May 2013

*A cooperative effort
between the
North Carolina Sedimentation
Control Commission, the
North Carolina Department of
Environment and Natural
Resources,
and the
North Carolina Agricultural
Extension Service.*

Erosion and Sediment Control Planning and Design Manual

Disclaimer

The contents of this publication were prepared by the authors and should not be interpreted as necessarily representing the policies or recommendations of other referenced agencies or organizations. Additional information from professionals, agencies, organizations and institutions with expertise in a particular area may be useful in selecting, designing, and installing certain practices.

The mention of trade names, products or companies does not constitute an endorsement.

This manual is intended for periodic update. Therefore sections of the manual may be changed as practices for erosion and sedimentation control evolve.

Preface

Thousands of acres of land are exposed each year in North Carolina for the construction of subdivisions, shopping centers, office centers, highways and other developments. Without protective measures these exposed areas are vulnerable to accelerated erosion and sedimentation that damages adjoining properties, streams and other water resources of the state.

The North Carolina Sedimentation Pollution Control Act of 1973 established a statewide program to control soil erosion and sedimentation. The law covers all land-disturbing activities in North Carolina, except those involving agriculture, forestry and mining.

The Act sets basic performance standards backed by rules and regulations. The law and the rules do not specify a rigid set of practices. Rather, they require the land developer to prepare an erosion and sedimentation control plan and employ appropriate measures to meet the performance standards.

As part of the educational requirements of the Act, the Commission is pleased to have sponsored the development of this manual. The manual is a basic reference for the preparation of a comprehensive erosion and sedimentation control plan and for the design, construction and maintenance of individual practices. It is intended to help land developers comply with the Act.

This manual is the "state of the art" and provides useful information for the implementation of a sound erosion control program that can be tailored to specific site conditions. The Commission will continue to support education and training to ensure sound and economical sedimentation control procedures to protect the streams, lakes, and estuaries of the state.

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The project team expresses sincere appreciation to the staff of the Land Quality Section of the North Carolina Department of Natural Resources and Community Development for their encouragement, cooperation and extensive reviews. We particularly acknowledge Charles H. Gardner, PE, S. Taylor Currin, PE, S. Craig Deal, Harlan K. Britt, PE and Randy M. Cotten who worked closely with us from start to finish, and Regional Engineers Richard A. Phillips, PE, Joseph E. Glass, Jerry W. Cook, John Holley, PE, Floyd Williams, Daniel Sams, PE and G. Douglas Miller, PE, for substantive contributions. Kathy Jones of the Attorney General's office advised us in interpreting the Sediment Control Act, and Ernest N. Hayhurst of SCS, assisted in developing the Soils Appendix.

The staff of the Agricultural Communications Department of N.C. State University guided us in design and production. Special thanks go to Robert B. Gregory, Karl E. Larson and Greg Miller for their creative and generous assistance.

Sandy Sullivan served as the graphic artist coordinating page layout, selecting, producing and arranging illustrations and preparing the camera-ready copy. Beth Pastore did many of the illustrations and all of the hand lettering. Cynthia Garver's editing helped refine the manual's style.

Reviewers included Harry Gibson, PE, Emmet Waller, Keith Salvo and Bobby Brock all of the Soil Conservation Service, Douglas S. Chamblee, Joseph M. DiPaola and H. Rooney Malcolm, Jr. of N.C. State University, Thomas N. Tysinger, Jr., P.E. formerly of the City of Greenville and Charles A. Musser, Jr.

The project received erosion and sediment control materials from many other states including Virginia, maryland, Illinois, New Jersey, South Carolina and Michigan. Mr. Scott Crafton from the Virginia Division of Conservation was particularly helpful.

Terri Hocutt and Kelly Hitchcock offered invaluable service in word processing and desk top publishing.

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1

North Carolina Sedimentation Control Law

1

North Carolina Sedimentation Control Law

The purpose of this section is to highlight the portions of the North Carolina Sedimentation Pollution Control Act of 1973 that may affect individuals involved in construction or other land-disturbing activities. The full text of the law is included in *Appendix 8.08*. Address specific questions regarding the interpretation of this law to your regional office of the Land Quality Section of the Department of Environment and Natural Resources (DENR).

This law is performance oriented: it prohibits visible off-site sedimentation from construction sites but permits the owner and developer to determine the most economical, effective methods for erosion and sedimentation control. This flexibility in the law allows for innovation and considers the uniqueness of each construction site; however, it also requires the developer to plan his activities carefully in light of their erosion potential. To control erosion and sedimentation and satisfy the intent of the law, the developer should employ an integrated system of control measures and management techniques. An effective control system is based on an understanding of the processes of erosion and sedimentation and the basic principles for their control. *Chapter 2* discusses these processes and principles.

Who is affected?

The law governs all land-distrubing activities except agriculture and mining, which is regulated by the Mining Act of 1971. *Erosion and sedimentation control are required regardless of the size of the disturbance*. The law requires land developers to plan and implement effective temporary and permanent control measures to prevent accelerated erosion and off-site sedimentation. Further, if the installed protective measures do not work, additional measures must be taken.

What does the law require?

The law requires installation and maintenance of sufficient erosion control practices to retain sediment within the boundaries of the site. It also requires that surfaces be non-erosive and stable within 15 working days or 90 calendar days after completion of the activity, whichever period is shorter. In certain High Quality watersheds this stabilization must be achieved within 15 working days or 60 calendar days after completion of the activity, whichever is shortest.

An erosion and sedimentation control plan must be submitted at least 30 days before land disturbance begins on any site 1 acre or larger. The erosion and sedimentation control plan must be approved by the regulatory agency before any land-disturbing activities are begun. The erosion control plan requires a thorough evaluation of the site and the proposed land-disturbing activities in the planning phase of the development. The details and requirements for this plan are found in *Chapter 4, Preparing the Erosion and Sedimentation Control Plan*. Primary requirements are as follows:

- A sufficient buffer zone must be retained or established along any natural watercourse or lake to contain all visible sediment to the first 25% of the buffer strip nearest the disturbed area. An undisturbed 25 foot buffer must be maintained along trout waters.
- The angle of cut-and-fill slopes must be no greater than that sufficient for proper stabilization. Graded slopes must be vegetated or otherwise stabilized within 21 calendar days of completion of a phase of grading.
- Off-site sedimentation must be prevented, and a ground cover sufficient to prevent erosion must be provided within 15 working days or 90 calendar days, whichever is shorter.

What are the performance standards?

Erosion and sedimentation control measures must be designed to provide protection from a rainfall event equivalent in magnitude to the 10-year peak runoff. In areas where High Quality Waters (HQW's) are a concern, the design requirement is the 25 year storm.

Runoff velocities must be controlled so that the peak runoff from the 10-year frequency storm occurring during or after construction will not damage the receiving stream channel at the discharge point. The velocity must not exceed the greater of:

- the maximum non-erosive velocity of the existing channel, based on soil texture (Table 8.05d, *Appendix 8.05*), or
- peak velocity in the channel prior to disturbance.

If neither condition can be met, then protective measures must be applied to the receiving channel.

Who is responsible for maintenance?

During construction, the person financially responsible for site development is responsible for maintenance of the erosion and sedimentation control practices installed. The landowner may also be held responsible.

After construction is complete and the surface is permanently stabilized, responsibility passes to the landowner or the person managing the land.

Who enforces the law?

The Sedimentation Pollution Control Act provides authority to the State or authorized local agencies to inspect land-disturbing activities and to prosecute violators. Citizens damaged by violations of the Act may also take action through the courts.

What are the penalties?

Civil penalties assessed by the state or authorized localities carry a maximum fine of $5000/day per violation for each day that the site in violation.

Criminal penalties for knowing or willful violations may be imposed to a maximum of 90 days in jail and a $5,000 fine.

Administrative stop-work orders or injunction issued by the courts.

Who is the governing/ responsible agency?

The law created the Sedimentation Control Commission to develop and administer North Carolina's sedimentation and erosion control program. This program is implemented by the DENR, Land Quality Section under the Commission's direction. Authorized local governments or agencies may adopt their own ordinances; however, local programs must be approved by the Commission and must meet or exceed the minimum standards set by the state. If their programs are approved, local governments administer and enforce them. Because these programs vary widely in content and scope, consult the administering agency to avoid violations of local ordinances.

What other activities does the state's program include?

The state assists and encourages local governments and other state agencies to develop their own erosion and sedimentation control programs. The DENR reviews local programs as needed to assure uniform enforcement of the Act.

The state develops educational and instructional materials to demonstrate methods and practices for erosion and sedimentation control.

The state has developed a set of rules pertinent to sedimentation and erosion control. These rules were adopted as Title 15A, Chapter 4 of the North Carolina Administrative Code. The complete text of these rules is provided in *Appendix 8.08 and 8.09.*

2

Processes and Principles of Erosion and Sedimentation

2

Processes and Principles of Erosion and Sedimentation

When land is disturbed at a construction site, the erosion rate accelerates dramatically. Since ground cover on an undisturbed site protects the surface, removal of that cover increases the site's susceptibility to erosion. Disturbed land may have an erosion rate 1,000 times greater than the pre-construction rate. Even though construction requires that land be disturbed and left bare for periods of time, proper planning and use of control measures can reduce the impact of man-induced accelerated erosion.

The major problem associated with erosion on a construction site is the movement of soil off the site and its impact on water quality. Millions of tons of sediment are generated annually by the construction industry in the United States. The rate of erosion on a construction site varies with site conditions and soil types but is typically 100 to 200 tons per acre and may be as high as 500 tons per acre. In N.C., 15% to 32% of eroded soil is transported to valuable water resources (SCS, 1977).

Identifying erosion problems at the planning stage and noting highly erodible areas, helps in selecting effective erosion control practices and estimating storage volumes for sediment traps and basins. This manual focuses primarily on the prevention of sedimentation problems associated with water-generated soil erosion.

THE EROSION AND SEDIMENTATION PROCESS

Types of Erosion

Erosion is a natural process by which soil and rock material is loosened and removed. Erosion by the action of water, wind, and ice has produced some of the most spectacular landscapes we know. Natural erosion occurs primarily on a geologic time scale, but when man's activities alter the landscape, the erosion process can be greatly accelerated. Construction-site erosion causes serious and costly problems, both on-site and off-site.

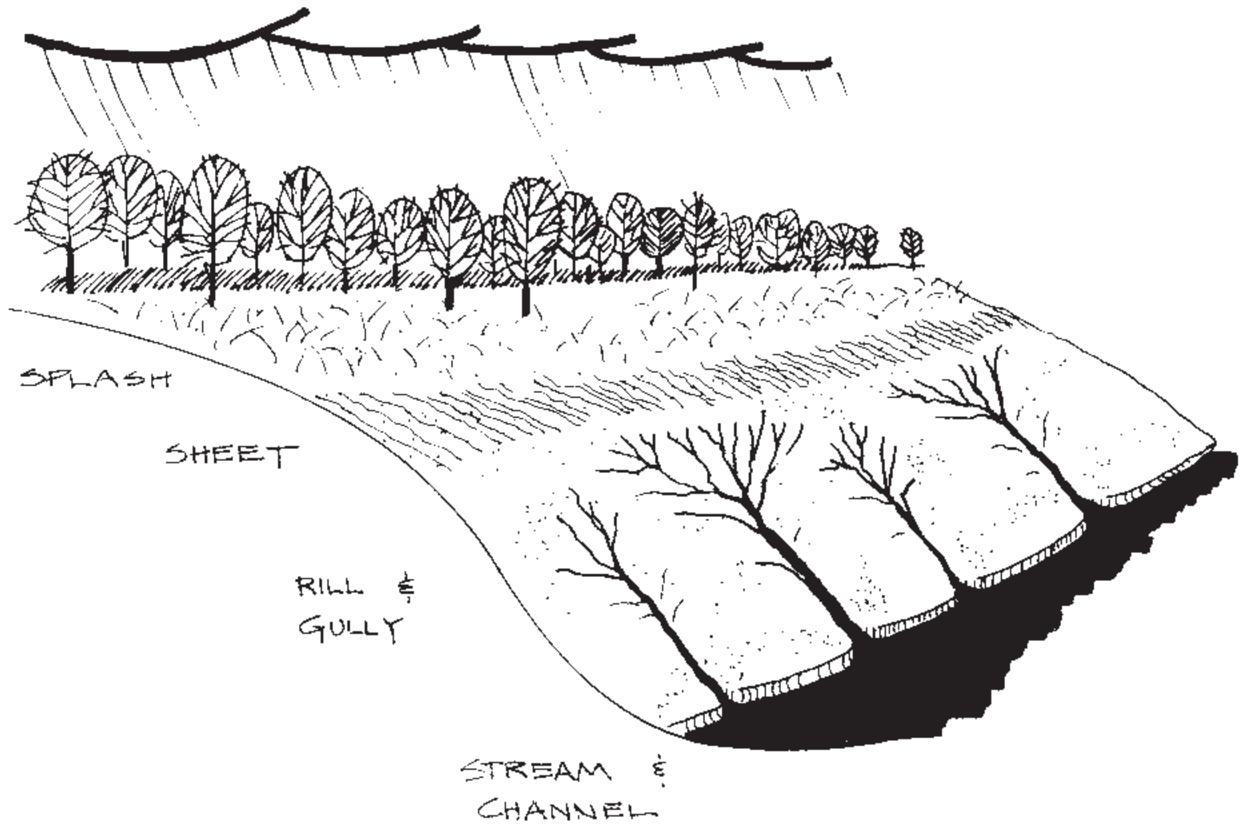


Figure 2.1 The four types of soil erosion on an exposed slope.

The soil erosion process begins by water falling as raindrops and flowing on the soil surface. Figure 2.1 illustrates the four types of soil erosion on exposed terrain: **splash, sheet, rill, and gully**, and **stream and channel**. Splash erosion results when the force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. Sheet erosion occurs when these soil particles are easily transported in a thin layer, or sheet, by water flowing. If this sheet runoff is allowed to concentrate and gain velocity, it cuts rills and gullies as it detaches more soil particles. As the erosive force of flowing water increases with slope length and gradient, gullies become deep channels and gorges. The greater the distance and slope, the more difficult it is to control the increasing volume and velocity of runoff and the greater the resultant damage.

Sedimentation

Sedimentation is the deposition of soil particles that have been transported by water and wind. The quantity and size of the material transported increases with the velocity of the runoff. Sedimentation occurs when the water in which the soil particles are carried is sufficiently slowed for a long enough period of time to allow particles to settle out. Heavier particles, such as gravel and sand, settle out sooner than do finer particles, such as clay. The length of time a particle stays in suspension increases as the particle size decreases. The colloidal clays stay in suspension for very long periods and contribute significantly to water turbidity.

Factors that Influence Erosion

The potential for an area to erode is determined by four principal factors: soils, surface cover, topography, and climate. These factors are interrelated in their effect on erosion potential. The variability in North Carolina's terrain, soils, and vegetation makes erosion control unique to each development.

Understanding the factors that effect the erosion process enables us to make useful predictions about the extent and consequences of on-site erosion. An empirical model developed for agricultural applications, the Universal Soil Loss Equation (USLE), predicts soil loss resulting from sheet and rill erosion. It considers both the effects of erosion control practices and the factors that influence erosion, so it is useful for evaluating erosion problems and potential solutions. The factors that influence erosion are soil characteristics, surface cover, topography, and climate.

Soils

A soil is a product of its environment. The vulnerability of a soil to erosion, known as its erodibility, is a result of a number of soil characteristics, which can be divided into two groups: those influencing infiltration, the movement of water into the ground; and those affecting the resistance to detachment and transport by rainfall and runoff. The soil erodibility factor (K) is a measure of a soil's susceptibility to erosion by water. Key factors that affect erodibility are soil texture, content of organic matter, soil structure, and soil permeability.

Soil texture is described by the proportions of sand, silt, and clay in the soil. High sand content gives a coarse texture, which allows water to infiltrate readily, reducing runoff. A relatively high infiltration rate coupled with resistance to transport by runoff results in a low erosion potential. Soils containing high proportions of silt and very fine sand are most erodible. Clay acts to bind particles and tends to limit erodibility; however, when clay erodes, the particles settle out very slowly.

Because **organic matter**, such as plant material, humus, or manure, improves soil structure, increases water-holding capacity, and may increase the infiltration rate, it reduces erodibility and the amount of runoff.

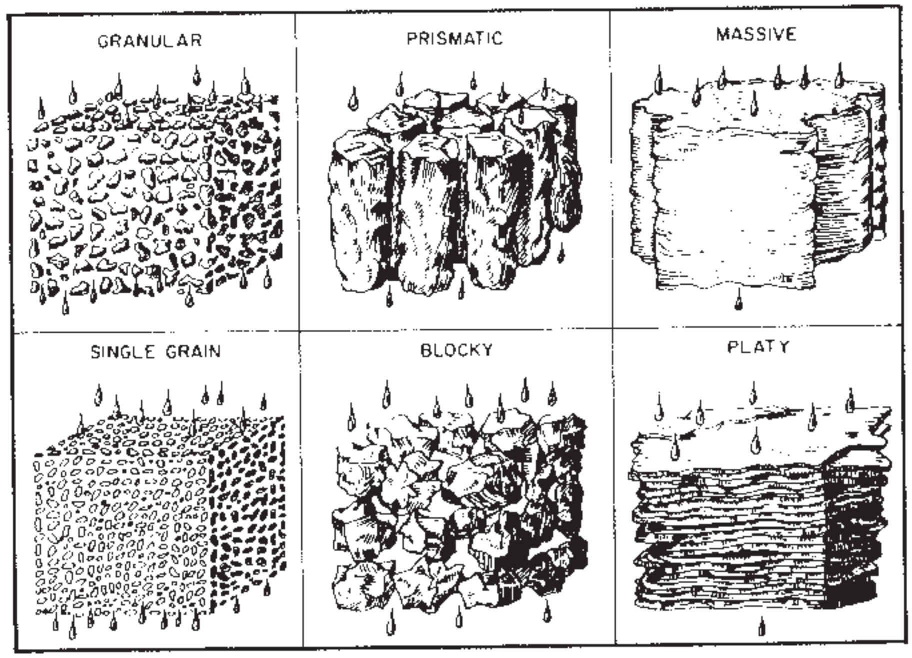
Soil structure is determined by the shape and arrangement of soil particles (Figure 2.2). A stable, sharp, granular structure absorbs water readily, resists erosion by surface flow, and promotes plant growth. Clay soils or compacted soils have slow infiltration capacities that increase runoff rate and create severe erosion problems.

Soil permeability refers to a soil's ability to transmit air and water. Soils that are least subject to erosion from rainfall and shallow surface runoff are those with high permeability rates, such as well-graded gravels and gravel-sand mixtures. Loose, granular soils reduce runoff by absorbing water and by providing a favorable environment for plant growth.

Surface Cover

Vegetation is the most effective means of stabilizing soils and controlling erosion. It shields the soil surface from the impact of falling rain, reduces flow velocity, and disperses flow. Vegetation provides a rough surface that slows the runoff velocity and promotes infiltration and deposition of sediment.

Figure 2.2 Soil structure influences the infiltration rate and movement of water in a soil. (Source: USDA and U.S. Department of the Interior, Agr. Inf. Bul. No. 199, 1959)



Plants remove water from the soil and thus increase the soil's capacity to absorb water. Plant leaves and stems protect the soil surface from the impact of raindrops, and the roots help maintain the soil structure.

The type and condition of ground cover influence the rate and volume of runoff. Although impervious surfaces protect the area covered, they prevent infiltration and thereby decrease the time of concentration for runoff. The result is high peak flow and increased potential for stream and channel erosion (Figure 2.3).

Nonvegetative covers such as mulches, paving, and stone aggregates also protect soils from erosion.

Topography

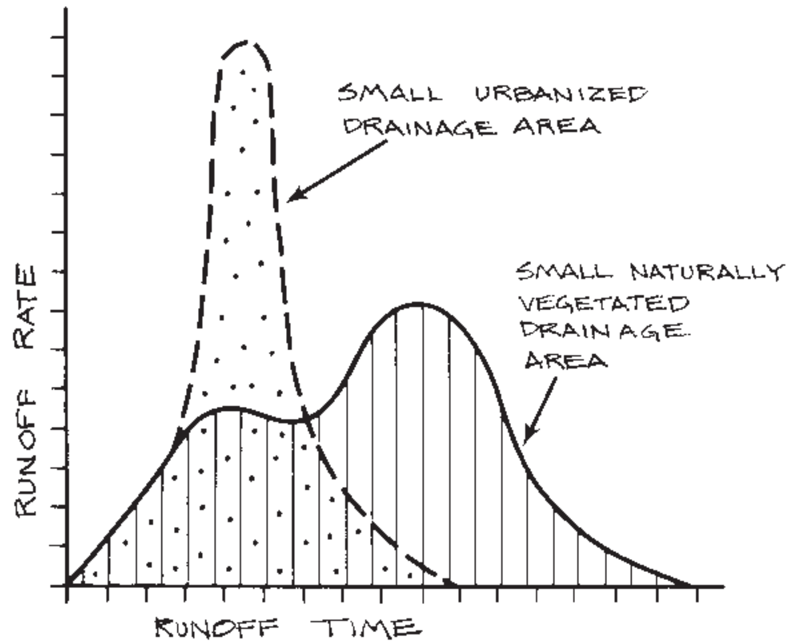
Topographic features distinctly influence erosion potential. Watershed size and shape, for example, affect runoff rates and volumes. Long, steep slopes increase runoff flow velocity. Swales and channels concentrate surface flow, which results in higher velocities. Exposed south-facing soils are hotter and drier, which makes vegetation more difficult to establish.

Climate

North Carolina has considerable diversity of climate. A hurricane season along the coastal region and snow and ice in the mountains are examples of the extremes in weather. High-intensity storms that are common in North Carolina produce far more erosion than low-intensity, long-duration storms with the same runoff volume.

The frequency, intensity, and duration of rainfall and the size of the area on which the rain falls are fundamental factors in determining the amount of runoff produced. Seasonal temperature changes also define periods of high erosion risk. For example, precipitation as snow creates no erosion, but repeated freezing and thawing breaks up soil aggregates, which can be transported readily in runoff from snowmelt.

Figure 2.3 Comparison of runoff in natural and urbanized drainage areas.



Impacts of Erosion and Sedimentation

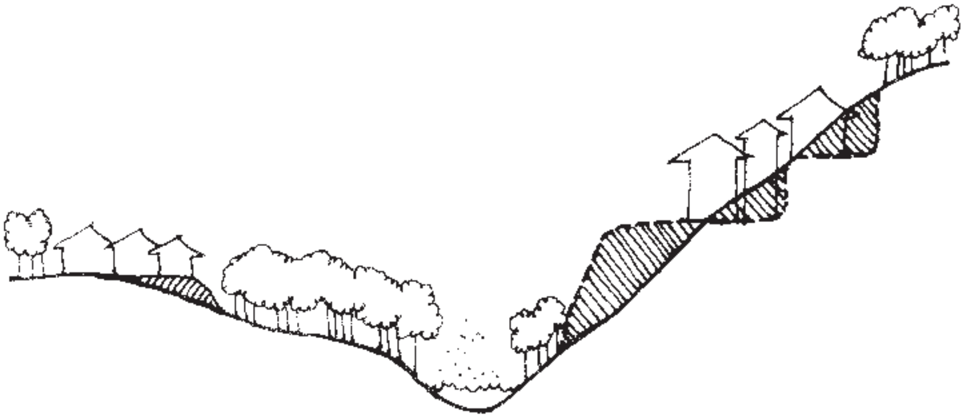
Damage from sedimentation is expensive both economically and environmentally. Sediment deposition destroys fish spawning beds, reduces the useful storage volume in reservoirs, clogs streams, may carry toxic chemicals, and requires costly filtration for municipal water supplies. Suspended sediment can reduce in-stream photosynthesis and alter a stream's ecology. Many environmental impacts from sediment are additive, and the ultimate results and costs may not be evident for years. The consequences of off-site sedimentation can be severe and should not be considered as just a problem to those immediately affected.

On-site erosion and sedimentation can cause costly site damage and construction delays. Lack of maintenance often results in failure of control practices and expensive cleanup and repairs.

PRINCIPLES OF EROSION AND SEDIMENTATION CONTROL

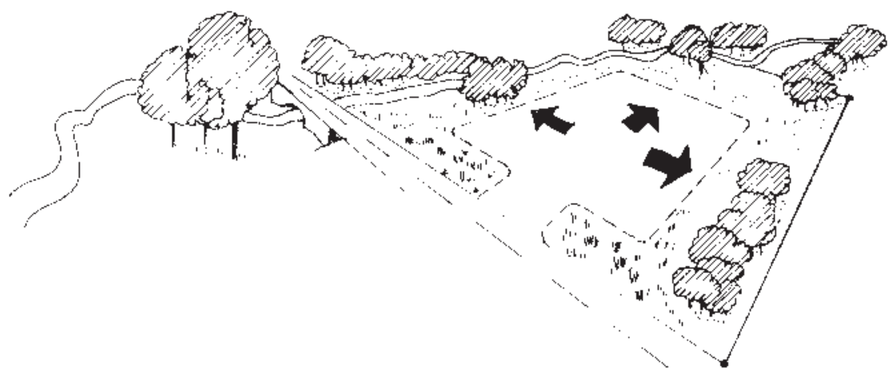
Effective erosion and sedimentation control requires first that the soil surface be protected from the erosive forces of wind, rain, and runoff, and second that eroded soil be capture on-site. The following principles are not complex but are effective. They should be integrated into a system of control measures and management techniques to control erosion and prevent off-site sedimentation.

Fit the Development to Existing Site Conditions



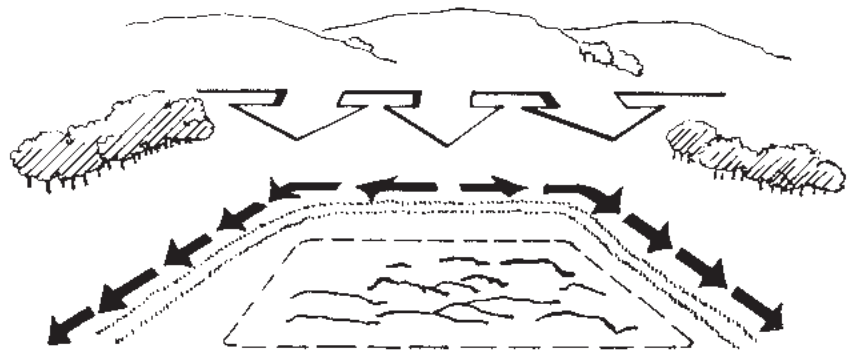
Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. **Any modifications of a site's drainage features or topography requires protection from erosion and sedimentation.**

Minimize the Extent and Duration of Exposure



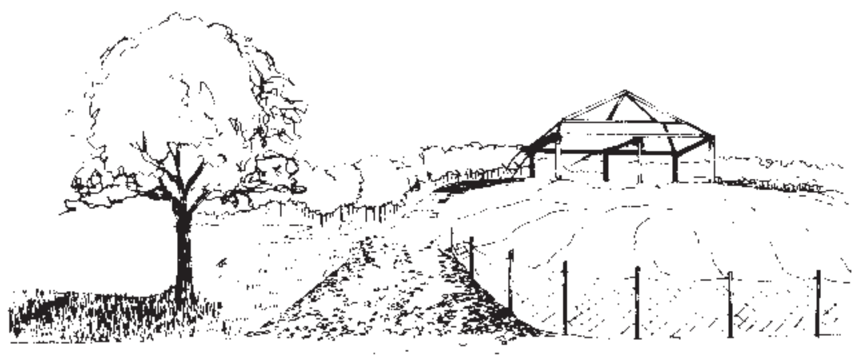
Scheduling can be a very effective means of reducing the hazards of erosion. Schedule construction activities to minimize the exposed area and the duration of exposure. In scheduling, take into account the season and the weather forecast. Stabilize disturbed areas as quickly as possible.

Protect Areas to be Disturbed from Stormwater Runoff



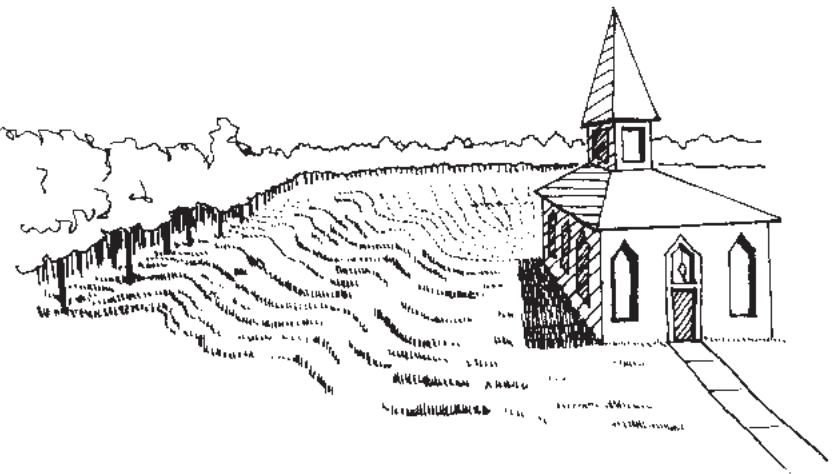
Use dikes, diversions, and waterways to intercept runoff and divert it away from cut-and-fill slopes or other disturbed areas. To reduce on-site erosion, install these measures before clearing and grading.

