inspections immediately. After the slopes are stabilized, flumes need only periodic inspection, and inspection after major storm events.

References

Surface Stabilization
6.11, Permanent Seeding

Runoff Conveyance Measures
6.30, Grass-lined Channels
6.31, Riprap-lined and Paved Channels

Outlet Protection
6.40, Level Spreader
6.41, Outlet Stabilization Structure

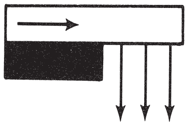
Other Related Practices
6.81, Subsurface Drain

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

INDEX

OUTLET PROTECTION

6.40



LEVEL SPREADER

Definition

A non-erosive outlet for concentrated runoff constructed to disperse flow uniformly across a slope.

Purpose

To convert concentrated flow to sheet flow and release it uniformly over a stabilized area.

Conditions Where Practice Applies

Where sediment-free storm runoff can be released in sheet flow down a stabilized slope without causing erosion.

Where a level lip can be constructed without filling.

Where the area below the spreader lip is uniform with the slope of 10% or less and is stable for anticipated flow conditions, preferably well-vegatated.

Where the runoff water will not re-concentrate after release.

Where there will be no traffic over the spreader.

Planning Considerations

The level spreader is a relatively low-cost structure to release small volumes of concentrated flow where site conditions are suitable (Figure 6.40a). The outlet area must be uniform and well-vegetated with slopes of 10% or less. Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil. Any depressions in the lip will concentrate the flow, resulting in erosion. Evaluate the outlet system to be sure that flow does not concentrate below the outlet (Figure 6.40b). The level spreader is most often used as an outlet for temporary or permanent diversions and diversion dikes. Runoff water containing high sediment loads must be treated in a sediment trapping device before release in a level spreader.

Design Criteria

Capacity—Determine the capacity of the spreader by estimating peak flow from the 10-year storm. Restrict the drainage area so that maximum flows into the spreader will not exceed 30 cfs.

Spreader dimensions—When water enters the spreader from one end, as from a diversion, select the appropriate length, width, and depth of the spreader from Table 6.40a.

Construct a 20-foot transition section in the diversion channel so the width of the diversion will smoothly meet the width of the spreader to ensure uniform outflow.

Table 6.40a
Minimum Dimensions for Level Spreader

Design Flow cfs	Entrance Width	Depth	End Width	Length
	----minimum dimension in feet----			
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	24	0.7	3	30

Level Spreader (not to scale)

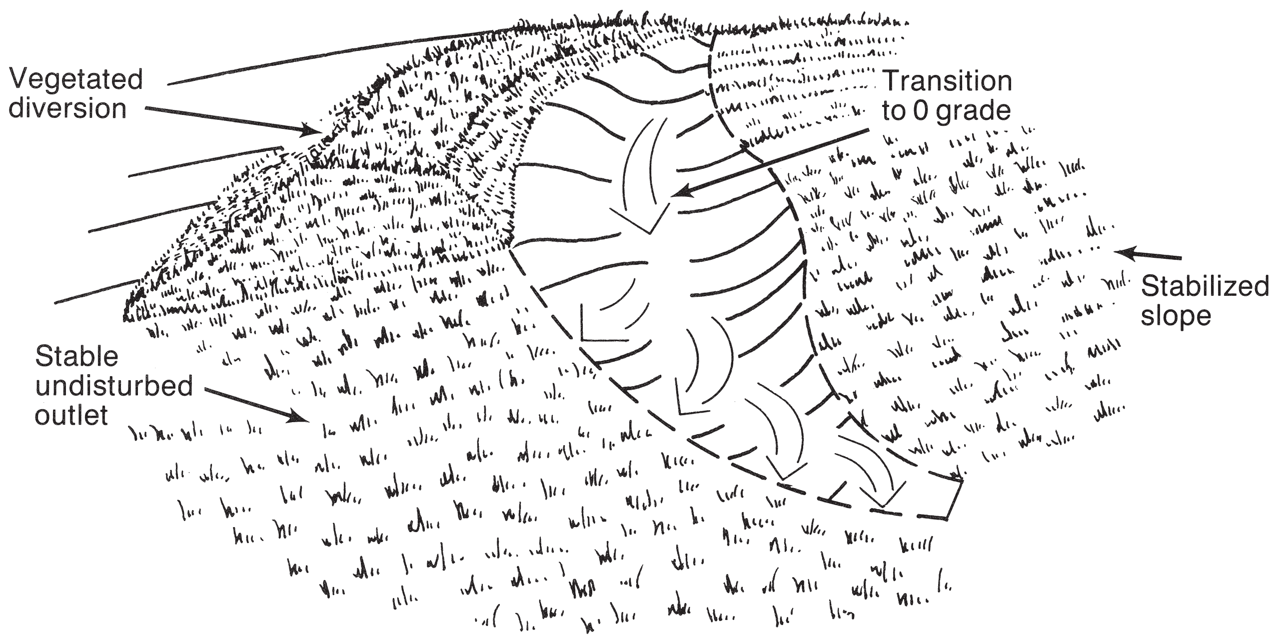


Figure 6.40a Level spreader is designed to disperse small volumes of concentrated flow across stable slopes.

Grade—The grade of the last 20 feet of the diversion channel should provide a smooth transition from channel grade to level at the spreader. The grade of the spreader should be 0%.

Spreader lip—Construct the level lip on undisturbed soil to uniform height and zero grade over the length of the spreader. Protect it with an erosion-resistant material, such as fiberglass matting, to prevent erosion and allow vegetation to become established.

Outlet area—The outlet disposal area must be generally smooth and well-vegetated with a maximum slope of 10%.

Vegetate all disturbed areas.

Construction Specifications

1. The matting should be a minimum of 4 feet wide extending 6 inches over the lip and buried 6 inches deep in a vertical trench on the lower edge. The upper edge should butt against smooth cut sod and be securely held in place with closely spaced heavy duty wire staples at least 12 inches long.

2. Ensure that the spreader lip is level for uniform spreading of storm runoff.

3. Construct the level spreader on undisturbed soil (**not** on fill).

4. Construct a 20-foot transition section from the diversion channel to blend smoothly to the width and depth of the spreader.

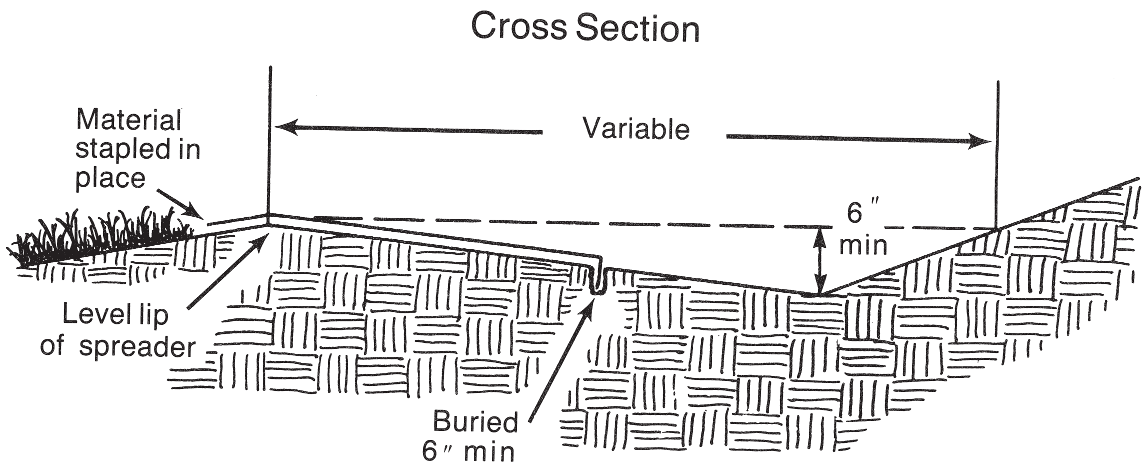


Figure 6.40b Detail of level spreader cross section.

5. Disperse runoff from the spreader across a properly stabilized slope not to exceed 10%. Make sure the slope is sufficiently smooth to keep flow from concentrating.

6. Immediately after its construction, appropriately seed and mulch the entire disturbed area of the spreader.

Maintenance

Inspect level spreaders after every rainfall until vegetation is established, and promptly make needed repairs. After the area has been stabilized, make periodic inspections, and keep vegetation in a healthy, vigorous condition.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding

Runoff Control Measures
6.20, Temporary Diversions
6.21, Permanent 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.

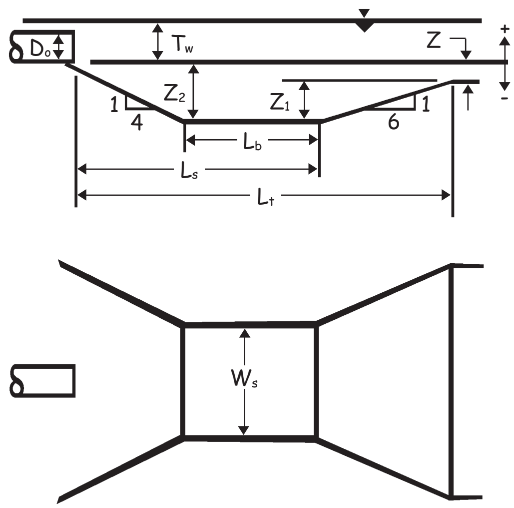
Design Criteria

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.

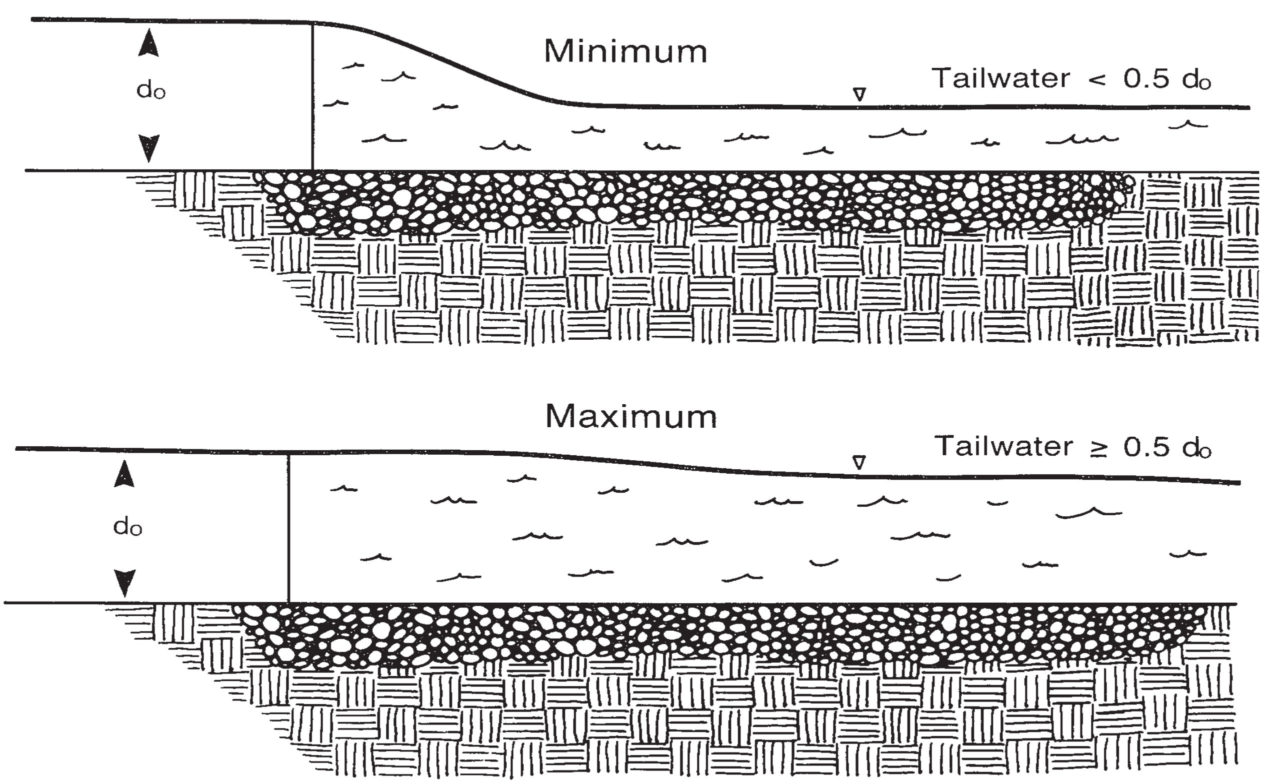


Figure 6.41b Stage showing maximum and minimum tailwater condition.

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*.

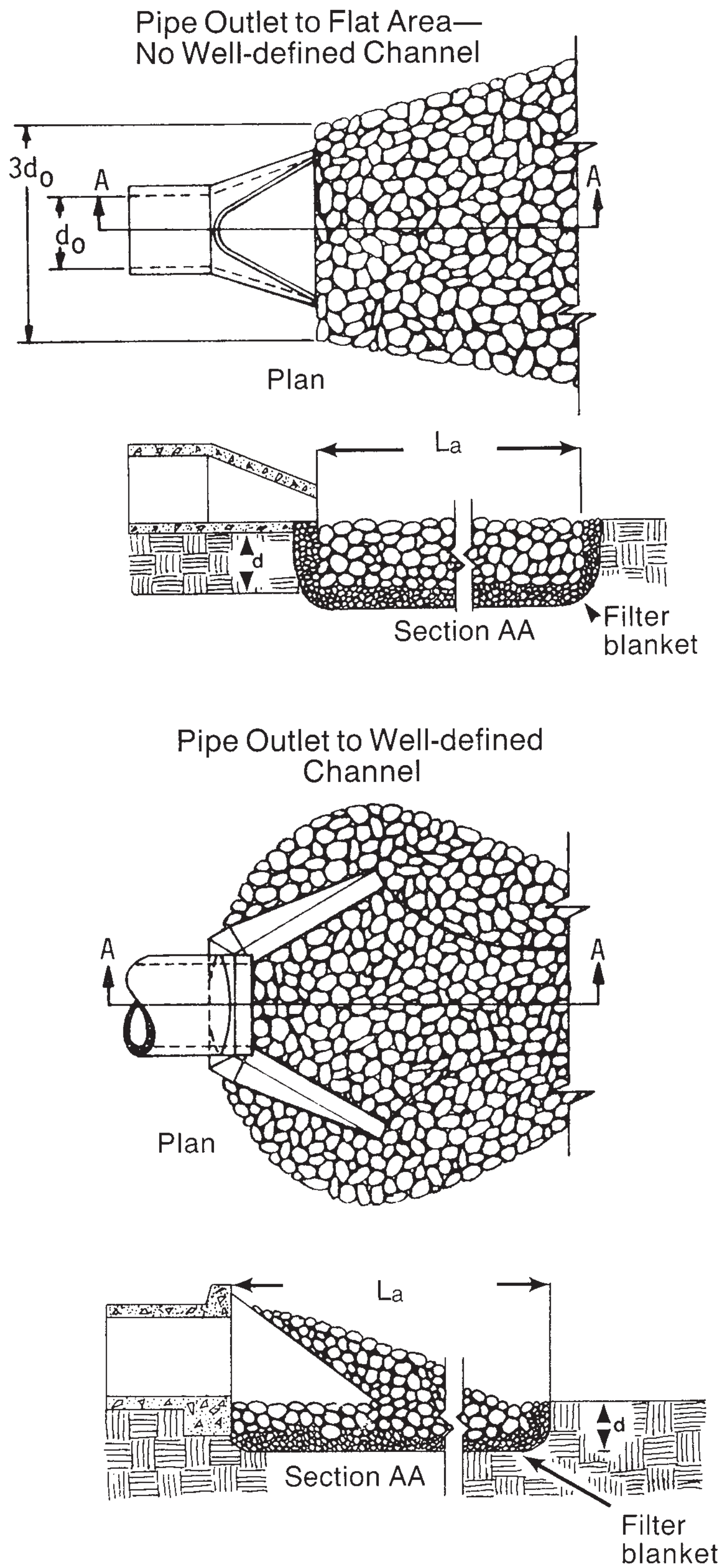


Figure 6.41c Riprap outlet protection (modified from Va SWCC).

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.

INDEX

INLET PROTECTION

6.50

EXCAVATED DROP INLET PROTECTION (Temporary)

Definition

An excavated area in the approach to a storm drain drop inlet or curb inlet.

Purpose

To trap sediment at the approach to the storm drainage systems. This practice allows use of permanent stormwater conveyance at an early stage of site development.

Conditions Where Practice Applies

Where storm drain drop inlets are to be made operational before permanent stabilization of the disturbed drainage area. This method of inlet protection is applicable where relatively heavy flows are expected, and overflow capability is needed (Figure 6.50a). Frequent maintenance is required and temporary flooding in the excavated area will occur. This practice can be used in combination with other temporary inlet protection devices such as Practice 6.51, *Hardware Cloth, and Gravel Inlet Protection* and Practice 6.52, *Block and Gravel Inlet Protection*.

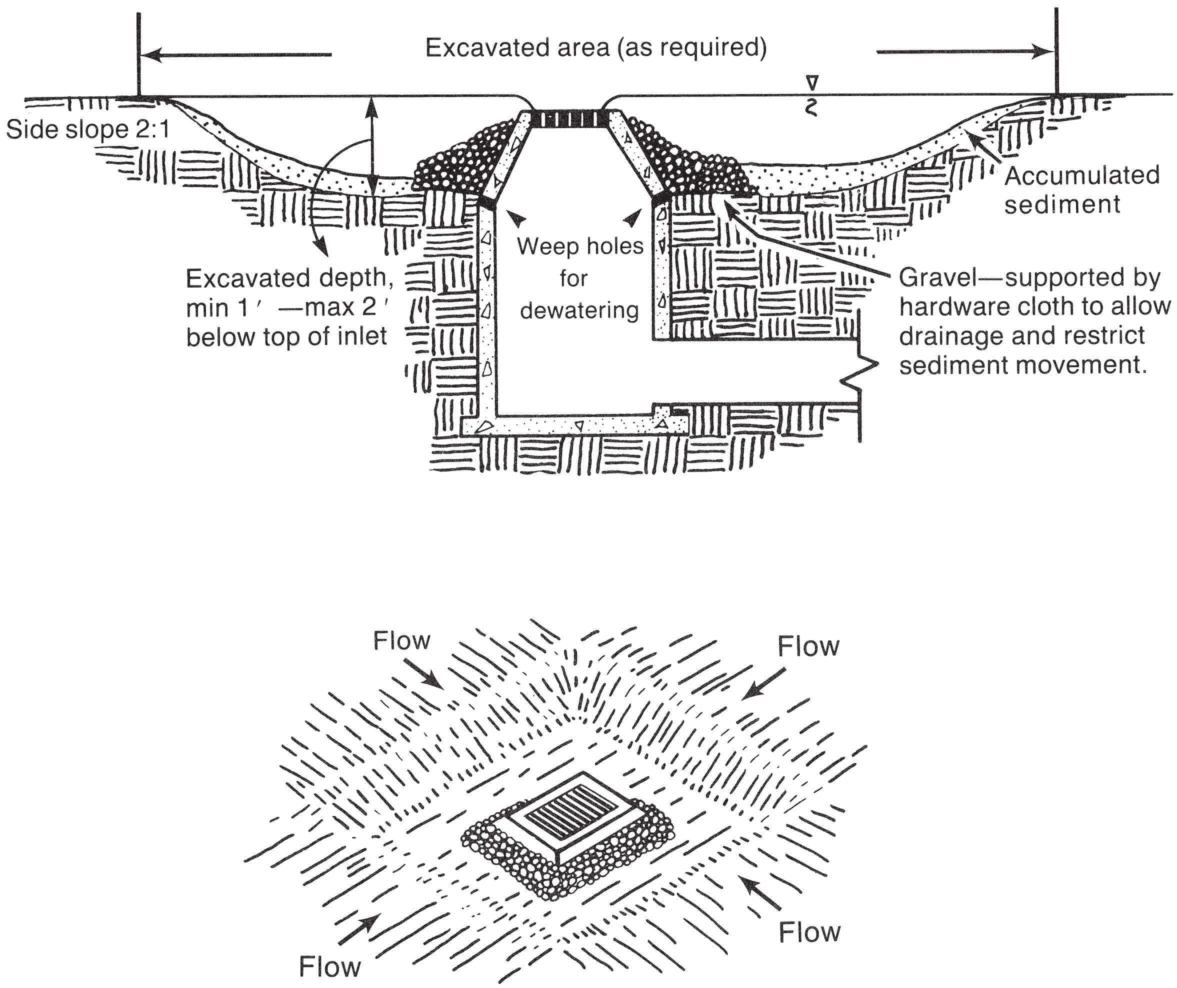


Figure 6.50a Excavated drop inlet protection.

Design Criteria

Limit the drainage area to 1 acre. Keep the minimum depth at 1 foot and the maximum depth of 2 feet as measured from the crest of the inlet structure.

Maintain side slopes around the excavation no steeper than 2:1

Keep the minimum volume of excavated area around the drop inlet at approximately 1800 ft^3/acre disturbed.

Shape the basin to fit site conditions, with the longest dimension oriented toward the longest inflow area to provide maximum trap efficiency.

Install provisions for draining the temporary pool to improve trapping efficiency for small storms and to avoid problems from standing water after heavy rains.

Construction Specifications

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

2. Grade the approach to the inlet uniformly.

3. Protect weep holes by gravel.

4. When the contributing drainage area has been permanently stabilized, seal weep holes, fill the basin with stable soil to final grading elevations, compact it properly, and stabilize.

Maintenance

Inspect, clean, and properly maintain the excavated basin after every storm until the contributing drainage area has been permanently stabilized. To provide satisfactory basin efficiency, remove sediment when the volume of the basin has been reduced by one-half. Spread all excavated material evenly over the surrounding land area or stockpile and stabilize it appropriately.

References

Inlet Protection
6.51, Hardware, Cloth, and Gravel Inlet Protection
6.52, Block and Gravel Inlet Protection (Temporary)

6.51 HARDWARE CLOTH & GRAVEL INLET PROTECTION

Definition

A temporary measure of wire-mesh hardware cloth around steel posts supporting washed stone placed around the opening of a drop inlet.

Purpose

To prevent sediment from entering yard inlets, grated storm drains or drop inlets during construction. This practice allows early use of the storm drain system.

Conditions Where Practice Applies

To be placed around a catch basin or a drop inlet and where the flow is light to moderate. If heavy flow is anticipated, use the rock doughnut inlet protection method (Practice 6.54, *Rock Doughnut Inlet Protection)*. It is also used where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area. This method of inlet protection is effective where the inlet is expected to drain shallow sheet flow. The immediate land area around the inlet should be relatively flat (less than 1 percent) and located so that accumulated sediment can be easily removed.

This practice must not be used near the edge of fill material and must not divert water over cut or fill slopes.

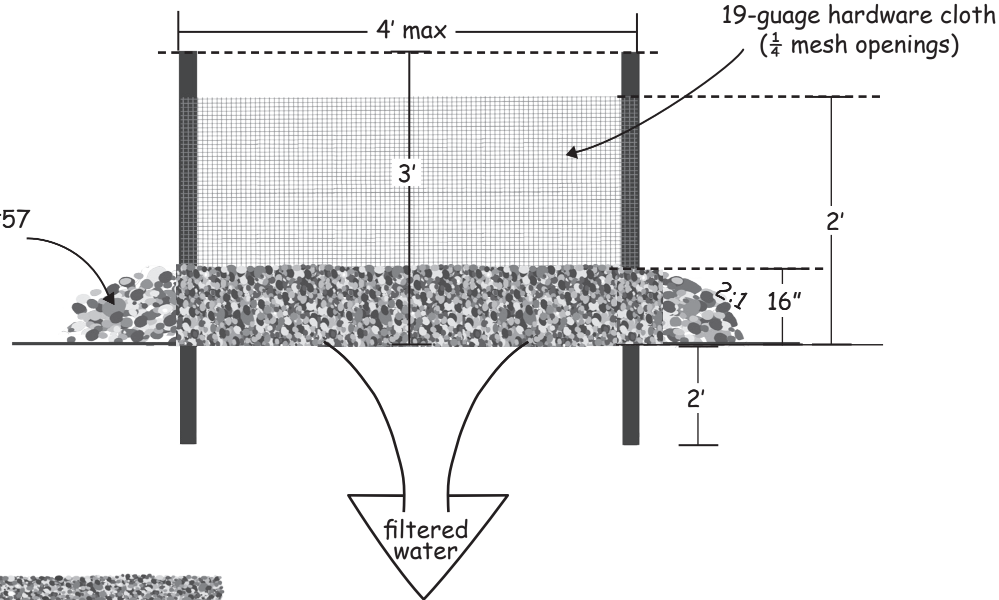
Design Criteria

Ensure that drainage areas do not exceed 1 acre per inlet.

For securing the wire mesh hardware cloth barriers, use steel T posts. The posts need to be 1.25 lb/linear ft steel with a minimum length of 5 feet. Make sure the posts have projections to facilitate fastening the hardware cloth. Securely drive each stake into the ground to a minimum depth of 2 feet. The maximum spacing for the posts is 4 feet.

The wire mesh should be at least a 19-gauge hardware cloth with a ¼ inch mesh opening. The total height should be a minimum of 2 feet. Providing a flap of hardware cloth on the ground projecting away from the inlet can aid in removal of the stone at the project's completion. The sediment control stone, with a height of 16 inches, should have a outside slope of 2:1.

The top elevation of the structure must be at least 12 inches lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure into the storm drain and not bypass the structure. Temporary dikes below the structure may be necessary to prevent bypass flow. Soil excavated when constructing the sediment pool may be used for this purpose (Figure 6.51a).



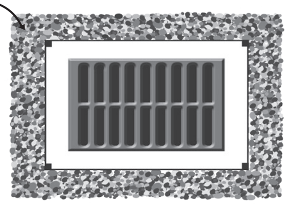


Figure 6.51a Hardware cloth and gravel inlet protection

Construction Specifications

1. Uniformly grade a shallow depression approaching the inlet.

2. Drive 5-foot steel posts 2 feet into the ground surrounding the inlet. Space posts evenly around the perimeter of the inlet, a maximum of 4 feet apart.

3. Surround the posts with wire mesh hardware cloth. Secure the wire mesh to the steel posts at the top, middle, and bottom. Placing a 2-foot flap of the wire mesh under the gravel for anchoring is recommended.

4. Place clean gravel (NC DOT #5 or #57 stone) on a 2:1 slope with a height of 16 inches around the wire, and smooth to an even grade.

5. Once the contributing drainage area has been stabilized, remove accumulated sediment, and establish final grading elevations.

6. Compact the area properly and stabilized it with groundcover.

Maintenance

Inspect inlets at least weekly and after each significant (½ inch or greater) rainfall event. Clear the mesh wire of any debris or other objects to provide adequate flow for subsequent rains. Take care not to damage or undercut the wire mesh during sediment removal. Replace stone as needed.

References

Inlet Protection
6.52, Block and Gravel Inlet Protection
6.54, Rock Doughnut Inlet Protection

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.52

BLOCK AND GRAVEL INLET PROTECTION (Temporary)

Definition

A sediment control barrier formed around a storm drain inlet by the use of standard concrete block and gravel.

Purpose

To help prevent sediment from entering storm drains before stabilizing the contributing watershed. This practice allows early use of the storm drain system.

Conditions Where Practice Applies

Where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area. This method of inlet protection applies to both drop inlets and curb inlets where heavy flows are expected, and an overflow capacity is necessary to prevent excessive ponding around the structure. Shallow temporary flooding after rainfall should be expected, however.

This practice must not be used near the edge of fill material, and must not divert water away from the storm drain.

Design Criteria

Keep the drainage area no greater than 1 acre unless site conditions allow for frequent removal and adequate disposal of accumulated sediment.

Keep the height of the barrier at least 12 inches and no greater than 24 inches. Do not use mortar. Limit the height to prevent excess ponding and bypass flow.

Recess the first course of blocks at least 2 inches below the crest opening of the storm drain for lateral support. Support subsequent courses laterally if needed by placing a 2 x 4-inch wood stud through the block openings that are perpendicular to the block course needing support. Lay some blocks on their side in the bottom row for dewatering the pool (Figure 6.52a).

Place gravel just below the top of the blocks on slopes of 2:1 or flatter. Place hardware cloth or comparable wire mesh with 1/2-inch openings over all block openings to hold gravel in place.

The top elevation of the structure must be at least 6 inches lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure and into the storm drain and not past the structure. Temporary diking below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

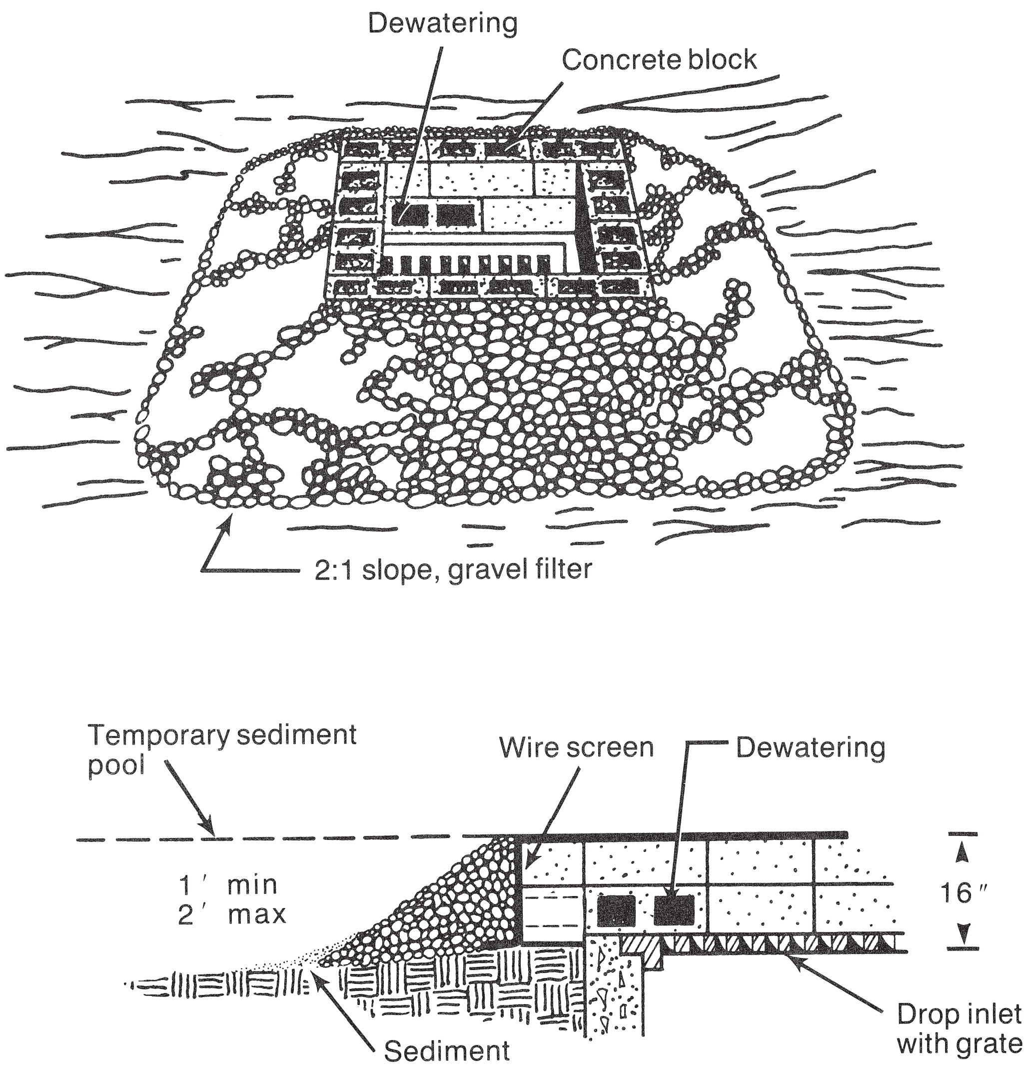


Figure 6.52a Block and gravel drop inlet protection.

Construction Specifications

1. Lay one block on each side of the structure on its side in the bottom row to allow pool drainage. The foundation should be excavated at least 2 inches below the crest of the storm drain. Place the bottom row of blocks against the edge of the storm drain for lateral support and to avoid washouts when overflow occurs. If needed, give lateral support to subsequent rows by placing 2 x 4 wood studs through block openings.

2. Carefully fit hardware cloth or comparable wire mesh with ½-inch openings over all block openings to hold gravel in place.

3. Use clean gravel, ¾- to ½-inch in diameter, placed 2 inches below the top of the block on a 2:1 slope or flatter and smooth it to an even grade. DOT #57 washed stone is recommended.

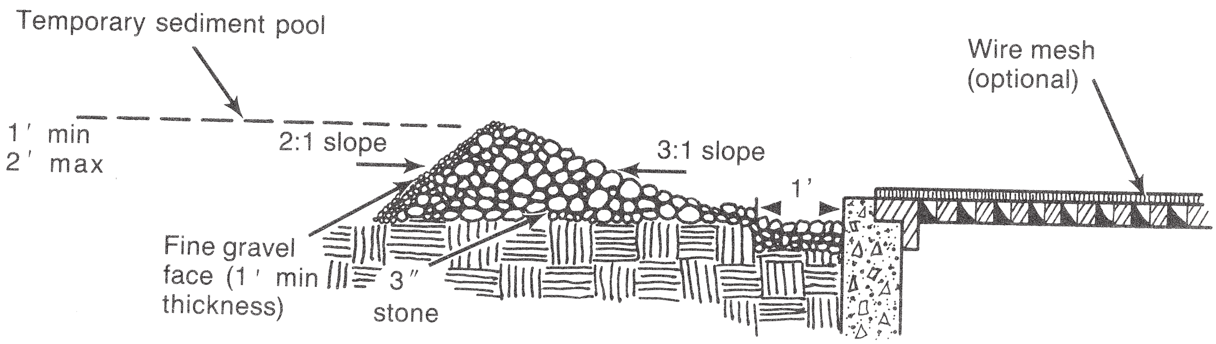


Figure 6.52b Gravel drop inlet protection (gravel donut).