Stabilize Disturbed Areas



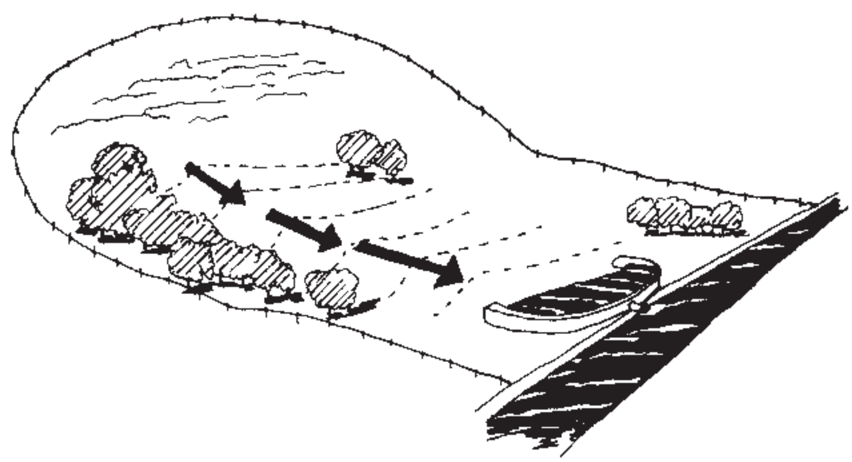
Removing the vegetative cover and altering the soil structure by clearing, grading, and compacting the surface increases an area's susceptibility to erosion. Apply stabilizing measures as soon as possible after the land is disturbed. Plan and implement temporary or permanent vegetation, mulches, or other protective practices to correspond with construction activities. Protect channels from erosive forces by using protective linings and the appropriate channel design. Consider possible future repairs and maintenance of these practices in the design.

Keep Runoff Velocities Low



Clearing existing vegetation reduces the surface roughness and infiltration rate and thereby increases runoff velocities and volumes. Use measures that break the slopes to reduce the problems associated with concentrated flow volumes and runoff velocities. Practical ways to reduce velocities include conveying stormwater runoff away from steep slopes to stabilized outlets, preserving natural vegetation where possible, and mulching and vegetating exposed areas immediately after construction.

Retain Sediment on the Site



Even with careful planning some erosion is unavoidable. The resulting sediment must be trapped on the site. Plan the location where sediment deposition will occur and maintain access for cleanout. Protect low points below disturbed areas by building barriers to reduce sediment loss. **Whenever possible, plan and construct sediment traps and basins before other land-disturbing activities.**

Inspect and Maintain Control Measures

Inspection and maintenance is vital to the performance of erosion and sedimentation control measures. If not properly maintained, some practices may cause more damage than they prevent. Always evaluate the consequences of a measure failing when considering which control measure to use, since failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can cause major gullies to form on a fill slope. It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop. Assign an individual responsibility for routine checks of operating erosion and sedimentation control practices.

3

Vegetative Considerations

3

Vegetative Considerations

EFFECTS OF VEGETATION ON EROSION, SEDIMENTATION, AND PROPERTY VALUE

Dense, vigorous vegetation protects the soil surface from raindrop impact, a major force in dislodging soil particles and moving them downslope. It also shields the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity.

The shielding effect of a plant canopy is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. Plants also reduce the moisture content of the soil through transpiration, thus increasing its capacity to absorb water (Figure 3.1)

Suitable vegetative cover affords excellent erosion protection and sedimentation control and is essential to the design and stabilization of many structural erosion control devices. Vegetative cover is relatively inexpensive to achieve and tends to be self-healing; it is often the only practical, long-term solution to stabilization and erosion control on most disturbed sites in North Carolina.

Planning from the start for vegetative stabilization reduces its cost, minimizes maintenance and repair, and makes structural erosion control measures more effective and less costly to maintain. Post-construction landscaping is also less costly where soils have not been eroded, slopes are not too steep, and weeds are not allowed to proliferate. Natural areas—those left undisturbed—can provide low-maintenance landscaping, shade, and screening. Large trees increase property value if they are properly protected during construction.

Besides preventing erosion, healthy vegetative cover provides a stable land surface that absorbs rainfall, cuts down on heat reflectance and dust, restricts weed growth, and complements architecture. The result is a pleasant environment for employees, tenants and customers, and an attractive site for homes. Property values can be increased dramatically by small investments in erosion control. Even the final landscaping represents only a small fraction of total construction costs and contributes greatly to the marketing potential of a development.

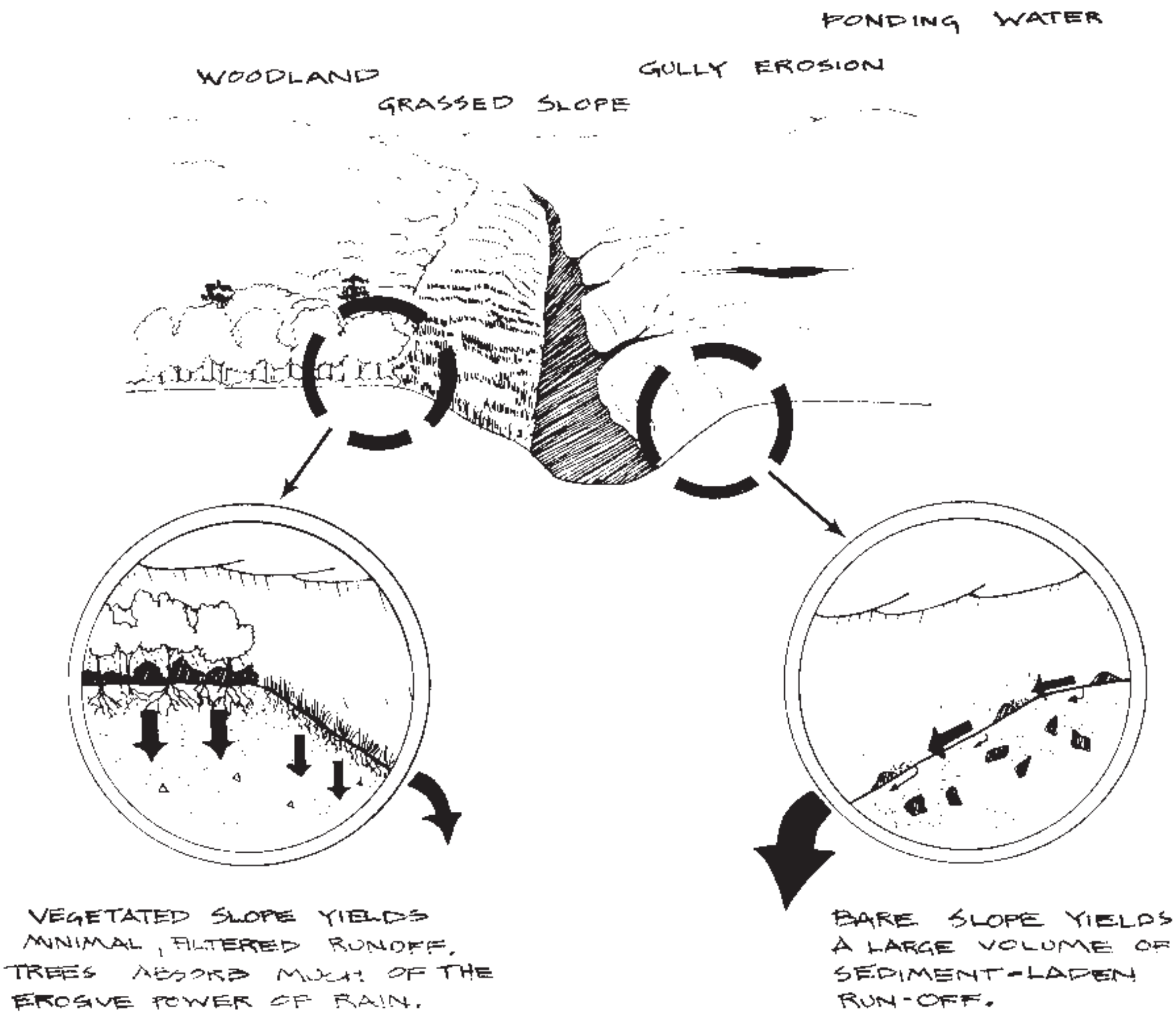


Figure 3.1 Effects of vegetation on erosion.

SITE CONSIDERATIONS

Species selection, establishment methods, and maintenance procedures should be based on site characteristics including soils, slope, aspect, climate, and expected management.

Slope

The steeper the slope, the more essential is a vigorous vegetative cover. Good establishment practices, including seedbed preparation, quality seed, lime, fertilizer, mulching and tacking are critical. The degree of slope may limit the equipment that can be used in seedbed preparation, planting, and maintenance; steep slopes also increase costs.

Aspect

Aspect affects soil temperature and available moisture. South-and west-facing slopes tend to be warmer and drier, and often require special treatment. For example, mulch is essential to retain moisture, and drought-tolerant plant

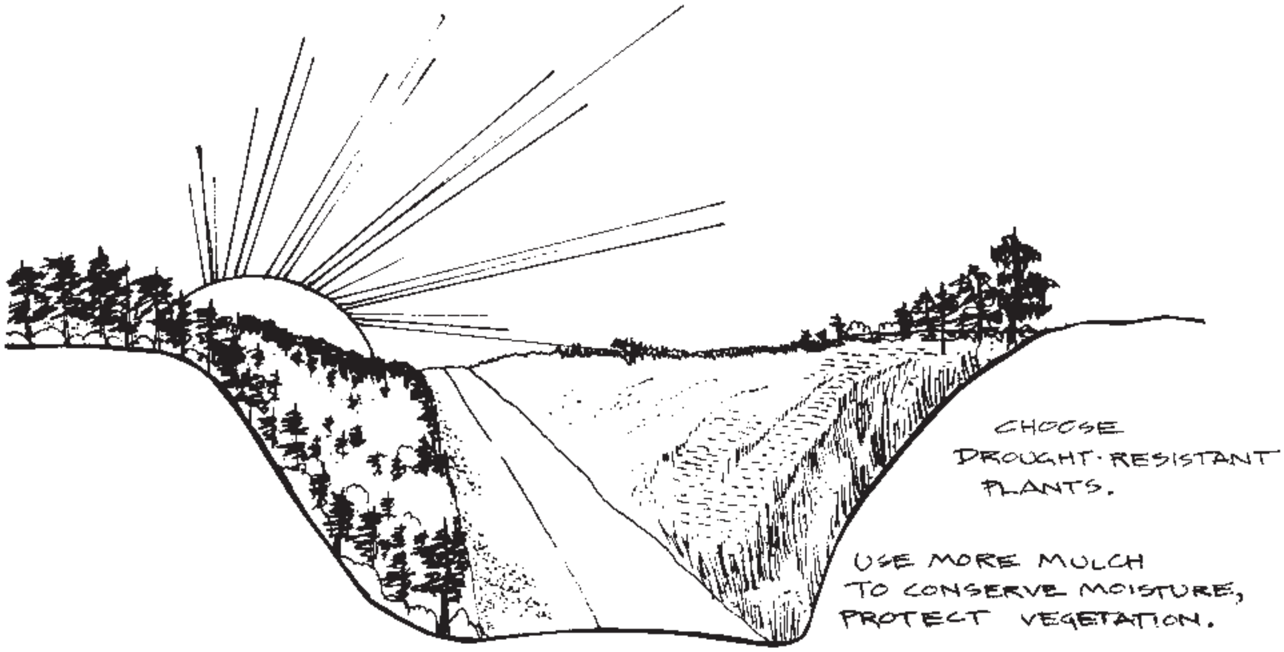


Figure 3.2 South- and west-facing slopes are hot and dry.

species should be added to the seed mixture (Figure 3.2). South- and west-facing slopes also may be subject to more frost heaving due to repeated cycles of freezing and thawing.

Climate

The regional climate must be considered in selecting well-adapted plant species. North Carolina recommendations are usually based on three broad physiographic regions: Mountain, Piedmont, and Coastal Plain. Climatic differences determine the appropriate plant selections based on such factors as cold-hardiness, tolerance to high temperatures and high humidity, and resistance to disease.

Management

When selecting plant species for stabilization, consider post-construction land use and the expected level of maintenance. In every case, future site management is an important factor in plant selection.

Where a neat appearance is desired, use plants that respond well to frequent mowing and other types of intensive maintenance. Likely choices for quality turf in the west are tall fescue, Kentucky bluegrass, and Bermudagrass, or in the east, Bermudagrass, centipedegrass, zoysiagrass, and Bahiagrass.

At sites where low maintenance is desired, longevity is particularly important. Sericea lespedeza, tall fescue, annual lespedeza, and, in some cases, Bermudagrass, redtop, or crownvetch are likely choices. Other species may be appropriate to intermediate levels of maintenance.

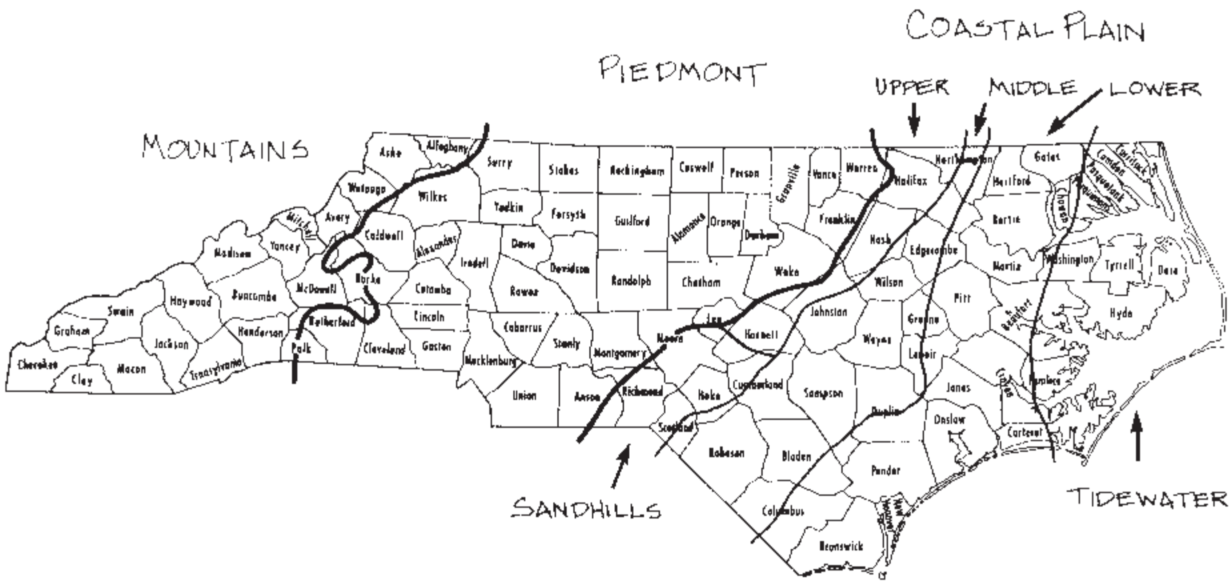


Figure 3.3 Major physiographic regions of North Carolina differ in relief, geology, climate, elevation, and major soil systems.

Soils

Many soil characteristics— including texture, organic matter, fertility, acidity, moisture retention, drainage, and slope—influence the selection of plants and the steps required for their establishment. The following is a very general description of North Carolina soils with respect to characteristics that affect stabilization of disturbed sites. Soil formation in North Carolina has been influenced primarily by parent materials and relief. As a result, soils differ among the major physiographic regions shown in Figure 3.3.

Mountain Region

Surface soils of the Mountain Region vary from sandy loam to clay loam, with shallow subsoils varying from silt loams to sandy loams. Steep slopes with shallow, stony, droughty soils are common. Many mountain soils have been severely eroded. On more level topography, deeper profiles provide greater water-storage capacity and room for root growth. Shallow, stony soils and steep slopes present major problems for vegetation establishment in this region. Permanent vegetation is normally selected from cool-season, winter-hardy perennials.

Piedmont Region

Piedmont soils are similar to those of the Mountains but, in general, are deeper, lower in organic matter, and have subsoils higher in clay. Deeper subsoils are typically silts, silt loams, and sandy loams. Surface soils vary from sandy loam to clay loam, and subsoils are commonly thick with heavy clay texture. While topography is gentler than in the Mountains, it is mostly rolling to hilly, with well-developed drainage patterns. Soils are generally well to excessively drained.

The sloping terrain and silty subsoils often result in severe erosion potential. As a result of previously poor management practices, many areas are moderately to severely eroded.

Piedmont soils generally support a wide variety of plants, including both cool- and warm-season species. Sites that are steep, shallow, stony, droughty, or severely eroded present problems for establishment of vegetation.

Coastal Plain Region

Coastal Plain soils include some of the easiest and some of the most difficult soils to vegetate. The Coastal Plain region has several different subregions to consider.

The Sand Hills region of the Coastal Plain is dominated by coarse, deep, excessively drained sand and rolling topography. These soils are extremely low in organic matter and plant nutrients. When disturbed, they are subject to both wind and water erosion. These are some of the most erodible soils in the State and need to be treated with the utmost caution. Due to their low water-holding capacity, revegetation requires highly drought-resistant species.

Upper and Middle Coastal Plain soils generally have well-drained sandy loam surface horizons underlain by sandy clay loam subsoils. Topography is undulating to nearly level. These soils retain more moisture and nutrients than the sands of the Sand Hills and coastal dunes, and support a wider variety of vegetation. However, they are still quite erodible when disturbed. The region also includes some poorly drained soils and some excessively drained "Sand Hills" soils.

Lower Coastal Plain soils vary from well-drained to poorly drained and from sand to silt loam in texture. The coarser soils are extremely erodible. Poorly drained soils ranging from sands to organics are limited in extent. Along the southern coast both old and young dune sands occur. Choice of species for revegetation is largely determined by moisture retention and drainage conditions. Dune sands require a unique group of species.

The Tidewater Region is dissected by sounds and numerous wide rivers. Soils may be wet and mostly organic or mineral soils with high clay content. Draining these soils can be difficult. The organic mucks and peats are most often underlain by sand, but may have silt or clay subsoils.

Nature of Disturbed Soils

Throughout the State, most disturbed sites end up, after grading, with a surface consisting of acid, infertile subsoil materials that are toxic to most plants (Figure 3.4). Such soils may not be capable of supporting the dense growth necessary to prevent erosion. Construction activities further decrease soil productivity by increasing compaction, making slopes steeper, and altering drainage patterns. Topsoiling, soil amendments, and special seedbed preparation are generally required to offset these problems.

Soil Sampling

A good sedimentation control plan should include thorough soil sampling in the area of planned construction. Different soils should be sampled separately. Containers for soil samples and instructions for sampling may be obtained from any local Agricultural Extension office or from the North Carolina Department of Agriculture. Analysis of soil samples is available from the NCDA soil testing lab. Test results include lime and fertilizer recommendations. Fertilizing

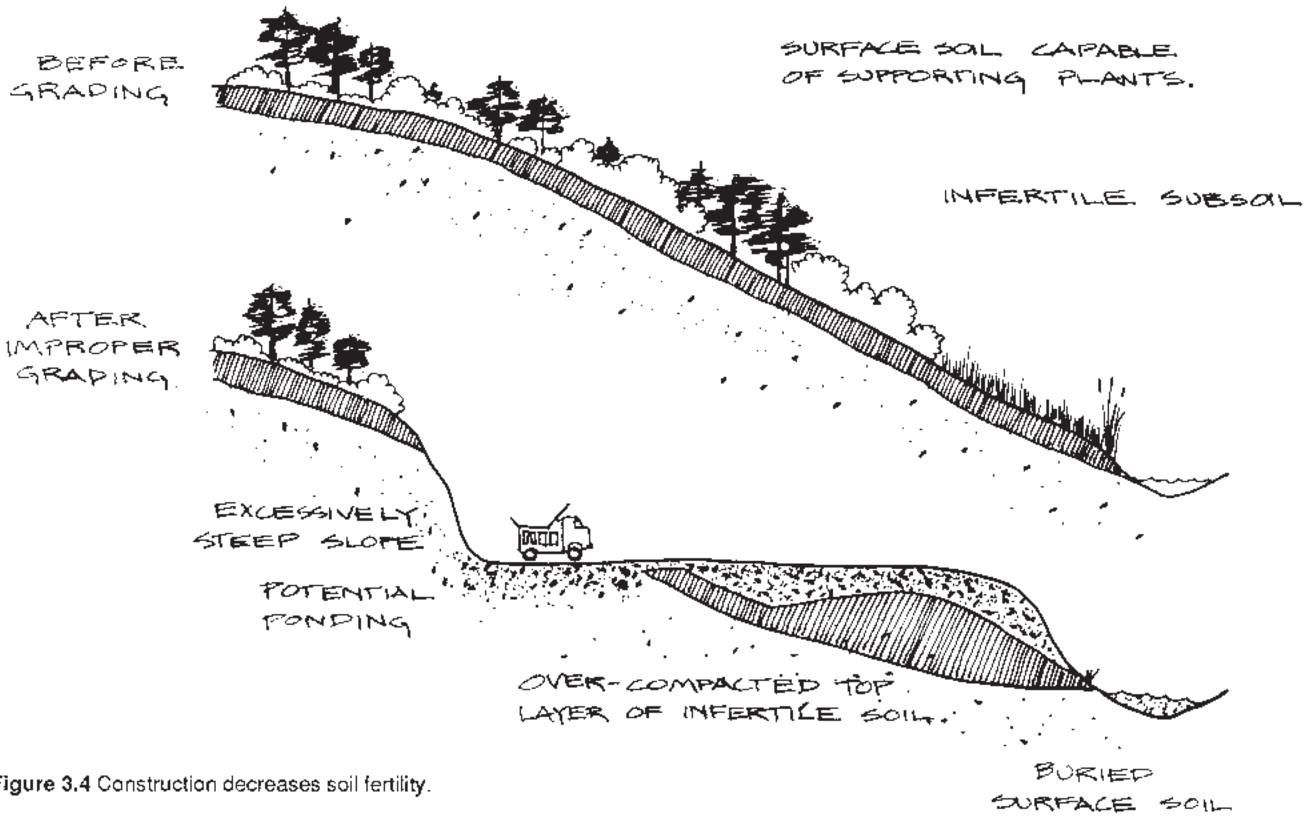


Figure 3.4 Construction decreases soil fertility.

according to the soil test ensures the most efficient expenditure of money for fertilizer and a minimum of excess fertilizer to pollute streams or groundwater. Soil sampling should begin well in advance of planting because 1 to 6 weeks are required to obtain soil test results.

Soil Limitations

Certain soil factors are difficult to modify and can impose severe limitations on plant growth. These include such things as depth, stoniness, texture, and properties related to texture such as water- and nutrient-holding capacity. Extremely coarse textures result in droughtiness and nutrient deficiencies. Fine textures, on the other hand, impede infiltration and decrease permeability, thereby increasing the volume of runoff. Toxic levels of elements such as aluminum, iron, and manganese are limiting to plant growth. However, these become less soluble as the pH is raised, so that toxicity problems can usually be eliminated by liming. Toxicities from industrial waste could also make the soil unsuitable for plant growth.

Portions of this manual refer to “poor” , “severe”, “droughty”, and “adverse” soils. These are subjective terms that require judgement based on experience in revegetating disturbed soils. They refer to soils that require special treatment beyond routine tillage and fertilization. *Appendix 8.01* provides guidance for identifying soils and predicting their characteristics.

SEASONAL CONSIDERATIONS

Newly constructed slopes and other unvegetated areas should be seeded and mulched, or sodded, as soon as possible after grading. Where feasible, grading operations should be planned around optimal seeding dates for the particular region. The most effective times for planting perennials generally extend from March through May and from August through October. Outside these dates the probability of failure is higher. If the time of year is not suitable for seeding permanent cover (perennial species), a temporary cover crop should be planted. Otherwise, the area must be stabilized with gravel or mulch. Temporary seeding of annual species (small grains, Sudangrass, or German millet) often succeeds at times of the year that are unsuitable for seeding permanent (perennial) species. Some annual species may be recommended for late winter through spring, summer, or late summer late fall. Planting dates differ with physiographic region.

Seasonality must be considered when selecting species. Grasses and legumes are usually classified as warm- or cool-season in reference to their season of growth. Cool-season plants produce most of their growth during the spring and fall and are relatively inactive or dormant during the hot summer months. Therefore fall is the most dependable time to plant them. Warm-season plants greenup late in the spring, grow most actively during the summer, and go dormant at the first frost in fall. Spring and early summer are preferred planting times for warm-season plants.

Variations in weather and local site conditions can modify the effects of regional climate. For this reason, mixtures including both cool- and warm-season species are preferred for low-maintenance cover, particularly in the Piedmont. Such mixtures promote cover adapted over a range of conditions. These mixtures are not desirable, however, for high-quality lawns, where variation in texture of the turf is inappropriate.

SELECTION OF VEGETATION

Species selection should be considered early in the process of preparing the erosion and sedimentation control plan. A diversity of vegetation can be grown in North Carolina, due to the variation in both soils and climate. However, for practical, economical stabilization and long-term protection of disturbed sites, species selection should be made with care. Many widely occurring plants are inappropriate for soil stabilization because they do not protect the soil effectively, or because they are not quickly and easily established. Plants that are preferred for some sites may be poor choices for others; a few can become troublesome pests.

Initial stabilization of most disturbed sites requires grasses and legumes that grow together without gaps. This is true even where part or all of the site is planted to trees or shrubs. In landscape plantings, disturbed soil between trees and shrubs must also be protected either by mulching or by permanent grass-legume mixtures. Although mulching alone is an alternative, it requires continuing maintenance.

Mixture vs Single-Species Plantings

Single-species plantings are warranted in many cases, but they are more susceptible than mixtures to damage from disease, insects, and weather extremes. In addition, mixtures tend to provide protective cover more quickly. Consequently, the inclusion of more than one species should always be considered for soil stabilization and erosion control. Mixtures need not be elaborate. The addition of a quick-growing annual provides early protection and facilitates establishment of one or two perennials. More complex mixtures might include a quick-growing annual, one or two legumes, and one or two perennial grasses (*Practice Standards and Specifications: 6.11, Permanent Seeding*).

Companion or "Nurse" Crops

The addition of a "nurse" crop (quick-growing annuals added to permanent mixtures) is a sound practice for soil stabilization, particularly on difficult sites—those with steep slopes; poor, stony, erosive soils; late seedings, etc.—or in any situation where the development of permanent cover is likely to be slow. The nurse crop germinates and grows rapidly, holding the soil until the slower-growing perennial seedlings become established (Figure 3.5). Nurse crop recommendations are included in *Practice Standards and Specifications: 6.11, Permanent Seeding*.

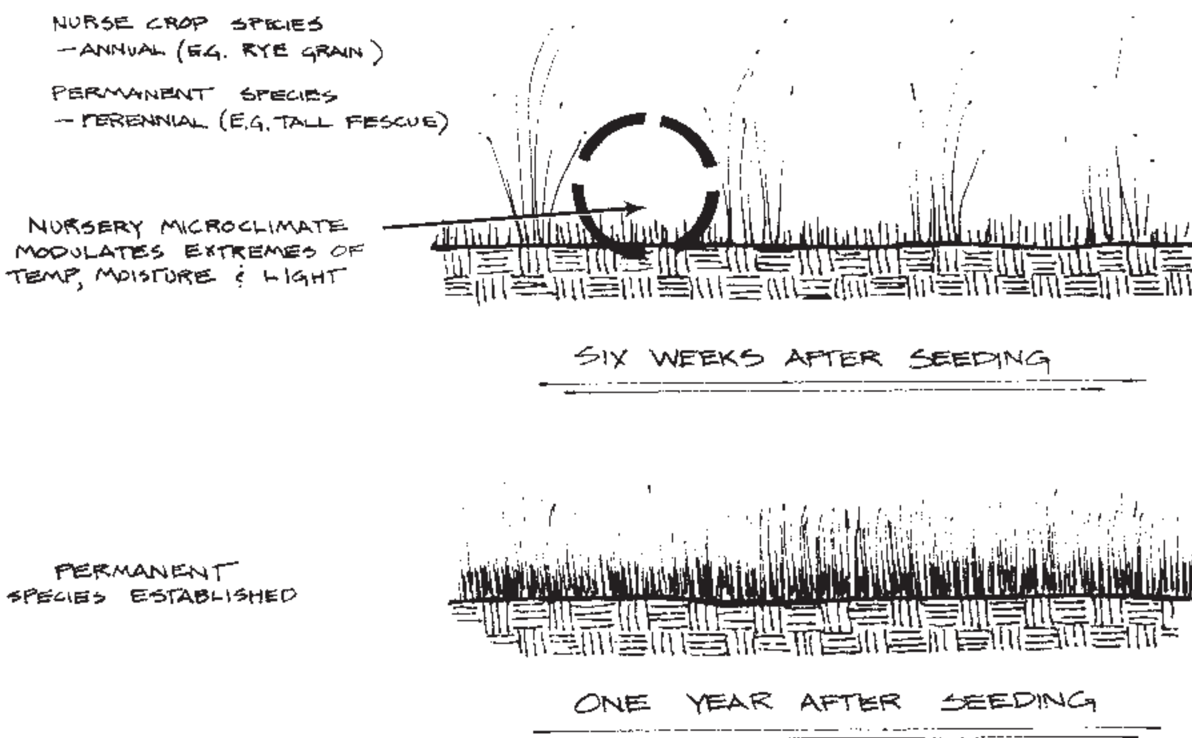


Figure 3.5 Nurse crops promote the establishment of permanent species.

Seeding rate of the nurse crop must be limited to avoid crowding, especially under optimum growing conditions. Seeding rates recommended in this manual are designed to avoid overcrowding. **Do not exceed the recommended rate.**

Plants Species Selection

Table 3.1 is a summary of the major plant species available for stabilization use in North Carolina. This summary is based on research and many years of field experience. Using this information makes plant selection straightforward for most situations. Recommended plants and some of more limited application are listed in Table 8.02a, *Appendix 8.02*, along with their botanical names. Specific seeding rates are given in *Practice Standards and Specifications: 6.10, Temporary Seeding*, and *6.11, Permanent Seeding*.

Annuals

Annual plants grow rapidly and then die in one growing season. The are useful for quick, temporary cover or as nurse crops for slower-growing perennials.

Winter rye (grain) is usually superior to other winter annuals (wheat, oats, crimson clover, etc.) both for temporary seeding and as a nurse crop in permanent mixtures. It has more cold-hardiness than other annuals and will germinate and grow at lower temperatures. By maturing early, it offers less competition during the late spring period. a critical time in the establishment of perennial species. Rye grain germinates quickly and is tolerant of poor soils. Including rye grain in fall-seeded mixtures is almost always advantageous. but it is particularly helpful on difficult soils and erodible slopes or when seeding is late. Overly thick stands of rye grain will suppress the growth of perennial seedlings. **Limit seeding rates to the suggested level.** About 50 lb/acre is the maximum for this purpose, and where lush growth is expected, that rate should either be cut in half, or rye grain should be eliminated from the mixture.

Table 3.1 Plants Recommended for Revegetating Disturbed Soils in North Carolina

	Annuals	Perennials
Cool-season grasses	Winter rye (grain)	Tall fescue Kentucky bluegrass Creeping Bentgrass Deertongue Indian Grass Indian Seaoats Viginia Wild Rye
Warm-season grasses	German millet Sudangrass	Bermudagrass Bahiagrass Big Bluestem Centipedegrass Little Bluestem Switchgrass
Legumes	Annual lespedeza Partridge Pea	Crownvetch Sericea lespedeza Roundhead lespedeza
Marsh plants		Smooth cordgrass Saltmeadow cordgrass Giant cordgrass
Dune plants		American beachgrass Sea oats Bitter panicum Saltmeadow cordgrass

Annual ryegrass is **not recommended** for use in North Carolina (Figure 3.6). It provides dense cover rapidly, but may be more harmful than beneficial in areas that are to be permanently stabilized. Annual ryegrass is highly competitive, and if included in mixtures, it crowds out most other species before it matures in late spring or early summer, leaving little or no lasting cover. It can be effective as a temporary seeding, but if allowed to mature the seed volunteers and seriously interferes with subsequent efforts to establish permanent cover. Winter rye (grain) is preferable in most applications.

German millet is a fine-stemmed summer annual, useful for temporary seeding, as a nurse crop, and for tacking mulch. It is better adapted to sandy soils than are the Sudangrasses. Normal seeding dates are between the last frost in spring and the middle of August.

Sudangrass—Only the small-stemmed varieties of Sudangrass should be used. Like German millet, Sudangrass is useful for temporary seeding and as a nurse crop, but it is adapted to soils higher in clay content. Seed for common Sudangrass is not always available, but other small-stemmed types may be used, such as the hybrid Trudan. **The coarse-stemmed sorghum-Sudangrass hybrids are not satisfactory as nurse plants and are not appropriate for erosion control**. Seeding dates are similar to those for German millet.

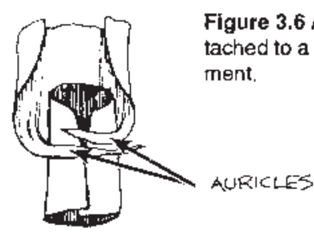


Figure 3.6 Annual ryegrass is recognized by flowers directly attached to a central stem and claw-like auricles at the leaf attachment.

Annual lespedeza is a warm-season, self-reseeding annual legume that is tolerant of low fertility and is adapted to climate and most soils throughout the state. It is an excellent nurse crop in the spring, filling in weak or spotty stands the first season without suppressing the perennial seedlings. It is often seeded with sericea lespedeza. Annual lespedeza can heal damaged areas in the perennial cover for several years after initial establishment. Two varieties of annual lespedeza are generally available: Kobe and Korean. Kobe is superior on sandy soils and generally preferable in the Coastal Plain. Both Kobe and Korean are satisfactory in the Piedmont. Korean is better in the mountains as the seeds mature earlier.

The preferred seeding dates for annual lespedeza are in late winter to early spring. It can be mixed with fall seedings. In which case some seeds remain dormant over the winter and germinate the following spring. However, it is more effective to overseed with lespedeza in February or March.

Partridge pea, *Chamaecrista fasciculate,* is an annual erect legume plant that reaches a height of 1 to 3 feet. The plant can be used along road banks and stream banks to control erosion. Partridge pea most commonly occurs as a pioneer or colonizer of disturbed areas. **Although partridge pea foliage is nutritious, it can be poisonous and should be considered potentially dangerous to cattle**. Drill seeds at 1/4 to 3/4 inch deep at a rate of 10 lbs/ac pure live seed.

If the seed is broadcast, increase seeding rate and cover seed by lightly disking or by cultipacking. Planting should be conducted late winter (March) to late spring (May) while soil moisture is still high. Germination is improved by scarification of the seed prior to planting. Seed should also be inoculated with the correct species of *Rhizobium* before planting. Fertilizer should be applied at the recommended rate, based on soil samples, at time of planting.

Cool-Season Perennials

Perennial plants remain viable over winter and initiate new growth each year. Stands of perennials persist indefinitely under proper management and environmental conditions. They are the principal components of permanent vegetative cover.

Cool-season perennials produce most of their growth during the spring and fall and are more cold-hardy than most warm-season species. Descriptions of the species recommended for vegetating disturbed soils follow.

Creeping Bentgrass is a tough, cool-season perennial grass tolerant of infertile, droughty, somewhat acid soils. It can be a useful component of mixtures on dry, stony slopes in the western half of the state, particularly in the Mountain region.

Deertongue, *Dichanthelium clandestinum,* is a native perennial, warm season grass that reaches a height of one to three feet. It grows well on non-cultivated soil. Because of its tolerance to low pH, high concentrations of aluminum, and droughty infertile conditions, it is commonly found to volunteer on such sites. Deertongue should be seeded as early as possible in the spring. Seed dormancy is easily overcome when deertongue is planted during cool weather, so that natural stratification in the soil will occur. If the site conditions restrict early spring planting, it is advisable to sow seed in the late fall or early winter, while dormant. On sites where conventional farm equipment can operate, prepare seedbed as normal for a pasture planting. Use a grain or grass drill; do not place seed deeper than one inch. In sand and gravel pits, the method of choice is to broadcast, then 'track' the seed with lime and fertilizer in with a bulldozer. Hydroseed steep or rough areas, but expect this method to result in less success than those outlined above. Expect slow establishment of seedings. Deertongue is most often planted in mixtures with other warm season grasses such as switchgrass with the total rate of 12-15 pounds per acre. Typically, deertongue does not exceed 3 pounds of the per-acre mix.

Eastern Bottlebrush Grass, *Elymus hystrix,* is a perennial bunch grass that grows 2 to 5 feet tall. It is useful for riparian plantings, preferring shade and moist soils. It is closely related to Virginia Wildrye, which is described below.

Kentucky bluegrass is the dominant lawn grass in the Mountains and Upper Piedmont. It has higher lime and fertility requirements than the other perennial grasses used in these regions. Bluegrass spreads by strong rhizomes and, where adapted, is an excellent soil stabilizer, readily filling in damaged spots. As with tall fescue, it has been the subject of intensive breeding activity in recent years, resulting in varieties with more heat tolerance and resistance to hot-weather diseases. Mixtures of these new varieties with improved types of tall fescue are becoming popular, particularly for Piedmont lawns, where they can be used in both sun and partial shade.

Tall fescue, a cool-season grass, is the most widely used species in the state for erosion control (Figure 3.7). It is well-adapted to all but the most droughty soils of the Sand Hills and Coastal Plain. It thrives in full sun to partial shade and is easy to establish. If seeded in the fall, it provides stabilization early in the first growing season. Because of tall fescue's bunchy growth habit, it is best used in mixtures. It does not fill in well where areas are damaged by disease or weather; however, short rhizomes enable individual plants to expand substantially in thin stands.

A number of new varieties of tall fescue are becoming available for lawn and other fine turf use and several offer definite improvements. However, their higher cost over the old standby, KY31, is seldom justified solely for purposes of stabilization and erosion control. Tall fescue tolerates a wide range of seeding dates, but, with the possible exception of high mountain elevations, it is most dependable when fall-planted. It is adapted to both high- and low-maintenance uses, tolerating frequent or no mowing. Liberal fertilization and proper liming are essential for prompt establishment of tall fescue, but once firmly in place it can tolerate minimal maintenance almost indefinitely.

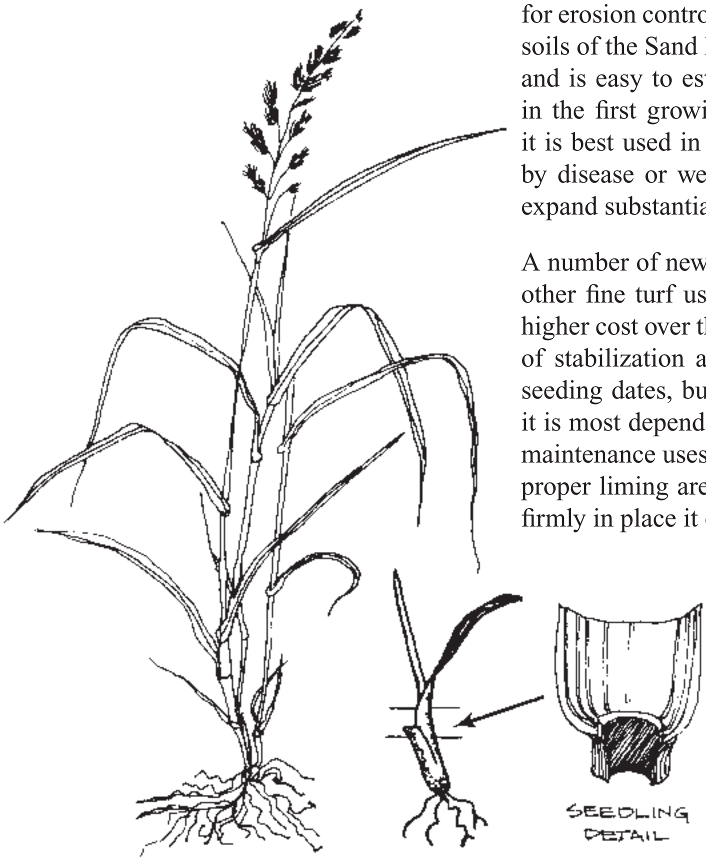


Figure 3.7 Tall fescue is a common perennial easily confused with ryegrass. Seedhead is branched, loose and open. Auricles are absent in young plants (compare with Figure 3.6).

Fox Sedge *Carex vulpinoidea,* is a perennial, clump-forming grass that grows to be 12 to 40 inches tall and spreads up to 24 inches wide. It is a pioneer species that colonizes wet open sites soon after disturbance. It grows in full sun to part shade and likes normal to wet soils. It is most abundant in clayey soils, but also does well in sand and loam. It is planted in locations that remain moist, near streams, springs, ponds, and moist woods. It is an excellent colonizer of wetland mitigation sites. Fox sedge seedlings should be spaced 1 to 2 feet apart. This converts to approximately 1000 roots per acre.

Indiangrass, *Sorghastrum nutans,* is a native, perennial, warm-season grass, and a major component of the tall grass vegetation which once dominated the prairies of the central and eastern United States. Indiangrass grows 3 to 5 feet tall. Indiangrass can be used on critical-area seeding, for roadside cover, and on areas subject to wind erosion. It grows best in deep, well-drained floodplain soils. However, it is highly tolerant of poorly to excessively well-drained soils, acid to alkaline conditions, and textures ranging from sand to clay. The optimum time to plant is from early May to late June. If seed is drilled for solid stands, use 6 to 8 pounds per acre rate PLS (pure live seed). For broadcast seedings, the rate should be between 12 and 15 pounds per acre. Seeding depth is ¼ inch. If seed is broadcast or hydroseeded, it is important to "incorporate" the seed by tracking with a heavy machine to improve the seed to soil contact.

Indian Seaoats, (Indian Woodoats) *Chasmanthium latifolium,* is a native, rhizomatous perennial often found in small colonies. The leaf shape and size are similar to many of the larger species of panic (*Panicum* species) grasses. The height of this grass and the inflorescence (seed cluster) somewhat resemble domestic oats; thus, the common name "wood, creek, or sea oats." It inhabits areas along streams and water banks, shaded slopes and bottomland hardwoods. It is never found on droughty sites.

Rice Cutgrass, *Leersia oryzoide,* is a native cool season grass that grows and flowers comparatively late in summer. Rice cutgrass is valuable for wildlife habitat improvement, wetland restoration, and erosion control in ditches and other watercourses. This plant's creeping rhizomes and spreading habit are good for sediment stabilization along the immediate shorelines of streams and lakes. Tolerant of highly acidic conditions (pH=3), the species is being studied for use in constructed wetlands and the treatment of acid mine drainage. Rice cutgrass can be found in a variety of wet, sunny, and partially shaded sites. Late summer or early fall seeding is recommended. Seeds will germinate the following spring. A seeding rate of 1 lb/acre of pure live seeds will result in 8 live seeds per square foot. Rarely sown alone due to cost, it typically comprises 1 to 20% of a seed mix.

Shallow Sedge, *Carex lurida,* is found in wet meadows, marshes, seeps, shores of ponds, lakes, and streams, open swamp forests, ditches, mostly in acidic, often sandy soils. Its grass-like leaves grow up to 3' tall from short stout rhizomes. The seedheads resemble small sweetgum balls but do not grow above the foliage. This sedge is less prone to summer dieback and remains attractive during warm weather. The sedge grows best in wet to moist soil in full sun to partial shade. It is used in water gardens and establishing native plants in wet meadows, swampy areas, or around bodies of water.

Soft Rush, (Common Rush) *Juncus effusus* is a slow spreading, clump forming, grass-like perennial which emerges from a stout branching rootstock. New shoots emerge and develop in late summer, reaching up to 4 feet tall at maturity the following spring. The dense stands that soft rush form have deep fibrous root systems, which provide very good shoreline protection, filtration, and nutrient up-take. It inhabits fresh to brackish marshes, swamps, ditches, and moist seasonal wetlands and meadows. Soft rush is tolerant of diverse site conditions, but thrives in direct sun, finely textured soils, pH from 4.0 to 6.0, and shallow water (less than 6 inches).

Sweet Woodreed, *Cinna arundinacea,* is a perennial bunch grass that grows to almost 5 feet in height. It is most common in moist woodlands and swamps, depressions, along streams, and in floodplain and upland woods, and is less frequent in wet meadows, marshes, and disturbed sites. It flowers in late summer to fall. It is shade tolerant and prefers moist soils.

Virginia wildrye, *Elymus virginicus,* is a native, cool season, perennial bunchgrass that grows two to three feet in height. Virginia wildrye prefers moist soils, high soil fertility, heavier soil textures, and it is shade tolerant. It can be found scattered on shaded banks, along fencerows and in open woodlands. Virignia wildrye can be drilled at a minimum of 10 pounds of pure live seed per acre, or broadcast at 20 pounds of pure live seed per acre. If it is a critical area planting or if dense coverage is desired, double the seeding rate. When including Virginia wildrye in a seed mixture, reduce the seeding rate accordingly.

Warm-Season Perennials

Warm-season perennials initiate growth later in the spring than cool-season species and experience their greatest growth during the hot summer months. Warm-season species are not generally used in the Mountains; most species thrive only in areas on the Coastal Plain. The following grasses have proven the most useful for soil stabilization.

Bermudagrass is an aggressive, sod-forming warm-season perennial adapted to a wide range of well-drained to excessively drained soils throughout the Piedmont and Coastal Plain. It is very drought-resistant, has considerable salt-tolerance, and can be very useful for erosion control, particularly on deep sands in the Sand Hills and near the coast. Bermudagrass is not at all shade tolerant.

Figure 3.8 Common Bermudagrass.

Common Bermudagrass (Figure 3.8) should be used with **extreme care** as it quickly becomes a pest in croplands, gardens, and landscape plantings, spreading rapidly both vegetatively and by seed. It is difficult to control and almost impossible to eradicate.

The turf- and hay-type hybrids do not produce viable seed and less aggressive. Therefore, they are much easier to control and are less likely to become pests. However, hybrid Bermudas are more costly to establish because they must be planted from sprigs or plugs. In fact, the cost involved in establishing turf-type hybrids makes them generally practical only for fine turf use.

Common Bermudagrass is normally seeded in late spring using "hulled" seed (seed from which the outer covering or bracts have been removed). Unhulled seed may be used in fall-seeded mixtures because it lies dormant over winter and germinates in the spring. Hybrid varieties are planted in early spring, while soil moisture is still adequate. They may be planted later if water is available for irrigation.

Bahiagrass is a warm-season perennial grass adapted to the lower Piedmont and Coastal Plain. It tolerates dry, acid, low-fertility soils. Bahiagrass produces a fairly dense sod suitable for low-maintenance lawns, were it not for the production of unsightly seedheads (1-2 ft high) throughout the growing season.

Unfortunately, the strain of Bahiagrass generally available, Pensacola, is occasionally subject to winter-kill at this latitude. Consequently, it should not be relied upon in pure stands. The Wilmington strain is more cold-tolerant, but seed is not generally available.

Big Bluestem, *Andropogon gerardii,* is a native, perennial, warm season grass that occurs from the short grass prairie region to the Atlantic Ocean. It is tufted, forms sod, and has short, scaly rhizomes. Big bluestem is tall, reaching a height of 6 to 8 feet on most sites where it is protected from grazing. Big bluestem is a top choice for erosion control plantings on sites with moderately well drained to excessively well-drained soils. Generally, it is planted in combination with other warm season grasses on these sites. Big bluestem should be seeded as early in the spring as possible. Conventional tillage should be used where practical. The seeding rate for broadcast or no-till methods should be 7 to 12 pounds PLS per acre.

Centipedegrass is adapted to well-drained, medium- to coarse-textured soils in the eastern Piedmont and Coastal Plain. Generally used as a low- to moderate-maintenance turf, it is tolerant of infertile, low pH soils, heat, drought, and cold.

A serious problem with centipedegrass is its slow growth rate. Also, when grown on dry sands, irrigation is required to avoid severe pest injury (pearl bug). It is not tolerant to traffic or compaction.

Centipedegrass can be established from seeds or sprigs, but a nurse crop must be used to provide initial erosion control. The best planting months are March through July.

Little Bluestem, *Schizachyrium scoparium,* is a medium height grass with coarse stems and basal leaves. As a warm season grass it begins growth in late spring and continues through the hot summer period until the first killing frost. It is easily mistaken for common broomsedge. Because of its growth habit and adaptability to a wide range of soil conditions, little bluestem is useful as a component of revegetation mixes. Little bluestem is one of the most widely distributed native grasses in North America. It will grow on a wide variety of soils but is very well adapted to well-drained, medium to dry, infertile soils. The plant has excellent drought and fair shade tolerance, and fair to poor flood tolerance. The seeding rate for establishing a pure stand with broadcast or no-till methods should be 7 to 12 pounds PLS per acre.

Switchgrass, *Panicum virgatum,* is a perennial sod-forming grass that grows 3 to 5 feet tall. It is a valuable soil stabilization plant on strip-mine spoils, sand dunes, dikes, and other critical areas. It performs well on shallow and droughty soil. Its slick, free-flowing seed can be planted with most seed drills or with a broadcast spreader. A planting rate of approximately 10 pounds PLS per acre is recommended. Seedbeds should be firmed with a roller prior to the drilling or broadcasting of seed. If seeds are planted using the broadcast method, the area should be rolled afterward to help cover the seed.

Weeping lovegrass seeds often germinate and become established under drier conditions than most other cultivated grasses, and it is quite drought-resistant.

It is a bunch grass, forming distinct clumps that spread very little. This makes perfect stands essential, otherwise erosion between clumps may become serious. Further, this species is usually rather short-lived in North Carolina. Lovegrass is sometimes mixed with sericea lespedeza, which fills in between the clumps and persists after the weeping lovegrass declines. However it can be too competitive as a nurse crop. Where permanent cover is desired, it is usually best to start with species that provide more complete cover of a more permanent nature.

Weeping lovegrass is not recommended because its clumping growth habit and lack of persistence reduce its value for erosion control under North Carolina conditions.

Perennial Legumes

Crownvetch is a deep-rooted, perennial legume with spreading rootstocks, adapted to the Mountain region and to the cool slopes (north and east exposures) in the Piedmont. It is useful on steep slopes and rocky areas that are likely to be left unmowed. Crownvetch requires a specific *Rhizobium* inoculant, which may have to be obtained by special order. It can be seeded in the spring or fall. Crownvetch does not respond well to mowing.

Roundhead lespedeza *Lespedeza capitata* is a palatable and nutritious native legume that is a desirable component in warm season grass mixtures, providing nitrogen fixation. It is drought tolerant and grows in full sun. This herbaceous, native, perennial plant has stiff, erect stems that are 2-5 feet tall. The flowers are crowded in conspicuous green ball like clusters that are grouped together at the tips of the stems. The pea-like flowers are easy to over look unless the plant is examined closely. Roundhead lespedeza can be easily established by using a native grass drill with a legume seed box attachment. For a solid stand seeding, plant in late fall or early spring into a firm seedbed at a rate of 4 pounds PLS (pure live seed) per acre. Seed should be planted at a depth of ¼ to ½ inch. Use scarified inoculated seed when seeding in the spring, and unscarified inoculated seed when making a fall dormant planting.

Sericea lespedeza is a deep-rooted, drought-resistant perennial legume, adapted to all but the poorly drained soils of the state. It is long-lived, tolerant of low-fertility soils, and pest free, and it fixes nitrogen. It can be a valuable component in most low-maintenance mixtures. Sericea is a slow starter and should not be expected to contribute much to prevention of soil erosion the first year; however, it strengthens rapidly and persists indefinitely on suitable sites. Seedings that include sericea require mulch and should include nurse plants such as German millet, Sudangrass, or annual lespedeza. "Scarified," or roughened, seed should be used for spring seeding of sericea because it germinates more readily. Un-scarified seed is recommended for fall-seed mixtures because many of the seeds will lie dormant over winter and germinate early the next spring.

Sericea does not tolerate frequent mowing and may be considered unsightly because the old top growth breaks down slowly.

Coastal Dune Vegetation

Revegetation of construction sites on the barrier islands of North Carolina requires special attention to selection of plant species. In the foredune area there are only a few plants that tolerate the stresses of the beach environment. They must be able to survive salt spray, sand blasting, burial by sand, saltwater flooding, drought, heat, and low nutrient supply. The species commonly planted in this environment is American beachgrass. Other well-suited plants are sea oats, bitter panicum, and coastal panicgrass. In areas behind the foredune, coastal Bermudagrass has been used effectively for stabilization. In low, moist areas saltmeadow cordgrass may be transplanted.

American beachgrass is a cool-season perennial dune grass. It is the principal species presently planted in North Carolina for dune building and as a stabilizer in the foredune zone. Easy to propagate, it establishes and grows rapidly, and is readily available from commercial nurseries. It is an excellent sand trapper capable of growing upward with 4 ft of accumulating sand in one season. New plantings are usually effective at trapping wind-blown sand by the middle of the first growing season.

While extremely valuable for initial stabilization and dune building in disturbed areas, this grass has several serious problems under North Carolina conditions. It is a northern species, probably occurring naturally only as far south as Currituck Banks. It is severely affected by heat and drought and tends to deteriorate and die behind frontal dunes as the sand supply declines. Also, it is susceptible to a fungal disease (Marasmius blight) and a soft scale insect (*Eriococcus carolinae*). Consequently, beachgrass plantings should be reinforced by the inclusion of sea oats and bitter panicum. Dead patches should be replanted to sea oats, bitter panicum, of seashore elder. Sea oats and bitter panicum may be planted without beachgrass, but these plants are more expensive.

The selection of adapted strains is important, as the southern limit of adaptation for this species is approached along the North Carolina coast. Hatteras, a North Carolina selection, has been used effectively for many years. Cape is a northern strain that looks good at first but does not persist well here. Bogue is a more recent selection, better than Cape but not as thoroughly tested as Hatteras.

Figure 3.9 Sea oats.

Sea oats (Figure 3.9) is the primary native dune builder from Currituck Banks southward to Mexico. It is a warm-season grass, vigorous, drought- and heat-tolerant, and an excellent sand trapper once fully established. The seed heads, borne on 3 to 4 ft stalks, are quite decorative, This plant is much more tolerant of reduced sand and nutrient supply than American beachgrass and may persist in backdune areas indefinitely.

Sea oats is limited in commercial availability. Pot-grown seedlings may be transplanted to the dunes when 12 to 16 inches in height.

Early growth in the dunes is generally slower than American beachgrass, and transplants are not effective in trapping sand the first season. This, and the scarcity of commercial supplies, make planting in pure stands generally impractical. However, on the North Carolina coast enough sea oat plants should be included in American beachgrass plantings to assure a future seed supply if there is not already one nearby. This will provide for gradual replacement as the beachgrass stand weakens.

Bitter panicum is a warm-season, perennial grass occurring on and near sand dunes from New England southward to Mexico. It rarely, if ever, produces viable seed and must be propagated vegetatively. It is also highly palatable to grazing animals. These characteristics probably account for its scarcity on many beaches.

Bitter panicum is most useful for inclusion in American beachgrass plantings to encourage long-term stability. It is relatively pest-free, both under nursery conditions and on the dunes. Commercial supplies are limited, but could be readily expanded to meet demand.

When buried, this grass will root at most nodes. Place runners in trenches, leaving several inches of the tip exposed, or set small plants, as with American beachgrass. Stands respond vigorously to nitrogen fertilization.

Saltmeadow cordgrass is a warm-season perennial useful for transplanting on low areas subject to saltwater flooding. It is a heavy seed producer and is often the first plant on moist sand flats. It collects and accumulates blowing sand, creating an environment suitable for dune plants.

Saltmeadow cordgrass is easy to transplant on moist sites but does not survive on dry dunes. Plants should be dug from young, open stands. Survival of transplants from older, thick stands is poor. Nursery production from seed is relatively easy, and the pot-grown seedlings transplant well. Propagation by seed is possible, but the percentage of viable seed varies.

Intertidal Vegetation

There is often a need to transplant vegetation in the intertidal zone of estuaries to reduce shoreline erosion, to stabilize dredged material, or for mitigation. The concept of mitigation—permitting disturbance of natural marshes in return for establishing new marshes—is receiving attention and has been tested in North Carolina. Such a trade-off may be justified if a small inclusion of marsh in a construction site is a problem. Decisions on permits are made on an individual basis by personnel of the appropriate State and Federal regulatory agencies.

In saltwater areas, smooth cordgrass is transplanted in the intertidal zone from mean sea level to mean high water, and saltmeadow cordgrass from mean high water to the storm tide level. In brackish water areas (10 parts per thousand or less of soluble salts), giant cordgrass may be used in the intertidal zone. Greenhouse-grown seedlings of these plants can be obtained from commercial sources, but usually only on special order. Transplants may also be dug from young, open natural stands in the case of smooth and saltmeadow cordgrass.

Smooth cordgrass is the dominant plant in the regularly flooded intertidal zone of saltwater estuaries along the Atlantic and Gulf Coast of North America. The plant is adapted to anaerobic, saline soils that may be clayey, sandy, or organic. It will tolerate salinities of 35 parts per thousand (ppt) but grows best from 10 to 20 ppt. Plant height varies from 1 to 7 ft depending on environmental conditions and nutrient supply. It produces a dense root and rhizome mat that helps prevent soil movement. Transplants can be obtained by digging from new, open stands of the grass or may be grown from seed in pots. Seed are collected in September and stored, covered with seawater, and refrigerated. The plants and seedlings grow rapidly when transplanted on favorable sites.

Saltmeadow cordgrass is a fine-leaved grass, 1 to 3 ft in height, that grows just above the mean high tide line in regularly flooded marshes, and throughout irregularly flooded marshes. It can be propagated in the same way as smooth cordgrass except that seed may be stored dry under refrigeration. A stand of saltmeadow cordgrass provides good protection from storm wave erosion.

Giant cordgrass grows in brackish, irregularly-flooded areas. Stems are thicker and taller than in the other cordgrasses, growing to a height of 9 to 10 ft. Seedlings are easy to produce in pots and these can be successfully transplanted, but survival of plants dug from existing stands is poor.

ESTABLISHING VEGETATION

Topsoiling

The surface layer of an undisturbed soil is often enriched in organic matter and has physical, chemical, and biological properties that make it a desirable planting and growth medium Those qualities are particularly beneficial to seedling establishment. Consequently, **where practical, topsoil should be stripped off prior to construction and stockpiled for use in final revegetation of the site**. Planning such stabilization measures from the beginning of the project may eliminate costly amendments and repair measures later. Topsoiling may not be required for the establishment of less demanding, lower maintenance plants, but it is essential on sites having critically shallow soils or soils with other severe limitations. It is essential for establishing fine turf and ornamentals.