4. If only stone and gravel are used, keep the slope toward the inlet no steeper than 3:1. Leave a minimum 1-foot wide level stone area between the structure and around the inlet to prevent gravel from entering inlet. On the slope toward the inlet, use stone 3 inches in diameter or larger. On the slope away from the inlet use ½ - ¾-inch gravel (NCDOT #57 washed stone) at a minimum thickness of 1 foot.

Maintenance

Inspect the barrier at least weekly and after each significant (½ inch or greater) rainfall and make repairs as needed.

Remove sediment as necessary to provide adequate storage volume for subsequent rains.

When the contributing drainage area has been adequately stabilized, remove all materials and any unstable soil, and either salvage or dispose of it properly. Bring the disturbed area to proper grade, then smooth and compact it. Appropriately stabilize all bare areas around the inlet.

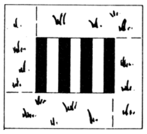
References

Inlet Protection
6.50, Excavated Drop Inlet Protection (Temporary)
6.51, Hardware Cloth, and Gravel Inlet Protection (Temporary)

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.53

SOD DROP INLET PROTECTION



Definition

A permanent grass sod filter area around a storm drain drop inlet in a stabilized, well-vegetated area.

Purpose

To limit sediment from entering storm drainage systems as a permanent protection measure.

Conditions Where Practice Applies

Where the drainage area of the drop inlet has been permanently seeded and mulched, and the immediate surrounding area is to remain in dense vegetation. This practice is well suited for lawns adjacent to large buildings.

Design Criteria

Keep velocity of design flow over the sod area at all points less than 5 ft/sec.

Place sod to form a turf mat completely covering the soil surface for a minimum distance of 4 feet from each side of the drop inlet where runoff will enter.

Maintain the slope of the sodded area no greater than 4:1.

Keep the drainage area no greater than 2 acres; maintain this area undisturbed or stabilize it.

Construction Specifications

1. Bring the area to be sodded to final grade elevation with top soil. Add fertilizer and lime, and install sod according to Practice 6.12, *Sodding*.

2. Lay all sod strips perpendicular to the direction of flows.

3. Keep the width of the sod at least 4 ft in the direction of flows.

4. Stagger sod strips so that adjacent strip ends are not aligned.

Maintenance

During the first 4 weeks, water sod as often as necessary to maintain moist soil to a minimum depth of 2 inches.

Maintain grass height at least 2 inches with no more than one-third the shoot height (grass leaf) removed in any mowing.

Apply fertilizer as necessary to maintain the desired growth and sod density. Add lime as needed to maintain the proper pH.

References

Surface Stabilization
6.12, Sodding

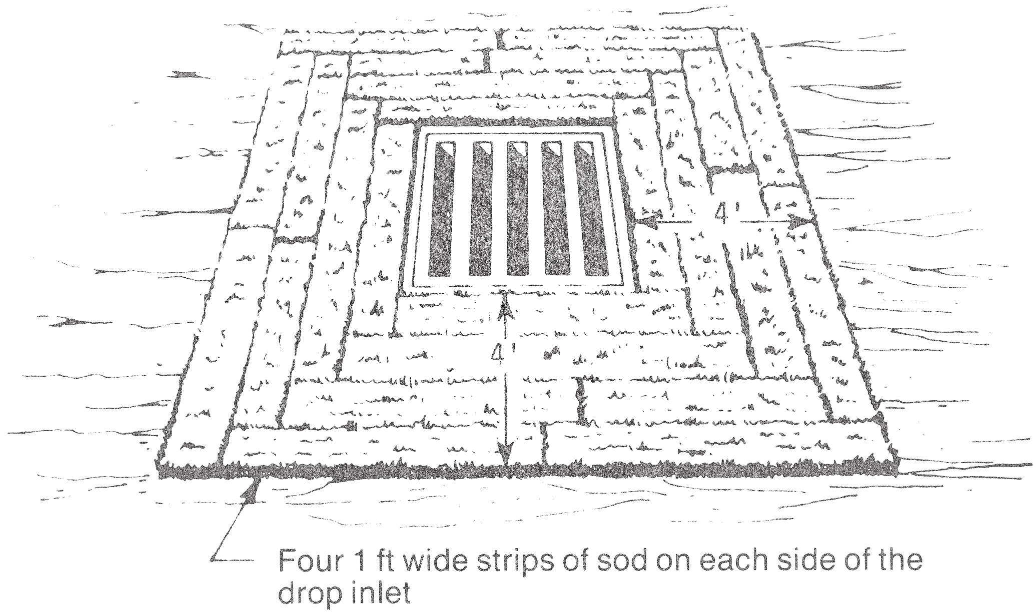


Figure 6.53a Sod strips protect inlet area from erosion (source: Va SWCC).

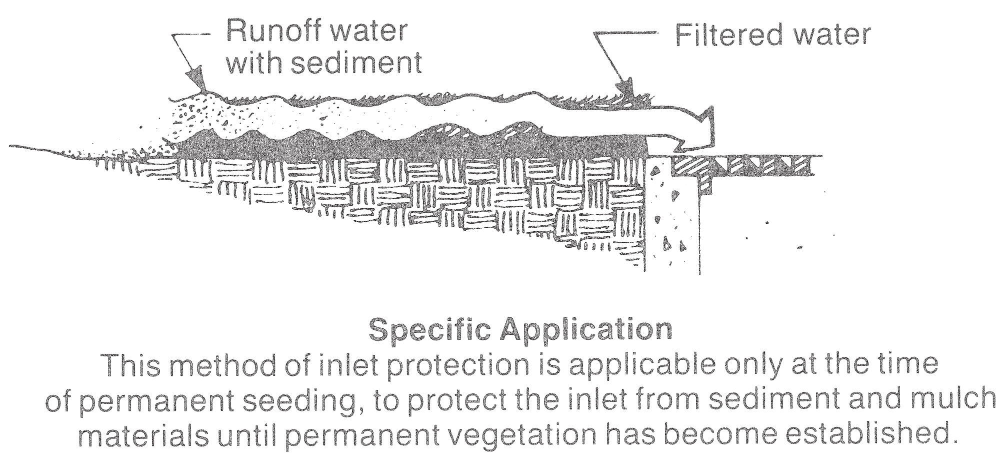


Figure 6.53b Sod drop inlet sediment filter (source: Va SWCC)

6.54

ROCK DOUGHNUT INLET PROTECTION (Temporary)

Definition

A doughnut shaped rock dam that prevents sediment from getting into a drop inlet. The rock dam has a built-in sediment storage area around the outside perimeter of the structure.

Purpose

To prevent sediment from entering a storm drain.

Conditions Where Practice Applies

To be used at drop inlets with large drainage areas or at drop inlets that receive high velocity water flows, possibly from many directions. Sediment is captured in an excavated depression surrounding the inlet. When drainage area exceeds 1 acre, additional measures are necessary. This practice must not divert water away from the storm drain.

Design Criteria

Place measure at least 30 feet away from vehicular traffic. This inlet protection can be modified to protect one side of the inlet if only one side receives flow.

Stone—A minimum 1-foot wide level area set 4 inches below the drop inlet crest will add protection against the entrance of material. Structural stone should be Class B riprap with 2:1 side slope, and a minimum crest width of 18 inches. The height of the stone should be from 2 to 3.5 feet. The outside face of the riprap should be covered in a 12-inch thick layer of #5 or #57 washed stone. Wire mesh with 2-inch openings may be placed over the drain grating but must be inspected frequently to avoid blockage by trash.

The top elevation of the stone structure must be at least 12 inches lower than the ground elevation downslope from the inlet. **It is important that all stormwater flow over the structure into the storm drain, and not past the structure.** Temporary diking below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose (Practice 6.52, *Block and Gravel Inlet Protection*).

Construction Specifications

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

2. Grade shallow depression uniformly towards the inlet with side slopes no greater than 2:1. Grade a 1-foot wide level area set 4 inches below the area adjacent to the inlet.

3. Install the Class B or Class I riprap in a circle around the inlet. The minimum crest width of the riprap should be 18 inches, with a minimum bottom width of 7.5 feet. The minimum height of the stone is 2 feet.

4. The outside face of the riprap is then lined with 12 inches of NC DOT #5 or #57 washed stone.

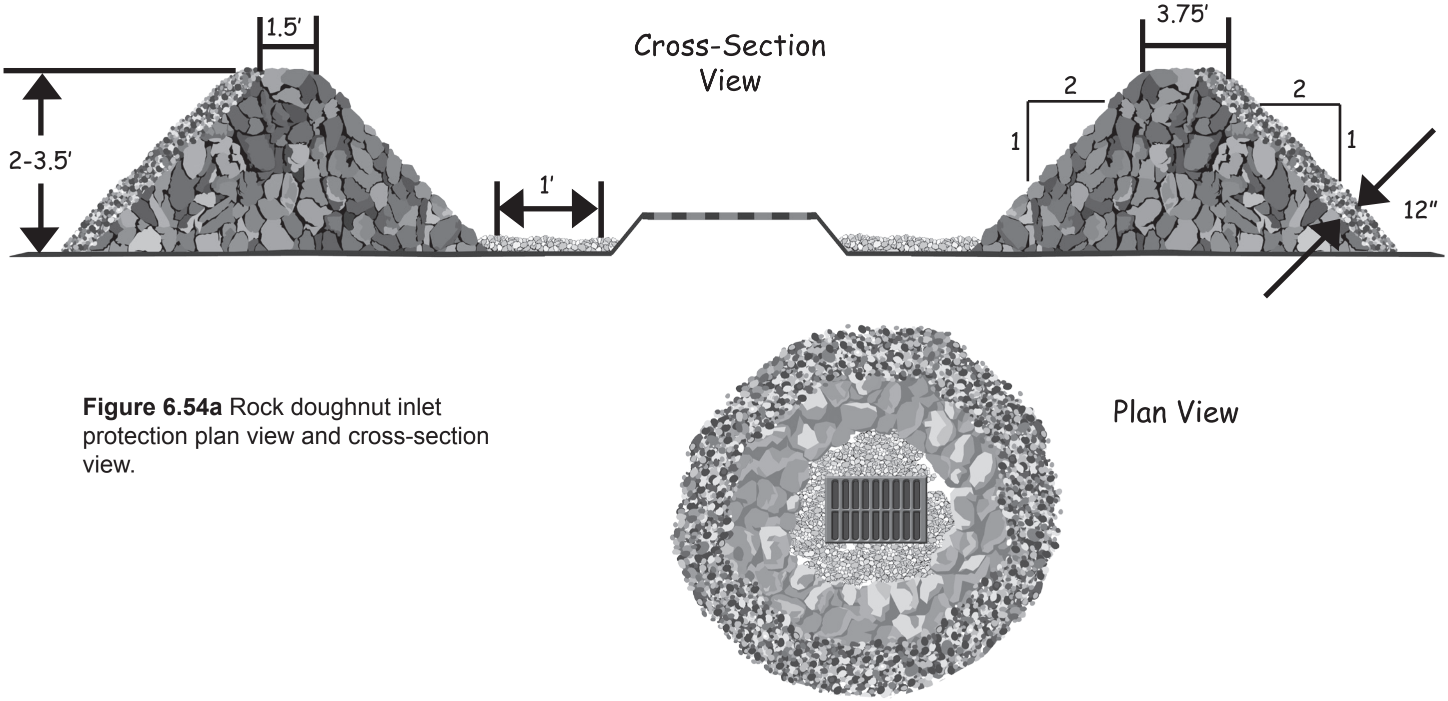


Figure 6.54a Rock doughnut inlet protection plan view and cross-section view.

Maintenance

Inspect rock doughnut inlet protection at least weekly and after each significant (½ inch or greater) rainfall event and repair immediately.

To provide satisfactory inlet protection efficiency, remove sediment from the sediment pool area when the volume is decreased by half. This will help provide adequate storage volume for the next rain. Stabilize excavated material appropriately.

Take care not to damage or undercut the structure during sediment removal. Remove debris from the inlet and replace stone as needed. If the inlet was covered with wire mesh the mesh should be cleaned of debris.

When the contributing drainage area has been adequately stabilized, remove all materials and dispose of sediment properly. Bring the disturbed area to the grade of the drop inlet. Smooth and compact it as needed.

Appropriately stabilize all bare areas around the inlet with ground cover.

References

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

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

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.

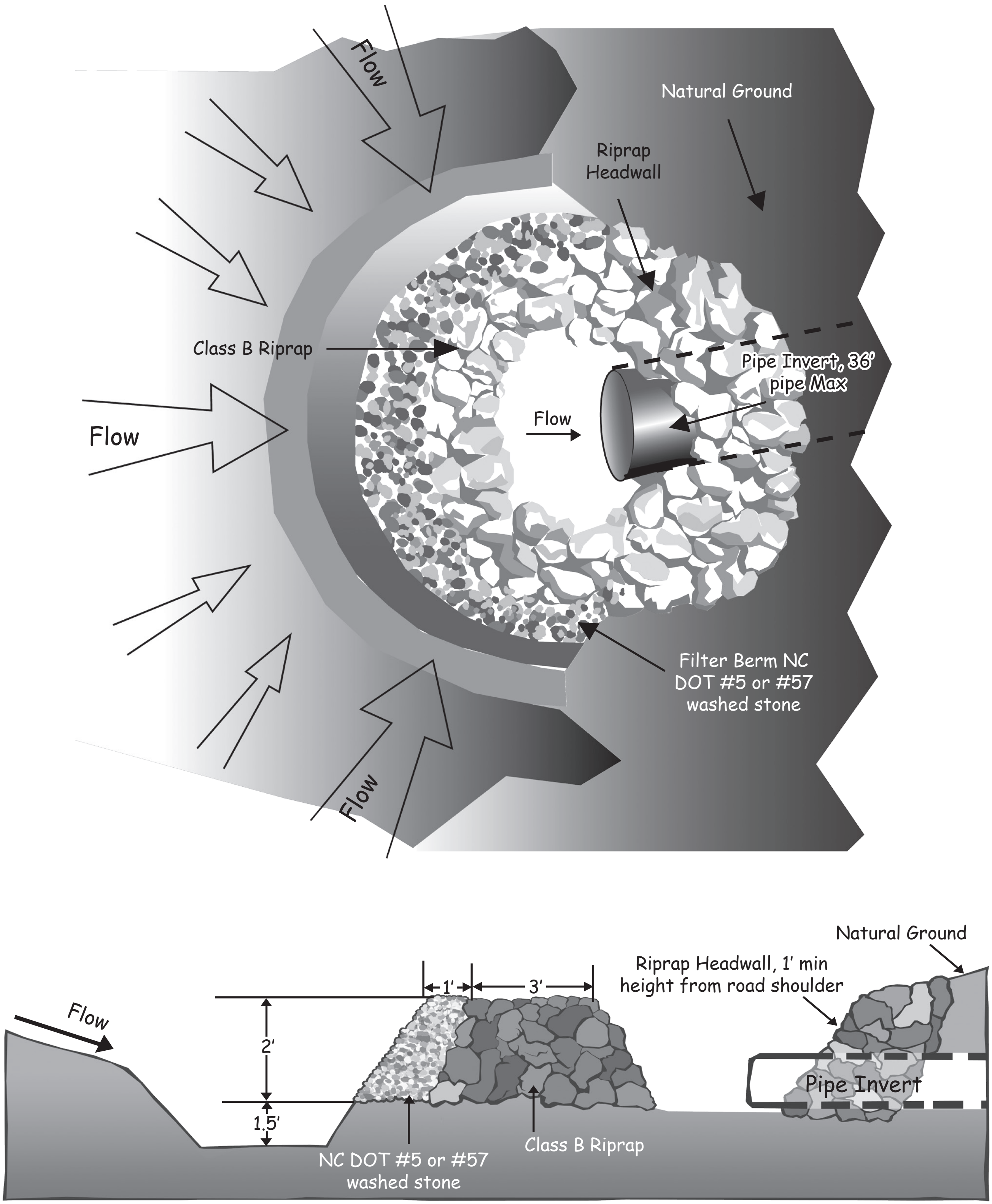


Figure 6.55a Rock pipe inlet protection plan view and cross-section view

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

INDEX

SEDIMENT TRAPS AND BARRIERS

6

6.60

TEMPORARY SEDIMENT TRAP

Definition

A small, temporary ponding basin formed by an embankment or excavation to capture sediment.

Purpose

To detain sediment-laden runoff and trap the sediment to protect receiving streams, lakes, drainage systems, and protect adjacent property.

Conditions Where Practice Applies

Specific criteria for installation of a temporary sediment trap are as follows:

- At the outlets of diversions, channels, slope drains, or other runoff conveyances that discharge sediment-laden water.
- Below areas that are draining 5 acres or less.
- Where access can be maintained for sediment removal and proper disposal.
- In the approach to a stormwater inlet located below a disturbed area as part of an inlet protection system.
- Structure life limited to 2 years.

A temporary sediment trap should not be located in an intermittent or perennial stream.

Planning Considerations

Select locations for sediment traps during site evaluation. Note natural drainage divides and select trap sites so that runoff from potential sediment-producing areas can easily be diverted into the traps. Ensure the drainage areas for each trap does not exceed 5 acres. Install temporary sediment traps before land disturbing takes place within the drainage area.

Make traps readily accessible for periodic sediment removal and other necessary maintenance. Plan locations for sediment disposal as part of trap site selection. Clearly designate all disposal areas on the plans.

In preparing plans for sediment traps, it is important to consider provisions to protect the embankment from failure from storm runoff that exceeds the design capacity. Locate bypass outlets so that flow will not damage the embankment. Direct emergency bypasses to undisturbed natural, stable areas. If a bypass is not possible and failure would have severe consequences, consider alternative sites.

Sediment trapping is achieved primarily by settling within a pool formed by an embankment. The sediment pool may also be formed by excavation, or by a combination of excavation and embankment. Sediment-trapping efficiency is a function of surface area and inflow rate (Practice 6.61, *Sediment Basin*). Therefore, maximize the surface area in the design. Because porous baffles improve flow distribution across the basin, high length to width ratios are not necessary to reduce short-circuiting and to optimize efficiency.

Because well planned sediment traps are key measures to preventing off-site sedimentation, they should be installed in the first stages of project development.

Design Criteria

Summary:	**Temporary Sediment Trap**
Primary Spillway:	Stone Spillway
Maximum Drainage Area:	5 acres
Minimum Volume:	3600 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
Minimum Depth:	3.5 feet, 1.5 feet excavated below grade
Maximum Height:	Weir elevation 3.5 feet above grade
Dewatering Mechanism:	Stone Spillway
Minimum Dewatering Time:	N/A
Baffles Required:	3

Storage capacity—Provide a minimum volume of 3600 ft^3/acre of disturbed area draining into the basin. Required storage volume may also be determined by modeling the soil loss with the Revised Universal Soil Loss Equation or other acceptable methods. Measure volume to the crest elevation of the stone spillway outlet.

Trap cleanout—Remove sediment from the trap, and restore the capacity to original trap dimensions when sediment has accumulated to one-half the design depth.

Trap efficiency—The following design elements must be provided for adequate trapping efficiency:

- Provide a surface area of 0.01 acres (435 square feet) per cfs based on the 10-year storm;
- Convey runoff into the basin through stable diversions or temporary slope drains;
- Locate sediment inflow to the basin away from the dam to prevent short circuits from inlets to the outlet;
- Provide porous baffles (Practice 6.65, *Porous Baffles*);
- Excavate 1.5 feet of the depth of the basin below grade, and provide minimum storage depth of 2 feet above grade.

Embankment—Ensure that embankments for temporary sediment traps do not exceed 5 feet in height. Measure from the center line of the original ground surface to the top of the embankment. Keep the crest of the spillway outlet a minimum of 1.5 feet below the settled top of the embankment. Freeboard may be added to the embankment height to allow flow through a designated bypass location. Construct embankments with a minimum top width of 5 feet and side slopes of 2:1 or flatter. Machine compact embankments.

Excavation—Where sediment pools are formed or enlarged by excavation, keep side slopes at 2:1 or flatter for safety.

Outlet section—Construct the sediment trap outlet using a stone section of the embankment located at the low point in the basin. The stone section serves two purposes: (1) the top section serves as a non-erosive spillway outlet for flood flows; and (2) the bottom section provides a means of dewatering the basin between runoff events.

Stone size—Construct the outlet using well-graded stones with a d_{50} size of 9 inches (Class B erosion control stone is recommended,) and a maximum stone size of 14 inches. The entire upstream face of the rock structure should be covered with fine gravel (NCDOT #57 or #5 wash stone) a minimum of 1 foot thick to reduce the drainage rate.

Side slopes—Keep the side slopes of the spillway section at 2:1 or flatter. To protect the embankment, keep the sides of the spillway at least 21 inches thick.

Depth—The basin should be excavated 1.5 feet below grade.

Stone spillway height—The sediment storage depth should be a minimum of 2 feet and a maximum of 3.5 feet above grade.

Protection from piping—Place filter cloth on the foundation below the riprap to prevent piping. An alternative would be to excavate a keyway trench across the riprap foundation and up the sides to the height of the dam.

Weir length and depth—Keep the spillway weir at least 4 feet long and sized to pass the peak discharge of the 10-year storm (Figure 6.60a). A maximum flow depth of six inches, a minimum freeboard of 1 foot, and maximum side slopes of 2:1 are recommended. Weir length may be selected from Table 6.60a shown for most site locations in North Carolina.

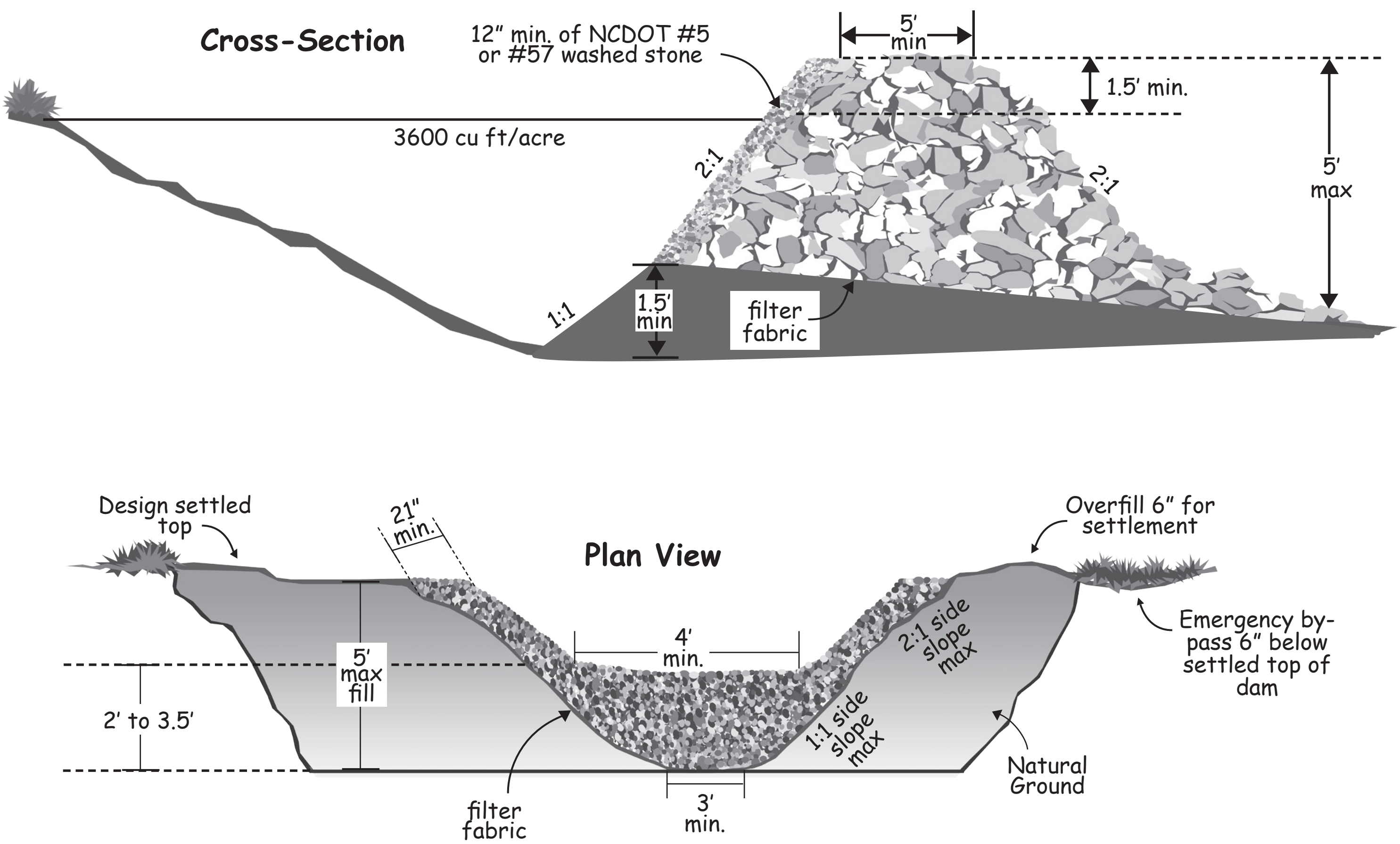


Figure 6.60a Plan view and cross-section view of a temporary sediment trap.

Table 6.60a
Design of Spillways

Drainage Area (acres)	Weir Length[1] (ft)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

[1] Dimensions shown are minimum.

Construction Specifications

1. Clear, grub, and strip the area under the embankment of all vegetation and root mat. Remove all surface soil containing high amounts of organic matter, and stockpile or dispose of it properly. Haul all objectionable material to the designated disposal area.

2. Ensure that fill material for the embankment is free of roots, woody vegetation, organic matter, and other objectionable material. Place the fill in lifts not to exceed 9 inches, and machine compact it. Over fill the embankment 6 inches to allow for settlement.

3. Construct the outlet section in the embankment. Protect the connection between the riprap and the soil from piping by using filter fabric or a keyway cutoff trench between the riprap structure and soil.

- Place the filter fabric between the riprap and the soil. Extend the fabric across the spillway foundation and sides to the top of the dam; or
- Excavate a keyway trench along the center line of the spillway foundation extending up the sides to the height of the dam. The trench should be at least 2 feet deep and 2 feet wide with 1:1 side slopes.

4. Clear the pond area below the elevation of the crest of the spillway to facilitate sediment cleanout.

5. All cut and fill slopes should be 2:1 or flatter.

6. Ensure that the stone (drainage) section of the embankment has a minimum bottom width of 3 feet and maximum side slopes of 1:1 that extend to the bottom of the spillway section.

7. Construct the minimum finished stone spillway bottom width, as shown on the plans, with 2:1 side slopes extending to the top of the over filled embankment. Keep the thickness of the sides of the spillway outlet structure at a minimum of 21 inches. **The weir must be level and constructed to grade to assure design capacity.**

8. Material used in the stone section should be a well-graded mixture of stone with a d_{50} size of 9 inches (class B erosion control stone is recommended) and a maximum stone size of 14 inches. The stone may be machine placed and the smaller stones worked into the voids of the larger stones. The stone should be hard, angular, and highly weather-resistant.

9. Discharge inlet water into the basin in a manner to prevent erosion. Use temporary slope drains or 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*).

10. Ensure that the stone spillway outlet section extends downstream past the toe of the embankment until stable conditions are reached and outlet velocity is acceptable for the receiving stream. Keep the edges of the stone outlet section flush with the surrounding ground, and shape the center to confine the outflow stream (*References: Outlet Protection*).

11. Direct emergency bypass to natural, stable areas. Locate bypass outlets so that flow will not damage the embankment.

12. Stabilize the embankment and all disturbed areas above the sediment pool and downstream from the trap immediately after construction (*References: Surface Stabilization*).

13. Show the distance from the top of the spillway to the sediment cleanout level (1/2 the design depth) on the plans and mark it in the field.

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

Maintenance

Inspect temporary sediment traps at least weekly and after each significant (½ inch or greater) rainfall event and repair immediately. Remove sediment, and restore the trap 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 part of the gravel facing that is impaired by sediment.

Check the structure for damage from erosion or piping. Periodically check the depth of the spillway to ensure it is a minimum of 1.5 feet below the low point of the embankment. Immediately fill any settlement of the embankment to slightly above design grade. **Any riprap displaced from the spillway must be replaced immediately.**

After all sediment-producing areas have been permanently stabilized, remove the structure and all unstable sediment. Smooth the area to blend with the adjoining areas, and stabilize properly (*References: Surface Stabilization*).

References

Outlet Protection
6.41, Outlet Stabilization Structure

Runoff Control Measures
6.20, Temporary Diversions
6.21, Permanent Diversions
6.22, Diversion Dike (Perimeter Protection)
6.23, Right-of-way Diversion (Water Bars)

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

Sediment Traps and Barriers
6.61, Sediment Basins
6.64, Skimmer Basins
6.65, Porous Baffles

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

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.

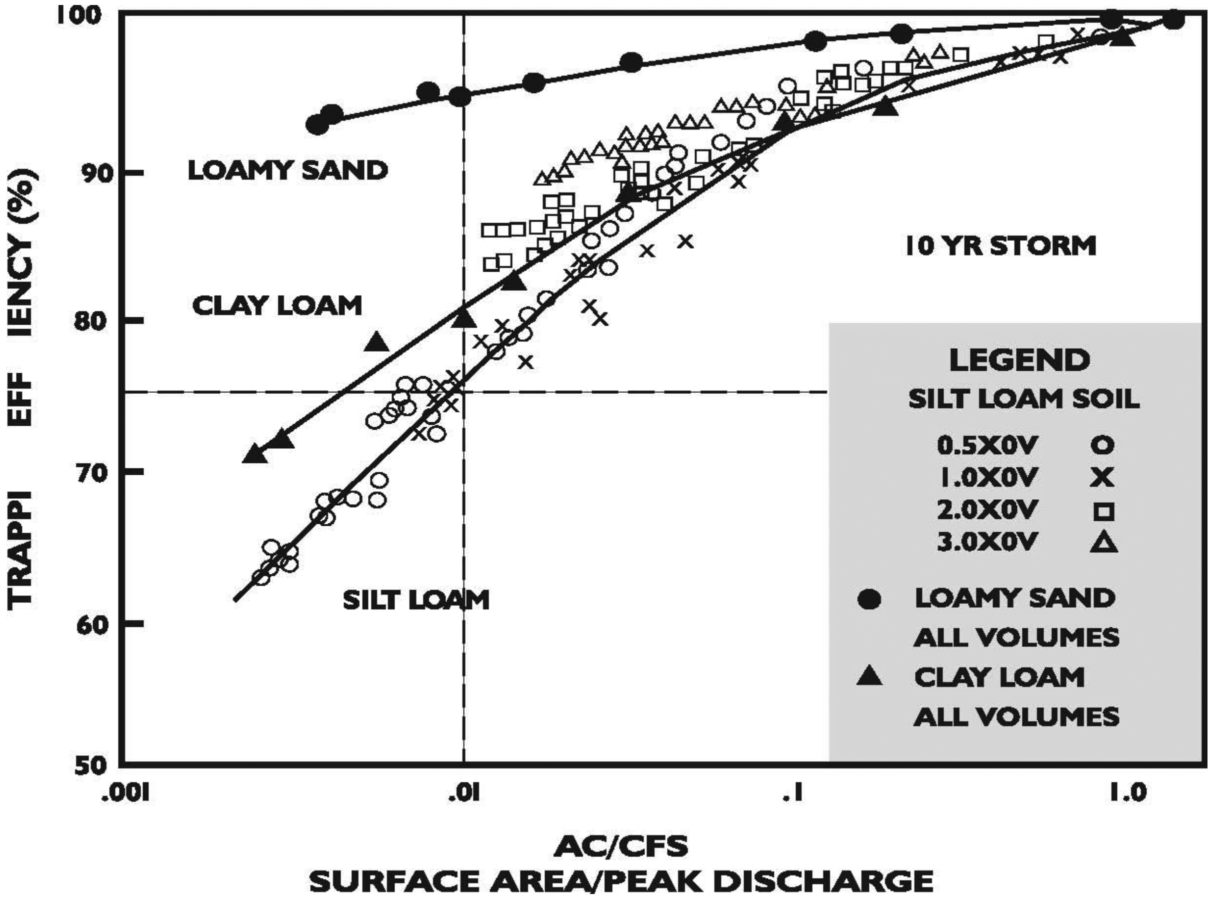


Figure 6.61a Relationship between the ratio of surface area to peak inflow rate and trap efficiency.

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*).

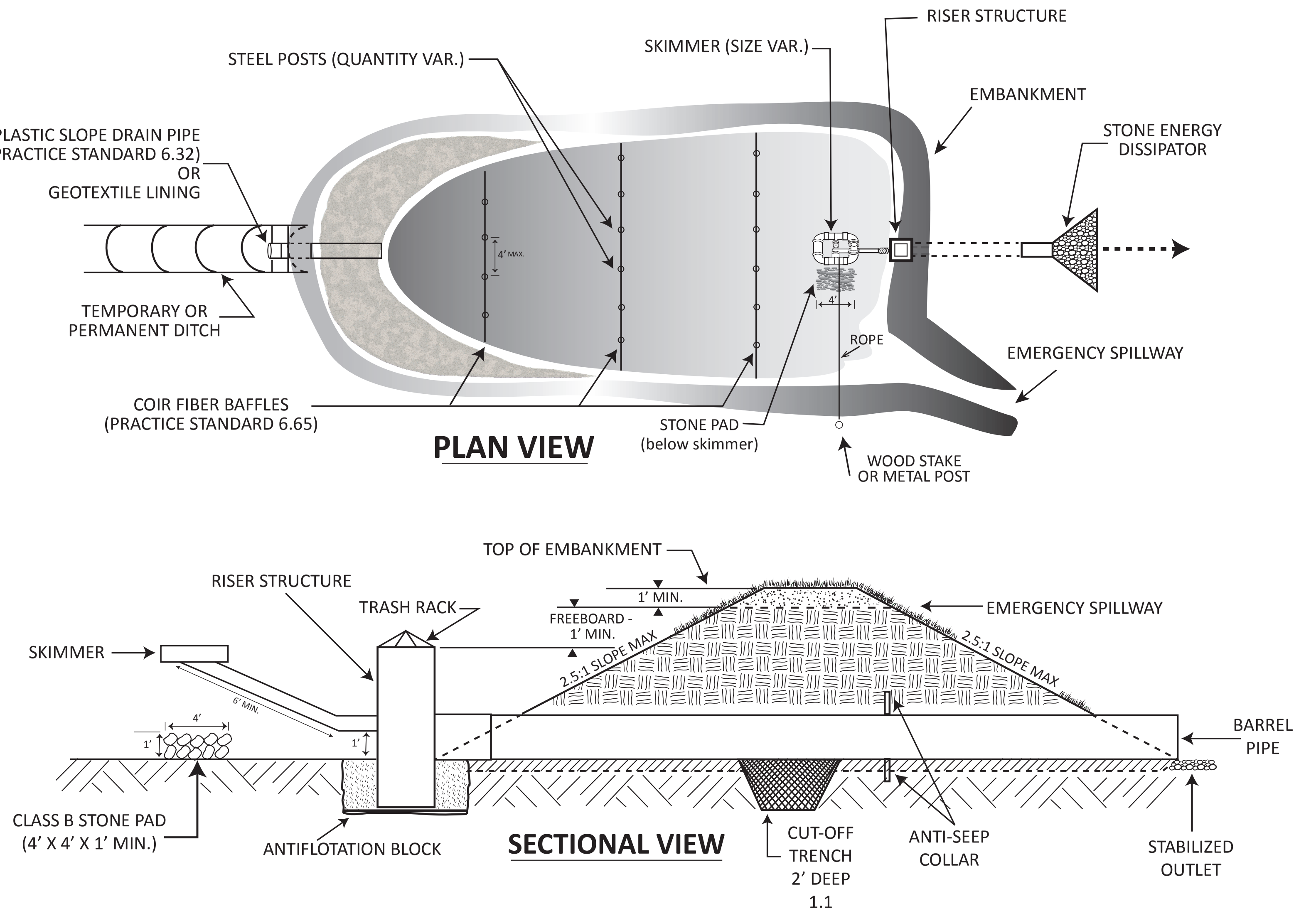
8. Install porous baffles as specified in Practice 6.65, Porous Baffles.

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.

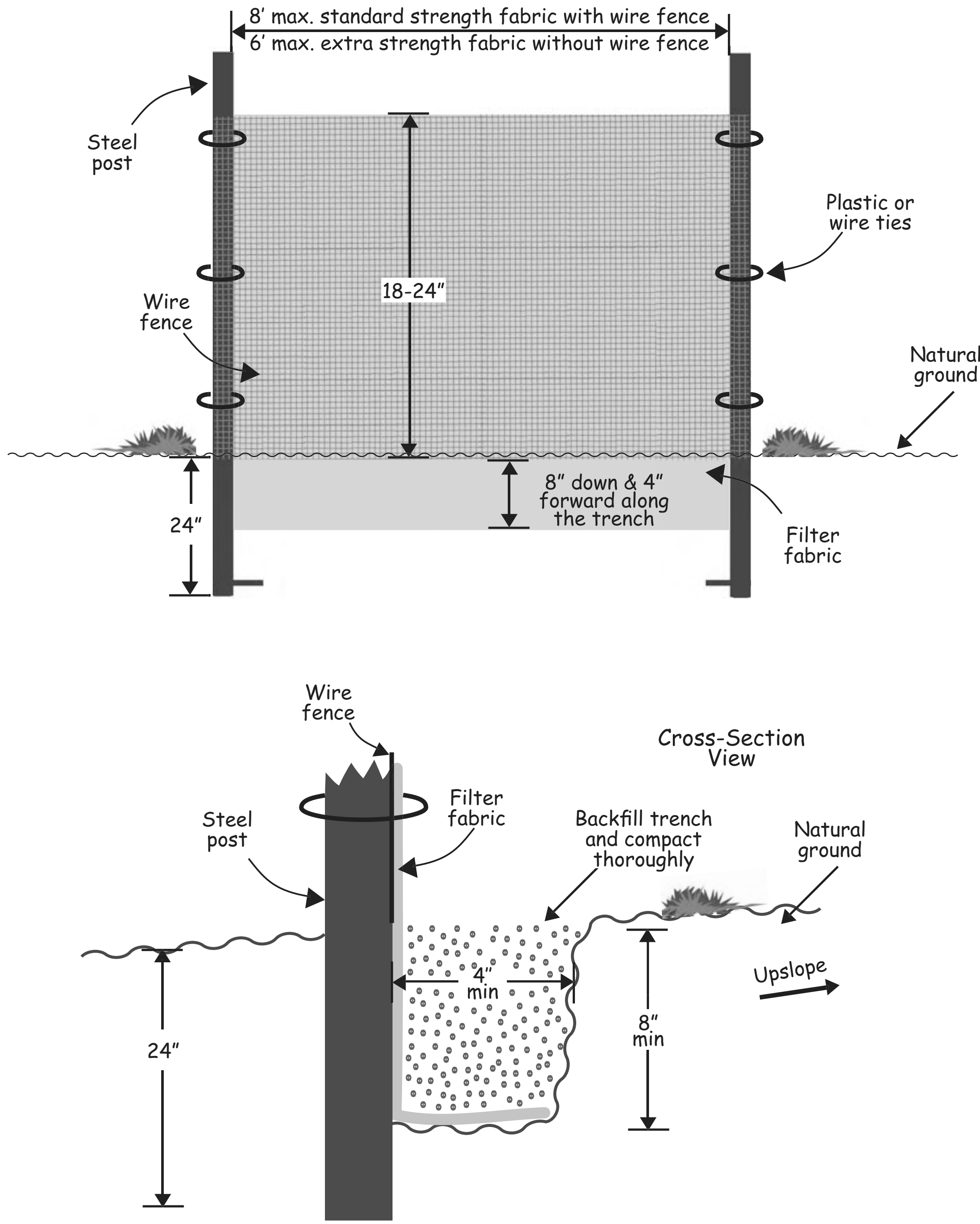


Figure 6.62a Installation detail of a sediment fence.

The Slicing Method

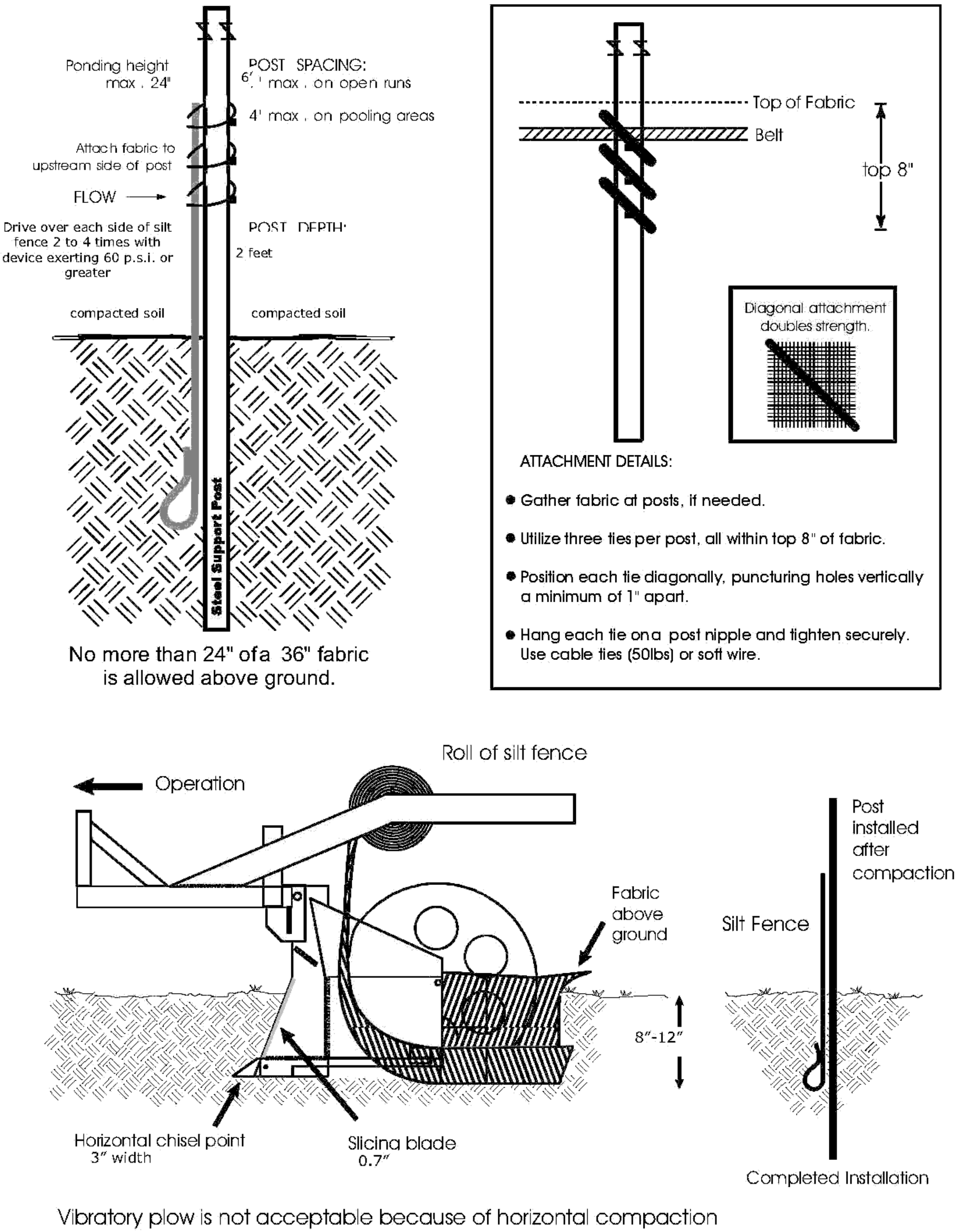


Figure 6.62b Schematics for using the slicing method to install a sediment fence. Adapted from *Silt Fence that Works*

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.

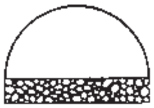
Runoff Control Measures
6.20, Temporary Diversions

Outlet Protection
6.41, Outlet Stabilization Structure

Appendix
8.03, Estimating Runoff

6.63

SEDIMENT BASIN WITH ROCK DAM



Definition

A rock embankment located to capture sediment in a naturally formed drainage feature.

Purpose

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

Conditions Where Practice Applies

The rock dam may be used in drainage areas too large for the use of a temporary sediment trap. The height of the dam is limited to 8 feet, and drainage area should be no larger than 10 acres.

The rock dam is preferred where a stable, earthen embankment would be difficult to construct, and riprap and gravel are readily available. The site must be accessible for periodic sediment removal.

A rock dam should not be located in a intermittent or perennial stream.

Planning Considerations

A sediment basin formed by a rock embankment is used primarily where it is desirable to have the top of the structure serve as the overflow outlet and where suitable rock is readily available. A long weir crest is designed to keep flow depth shallow and discharge velocities low. The inside face of the rock dam must be covered with gravel to reduce the rate of seepage through the dam so that a sediment pool will form during runoff events. The pool should drain slowly through the gravel.

The abutments of the rock dam must be higher than the top of the dam to prevent any water from flowing against the soil. Suitable filter fabric should be placed between the rock structure and its soil base and abutments. This practice prevents “piping” or soil movement in the foundation and abutments. Rock should extend downstream from the toe of the dam, on zero grade, and a sufficient distance to stabilize flow and prevent erosion.

For other planning considerations see Practice 6.61, *Sediment Basin*.

Design Criteria

Summary:	Temporary Rock Dam
Primary Spillway:	Stone Spillway
Maximum Drainage Area:	10 acres
Minimum Sediment Storage Volume:	3600 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
Minimum Depth:	3.5 feet, 1.5 feet excavated below grade
Maximum Height:	Weir elevation 6 feet above grade
Dewatering Mechanism	Stone Spillway
Minimum Dewatering Time:	N/A
Baffles Required:	3

Design basin life—3 years or less.

Dam height—limited to 8 feet.

Basin locations—select areas that:

- provide a large surface area to trap sediment;
- intercept runoff from disturbed areas;
- are accessible for periodic sediment removal; and
- interfere minimally with construction activities.

Basin volume—The volume of the basin should be at least 3600 cubic feet per acre based on disturbed area draining into the basin, and measured 1 foot below the spillway crest. A sediment cleanout elevation, where the sediment pool is 50% full, should be marked in the field with a permanent stake.

Trap efficiency—The following design elements must be provided for adequate trapping efficiency:

- provide a surface area of 0.01 acres (435 square feet) per cfs based on the area draining to the rock dam.
- locate sediment inflow to the basin away from the dam to prevent short circuits from inlets to the outlet;
- provide porous baffles (Practice 6.65, *Porous Baffles*); and
- excavate 1.5 feet of the depth of the basin below grade, and a minimum of 2 feet above grade.

Spillway capacity—The spillway should carry peak runoff for a 10-year storm with maximum flow depth of 6 inches and a minimum freeboard of 1 foot. The top of the rock embankment may serve as the spillway.

Embankment—

Top width— 5 feet minimum
Side Slopes— Maximum: 2:1 upstream slope
3:1 downstream slope

Rock abutments should extend to an elevation at least 2 feet above the spillway. Abutments should be 2 feet thick with 2:1 side slopes. The rock abutments should extend down the downstream face of the dam to the toe, at least 1 foot higher than the rest of the dam to protect the earth abutments from scour.

Outlet protection—A rock apron, at least 1.5 feet thick, should extend downstream from the toe of the dam on zero grade. A sufficient distance or a distance equal to the height of the dam (whichever is greater) is needed to prevent channel erosion.

Rock fill—Rock should be well graded, hard, erosion resistant stone with a minimum d_{50} size of 12 inches. Typically, a rock dam should be constructed of a downstream layer of Class II riprap providing 3 feet of the crest width and an upstream layer of Class I riprap providing 2 feet of the crest width.

Protection from "piping"—To prevent soil movement and piping under the dam, the entire foundation including both earth abutments must be covered by filter fabric. Overlap 1 foot at all joints, with the upstream strip over the downstream strip.

Basin dewatering—The entire upstream face of the rock structure should be covered with fine gravel (NC DOT #57 or #5 washed stone) a minimum of 1 foot thick to reduce the drainage rate.

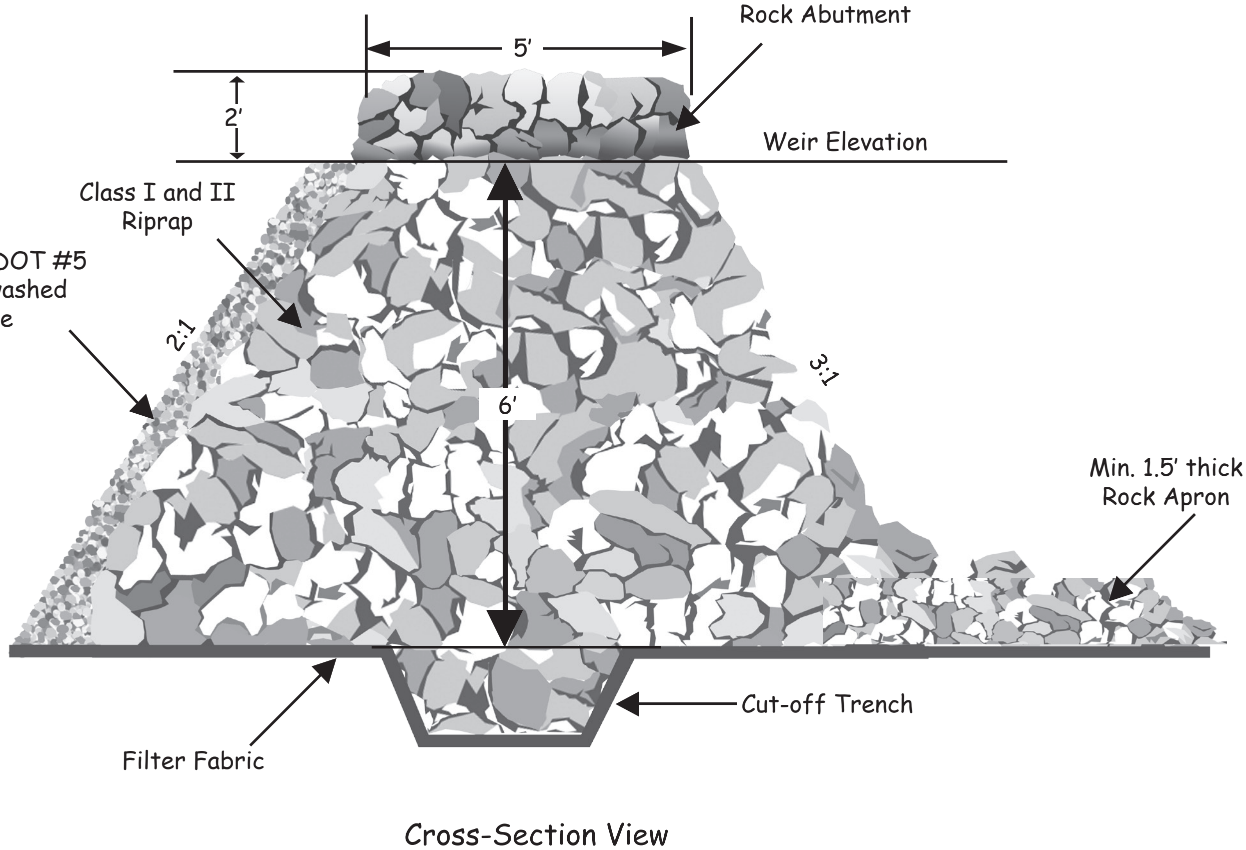


Figure 6.63a Rock Dam cross section

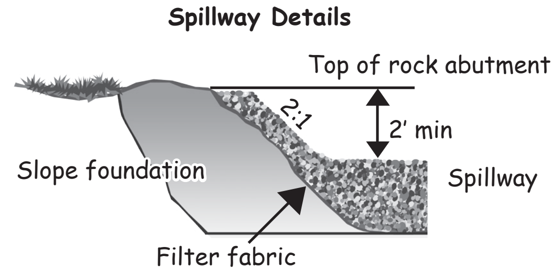
Construction Specifications

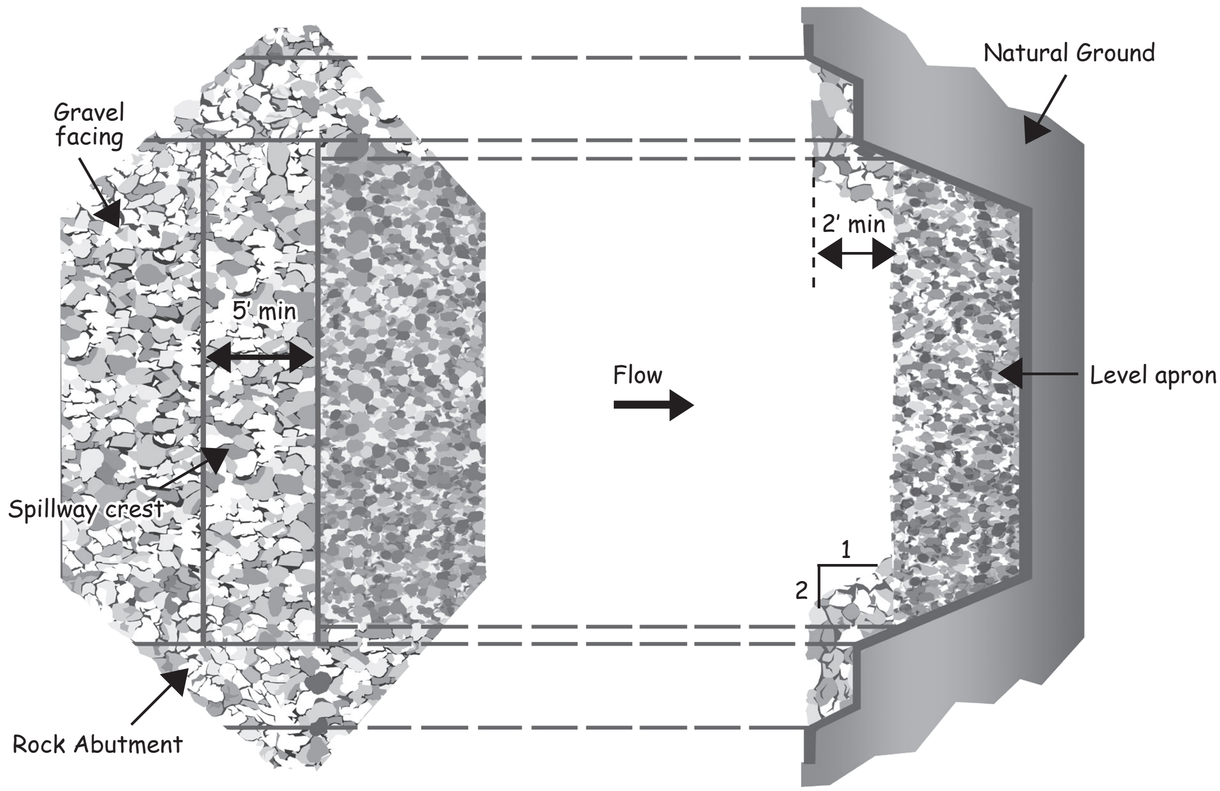
1. Clear the areas under the embankment and strip of roots and other objectionable material. Delay cleaning the reservoir area until the dam is in place.

2. Cover the foundation area including the abutments with extra-strength filter fabric before backfilling with rock. If a cutoff trench is required, excavate at center line of dam, extending all the way up the earth abutments. Apply filter fabric under the rockfill embankment from the upstream edge of the dam to the downstream edge of the apron. Overlap fill material a minimum of 1 foot at all joints, with the upstream strip laid over the downstream strip.

3. Construct the embankment with well-graded rock and gravel to the size and dimensions shown on the drawings. It is important that rock abutments be at least 2 feet higher than the spillway crest and at least 1 foot higher than the dam, all the way to the downstream toe, to prevent scour and erosion at the abutments.

Figure 6.63b Rock Dam plan view and spillway details





4. Sediment-laden water from the construction site should be diverted into the basin reservoir at the furthest area from the dam.

5. Construct the rock dam before the basin area is cleared to minimize sediment yield from construction of the basin. Immediately stabilize all areas disturbed during the construction of the dam except the sediment pool (*References: Surface Stabilization*).

6. Safety—Sediment basins should be considered dangerous because they attract children. Steep side slopes should be avoided. Fences with warning signs may be needed if trespassing is likely. All state and local requirements must be followed.

Maintenance

Check sediment basins after each rainfall. Remove sediment and restore original volume when sediment accumulates to about one-half the design volume. Sediment should be placed above the basin and adequately stabilized.

Check the structure for erosion, piping, and rock displacement weekly and after each significant (½ inch or greater) rainstorm and repair immediately.

Remove the structure and any unstable sediment immediately after the construction site has been permanently stabilized. Smooth the basin site to blend with the surrounding area and stabilize. All water and sediment should be removed from the basin prior to dam removal. Sediment should be placed in designated disposal areas and not allowed to flow into streams or drainage ways during structure removal.

References

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

Sediment Traps and Barriers
6.61, Sediment Basins
6.65, Porous Baffles

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.64

SKIMMER SEDIMENT BASIN

Definition

An earthen embankment suitably located to capture runoff, with a trapezoidal spillway lined with an impermeable geotextile or laminated plastic membrane, and equipped with a floating skimmer for dewatering.

Purpose

Sediment basins are designed to provide an area for runoff to pool and settle out a portion of the sediment carried down gradient. Past designs used a perforated riser for dewatering, which allowed water to leave the basin from all depths. One way to improve the sediment capture rate is to have an outlet which dewaters the basin from the top of the water column where the water is cleanest. A skimmer is probably the most common method to dewater a sediment basin from the surface. The basic concept is that the skimmer does not dewater the basin as fast as runoff enters it, but instead allows the basin to fill and then slowly drain over hours or days. This process has two effects. First, the sediment in the runoff has more time to settle out prior to discharge. Second, a pool of water forms early in a storm event and this further increases sedimentation rates in the basin. Many of the storms will produce more volume than the typical sediment basin capacity and flow rates in excess of the skimmer capability, resulting in flow over the emergency spillway. This water is also coming from the top of the water column and has thereby been "treated" to remove sediment as much as possible. (Adapted from SoilFacts: Dewatering Sediment Basins Using Surface Outlets. N. C. State University, Soil Science Department.)

Conditions Where Practice Applies

Skimmer sediment basins are needed where drainage areas are too large for temporary sediment traps. Do not locate the skimmer sediment basin in intermittent or perennial streams.

Planning Considerations

Select locations for skimmer basins during initial site evaluation. Install skimmer sediment basins before any site grading takes place within the drainage area.

Select skimmer sediment basin sites to capture sediment from all areas that are not treated adequately by other sediment control measures. 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.

A skimmer is a sedimentation basin dewatering control device that withdraws water from the basin's water surface, thus removing the highest quality water for delivery to the uncontrolled environment. A skimmer is shown in Figure 6.64a. By properly sizing the skimmer's control orifice, the skimmer can be made to dewater a design hydrologic event in a prescribed period. Because the spillway is actually used relatively frequently, it should be carefully stabilized using geotextiles, or rock if necessary, that can withstand the expected flows. The spillway should be placed as far from the inlet of the basin as possible to maximize sedimentation before discharge. The spillway should be located in natural groundcover to the greatest extent possible

The costs of using a skimmer system are similar, or occasionally less, than a conventional rock outlet or perforated riser. However, the basin is more efficient in removing sediment. Another advantage of the skimmer is that it can be reused on future projects. The main disadvantage of the skimmer is that it does require frequent maintenance, primarily in removing debris from the inlet.

A skimmer must dewater the basin from the top of the water surface. The rate of dewatering must be controlled. A dewatering time of 2-5 days is required. **Any skimmer design that dewaters from the surface at a controlled rate is acceptable.**

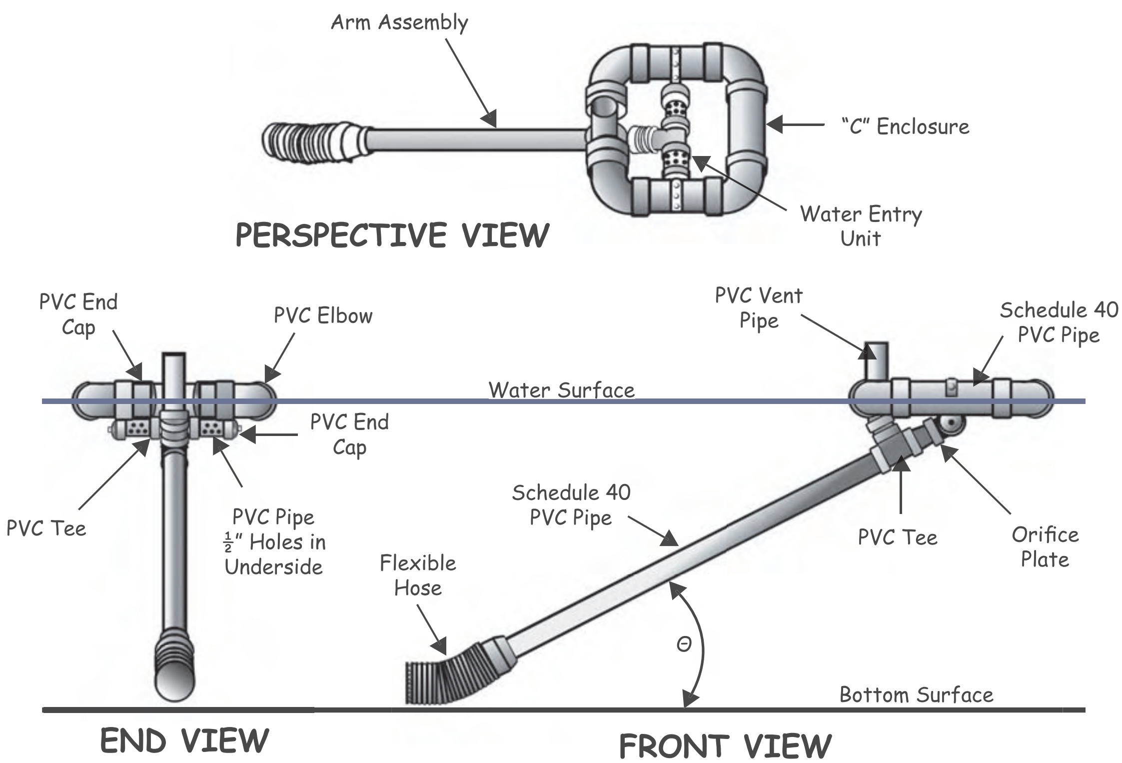


Figure 6.64a Schematic of a skimmer, from Pennsylvania Erosion and Sediment Pollution Control Manual, March, 2000.

SKIMMER ORIFICE DIAMETER

The orifice of a skimmer should be selected in order to achieve the desired dewatering time. **Three days** is probably the optimal length of time for temporary sediment controls. It allows longer settling time for suspended solids remaining in the basin after a storm event, while dewatering the basin in less time than the average interval between rainfall events. Design criteria for permanent stormwater detention basins in the Division of Water Quality Stormwater BMP Manual require 2-5 days for dewatering.

Procedure

First determine the desired dewatering time in days (t_d) and the volume (V) of water to be released in that time period. Dividing the volume in cubic feet by the dewatering time in days gives a flow rate Q_d in cubic feet per day.

$$Q_d = V / t_d \ \ (ft^3/day)$$

Next determine the head on the skimmer orifice. Table 6.64a has the values for various sizes of the Faircloth skimmer.

Table 6.64a Head on orifice of various skimmer sizes

Skimmer Size (in.)	Head on Orifice (ft.)
1.5	0.125
2	0.167
2.5	0.208
3	0.25
4	0.333
5	0.333
6	0.417
8	0.5

The desired orifice diameter (D) in inches can now be calculated using the equation

$$D = \sqrt{Q_d /(2310 * \sqrt{H})} \quad \text{(inches)}$$

Example: Select a skimmer that will dewater a 20,000 ft^3 skimmer basin in 3 days.

1. $Q_d = V / t_d$ (ft^3/day) = 20,000 ft^3 / 3 days = 6670 (ft^3/day).

2. Try a 4 inch skimmer, with H = 0.333 ft. (Table 6.64a)

3. $D = \sqrt{Q_d /(2310 * \sqrt{H})}$ (in.) $= \sqrt{6670 \text{ ft}^3\text{/day} /(2310 * \sqrt{0.333 \text{ ft.}})}$ (in.)

   = 2.24 inches (Use 2 ¼ inches)

The desired dewatering time can also be achieved by adjusting the skimmer size and orifice diameter using the spreadsheet entitled "Sediment Control Measures", which is available at http://portal.ncdenr.org/web/lr/links

Figure 6.64b Example Excel Spreadsheet

4	Skimmer Size (inches)
0.333	Head on Skimmer (feet)
2.25	Orifice Size (1/4 in increment)
2.96	Dewatering Time (days)

Skimmer Size (Inches)	Head on Skimmer (Feet)
1.5	0.125
2	0.167
2.5	0.208
3	0.25
4	0.333
5	0.333
6	0.417
8	0.5

Adapted from training materials developed by Albert R. Jarrett, Ph.D. for Erosion and Sediment Control/Stormwater Certification for NC DOT Projects Level IIIA and IIIB, N.C. State University, Department of Biological and Agricultural Engineering, 2007.

Design Criteria

Summary:	**Skimmer Sediment Basin**
Primary Spillway:	Trapezoidal spillway with impermeable membrane
Maximum Drainage Area:	10 acres
Minimum Volume:	1800 cubic feet per acre of disturbed area
Minimum Surface Area:	325 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
Minimum Dewatering Time:	2 days
Baffles Required:	3 baffles*

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

Drainage areas—Limit drainage areas to 10 acres.

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

Dam height—Limit dam height to 5 feet.

Basin locations—Select areas that:

- Provide capacity for storage of sediment 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;
- 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. 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 cubic feet per acre for the disturbed area draining into the basin (1,800 cubic feet is equivalent to half an inch of sediment per acre of basin disturbed 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 of freeboard in the spillway. Base runoff computations on the disturbed soil cover conditions expected during the effective life of the structure.

Sediment cleanout elevation—Determine the elevation at which the invert of the basin would be half-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).

Basin dewatering—The basin should be provided with a surface outlet. A floating skimmer should be attached to a Schedule 40 PVC barrel pipe of the same diameter as the skimmer arm. The orifice in the skimmer will control the rate of dewatering. The skimmer should be sized to dewater the basin in 2-5 days).

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

Basin spillway—Construct the entire flow area of the spillway in undisturbed soil if possible. Make the cross section trapezoidal with side slopes of 3:1 or flatter.

- Capacity—The minimum design capacity of the spillway must be the peak rate of runoff from the 10-year storm. Maximum depth of flow during the peak runoff should be 6 inches. In no case should the freeboard of the spillway be less than 1 foot above the design depth of flow.
- Velocity—Ensure that the velocity of flow discharged from the basin is nonerosive for the existing conditions. When velocities exceed that allowable for the receiving areas, provide outlet protection (References: *Outlet Protection*).

Embankment—Ensure that embankments for skimmer sediment basins do not exceed 5 feet in height (measured at the center line from the original ground surface to the top of the embankment). Keep the crest of the spillway outlet a minimum of 1.5 feet below the top of the embankment. Additional freeboard may be added to the embankment height which allows flow through a designated bypass location. Construct embankments with a minimum top width of 5 feet and side slopes of 2:1 or flatter. Machine compact the embankments.