The need for topsoiling should be evaluated, taking into account the amount and quantity of available topsoil and weighing this against the difficulty of preparing a good seedbed on the existing subsoil. Where a limited amount of topsoil is available, it should be reserved for use on the most critical areas. In many cases topsoil has already been eroded away or, as in wooded sites, it may be too trashy.

Site Preparation

The soil on a disturbed site must be modified to provide an optimum environment for germination and growth. Addition of topsoil, soil amendments, and tillage are used to prepare a good seedbed. At planting the soil must be loose enough for water infiltration and root penetration, but firm enough to retain moisture for seedling growth. Tillage generally involves disking, harrowing, raking, or similar method. Lime and fertilizer should be incorporated during tillage.

Soil Amendments

Liming is almost always required on disturbed sites to decrease the acidity (raise pH), reduce exchangeable aluminum, and supply calcium and magnesium. Even on the best soils, some fertilizer is required. Suitable rates and types of soil amendments should be determined through soil tests. Limestone and fertilizer should be applied uniformly during seedbed preparation and mixed will with the top 4 to 6 inches of soil.

Organic amendments, in addition to lime and fertilizer, may improve soil tilth, structure, and water-holding capacity—all of which are highly beneficial to seedlings establishment and growth. Some amendments also provide nutrients. Examples of useful organic amendments include well-rotted sawdust, well-rotted animal manure and bedding, crop residue, peat, and sludge from municipal sewage or industrial waste.

Organic amendments are particularly useful where topsoil is absent, where soils are excessively drained, and where soils are high in clay. The application of several inches of topsoil usually eliminates the need for organic amendments.

Sludge is an inexpensive amendment that can be very beneficial to plant growth, but proper planning and careful management are essential to its use. Sludge adds nutrients, primarily nitrogen and phosphorus, improves soil structure, and increases organic matter. Types of sludge available include municipal sewage, and waste from textile, wood processing, and fermentation industries. Nutrient content of the sludge depends on the source, but is much lower than that of commercial fertilizers. Sewage sludge may be used in reclamation of disturbed sites, **but always check local or State regulations before attempting to use sewage sludge**.

Sludges may sometimes be high in heavy metals such as nickel and cadmium. North Carolina has published guidelines for the use of sludges which must be followed to maximize effectiveness and avoid pollution of streams. Runoff and erosion control are essential where sludge has been applied. Near residential areas odors can also be a problem. Sludge is available in either solid or liquid forms. Solid or semi-solid forms are broadcast on sod or soil and may or may not be incorporated. Liquid sludge is irrigated, broadcast, broadcast and incorporated, or injected directly beneath the surface.

Surface Roughening

A rough surface is especially important to seeding sloped areas. Contour depressions and loose surface soil help retain lime, fertilizer, and seed. A rough surface also reduces runoff velocity and increases infiltration.

Because slopes steeper than 3:1 are not usually mowed, they can be left quite rough by grooving, furrowing, tracking, or stairstep grading (*Practice Standards and Specifications: 6.03, Surface Roughening*). Stairstep grading is particularly helpful where there are large amounts of soft rock, because each step catches material in which vegetation can become established.

Slopes flatter than 3:1, which may be mowed, should be grooved by disking, harrowing, raking, or operating planting equipment on the contour. On gentle slopes with sufficient mulch, this is sufficient to retain seed and soil amendments and promote infiltration. Seed should be broadcast soon after surface roughening, before the surface is sealed by rainfall.

Planting Methods

Seeding is by far the fastest and most economical method that can be used with most species. However, some grasses do not produce seed and must be planted vegetatively. Seedbed preparation, liming, and fertilization are essentially the same regardless of the method chosen.

Seeding

Uniform seed distribution is essential. This is best obtained using a cyclone seeder (hand-held), drop spreader, conventional grain drill, cultipacker seeder, or hydraulic seeder. The grain drill and cultipacker seeders (also called grass seeder packer or Brillion drill) are pulled by a tractor and require a clean, even seedbed.

On steep slopes hydroseeding may be the only effective seeding method. Surface roughening is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged and even trashy seedbed gives the best result.

The "insurance" effect of extra seed has been taken into account in arriving at the rates recommended in this manual. **Rates exceeding those given are not recommended because over-dense stands are more subject to drought and competitive interference**.

Because uniform distribution is difficult to achieve with hand-broadcasting, it should be considered only as a last resort. When hand-broadcasting of seed is necessary, uneven distribution may be minimized by applying half the seed in one direction and the other half at right angles to the first. Small seed should be mixed with sand for better distribution.

A "sod seeder" (no-till planter) is used to restore or repair weak cover. It can be used on moderately stony soils and uneven surfaces. It is designed to penetrate the sod, open narrow slits, and deposit seed with a minimum of surface disturbance. Fertilizer is applied in the same operation.

Inoculation of legumes—Legumes have bacteria, rhizobia, which invade the root hairs and form gall-like "nodules." The host plant supplies carbohydrates to the bacteria, which supply the plant with nitrogen compounds fixed from the atmosphere. A healthy stand of legumes, therefore, does not require nitrogen fertilizer. *Rhizobium* species are host specific—a given species will inoculate some legumes but not others. Successful establishment of legumes, therefore, requires the presence of specific strains of nodule-forming, nitrogen-fixing bacteria on their roots. In areas where a legume has been growing, sufficient bacteria may be present in the soil to inoculate seeded plants, but in other areas the natural *Rhizobium* population may be too low.

In acid subsoil material, if the specific *Rhizobium* is not already present, it must be supplied by mixing it with the seed at planting. Cultures for this purpose are available through seed dealers.

Sprigging and Plugging

Sprigging refers to planting stem fragments consisting of runners (stolons) or lateral, below-ground stems (rhizomes), which are sold by the bushel. This method can be used with most warm-season grasses and with some ground covers, such as periwinkle. Certain dune and marsh grasses are transplanted using vertical shoots with attached roots or rhizomes. Sprigs can be broadcast or planted in furrows using a tobacco transplanter. Under favorable conditions, the hay-type, hybrid Bermudagrasses will cover-over in one growing season from sprigs spaced on 6-ft centers. Lawn-type plants are usually sprigged much more thickly.

Broadcasting is easier but requires more planting material—3 to 10 bu/1,000ft^2 for Bermudagrass. Broadcast sprigs must be pressed into the top 1/2 to 1 inch of soil by hand or with a smooth disk set straight, special planter, cultipacker, or roller.

Plugging differs from sprigging only in the use of plugs cut from established sod, in place of sprigs. It is usually used to introduce a superior grass into an old lawn. It requires more planting stock, but usually produces a complete cover more quickly than sprigging.

Sodding

In sodding, the soil surface is completely covered by laying cut section of turf. It is practiced in this region with turf-type Bermudas, Kentucky bluegrass, tall fescue, and blugrass-tall fescue mixtures, and is limited primarily to lawns, steep slopes, and sod waterways. A commercial source of high-quality turf is required and water must be available. Plantings must be wet down immediately after planting, and kept well watered for a week or two thereafter.

Sodding, though quite expensive, is warranted where immediate establishment is required, as in stabilizing drainage ways and steep slopes, or in the establishment of high-quality turf. If properly done, it is the most dependable method and the most flexible in seasonal requirements. Sodding is feasible almost any time the soil is not frozen.

Irrigation

Irrigation, though not generally required, can extend seeding dates into the summer and insure seedling establishment. Damage can be caused by both under- and over-irrigating. If the amount of water applied penetrates only the first few inches of soil, plants may develop shallow root systems that are prone to desiccation. **If supplementary water is used to get seedlings up, it must be continued until plants become firmly established**.

Irrigation requirements depend upon current weather conditions—rainfall, temperature, humidity, etc. A statewide weather forecast including information on planting and growing conditions is available through the North Carolina Agricultural Extension Service by calling "Teletip" (1-800-662-7301). This can be used to determine day-to-day watering needs.

Mulching

Mulch is essential to the revegetation of most disturbed sites, especially on difficult sites such as southern exposures, channels, and excessively dry soils. The steeper the slope and the poorer the soil, the more valuable it becomes. In addition, mulch fosters seed germination and seedling growth by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature changes.

Mulch may also protect surfaces that cannot be seeded. Mulch prevents erosion in the same manner as vegetation, by protecting the surface from raindrop impact and by reducing the velocity of overland flow. There are a number of organic and a few chemical mulches that may be useful, as well as nets and tacking materials (*Practice Standards and Specifications: 6.14, Mulching*).

Grain straw (wheat, oats, barley, rye) is the most widely used and one of the best mulches. However, there are other materials that work well but may be only locally available. Mulching materials covered in this manual have their respective advantages and appropriate applications, and a material should not be selected on the basis of cost alone.

MAINTENANCE

Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if left unattended, can allow serious soil loss from an otherwise stable surface. A single heavy rain is often sufficient to greatly enlarge bare spots, and the longer repairs are delayed, the more costly they become. Prompt action will keep sediment loss and repair cost down. New seedlings should be inspected frequently and maintenance performed as needed. If rills and gullies develop, they must be filled in, re-seeded, and mulched as soon as possible. Diversions may be needed until new plants take hold (Figure 3.10).

Maintenance requirements extend beyond the seeding phase. Damage to vegetation from disease, insects, traffic, etc., can occur at any time. Herbicides and regular mowing may be needed to control weeds—dusts and sprays may be needed to control insects. Herbicides should be used with care where desirable plants may be killed. **Weak or damaged spots must be relimed, fertilized, mulched, and reseeded as promptly as possible**. Refertilization may be needed to maintain productive stands.

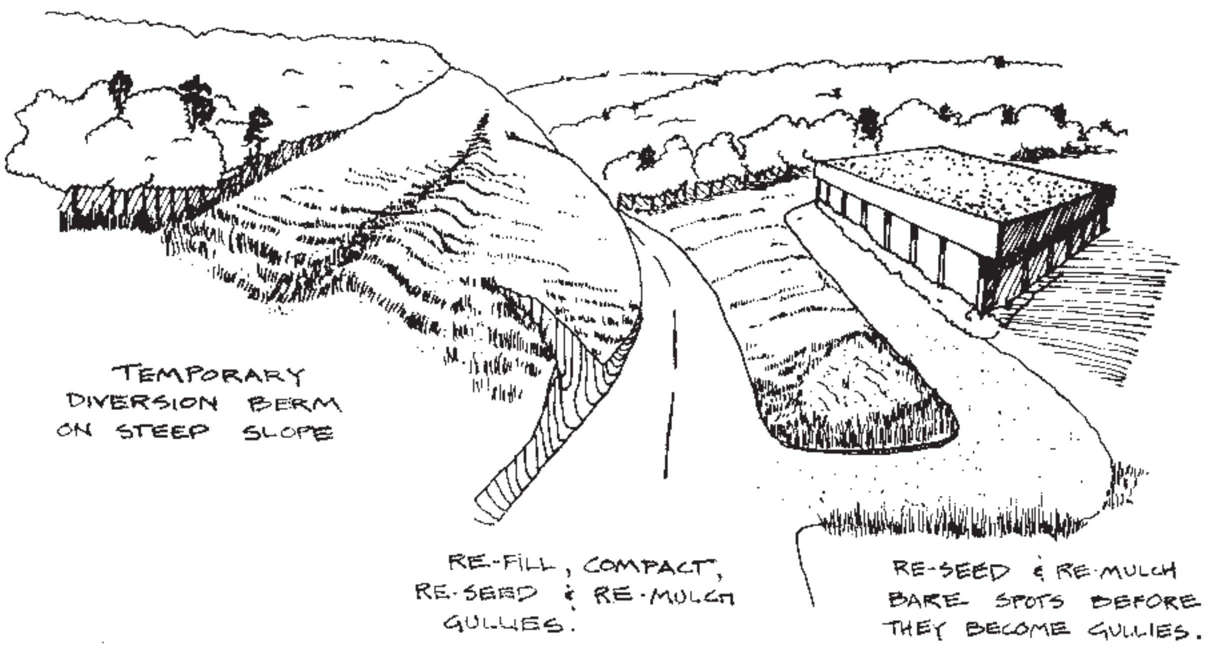


Figure 3.10 Maintenance of vegetative cover.

Vegetation established on disturbed soils often requires additional fertilization. Frequency and amount of fertilization can best be determined through periodic soil testing. A fertilization program is required for the maintenance of fine turf and sod that is mowed frequently. Maintenance requirements should always be considered when selecting plant species for revegetation.

4

Preparing the Erosion and Sedimentation Control Plan

4

Preparing the Erosion and Sedimentation Control Plan

GENERAL CONSIDERATIONS

Before preparing an erosion and sedimentation control plan, the designer should have a sound understanding of the requirements of the North Carolina Sedimentation Control Law (*Chapter 1*), erosion and sedimentation control principles (*Chapter 2*), the role of vegetation and other surface protection in the erosion process (*Chapter 3*), and the appropriate uses of the principal erosion and sedimentation control practices (*Chapter 5*).

Developers and builders can minimize erosion, sedimentation, and other construction problems by selecting areas appropriate for the intended use. Tracts of land vary in suitability for development. Knowing the soil type, topography, natural landscape values, drainage patterns, flooding potential, and other pertinent data helps identify both beneficial features and potential problems of a site.

Purpose of the Plan

The purpose of an erosion and sedimentation control plan is to establish clearly which control measures are intended to prevent erosion and off-site sedimentation. The plan should serve as a blueprint for the location, installation, and maintenance of practices to control all anticipated erosion and prevent sediment from leaving the site.

The approved erosion and sedimentation control plan—showing the location, design, and construction schedule for all erosion and sedimentation control practices—should be a part of the general construction contract. State specifically the method of payment for implementing this plan in the contract, and consider erosion and sedimentation control an early pay item.

Elements of the Plan

An erosion and sedimentation control plan must contain sufficient information to describe the site development and the system intended to control erosion and prevent off-site damage from sedimentation. As a minimum, include in the plan:

- a site location or vicinity map,
- a site development drawing,

- a site erosion and sedimentation control drawing,
- drawings and specifications of practices designated with supporting calculations and assumptions,
- vegetation specifications for temporary and permanent stabilization,
- a construction schedule,
- a financial/ownership form, and
- a brief narrative.

Although a narrative is not specifically required by the law, it can clarify details of the plan as an aid for the inspector and the contractor. The narrative should be concise, but should describe:

- the nature and purpose of the proposed development,
- pertinent conditions of the site and adjacent areas, and
- the proposed erosion and sedimentation control measures.

The designer should assume that the plan reviewer has not seen the site, and is unfamiliar with the project. Map scales and drawings should be appropriate for clear interpretation.

Data Collection and Preliminary Analysis

The base map for the erosion control plan is prepared from a detailed topographic map. If available, a soil map should be obtained from the local office of the USDA Soil Conservation Service. Transferring the soil survey information to the topographic map is helpful for site evaluation.

The design engineer responsible for the plan should inspect the site to verify the base map with respect to natural drainage patterns, drainage areas, general soil characteristics, and off-site factors.

The base map should reflect such characteristics as:

- soil type and land slopes,
- natural drainage patterns,
- unstable stream reaches and flood marks,
- watershed areas,
- existing vegetation (noting special vegetative associations),
- critical areas such as steep slopes, eroding areas, rock outcroppings, and seepage zones,
- unique or noteworthy landscape values to protect,
- adjacent land uses—especially areas sensitive to sedimentation or flooding, and
- critical or highly erodible soils that should be left undisturbed.

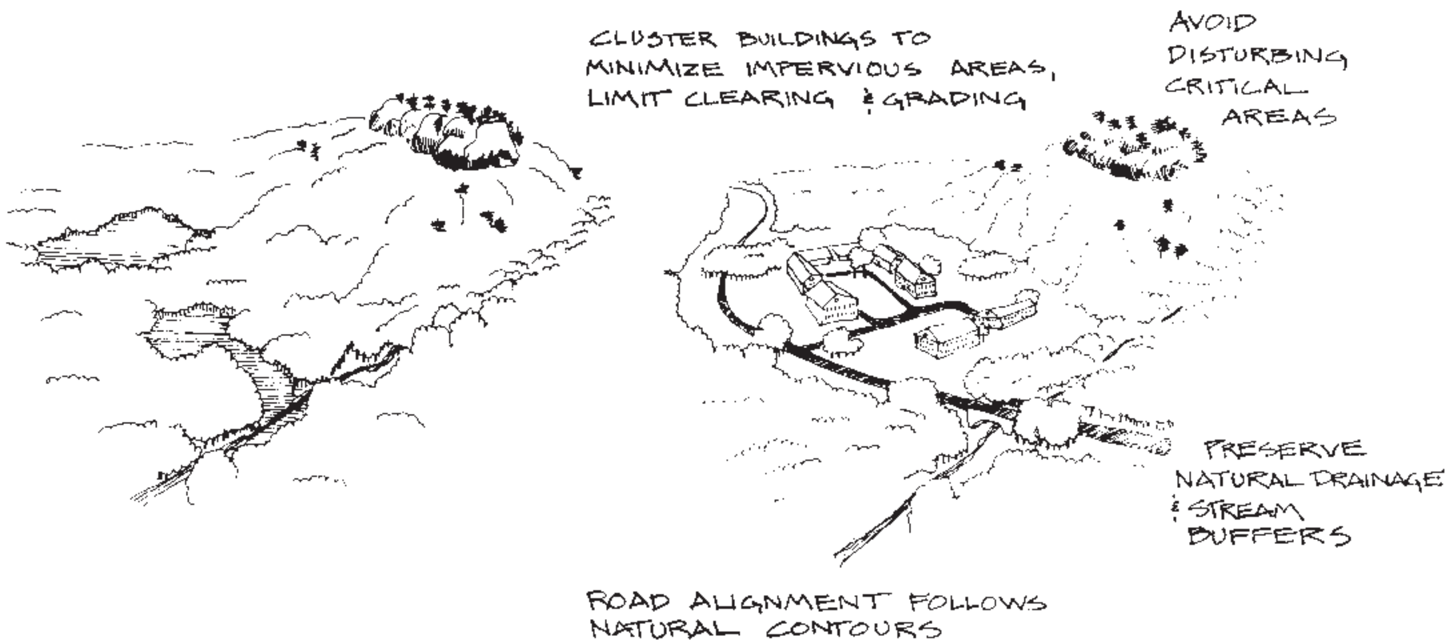


Figure 4.1 Site evaluation.

In the analysis of these data, identify:

- buffer zones,
- suitable stream crossing areas,
- access routes for construction and maintenance of sedimentation control devices,
- borrow and waste disposal areas, and
- the most practical sites for control practices.

The analysis of the topography, soils, vegetation, and hydrology should define the limitations of the site and identify locations suitable for development.

Principles of Site Development

The site evaluation data and the information shown on the field map serve as the basis for both the site development plan and the erosion and sedimentation control plan (Figure 4.1). Plan development to fit the proposed site, recognizing constraints determined in the site analysis. To determine the best layout of the site, observe the following principles:

Fit the development to the site—Follow natural contours as much as possible. Preserve and use natural drainage systems.

Limit clearing and grading—Clearly define work limit lines. Grade to minimize cut-and-fill slopes, preserve natural buffer areas, and limit the time that bare soil is exposed.

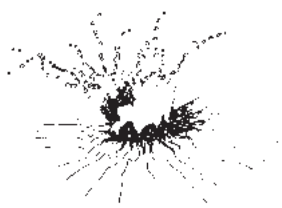
Minimize impervious areas—Build in clusters to provide more open space, minimize parking areas, and reduce disturbance for utility line construction. Use porous paving materials when practical. Maintain existing vegetation where possible.

Avoid disturbing critical areas—Identify and avoid areas vulnerable to concentrated runoff.

Maintain and enhance existing site values—Retain significant trees and other plant groups. Avoid disturbing unique land forms, very steep slopes, and rock outcroppings.

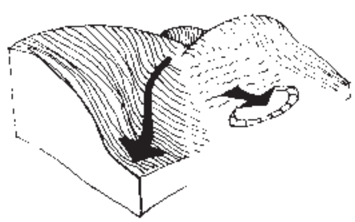
Strategy

The erosion and sedimentation control plan should seek to protect the soil surface from erosion, control the amount and velocity of runoff, and capture all sediment on-site during each phase of the construction project. Strategies for controlling erosion and sedimentation should consider the following elements:

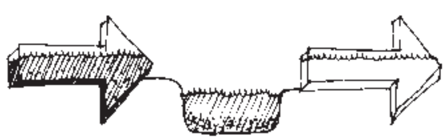


Schedule activities—Coordinate the installation of erosion and sedimentation control practices to coincide with the construction activities as the most cost-effective control strategy. Many sedimentation control practices should precede grading activities.

Protect the soil surface—Limit the extent of disturbance, and stabilize the soil surface immediately. Once the surface has been disturbed, it is subject to accelerated erosion, and should be protected with appropriate cover, such as mulch or vegetation, in an expedient manner.



Control surface runoff—Divert water from undisturbed areas to avoid disturbed areas. Break up long slopes with temporary diversions to reduce the velocity of runoff. Divert sediment-laden water to sediment impoundments. Make all outlets and channels stable for the intended flow.



Capture sediment on-site—Divert runoff that transports sediment to an adequate sediment-trapping device to capture sediment on the site.

Chapter 5 provides a practice selection guide (Table 5.1) for the selection of appropriate control practices. *Chapter 6* contains standards and specifications for the implementation of recommended erosion and sedimentation control practices.

WRITING THE PLAN

Phase I: Runoff-Erosion Analysis

Development of the erosion and sedimentation control plan can be viewed as a series of phases that occur in approximate chronological order. The phases overlap considerably and so are not presented as steps.

Landscape—Evaluate proposed changes in the landscape to determine their effect on runoff and erosion. Note all physical barriers to surface runoff, such as roads, buildings, and berms. Check slope grades and lengths for potential erosion problems. Designate intended collection points for concentrated flow and specify controls to dissipate energy or stabilize the surface. Designate areas to be protected or used as buffer zones in this phase (Figure 4.2).

Runoff yield—Evaluate surface runoff for the entire contributing drainage area—on-site and off-site. Delineate small subwatersheds on-site, and estimate peak runoff rates and volumes at selected collection points identified. Base runoff determinations on the peak discharge from the 10-year storm with site conditions during and after development—**not predisturbance conditions**. See *Appendix 8.03* for procedures for estimating peak runoff.

Sediment yield—Estimate sediment yield by subwatersheds. This aids in identifying preferred locations for sediment traps and barriers, and can be used to estimate the expected cleanout frequency. An area that is subject to excessive erosion may call for extra storage capacity in traps or additional precautions during construction.

Phase II: Sediment Control

Erosion control practices reduce the amount of sediment generated, but they do not eliminate the need for sediment control devices such as barriers and traps. Sediment control practices operate by reducing flow velocity, and creating shallow pools that reduce the carrying capacity of runoff. Thus, sedimentation occurs on-site rather than off-site. Sediment is generally not controlled by filtering, but by deposition. The designer should locate all traps and barriers

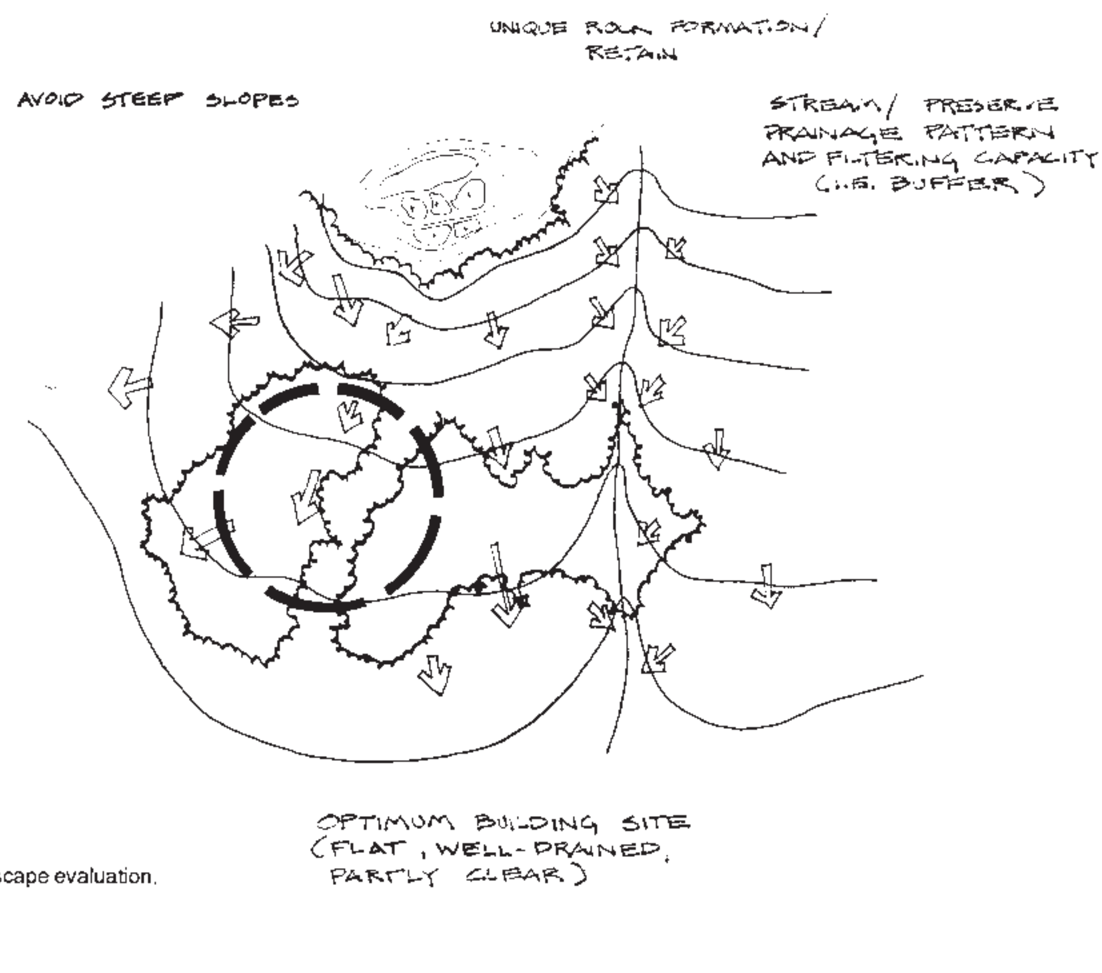


Figure 4.2 Landscape evaluation.

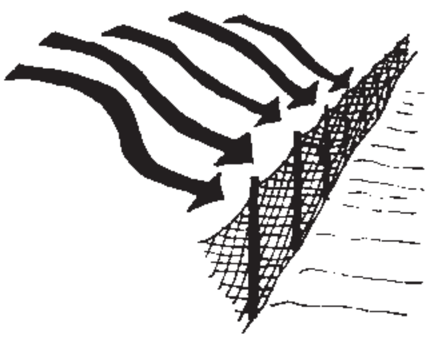
recognizing that they represent deposition points where access for maintenance will be necessary.

Sediment basins and traps—Select sites and install sediment basins and traps before other construction activities are started. Also consider locations for diversions, open channels, and storm drains at this time so that all sediment-laden runoff can be directed to an impoundment structure before leaving the construction site.

Divert sediment-free water away from sediment basins, and release it through stable outlets. This reduces construction costs, and improves basin efficiency.

This plan should show access points for cleanout of all traps and basins and indicate sediment disposal areas. Maintenance of storage capacity is essential throughout the construction period.

Practice standards in *Chapter 6* provide design criteria and construction specifications for sediment traps (Practice 6.60), sediment basins (Practice 6.61), rock dams (Practice 6.63), and skimmer sediment basins (Practice 6.64). Procedures for the design of sediment basins are contained in *Appendix 8.07*.



Sediment fences—Sediment fences (Practice 6.62) provide effective control of sediment carried in sheet flow. They are particularly useful where there is limited space to work such as near property lines, among trees, or near sidewalks or streets.

Sediment fences should never be used across streams, ditches, channels, or gullies.

The sediment fence operates primarily by reducing flow velocity and causing a shallow pool to form. If filtering action is required, the designer should assume that the barrier will clog rapidly so that all runoff must be retained behind the fence or released through a designated outlet. Any outlet points must be reinforced and stabilized, and should be designated in the plan.

Place sediment fences on relatively flat ground with sufficient area for a pool to develop without putting unnecessary strain on the fence. If a level area is not available at the fence location, excavate a trench directly upslope from the fence.

Show sediment fences on the topographic map, and clearly indicate deposition areas and needed overflow or bypass outlet points. Also show access routes for maintenance.

Inlet protection—Inlet protection devices for storm sewers, conduits, slope drains, or other structures make effective, low-cost deposition areas for trapping and holding sediment. A shallow excavation in conjunction with a sediment barrier can be effective at many locations. In the plan, show where these measures will be located, what type of device will be used, and how these devices will be constructed and maintained. Practice standards for the design of several types of inlet protection devices are included in *Chapter 6* (Practices 6.50, 6.51, 6.52, 6.53, 6.54, and 6.55).

Phase III: Protection of Disturbed Areas

Once an area is disturbed, it is subject to accelerated erosion. In the plan, show how erosion will be controlled on these disturbed areas. Erosion control can be achieved by:

- limiting the size of clearing and time of exposure by proper scheduling,
- reducing the amount of runoff over the disturbed surface,
- limiting grades and lengths of slopes, and
- re-establishment protective cover immediately after land-disturbing activities are completed or when construction activities are delayed for 30 or more working days.

Cut-and-fill slopes—Steep cut or fill slopes are particularly vulnerable to erosion. Protect such slopes by temporary or permanent diversions just above the proposed slope before it is disturbed. Provide a stable channel, flume, or slope drain, where it is necessary to carry water down a slope. Flow conveyances may have vegetative, mechanical, or combined vegetative and mechanical liners, depending on slope and soil conditions.

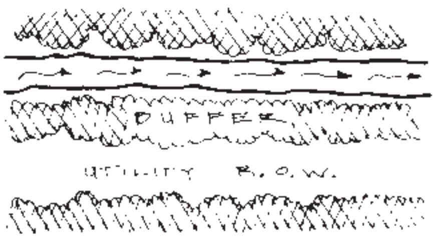
Shorten long slopes by installing temporary diversions across the slope to reduce flow velocity and erosion potential. Install permanent diversions with slope drains and protected outlets on long steep slopes (over 20%) as the slopes are constructed.

Finish final slope grades without delay, and apply the appropriate surface stabilization measures as soon as possible. Roughen slope surfaces to improve the success of vegetative stabilization. Consider both the stabilization measures and how they will be maintained before planning the steepness of the finished slope. For example, if the finished slope is to have smooth grass cover, it should be constructed on a grade of 3:1 or flatter to allow mowing.

Surface covers—Riprap, gravel, straw and other land covers can provide immediate surface protection to disturbed soil areas. Riprap is especially useful where concentrated runoff over steep slopes occurs. Riprap should be installed on a gravel or filter fabric bed.

Construction traffic—Carefully plan stabilization of construction access areas, construction roads, and parking areas. Ensure that traffic patterns follow site contours, and limit the length of routes up steeper slopes. Generally, road grades should not exceed 12%. Controlling surface runoff is necessary to prevent serious roadside erosion. Proper grading of the road surface, stable channel design, the use of water bars, other diversions, and culverts help prevent erosive flows. Where water tables are high, subsurface drainage may be needed to stabilize the sub-grade. Storm drains should be considered for water disposal where channel grade exceeds 5%. Plans should show all stabilization measures needed to control surface runoff from all roads.

Borrow and waste disposal areas—Clear borrow and waste disposal areas only as needed and protect them from surface runoff. Maintain berms as fill slopes are constructed to reduce slope length and control runoff. Slope all areas to provide positive drainage, and stabilize bare soil surfaces with permanent vegetation or mulch as soon as final grades are prepared. Direct all runoff that contains sediment to a sediment-trapping device. In large borrow and disposal sites, shape and deepen the lower end to form an in-place sediment trap, if site conditions warrant it. Off-site borrow areas may be governed by the N.C. Mining Act.



Utilities—Use the spoil from utility trench excavations to divert flow from upslope areas, but use care in spoil placement to avoid blocking natural surface outlets. Diversions and water bars can reduce erosion when properly spaced across utility rights-of-way. When utilities are located near a stream, maintain an undisturbed buffer zone wherever possible. If site dewatering is necessary, pump or divert muddy water to sediment traps before discharging it to the stream. If streams must be crossed, make sure all necessary materials and equipment are on-site before construction begins, and complete work quickly. Finish all disturbed surfaces to design grade and immediately stabilize them with permanent vegetation or other suitable means. When utilities cross the stream, you must specify the plans to prevent sedimentation.

Perimeter protection—Consider diversion dikes for perimeter protection for all proposed developments, and install them where appropriate before clearing the site. Exercise care not to create flooding or erosion by blocking the natural drainage pattern. Be sure to provide an adequate outlet.

Dust control—Exposed soil surfaces that are nearly level have little potential for runoff erosion, but may be subject to severe wind erosion. Keeping the disturbed surface moist during windy periods is an effective control measure, especially for construction haul roads.

Preserving vegetation—Preserve existing vegetation on the site as long as possible as a cost-effective way to prevent on-site erosion and off-site sedimentation.

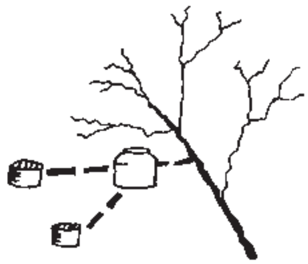
Phase IV: Runoff Conveyance

The safe conveyance of runoff water from a construction site is achieved by: (1) utilizing and supplementing existing stable watercourses, (2) designing and constructing stable open channels, or (3) installing storm drains with stable outlets. The plan should indicate locations and designs for these facilities. Complete and stabilize outlets for channels, diversions, slope drains, or other structures before installing the conveyance measure.

Existing watercourses—When using existing watercourses, either show that flow velocities are acceptable for increased runoff conditions, or indicate how necessary stabilization will be achieved.

Excavated channels—When channels are to be excavated, base a stability analysis on allowable velocity, or tractive force procedures. Include all calculations as part of the plan documentation.

Wide, shallow channels with established grass linings are usually stable on slopes up to 5%. These channels must be protected with temporary liners until grass is established. If channel gradients are too steep to use vegetation, riprap or concrete linings may be required, and in some instances grade stabilization structures may be needed.



Storm drains—Where the site plan calls for a system of storm drains, the drains may be used effectively in the erosion and sedimentation control plan. Build junction boxes or inlets early in the construction sequence, and grade the adjacent area to drain toward the inlet. Install an inlet protection device at all open pipe inlets, and excavate a shallow basin in the approach to the inlet for sediment storage. The storm drain flow from the protected inlets may be diverted to a sediment basin for additional sediment control. Restrict the drainage area for inlets to less than 1 acre, and frequently inspect inlet protections for needed maintenance.

Standards for runoff conveyance (Practices 6.30, 6.31, 6.32, and 6.33) and outlet protection measures (Practices 6.40 and 6.41) in *Chapter 6* provide the criteria necessary for the design of these practices. Design procedures for channels and outlet structures are contained in *Appendices 8.05, 8.06,* and *8.07*. Standards for the design of storm drains are not included.

Phase V: Stream Protection

Streambanks, streambeds, and adjoining areas are susceptible to severe erosion if not protected. Include sufficient detail to show that streams are stable for the increased velocities expected from the development activity. At a minimum, all streams should be stable for flows from the peak runoff from the 10-year storm.

When stability analysis shows that the stream requires protection, vegetation is usually the preferred approach because it maintains the stream nearest to its natural state. When flow velocities approach 4-6 ft/sec, or if frequent periods of bankful flows are expected, structural measures such as riprap lining or grade stabilization structures are usually necessary. In the plan, show where stream protection is needed, and how it will be accomplished.

Runoff into stream—Only sediment-free runoff may be discharged from construction sites directly into streams. Ensure that all other flows enter from desilting pools formed by sediment traps or barriers.

Velocity control—Keep the velocity of flow discharged into a stream within acceptable limits for site conditions. Control velocity by installing an appropriate outlet structure. Standards for two types of outlet protection devices are given in *Chapter 6* (Practices 6.40 and 6.41). Design procedures for riprap outlet structures are contained in *Appendix 8.06*.

Buffer zone—Areas adjoining streams should be left undisturbed as buffers (Figure 4.3). Existing vegetation, if dense and vigorous, will reduce flow velocities and trap sediment from sheet flow. However, the principal benefit of leaving natural buffer zones along streams is that they prevent excessive erosion in these sensitive areas. Maintaining stream canopies also protects fish and wildlife habitats; provides shade, wind breaks and noise barriers; protects the bank from out-of-bank flood flows; and generally preserves natural site aesthetics.

Indicate stream buffer zones in plans that involve natural streams. The width is determined by site conditions, but generally should not be less than 25 feet on each side of the stream. Where natural buffers are not available, provide artificial buffers. **Where work is required along a stream, you must provide a mechanical or artificial buffer**.

Figure 4.3 Wooded buffer zone.

Off-site stream protection—Increased rate and volume of runoff from development activities may cause serious erosion at points some distance downstream. The developer should work with downstream property owners to stabilize sensitive downstream channel areas.

Stream crossing—Minimize the number of stream crossings. Construct crossings during dry periods; if necessary, divert water during construction. The plan should show the type of crossing to be used and the associated control measures to minimize erosion from surface runoff such as diversions, outlet structures, riprap stabilization, etc. Design guidelines are given in *Chapter 6* (Practices 6.70, 6.71, 6.72, 6.73, and 6.74) for stream protection practices.

Phase VI: Construction Scheduling

Appropriate sequencing of construction activities can be the most effective means for controlling erosion and sedimentation. Consequently, present the construction activity schedule of the general contract as part of the erosion and sedimentation control plan. **Put into place the primary erosion and sedimentation control practices for the site, i.e., sediment basins and traps, and a water conveyance system before undertaking major land-disturbing activities**.

Install sediment basins and primary sedimentation control practices as the first structural measures. Next install the overall water disposal outlet system for the site.

Stabilize all construction access routes, including the construction entrance/exit and the associated drainage system, as the roads are constructed. Install storm drains early in the construction sequence, and incorporate them in the sedimentation control plan. Then install low-cost inlet protection devices for efficient sedimentation control in the area around the inlets. This allows early use of the inlets and the drain system.

Install diversions above areas to be disturbed and, where appropriate, locate diversion dikes along boundaries of areas to be graded before grading takes place.

After all principal erosion and sedimentation control measures are in place, perform the land clearing and rough grading. Clear areas only as needed.

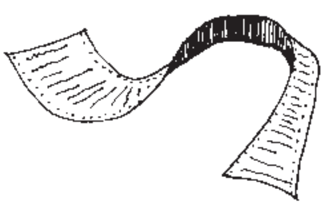
Complete final grading and surface stabilization in an expedient manner and within the construction schedule. Minimize the time of exposure, and select temporary ground cover according to the location and season. Temporary surfaces should be stabilized as soon as active grading is suspended, and graded slopes and fills must be stabilized within 21 calendar days, regardless of the time of year.

Phase VII: Maintenance

In the erosion and sedimentation control plan, indicate who is responsible for maintenance and when it will be provided. The maintenance schedule should be based on site conditions, design safeguards, construction sequence, and anticipated weather conditions. Specify the amount of allowable sediment accumulation, design cross-section, and required freeboard for each practice and what will be done with the sediment removed. The plans should also state when temporary practices will be removed and how these areas and waste disposal areas will be stabilized.

Phase VIII: Performance Requirement

Even though the developer may have an approved plan that is properly installed and maintained, he/she is not relieved of responsibility for off-site sediment damage resulting from his/her construction activities. Therefore, frequently inspect the property boundary for evidence of sedimentation. If off-site damage occurs, the developer may be responsible for immediate corrective measures. Modification of the plan and re-approval may also be necessary.



The erosion and sedimentation control plan should be flexible enough to allow for modification to correct problems. It is common for unanticipated events or construction changes to occur during project development that may require major alterations in the plan. Resubmit significant changes for approval before they are implemented.

Phase IX: Preconstruction Conference

A preconstruction conference with the owner, contractor, and erosion control personnel at the site is recommended as a means of assuring proper implementation of the erosion and sedimentation control plan. This conference is required by some local ordinances. A preconstruction conference allows all parties to meet, review the plans and construction schedule, and agree on responsibility and degree of control expected. Discuss maintenance requirements, phasing of operations, and plan revisions at this time.

A preconstruction meeting is especially important for large, complex jobs or when the contractor and/or developer has had little experience in this type of work.

If the job foreman assigned responsibility for on-site sediment control cannot be present at the conference, give his/her name to the erosion control representative at this time.

4

5

Overview of Erosion and Sedimentation Control Practices

5

Overview of Erosion and Sedimentation Control Practices

This chapter provides an overview of the practices recommended for control of erosion and sedimentation on construction sites, a key to symbols, and a practice selection guide. The practice selection guide refers the reader to principal control practices for construction considerations and site characteristics. Following the selection guide is a key to symbols which may be used on erosion control plans to represent each of the practices discussed in the manual. In the remainder of the chapter each practice is illustrated and described briefly. Additional details for planning, design, construction, and maintenance of practices are presented in *Chapter 6*. Many of these practices are also used in the sample erosion and sedimentation control plan presented in *Chapter 7*.

Table 5.1
Practice Selection Guide

CONSTRUCTION CONSIDERATIONS	SITE CHARACTERISTICS	PRINCIPAL CONTROL PRACTICES [1]
I. Scheduling	Disturbed areas	**Site Preparation:** Const. Scheduling **6.01**
II. Installing access routes, and controlling runoff from roads.	Slopes <5%	**Site Preparation:** Tree Preservation . . . . . . **6.05** Construction Entrance/Exit. . . . . **6.06** **Other Related Practices:** Road Stabilization . . . . . . **6.80** **Surface Stabilization:** Temp. Seeding . . . . **6.10** Mulching . . . . **6.14** Riprap . . . . **6.15** RECP . . . . **6.17** **Runoff Control:** Temp. Diversions . . . . . . **6.20** Water Bars . . . . **6.23** **Runoff Conveyance:** All practices. . . . . . . **6.30-6.33** **Outlet Protection:** Outlet Stabilization Structure . . . . **6.41** **Inlet Protection:** (for storm drains) Excavated . . . . **6.50** Hardware cloth . . . . **6.51** Block and Gravel. **6.52**
	Slopes 5 - 12%	Same as above except **Runoff Conveyance:** Riprap-lined and Paved Channels. . . . . **6.31** Note: Grass-lined channels not generally recommended
III. Sediment Retention (measures to be installed before major land disturbance begins)	Disturbed areas <2 acres	**Sediment Traps and Barriers:** Temp. Sediment Trap . . . **6.60** Sediment Fence . . . . **6.62** Skimmer Basin **6.64**
	Disturbed areas 2-5 acres	**Sediment Traps and Barriers:** Temp. Sediment Trap . . . **6.60** Sediment Basin. . . . . **6.61** Rock Dam . . . . **6.63** Skimmer Basin **6.64**
	Disturbed areas 5-10 acres	**Sediment Traps and Barriers:** Sediment Basin. . . . . **6.61** Rock Dam . . . . **6.63** Skimmer Basin **6.64**
	Disturbed areas >10 acres	**Sediment Traps and Barriers:** Sediment Basin. **6.61**

[1]Additional practices may be needed depending on site conditions.

Table 5.1 (continued)

CONSTRUCTION CONSIDERATIONS	SITE CHARACTERISTICS	PRINCIPAL CONTROL PRACTICES [1]
IV. Runoff Disposal	Slopes <5%, Drainage area <20 acres	**Runoff Conveyance:** All practices. . . . . . . **6.30-6.33** **Outlet Protection:** All practices. . . . . . . **6.40-6.41** **Inlet Protection for storm drains:** All practices. . . . . . . **6.50-6.55** **Runoff Control Measures:** All practices. **6.20-6.23**
	Slopes > 5% Drainage area <20 acres	**Same as above except Runoff Conveyance:** Riprap-lined and Paved Channels. . . . . **6.31** Note: Grass-lined channel not generally recommended
	Drainage area >20 acres	**Special Considerations**
V. Stabilizing Streambanks	Design Velocity <6 ft/sec	**Stream Protection:** Natural Channels **6.71**
	Design Velocity >6 ft/sec	**Stream Protection:** Structural Streambank Stabilization. **6.73**
VI. Crossing Streams	Temporary use (to move equipment)	**Stream Protection:** Temp. Stream Crossing . **6.70** **Surface Stabilization:** Temp. Seeding . . . . **6.10** Mulching . . . . **6.14** Riprap . . . . **6.15** RECP **6.17**
	Permanent use (to carry traffic)	**Stream Protection:** Perm. Stream Crossing. . **6.71** **Surface Stabilization:** Perm. Seeding . . . . **6.11** Mulching . . . . **6.14** Riprap . . . . **6.15** RECP **6.17**
VII. Clearing and Grading	Disturbed Areas	**Site Preparation:** All practices. . . . . . . **6.01-6.06** **Surface Stabilization:** Temp. Seeding . . . . **6.10** Perm. Seeding . . . . **6.11** Mulching . . . . **6.14** Riprap . . . . **6.15** RECP **6.17**

[1]Additional practices may be needed depending on site conditions.

Table 5.1 (continued)

CONSTRUCTION CONSIDERATIONS	SITE CHARACTERISTICS	PRINCIPAL CONTROL PRACTICES [1]
VII. Clearing and Grading (continued)		**Runoff Control:** All practices. . . . . . . **6.20-6.23** **Runoff Conveyance:** See IV. Runoff Disposal **Sediment Traps and Barriers:** See III. Sediment Retention **Other Related Practices:** Dust Control **6.84**
VIII. Installation of Utilities and Building Construction	Disturbed areas	**Surface Stabilization:** Temp. Seeding . . . . **6.10** Perm. Seeding . . . . **6.11** Mulching . . . . **6.14** RECP . . . . **6.17** **Runoff Control:** Temp. Diversions . . . . . . **6.20** Water Bars . . . . **6.23** **Sediment Traps and Barriers:** Temp. Sediment Trap . . . **6.60** Sediment Fence . . . . **6.62** Check Dam With Weir. . . **6.87** **Other Related Practices:** Road Stabilization **6.80**
IX. Borrow and Waste Disposal, Topsoil Stockpiling	Disturbed areas	**Surface Stabilization:** Temp. Seeding . . . . **6.10** Perm. Seeding . . . . **6.11** Trees, Shrubs, Vines, and Ground Covers. . . . . **6.13** Mulching . . . . **6.14** **Runoff Control:** Temp. Diversions . . . . . . **6.20** **Sediment Traps and Barriers:** See III. Sediment Retention
X. Special Site Problems	Seepage areas or high water table	**Other Related Practices:** Subsurface Drainage . . **6. 81**
	Unstable Temp. channels	**Surface Stabilization:** RECP . . . . **6.17** **Other Related Practices:** Check Dams . . . . **6. 83** Check Dam With Weir. . . **6.87**
	Unstable Perm. channels	**Runoff Conveyance:** Riprap-lined and Paved Channels. . . . . **6.31** **Other Related Practices:** Grade Stabilization Structure **6. 82**

[1]Additional practices may be needed depending on site conditions.

Table 5.1 (continued)

CONSTRUCTION CONSIDERATIONS	SITE CHARACTERISTICS	PRINCIPAL CONTROL PRACTICES [1]
X. Special Site Problems (continued)	Rill and gully erosion	**Runoff Control:** All practices. . . . . . .**6.20-6.23** **Runoff Conveyance:** Riprap-lined and Paved Channels. . . . .**6.31** Temp. Slope Drains. . . . .**6.32** Paved Flumes . . . .**6.33** **Outlet Protection:** Outlet Stabilization Structure . . . .**6.41** **Surface Stabilization:** All practices. **6.10-6.17**
	Blowing dust or sand	**Other Related Practices:** Dust Control . . . .**6.84** Sand Fence. **6.85**
	Dune reinforcement and stabilization	**Surface Stabilization:** Vegetative Dune Stabilization. . . . .**6.16** **Other Related Practices:** Sand Fence. **6.85**
XI. Final Site Stabilization	Disturbed areas	**Surface Stabilization:** All Practices . . . . . .**6.10-6.17** RECP . . . .**6.17** **Runoff Control:** Perm. Diversions. . . . . . .**6.21** **Runoff Conveyance:** Grass-lined Channels . . .**6.30** Riprap-lined and Paved Channels. . . . .**6.31** Paved Flume. . . . .**6.33** **Outlet Protection:** Outlet Stabilization Structure . . . .**6.41** **Inlet Protection:** Sod Drop Inlet Protection . . . .**6.50** (or perm. paving) Rock Doughnut . . . .**6.54** Rock Pipe **6.55**

[1]Additional practices may be needed depending on site conditions.

SYMBOLS FOR EROSION AND SEDIMENT CONTROL PRACTICES

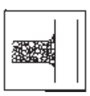
SITE PREPARATION


6.02
Land Grading


6.03
Surface Roughening


6.04
Topsoiling


6.05
Tree Preservation & Protection


6.06
Temp. Gravel Const. Enter/Exit

SURFACE STABILIZATION

(TS) 6.10
Temporary Seeding

(PS) 6.11
Permanent Seeding

(S) 6.12
Sodding

(GC) 6.13
Trees, Shrubs, Vines & GC

(M) 6.14
Mulching

(RR) 6.15
Riprap

(DS) 6.16
Vegetation Dune Stabilization

6.17
Rolled Erosion Control Prod.

RUNOFF CONTROL MEASURES

→ TD → 6.20
Temporary Diversions

→ PD → 6.21
Permanent Diversions

→ D → 6.22
Diversion Dike (Perimeter)

→ WB → 6.23
Right-of-Way Diversions

RUNOFF CONVEYANCE MEASURE

6.30
Grass-lined Channels

6.31
Riprap-lined Channels

Paved Channels

6.32
Temporary Slope Drains


6.33
Paved Flume (Chutes)

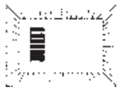
OUTLET PROTECTION


6.40
Level Spreader


6.41
Outlet Stabilization Structure

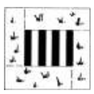
Practice Symbols (cont'd)

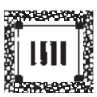
INLET PROTECTION

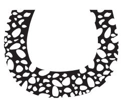

6.50
Temp. Exc. Drop Inlet Prot.


6.51
Hardware Cloth & Gravel Inlet Prot.


6.52
Temp. Block & Gravel Intel Prot.


6.53
Sod Drop Inlet Protection


6.54
Rock Doughnut Inlet Prot.

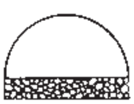

6.55
Rock Pipe Inlet Protection

SEDIMENT TRAPS & BARRIERS

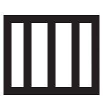

6.60
Temp. Sediment Trap


6.61
Sediment Basin

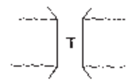

6.62
Sediment Fence


6.63
Rock Dam

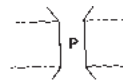

6.64
Skimmer Sediment Basin


6.65
Porous Baffles

STREAM PROTECTION



6.70
Temp. Stream Crossing



6.71
Perm. Stream Crossing

6.72
Vegetative Streambank Stab.

6.73
Structural Streambank Stab.

6.74
Buffer Zone

OTHER RELATED PRACTICES

6.80
Constr. Road Stabilization

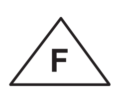
6.81
Subsurface Drain


6.82
Grade Stabilization Structure


6.83
Check Dam

6.84
Dust Control

6.85
Sand Fence (Wind Fence)



6.86
Flocculants


6.87
Check Dam with Weir

Practice no. 6.01

CONSTRUCTION SEQUENCE SCHEDULE

Following a specified work schedule that coordinates the timing of land-disturbing activities and the installation of control measures is perhaps the most cost-effective way of controlling erosion during construction.

The removal of surface ground cover leaves a site vulnerable to accelerated erosion. Construction procedures that limit land clearing, provide the timely installation of erosion and sedimentation controls, and restore protective cover quickly can significantly reduce the erosion potential of a site.

The construction sequence schedule is an orderly listing of all major land-disturbing activities together with the necessary erosion and sedimentation control measures planned for a project. This type of schedule guides the contractor on work to be done before other work is started so that serious erosion and sedimentation problems can be avoided.

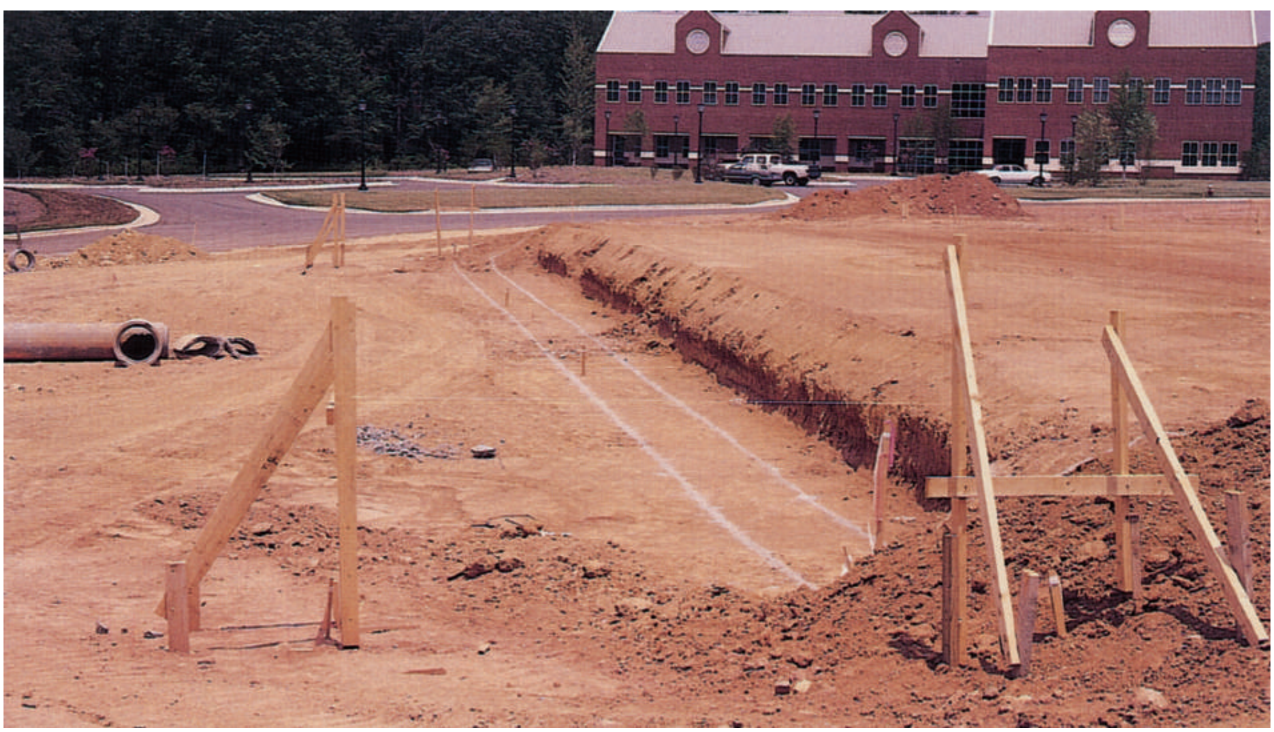
Construction sequence schedule allows completed area to be vegetated while active construction continues on adjacent area. Note sediment control measures in place.

Practice no. 6.02 LAND GRADING

Reshaping the ground surface by grading is common in site development. It is also the primary cause of erosion and sedimentation from construction activities. Fitting a proposed development to the natural configurations of the landscape reduces the erosion potential of the site and the cost of installing control measures.

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

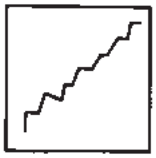
The grading plan establishes drainage areas, directs drainage patterns, and affects runoff velocities. The plan should include all necessary erosion and sedimentation control measures such as sediment basins, diversions, mulching, vegetation, vegetated and lined waterways, grade stabilization structures, and surface and subsurface drains.



Land grading shapes the surface to a specific line and grade.

Practice no. 6.03

SURFACE ROUGHENING



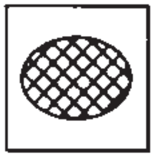
Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope.

Consider surface roughening for all slopes. The amount of roughening required depends on the steepness of the slope and the type of soil. Stable sloping rocky faces may not require roughening or stabilization, while erodible slopes steeper than 3:1 require special surface roughening.

Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used. The final face of slopes should not be bladed or scraped to give a smooth hard finish.

Surface roughening is the first step in vegetative stabilization.

Practice no. 6.04 — TOPSOILING



Topsoil provides the major zone for root development and biological activities for plants, and should be stockpiled and used wherever practical for establishing permanent vegetation.

Advantages of topsoil include higher organic matter, more friable consistency, and greater available water-holding capacity and nutrient content. In some cases, however, handling costs may be too high to make this practice cost-effective. In site planning, compare the option of topsoiling with that of preparing a suitable seedbed in the existing subsoil.

Topsoiling is a common practice 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, very stony areas, and soils of critically low pH.

Do not place topsoil on slopes steeper than 2:1 to avoid slippage.

Topsoil is stockpiled for final site preparation and stabilization.

Practice no. 6.05

TREE PRESERVATION AND PROTECTION

Preserving and protecting trees can often result in a more stable and aesthetically pleasing development. Trees stabilize the soil and help prevent erosion, decrease storm water runoff, moderate temperature, provide buffers and screens, filter pollutants from the air, supply oxygen, provide habitat for wildlife, and increase property values.

Some desirable characteristics to consider in selecting trees to be protected include: tree vigor, tree species, tree age, tree size and shape, and use as wildlife food source.

Construction activities are likely to injure or kill trees unless adequate protective measures are taken. Direct contact by equipment is the most obvious problem, but damage is also caused by root zone stress from filling, excavating, or compacting too close to trees.

Trees to be saved should be clearly marked so that no construction activity will take place within the dripline of the tree.

Tree preservation and protection somtimes requires special effort.

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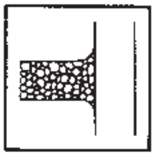
Tree preservation and protection somtimes requires special effort.

Practice no. 6.06



TEMPORARY GRAVEL CONSTRUCTION ENTRANCE/EXIT

A graveled area should be located where vehicles enter and leave a construction site to provide a buffer for the deposition of mud and sediment. This is especially important where vehicles exit construction areas directly onto public roads or other off-site paved areas.

Make the gravel pad the full width of the entrance area, sufficiently long for vehicles to drop their mud and sediment and stable enough for construction traffic. Avoid entrances on steep grades or at curves in public roads.