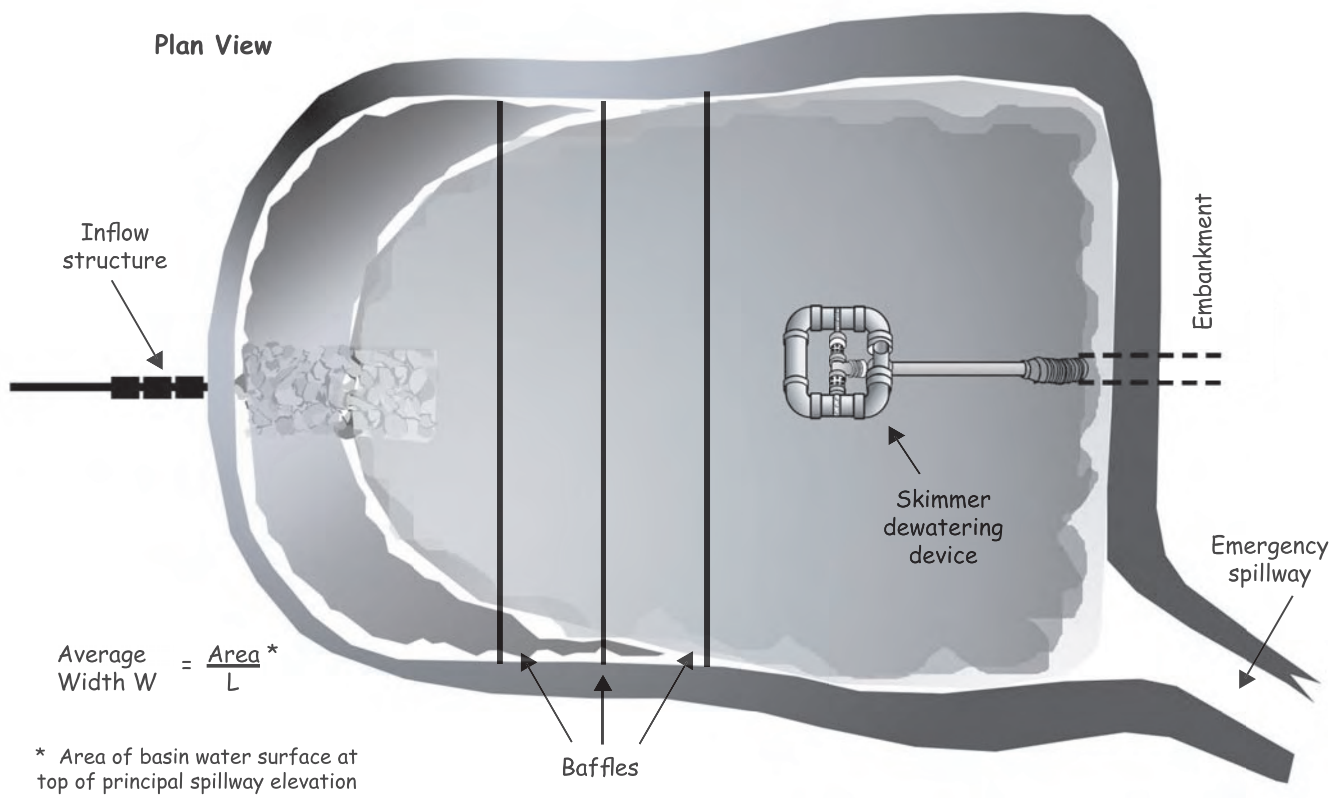
Excavation—Where sediment pools are formed or enlarged by excavation, keep side slopes at 2:1 or flatter for safety.

Erosion protection—Stabilize all areas disturbed by construction (except the lower half of the sediment pool) by suitable means immediately after completing the basin (References: *Surface Stabilization*).

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.
- Length—Maximize the length-to-width ratio of the basin to prevent short circuiting, and ensure use of the entire design settling area.
- Baffles—Provide a minimum of three porous baffles to evenly distribute flow across the basin and reduce turbulence.
- Inlets—Area between the sediment inlets and the basin should be stabilized by geotextile material, with or without rocks (Figure 6.64c shows the area with rocks). The inlet to basin should be located the greatest distance possible 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.



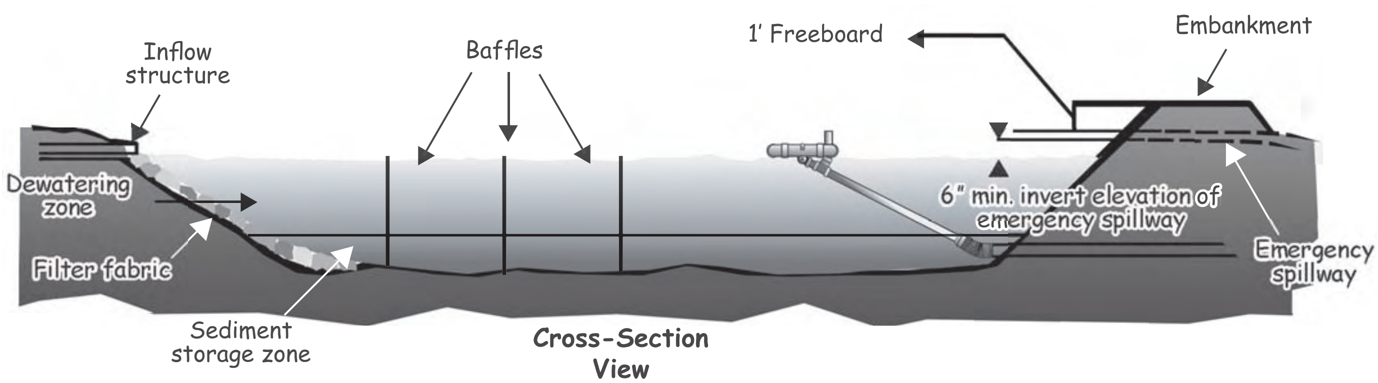


Figure 6.64c Example of a sediment basin with a skimmer outlet and emergency spillway. From Pennsylvania Erosion and Sediment Pollution Control Manual, March, 2000.

Construction Specifications

1. Clear, grub, and strip the area under the embankment of all vegetation and root mat. Remove all surface soil containing high amounts of organic matter and stockpile or dispose of it properly. Haul all objectionable material to the designated disposal area. Place temporary sediment control measures below basin as needed

2. Ensure that fill material for the embankment is free of roots, woody vegetation, organic matter, and other objectionable material. Place the fill in lifts not to exceed 9 inches, and machine compact it. Over fill the embankment 6 inches to allow for settlement.

3. Shape the basin to the specified dimensions. Prevent the skimming device from settling into the mud by excavating a shallow pit under the skimmer or providing a low support under the skimmer of stone or timber.

4. Place the barrel (typically 4-inch Schedule 40 PVC pipe) 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. 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 the 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. In no case should the pipe conduit be installed by cutting a trench through the dam after the embankment is complete.

5. Assemble the skimmer following the manufacturers instructions, or as designed.

6. Lay the assembled skimmer on the bottom of the basin with the flexible joint at the inlet of the barrel pipe. Attach the flexible joint to the barrel pipe and position the skimmer over the excavated pit or support. Be sure to attach a rope to the skimmer and anchor it to the side of the basin. This will be used to pull the skimmer to the side for maintenance.

7. Earthen spillways—Install the spillway in undisturbed soil to the greatest extent possible. The achievement of planned elevations, grade, design width, and entrance and exit channel slopes are critical to the successful operation of the spillway. The spillway should be lined with laminated plastic or impermeable geotextile fabric. The fabric must be wide and long enough to cover the bottom and sides and extend onto the top of the dam for anchoring in a trench. The edges may be secured with 8-inch staples or pins. The fabric must be long enough to extend down the slope and exit onto stable ground. The width of the fabric must be one piece, not joined or spliced; otherwise water can get under the fabric. If the length of the fabric is insufficient for the entire length of the spillway, multiple sections, spanning the complete width, may be used. The upper section(s) should overlap the lower section(s) so that water cannot flow under the fabric. Secure the upper edge and sides of the fabric in a trench with staples or pins. (Adapted from "A Manual for Designing, Installing and Maintaining Skimmer Sediment Basins." February, 1999. J. W. Faircloth & Son.).

8. Inlets—Discharge water into the basin in a manner to prevent erosion. Use temporary slope drains or 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*).

9. 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*).

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

11. 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 stabilize properly (References: *Surface Stabilization*).

Maintenance

Inspect skimmer sediment basins at least weekly and after each significant (one-half inch or greater) rainfall event and repair immediately. Remove sediment and restore the basin to its original dimensions when sediment accumulates to one-half the height of the first baffle. Pull the skimmer to one side so that the sediment underneath it can be excavated. Excavate the sediment from the entire basin, not just around the skimmer or the first cell. Make sure vegetation growing in the bottom of the basin does not hold down the skimmer.

Repair the baffles if they are damaged. Re-anchor the baffles if water is flowing underneath or around them.

If the skimmer is clogged with trash and there is water in the basin, usually jerking on the rope will make the skimmer bob up and down and dislodge the debris and restore flow. If this does not work, pull the skimmer over to the side of the basin and remove the debris. Also check the orifice inside the skimmer to see if it is clogged; if so remove the debris.

If the skimmer arm or barrel pipe is clogged, the orifice can be removed and the obstruction cleared with a plumber's snake or by flushing with water. Be sure and replace the orifice before repositioning the skimmer.

Check the fabric lined spillway for damage and make any required repairs with fabric that spans the full width of the spillway. 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 skimmer and pool areas.

Freezing weather can result in ice forming in the basin. Some special precautions should be taken in the winter to prevent the skimmer from plugging with ice.

Reference

Jarrett, A. R. Proper Sizing of the Control Orifice for the Faircloth Skimmer. Pennsylvania State University Department of Agricultural and Biological Engineering Fact Sheet #252. http://www.age.psu.edu/extension/factsheets/f/F252.pdf

Jarrett, A. R. Controlling the Dewatering of Sedimentation Basins. Pennsylvania State University Department of Agricultural and Biological Engineering Fact Sheet #253. http://www.age.psu.edu/extension/factsheets/f/F253.pdf

Erosion and Sediment Pollution Control Manual, March, 2000. Commonwealth of Pennsylvania Dept. of Environmental Protection, Office of Water Management, Document #363-2134-008. http://www.co.centre.pa.us/conservation/esmanual.pdf.

McLaughlin, Richard. SoilFacts: Dewatering Sediment Basins Using Surface Outlets. N. C. State University, Soil Science Department.

A Manual for Designing, Installing and Maintaining Skimmer Sediment Basins. February, 1999. J. W. Faircloth & Son.

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
6.41, Outlet Stabilization Structure

Sediment Traps and Barriers
6.65, Porous Baffles

Appendices
8.03, Estimating Runoff
8.07, Sediment Basin Design

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.

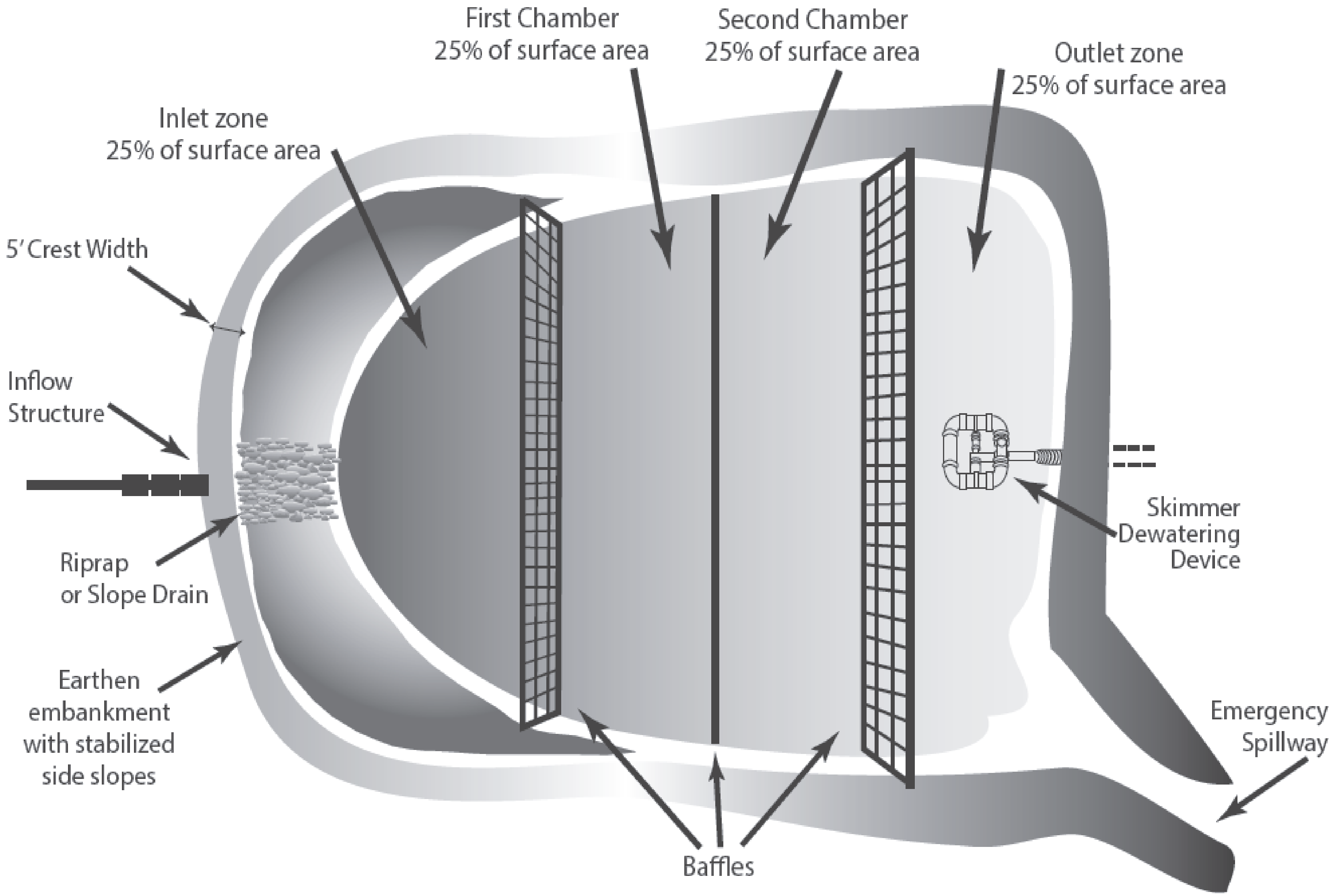
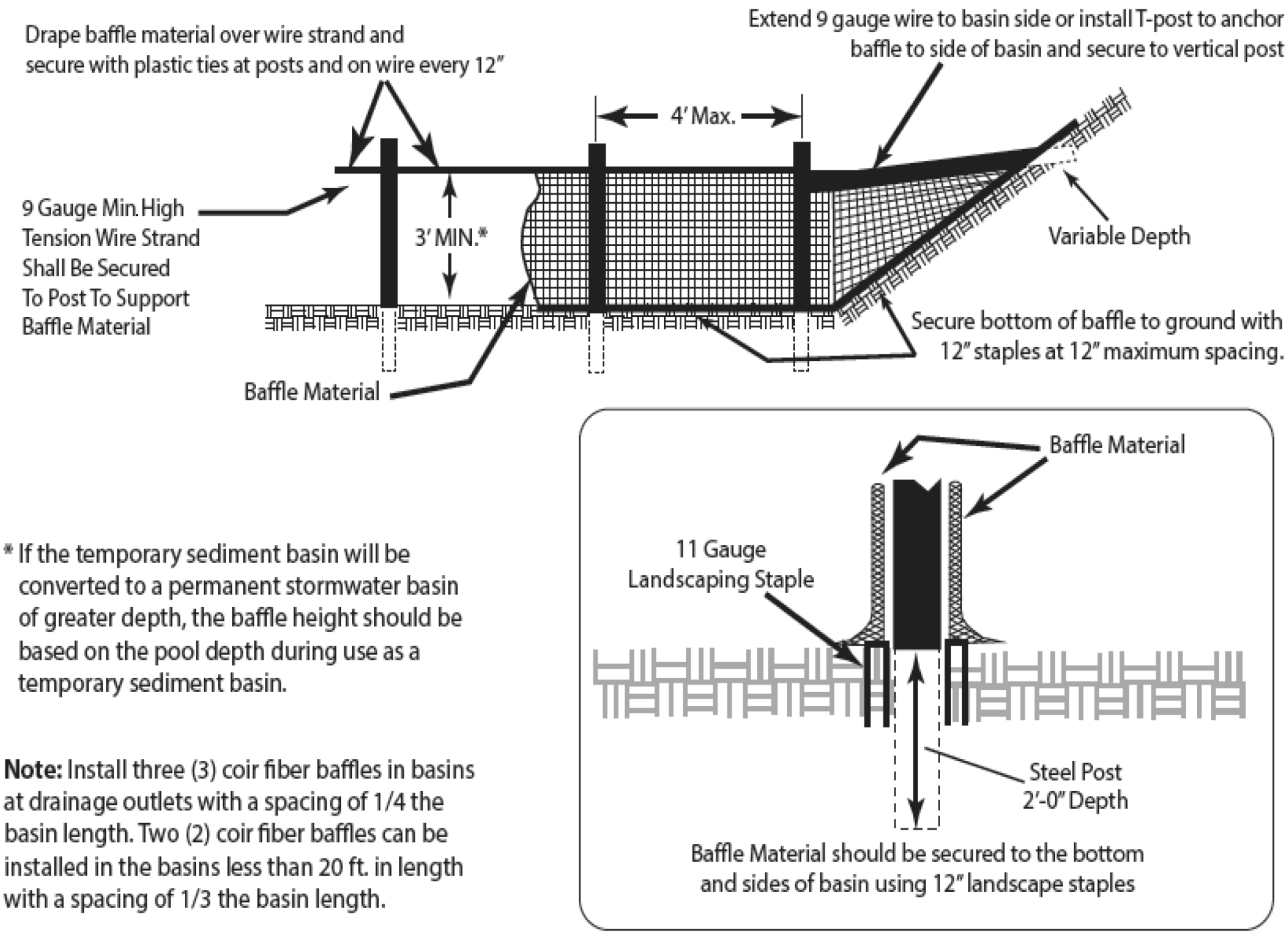


Figure 6.65a Porous baffles in a sediment basin. The flow is distributed evenly across the basin to reduce flow rates and turbulence, resulting in greater sediment retention.

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.

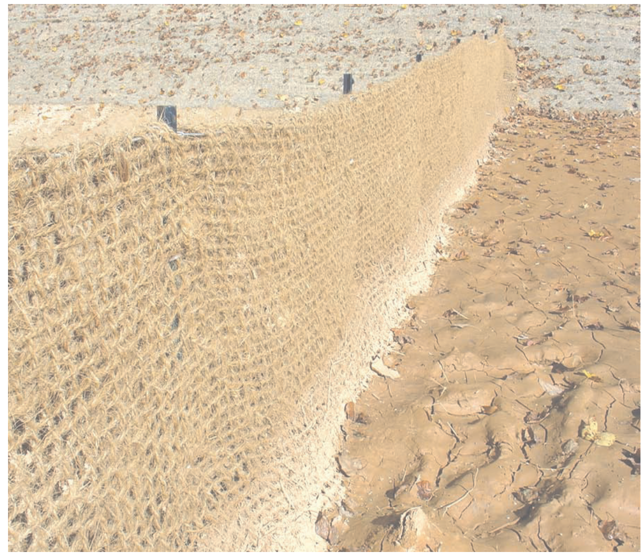


Figure 6.65d Close-up of a porous baffle.

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.

6.66 COMPOST SOCK

C SOCK

Definition

A compost sock is a three-dimensional tubular sediment control and storm water runoff device typically used for perimeter control of sediment and soluble pollutants (such as phosphorous and petroleum hydrocarbon), on and around construction activities. Compost socks trap sediment and other pollutants in runoff water as it passes through the matrix of the sock and by allowing water to temporarily pond behind the sock, allowing deposition of suspended solids. Compost socks are also used to reduce runoff flow velocities on sloped surfaces.

Compost products acceptable for this application should meet the chemical, physical and biological properties specified for Practice 6.18, *Compost Blankets.*

Figure 6.66a – Compost Sock
Photo Credit – Filtrexx International

Conditions Where Practice Applies

Compost socks are to be installed down slope of disturbed areas requiring erosion and sediment control. Compost socks are effective when installed perpendicular to sheet flow, in areas where sediment accumulation of less than six inches is anticipated. Acceptable applications include (Fifield, 2001):

- Site perimeters
- Below disturbed areas subject to sheet runoff, with minor sheet or rill erosion. Compost socks should not be used alone below graded slopes greater than 10 feet in height.
- Above graded slopes to serve as a diversion berm.

- Check dams
- Along the toe of stream and channel banks
- Around area drains or inlets located in a storm drain system
- Around sensitive trees where trenching of silt fence is not beneficial for tree survival or may unnecessarily disturb established vegetation.
- On paved surfaces where trenching of silt fence is impossible.

A compost sock can be applied to areas of sheet runoff, on slopes up to a 2:1 grade with a maximum height of 10 feet, around inlets, and in other disturbed areas of construction sites requiring sediment control. Compost socks may also be used in sensitive environmental areas, or where trenching may damage roots.

The weight of a filled sock (40 lbs / linear ft. for 8" diameter) effectively prevents sediment migration beneath the sock. It is possible to drive over a compost sock during construction (although not recommended); however, these areas should be immediately repaired by manually moving the sock back into place, if disturbed. Continued heavy construction traffic may destroy the fabric mesh, reduce the dimensions, and reduce the effectiveness of the compost sock. Vegetating the compost sock should be considered.

Planning Considerations

Compost socks shall either be made on site or delivered to the jobsite assembled. The sock shall be produced from a 5 mil thick continuous HDPE or polypropylene, woven into a tubular mesh netting material, with openings in the knitted mesh of ⅛" - ⅜" (3-10mm). This shall then be filled with compost meeting the specifications outlined in Practice 6.18*, Compost Blankets,* with the exception of particle size, to the diameter of the sock. Compost sock netting materials are also available in biodegradable plastics for areas where removal and disposal are not desired (i.e., when using pre-seeded socks). Compost socks contain the compost, maintaining its density and shape.

Compost socks should be installed parallel to the base of the slope or other affected area, perpendicular to sheet flow. The sock should be installed a minimum of 10 feet beyond the top of graded slopes. When runoff flows onto the disturbed area from a land above the work zone, a second sock may be constructed at the top of the slope in order to dissipate flows.

On locations where greater than a 200-foot long section of ground is to be treated with a compost sock, the sock lengths should be sleeved. After one sock section (200 feet) is filled and tied off (knotted) or zip tied, the second sock section shall be pulled over the first 1-2 feet and 'sleeved' creating an overlap. Once overlapped, the second section is filled with compost starting at the sleeved area to create a seamless appearance. The socks may be staked at the overlapped area (where the sleeve is) to keep the sections together. Sleeving at the joints is necessary because it reduces the opportunity for water to penetrate the joints when installed in the field.

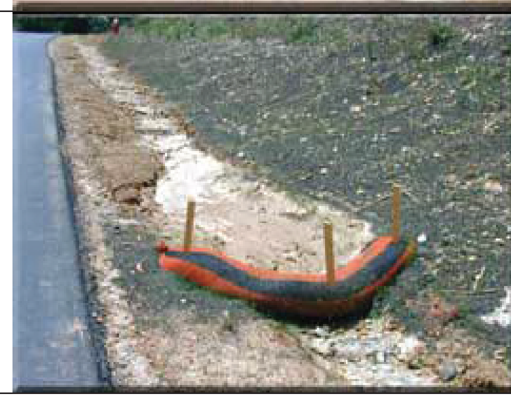
Compost Sock BMP	Conventional Application	Product Description	Example
Silt Socks	Silt Fence (on smaller areas)	A 3-dimensional sediment control measure used for sediment removal	
Inlet Socks	Inlet Protection	Designed to allow stormwater to enter inlets while removing sediment and protecting inlets from clogging	
Ditch Check	Rock Check Dams	Contours to ditch shape and eliminates gullies	

Table 6.66a Compost Sock BMPs as Replacements for Current Erosion Control Practices
Photo credits: Filtrexx International

After filling, the compost sock must be staked in place. Oak or other durable hardwood stakes 2”x 2” in cross section should be driven vertically plumb, through the center of the compost sock. Stakes should be placed at a maximum interval of 4 feet, or a maximum interval of 8 feet if the sock is placed in a 4 inch trench. See Figure 6.66b. The stakes should be driven to a minimum depth of 12 inches, with a minimum of 3 inches protruding above the compost sock.

If the compost sock is to be left as part of the natural landscape, it may be seeded at time of installation for establishment of permanent vegetation using the seeding specification in the erosion and sedimentation control plan. A maximum life of 2 years for photodegradable netting and 6 months for biodegradable netting should be used for planning purposes.

Compost socks may be used as check dams in ditches not exceeding 3 feet in depth. Normally, 8 to 12 inch diameter socks should be used. Be sure to stake the sock perpendicular to the slope of the ditch. When used as check dams, installation should be similar to that of natural fiber wattles. The ends and middle of the sock should be staked, and additional stakes placed at a 2-foot maximum interval. See Table 6.66b for spacing.

Design Criteria

The sediment and pollutant removal process characteristic to a compost sock allows deposition of settling solids. Ponding occurs when water flowing to the sock accumulates faster than the hydraulic flow through rate of the sock. Typically, initial hydraulic flow-through rates for a compost sock are 50% greater than geotextile fabric (silt fence). However, installation and maintenance is especially important for proper function and performance. Design consideration should be given to the duration of the project, total area of disturbance, rainfall/runoff potential, soil erosion potential, and sediment loading when specifying a compost sock.

Runoff Flow:

The depth of runoff ponded above the compost sock should not exceed the height of the compost sock. If overflow of the device is a possibility, a larger diameter sock should be constructed, other sediment control devices may be used, or management practices to reduce runoff should be installed. Alternatively, a second sock may be constructed or used in combination with Practice 6.17, *Rolled Erosion Control Products* or Practice 6.18, *Compost Blankets* to slow runoff and reduce erosion.

Level Contour:

The compost sock should be placed on level contours to assist in dissipating low concentrated flow into sheet flow and reducing runoff flow velocity. Do not construct compost socks to concentrate runoff or channel water. Sheet flow of water should be perpendicular to the sock at impact and un-concentrated. Placing compost socks on undisturbed soil will reduce the potential for undermining by concentrated runoff flows.

Runoff and Sediment Accumulation:

The compost sock should be placed at a 10 foot minimum distance away from the toe of the slope to allow for proper runoff accumulation for sediment deposition and to allow for maximum sediment storage capacity behind the device. On flat areas, the sock should be placed at the edge of the land-disturbance.

End Around Flow:

In order to prevent water flowing around the ends of the compost sock, the ends of the sock must be constructed pointing upslope so the ends are at a higher elevation. A minimum of 10 linear feet at each end placed at a 30 degree angle is recommended.

Vegetated Compost Sock:

For permanent areas the compost sock can be directly seeded to allow vegetation established directly on the device. Vegetation on and around the compost sock will assist in slowing runoff velocity for increased deposition of pollutants. The option of adding vegetation should be shown on the erosion and sedimentation control plan. No additional soil amendments or fertilizer are required for vegetation establishment in the vegetated compost sock.

Slope Spacing & Drainage Area:

Maximum drainage area to and spacing between the compost socks is dependent on rainfall intensity and duration used for specific design/plan, slope steepness, and width of area draining to the sock.

A compost sock across the full length of the slope is normally used to ensure that stormwater does not break through at the intersection of socks placed end-to-end. Ends are jointed together by sleeving one sock end into the other. The diameter of the compost sock used will vary depending upon the steepness and length of the slope; example slopes and slope lengths used with different diameter compost socks are presented in Table 6.66b.

Table 6.66b - Compost Sock Spacing versus Channel Slope

Channel Slope (%)	Spacing Between Socks (feet)	
	8-inch Diameter Sock	12-inch Diameter Sock
1	67	100
2	33	50
3	22	33
4	17	25
5	13	20

Source: B. Faucette – 2010

Material:

The compost media shall be derived from well-decomposed organic matter source produced by controlled aerobic (biological) decomposition that has been sanitized through the generation of heat and stabilized to the point that it is appropriate for this particular application. Compost material shall be processed through proper thermophilic composting, meeting the US Environmental Protection Agency's definition for a 'Process to Further Reduce Pathogens' (PFRP), as defined at 40 CFR Part 503. The compost portion shall meet the chemical, physical and biological properties specified in Practice 6.18, *Compost Blankets* Table 6.18a, with the exception of particle size. Slightly more coarse compost is recommended for the socks, as follows:

<u>Particle Size Distribution</u>

Sieve Size	Percent Passing Selected Sieve Mesh Size, Dry Weight Basis
2"	99 % (3" Maximum Particle Size)
3/8"	30-50 %

See Practice 6.18, *Compost Blankets* for complete information on compost parameters and tests. Installer should provide documentation to support compliance of testing required in the compost specification.

This specification covers compost produced from various organic by-products, for use as an erosion and sediment control measure on sloped areas. The product's parameters will vary based on whether vegetation will be established on the treated slope. Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used in this application. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limit standards pertaining to the feedstocks (source materials) in which it are derived.

In regions subjected to higher rates of precipitation and/or greater rainfall intensity, larger compost socks should be used. In these particular regions, coarser compost products are preferred as the compost sock must allow for an improved water percolation rate. The designer should check the flow rate per foot of sock in order to ensure drainage rate of the compost sock being used is adequate. The required flow rates are outlined in Table 6.66c.

Table 6.66c – Compost Sock Initial Flow Rates

Compost Sock Design Diameter	**8 inch (200mm)**	**12 inch (300mm)**	**18 inch (450mm)**	**24 inch (600mm)**	**32 inch (800mm)**
Maximum Slope Length (<2%)	**600 ft (183m)**	**750 ft (229m)**	**1,000 ft (305m)**	**1,300 ft (396m)**	**1,650 ft (500m)**
Hydraulic Flow Through Rate	**7.5 gpm/ft (94 l/m/m)**	**11.3 gpm/ft (141 l/m/m)**	**15.0 gpm/ft (188 l/m/m)**	**22.5gpm/ft (281 l/m/m)**	**30.0 gpm/ft (374 l/m/m)**

Source: B. Faucette-2010

Construction Specifications

INSTALLATION

1. Materials used in the compost sock must meet the specifications outlined above and in Practice 6.18, Compost Blankets.

2. Compost socks should be located as shown on the erosion and sedimentation control plan.

3. Prior to installation, clear all obstructions including rocks, clods, and other debris greater than one inch that may interfere with proper function of the compost sock.

4. Compost socks should be installed parallel to the toe of a graded slope, a minimum of 10 feet beyond the toe of the slope. Socks located below flat areas should be located at the edge of the land-disturbance. The ends of the socks should be turned slightly up slope to prevent runoff from going around the end of the socks.

5. Fill sock netting uniformly with compost to the desired length such that logs do not deform.

6. Oak or other durable hardwood stakes 2" X 2" in cross section should be driven vertically plumb, through the center of the compost sock. Stakes should be placed at a maximum interval of 4 feet, or a maximum interval of 8 feet if the sock is placed in a 4 inch trench. See Figure 6.66b. The stakes

should be driven to a minimum depth of 12 inches, with a minimum of 3 inches protruding above the compost sock.

7. In the event staking is not possible (i.e., when socks are used on pavement) heavy concrete blocks shall be used behind the sock to hold it in place during runoff events.

8. If the compost sock is to be left as part of the natural landscape, it may be seeded at time of installation for establishment of permanent vegetation using the seeding specification in the erosion and sedimentation control plan.

9. Compost socks are not to be used in perennial or intermittent streams.

Maintenance

Inspect compost socks weekly and after each significant rainfall event (1/2 inch or greater). Remove accumulated sediment and any debris. The compost sock must be replaced if clogged or torn. If ponding becomes excessive, the sock may need to be replaced with a larger diameter or a different measure. The sock needs to be reinstalled if undermined or dislodged. The compost sock shall be inspected until land disturbance is complete and the area above the measure has been permanently stabilized.

DISPOSAL/RECYCLING

Compost media is a composted organic product recycled and manufactured from locally generated organic, natural, and biologically based materials. Once all soil has been stabilized and construction activity has been completed, the compost media may be dispersed with a loader, rake, bulldozer or similar device and may be incorporated into the soil as an amendment or left on the soil surface to aid in permanent seeding or landscaping. Leaving the compost media on site reduces removal and disposal costs compared to other sediment control devices. The mesh netting material will be extracted from the media and disposed of properly. The photodegradable mesh netting material will degrade in 2 to 5 years if left on site. Biodegradable mesh netting material is available and does not need to be extracted and disposed of, as it will completely decompose in approximately 6 to 12 months. Using biodegradable compost socks completely eliminates the need and cost of removal and disposal.

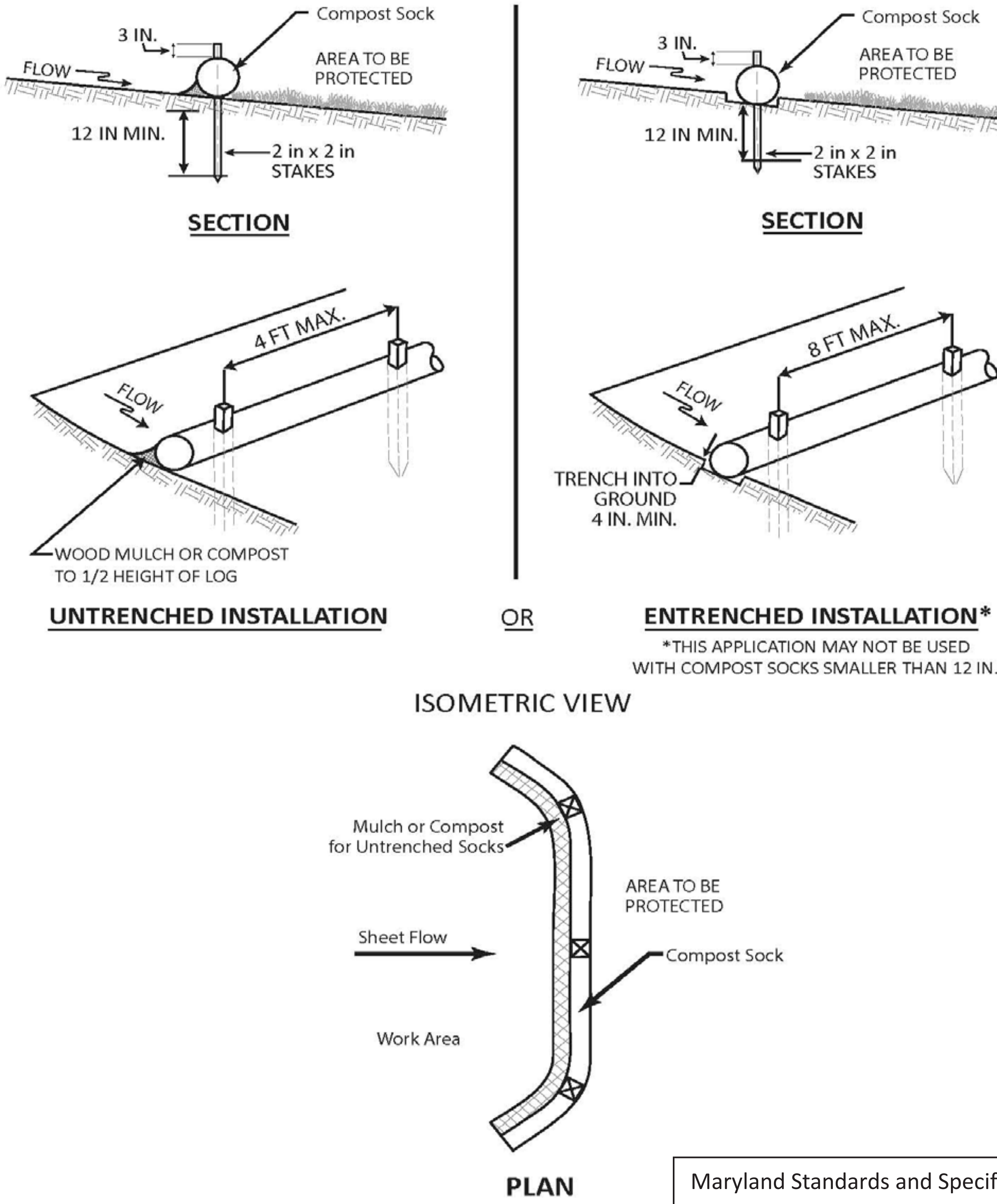


Figure 6.66b Compost Sock Installation

Maryland Standards and Specifications for Soil Erosion and Sediment Control, 2011, Maryland Department of Environment, Water Management Administration

References

Chapter 3 Vegetative Considerations
Chapter 6 Practice Standard and Site Specifications
6.10, Temporary Seeding
6.11, Permanent Seeding
6.17, Rolled Erosion Control Products
6.18, Compost Blankets

Tyler, R., A. Marks, B. Faucette. 2010. The Sustainable Site: Design Manual for Green Infrastructure and Low Impact Development Forester Press, Santa Barbara, CA.