In some cases it may be necessary to wash vehicle tires in this area. Stabilize the graveled area well at these points, and provide drainage to a sediment trap.

Construction entrance/exit provides an immediate buffer for on-site deposition of mud and sediment.

Practice no. 6.10

TEMPORARY SEEDING

TS

Protective cover must be established on all graded slopes and fills within 21 days after a phase of grading is completed. Temporary seeding and mulching are the most common methods used to meet this requirement.

Annual plants that are adapted to site conditions and that sprout and grow rapidly should be used for temporary plantings. Proper seedbed preparation and the use of quality seed are also important.

Because temporary seedings provide protective cover for less than one year, areas must be reseeded annually or planted with perennial vegetation.

Temporary seeding is used to protect earthen sediment control practices and to stabilize denuded areas that will not be brought to final grade for several weeks or months. Temporary seeding can provide a nurse crop for permanent vegetation, provide residue for soil protection and seedbed preparation, and help prevent dust during construction.

Seeding of temporary vegetative cover provides quick, effective erosion control.

Practice no. 6.11 PERMANENT SEEDING

PS

Permanent vegetation controls erosion by physically protecting a bare soil surface from raindrop impact, flowing water, and wind. Vegetation binds soil particles together with a dense root system, and reduces the velocity and volume of overland flow. It is the preferred method of surface stabilization wherever site conditions permit.

Permanent seeding of grasses and legumes is the most common and economical means of establishing protective cover. The advantages of seeding over other means of establishing plants include the relatively small initial cost, wide variety of grasses and legumes available, lower labor input, and ease of application. Problems to consider are potential for erosion during the establishment period, the need to reseed areas, seasonal limitations on seeding dates, weed competition, and the need for water during germination and early growth.

Give special attention to selecting the most suitable plant material for the site and intended purpose. Good seedbed preparation, adequate liming and fertilization, and timely planting and maintenance are also important.

Permanent seeding of slopes requires use of a protective mulch until grass becomes established.

Practice no. 6.12 SODDING

Sodding is an erosion control practice, especially effective where immediate cover is required. It allows the use of vegetation to protect channels, spillways, and drop inlets where design flow velocities may reach the maximum allowable for the type of vegetation to be used. Sodding should also be considered in locations where a specific plant material cannot be established by seed or when immediate use is desired for aesthetics such as landscaping.

Some additional advantages of sod are nearly year-round establishment capability, less chance of failure, freedom from weeds, and immediate protection of steep slopes. Disadvantages include high installation costs, especially on large areas, and the necessity for irrigation in the early weeks. Sod also requires careful handling and is sensitive to transport and storage conditions. Soil preparation, installation, and proper maintenance are as important with sod as with seed.

Choosing the appropriate type of sod for site conditions and intended use is of utmost importance.

Sodding is an effective way to immediately stabilize a critical area (Source: NC DOT).

Practice no. 6.13

TREES, SHRUBS, VINES, AND GROUND COVERS

GC

Trees, shrubs, vines, and ground covers can provide superior, low-maintenance, long-term erosion protection. They may be particularly useful where site aesthetics are important.

Woody plants and ground covers are particularly adapted for use on steep or rocky slopes where maintenance is difficult, in shaded areas, for wildlife habitat improvement, as windbreaks or screens, and for other special landscape uses.

There are many different species of plants from which to choose, but care must be taken in their selection. It is essential to select planting material suited to both the intended use and specific site characteristics. None of these plants, however, is capable of providing the rapid cover possible by using grass and legumes. Vegetative plans must include close-growing plants or an adequate mulch with all plantings of trees, shrubs, vines, and ground covers.

Trees, shrubs, vines and ground covers, in combination with a suitable mulch, beautify and provide long-term protection to sloping areas.

Practice no. 6.14

MULCHING

M

Surface mulch is the most effective, practical means of controlling erosion on disturbed areas before establishing vegetation. Mulch protects the soil surface, reduces runoff velocity, increases infiltration, slows soil moisture loss, helps prevent soil crusting and sealing, moderates soil temperatures, and improves the microclimate for seed germination.

Organic mulch such as straw, wood chips, and shredded bark are effective for general use where vegetation is to be established. In recent years a variety of mats and fabrics have been developed that make effective mulches for use in critical areas such as waterways and channels. Various types of tacking and netting materials are used to anchor organic mulches. Netting is generally not effective when used alone.

Mechanical mulches, such as gravel, are used in critical areas where conditions preclude the use of vegetation for permanent stabilization.

Mulch must be held in place—especially on slopes (source: NC DOT).

Practice no. 6.15 RIPRAP

RR

A properly designed layer of stone can be used in many ways and in many locations to control erosion and sedimentation. Riprap protects the soil surface from direct erosive forces. It is often used on steep cut-and-fill slopes subject to severe weathering or seepage, for channel liners, for inlet and outlet protection at culverts, for streambank protection, and to protect shore lines subject to wave action.

Well-graded riprap forms a dense, flexible, seal-healing cover that will adapt well to uneven surfaces. Care must be exercised in the design so that stones are of good quality, sized correctly, and placed to proper thickness. Riprap should be placed on a proper filter material of sand, gravel, or fabric to prevent soil “piping.”

Riprap can be used to line slopes or channels to prevent erosion.

Practice no. 6.16

VEGETATIVE DUNE STABILIZATION

DS

Coastal dunes protect backshore areas from ocean storms, shoreline erosion, and encroachment by migrating sand. Adapted native vegetation can be used to stabilize coastal dunes and sandy areas disturbed by construction, and to rebuild frontal dunes. In North Carolina the perennial grasses American beachgrass, sea oats, and bitter panicum are the primary dune stabilizers, and have been extensively planted for this purpose. Vegetative planting is the most effective way to establish these grasses. Primary considerations in planning dune grass plantings include finding a source of plant material and timing plantings so they have maximum chance of success.

American beachgrass is excellent for initial dune stabilization, but is often not persistent. If 10% sea oats and bitter panicum are included in beachgrass plantings these will fill in bare spots and provide persistent cover.

Sand fences accelerate sand accumulation and can be used in combination with vegetation to rebuild frontal dunes. Dune grasses grow upward through accumulating sand to hold it as the dune grows.

Dune stabilization with appropriate vegetation impedes sand migration, and helps maintain a buffer against wave overwash.

Practice no. 6.17 ROLLED EROSION CONTROL PRODUCTS

RECP

Many different types of rolled erosion control products are used to prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. These products are temporary degradable or long-term nondegradable material manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation. Use the RECP's to help permanent vegetative stabilization of slopes 2:1 or greater and with more that 10 feet of vertical relief, as well as, channels when runoff velocity exceeds 2 feet per second on bare earth during the 2-year rainfall event.

Installation is critical to the effectiveness of these products. When close ground contact is not properly achieved, runoff can concentrate under the product, causing significant erosion. Monitor the products on a regular basis to avoid significant problems caused by rainfall.

Rolled erosion control products hold seeds and mulch in place until vegetation is able to establish on steep slopes or channels.

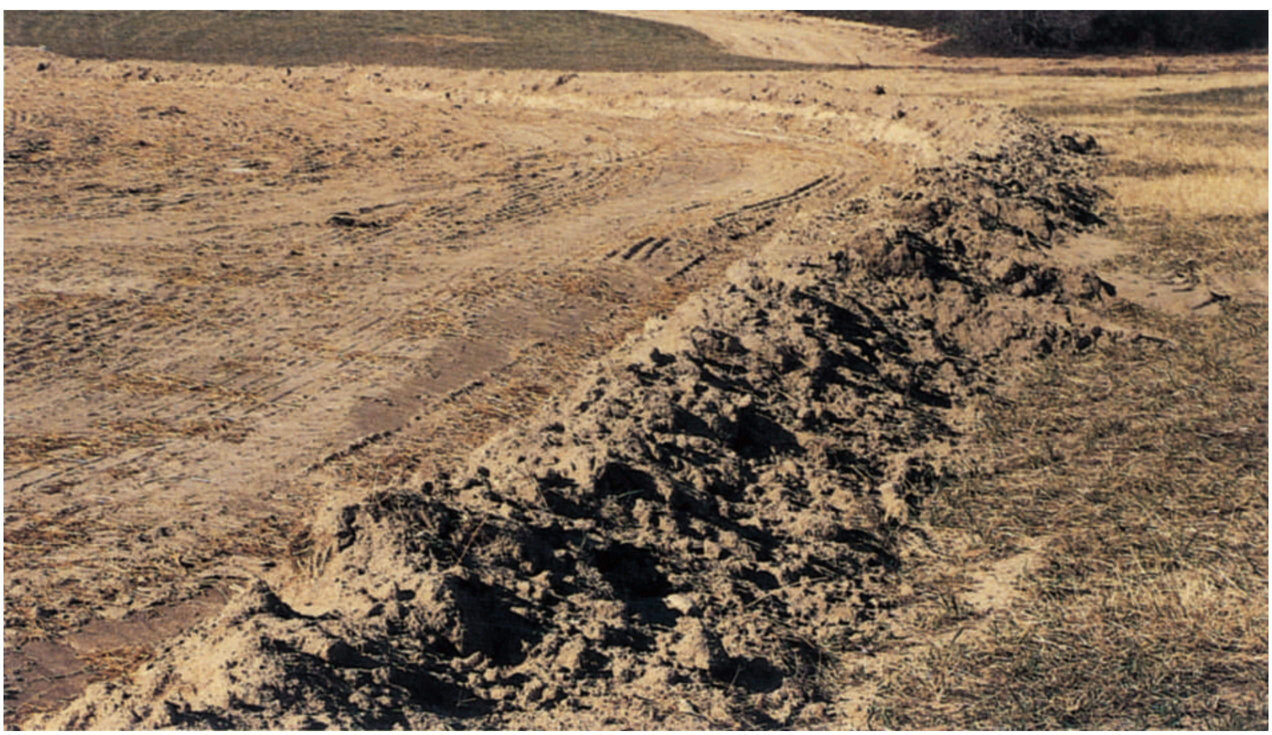
Practice no. 6.20 TEMPORARY DIVERSIONS

→ TD →

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation. They can be permanent or temporary and can serve special purposes such as diversion dikes or right-of-way diversions.

Temporary diversions may be planned to function one year or more, or may be rebuilt at the end of each day's operation to protect freshly graded cuts or fills. Temporary diversions are used above disturbed slopes to prevent flow across unprotected slopes, to reduce slope length, and to divert excess runoff away from level areas. Diversions help maintain good working conditions and reduce erosion potential. A diversion may also serve as a sediment trap when overexcavated and located on relatively flat grade adjacent to a sediment fence.

Temporary diversions are usually constructed by excavating a channel and using the spoil to form a ridge or dike on the downhill side. It is important that diversions be designed, constructed, and maintained properly since they concentrate flow and increase erosion potential if failure occurs. Outlets for diversions must be stable for the expected flow and reinforced before the diversion is installed.



Temporary diversion across a slope helps prevent sheet and rill erosion.

Practice no. 6.21

PERMANENT DIVERSIONS

—— D ——

Permanent diversions subdivide a development site and control the direction and velocity of runoff throughout the life of the development. They should be located during initial site planning, and sloped and stabilized as appropriate to enhance site appearance. Permanent diversions may be used as temporary diversions until the site is stabilized and then completed as a permanent measure.

Permanent diversions may control runoff above steep slopes, across long slopes, below steep grades, and around buildings to other areas subject to damage from runoff. The capacity of the diversion should be based on the runoff characteristics of the completed site and the potential damage from runoff after development.

Functional need, velocity control outlet stability, site aesthetics, and maintenance requirements are key considerations in the planning and design of permanent diversions.

Permanent diversion controls the direction and velocity of runoff for erosion control and flood protection.

Practice no. 6.22 — DIVERSION DIKE (Perimeter Protection)

→ PD →

The 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 design cross section, method of stabilization, and outlet requirements are designed for the existing topography at the work boundary or property boundary.

Diversion dikes may be located at the upslope side of a construction site to limit inflow or at the downslope side to divert sediment-laden runoff to on-site sediment traps. Diversion dikes do not usually encircle the entire work area. Caution must be exercised in the design to be certain that the diverted flow will not cause flood damage in adjacent areas.

Diversion dikes must be vegetated immediately after construction, and the channel area stabilized according to flow conditions.

Frequent maintenance inspection and immediate damage repair is of prime importance.

Diversion dike protects work areas and prevents sediment from leaving the site.

Practice no. 6.23

RIGHT-OF-WAY DIVERSIONS (Water Bars)

——→ WB ——→

Narrow rights-of-way on long slopes used by vehicles can be subject to severe erosion. Surface disturbance and tire compaction promote gully formation by increasing the concentration and velocity of runoff.

Right-of-way diversions or water bars limit the accumulation of erosive volumes of water by diverting surface runoff at predesignated intervals. Water bars are constructed by forming a ridge or ridge and channel diagonally across the sloping right-of-way. Each outlet should be stable, considering the cumulative effect of upslope diversion outlets. The height and side slopes of the ridge and channel are designed to divert water and allow vehicles to cross.

Right-of-way diversions (water bars) prevent erosion from long narrow slopes.

Practice no. 6.30

GRASS-LINED CHANNELS

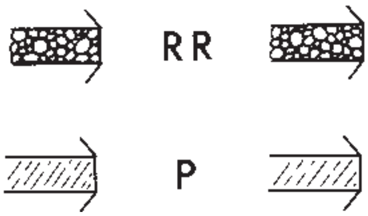
Grass-lined channels resemble natural systems, and are usually preferred where design velocities are suitable. Select appropriate vegetation and construct channels early in the construction schedule before grading and paving increase runoff rates.

Generally, grass-lined channels are constructed in stable, low areas to conform with the natural drainage systems, but they may also be needed along roadways or property boundary. To reduce erosion potential, design the channel to avoid sharp bends and steep grades.

The channel cross section should be wide and shallow with relatively flat side slopes so surface water can enter over the vegetated banks without erosion. Riprap may be needed to protect the channel banks at the intersections where flow velocities approach allowable limits and turbulence may occur.

Grass-lined channels are preferred where flow velocities are within permissible limits.

Practice no. 6.31 RIPRAP-LINED AND PAVED CHANNELS



Where flow velocities exceed allowable limits for grass-lined channels, more durable liners such as riprap or paving should be used.

Riprap liners are considered flexible an are usually preferred to rigid liners. Riprap is less costly, adjusts to unstable foundation conditions, is less expensive to repair, and reduces outlet flow velocity.

Paved channels are preferred where space is limited, slopes are very steep, or the channel setting warrants the use of special paving materials. Care must be exercised to see that foundation conditions are stable and high exit velocities can be controlled to protect the receiving stream.

Riprap or paved channels can be constructed with grass-lined side slopes where site conditions warrant.

Riprap or paved channels are necessary where flow velocities are too high for vegetation.

Practice no. 6.32

TEMPORARY SLOPE DRAINS

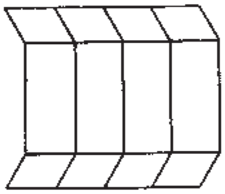
A temporary flexible tubing, designed to convey concentrated runoff down the face of a disturbed slope, is an effective gully prevention practice especially in the early stages of project development. Temporary slope drains are usually installed in conjunction with temporary diversions that are located above cut or fill slopes. They may also serve as outlets for natural drainageways.

It is important that these temporary structures be sized, installed, and maintained properly as their failure will usually result in severe erosion of the slope. Proper backfilling and compaction are essential. Slope drains must extend downslope to stable outlets, or special outlet protection must be provided.

Temporary slope drains are often replaced with permanent structures when final grading is complete.

Temporary slope drain conveys concentrated flow safely down a steep slope until permanent measures are installed.

Practice no. 6.33 — PAVED FLUMES (Chutes)



Paved flumes are small concrete-lined channels designed to convey storm runoff down steep slopes. They are part of the permanent erosion control system for the development.

Paved flumes or chutes can be readily installed in most locations, offer large freeboard capacity at low cost, are less subject to failure from blockage than closed drains, and require little maintenance.

In planning paved flumes, give special attention to flow entrance conditions, stability of the foundation, outlet energy dissipation, and freeboard capacity.

The upper portion of the side slopes may be grassed to improve appearance and reduce cost.

Paved flumes carry high velocity flows down steep slopes as part of the permanent erosion control system.

Practice no. 6.40

LEVEL SPREADER

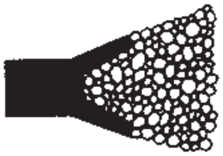
Level spreaders provide a non-erosive outlet for concentrated runoff by dispersing flow uniformly across a stable slope. They are relatively low-cost structures designed to release small volumes of water safely. The drainage area should be limited to 5 acres, and the size of the spreader based on design runoff.

Construct level spreaders in undisturbed soil. The lip must be level to ensure uniform spreading of storm runoff, and the outlet slope uniform to prevent the flow from concentrating. Water containing high sediment loads should enter a sediment trap before release in a level spreader.

Level spreader releases flow from a diversion onto a uniform stable area.

Practice no. 6.41

OUTLET STABILIZATION STRUCTURE



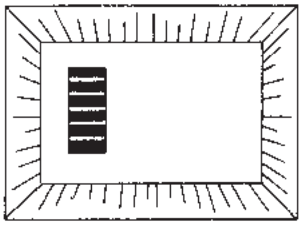
Erosion at the outlet of channels, culverts, and other structures is common, and can cause structural failure with serious downstream problems. It is necessary that exit velocities into streams be non-erosive for site conditions. Outlet stabilization structures are often installed to provide the necessary energy dissipation. A riprap-lined apron is the most commonly used structure for this purpose because it has relatively low cost and can be installed easily on most sites.

Other types of outlet stabilization structures include plunge pools, concrete impact basins, and paved outlets.

Outlet stabilization with riprap prevents erosion from high-velocity, concentrated flow.

Practice no. 6.50

EXCAVATED DROP INLET PROTECTION (Temporary)



Protection against sediment entering a storm drain drop inlet can be provided by excavating an area in the approach to the drain. This temporary sediment-trapping device allows the storm drain to operate before the drainage area is permanently stabilized. The early use of storm drains during project development significantly reduces erosion problems.

The drainage area for a protected drain is limited to 1 acre, and the size, shape, and depth of excavation are designed for optimal sediment trapping. Weep holes are provided to drain the shallow pool. Frequent maintenance is required.

This practice can be used effectively in combination with other inlet protection devices.

Temporary excavated drop inlet protection creates an effective settling pool to remove sediment at a stormwater inlet.

Practice no. 6.51

HARDWARE CLOTH AND GRAVEL INLET PROTECTION

Hardware cloth and gravel inlet protection is used to temporarily protect yard inlets, grated storm drains, or drop inlets from sedimentation during construction. A wire-mesh hardware cloth is supported by steel posts and is surrounded by washed stone. It should be used where flow is light to moderate and is most effective where the inlet is expected to drain shallow sheet flow.

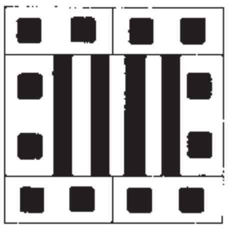
The drainage area should not exceed 1 acre per inlet. The immediate land area around the inlet should be relatively flat and located so that accumulated sediment can be easily removed. Frequent maintenance is required and excess sediment should be removed from the pool after each rainfall for maximum efficiency.

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

Hardware cloth and gravel inlet protection keeps sediment and debris from construction out of this drop inlet.

Practice no. 6.52

BLOCK AND GRAVEL INLET PROTECTION (Temporary)



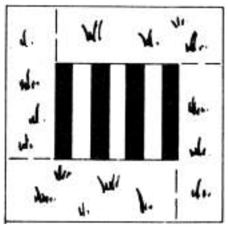
A small, sturdy barrier to trap sediment at the entrance to a storm drain can be formed for standard concrete block and gravel. Preventing sediment from entering the drain allows it to be used for stormwater disposal early in project development.

Lay blocks without mortar closely around the drain. Lay some blocks sideways to provide drainage. Place gravel around the outside of the blocks to restrict the flow and form a sedimentation pool. The pool should drain slowly through the gravel. Drainage area is limited to 1 acre and pool depth is limited to 2 feet. Frequent maintenance is required.

Block and gravel inlet protection prevents sediment from entering this storm drain during construction.

Practice no. 6.53

SOD DROP INLET PROTECTION



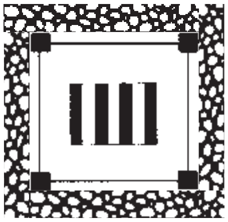
Grass sod properly placed around a storm drain can provide permanent stabilization of the drain entrance under certain site conditions. The drainage area should not exceed 2 acres, the entrance flow velocity must be low, and the general area around the inlet should be planned for vegetation. Maintain the sod in a healthy, vigorous condition.

Although the storm drain entrance could be stabilized by paving, using pre-cast blocks, or other structural means, the use of permanent vegetation is usually preferred for aesthetic reasons.

Sod drop inlet provides permanent protection for a storm drain after the drainage area is stabilized.

Practice no. 6.54

ROCK DOUGHNUT INLET PROTECTION



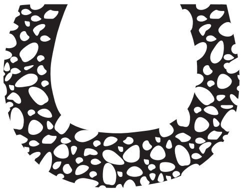
A rock doughnut inlet protection is used to prevent sediment from getting into drop inlets with 1 acre drainage areas, or inlets that receive high velocity water flows from many directions. Sediment is captured in an excavated depression surrounding the inlet. Other measures may be necessary for a larger drainage area.

The stone structure must have a top elevation of at least 12 inches lower than the ground elevation downslope from the inlet. The practice may be altered if the flow is received from only one direction.

Frequent maintenance is required and excess sediment should be removed from the pool after each rainfall for maximum efficiency.

Rock Doughnut Inlet Protection uses larger riprap for the structure base and smaller washed stone to keep smaller particles of sediment from entering the storm drain inlet.

Practice no. 6.55 ROCK PIPE INLET PROTECTION



The rock pipe inlet protection allows the early use of the storm drain system. Prior to stabilization of the disturbed area, this practice prevents sediment from entering, accumulating in, and being transferred by a culvert or storm drain system. The horseshoe shaped rock dam structure may protect a pipe 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. The maximum drainage area should not exceed 5 acres. When used as a sediment trap, the surface area and volume requirements must be met. Frequent inspections are necessary.

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

Rock Pipe Inlet Protection uses a small rock dam-type barrier to divert sediment laden water away from the pipe.

Practice no. 6.60

TEMPORARY SEDIMENT TRAP

Trapping sediment at selected points in a construction area reduces potential for sediment damage, simplifies structural design, provides for convenient removal of sediment, and limits damage should a structure fail.

Small sediment traps are often installed in outlets for diversions, channels, slope drains, and other points where sediment-laden water is concentrated. Restrict the drainage area to 5 acres or less and limit the embankment height. Locate sites where emergency bypass flow is possible and potential damage from failure is low. Include 3 baffles in the sedimentation pool to maximize trapping efficiency. Traps must be readily accessible for periodic sediment removal and other necessary maintenance.

The trap is usually formed by constructing an earthen embankment across a low area to form a sedimentation pool during rainfall runoff events. It may also be made by excavation or a combination of excavation and fill. The outlet spillway section is constructed of stone, and provides drainage for the pool. The inside face of the outlet section is lined with gravel to slow the release of drainage water and improve sediment trap efficiency.

Temporary sediment trap provides a settling pool for a small drainage area. Gravel allows dewatering and a stable outlet.

Practice no. 6.61

SEDIMENT BASIN

Sediment basins are usually constructed by building a low earthen dam across a drainageway to form a temporary sediment storage pool. A properly designed spillway outlet with adequate freeboard is essential. The embankment should be well compacted and vegetated. Sediment basins may also be formed by excavation, but these are usually more costly. A combination embankment/excavated basin is often utilized.

Basins are located to capture sediment from as much of the disturbed area of the site as possible and should be installed before clearing and grading begin. Ease of basin cleanout and spoil disposal should be considered in site selection.

To improved trap efficiency the basin should have the maximum surface area possible, and sediment should enter the basin as far from the outlet as possible. Baffles should be installed in the sedimentation pool to maximize trapping efficiency.

Dams should not be constructed in intermittent or perennial streams or where failure might cause loss of life or serious property damage.

Sediment basins are strategically located to trap sediment near the outlet of a work site.

Practice no. 6.62 SEDIMENT FENCE (Silt Fence)

A sediment fence is a permeable barrier erected on small disturbed areas to capture sediment from sheet flow. It is made of filter fabric buried at the bottom, stretched and supported by steel posts.

The sediment fence reduces the velocity of flow, allows deposition, and retains sediment. Because sediment fences are not designed to withstand high heads, the drainage area must be restricted and the fence located so that water depth does not exceed 1.5 feet at any point. Sediment fences may be designed to store all the runoff from the design storm, or located to allow bypass flow when the temporary sediment pool reaches a predetermined level. Sediment fences may also divert small volumes of flow to protected outlets.

In the design of a sediment fence exercise care to prevent failure from undercutting, overtopping, or collapsing. Ensure that flow bypass areas and overflow outlets are stable.

Check sediment fences after each significant rainfall, remove the necessary sediment, and make repairs promptly. The design life of a synthetic sediment fence is 6 months or less.

Do not install sediment fence across streams or ditches where flows are concentrated.

Sediment fences help prevent off-site sedimentation when properly located, installed, and maintained.

Practice no. 6.63 ROCK DAM

A rock dam is a rock embankment that forms a sedimentation basin. It may be used in drainage areas too large for temporary sediment traps, but not over 10 acres. The rock dam is suitable for sites where a stable earthen embankment would be difficult to construct, and riprap and gravel are readily available. The maximum height is 8 feet at the spillway.

The spillway is designed with a long weir crest to keep flow shallow and discharge velocities low. To further reduce sedimentation, install baffles for more effective filtration of smaller particles. The inside face of the dam is lined with gravel to reduce seepage velocity and maintain a sedimentation pool during runoff events. The pool should drain slowly between runoff events.

The rock dam should never be located in an intermittent or perennial stream.

Rock dam forms a sedimentation basin with a broad-crested principal spillway to keep flow depth and discharge velocity low.

Practice no. 6.64 SKIMMER SEDIMENT BASIN

Skimmer sediment basins are an earthen embankment suitably located to capture sediment, with a trapezoidal spillway lined with an impermeable geotextile or laminated plastic membrane, and equipped with a floating skimmer for dewatering. The skimmer is a sedimentation basin dewatering control device that withdraws water from the basin's water surface, thus removing the highest quality water for discharge downstream.

These practices are needed where drainage areas are too large for temporary sediment traps, and may require less volume and area than a temporary sediment trap or a rock dam. The maximum drainage area is 10 acres. Baffles should be installed in the sedimentation pool to maintain trapping efficiency.

Do not locate the skimmer sediment basin in intermittent or perennial streams.

All parts of the basin require frequent inspection and maintenance as needed to remain efficient and prevent failures.

Skimmer sediment basins dewater the sedimentation pool from the surface to ensure the highest quality water is being discharged.

Practice no. 6.65 BAFFLES

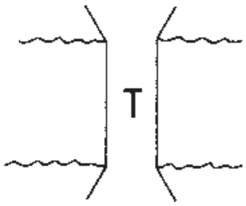
Porous baffles are installed inside temporary sediment traps, rock dams, skimmer basins, and sediment basins to reduce the velocity and turbulence of the water flowing through the measure, and facilitate the settling of sediment from the water before discharge. Baffles improve the rate of sediment retention by distributing the flow and reducing turbulence. This process can improve sedimentation retention and allow the capture of soil particles 50 percent smaller than those that can be captured without baffles.

Recommended materials for the baffles include jute backed by coir erosion blankets, coir mesh, and tree protection fence folded over to reduce pore size. Installation is similar to a sediment fence. It is essential to install the measure securely to avoid blow outs and other malfunctions. Frequent inspections are required.

Baffles reduces the velocity and turbulence of water flowing through a measure and assists in the settling of sediment before the water exits the site.

Practice no. 6.70

TEMPORARY STREAM CROSSING

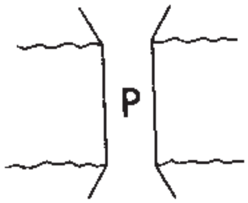


Stream crossings are direct sources of water pollution. They cause flooding and safety hazards, and can be expensive to construct. If washed out or damaged, they can also cause costly construction delays. Plan the development to complete work on each side separately to minimize stream crossings.

Stream crossings are of three general types: bridges, culverts, and fords. In selecting a stream crossing practice consider: frequency and kind of use, stream channel conditions, overflow areas, potential flood damage, surface runoff control, safety requirements, and installation and maintenance costs. Temporary crossings may overflow during peak storm periods, however, the structure and approaches must remain stable.

Temporary stream crossing may be a ford, culvert or bridge. Bridges allow full stream flow, but must be designed and built to support expected loads.

Practice no. 6.71 — PERMANENT STREAM CROSSING



Permanent stream crossings provide suitable means for crossing streams or other watercourses during and after construction.

Planning considerations for permanent stream crossings are essentially the same as for temporary stream crossings except that permanent stream crossings should be subject to less frequent overflow. Flooding and erosion can be minimized by locating permanent stream crossings in higher, better drained stream sections.

Depending on location and ultimate use, permanent stream crossings may have to meet local government or NCDOT standards. Considerations include maximum anticipated loads, safety, and flow capacities.

Permanent stream crossings require structures that will not erode, overtop, or cause flooding.

Practice no. 6.72

VEGETATIVE STREAMBANK STABILIZATION

Upstream development accelerates channel erosion be increasing the velocity, frequency, and duration of flow. As a result, many natural channels that were stable become unstable following urbanization.

Stream channels may be stabilized by selected vegetation or by structural means. In many cases a combination of vegetative and structural measures should be used. Wherever possible, it is best to protect banks with living plants that are adapted to the site. Natural plant communities are aesthetically pleasing, provide a habitat for fish and wildlife, afford a self-maintaining cover, and are less expensive and damaging to the environment.

Evaluated the erosion potential of the channel carefully and establish appropriate vegetation wherever sire conditions permit. Stream channel velocities for the 10-year storm should generally be less than 6 feet per second for effective stabilization by vegetative means.

Vegetative Streambank Stabilization protect streamsbanks from erosion

Practice no. 6.73

STRUCTURAL STREAMBANK STABILIZATION

Consider structural measures for streambank stabilization where it is evident that vegetative stabilization will be inadequate. Channel reaches are often made stable by establishing vegetation where erosion potential is low and installing structural measures where the attack is more severe, such as the outside of channel bends and where the natural grade steepens.

Riprap is the most common structural method used, but other methods such as gabions, deflectors reinforced concrete, log cribbing, and grid pavers should be considered, depending on site conditions.

Structural streambank stabilization such as gabions and riprap is necessary where stream velocities are high and side slopes are steep.

Practice no. 6.74 BUFFER ZONES

A buffer zone is a natural area of vegetation that is adjacent to a natural stream, lake, wetland, marsh, or any other type of watercourse. The buffers protect the water courses by reducing the impact of upland pollution. They are most effective at filtering surface runoff and groundwater, filter dust from surrounding land-disturbing activities, cycle nutrients from vegetative roots, and provide leaves and woody debris used for food and shelter by aquatic organisms.

The protective buffer zones should be used for perennial streams, intermittent streams, lakes, ponds, estuaries, and modified natural streams. 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.

Buffer zones are a crucial natural area of vegetation between a body of water and a construction site used to filter out sediment and other pollutants that could contaminate the water resource.

Practice no. 6.80

CONSTRUCTION ROAD STABILIZATION

CRS

Properly located and stabilized construction roads can significantly reduce on-site erosion during construction.

Ensure that construction routes follow the natural contour of the terrain where possible. Avoid steep slopes, excessively wet areas, and highly erodible soils.

Controlling surface runoff from the road surface and adjoining area is a key erosion control consideration. Construction traffic routes are especially susceptible to erosion because they become compacted and rutted, and collect and convey runoff water along their surfaces, often at erosive velocities. Provide surface drainage, and divert excess runoff to stable areas.

Proper grading and stabilization of construction roads and parking areas with stone often saves money for the contractor by reducing erosion, avoiding dust problems, and improving the overall efficiency of the construction operation.

Construction road stabilization improves work efficiency and prevents erosion.

Practice no. 6.81

SUBSURFACE DRAIN

A subsurface drain is often needed in construction operations and in developing areas to remove excess water from the soil. Drains usually consist of perforated, flexible conduit installed in a trench at designed depth and grade. The conduit is often placed in a sand-gravel filter or gravel envelope and sized to carry the design flow. Backfill over the drain should be an open, granular soil of high permeability.

Drains improve soil-water conditions for vegetative growth, prevent sloughing of steep slopes due to ground water seepage, and stabilize wet foundation conditions for erosion control structures and other installations.

Make sure the soil to be drained has sufficient depth and permeability to permit proper installation of an effective drainage system. An adequate outlet must be available. Properly designed and installed drains require little maintenance.

Subsurface drains remove excess water from the soil profile to improve stability and plant environment.

Practice no. 6.82 GRADE STABILIZATION STRUCTURE

Grade stabilization structures are used to control the grade in natural or constructed channels to prevent erosion. They may be vertical drop weir spillways, chutes, or pipe drop structures, and may be made of reinforced concrete, steel sheet piling, concrete block, riprap, corrugated metal, plastic, or concrete pipe, depending on the site conditions.

Grade stabilization structures control head cutting, or major gully erosion in channels on steep slopes, in locations where beds of intersecting channels are at different elevations, and where flatter grades are needed in proposed channels to control velocities.

Locate these structures in straight channel sections. Stabilize foundation materials, and ensure that flood bypass capability is available to protect the structure from flows greater than design. The design of large structures (100 cfs or larger) should be undertaken only by a qualified engineer, experienced in hydraulics and structural design.

Maintenance of grade stabilization structures should be minimal, but it is important that inspections be made periodically and after all major storms through the life of the structure.

Grade stabilization structure prevents head cutting in a vegetated channel.

Practice no. 6.83 CHECK DAM

Check dams are used to reduce gullying in the bottom of small channels or drainage ways that will be filled or permanently stabilized at a later date. These small channel blocks serve to reduce the velocity of flow by ponding runoff in the channel.

Check dams are usually made of stone. The center section must be lower than the edges. Space the dams so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Ensure that overflow areas along the channel are resistant to erosion from out-of-bank flow caused by the check dams. Restrict the drainage area to one half acre.

Check dams are temporary expedient practices to reduce channel erosion until permanent stabilization measures can be installed. Inspect the dams weekly and after significant rainfall events.

Check dams slow velocity of flow in temporary, low-flow channels.

Practice no. 6.84 DUST CONTROL

DC

Large quantities of dust can be generated during land grading activities for commercial, industrial, or subdivision development, especially during dry, windy weather. In planning for dust control, it is important to schedule construction activities so that the least area of disturbed soil is exposed at one time. Install temporary or permanent surface stabilization measures immediately after completing a land grading unit.

For disturbed areas not subject to traffic, vegetation (temporary or permanent) provides the most practical and effective means of dust control. For other areas, control measures include mulching, sprinkling, spraying adhesive or calcium chloride, wind barriers, and surface roughening by tillage.

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

Dust control by watering provides immediate protection, but water must be applied periodically throughout dry periods (source: SCS).

Practice no. 6.85 SAND FENCE (Wind Fence)

A sand or wind fence is a low fence of wooden slats erected perpendicular to the prevailing wind. The fence traps blowing sand by reducing the wind velocity at the ground surface.

Wind fences are used primarily to build frontal ocean dunes to help prevent flooding and erosion from wave overwash, but they may also serve to prevent sand from blowing onto roads or other off-site areas.

Wind fences are usually made commercially of light wooden slats wired together with spaces between the slats. The fences are erected 2 to 4 feet high in parallel rows spaced 20 to 40 feet apart over the area to be protected. Fences are supported by wooded posts.

When wind fences are approximately two-thirds full, another series of fences is erected. In this manner, dunes can be built 2 to 6 feet high or more during a single season. When the dune has reached the approximate height of other mature dunes or when the building process slows significantly, stabilize with appropriate vegetation.

When wind fences are used to protect off-site areas from blowing sand, maintain them until the sand source has been stabilized.

Sand fence captures blowing sand to rebuild frontal dune. Natural or planted vegetation helps stabilize the dune.

Practice no. 6.86 FLOCCULANTS

F

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. Soil that is exposed during construction or stormwater runoff can be picked up and carried to the nearest water conveyance. As the flow rate slows, the larger sand or pebble particles will settle out of the water, however, the smaller particles take a much longer time to settle out. The flocculants will cause the clay particles to clump together and settle out more quickly.

Water that is discharged from sediment traps and basins can still contain high levels of suspended clays and fine silts that are very difficult to settle out. Other ways to reduce the suspended sediment are storing the runoff long enough for the small particles to settle or to filter it further and store until settlement. Flocculants are often the most practical method to settle fine particles.

Flocculants should be used to prevent sedimentation damage to sensitive water resources such as ponds, lakes, and trout streams, or whenever turbidity control is required. Application of flocculants is very soil-type dependent.

Flocculants are used to pull the finer particles out of the water to reduce turbidity, and protect sensitive water reources.

Practice no. 6.87

CHECK DAM WITH WEIR

→ →

A temporary check dam with a weir is a small dam structure with a weir outlet. They are used to reduce erosion in the drainage channel by restricting the velocity of flow and trap sediment, allowing the channel to stabilize.

The dams are temporary practices that can be used at outlets of temporary diversions, graded channels, temporary slope drains, and 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.

Riprap and wash stone are the most common materials for this practice. The weir length varies due to the drainage area. The center of the check dam should always be at least 9 inches lower than the outer edges at natural ground level. Frequent inspections are required.

Check dams with weirs control the velocity of runoff through channels and reduce erosion.

6

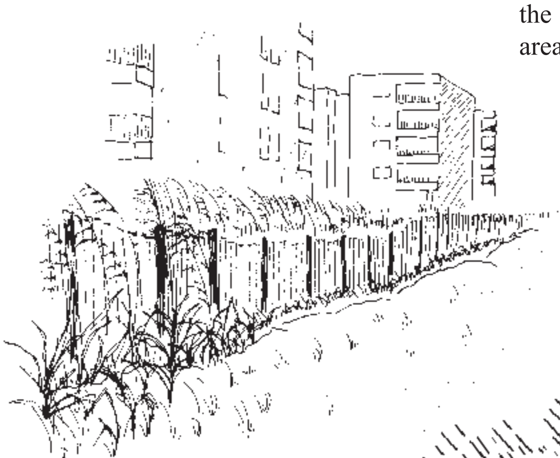
Practice Standards and Specifications

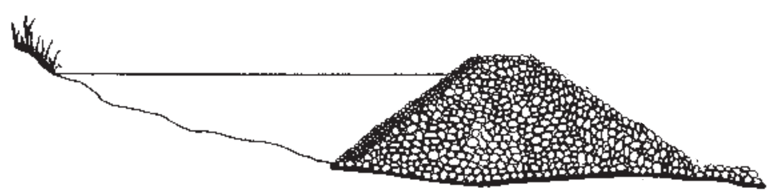
6

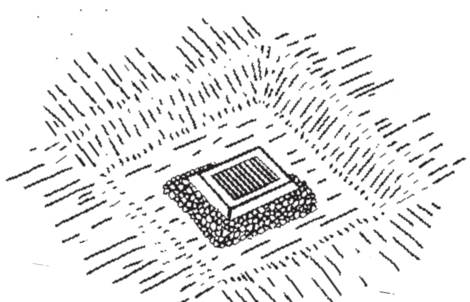
Practice Standards and Specifications

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.







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Practice Standards and Specifications

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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.

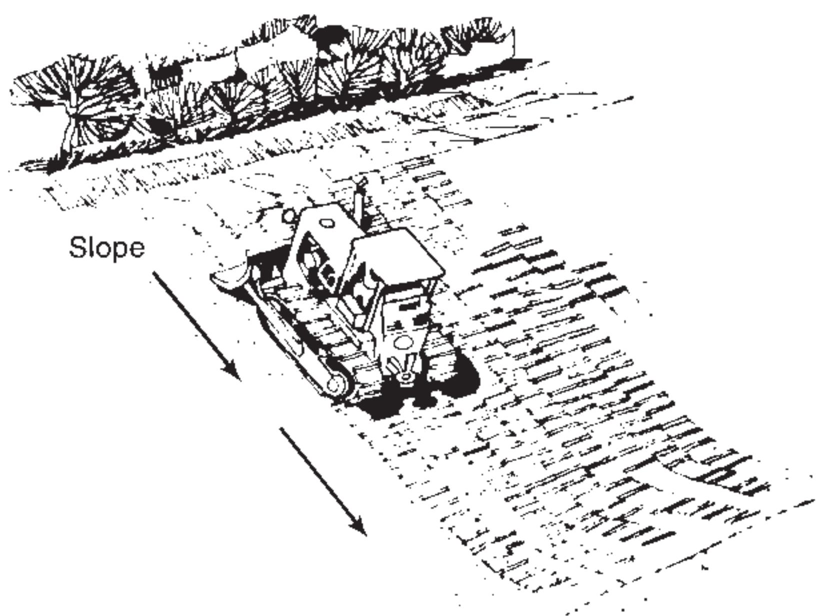


Figure 6.03a Bulldozer treads create grooves perpendicular to the slope. The slope face should not be back-bladed during the final grading operation (source: Va SWCC).

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.

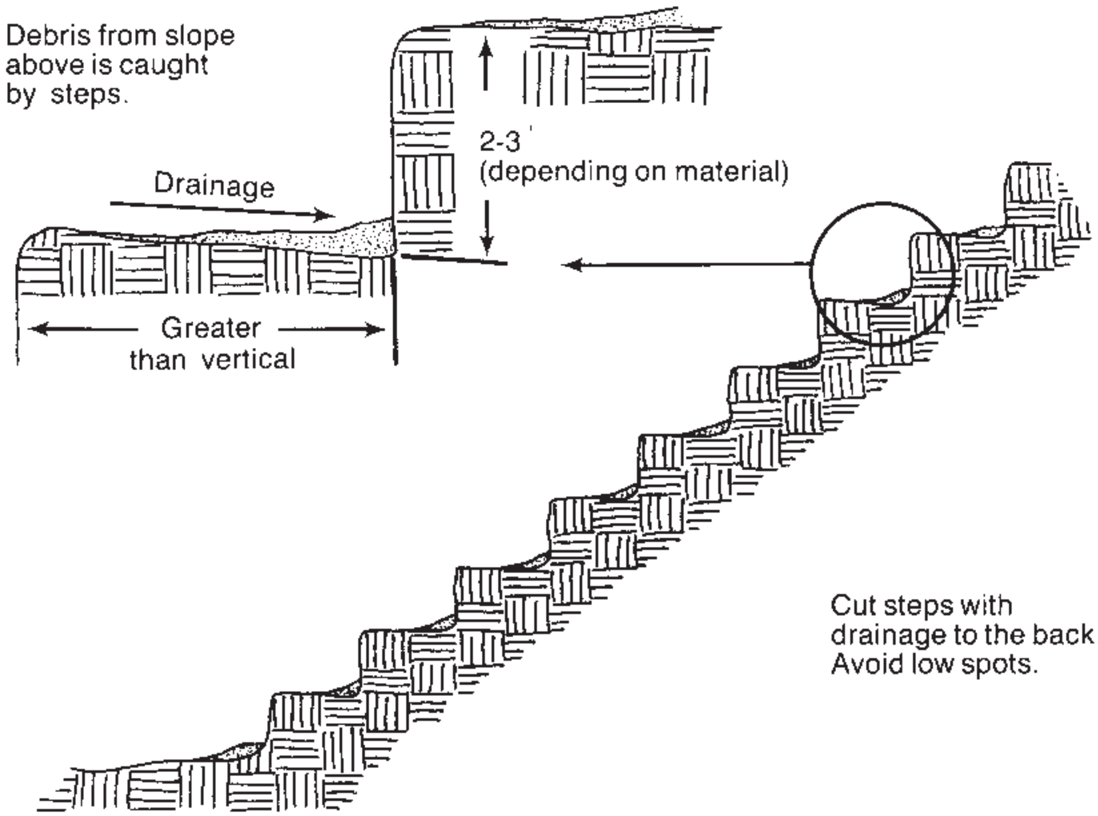


Figure 6.03b Stair stepping cut slopes (modified from Va SWCC).

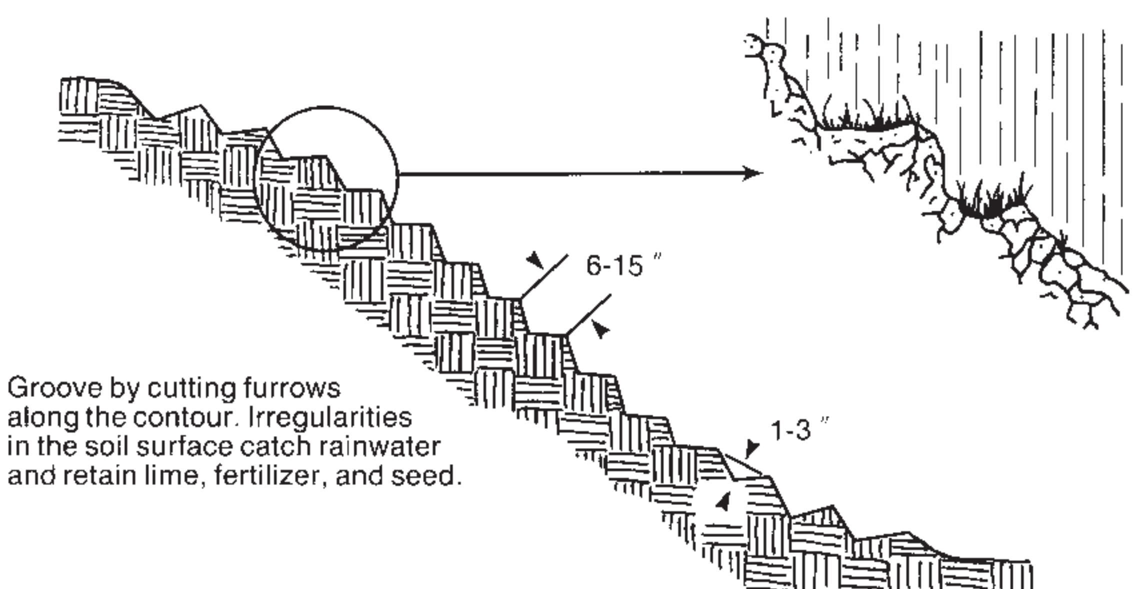


Figure 6.03c Grooving slopes (modified from Va SWCC).

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.

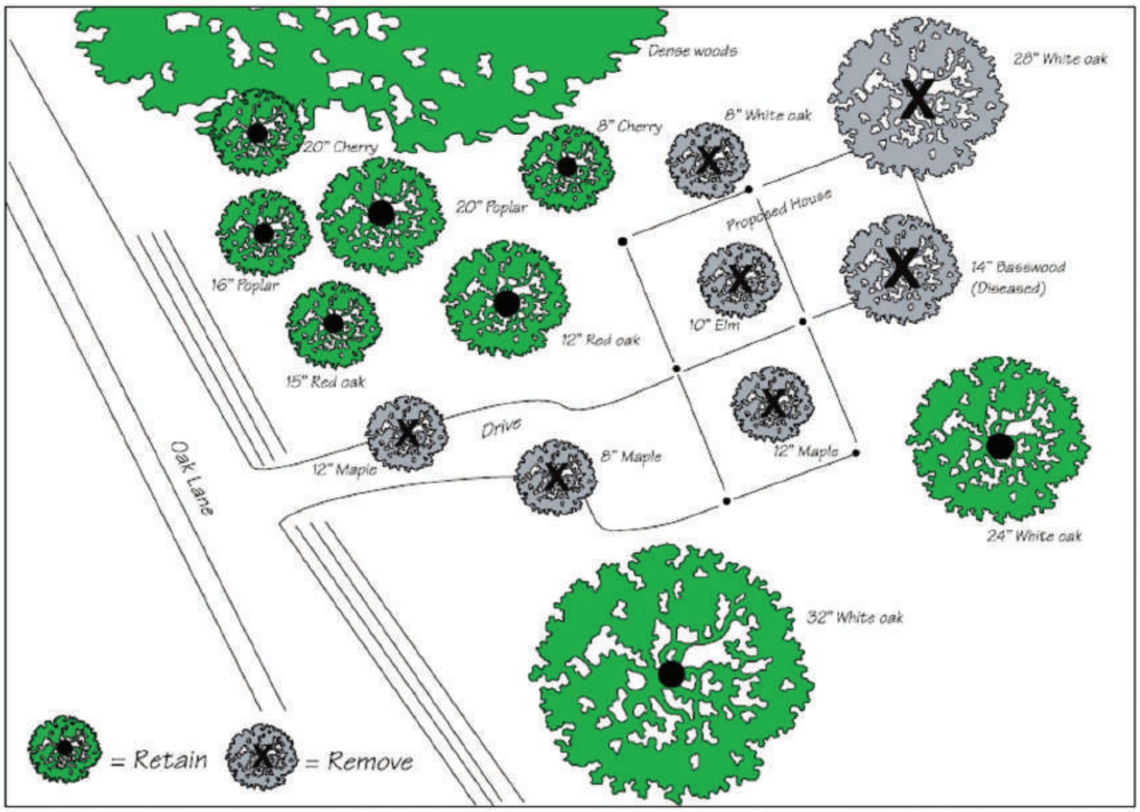


Figure 6.05b Simple tree protection plan. A plan identifies the size and species of existing trees, designates trees that must be protected, and marks trees to be removed. It also indicates planned structures, vehicle access, and excavation areas.

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.

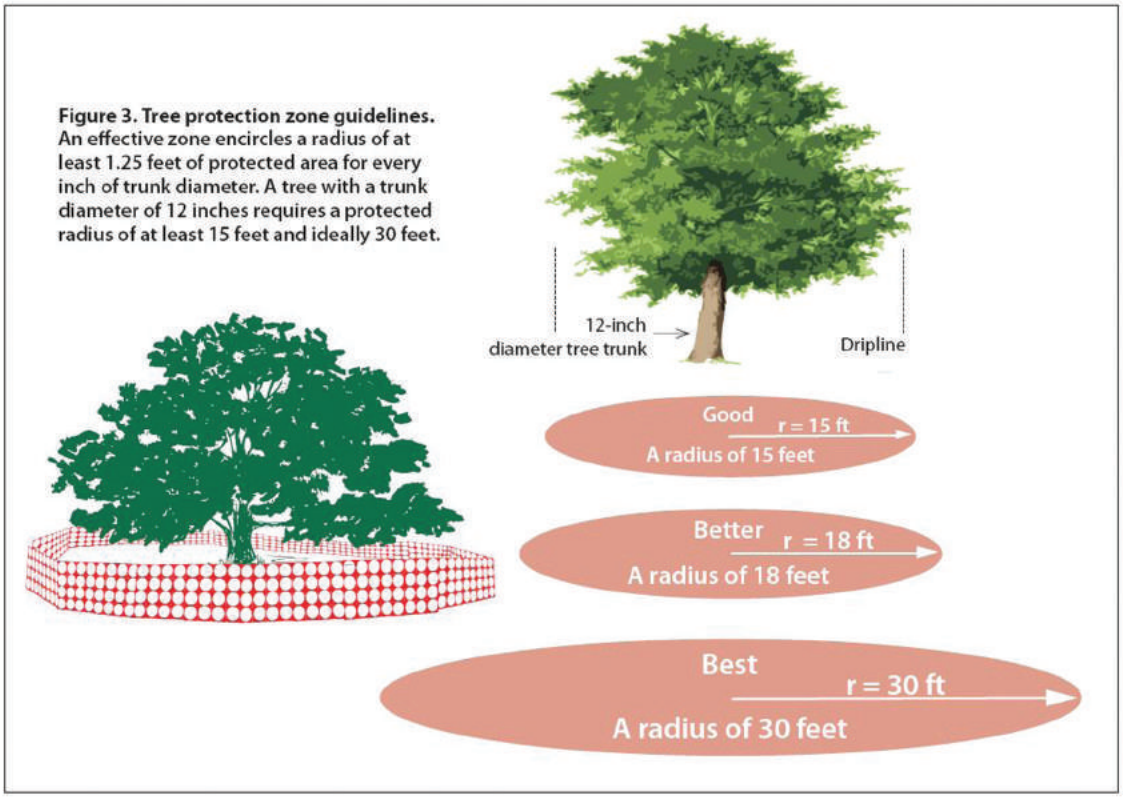
• Assess crew and contractor penalties, if necessary, to keep the TPZs intact.

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.



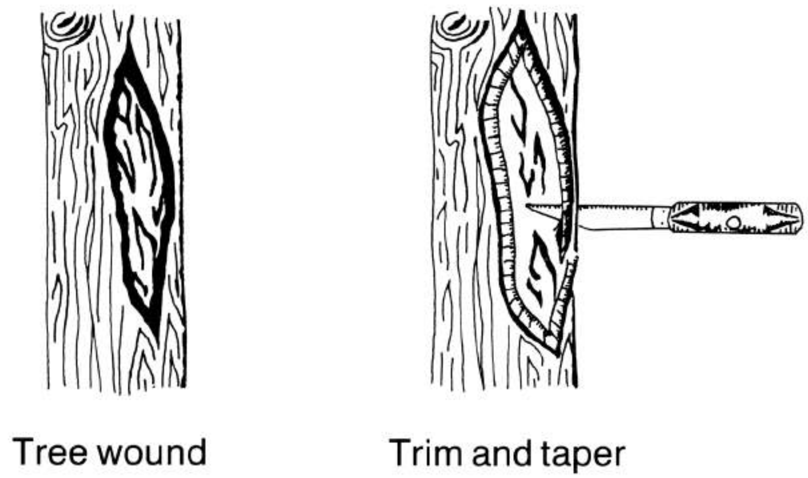
Maintenance

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:

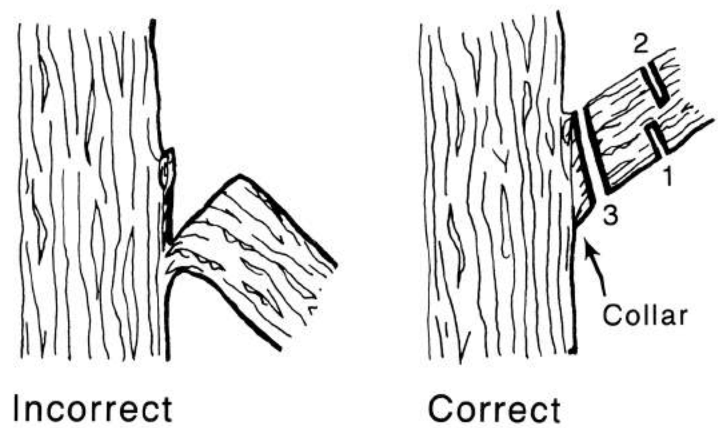
- Remove tree protection zone fences.
- Prune any damaged trees. In spite of precautions, some damage to protected trees may occur. In such cases, repair any damage to the crown, trunk, or root system immediately.
  - Repair roots by cutting off the damaged areas and painting them with tree paint. Spread 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.



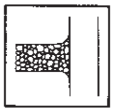
Prune damaged branches with three cuts to avoid peeling bark from the trunk when limb falls.



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.

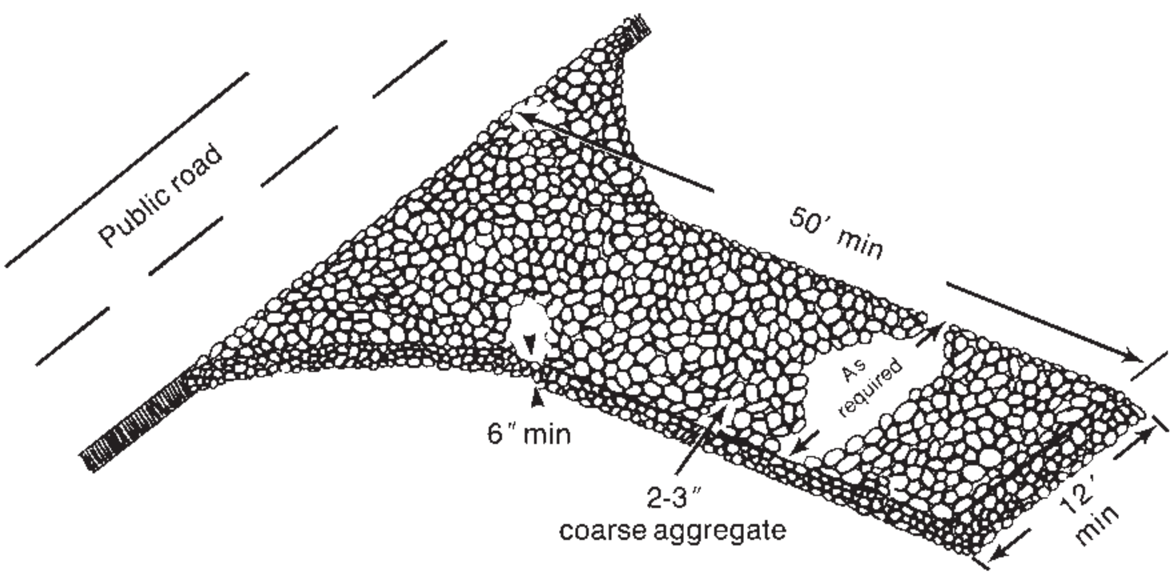


Figure 6.06a Gravel entrance/exit keeps sediment from leaving the construction site (modified from Va SWCC).

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.