Fifield, J. 2001. Designing for Effective Sediment and Erosion Control on Construction Sites. Forester Press, Santa Barbara, CA.

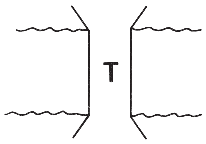
Maryland Department of Environment, Water Management Administration, 2011, *Maryland Standards and Specifications for Soil Erosion and Sediment Control*, Filter Log

6

INDEX

STREAM PROTECTION

6.70



TEMPORARY STREAM CROSSING

Definition

A bridge, ford or temporary structure installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment.

Purpose

To provide a means for construction vehicles to cross streams or watercourses without moving sediment into streams, damaging the streambed or channel, or causing flooding.

Conditions Where Practice Applies

Where heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles must cross the stream channel frequently for a short period of time.

Planning Considerations

Careful planning can minimize the need for stream crossings. Try to avoid crossing streams. Whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream. Temporary stream crossings can be a direct source of water pollution; they may create flooding and safety hazards; they can be expensive to construct; and they can cause costly construction delays if washed out.

Both fords and culverts may involve placing fill in an intermittent or periennial stream or wetland. The need for permits from the U.S. Army Corps of Engineers or the N. C. Division of Water Quality should be determined when planning the project.

Select locations for stream crossings where erosion potential is low. Evaluate stream channel conditions, overflow areas, and surface runoff control at the site before choosing the type of crossing. When practical, locate and design temporary stream crossings to serve as permanent crossings to keep stream disturbance to a minimum.

Plan stream crossings in advance of need and, when possible, construct them during dry periods to minimize stream disturbance and reduce cost. Ensure that all necessary materials and equipment are on-site before any work is begun. Complete construction in an expedient manner, and stabilize the area immediately.

Often stream crossings are provided in conjunction with operations in a natural watercourse. Land disturbing activity in connection with construction in, on, over, or under a lake or natural watercourse shall minimize the extent and duration of disruption of the stream channel. Where relocation of a stream forms an essential part of the proposed activity, the relocation shall minimize unnecessary changes in the stream flow characteristics. Pumping or diverting stream flow around a work area is often the best way to minimize the disruption of the stream channel. Any diversions should be stabilized with adequate geotextile fabric or stone.

After the bypass is completed and stable, the stream may be diverted (Practice 6.15, Riprap). Small stream flows may be diverted around work areas with a coffer dam and pump instead of construction of a bypass channel.

Unlike permanent stream crossings, temporary stream crossings may be allowed to overtop during peak storm periods. However, the structure and approaches should remain stable. Keep any fill needed in flood plains to a minimum to prevent upstream flooding and reduce erosion potential. Use riprap to protect locations subject to erosion from overflow.

If permanent utility crossings are planned, stream crossings may be located at these locations to minimize stream impacts.

Stream crossings are of the three general types: bridges, culverts, and fords. Consider which method best suits the specific site conditions.

Bridges—Where available materials and designs are adequate to bear the expected loadings, bridges are preferred for temporary stream crossing.

Bridges usually cause the least disturbance to the stream bed, banks, and surrounding area. They provide the least obstruction to flow and fish migration. They generally require little maintenance, can be designed to fit most site conditions, and can be easily removed and materials salvaged. However, bridges are generally the most expensive to design and construct. Further, they may offer the greatest safety hazard if not adequately designed, installed, and maintained, and if washed out, they cause a longer construction delay and are more costly to repair.

In steep watersheds it is recommended to tie a cable or chain to one corner of the bridge frame with the other end secured to a large tree or other substantial object. This will prevent flood flows from carrying the bridge downstream where it may cause damage to other property.

Culvert crossings—Culverts are the most common stream crossings. In many cases, they are the least costly to install, can safely support heavy loads, and are adaptable to most site conditions. Construction materials are readily available and can be salvaged. However, the installation and removal of culverts causes considerable disturbance to the stream and surrounding area. Culverts also offer the greatest obstruction to flood flows and are subject, therefore, to blockage and washout. Clean stone should be used for back fill around culverts

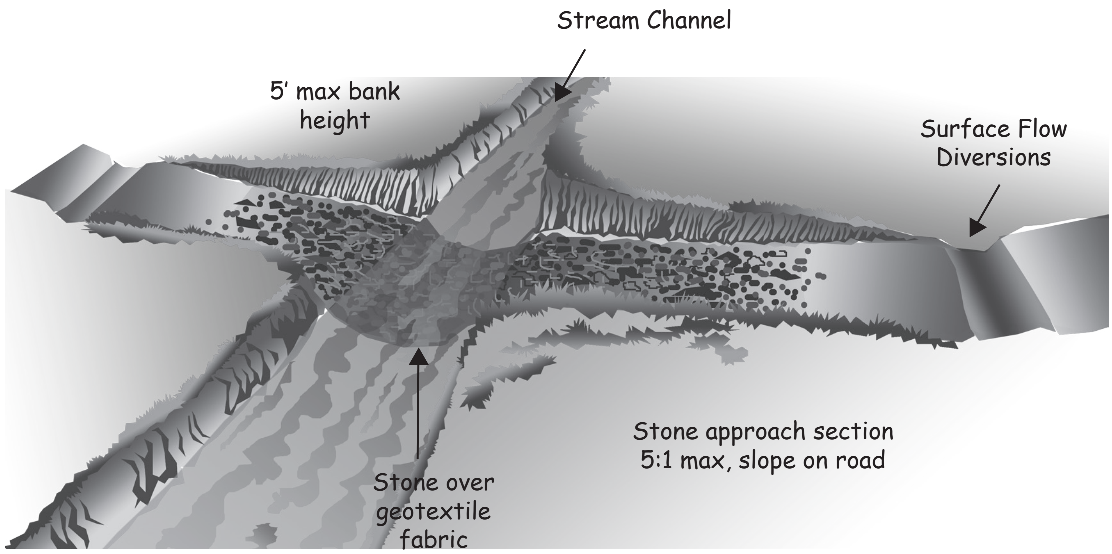
Culverts should be used when vehicles will make repeated trips across the stream during construction, or track mud into the stream.

Fords—Fords, made of stabilization material such as rock, are often used in steep areas subject to flash flooding, where normal flow is shallow (less than 3 inches deep) or intermittent. Fords should only be used where crossings are infrequent. Fords are especially adapted for crossing wide, shallow watercourses (Figure 6.70a).

When properly installed, fords offer little or no obstruction to flow, can safely handle heavy loadings, are relatively easy to install and maintain, and in most cases, may be left in place at the end of the construction.

Problems associated with fords include the following:

1. Approach sections are subject to erosion. Generally, do not use fords where the bank height exceeds 5 feet.
2. Excavation for the installation of the riprap-gravel bottom and filter material causes major stream disturbance. In some cases, fords may be adequately constructed by shallow filling without excavation.
3. The stabilizing material is subject to washing out during storm flows and may require replacement.
4. Mud and other contaminants are brought directly into the stream on vehicles unless crossings are limited to no flow conditions.



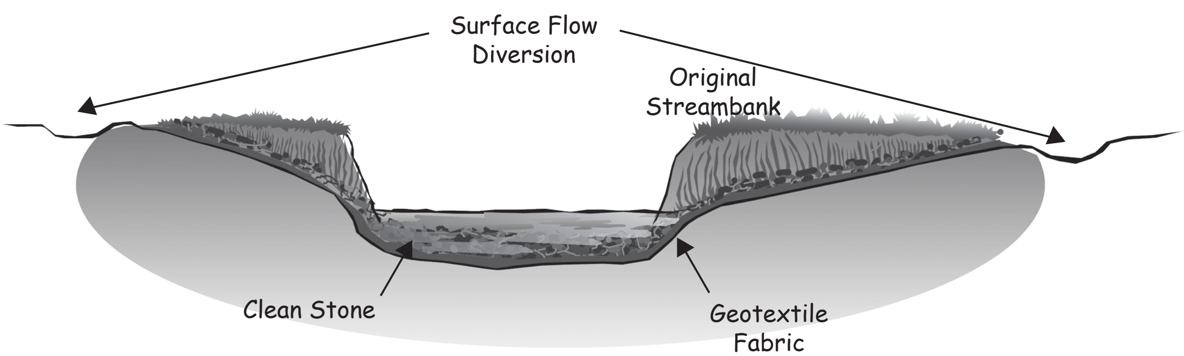


Figure 6.70a A well constructed ford offers little obstruction to flow while safely handling heavy loading.

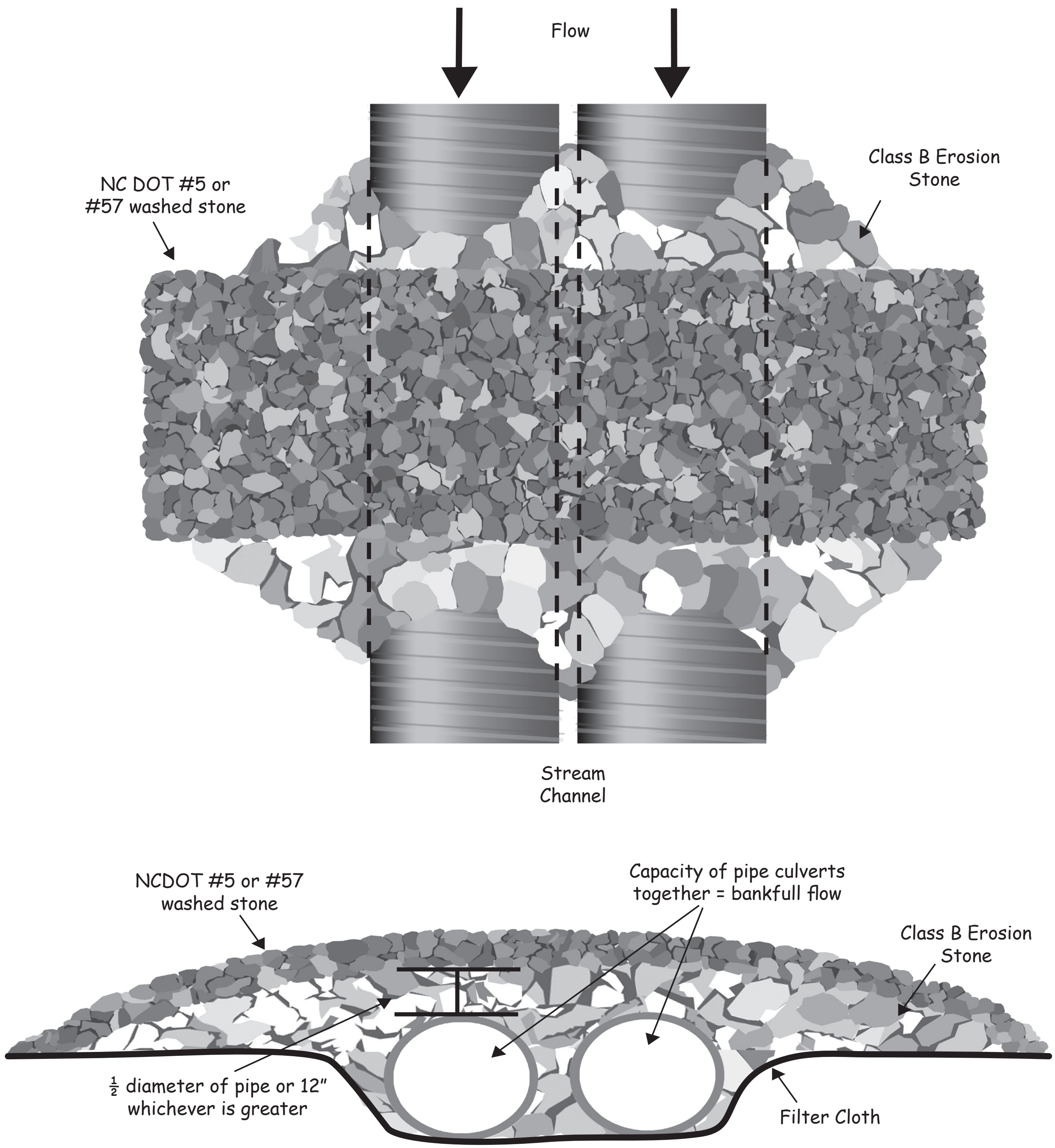


Figure 6.70b Temporary culvert backfilled with stone.

Permitting requirements from the U.S. Army Corps of Engineers and the NC Division of Water Quality should be determined for stream crossings. Permit conditions may require that pipes be buried below stream bottom elevation.

Small stream flows may be diverted around work areas with a cofferdam and pump instead of construction of a bypass channel.

If permanent utility crossings are planned, stream crossings may be located at these locations to minimize stream impacts.

Design Criteria

In addition to erosion and sedimentation control, structural stability, utility, and safety must also be taken into consideration when designing temporary stream crossings. Bridge designs, in particular, should be undertaken by a qualified engineer.

- The anticipated life of a temporary stream crossing structure is usually considered to be 1 year or less. Remove the structure immediately after it is no longer needed.
- As a minimum, design the structure to pass bankfull flow or peak flow, whichever is less, from a 2-year peak storm, without over topping. Ensure that no erosion will result from the 10-year peak storm.
- Ensure that design flow velocity at the outlet of the crossing structure is non-erosive for the receiving stream channel (References: Outlet Protection).
- Consider overflow for storms larger than the design storm, and provide a protected overflow area.
- Design erosion control practices associated with the stream crossing to control erosion from surface runoff at the crossing and during a 10-year peak storm runoff.

Construction Specifications

1. Keep clearing and excavation of the stream banks and bed and approach sections to a minimum.

2. Divert all surface water from the construction site onto undisturbed areas adjoining the stream.

3. Keep stream crossings at right angles to the stream flow.

4. Align road approaches with the center line of the crossing for a minimum distance of 30 feet. Raise bridge abutments and culvert fills a minimum of 1 foot above the adjoining approach sections to prevent erosion from surface runoff and to allow flood flows to pass around the structure.

5. Stabilize all disturbed areas subject to flowing water, including planned overflow areas, with riprap or other suitable means if design velocity exceeds the allowable for the in-place soil (Table 8.05a, *Appendix 8.05*).

6. Ensure that bypass channels necessary to dewater the crossing site are stable before diverting the stream. Upon completion of the crossing, fill, compact, and stabilize the bypass channel appropriately.

7. Remove temporary stream crossings immediately when they are no longer needed. Restore the stream channel to its original cross-section, and smooth and appropriately stabilize all disturbed areas.

8. Any in-stream sediment control measures must be removed upon stabilization of the area.

Maintenance

Inspect temporary stream crossings after runoff-producing rains to check for blockage in channel, erosion of abutments, channel scour, riprap displacement, or piping. Make all repairs immediately to prevent further damage to the installation.

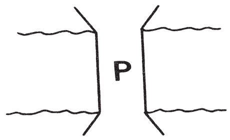
References

Surface Stabilization
6.15, Riprap

Outlet Protection
6.41, Outlet Stabilization Structure

Appendices
8.05, Design of Stable Channels and Diversions

6.71



PERMANENT STREAM CROSSING

Definition A structure installed across a stream or watercourse.

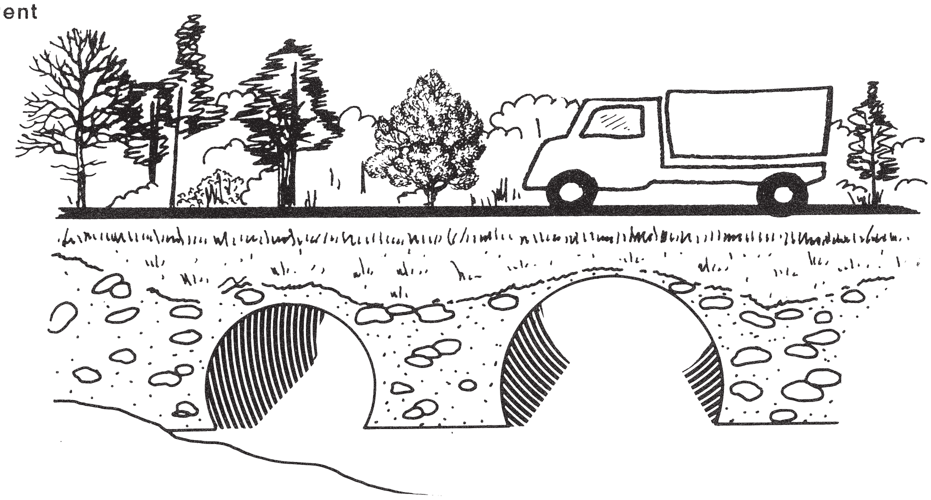
Purpose To provide a suitable means for construction and post-construction traffic to cross a watercourse.

Planning Considerations Planning considerations for permanent stream crossings are essentially the same as for temporary stream crossings except the permanent stream crossings should not be subject to overflow.

Permanent stream crossing locations are selected primarily on flooding potential, traffic safety, and traffic patterns of the area served, but erosion and sediment control must also be considered. To minimize flooding and erosion problems, locate permanent stream crossings in the higher, better drained sections of the stream reach whenever practical.

Where road water enters the stream, install permanent protection measures, such as paved flumes, concrete head walls, riprap outlet structures, or stabilized pipe drops, to prevent erosion (Figure 6.71a). During installation of the crossing, locate sedimentation control measures to protect the stream. Protect the stream section at the crossing from erosion from flood flow velocities by using paving or properly designed riprap (*References: Outlet Protection*).

Figure 6.71a Permanent stream crossing with culverts designed to prevent overtopping.



Design Criteria

Design permanent stream crossings in accordance with N.C. Department of Transportation standards and specifications, considering maximum loadings anticipated, safety, flow capacities, and other requirements for DOT installation approval. The local DOT can provide necessary guidance.

Minimum design criteria for erosion control are:

- Ensure that the 10-year peak flow velocity at the stream crossing outlet is nonerosive to the receiving stream.
- Ensure that all permanent erosion control practices provide adequate protection for the 10-year peak storm runoff.

Construction Specifications

1. Keep clearing and excavation of the stream banks and bed, and approach sections to a minimum.

2. Divert all surface water from the construction site onto undisturbed areas adjoining the stream. Line unstable stream banks with riprap, or otherwise appropriately stabilize them.

3. Keep stream crossing at right angles to the stream flow. This is particularly important when culverts are used.

4. Align road approaches with the center line of the crossing for a minimum distance of 30 feet. Raise bridge abutments and culvert fills a minimum of 1 foot above the adjoining approach sections to prevent erosion from surface runoff and to allow flood flows to pass around the structure.

5. Ensure that bypass channels, necessary to dewater the crossing site, are stable before diverting the stream. Upon completion of the crossing, fill, compact, and stabilize the bypass channel appropriately.

6. Install protective ground covers to provide permanent erosion protection and improve visual quality, but not interfere with driver line of sight from the roadway.

7. Ensure that permanent measures needed to control erosion from road water runoff (such as riprap and paved channels, paved flumes, or riprap outlet protection) meet all construction requirements for those practices.

Maintenance

Inspect permanent stream crossings periodically and after major storms to check for channel blockage, erosion of abutments, channel degradation, riprap displacement, slope failure, and piping. Make all needed repairs immediately to prevent further damage to the installation.

References

Surface Stabilization
6.11, Permanent Seeding
6.13, Trees, Shrubs, Vines, and Ground Covers
6.15, Riprap

Runoff Control Measures
6.21, Permanent Diversions

Runoff Conveyance Measures
6.31, Riprap-lined Channels
6.33, Paved Flume

Outlet Protection
6.41, Outlet Stabilization Structure

6.72

VEGETATIVE STREAMBANK STABILIZATION

This practice standard has been adapted from the Natural Resource Conservation Service *National Engineering Handbook, Part 654, Technical Supplement 14I, Streambank Soil Bioengineering.* At publication this document was not listed online with older NRCS publications, but was available through NRCS eDirectives at http://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

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 cannot be approved 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 streambanks, wetlands and riparian buffers to comply with permitting requirements of other agencies, as well as provide adequate ground cover.

Stabilizing streambanks with natural vegetation has many advantages over hard armor linings. Compared to streams without vegetated banks, streams with well-stabilized vegetation on their banks have better water quality and fish and wildlife habitats. Vegetation is an extremely important component of biological and chemical health, as well as the stability of the system. Streambank soil bioengineering is defined as the use of live and dead plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment (Allen and Leech 1997). Streambank soil bioengineering uses plants as primary structural components to stabilize and reduce erosion on streambanks, rather than just for aesthetics. As a result of increased public appreciation of the environment, many Federal, state, and local governments, as well as grass roots organizations, are actively engaged in implementing soil bioengineering treatments to stabilize streambanks.

Riparian planting zones

Success of streambank soil bioengineering treatments depends on the initial establishment and long-term development of riparian plant species. It is important to note the location and types of existing vegetation in and adjacent to the project area. The elevation and lateral relationships to the stream can be described in terms of riparian planting zones. Proposed streambank soil bioengineering techniques should also be assessed and designed in terms of the location of the plants relative to the stream and water table. These riparian planting zones can be used to determine where riparian species should be planted in relation to the waterline during different periods of flow. Figure 6.72a illustrates an idealized depiction of riparian planting zones.

Toe zone—This zone is located below the average water elevation or baseflow. The cross-sectional area at this discharge often defines the limiting biologic condition for aquatic organisms. Typically, this is the zone of highest stress. It is vitally important to the success of any stabilization project that the toe is stabilized. Due to long inundation periods, this zone will rarely have any woody vegetation. Often riprap or another type of inert protection is required to stabilize this zone.

Bank zone—The bank zone is located between the average water elevation and the bankfull discharge elevation. While it is generally in a less erosive environment than the toe zone, it is potentially exposed to wet and dry cycles, ice scour, debris deposition, and freeze-thaw cycles. The bank zone is generally vegetated with early colonizing herbaceous species and flexible stemmed woody plants such as willow, dogwood, elderberry, and low shrubs. Sediment transport typically becomes an issue for flows in this zone, especially for alluvial channels.

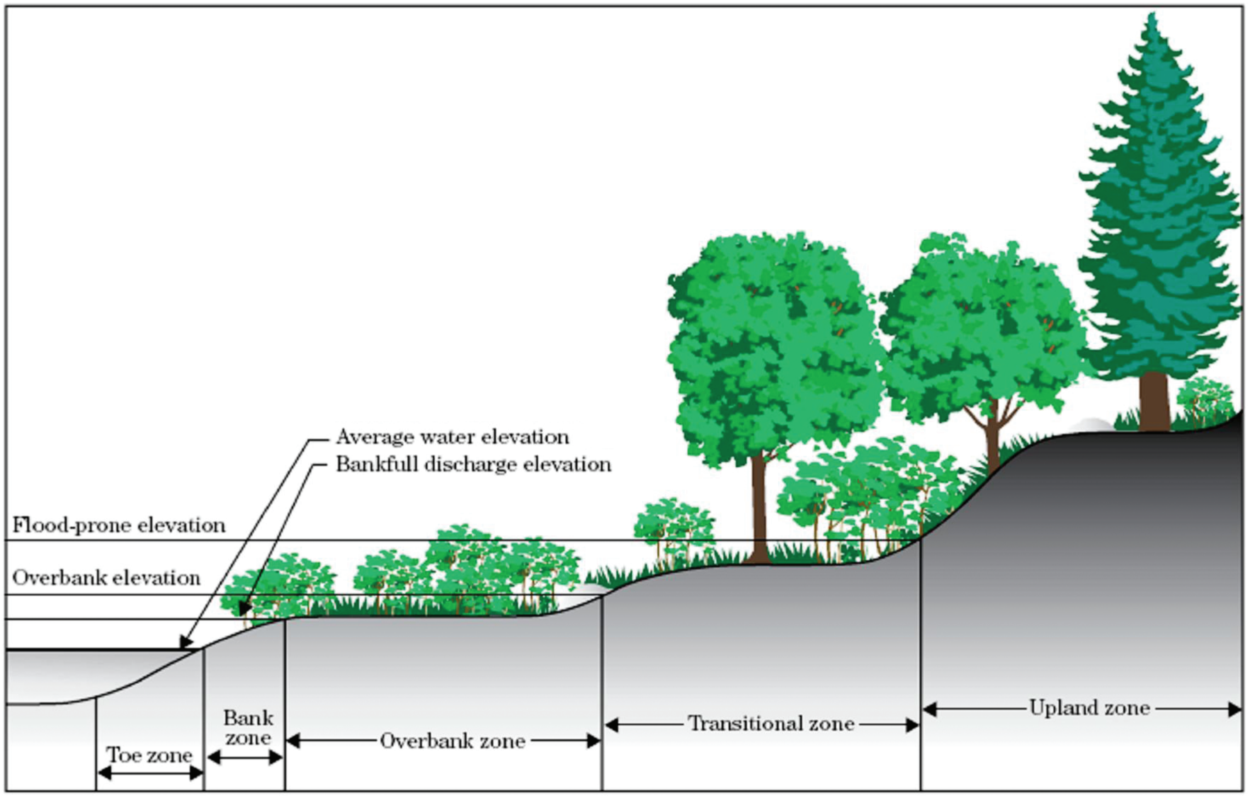
Bankfull channel elevation—Bankfull stage is typically defined at a point where the width-to-depth ratio is at a minimum. Practitioners use other consistent morphological indices to aid in its identification. Often, the flow at the bankfull stage has a recurrence interval of 1.5 years. Due to the high velocities and frequent inundation, some high risk streambank soil bioengineering projects frequently incorporate hard structural elements, such as rock, below this elevation. Where there is a low tolerance for movement, many projects rely on inert or hard elements in this zone. Bankfull flow is often considered to be synonymous with channel-forming discharge in stable channels and is used in some channel classification systems, as well as for an initial determination of main channel dimensions, plan, and profile. In many situations, the channel velocity begins to approach a maximum at bankfull stage. In some cases, on wide, flat flood plains, channel velocity can drop as the stream overtops its bank and the flow spills onto the flood plain. In this situation, it may be appropriate to use the bankfull hydraulic conditions to assess stability and select and design streambank protection. However, when the flood plain is narrower or obstructed, channel velocities may continue to increase with rising stage. As a result, it may also be appropriate to use a discharge greater than bankfull discharge to select and design streambank protection treatments.

Overbank zone—This zone is located above the bankfull discharge elevation. This typically flat zone may be formed from sediment deposition. It is sporadically flooded, usually about every 2 to 5 years. Vegetation found in this zone is generally flood tolerant and may have a high percentage of hydrophytic plants. Shrubby willow with flexible stems, dogwoods, alder, birch, and others may be found in this zone. Larger willows, cottonwoods, and other trees may be found in the upper end of this zone.

Transitional zone—The transitional zone is located between the overbank elevation and the flood-prone elevation. This zone may only be inundated every 50 years. Therefore, it is not exposed to high velocities except during high-water events. Larger upland species predominate in this zone. Since it is infrequently flooded, the plants in this zone need not be especially flood tolerant.

Upland zone—This zone is found above the floodprone elevation. Erosion in this zone is typically due to overland water flow, wind erosion, improper farming practices, logging, development, overgrazing, and urbanization. Under natural conditions the upland zone is typically vegetated with upland species.

Figure 6.72a



Plants for soil bioengineering

Consult local expertise and guidelines when selecting the appropriate plant material. Where possible, it is best to procure harvested cuttings from areas that are similar in their location, relative to the stream. Installation will be most successful where the soil, site, and species match a nearby stable site. Harvest three or more species from three to five different locations.

Woody plants

Adventitiously rooting woody riparian plant species are used in streambank soil bioengineering treatments because they have root primordia or root buds along the entire stem. When the stems are placed in contact with soil, they sprout roots. When the stem is in contact with the air, they sprout stems and leaves. This ability to root, independent of the orientation of a stem, is a reproductive strategy of riparian plants that has developed over time in response to flooding, high stream velocities, and streambank erosion. Many woody riparian plant species root easily from dormant live cuttings. They establish quickly and are fast-growing plants with extensive fibrous root systems. These plants are typically hardy pioneer species that can tolerate both inundation and drought conditions. The keystone species that meet these criteria are willows, cottonwoods, and shrub dogwoods. These traits allow their use in treatments such as fascines, brush mattress, brush layer, and pole cuttings. Typically, the most consistently successful rooting plants are the willow (*Salix* spp.). Data from projects nationwide indicate that shrub willows root successfully on average 40 to 100 percent of the time. Shrub dogwoods (*Cornus* spp.), on the other hand, are more variable in their rooting success, ranging from 10 to 90 percent, but more typically averaging in the 30 to 60 percent range. Rooting success of both willows and dogwoods can be affected by the timing of planting, age of the material used, handling and storage, installation procedures, and placement in the proper hydrologic regime on the streambank. Cottonwoods and poplars (*Populus* spp.) have also been used successfully in streambank soil bioengineering. However, typical riparian species such as birches (*Betula* spp.) and alders (*Alnus* spp.) do not root well from unrooted hardwood cuttings; therefore, they are not suitable for certain soil bioengineering techniques such as poles or live stakes. They are, however, useful as rooted plant stock for many soil bioengineering measures including hedgelayers, branch packing, cribwalls, vegetated reinforced soil slopes, and live siltation construction. Additionally, these and other species can be included in a riparian seed mix or installed as rooted plants as part of the stream and riparian restoration. In some cases, a pilot study will allow wise selection of some nonstandard plant materials by testing how effectively locally available genotypes are adapted to soil and hydrologic conditions on site.

Limiting velocity and shear criterion

The effects of the water current on the stability of any streambank protection treatment must be considered. This evaluation includes the full range of flow conditions that can be expected during the design life of the project. Two approaches that are commonly used to express the tolerances are allowable velocity and allowable shear stress.

Flow in a natural channel is governed in part by boundary roughness, gradient, channel shape, obstructions, and downstream water level. If the project represents a sizable investment, it may be appropriate to use a computer model such as the U.S. Army Corps of Engineers (USACE) HEC–RAS computer program to assess the hydraulic conditions. However, if a normal depth approximation is applicable, velocity can be estimated with Manning's equation. It is important to note that this estimate will be an average channel velocity. In some situations, the velocity along the outer bank curves may be considerably larger. The average shear stress exerted on a channel boundary can be estimated with the equation provided below, assuming the flow is steady, uniform, and two dimensional.

$\tau = \gamma R S_f$ where:

τ = average boundary shear (lb/ft2)
γ = specific weight of water (62.4 lb/ft3)
R = hydraulic radius (A/P, but can be approximated as depth in wide channels)
S_f = friction slope (can be approximated as bed slope)

The local maximum shear can be up to 50 percent greater than the average shear in straight channels and larger along the outer banks of sinuous channels. Temporal maximums may also be 10 to 20 percent larger, as well. Recommendations for limiting velocity and shear vary widely Table 6.72a. Not all techniques presented in this technical supplement are noted in this table. However, the designer can compare techniques with similar attributes to those listed in the table to estimate the limiting shear. The designer should proceed cautiously and not rely too heavily on these values. Judgment and experience should be weighed with the use of this information. The recommendations in Table 6.72a were empirically determined and, therefore, are most applicable to the conditions in which they were derived. The recommendations must be scrutinized and modified according to site-specific conditions such as duration of flow, soils, temperature, debris and ice load in the stream, plant species, as well as channel shape, slope and planform. Specific cautions are also noted in the table. However, there are anecdotal reports that mature and established practices can withstand larger forces than those indicated in Table 6.72a.

Table 6.72a Compiled permissible shear stress levels for streambank soil bioengineering practices

Practice	**Permissible shear stress (lb/ft2)***	**Permissible velocity (ft/s)***
Live poles (Depends on the length of the poles and nature of the soil)	Initial: 0.5 to 2 Established: 2 to 5+	Initial: 1 to 2.5 Established: 3 to 10
Live poles in woven coir TRM (Depends on installation and anchoring of coir)	Initial: 2 to 2.5 Established: 3 to 5+	Initial: 3 to 5 Established: 3 to 10
Live poles in riprap (joint planting) (Depends on riprap stability)	Initial: 3+ Established: 6 to 8+	Initial: 5 to 10+ Established: 12+
Live brush sills with rock (Depends on riprap stability)	Initial: 3+ Established: 6+	Initial: 5 to 10+ Established: 12+
Brush mattress (Depends on soil conditions and anchoring)	Initial: 0.4 to 4.2 Established: 2.8 to 8+	Initial: 3 to 4 Established: 10+
Live fascine (Very dependent on anchoring)	Initial: 1.2 to 3.1 Established: 1.4 to 3+	Initial: 5 to 8 Established: 8 to 10+
Brush layer/branch packing (Depends on soil conditions)	Initial: 0.2 to 1 Established: 2.9 to 6+	Initial: 2 to 4 Established: 10+
Live cribwall (Depends on nature of the fill (rock or earth), compaction and anchoring)	Initial: 2 to 4+ Established: 5 to 6+	Initial: 3 to 6 Established: 10 to 12
Vegetated reinforced soil slopes (VRSS) (Depends on soil conditions and anchoring)	Initial: 3 to 5 Established: 7+	Initial: 4 to 9 Established: 10+
Grass turf— excellent stand (Depends on vegetation type and condition)	Established: 3.2	Established: 3 to 8
Live brush wattle fence (Depends on soil conditions and depth of stakes)	Initial: 0.2 to 2 Established: 1.0 to 5+	Initial: 1 to 2.5 Established: 3 to 10
Vertical bundles (Depends on bank conditions, anchoring, and vegetation)	Initial: 1.2 to 3 Established: 1.4 to 3+	Initial: 5 to 8 Established: 6 to 10+

* (USDA NRCS 1996b; Hoag and Fripp 2002; Fischenich 2001; Gerstgrasser 1999; Nunnally and Sotir 1997; Gray and Sotir 1996; Schiechtl and
Stern 1994; USACE 1997; Florineth 1982; Schoklitsch 1937)

Streambank soil bioengineering
Techniques

Many types of streambank soil bioengineering treatments have been used throughout the country. A collection of techniques that are broadly applicable have been divided into sections that address the different bank zones. It is appropriate to modify these treatments to account for site-specific conditions, cost of materials, and material availability. Many variations of these techniques exist. Many of the techniques listed are often combined with other streambank soil bioengineering techniques or with harder, inert structures.

Toe treatments

Coir fascines

This is a manufactured product also known as coir logs or coconut fiber rolls. Coir fascines consist of coconut husk fibers bound together in a cylindrical bundle by natural or synthetic netting and are manufactured in a variety of standard lengths, diameters, and fill densities for different energy environments. Coir fascines are flexible and can be fitted to the existing curvature of a streambank. They provide immediate toe protection and bank stabilization, while trapping sediment within the coir fascine, which encourages plant growth. Coir fascines are well suited for establishing herbaceous materials, and they can be prevegetated prior to installation. A key advantage of this method is the modularization and standardization of the materials that result in relatively predictable and reliable performance. A disadvantage of coir fascines is that they are expensive to purchase and ship. They require additional anchoring systems, which increases the initial costs and installation time.

Figure 6.72b Coir log installation, NC Ecosystem Enhancement Program

Materials

• Fascines fabricated from and filled with 100 percent coir (coconut husk) are preferred for streambank stabilization work because they serve as a stable growing medium on which seeds and young plants can become established. This material provides some resistance to damage from ice flows, floating debris, and other impacts, and provides a reinforcing framework for vegetation until the coir filling decays, at which point the plants should be able to protect the banks.
• For most settings, high tensile strength (minimum 200 lb tensile strength) synthetic mesh is desirable for the knotted or braided mesh exterior of the coir fascine. Although coir mesh versions are available, the mesh frequently loses its strength before vegetation can become fully established, making the material vulnerable to failure. Therefore, coir mesh versions are typically used on sites with low stress levels.
• The most sturdy and resistant coir fascines are manufactured with a density of 9 pounds per cubic foot. Where ice, debris, steep banks, and other stress factors are not a problem, lower density materials may offer a more cost-effective alternative.

• The most commonly used size is 12-inch diameter, although they are available in both larger and smaller sizes.
• Coir fascines are typically anchored with wooden stakes or earth anchors with cable assemblies.

Installation

• Coir fascines may be installed during any season, provided that the ground can be worked adequately for placement and anchoring. Planting into the coir fascine may be planned for later in a more desirable season, as needed.
• Coir fascines can either be placed so that they help position the toe of a bank, where it was located prior to an erosion event, or in direct contact with the current bank profile. Typically, they are positioned so that the top of the coir fascine is located at the mean water level during the summer growing season. In most cases, this zone best supports herbaceous vegetation. Due to the distance from the plant to the soil, it is imperative that the coir fascine remain wet.
• Coir fascines are frequently planted with 2- inch-diameter plugs of herbaceous species which, preferably, have been rooted in a coir fiber matrix to provide good frictional contact.
• Coir fascines require protection against scouring and flanking that should be addressed in the design.
• The anchoring system must be adequate to seat the coir fascine securely in contact with the adjacent soil. Normally, this means a pair of stakes placed every 2 feet along the coir fascine, one on each side. In cold climates, earth anchors or rope tie-downs are necessary to prevent lifting of the coir fascine as ice forms. Always place wooden stakes between the cable or rope and the coir to keep the cable or rope from cutting clear through the coir fascine. Piercing a high-density coir fascine with stakes should be avoided. The stakes should be driven alongside the coir fascine. The coir fascine is secured by either tightly sandwiching the coir fascine between the stakes or by using ropes or cables to tie around the coir fascine.
• To form a continuous unit, coir fascines must be tied together end to end. This is most convenient to do while the coir fascines are still on dry land, laid out along the top of bank. Strong synthetic rope is used to stitch the ends together, with knots tied at frequent intervals to ensure a reliable connection.
• When coir fascines are stacked to provide coverage of a wider strip of bank, they must be placed together on the edges where they touch. One row of lacing is typically adequate to hold two tiers together, although two rows of lacing will result in a tighter contact between the tiers, which is useful at holding back concohesive soils. All tiers require appropriate staking or anchoring.
• After anchoring is complete, coir fascines may be planted . Either live cuttings may be inserted through the coir fascine itself, or 2-inch-diameter plugs may be inserted 6 inches on center along the length of the coir fascine.
• When the coir fascines are stacked, live poles, live cuttings, or rooted plants may be placed on the first (lower) coir fascine, prior to placing the next one above it.

Fascines

A fascine is a long bundle of live cuttings bound together into a rope or sausage-like bundles. The structure provides immediate protection for the toe. Since this is a surface treatment, it is important to avoid sites that will be too wet or too dry. The live cuttings eventually root and provide permanent reinforcement.

Figure 6.72c Combining fascines and fabric

Materials

- Live cuttings—3/4 to 2 inches in diameter, 5 to 15 feet long
- Cord, braided manila, sisal or prestretched cotton twine, or small-gauge, nongalvanized wire
- Dead stout stakes—wedge-shaped wooden stakes, 2 to 3 feet long depending on soil conditions
- Tools—machete, shovels, clippers, hammer, sledge hammer, saw, and chain saw
- Fertilizer and other soil amendments

Installation

- Collect and soak live cuttings for 14 days, or install them the day they are harvested and fabricated. Leave side branches intact.
- Stagger the live cuttings in a uniform bundle built to a length of about 8 feet. Vary the orientation of the cuttings. Use 8- to 10-foot bundles for ease of handling, and transport in a pickup bed. They can also be easily spliced together to create a fascine long enough to fit the particular project site.
- Tie bundles with twine at approximately 2-foot intervals. The bundles should be 6 to 24 inches in diameter, depending on their application.
- Start installation from a stable point at the upstream end of the eroding bank.
- Excavate a trench into the bed of the stream, where the bank meets the bed. The trench should be about a half to three-quarters the diameter of the bundle.
- Align the fascine along the toe of the bank of the eroding section.
- Place the bundle in the trench and stake (use wedge shaped dead stout stakes) directly through the bundle 3 feet on center. Allow the stake to protrude 2 inches above the top of the bundle. To improve depth of reinforcement and rooting, install live stakes (2 to 3 ft in length) just below (downslope) and in between the previously installed dead stout stakes, leaving 3 inches protruding from the finished ground elevation.

• Cover the fascine with soil, ensuring good soil to stem contact. Wash it in with water to get around the inner stems of the bundle. Some of the bundle should remain exposed to sunlight to promote sprouting. Use material from the next upbank trench. It may be desirable to use erosion control fabric to hold the soil adjacent to and in between the fascine bundles, especially in wet climates. When using erosion control fabric between the fascine bundles, the fabric is first placed in the bottom of the trench, an inch of soil is placed on top and up the sides of the trench and erosion control fabric, and the fascine bundle is then placed in the trench and staked down.

Note: Fascines can be oriented perpendicular to the streambank contours. This practice is often called the vertical bundle method. The primary difference between the construction of a vertical bundle and a fascine is that all of the cuttings in a vertical bundle are oriented so the cut ends are in the water. It is particularly applicable in areas where there is uncertainty in determining the water table.

Bank treatments

Live pole cuttings or live stakes

Live pole cuttings are dormant stems, branches, or trunks of live, woody plant material inserted into the ground with the purpose of getting them to grow. Live stakes are generally shorter material that are also used as stakes to secure other soil bioengineering treatments such as fascines, brush mattresses, erosion control fabric, and coir fascines. However, the terms live stakes and live pole cuttings are often used interchangeably. Both live poles and live cuttings can be used as anchoring stakes. They are live material so they will also root and sprout. Live pole cuttings are 3 to 10 feet long, and 3/4 to 3 inches in diameter. These cuttings typically do not provide immediate reinforcement of soil layers, as they normally do not extend beyond a failure plane. Over time, they provide reinforcement to the soil mantle, as well as surface protection and roughness to the streambank and some control of internal seepage. They assist in quickly reestablishing riparian vegetation and cause sediment deposition in the treated area.

Figure 6.72d Live cuttings installed in fabric

Materials
• Live cuttings—3/4 to 3 inches in diameter, 3 to 20 feet long
• Tools—machete, clippers, dead blow hammer, saw, chain saw, loppers, and rebar

Installation
• Cleanly remove all side branches and the top growth. Cut the basal (bottom) end to a 45-degree angle, or sharpen into a pointed end. The top end should be cut flat. At least two buds or bud scars should be present above the ground in the final installation, depending on the surrounding vegetation height. The live cuttings should be taller than the surrounding vegetation to ensure that they are not shaded.
• Collect and soak the live cuttings for 14 days, or install them the day that they are harvested and fabricated.
• Use a punch bar or hand auger to create a pilot hole that is perpendicular to the slope. The depth of the hole should be 2/3 to 3/4 the length of the live cutting. Make the hole diameter as close to the cutting's diameter as possible to obtain the best soil-to-stem contact. The hole should be deep enough to intercept the lowest water table of the year or a minimum of 2 feet.
• To achieve good soil-to-stem contact, fill the hole around the pole with a water-and-soil slurry mixture. Add soil around the cutting as the water percolates into the ground and the soil in suspension settles around the cutting. Another method is to tamp soil around the cutting with a rod. Throw a small amount of soil in the hole around the cutting and tamp it down to remove all air pockets. This is similar to installing a wooden fence post.
• Install the pole into the ground at a right angle to the slope face. Use a dead blow hammer to tap the cutting into the ground. Insert the cutting at a 90-degree angle to the face of the slope. Ensure that the sharpened basal end is installed first.
• Place stakes on 2- to 4-foot spacing in either a random pattern or triangular grid for most shrub species. Spacing depends on species, moisture, aspect, and soil.

Joint plantings
Joint plantings or vegetated riprap are cuttings of live, woody plant material inserted between the joints or voids of riprap and into the ground below the rock. Joint planting cuttings are 30 to 48 inches long, and from 3/4 to 2 inches in diameter. These live cuttings typically do not provide immediate reinforcement of soil layers, as they normally do not extend beyond the failure plane. The live cuttings are intended to root and develop top growth providing several adjunctive benefits to the riprap. Over time, these installations provide reinforcement to the soil on which the riprap has been placed, as well as providing roughness (top growth) that typically causes sediment deposition in the treated area. Some control of internal seepage is also provided. These joint planting installations assist in quickly reestablishing riparian vegetation. Joint plantings are frequently used on the lower part of the bank.
Materials
• Joint plantings—live cuttings 3/4 to 2 inches in diameter and 2.5 to 4 feet long. They should be long enough so that at least 1 foot of the cutting will extend into the ground below the riprap.
• Tools—machete, clippers, dead blow hammers, sledge hammer, saw, chain saw, loppers, and rebar

Installation

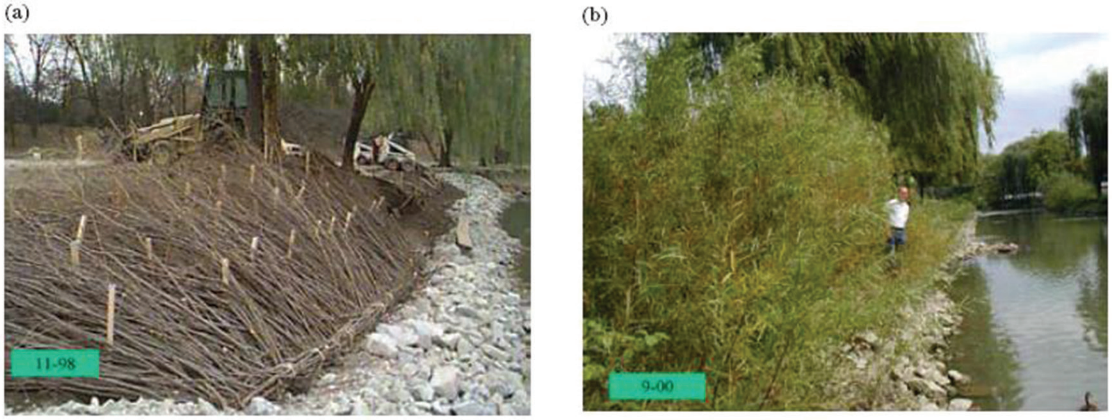
• Cleanly remove all side branches and the top growth from the cuttings. Cut the basal end to a 45-degree angle, or sharpen to a point. The top end should be cut flat. At least two buds or bud scars should be present above the ground in the final installation, depending on the surrounding vegetation height. The live cuttings should be taller than the surrounding vegetation to ensure that they are not shaded.
• Collect and soak the live cuttings for 14 days, or install them the day they are harvested and fabricated.
• Make a pilot hole by hammering in a piece of rebar between the rock. A steel stinger can also be used. Carefully extrude the rebar and tamp in the joint planting stem. Insert the basal end first.
• To achieve good soil to stem contact, fill the hole around the cutting with a water and soil slurry mixture.
• Plant live cuttings on 1.5- to 2-foot spacing in a random pattern or triangular grid. Spacing depends on species, moisture, aspect, and soil characteristics.

Brush mattress

A brush mattress is a layer of live cuttings placed flat against the sloped face of the bank. Dead stout stakes and string are used to anchor the cutting material to the bank. This measure is often constructed using a fascine, joint planting, or riprap at the toe, with live cuttings in the upper mattress area. The branches provide immediate protection from parallel streamflow. The cuttings are expected to root into the entire bank face and provide surface reinforcement to the soil.

Figure 6.72e (a) Brush mattress being installed; (b) Brush mattress after one growing season

(a) (b)



Materials

• Live cuttings—3/4 to 1 inch in diameter. The cuttings should be approximately 2 feet taller than the bank face. This will allow the basal ends to be placed in or at the edge of the water. Up to 20 percent of the cuttings can be dead material to add bulk.
• Dead stout stakes—wedge shaped, 1.5 to 4 feet long, depending on soil texture
• Ties—string, braided manila, sisal or prestretched cotton twine, or galvanized wire
• Tools—machete, shovels, clippers, hammer, sledge hammer, punch bar, saw, and machine to shape the bank
• Fertilizer and other soil amendments

Installation

• Collect and soak the live cuttings for 14 days, or install them the day they are harvested. Leave side branches intact.

• Cut a 2- by 4-inch board diagonally and at desired length to create the dead stout stakes.

• Excavate the bank to a slope of 1V:2H or flatter. The distance from the top of the slope to the bottom of the slope is typically 4 to 20 feet. Excavate a 1-foot-wide and 8- to 12-inch-deep trench along the toe.

• Drive the dead stout stakes 1 to 3 feet into the ground up the face of the prepared bank. Space the installation of the dead stout stakes on a grid that is 1.5 to 3 foot square. Start the lowest row of dead stout stakes below bankfull width or a fourth of the height of the bank. The tops of the dead stout stakes should extend above the ground 6 to 9 inches. Live cuttings may also be mixed with the dead stout stakes, and tamped in between to add deeper initial rooting. However, the live cuttings cannot generally be driven-in as securely as the dead stout stakes and should not be relied upon solely for anchoring the brush mattress.

• Lay the live cuttings up against the face of the bank. The basal ends of the cuttings are installed into the trench with the growing tips oriented upbank. The live cuttings' side branches should be retained and should overlap in a slight crisscross pattern. Depending on the size of the branches, approximately 8 to 15 branches are installed per linear foot of bank.

• Use a fascine or some form of anchoring along the bottom portion of the brush mattress to ensure the basal ends of the live cuttings are pressed against the bank.

• Stand on the live cuttings and secure them by tying string, cord, wire, braided manila, sisal, or prestretched cotton twine in a diamond pattern between the dead stout stakes. Short lengths of tying material are preferred over long lengths. In the event of a failure, only a small portion of the treatment would be compromised if short lengths are used. Otherwise, there are risks of losing larger portions of the project if long lengths of tying material are used to anchor the cuttings to the dead stout stakes.

• After tying the string to the stakes, drive the dead stout stakes 2 to 3 inches further into the bank to firmly secure the live cuttings to the bank face. This improves the soil-to-stem contact.

• Wash loose soil into the mattress between and around the live cuttings so that the bottom half of the cuttings is covered with a 3-4 –inch layer of soil.

• Backfill the trench with soil or a suitable toe protection such as rock.

• Trim the terminal bud at the top of bank so that stem energy will be routed to the lateral buds for more rapid root and stem sprouting.

Top of bank/flood plain treatments

Brush trench

A brush trench is a row of live cuttings that is inserted into a trench along the top of an eroding streambank parallel to the stream (Figure 6.72e). The live cuttings form a fence that filters runoff and reduces the likelihood of rilling. The live cuttings eventually root and provide a permanent living structure. Brush trenches are often used to supplement other soil bioengineering treatments.

Materials
• Live cuttings—3/4 to 3 inches in diameter, 2.5 to 5 feet long
• Tools—machete, clippers, shovel, saw, hammer, and excavator
• Fertilizer and other soil amendments

Figure 6.72e (a) Brush trench after installation; (b) 1 year later

(a) (b)

Installation
• Collect and soak the live cuttings for 14 days or install them the day they are harvested. Leave the side branches intact. It is important to select low-growing species that will remain supple.
• Install appropriate bank and toe protection prior to excavating the brush trench.
• If a moderate amount of runoff currently flows over the bank, consider using a low berm along the top of the bank and directing the flow to a stable outfall away from the bank.
• Excavate a trench that is 10 to 12 inches wide and 1 to 2 feet deep. The trench should be no less than 1 foot back from the top of the bank so that it does not weaken the bank.
• Pack the branches tightly with the basal ends down, forming an intertwined mat. Make sure that the basal ends touch the bottom of the trench. Install 8 to 15 live cuttings per linear foot of trench. The branches protruding from the top of the trench should be taller than the height of competing vegetation.
• Avoid gaps in the vegetation.
• Fill in around the live cuttings with soil, then wash in to assure good soil-to-stem contact. All gaps between the plant materials within the trench should be filled with soil.
• Cut off the terminal end or buds to promote root growth. After the installation is completed, water the entire area. Supplemental irrigation may also be required as the vegetation becomes established.

Monitoring and maintenance

While soil bioengineering projects tend to be self-renewing and grow stronger with time, project areas require periodic monitoring and maintenance, particularly during the establishment stage. Maintenance is especially important on highly erosive sites. Maintenance could include removal of debris and elimination of invasive or undesirable species, as well as replanting vegetation in spot areas. The success of a soil bioengineering streambank stabilization project obviously depends on the establishment and growth of the vegetative component. Allen and Leach (1997) noted that it is important to monitor soil bioengineering projects after project completion to assure plant survival and development. For example, supplemental irrigation may be necessary for exceptionally dry conditions. A fungicide or insecticide may need to be applied if insects or disease are an issue. Beaver, geese, livestock, deer, and other herbivores may also eat the plants in a streambank soil bioengineering project. The loss of a predetermined percentage of the planting may be used to trigger a requirement for remedial planting. If a moderate storm occurs before establishment of the vegetative component of a streambank soil bioengineering project, there is a potential for significant damage to the project. In fact, depending on the nature of the stream and the project, this damage may be severe enough that the vegetative component of the project may not recover. Therefore, it is recommended that most soil bioengineering projects be inspected after moderate flows, as well as on a periodic basis. These inspections are often enough to determine if remedial action will be necessary. One of the most common problems identified with newly installed bioengineered treatments is herbivory, or consumption by plant-eating animals. At times, Canada geese or muskrats may decimate a new herbaceous planting, or beaver may trim every shrub and tree sprout down to ground level. This comes as a shock and disappointment when it occurs, especially after completing a project or even after a robust initial growing phase. Most woody plantings rebound quickly from such impacts, and therefore, can be considered indications of beneficial habitat use. Many herbaceous plantings also rebound well, but if unrooted or repeatedly grazed down to the ground, the damage can be permanent. If this is a possibility, it may be advisable to provide a measure in the plans for inspection and replacement of lost material.

Conclusion

Streambank soil bioengineering is the use of living and nonliving herbaceous and woody plant materials in combination with natural or synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment. This technique has a rich history and uses plants and sometimes inert material to increase the strength and structure of the soil. The use of streambank soil bioengineering treatments is increasing in popularity for a number of reasons: improved aesthetics, increased scrutiny by regulatory agencies, improved water quality benefits, restored fish and wildlife habitat, and decreased costs. The long-term goal of many streambank soil bioengineering stabilization projects is to mimic natural conditions within a natural or newly altered regime. Unaltered channels in their natural environments can be expected to move and erode during large storms. Therefore, where the goal is to allow the system to remain natural, the bank will likely not be static, and periodic bank erosion should be expected. This condition can be contrasted to more urban situations where the proposed conditions of the channel typically do not allow for bank erosion. In these cases, the selected streambank soil bioengineering methods incorporate hard or inert elements that can handle higher velocity flows and to limit the flexibility of the protected bank. Many types of soil bioengineering treatments can be used to stabilize streambanks and can withstand varying shear limits and velocities. Streambank soil bioengineering treatments are a viable alternative to hard structures, as long as the risks are clearly understood and planned for. Understanding the riparian planting zones is particularly important to ensure that the vegetation is planted in the right zone.

6.73

STRUCTURAL STREAMBANK STABILIZATION

This practice standard has been adapted from the Natural Resource Conservation Service *National Engineering Handbook, Part 654, Technical Supplement 14K, Streambank Armor Protection with Stone Structures*. At publication this document was not listed online with older NRCS publications, but was available through NRCS eDirectives at http://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Land disturbing activity involving streams, wetlands or other waterbodies may also require permitting by the U.S. Army Corps of Engineers of 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 cannot be approved 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 structural stabilization of streambanks to comply with permitting requirements of other agencies, as well as provide adequate ground cover.

Introduction

Stone has long been used to provide immediate and permanent stream and river protection. It continues to be a major component in many of the newer and more ecologically friendly projects, as well. Many situations still require rock riprap to some degree. Rock riprap measures have a great attraction as a material of choice for emergency type programs, where quick response and immediate effectiveness are critical. Rock riprap is needed for many streambank stabilization designs, especially where requirements for slope stability are restrictive, such as in urban areas. It is one of the most effective protection measures at the toe of an eroding or unstable slope. The toe area generally is the most critical concern in any bank protection measure. The primary advantages of stone over vegetative approaches are the immediate effectiveness of the measure with little to no establishment period. The use of stone may offer protection against stream velocities that exceed performance criteria for vegetative measures.

Stone considerations

Not all rocks are created equal. A variety of important stone design characteristics and requirements exist that must be accounted for to successfully use rock in the stream.

Stone size

The stone used in a project, whether it is part of a combined structure or used as a traditional riprap revetment, must be large enough to resist the forces of the streamflow during the design storm. A stone-sizing technique appropriate for the intended use must also be selected. Many established and tested techniques are available for sizing stone. Most techniques use an estimate of the stream's energy that the rock will need to resist, so some hydraulic analysis is generally required.

Stone shape

Some methods use different dimensions to characterize stone size. The critical dimension is the minimum sieve size through which the stone will pass. Some techniques assume that riprap is the shape of a sphere, cube, or even a football shape (prolate spheroid). To avoid the use of thin, platy rock, neither the breadth nor the thickness of individual stones is less than a third of its length. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) specifies riprap to be a spheroid three times as long as it is thick (L/B = 3). Note that the shape of most riprap can be represented as the average between a sphere and a cube. An equation for an equivalent diameter of riprap shaped between a cube and a sphere is:

$$D = \left[\frac{2 \times W}{\gamma_s \times \left(1 + \frac{\pi}{6}\right)} \right]$$

where:
W = weight of the stone, lb
γ = density of the stone, approx. 165 lb/ft3,
D = equivalent diameter, ft

This relationship may be helpful if a conversion between size and weight is necessary for angular riprap with this shape. Riprap should be angular to subangular in shape. Field experience has shown that both angular (crushed limestone) and rounded rock (river stones) can be used for riprap protection with equal success, but shape differences do require design adjustments. Rounded rock does not interlock as well as angular rock. Generally, rounded rock must be 25 to 40 percent larger or more in diameter than angular rock to be stable at the same discharge.

Stone gradation

Stone gradation influences resistance to erosion. The gradation is often, but not always, considered by the technique used to determine the stone size. For most applications, the stone should be reasonably well graded (sizes are well distributed) from the minimum size to the maximum size. Onsite rock material may be used for rock riprap when it has the desired size, gradation, and quality. A well-graded distribution will have a wider range of rock sizes to fill the void spaces in the rock matrix. The stone gradation influences the design and even the need for a filter layer or geotextile. Further information on the design, use, and application of geotextiles is provided later in this section.

Design considerations

Stabilizing channel banks is a complex problem and does not always lend itself to precise design. The success of a given installation depends on the judgment, experience, and skill of the planners, designers, technicians, and installers. Several important issues that must be considered for the successful design of projects that depend on the rock performance are briefly described.

Filter layer

Where stone is placed against a bank that is composed of fine-grained or loose alluvium, a filter layer or bedding is often used. This filter layer prevents the smaller grained particles from being lost through the interstitial spaces of the riprap material, while allowing seepage from the banks to pass. This filter layer needs to be appropriately designed to protect the in-place bank material and remain beneath the designed stone or riprap. Therefore, the gradation is based in part of the gradation of the riprap layer and the bank material. The filter layer typically consists of a geosynthetic layer or an 8-inch-thick layer of sand or gravel.

Bank slope

Many stone sizing techniques also require information about the bank slope. In addition, a geotechnical embankment analysis may impose a limit on the bank slope. The recommended maximum slope for most riprap placement is 2H:1V. Short sections of slopes at 1.5H:1V are sometimes unavoidable, but are not desirable. Most rock cannot be stacked on a bank steeper than 1.5H:1V and remain there permanently. For riprap placement of 1.5H:1V and steeper, grouting of the rock to keep it in place must be strongly considered. Alternative measures, such as gabion baskets, are well suited to steep banks. Also, flatter slopes increase the opportunity for vegetation establishment.

Height

Stone should extend up the bank to a point where the existing vegetation or other proposed treatment can resist the forces of the water during the design event. In a soil bioengineering project, a stone revetment typically does not exceed the elevation of the level of the channel-forming flow event. However, there are exceptions where it is advisable to extend the riprap to the top of the bank.

Thickness

Different stone-sizing techniques may have different assumptions concerning the blanket thickness. The thickness of the placed rock should equal or exceed the diameter of the largest rock size in the gradation. In practice, this thickness will be one and a half to three times the median rock diameter (D50). A typical minimum thickness is the greater of 0.75 times the D100 or one and a half times the D50.

Scour

Toe scour is the most frequent cause of failure in streambank armor protection projects. Scour can be long term, general, and local. The greatest scour depths generally occur on the outside and lower portion of curves. Scour depths may increase immediately below and adjacent to structural protection due to the higher velocity section of a stream adjacent to the relatively smooth structure surface. This may undermine the structure and result in failure. Common methods for providing toe protection are:

- placing the stone to the maximum expected scour depth
- placing sufficient stone along the toe of the revetment to launch or fall in, and fill any expected scour
- providing a sheet-pile toe to a depth below the anticipated depth of scour or to a hard point
- paving the bed the most commonly employed method is to extend (or key-in) the bank protection measures down to a point below the probable maximum depth of the anticipated bed scour.

A typical rule of thumb for a minimum key-in depth is one and a half times the riprap thickness or a minimum of 2 feet below the existing streambed. This practical solution generally gives good protection against undermining.

Placement of rock

Rock should be placed from the lowest to the highest elevation to allow gravitational forces to minimize void spaces and help lock the rock matrix together. It is important that riprap be placed at full-course thickness in one operation. Final finished grade of the slope should be achieved as the material is placed. Care should be taken not to segregate or group material sizes together during placement. Allowing the stone to be pushed or rolled downslope will cause stone size segregation. See ASTM D6825 on placement of riprap revetments. An advantage of using riprap structures is that materials are generally readily available, and contractors with appropriate equipment and experience can be found. However, careful consideration should be given early in the design process to the stone installation method. Two commonly employed installation methods are described below.

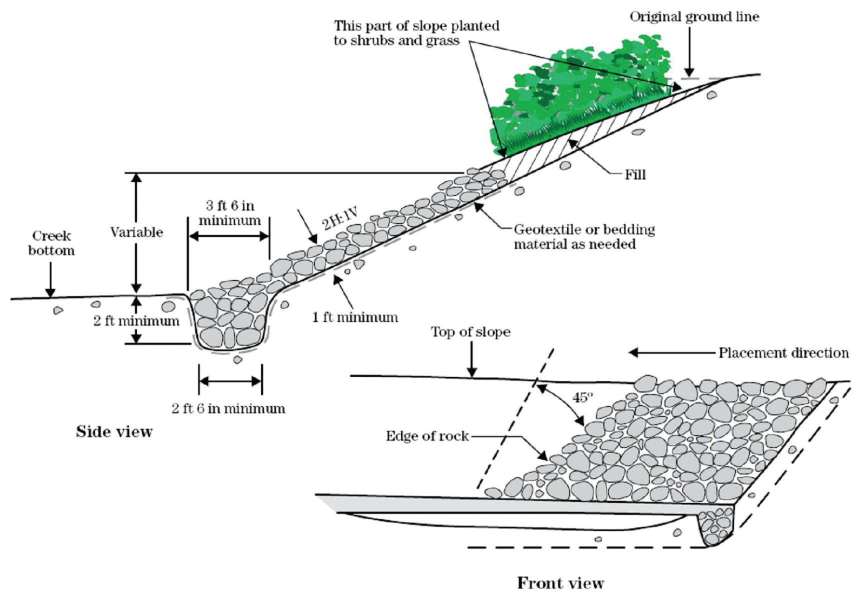
Dumped rock riprap

This method of protection may be necessary where access to the streambed is limited or for emergency situations. Streambank work using dumped rock requires a source of low-cost rock. Access roads must be available near the stream channel, so that rock can be hauled to the streambank and either dumped over the bank or along the edge. If the job requires large quantities of rock, the operation must be set up to accommodate regular deliveries to the job site. In some cases, the banks may be too weak to support a loaded truck, thereby preventing dumping of rock directly over the streambank. In such cases, the rock may be dumped as close to the edge as possible and pushed over the edge with a bulldozer or front-end loader. Larger rock should be placed at the bottom of the revetment work to provide a stable toe section. The use of a front-end loader may be useful to select rock by size and push it over the bank. This type of placement usually results in a poor gradation of material due to material segregation, requiring more volume to make up for the lack of gradation. While this type of bank protection requires more stone per square yard of bank protection than machine placed riprap, it generally requires less labor and equipment operating hours.

Machine-placed riprap

This type of riprap is placed using a track-mounted backhoe or a power crane with a clam shell or orange peel bucket. The riprap is placed on a prepared slope of the streambank to a minimum design thickness of 12 to 18 inches. The larger stones are placed in a toe trench at the base of the slope. This method requires an experienced equipment operator to achieve uniform and proper placement. The toe or scour trench can be dug with the backhoe or clam shell as the machine moves along the slope. The machine can do the backfilling with rock in the same manner. The bank sloping or grading generally is accomplished with a backhoe or sometimes a Gradall®. If a power crane is used, a dragline bucket must be used with the crane for slope grading. A perforated dragline bucket works best because it allows excess water to drain from the bucket. Appropriate bedding and/or geotextile can be installed after the grading and slope preparation are completed. The primary function of these materials is for filtration— to prevent movement of soil base materials through the rock riprap. Bedding is normally placed by dump truck and spread to the desired thickness with a backhoe bucket, a front-end loader, or a small dozer. Geotextile must be placed by hand, secured in place as recommended by the manufacturer, consistent with site specifications. It is important that the geotextile be placed in intimate contact with the base to preclude voids beneath the geotextile. Under larger stone, a coarse bedding may be placed on the geotextile to assure that the geotextile stays in contact with the subbase. In some locations, geotextiles may also be used as a reinforcement in very soft foundation conditions. As previously noted, there will also be situations where the banks may have sufficient gravel content, so that neither bedding nor geotextiles are needed. Riprap should be placed to provide a reasonably wellgraded and dense mass of rock with a minimum of voids and with the final surface meeting the specified lines and grades. The larger stones should be placed in the toe trench or well distributed in the revetment. The finished stone protection should be consolidated by the backhoe bucket or other acceptable means so that the surface is free from holes, noticeable projections, and clusters or pockets of only small or only large stones. Riprap placement should begin at the toe trench and progress up the slope maintaining the desired rock placement thickness as the work proceeds. After the toe trench has been filled to the original stream bottom level, the operator should build a wall or leading edge with the riprap, which is the full layer thickness. That thickness should be maintained throughout the placement of the riprap. The wall should be maintained at about a 45-degree angle from a transverse line down the slope, as the placement progresses from the initial starting point at the streambed and progresses up and across the slope (fig. TS14K–2). Riprap rock should be handled and placed to the full layer thickness in one operation so that segregation is minimized and bedding or geotextile materials used under the riprap are not disturbed after the initial rock placement. Adding rock to the slope or removing it after the initial placement is not practical and generally produces unsatisfactory results. Dumping stone from the top and rolling it into place should also be avoided. This type of operation causes segregation and defeats the purpose of a rock gradation. Running on the riprap slope with track equipment, such as a bulldozer or rubber tire mounted front end loader, should also be avoided. It can damage the rock mass already in place. This operation can also tear the geotextile or damage the bedding by displacing material throughout the rock course. Tamping of the rock with the backhoe bucket can sometimes be used effectively to even up the surface appearance of riprap placement and further consolidate the rock course. It is advisable to have a test section when riprap is being placed over geotextile to check for geotextile puncturing. After the riprap is placed, it is removed, and the geotextile is evaluated.

Figure 6.73a Typical riprap section



Treatment of high banks

The application of rock riprap protection on streambanks that are too high to be practically sloped can be accomplished using the following two methods:

• embankment bench

• excavated bench

Embankment bench method

The embankment bench method provides a reasonable approach to stabilize steep banks with little or no disturbance at the top of the slope and minimal disturbance to the streambed. The method also lends itself to an appropriate blend of structural, soil bioengineering, and vegetative stabilization treatments. This method, or some variation of it, is the most practical and preferred method of treating high, eroding streambanks. The embankment bench method involves the placement of a gravel bench along the base of the eroding bank (Figure 6.73b). The elevation of the bench should be set no lower than the height of the opposite bank and, where practicable, 1 to 2 feet higher. This gravel bench provides drainage and protection at the base of the bank and a stable fill to support the structural toe protection. It also provides a working space for the equipment to place the toe protection, which is most often rock riprap or a combination of riprap and soil bioengineering practice. The embankment bench method requires that the convex side (low bank) of the channel be shaped by excavation of channel bed materials, normally bar removal, to compensate for the reduction in area taken by the bench projection. Offsite materials could be used for the bench in lieu of channel bed materials, but costs would be higher, and the resultant channel restriction could endanger the project. The high bank is generally left in its natural state and appropriately vegetated to assist stability. Some sloughing of the bank onto the prepared bench may occur before a good vegetative cover is established. Willows and other soil bioengineering materials can be established on the bench to help stabilize the toe of the bank and provide vegetative cover. By joint planting in the rock or by sediment accumulation and volunteer vegetation, the bench often can become a self-sustaining solution.

Excavated bench method

The excavated bench method (Figure 6.73c) is used in situations similar to the embankment bench. The excavated bench method does not require the gravel fill material or enlarging of the channel to compensate for the encroachment of the bench area. Instead, it involves shaping the upper half or more of the high bank to allow the formation of a bench to stabilize the toe of the slope. This is accomplished in a manner which leaves the upper part of the excavated slope at least in no worse shape than it was before the excavation. This solution is rarely practical, but may be necessary in cases where stream access is restricted or not allowed. It may also be a solution on lower banks where the excavation quantity is relatively small.

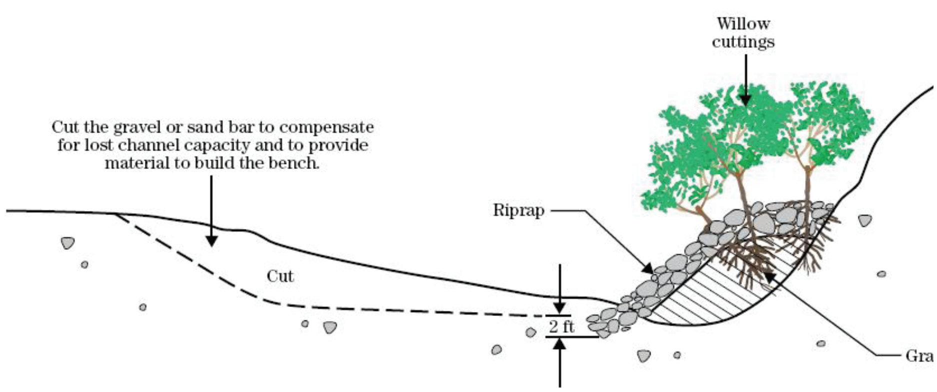


Figure 6.73b Embankment bench method

Surface flow protection

The damage to high banks is often exacerbated by surface runoff. If this is not treated, any protection at the toe may be damaged. High banks subject to damage by surface water flow can be protected by using diversion ditches constructed above the top slope of the bank. Water from active seepage in the high banks should be collected by interceptor drainage and conveyed to a safe outlet. Trees or other vegetative materials in a buffer strip along the top of the bank can be used to help control the active seepage by plant uptake and transpiration. Some soil bioengineering designs can also include ancillary drainage as a function.

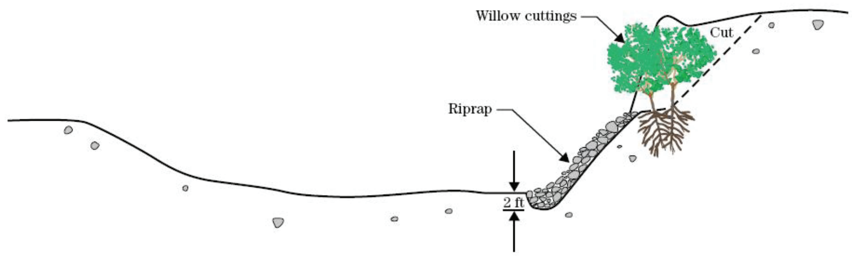


Figure 6.73c Excavated bench method

Wire mesh gabions

Gabions offer important advantages for bank protection. They can provide vertical protection in high-energy environments where construction area is restricted. Gabions can also be a more affordable alternative, especially where rock of the needed size for riprap is unavailable. Gabion wire mesh baskets can be used to stabilize streambank toes and entire slopes. Gabions can also be compatible with many soil bioengineering practices. Gabions come in two basic types: woven wire mesh and welded wire mesh. Woven wire mesh is a double-twisted, hexagonal mesh consisting of two wires twisted together in two 180-degree turns. Welded wire mesh has a uniform square or rectangular pattern and a resistance weld at each intersection. Within these two types there are two styles of gabions: gabion baskets and gabion mattresses. Baskets are 12 inches or more in height, while mattresses typically range from 5 to 12 inches in height. Gabion baskets can be particularly effective for toe stabilization on problem slopes. They provide the size and weight to stay in place, with the further advantage of being tied together as a unit. Baskets can be installed in multiple rows to increase stability and provide a foundation for other measures above them. Gabion mattresses are best suited for revetment type installations, channel linings, and waterways. They may also be used for basket foundations and scour aprons.

All baskets and mattresses are of galvanized wire for corrosion protection. If the baskets are to be installed where abrasion from stream sediments is likely, PVC coated material should be used. PVC coating adds significantly to the durability and longevity of the gabion installation. This coating provides long-term benefits for a relatively small increase in material costs. It is important to use good quality rock of the proper size for gabion installation (Table 6.73a). Additional guidance on quality and sizing of rock can be found in ASTM 6711. Many manufacturers of gabions also provide guidance on the design and construction of their products.

Table 6.73a Specified rock sizes for gabions (from CS#64)

Gabion	Predominant rock size (in)	Minimum rock dimension (in)	Maximum rock dimension (in)
12-, 18-, or 36-in basket	4 to 8	4	9
6-, 9-, or 12-in mattress	3 to 6	3	7

Gabions can be delivered to the work site in a roll and in panels and can be partially or fully assembled. Assembly generally must be accomplished at the work site. Important in all aspects of assembly are thesizing, bracing, and stretching of the baskets or mattresses. Assembly and installation procedures are well covered in NRCS National Construction Specification (CS) #64 (USDA NRCS 2005). Details for assembly and placement of double-twisted, wire mesh gabions can also be found in ASTM D7014. Important considerations in gabion placement are:

• The gabion is stretched and carefully filled with rock by machine or hand placement ensuring alignment, avoiding bulges, and providing a compact mass.
• Machine placement will require some hand work to ensure the desired results.
• The cells in any row shall be filled in stages so that the depth of stone placed in any cell does not exceed the depth of the stone in any adjoining cell by more than 12 inches.
• Along all exposed faces, the outer layer of stone shall be placed and arranged by hand to achieve a neat and uniform appearance (Figure 6.73d).

The tops of gabions will also require some hand work to make them level and full prior to closing and fastening the basket lids. It is important that the gabion basket or mattress is full and the lids fit tightly. Appropriate tools need to be used in this operation and care taken not to damage the lids by heavy prying.

Various types of fasteners and lacing are used to assemble and secure gabion baskets and mattresses. The manufacturer's recommendations should be followed along with the applicable provisions in CS #64.

Figure 6.73d Gabions showing a neat, compact, placement of stone with a uniform appearance

Figure 6.73e Vegetated gabions under construction

Vegetated gabion

In some locations, traditional gabions may be unacceptable from either an aesthetic or ecological perspective. A modification to traditional gabion protection that may satisfy these concerns is the vegetated gabion. A vegetated gabion incorporates topsoil into the void spaces of the gabion. The resulting gabion volume consists of 30 to 40 percent soil that allows root propagation between the stones. The resulting structure is interlocked with stone, wire, and roots (Figure 6.73e).

Conclusion

Many restoration designs require the use of rock in the stream. Riprap is one of the most effective protection measures at the toe of an eroding or unstable slope. Rock use has distinct advantages in terms of accepted design techniques and established contracting and construction procedures. In addition, many innovative bank stabilization and habitat enhancement projects use stone to perform important functions. Rock does present some drawbacks concerning cost, aesthetics, and ecological and geomorphic impacts. The challenge is to integrate more vegetative and geomorphic solutions without materially increasing the exposure time and risk of failure and meeting the goals of the project. This approach produces a long-term solution that will be complementary to the natural environment and will be more self-sustaining.

6.74

BUFFER ZONES

Definition

Buffer zone means the strip of land adjacent to a lake or natural water course (stream, river, swamp, canal, estuary, etc.).

Purpose

Buffer zones are used to reduce the impact of upland pollution by,

- filtering surface runoff and groundwater,
- filter dust from surrounding land-disturbing activities,
- taking up nutrients through vegetative roots, and
- provide leaves and woody debris used for food and shelter by aquatic organisms.

Conditions Where Practice Applies

Protective buffers should be used for,

- perennial streams,
- intermittent streams,
- lakes, and ponds, natural or impounded, and
- any river, brook, swamp, sound, bay, creek run, branch, canal, waterway or estuary which could be damaged by sedimentation.

Plan designers and others involved in land-disturbing activites should check with local, state, and federal agencies about the assigned surface water classification for a water-body or stream on or adjacent to a property where land-disturbing activity is planned to take place, especially for Division of Water Quality (DWQ) classified trout waters (*Tr*). To determine a North Carolina water-body and stream classification visit http://h2o.enr.state.nc.us/bims/Reports/reportsWB.html.

Planning Considerations

As stated in the *Sedimentation Pollution Control Act of 1973 (As Amended through 2005)* § 113A-57(1) "No land-disturbing activity during periods of construction or improvement to land shall be permitted in proximity to a lake or natural watercourse unless a buffer zone is provided along the margin of the watercourse of sufficient width to confine visible siltation within the twenty-five percent (25%) of the buffer zone nearest the land-disturbing activity. Waters that have been classified as trout waters by the Environmental Management Commission shall have an undisturbed buffer zone 25 feet wide or of sufficient width to confine visible siltation within the twenty-five percent (25%) of the buffer zone nearest the land-disturbing activity, whichever is greater. Provided, however, that the Sedimentation Control Commission may approve plans which include land-disturbing activity along trout waters when the duration of said disturbance would be temporary and the extent of said disturbance would be minimal. This subdivision shall not apply to a land-disturbing activity in connection with the construction of facilities to be located on, over, or under a lake or natural watercourse." Rule 15A NCAC 04B .0112 requires that "Land-disturbing activity in connection with construction in, on, over, or under a lake or natural watercourse shall minimize the extent and duration of disruption of the stream channel."

Width is a very important consideration in the overall effectiveness of buffers. The appropriate buffer width can vary depending on site conditions, soils, topography, hydrology, adjacent land use, and benefits one is trying to gain by installing a buffer. Guidance is provided for determining the width of undisturbed vegetation zones with percent slope considerations.

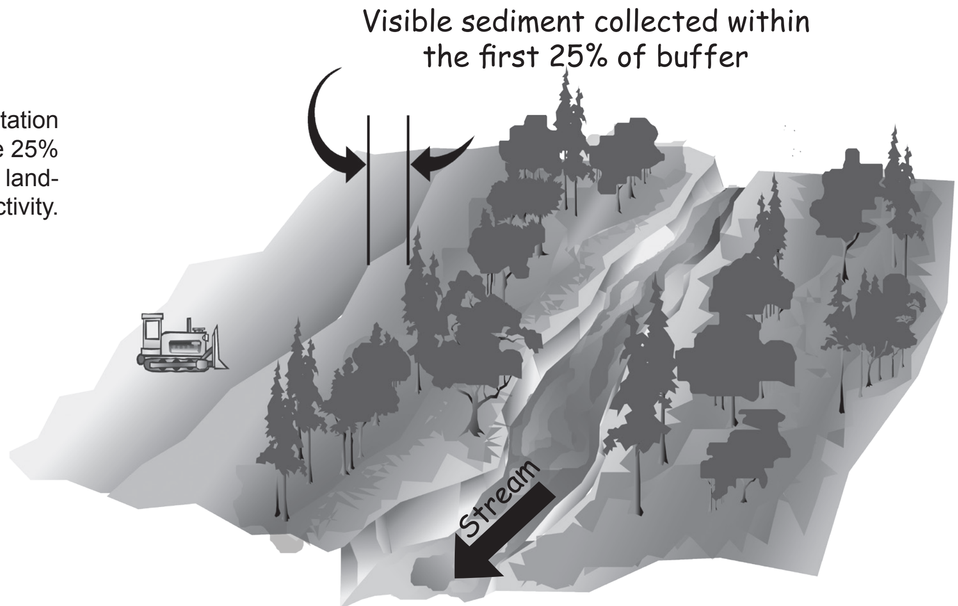


Figure 6.74a Visible siltation should be kept within the 25% buffer zone nearest the land-disturbing activity.

Guidance for Determining Width of Undisturbed Vegetation Zones

Zones of undisturbed vegetation may be used to ensure compliance with the statutory requirement of G.S. 113A-57(1) that "all visible siltation be retained within the 25% of the buffer zone closest to the land disturbing activity" even in the event of failure of other erosion and sedimentation control measures and practices. The use of such zones of undisturbed vegetation is also a reasonable method for ensuring "protection of public and private property from damage caused by land disturbing activities," as required by Commission Rule 15A NCAC 04B .0105. The information given below provides guidance for determining the appropriate width of such zones of undisturbed vegetation for use during all phases of site development; good engineering judgment must provide for exceptions.

Buffer zones indicated on Erosion and Sedimentation Control Plans should include, immediately adjacent to the stream bank, a minimum zone of undisturbed vegetation of a width dependent upon the average slope of the land perpendicular to the stream. The following guidance indicates suggested zone widths:

Guidance for Determining Width of Undisturbed Vegetation Zones (continued)

Slope (%)	Width of Zone of Undisturbed Vegetation
0-1	15 feet
1-3	20 feet
3-5	25 feet
>5	25 feet + (% of slope - 5) [Ex. 6% slope = 26 ft Zone of Undisturbed Vegetation (25 ft + 1 ft), and 50 % slope = 70 ft Zone of Undisturbed Vegetation (25 ft + 45 ft)]

Zones of undisturbed vegetation are to be used in conjunction with, not in place of, other measures and practices located outside of the zones of undisturbed vegetation so that the performance objectives of the statute are realized.

The slope % is that slope, perpendicular to the stream, naturally occurring within the buffer zone. The average slope should be calculated for every 100 foot segment of stream frontage for the land disturbing activity described in the Erosion and Sedimentation Control Plan. This average should be used to determine the appropriate width of the zone of undisturbed vegetation across any given 100 foot segment (i.e., the appropriate width of the zone of undisturbed vegetation may vary with each 100 foot segment depending upon the topography of the site).

Once the appropriate width has been determined for a given segment, the zone of undisturbed vegetation should be measured from the edge of the water to the nearest edge of the disturbed area as specified in Commission Rule 15A NCAC 04B .0125(a). Other practices and measures for erosion and sedimentation control may be located in the 25% of the buffer zone nearest the land disturbing activity; such practices and measures should not be located within the zone of undisturbed vegetation.

NOTE: Certain projects may be subject to riparian buffers under the statutes and rules regulating development activities in specified river basins or coastal areas. Use of the above-stated guidance may not satisfy the requirements of these applicable laws. The wider of 1) the riparian buffer, if applicable, or 2) the zone of undisturbed vegetation, allowing for exceptions based on good engineering judgment, should be applied on a site specific basis.

References

Best Management Practices for Construction and Maintenance Activities, North Carolina Department of Transportation. August, 2003. Appendix D.

6

INDEX

OTHER RELATED PRACTICES

6.80

CRS

CONSTRUCTION ROAD STABILIZATION

Definition

The stabilization of temporary construction access routes, on-site vehicle transportation routes, and construction parking areas.

Purpose

To control erosion on temporary construction routes and parking areas.

Conditions Where Practice Applies

All traffic routes and parking areas for temporary use by construction traffic.

Planning Considerations

Improperly planned and maintained construction roads can become a continual erosion problem. Excess runoff from roads causes erosion in adjacent areas, and an unstabilized road may become a dust problem. Construction vehicle traffic routes are especially susceptible to erosion because they become compacted, and collect and convey runoff water along their surfaces. Rills, gullies, and troublesome muddy areas form unless the road is stabilized.

During wet weather, unstabilized dirt roads may become so muddy they are virtually unusable, generating sediment and causing work interruption. Proper grading and stabilization of construction routes often saves money for the contractor by improving the overall efficiency of the construction operation while reducing the erosion problem.

Situate construction roads to reduce erosion potential, following the natural contour of the terrain. Avoid steep slopes, wet or rocky areas, and highly erosive soils.

Controlling surface runoff from the road surface and adjoining areas is a key erosion control consideration. Generally locate construction roads in areas where seasonally high water tables are deeper than 18 inches. Otherwise, subsurface drainage may be necessary. Minimize stream crossings and install them properly (Practices 6.70, *Temporary Stream Crossing* and 6.71, *Permanent Stream Crossing*).

When practical, install permanent paved roads and parking areas and use them for construction traffic early during the construction operation to minimize site disruption.

Design Criteria

Road grade—A maximum grade of 10% to 12% is recommended, although grades up to 15% are possible for short distances.

Road width—14 feet minimum for one-way traffic
—20 feet minimum for two-way traffic

Side slope of road embankment—2:1 or flatter.

Ditch capacity—Roadside ditch and culvert capacities—10-year peak runoff.

Stone surface—Use a 6-inch course of "ABC" or "base course" or larger as specified in N.C. Department of Transportation Standard Specifications for Roads and Structures.

Permanent road standards—Design standards are available from the N.C. Department of Transportation Division of Highways District Engineer. Follow these specifications for all permanent roads.

Construction Specifications

1. Clear roadbed and parking areas of all vegetation, roots, and other objectionable material.

2. Ensure that road construction follows the natural contours of the terrain if it is possible.

3. Locate parking areas on naturally flat areas, if they are available. Keep grades sufficient for drainage, but generally not more than 2 to 3%.

4. Provide surface drainage, and divert excess runoff to stable areas by using water bars or turnouts (*References: Runoff Control Measures*).

5. Keep cuts and fills at 2:1 or flatter for safety and stability and to facilitate establishment of vegetation and maintenance.

6. Spread a 6-inch course of "ABC" crushed stone evenly over the full width of the road and smooth to avoid depressions.

7. Where seepage areas or seasonally wet areas must be crossed, install subsurface drains or geotextile fabric cloth before placing the crushed stone (Practice 6.81, *Subsurface Drain*).

8. Vegetate all roadside ditches, cuts, fills, and other disturbed areas or otherwise appropriately stabilize as soon as grading is complete (*References: Surface Stabilization*).

9. Provide appropriate sediment control measures to prevent off-site sedimentation.

Maintenance

Inspect construction roads and parking areas periodically for condition of surface. Topdress with new gravel as needed. Check road ditches and other seeded areas for erosion and sedimentation after runoff-producing rains. Maintain all vegetation in a healthy, vigorous condition. Sediment-producing areas should be treated immediately.

References

Surface Stabilization
6.10, Temporary Seeding
6.11, Permanent Seeding

Runoff Control Measures
6.20, Temporary Diversions
6.23, Right-of-way Diversions (Water Bars)

Runoff Conveyance Measures
6.30, Grass-lined Channels
6.31, Riprap-lined Channels

Other Related Practices
6.81, Subsurface Drain
6.84, Dust Control

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.81

SUBSURFACE DRAIN

Definition

A perforated conduit or pipe installed to a design depth and grade below ground surface to intercept, collect, and convey excess ground water to a satisfactory outlet.

Purpose

To improve soil-water conditions for vegetative growth, to improve slope stability, and to improve stability of structures with shallow foundations by lowering the water table.

Conditions Where Practice Applies

Subsurface drains apply where excess ground water must be removed to improve soil-water conditions for plant growth, to provide a stable base for construction, or to reduce hydrostatic pressure. The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

An adequate outlet for the drainage system must be available either by gravity or by pumping. The quantity and quality of discharge should not damage the receiving stream.

This standard does not apply to subsurface drains for building foundations or deep excavations.

Planning Considerations

From a functional standpoint, subsurface drainage systems fall into two classes: relief drains and interceptor drains.

Relief drains are generally used to lower the water table in large, relatively flat areas that frequently become too wet to support desirable vegetation. Although surface water may also be carried through relief drains, it is generally better to install a separate drain for this purpose.

Relief drains may be installed in a grid, herringbone, or random pattern (Figure 6.81a), depending on specific site conditions. In locations where it is desirable to control the water table (raise or lower it) for optimum plant growth, the system may be designed as a combination subirrigation/drainage system. Special on-site investigations are needed, however, to design such dual-purpose systems.

Interceptor drains (Figure 6.81b) remove excess ground water from a slope, stabilize steep slopes and lower the water table immediately below a slope. They may also be used to stabilize shallow foundations such as paved channels or construction access roads.

Interceptor drains usually consist of a single pipe or a series of single pipes buried perpendicular to the slope.

The capacity of an interceptor drain is determined by calculating the maximum rate of ground water flow to be intercepted. Therefore, it is good practice to make complete subsurface investigations including hydraulic conductivity of the soil before designing a subsurface drainage system.

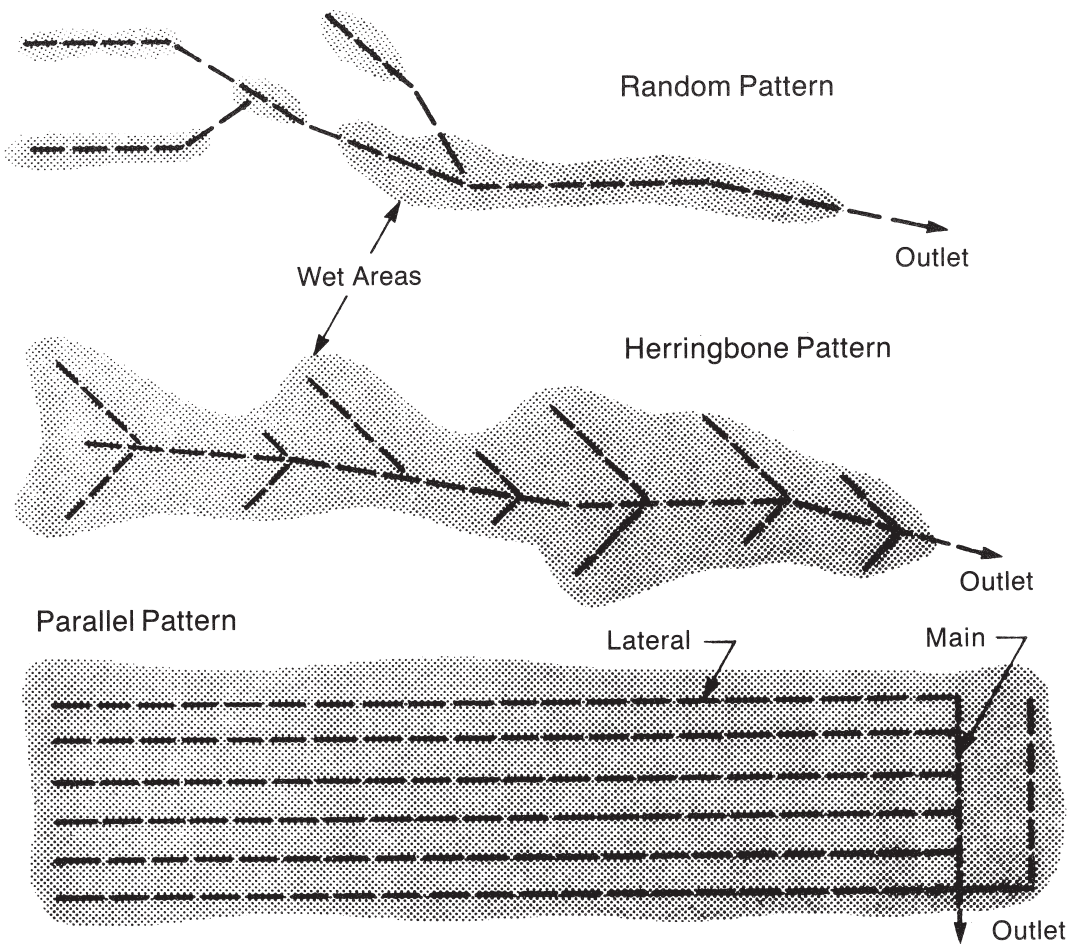


Figure 6.81a Subsurface relief drain layouts (source: USDA-SCS).

Design Criteria

Location—Do not install drain lines within 50 feet of trees to avoid tree roots that may clog the line. Use solid pipe with watertight connections where it is necessary to pass a subsurface drainage system through a stand of trees.

Arrange relief drains in a pattern that will drain the entire wet area evenly. Main lines are usually located through the lowest portion of the landscape (Figure 6.81a).

Locate interceptor drains to proper depth on the uphill side of wet, unstable areas and install on a positive grade across the slope.

Capacity of relief drains—Minimum removal rate is 1 inch of ground water in 24 hours (0.042cfs/acre). When surface water is allowed to enter directly into the drain, the design capacity must be increased accordingly. Design rates may be decreased if a good independent surface drainage system is installed.

Capacity of interceptor drains—Table 6.81a may be used to determine the capacity requirements for interceptor drains for most soils in North Carolina. Note the limitations in the chart.

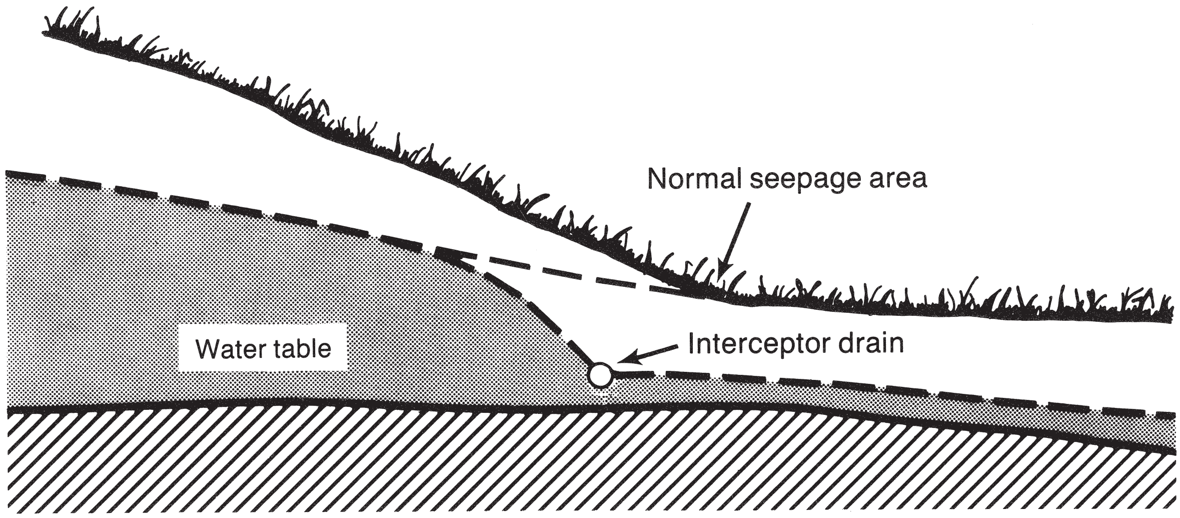


Figure 6.81b Interceptor drain to control seepage.

If spring flow or surface water enters the drain directly, the capacity must be increased to accommodate the excess. When anticipated seepage rates are high (greater than 20 inches/hour) or extensive drainage is require, an individual design may be based on the following equation:

$$Q_i = \frac{K\, i\, d_e\, L}{43{,}200}$$

where:

Q_i = design discharge in cfs,

K = hydraulic conductivity in inches/hour (sufficient in-place tests must be made to determine this value),

i = hydraulic gradient of the undisturbed water table in feet/feet (should be made during wet conditions),

d_e = the average effective depth in feet (the depth of the proposed drain invert below the undisturbed water table), and

L = length of the drain in feet.

Where hydraulic conductivity rates vary greatly, such as in gravel layers, a pilot trench may be dug to design depth and the actual flow rate measured under wet conditions.

Size of drain—Size subsurface drains to carry the required capacity without pressure flow. Minimum diameter for a subsurface drain is 4 inches.

Depth and spacing of relief drains—Relief drains should be installed in a uniform pattern with equal spacing between the drains and all drains at the same depth. The maximum depth is limited by the allowable load for the type of pipe, depth to an impermeable layer, and outlet conditions.

Spacing between drains depends primarily on soil hydraulic conductivity (permeability) and the depth of the drain. In most cases, a depth of 3 to 4 feet and a spacing of 50 feet is adequate.

Table 6.81a Design Flow Rates for Interceptor Drains in Sloping Land

Slope of Underground Water Surface[1]	Minimum Capacity[2]
<5%	0.3 cfs/1,000 ft
5 - 10%	0.6 cfs/1,000 ft
10 - 20%	1.0 cfs/1,000 ft
>20%	1.5 cfs/1,000 ft

[1] Use the slope of the land surface above the interceptor line if water table surface slope is not known.

[2] If hydraulic conductivity of the soil above the interceptor line exceeds 20 inches per hour, design should be based on specific site data.

When large areas are to be drained, specific site designs should be prepared. One reference for this purpose is the National Engineering Handbook, Section 16, Drainage of Agricultural Land, prepared by USDA, Soil Conservation Service.

Depth and spacing of interceptor drains—The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a permeability-restricting layer. The maximum depth is limited by the allowable load for the type of pipe used and the depth to an impermeable layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit.

One interceptor drain is usually sufficient, especially when the drain can be located on or just above an impermeable layer. Where more than one interceptor drain may be needed, it may be acceptable to install only the upper drain—then if seepage problems occur downslope, additional drains can be installed in the same manner as the first line. An alternative approach is to make sufficient soil borings and hydraulic conductivity tests to define (1) the surface of the impervious layer, (2) the undisturbed slope of the water table during wet conditions, and (3) the in-place saturated hydraulic conductivity of the soil materials upslope of the problem area. The minimum number of individual interceptor lines can then be sized and placed to the proper depth and location to control the underground water level to a minimum depth of 2 feet below the ground surface.

Envelopes and filters—Bed all drains in gravel as shown in Figure 6.81c to improve flow into the drain. If soil material is used for the backfill, place filter cloth over the top of the gravel before backfilling to prevent soil from moving into the gravel. If sand is used, it should conform to NCDOT Standard size No. 2S subsurface drain material (NCDOT Section 905-3). Envelopes and filters should surround the drain to a minimum of 3-inch thickness.

Velocity limitations—The minimum velocity to prevent silt deposition in drain lines is 1.4 ft/sec. The maximum allowable velocity using a sand-gravel filter or envelope is 9 ft/sec.

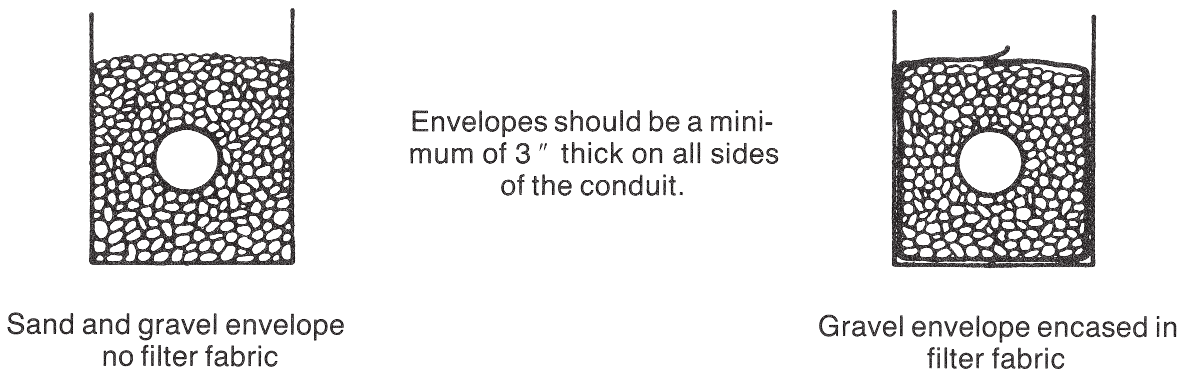


Figure 6.81c Drainage envelopes and filters (modified from USDA-SCS).

Outlet—Ensure that the outlet of a drain empties into a channel or other watercourse above the normal water level.

Use outlet pipe of corrugated metal, cast iron, steel pipe, or heavy-duty plastic without perforations and at least 10 feet long. Do not use an envelope or filter material around the outlet pipe, and bury at least two-thirds of the pipe length.

When outlet velocities exceed those allowable for the receiving stream, outlet protection must be provided (*References: Outlet Protection*).

Secure an animal guard to the outlet end of the pipe to keep out rodents.

Material—Acceptable materials for subsurface drains include perforated, continuous closed-joint conduits of corrugated plastic, corrugated metal, concrete, and bituminized fiber. Ensure that the strength and durability of the pipe meet the requirements of the site and are in keeping with the appropriate ASTM specification for the materials used.

Construction Specifications

1. Dig a trench to grade 3 inches below the design bottom elevation of the pipe to accommodate the envelope or filter material.

2. Stabilize any soft, yielding soils under the drain with gravel or other suitable material.

3. Lay pipe on the design grade and elevation avoiding reverse grade or low spots.

4. Do not use damaged, deformed, warped, or otherwise unsuitable pipe.

5. Place envelope or filter material around pipe with at least 3 inches of material on all sides.

6. Ensure that gravel for envelopes around flexible pipe does not exceed 3/4 inch in size to prevent damage to the pipe.

7. Place filter cloth over gravel envelopes to prevent movement of soil into the gravel.

8. Backfill immediately after placement of the pipe. Ensure that the backfill material does not contain rocks or other sharp objects and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.

9. For the outlet section of the drain, use at least 10 feet of nonperforated corrugated metal, cast iron, steel, or heavy-duty plastic pipe. Cover at least two-thirds of the pipe length with well-compacted soil.

10. Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion and wash-out from surface runoff.

11. Place a suitable animal guard securely over the pipe outlet to keep out rodents.

12. Cap the upper end of each drain with a standard cap made for this purpose or with concrete or other suitable material to prevent soil from entering the open end.

Maintenance

A properly designed and installed subsurface drain requires little maintenance. However, check drains periodically and especially after heavy rains to see that they are operating properly. Keep the outlet free of sediment and other debris, and keep the animal guard in place and functional. Investigate any wet areas along the line for possible cave-in due to vehicle traffic, blockage by roots, or other problems. Make all needed repairs promptly.

References

Runoff Conveyance Measures
6.30, Grass-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

USDA Soil Conservation Service
National Engineering Handbook, Section 3,
Drainage of Agricultural Land

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

6.82

GRADE STABILIZATION STRUCTURE

Definition

A structure designed to reduce channel grade in natural or constructed watercourses.

Purpose

To prevent erosion of a channel that results from excessive grade in the channel bed. This practice allows the designer to adjust channel grade to fit soil conditions.

Conditions Where Practice Applies

This practice applies where structures are required to prevent head cutting or stabilize gully erosion. Specific locations are:

- Where head cutting or gully erosion is active in natural or constructed stream channels.
- Where beds of intersecting channels are at different elevations.
- Where a flatter grade is needed for stability in a proposed channel or water disposal system.

Planning Considerations

Grade stabilization structures are usually installed as part of a vegetated water disposal system. If the channel grade is erosive with a vegetative liner, the designer should consider using nonerodible channel liners (riprap or paving), or a vegetated channel in combination with grade stabilization structures. In deciding which type of system to use, the designer should consider:

- the differences in channel depths, widths, and spoil disposal,
- the effect the deeper channel will have on the water table, especially near the structure,
- entrance of surface water into the deeper channel system, and the need for an emergency bypass, at structure locations,
- side slope stability,
- outlet velocities,
- environmental impacts,
- site aesthetics, and
- cost comparisons including maintenance.

In general, shallow channels stabilized with riprap or concrete are preferred to deeper earth channels that require grade stabilization structures.

Grade stabilization structures are often used to stabilize progressive head cutting in an existing channel. Make an on-site evaluation to determine that the channel upstream and downstream from the proposed structure will be stable for the design flow conditions. Base the stability evaluation on clear water flow, as another head cut may begin below the structure once sediment sources upslope are controlled.

Grade stabilization structures may be vertical drop structures, concrete or riprap chutes, gabions, or pipe drop structures. Permanent ponds or lakes may be part of a grade stabilization system.

Where flows exceed 100 cfs and grade drops are higher than 10 feet, consider concrete chutes. This type of grade control structure is often used as an outlet for large water impoundments.

Where flows exceed 100 cfs and the drop is less than 10 feet, a vertical drop weir constructed of reinforced concrete or sheet piling with concrete aprons is generally recommended. Small flows allow the use of prefabricated metal drop spillways or pipe overfall structures.

Pipe drop grade stabilization structures are commonly used where channels intersect at different elevations, especially when flows are less than 50 cfs. Pipe drop structures also make convenient permanent channel crossings.

Design Criteria

Designs for grade stabilization structures can be complex and usually require detailed site investigations. Design of large structures (100 cfs) require a qualified engineer familiar with hydraulics and experienced in structure design. Advice on the control of stream channel erosion may be obtained from the local USDA Soil Conservation Service office serving each country.

Location of structure—Locate the structure on a straight section of channel with no upstream or downstream curves within 100 feet.

Ensure that the foundation material at the site is stable, relative homogenous, mineral soil with sufficient strength to support the structure without uneven settling. Piping potential of the soil should be low.

Ensure that flood bypass capability is available at the site to protect the structure from flows greater than design capacity. Protect the area where bypass flow enters the channel downstream (Figure 6.82a).

Consider diversion of flow for dewatering during construction as part of site evaluation.

Capacity—At a minimum, design the structure to control the peak runoff from the 10-year storm or to meet the bankfull capacity of the channel, whichever is greater.

Ensure that bypass capacity prevents structural failure from larger storms, based on the expected structure life and consequences of failure. **Large structures require greater design factors because of safety considerations**.

Grade elevations—Set the crest of the structure's inlet at an elevation that will stabilize the grade of the upstream channel. Set the outlet section at an elevation that will provide a stable grade downstream to assure stability.

Structural dimensions—The National Engineering Handbook (Drop Spillways, Section 11, and Chute Spillways, Section 14), prepared by the USDA Soil Conservation Service, gives detailed information useful in the design of grade stabilization structures.

Foundation drainage is needed to reduce hydrostatic loads on drop spillway structures. New products such as plastic, prefabricated drainage devices are available that provide positive drainage, are easy to install, and may be less costly than conventional drainage methods.

Outlet conditions—Keep the velocity of flow at the outlet within the allowable limits for the receiving stream (Table 8.05d). Place a transition section consisting of properly sized riprap at the toe of the structure to prevent erosion of the channel bed (Practice 6.41, *Outlet Stabilization Structure*).

Construction Specifications

1. Divert all surface runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structural appertenances.

2. Ensure that the concrete conforms to standards for reinforced structural concrete. Make adequate tests, including breaking test cylinders to see that the concrete meets all design specifications for the job. Failure of a large grade stabilization structure may be costly and extremely hazardous.

3. Hand-compact backfill in 4-inch layers around the structure.

4. Make the end of the riprap section as wide as the receiving channel, and make sure the transition section of riprap between the structure end sill and the channel is smooth.

5. Ensure that there is no overfall from the end sill along the surface of the riprap to the existing channel bottom.

6. Locate emergency bypass areas so flood flow in excess of spillway capacity enters the channel below the structure without serious erosion or damage to the structure.

7. Stabilize all disturbed areas as soon as construction is complete.

Since these structures are located in watercourses, take special precautions to prevent erosion and sedimentation during construction of the structure.

Maintenance

Once a grade stabilization structure has been properly installed and the area around it stabilized, maintenance should be minimal. Inspect the structure periodically and after major storms throughout the life of the structure. Check the fill around the structure for piping, erosion, and settlement and to ensure that good protective vegetation is maintained. Check the channel at the structure entrance and outlet for scour and debris accumulation that may cause blockage or turbulence. Check the structure itself for cracking or spauling of the concrete, uneven or excessive settlement, piping, and proper drain functioning. Check emergency bypass areas around the structure for erosion, especially where flow re-enters the channel. Repair or replace failing structures immediately.

References

Runoff Conveyance Measures
6.31, Riprap-lined Channels

Outlet Protection
6.41, Outlet Stabilization Structure

Appendix
8.05, Design of Stable Channels and Diversions

USDA Soil Conservation Service
National Engineering Handbook, Sections 11 and 14.
Washington, D.C.

6.83

→ ▶ → ▶ →

CHECK DAM

Definition

A small temporary stone dam constructed across a drainage way.

Purpose

To reduce erosion in a drainage channel by reducing the velocity of flow.

Conditions Where Practice Applies

This practice may be used as a temporary measure to limit erosion by reducing velocity in small open channels. When needed, they can be used in channels, roadside ditches, and temporary diversions.

Check dams may be used to:

- reduce velocity in small temporary channels that are degrading, but where permanent stabilization is impractical due to their short period of usefulness;
- reduce velocity in small eroding channels where construction delays or weather conditions prevent timely installation of nonerosive liners.

Do not use check dams in intermittent or perennial streams.

Planning Considerations

Check dams are an expedient way to reduce gullying in the bottom of channels that will be filled or stabilized at a later date. The dams should only be used while permanent stabilization measures are being put into place.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after it rains is too long and/or silting is excessive. All stone and riprap must be removed if mowing is planned as part of vegetative maintenance.

Design Criteria

The following criteria should be used when designing a check dam:

- The drainage area is limited to one half acre.
- Keep a maximum height of 2 feet at the center of the dam.
- Keep the center of the check dam at least 9 inches lower than the outer edges at natural ground elevation.
- Keep the side slopes of the dam at 2:1 or flatter.
- Ensure that the maximum spacing between dams places the toe of the upstream dam at the same elevation as the top of the downstream dam (Figure 6.83a).
- Stabilize outflow areas along the channel to resist erosion.
- Use NC DOT Class B stone and line the upstream side of the dam with NC DOT #5 or #57 stone.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 1.5 feet to avoid washouts from overflow around the dam.

Construction Specifications

1. Place stone to the lines and dimensions shown in the plan on a filter fabric foundation.

2. Keep the center stone section at least 9 inches below natural ground level where the dam abuts the channel banks.

3. Extend stone at least 1.5 feet beyond the ditch bank (Figure 6.83b) to keep water from cutting around the ends of the check dam.

4. Set spacing between dams to assure that the elevation at the top of the lower dam is the same as the toe elevation of the upper dam.

5. Protect the channel after the lowest check dam from heavy flow that could cause erosion.

6. Make sure that the channel reach above the most upstream dam is stable.

7. Ensure that other areas of the channel, such as culvert entrances below the check dams, are not subject to damage or blockage from displaced stones.

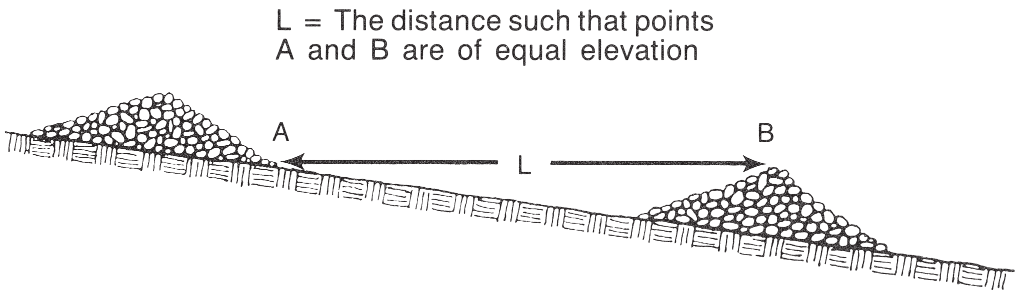


Figure 6.83a Space check dams in a channel so that the crest of downstream dam is at elevation of the toe of upstream dam.

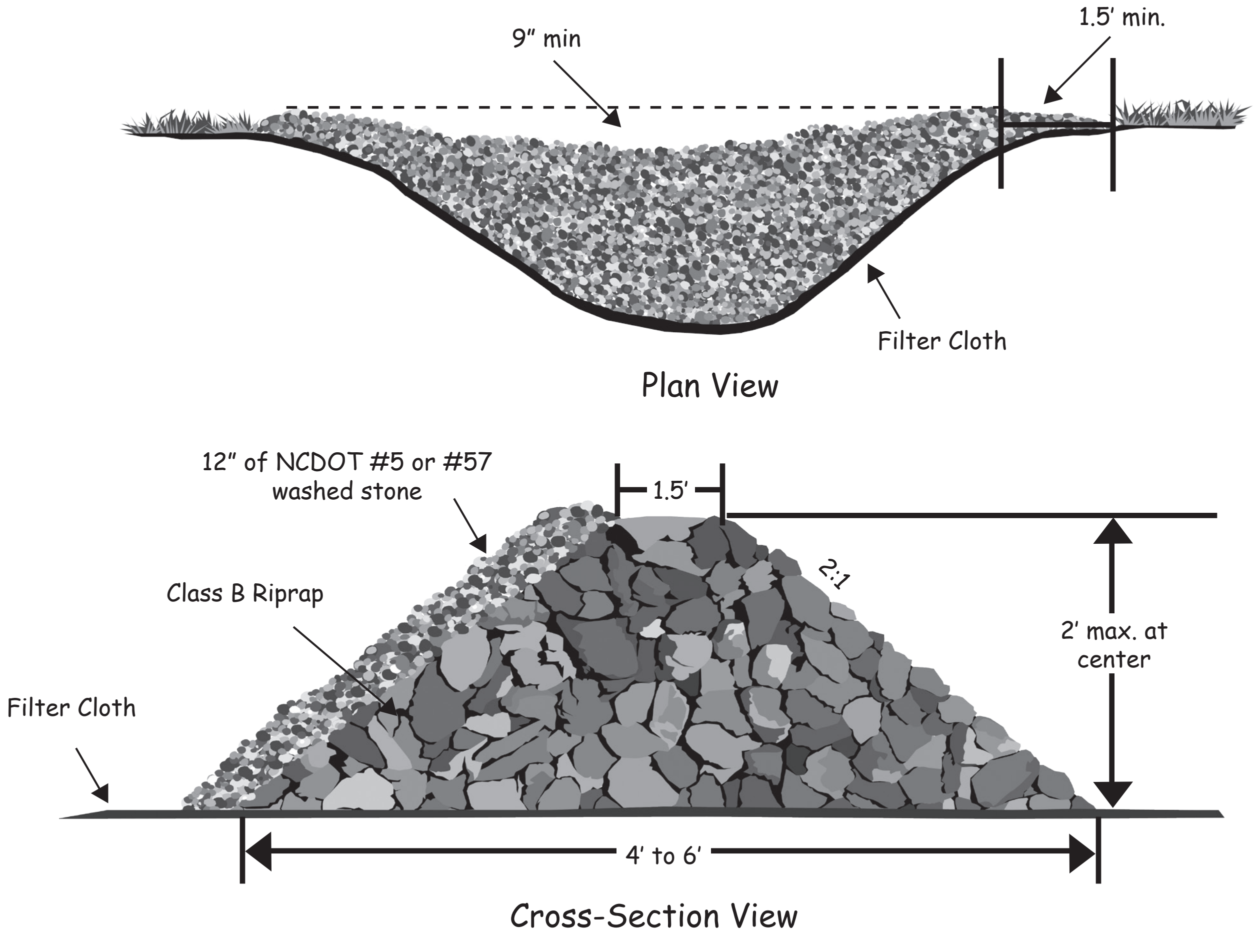


Figure 6.83b Stone check dam stone should be placed over the channel banks to keep water from cutting around the dam.

Maintenance

Inspect check dams and channels at least weekly and after each significant (1/2 inch or greater) rainfall event and repair immediately. Clean out sediment, straw, limbs, or other debris that could clog the channel when needed.

Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam. Correct all damage immediately. If significant erosion occurs between dams, additional measures can be taken such as, installing a protective riprap liner in that portion of the channel (Practice 6.31, *Riprap-line and Paved Channels*).

Remove sediment accumulated behind the dams as needed to prevent damage to channel vegetation, allow the channel to drain through the stone check dam, and prevent large flows from carrying sediment over the dam. Add stones to dams as needed to maintain design height and cross section.

References

Runoff Conveyance Measures
6.30, Grass-lined Channels
6.31, Riprap-lined and Paved Channels

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

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

6.85

SAND FENCE (Wind Fence)

Definition

An artificial barrier of evenly spaced wooded slats or approved fabric erected perpendicular to the prevailing wind and supported by posts.

Purpose

To reduce wind velocity at the ground surface, and trap blowing sand.

Conditions Where Practice Applies

Across open, bare, sandy soil areas subject to frequent winds, where the trapping of blowing sand is desired. Wind fences are used primarily to build frontal ocean dunes (to control erosion from wave overwash and flooding). They may also prevent sand from blowing off disturbed areas onto roads or adjacent property.

Planning Considerations

Soil movement by wind depends on the physical character and condition of the soil. Normally, only dry soils are moved by wind. The structure of soil in an air-dry state is the index to its erodibility. Loose, fine-textured soils are the most readily blown.

There are three types of soil movement operating simultaneously in the process of wind erosion:

- suspension—fine dust particles are carried and suspended in air,
- saltation—movement of particles in short bounces on the ground, and
- surface creep—movement of large particles on the ground by both direct wind and bombardment by smaller particles.

Sand fences act as barriers that catch and hold blowing sand in much the same way as a snow fence prevents snow drift. The fence consists of evenly spaced wooded slats. The spaces between slats allow wind and sand to pass through the fence, but the wind velocity is reduced, causing sand deposition along the fence and between rows of fence (Figure 6.85a).

Figure 6.85a Sand fences trap blowing sand to rebuild frontal dune.

Sand fences, commonly used to build up low areas of frontal dunes along the coast line, can trap large amounts of sand. Their effectiveness depends on the source of sand and the frequency and velocity of onshore wind. As a windward fence is filling, some sand drifts to the next leeward fence. When the dune is sufficiently wide and fences are approximately two-thirds filled with sand, another series of fences may be erected. In this manner, 2 to 6 feet dunes are built in a single season.

There is a limit to how high the frontal dune will form. The natural process of the rise and fall of the tide with an onshore wind provides the sand source to build the dune. The high tide, driven by an onshore wind, carries sand onto the beach. As the tide recedes, the sun and wind dry the sand, and the wind blows it up the dune where it is caught by the fence. The process is repeated as the tides change. As the dune grows, it takes a progressively stronger wind to carry sand over the dune; but as the wind increases, the tides increase and water covers more of the beach. With less available beach sand, strong winds may remove sand along the fence instead of depositing it. In addition, the waves may reach the toe of the dune, causing it to cave and flatten. A change of wind direction more parallel to the coast will speed the erosion process because sand is carried along the beach instead of being deposited below the dune. Therefore, a wind fence must be located well above the expected high water mark to be effective.

When the dune has reached the level of other mature dunes in the area, stabilize it with vegetation. American beachgrass, sea oats, and other adapted vegetation will hold the captured sand in place and gradually capture more sand until the natural maximum dune height is reached. Dunes may be built by vegetation alone, but it usually takes a longer period of time (Practice 6.16, *Vegetative Dune Stabilization*).

Dunes built by wind fences and stabilized with appropriate beach vegetation do not provide permanent protection from beach erosion. However, they do speed up the rebuilding of the natural dune barrier and tend to reduce the average annual loss of frontal dunes.

Keep beach development at least 100 feet behind frontal dunes. Generally, do not attempt beach development in areas where the estimated average frontal dune loss is more than 2 ft/yr, or in particularly vulnerable locations, such as areas adjoining ocean inlets.

Sand fences also trap blowing sand at construction sites to prevent off-site damage to roads, streams, and adjacent property. Generally, locate them perpendicular to the prevailing wind and as near to parallel as possible on the leeward side of the area. Wind fences have been found to be effective up to 22 1/2 degrees from perpendicular to the wind.

Design Criteria

No formal design criteria have been developed for wind fences. Construction Specifications below describe typical wind fence installation.

Construction Specifications

1. Normally, locate sand fences perpendicular to the direction of the prevailing wind, but they may be as much as 22 1/2 degrees from perpendicular and still be very effective.

2. Commercial sand fences usually consist of wooden slats wired together with spaces between the slats. The distance between slats is approximately equal to the slat width (about 1 1/2 inches). Other materials such as discarded Christmas trees have been used to capture sand, but trees must be securely fastened in place and spaced to touch each other in the row.

3. Erect sand fences in parallel rows 20 to 40 feet apart and 2 to 4 feet high. The number of rows installed depends on the degree of protection needed. When fences are approximately two-thirds full, erect another series of fences.

4. In dune building, when the elevation of other mature dunes in the area is almost reached, or when the building process slows significantly, stabilize the dune immediately with appropriate vegetation.

Maintenance

Maintain sand fences, and erect additional fences as needed until the eroding area has been permanently stabilized, or in the case of dune building, until the dune has reached the desired height and is properly vegetated.

References

Surface Stabilization
6.11, Permanent Seeding
6.16, Vegetative Dune Stabilization

6.86

FLOCCULANTS

F

Definition

Flocculation is the process of causing small, suspended materials to stick to each other to form "flocs". These flocs more readily settle out compared to the individual particles.

Purpose

When soil is exposed during construction, stormwater runoff can pick up soil particles and carry them to the nearest water conveyance. The larger particles, such as pebbles and sand, will fall quickly to the bottom once the flow rate slows. However, clays and fine silts will tend to stay suspended because they are much lighter and slower to settle out. The resulting suspended sediment can travel many miles in streams or keep ponds and lakes muddy looking for a long time after a storm. Suspended sediment reduces the biological productivity of the affected waters, decreases recreational value, and increases water treatment costs for industrial or drinking water plants. The purpose of flocculants is to treat the water so that suspended clays and fine silts will settle out of the water quickly before leaving the construction site.

Conditions Where Practice Applies

Construction sites over one acre are required to install measures to retain sediment within the site. These measures include silt fence, sediment traps, storm drain inlet protection, and others. However, water discharged from these devices can have high concentration of suspended clays and fine silts that are very difficult to settle out. There are three ways to reduce suspended sediment: (1) store the runoff long enough for the materials to settle, (2) store and filter runoff, or (3) treat water with chemical flocculants. Filtering water can be high maintenance and expensive. The most practical and least expensive option for most situations is flocculation. A chemical called polyacrylamide (PAM) can create flocs in many sediment types found in North Carolina. Gypsum or moulding plaster can coagulate or bridge clay particles, which also accelerates settling. Flocculants should be used to prevent damage to sensitive water resources such as ponds, lakes and trout streams or whenever turbidity control is required. However, sediment at each site has to be evaluated individually for responsiveness to PAM, gypsum, or other flocculant/coagulants. The use of flocculants is very soil-type dependent and requires a screening process to determine the best chemical for each specific location.

Planning Considerations

PAM is a term describing a wide variety of chemicals based on the acrylamide unit. When linked in long chains, a portion of the acrylamide units can be modified to result in a net positive, neutral, or negative charge on the PAM molecule. The positively charged (cationic) PAM's have not been widely used because they can be toxic to fish and other aquatic organisms if they enter water bodies in sufficient concentrations. The negatively charged (anionic) PAM's are much less toxic to aquatic organisms and are widely used in furrow irrigation agriculture. This is the type of PAM which is commonly allowed for use in stormwater treatment. PAM is available as a crystalline powder, emulsion, solution, or as a solid block or "log." One of the ingredients used to make PAM is acrylamide, which is a known carcinogen, so the PAM's available for public uses are required to have <0.05% free acrylamide. This purity allows them to be used in food processing, drinking water treatment, and other uses where human exposure is likely.

Figure 6.86a Flocculation of sediment with PAM.

PAM is water soluble, but it dissolves slowly and requires considerable agitation and time to dissolve. Water with over 0.1% PAM is often noticeably viscous and most PAM's have a maximum concentration of 0.5-1% in water. When dry PAM becomes wet, it is very slippery and sticky. As a result, it can create a slip hazard.

Gypsum is a natural mineral deposited widely around the earth. It is made up of calcium sulfate and water in the formula $Ca(SO_4)*2(H_2O)$. Moulding plaster is similar, but has a slightly different formula $Ca(SO_4)*0.5(H_2O)$. The largest use of gypsum is in the manufacture of wallboard, but it is also used in water, wastewater treatment, and other industrial processes.

Design Criteria

PAM's mixed with water with high suspended solid loads can greatly reduce turbidity and suspended solid concentrations. It may be used in dewatering operation discharge from borrow pits or construction excavations, from discharge settling ponds, or from stormwater from land disturbance. It is critical that an application system be in place that minimizes the chances of malfunctions that could result in over-application of PAM's and subsequent adverse effects to aquatic life. It is especially important to be cautious near sensitive streams, such as those classified as "High Quality" or "Outstanding Resource Waters."

In using any form of PAM, several basic guidelines should be followed:

1. PAM's should be used **only** after all appropriate physical BMP's have been implemented at a particular site.

2. Only PAM's that pass the chronic toxicity testing requirements, established by the Division of Water Quality, may be used. A laboratory that is certified to conduct NC DWQ whole effluent toxicity (WET) testing must perform a multi-dilution (five test concentrations plus the control) chronic Ceriodaphnia test to determine the IC25 endpoint of the product. For products that are intended for use in NC waters that are not classified as Trout waters, this testing may be performed in water with a turbidity of 60 Nephelometric Turbidity Units (NTU). For products that are intended for use in NC waters classified as Trout waters, this testing must be performed in water not exceeding 20 NTU's. The test protocol utilized may be either the NC DWQ or the standard EPA protocol. The approved maximum application rate must be less than the IC25.

3. PAM's must not be applied directly to surface waters of the state.

4. A sediment basin or similar structure between the application point of PAM's and surface waters is required. Choose the appropriate PAM for the soil type.

5. Before specifying the use of powder or liquid application of PAM's to a settling basin or run-off conveyance, submit a particular product's label, application instructions, and Material Safety Data Sheet (MSDS) to the Division of Water Quality Aquatic Toxicology Unit for evaluation and determination of the product's safe application rate. The product's vendor should be able to provide the required information. PAM information should be submitted to the Aquatic Toxicology Unit, NC DENR Division of Water Quality, 1621 Mail Service Center, Raleigh, NC 27699-1621, fax number (919) 733-9959, and phone (919) 733-2136, Currently the Division of Water Quality Wetlands and Stormwater Branch maintains a list of PAM's with established application rates.

Construction Specifications

One of the key factors in making a flocculant work is to ensure that it is dissolved and thoroughly mixed with the runoff water, which can be accomplished in several ways. Introducing the PAM to the runoff at a point of high velocity will help to provide the turbulence and mixing needed to maximize the suspended sediment exposure to the large PAM molecules. Examples include a storm drain junction box where a pipe is dropping water, inside a slope drain, or other areas of falling or fast moving water upslope from a sediment trap or basin.

As mentioned before, PAM can be purchased as a powder, an emulsion, or a solid block. Because it dissolves slowly, introducing the powder directly into runoff is not effective. The granules will not dissolve fast enough before the water leaves the site. Instead, the powders need to be dissolved in water and metered into the runoff. This solution is often used in PAM furrow irrigation using a PAM solution of 5mg/L (parts per million). However, there is little information on this type of PAM use for storm runoff. Tests in North Carolina have consistently shown that 1-5mg/L (parts per million), or 1-5oz PAM/1,000 cubic feet of water is the optimal dose for effective flocculation (Table 6.86a). Some of the technical challenges include: ways to adjust the amount of solution added to runoff flow to maintain proper PAM concentrations, the stability of the PAM once in solution, and freezing of the PAM solution during colder months.

Table 6.86a Volume of concentrated PAM solution

Final PAM Concentration Desired In Basin	**Volume Needed** (Gallons concentrated PAM mix/1000 cubic feet water treated)
1 ppm	6.7
5 ppm	33

Another option for introducing PAM into runoff involves running the water over a solid form of PAM. Powders can be sprinkled on various materials, such as jute, coir, or other geotextiles. When wet, PAM granules become very sticky, and bind to the geotextile fabric. The product binds to the material, and resists removal by flowing water rendering it ineffective for turbidity control. PAM's may also be purchased as solid blocks or 'logs". The logs are designed to be placed in flowing water to dissolve the PAM from the log somewhat proportionately to flow. While using these solid forms of PAM does not have the same challenges as liquid forms, they do have drawbacks. The amount of PAM released is not adjustable and is generally unknown, so the user has to adjust the system by moving or adding logs to get the desired effect. Because the PAM is sticky when wet, it can accumulate materials from the runoff and become coated, releasing little PAM. The solid forms also tend to harden when allowed to dry. This causes less PAM to be released initially during the next storm until the log becomes moist again.

To avoid these problems, the user must do two things to ensure PAM releases from the solid form:

- Reduce sediment load in the runoff upstream of the PAM location. This avoids burying the PAM under accumulated sediment.
- Create constant flow across or onto the solid PAM. The flow will help dissolve and mix the PAM as well as prevent suspended solids from sticking to the PAM product.

Once the PAM is introduced into the runoff and thoroughly mixed, the runoff needs to be captured in a sediment trap or basin in order for the flocs to settle out. It is important that the inlet of this structure be stabilized with geotextile or stone to prevent gully erosion at the upper end of the basin. Such erosion can contribute significantly to the turbidity in the basin and overwhelm the treatments. Other modifications may also be useful such as installing baffles across the basin or dewatering from the surface using a skimmer or similar device. Baffles using jute or coconut fiber are highly effective in reducing velocity and turbulence in sediment basins. Other, similar porous materials may also be effective, such as 700 g/m^2 coir matting.

Because sediment characteristics are very different across the state, it is important that the correct PAM is matched to the sediment type at the site. Large sites, may require more than one PAM formulation in order to flocculate sediment at different places on the site. At present, the only way to match sediment type to the PAM formulation is to test a number of PAM's for effectiveness. This testing can be done by mixing a small amount of PAM in a jar of water with a small amount of sediment, shaking, and then determining which PAM clears the water the quickest. This process is usually done by the

PAM dealer or supplier because they can maintain a large stock of different PAM's. The appropriate application rate for a product should be determined to provide effective treatment while remaining non-toxic. It is extremely important not to over apply the PAM; it may actually decrease the effectiveness of the product.

Moulding plaster and gypsum have also been demonstrated to settle solids in sediment basins. The material is applied by hand directly to the water after each storm. The dose rate of 20-30lb/1,000 cubic feet of water, spread evenly to the surface, has been found to reduce suspended sediments. This application has not been widely tested, but is one option. The obvious drawback is that the material has to be spread by hand after each storm, which is not only labor intensive, but also means the basin has to be large enough to store the runoff. Otherwise, a major portion of the runoff will be missed before treatment. The dose to result in less than 250mg SO_4/L, as required in North Carolina, is 25lb/1,000 cubic feet for moulding plaster (66% SO_4) and 30lb/1,000 cubic feet for gypsum (56% SO_4).

Maintenance

1. Dosing systems using pumps should be checked daily.

2. Floc logs should be checked at least weekly or after a rainfall event of ½ inch or greater to make sure the logs remain in place, are moist, and are not covered in sediment.

References

SoilFacts: Using Polyacrylamide (PAM) to Control Turbidity, Richard McLaughlin, North Carolina State University Cooperative Extension Service Fact Sheet AGW-439-59.

6.87

CHECK DAM WITH A WEIR

Definition

A small stone dam structure with a weir outlet with a sediment storage area on the upper side.

Purpose

To reduce erosion in a drainage channel by restricting the velocity of flow. This structure also has some ability to provide sediment control.

Conditions Where Practice Applies

This temporary practice may be used in the following locations:

- At outlets of temporary diversions, graded channels, and temporary slope drains;
- In small natural drainage turnouts; and
- In locations where the dams can be easily cleaned and maintained on a regular basis.

Do not use a check dam with a weir in intermittent or perennial streams.

Planning Considerations

Check dams are an expedient way to reduce gullying in the bottom of channels that will be filled or stabilized at a later date. The dams should only be used while permanent stabilization measures are being put into place.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after it rains is too long and/or sedimentation is excessive. All stone and riprap must be removed if mowing is planned as part of vegetative maintenance.

Design Criteria

The following criteria should be used when designing a check dam with a weir:

- Keep the weir at least 9 inches lower than the outer edges at natural ground elevation. The weir length is variable to the size of the drainage area and peak runoff. The weir length may be sized as:

$$L\text{ (ft)} = \frac{Q\text{ peak (csf)}}{0.88}$$

- Keep the side slope of the stone at 2:1 or flatter.
- The apron length (lower side of dam) should be approximately three times the height of the dam with a minimum length of 4 feet. Stabilize outflow areas along the channel to resist erosion.
- The maximum spacing between dams places the toe of the upstream dam at the same elevation as the top of the downstream dam (Figure 6.84a).
- Use NC DOT Class B stone and line the upstream side of the dam with NC DOT #5 or #57 stone.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 1.5 feet to avoid washouts from overflow around the dams.
- Sediment storage area should be sized for the anticipated volume of sedimentation.

Construction Specifications

1. Place structural stone (Class B) to the lines and dimensions shown on the plan on a filter fabric foundation. The crest width of the dam should be a minimum of 2 feet.

2. Keep the center stone section at least 9 inches below the end where the dam abuts the channel banks.

3. Place sediment control stone (#5 or #57) on the upstream side of the dam that is a minimum of 1 foot thick.

4. Provide an apron that is 3 times the height of the dam. The apron width is at least 4 feet long. Undercut the apron so that the top of the apron is flush with the surrounding grade.

5. Extend the stone at least 1.5 feet beyond the ditch bank to keep water from cutting around the ends of the check dam.

6. Excavate sediment storage area to the dimensions shown on the plan

Maintenance

Inspect check dams and channels at least weekly and after each significant (1/2 inch or greater) rainfall event and repair immediately. Clean out sediment, straw, limbs, or other debris that could clog the channel when needed.

Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam. Correct all damage immediately. If significant erosion occurs between dams, additional measures can be taken such as, installing a protective riprap liner in that portion of the channel (Practice 6.31, *Riprap-line and Paved Channels*).

Remove sediment accumulated behind the dams as needed to prevent damage to channel vegetation, allow the channel to drain through the stone check dam, and prevent large flows from carrying sediment over the dam. Add stones to dams as needed to maintain design height and cross section.

References

Runoff Conveyance Measures
6.31, Riprap-lined and Paved Channels

North Carolina Department of Transportation
Standard Specifications for Roads and Structures

7

Sample Erosion a Sedimentation Control Plan