HERBACEOUS PLANTS-Seeding recommendations for immediate stabilization/nurse crops

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

Table 6.11.a

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

					Optimal Planting Dates								
Common Name	Botanical Name / Cultivar	Native / Introduced	Broadcast Seeding Rates lbs/acre	Fertilization/ limestone lbs/acre	Mountains	Piedmont	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

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
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

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
Indiangrass	*Sorghastrum nutans / Cheyenne*	N	B	By soil test	12/1-4/15	12/1 - 4/1	12/1-4/1	Sun	NR	Well drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Western coastal plain only
Indiangrass	*Sorghastrum nutans / Lomenta*	N	B	By soil test	NR	12/1 - 5/1	1/1 -5/1	Sun	NR	Well drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Only Indiangrass adaptable to Eastern coastal plain (Zone 8)
Deertongue	*Dichanthelium clandestinum / Tioga*	N	C	By soil test	5/1-4/15	5/1 - 4/1	NR	Sun & Shade	Yes	Poorly drained to drought	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	
Big Bluestem	*Andropogon gerardii / Rountree*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Big Bluestem	*Andropogon gerardii / Kaw*	N	D	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Big Bluestem	*Andropogon gerardii / Earl*	N	D	By soil test	12/1-4/15	12/1 - 4/1	12/1-5/1	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Little Bluestem	*Schizachyrium scoparium / Aldous*	N	E	By soil test	12/1-4/15	NR	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass
Little Bluestem	*Schizachyrium scoparium / Cimmaron*	N	E	By soil test	12/1-4/15	12/1 - 4/1	NR	Sun	NR	Welll drained	No	Responds well to controlled burns. Mix with 3 to 5 other seed varieties that have similar soil drainage adaptations.	Warm season grass

HERBACEOUS PLANTS-Seeding recommendations for primary stabilization

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

Table 6.11.c (con't)

NATIVE SPECIES

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

NOTE:
1. Seeding rates are for hulled seed unless otherwise noted.
2. Fertilizer & Limestone - rates to be applied in absense of soils tests. Recommended application rate assumes significantly disturbed site soils with little or no residual value.
3. NR means Species not recommended for this region or application area.
4. Native, warm season grasses require six or more months to germinate under optimum conditions. If they are planted in the summer, then a whole 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.

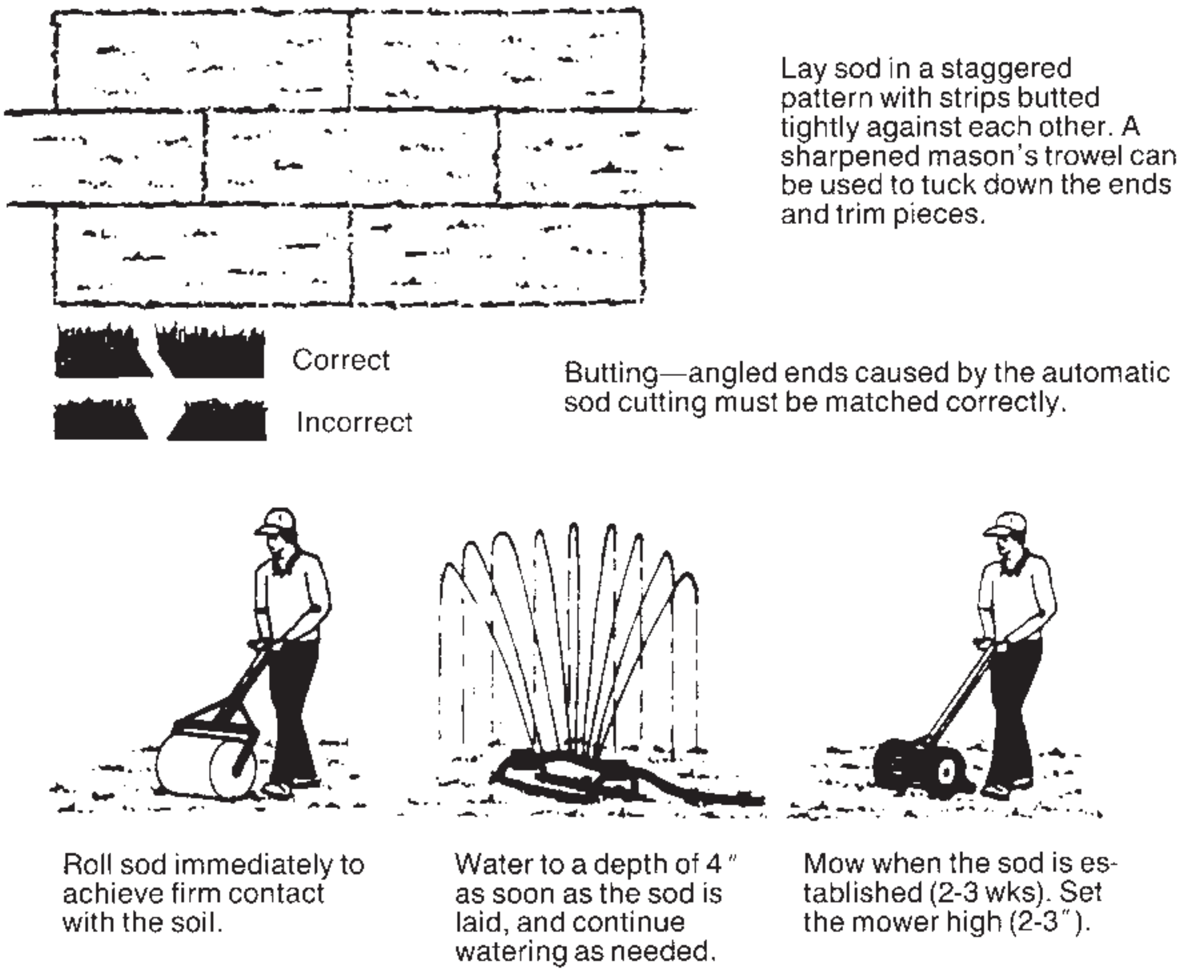


Figure 6.12a Proper installation of grass sod (modified from Va SWCC).

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).

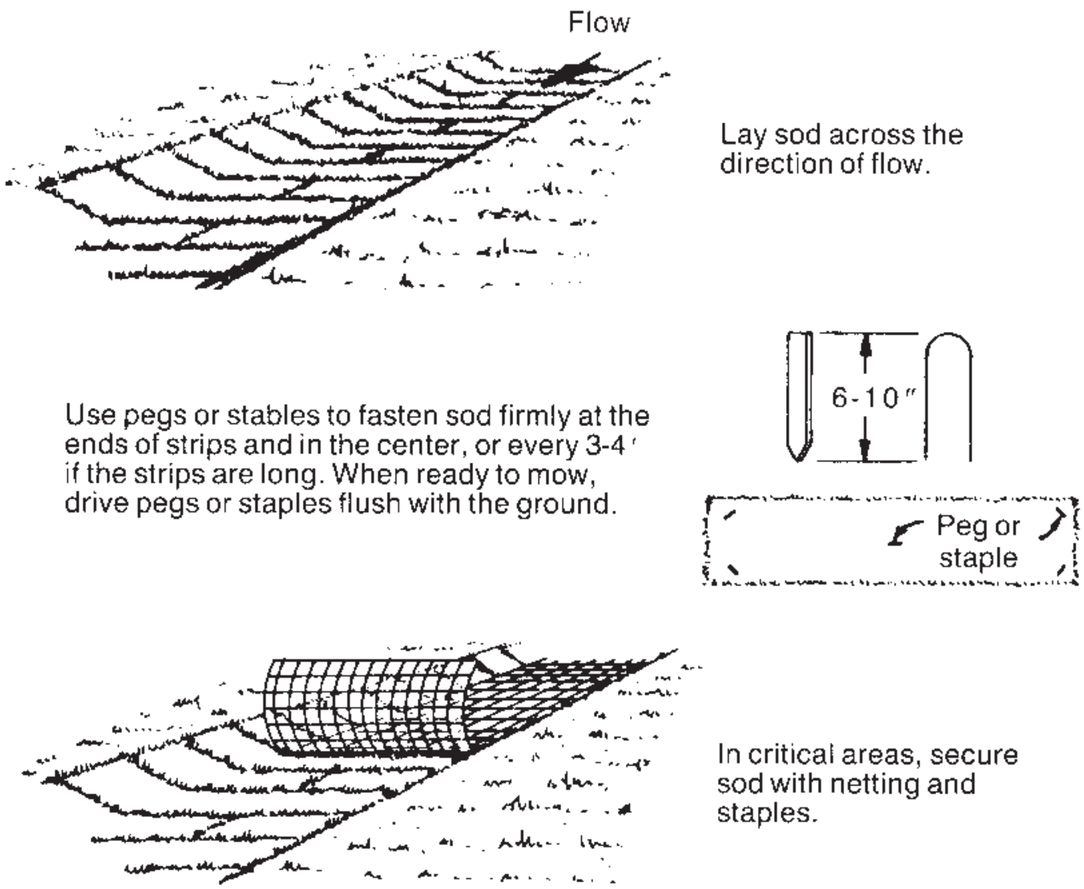


Figure 6.12b Installation of sod in waterways (modified from Va SWCC).

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.

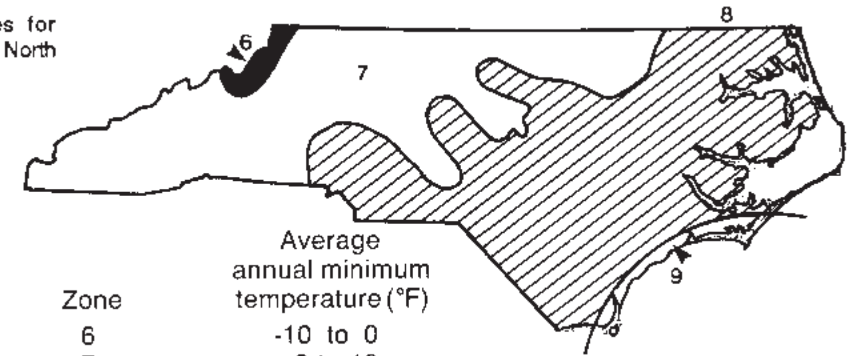
The large selection of available plant material makes it impractical to give planting specifications for even the most common species. Instead, general planting guidelines are given here.

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.

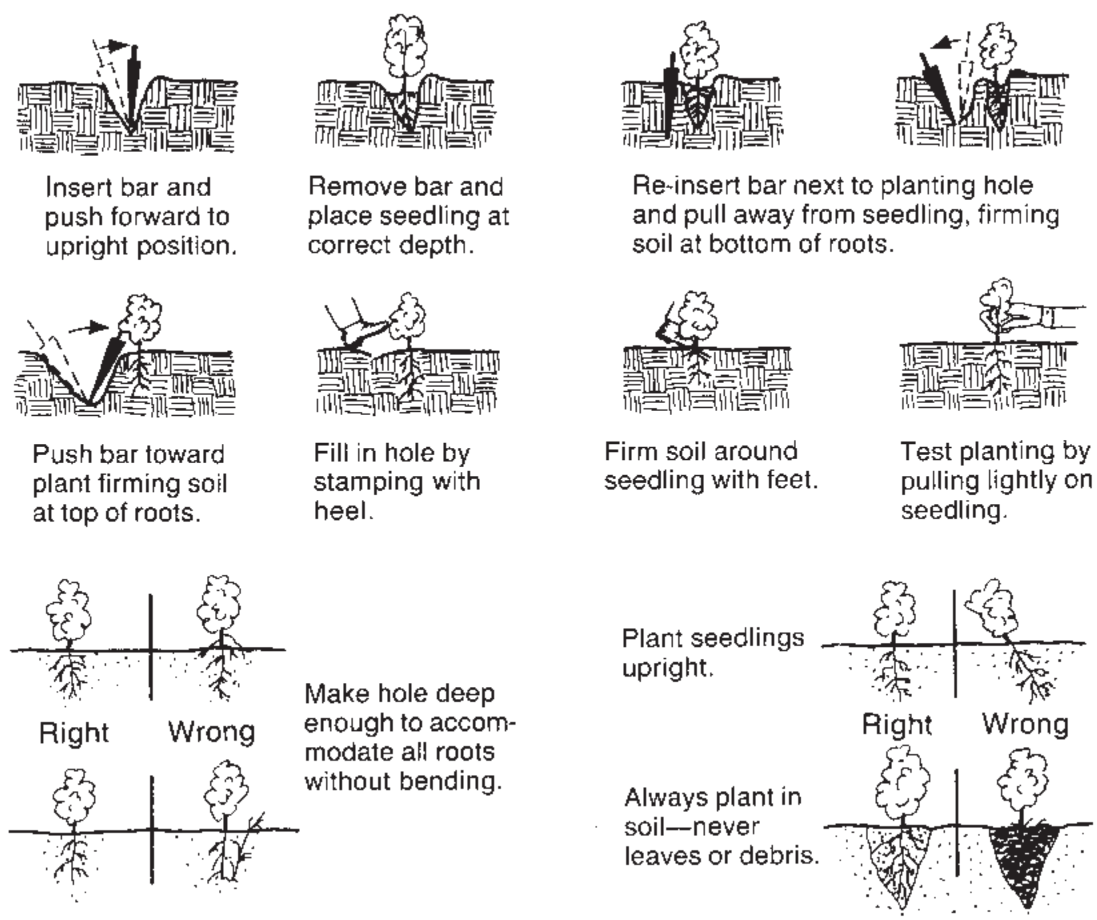


Figure 6.13b Planting bare-root seedlings (modified from Va. Div. of Forestry).

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.

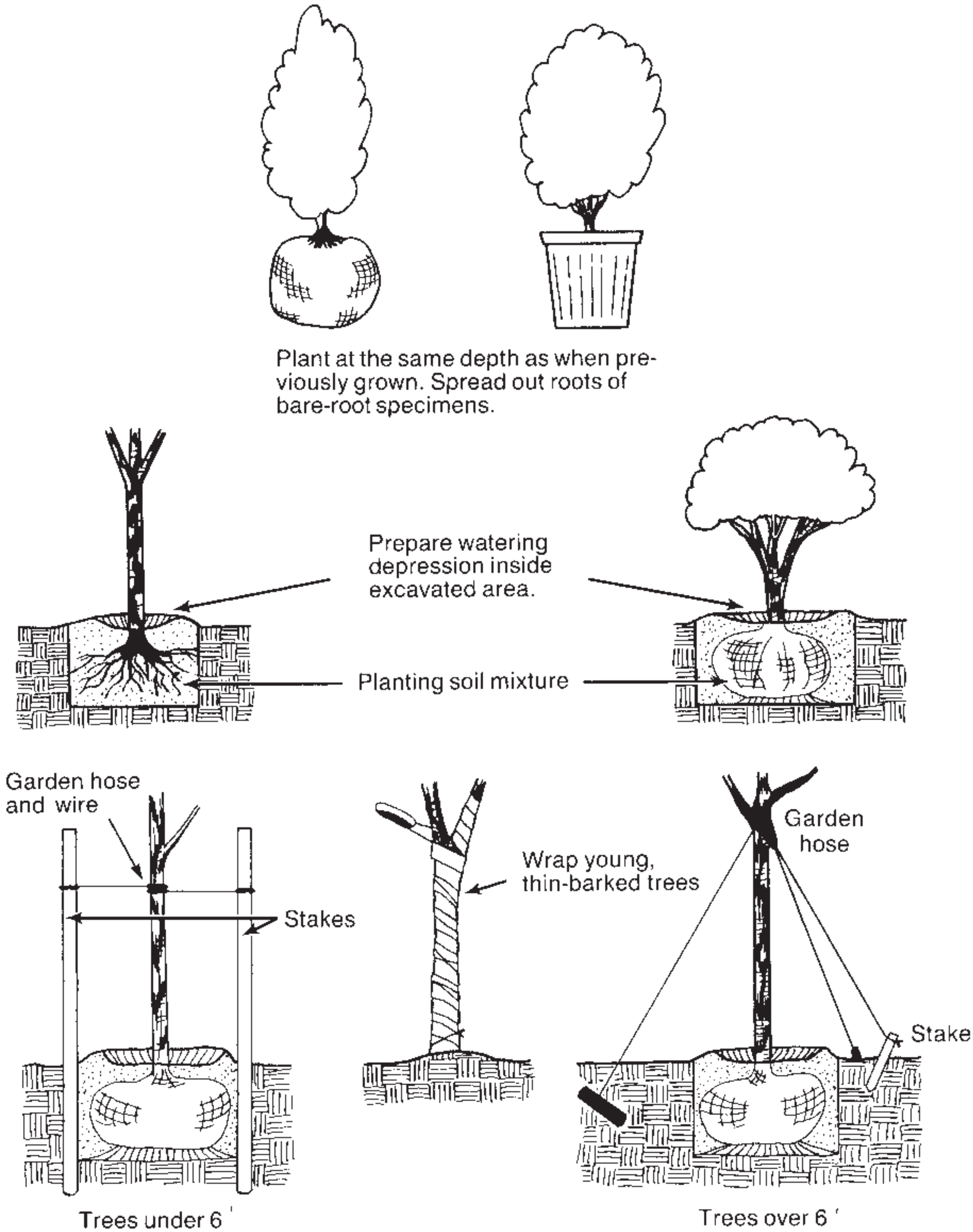


Figure 6.13c Planting balled-and-burlapped and container-grown trees (modified from Va. Div. of Forestry).

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

Definition

Application of a protective blanket of straw or other plant residue, gravel, or synthetic material to the soil surface.

Purpose

To protect the soil surface from the forces of raindrop impact and overland flow. Mulch fosters the growth of vegetation, reduces evaporation, insulates the soil, and suppresses weed growth. Mulch is frequently used to accent landscape plantings.

Conditions Where Practice Applies

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

Planning Considerations

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

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

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

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

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

ORGANIC MULCHES

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

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

Table 6.14a
Mulching Materials and Application Rates

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

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

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

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

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

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

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

CHEMICAL MULCHES AND SOIL BINDERS

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

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

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

NETS, MATS, AND ROVING

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

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

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

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

Construction Specifications

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHEMICAL MULCHES

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

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

FIBERGLASS ROVING

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

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

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

NETS AND MATS

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

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

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

INSTALLATION OF NETTING AND MATTING

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

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

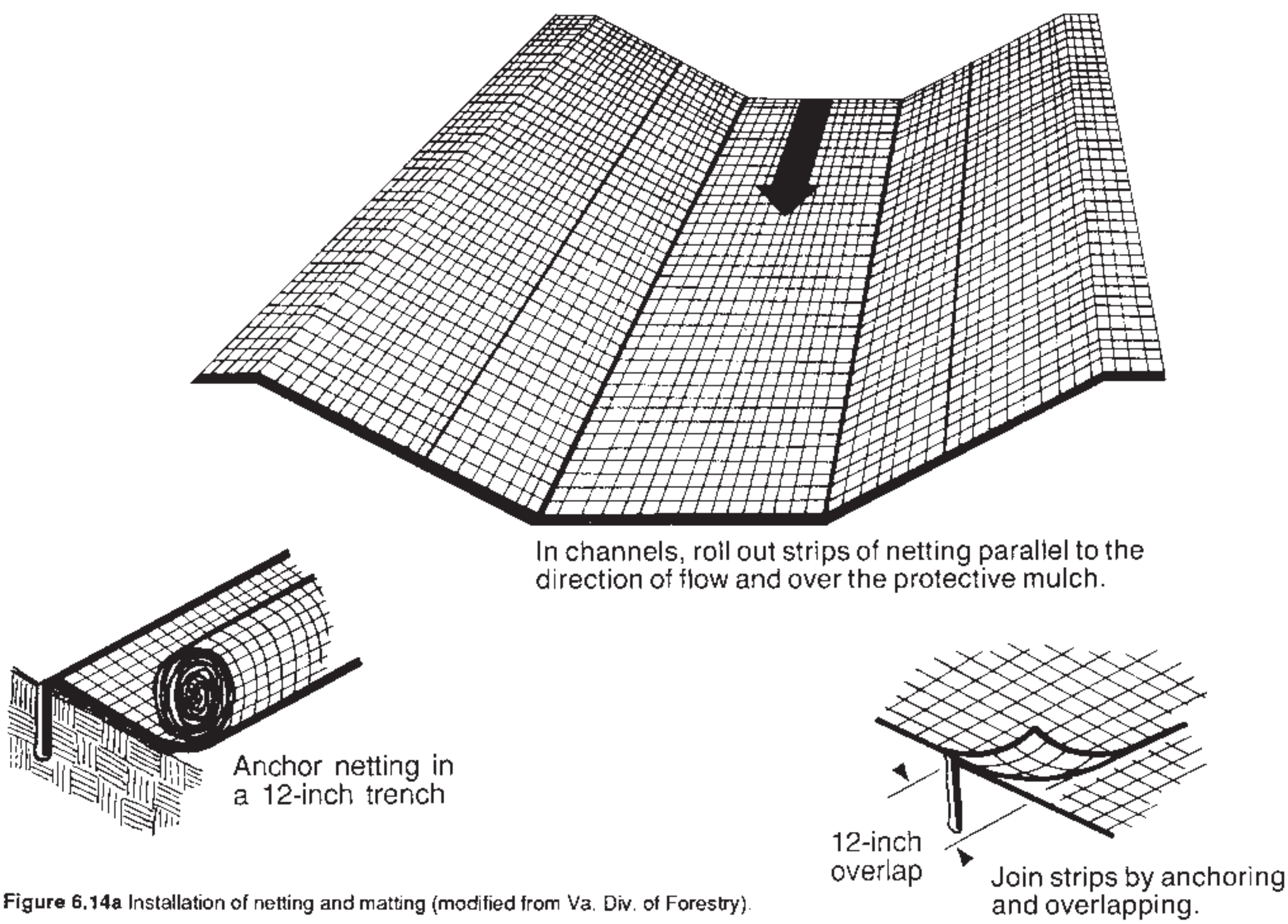


Figure 6.14a Installation of netting and matting (modified from Va. Div. of Forestry).

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

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

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

Maintenance

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

References

Surface Stabilization
6.11, Permanent Seeding

Appendix
8.02, Vegetation Tables

6.15

RIPRAP

RR

Definition

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

Purpose

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

Conditions Where Practice Applies

Riprap is used for the following applications:

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

Planning Considerations

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

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

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

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

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

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

Table 6.15a
Size or Riprap Stones

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

source: Va SWCC

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

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

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

Design Criteria

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

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

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

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

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

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

source: North Carolina Aggregates Association

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

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

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

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

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

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

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

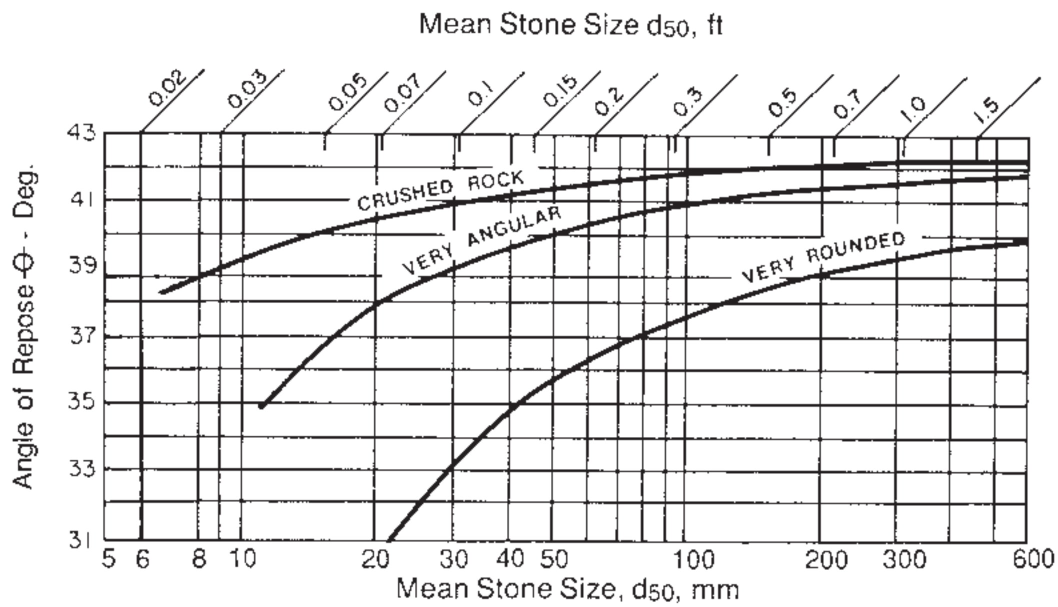


Figure 6.15a Angle of repose for different rock shapes and sizes.
Adapted from: FHWA, HEC-15, pg. 49 - April 1988

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

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

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

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

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

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

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

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

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

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

- Filter fabric covering other soils:

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

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

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

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

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

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

Construction Specifications

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

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

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

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

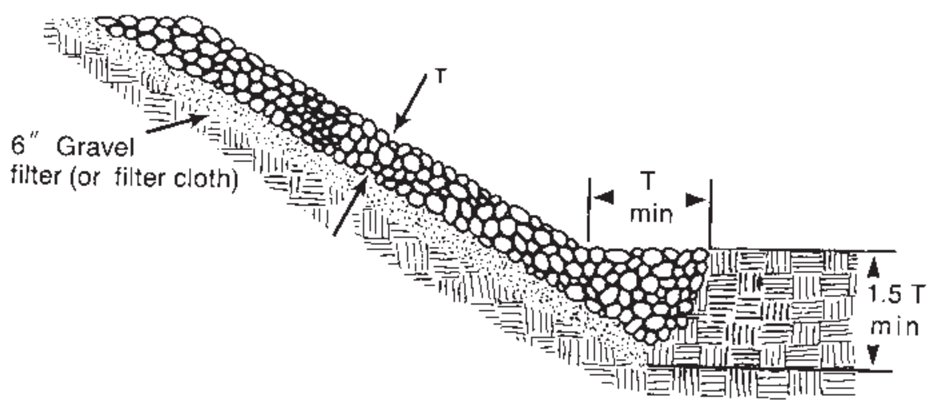
Where large stones are used or machine placement is difficult, a 4-inch layer of fine gravel or sand may be needed to protect the filter cloth.

Stone placement—Placement of riprap should follow immediately after placement of the filter. Place riprap so that it forms a dense, well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, and controlled dumping during final placement. Place riprap to its full thickness in one operation. Do not place riprap by dumping through chutes or other methods that cause segregation of stone sizes. Take care not to dislodge the underlying base or filter when placing the stones.

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

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

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



Maintenance

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

References

Runoff Conveyance Measures
6.31, Riprap-lined and Paved Channels

Outlet Protection
6.41, Outlet Stabilization Structure

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

6.16

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

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

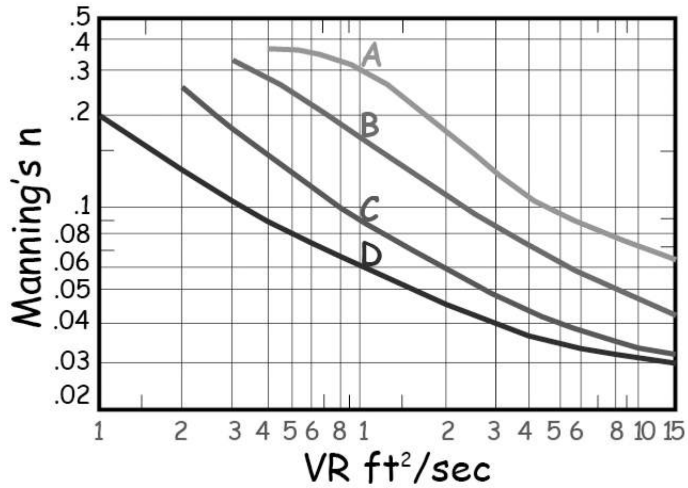


Figure 6.17b Limiting values for bare and TRM protected soils

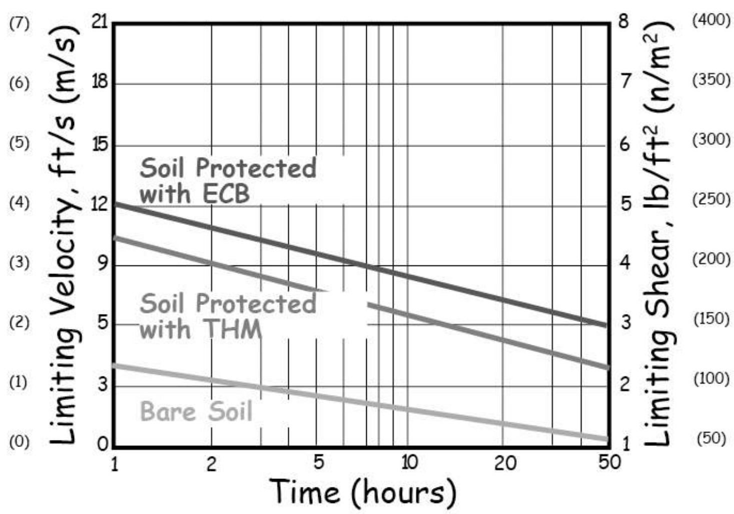
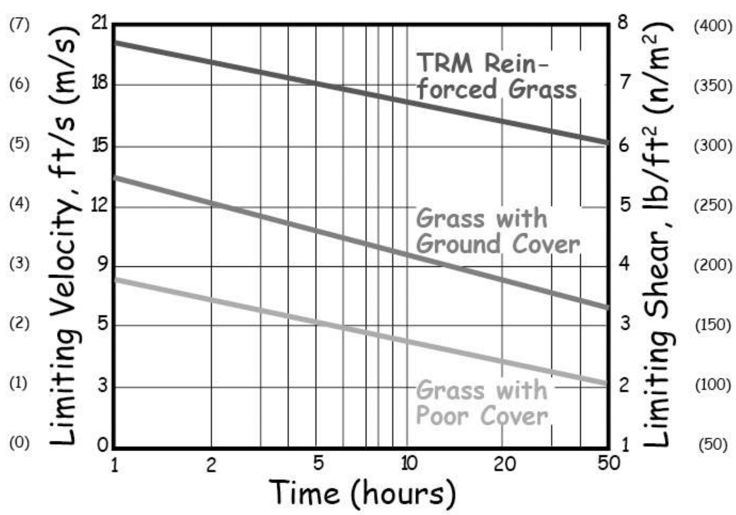


Figure 6.17c Limiting values for plain and TRM reinforced grass



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.

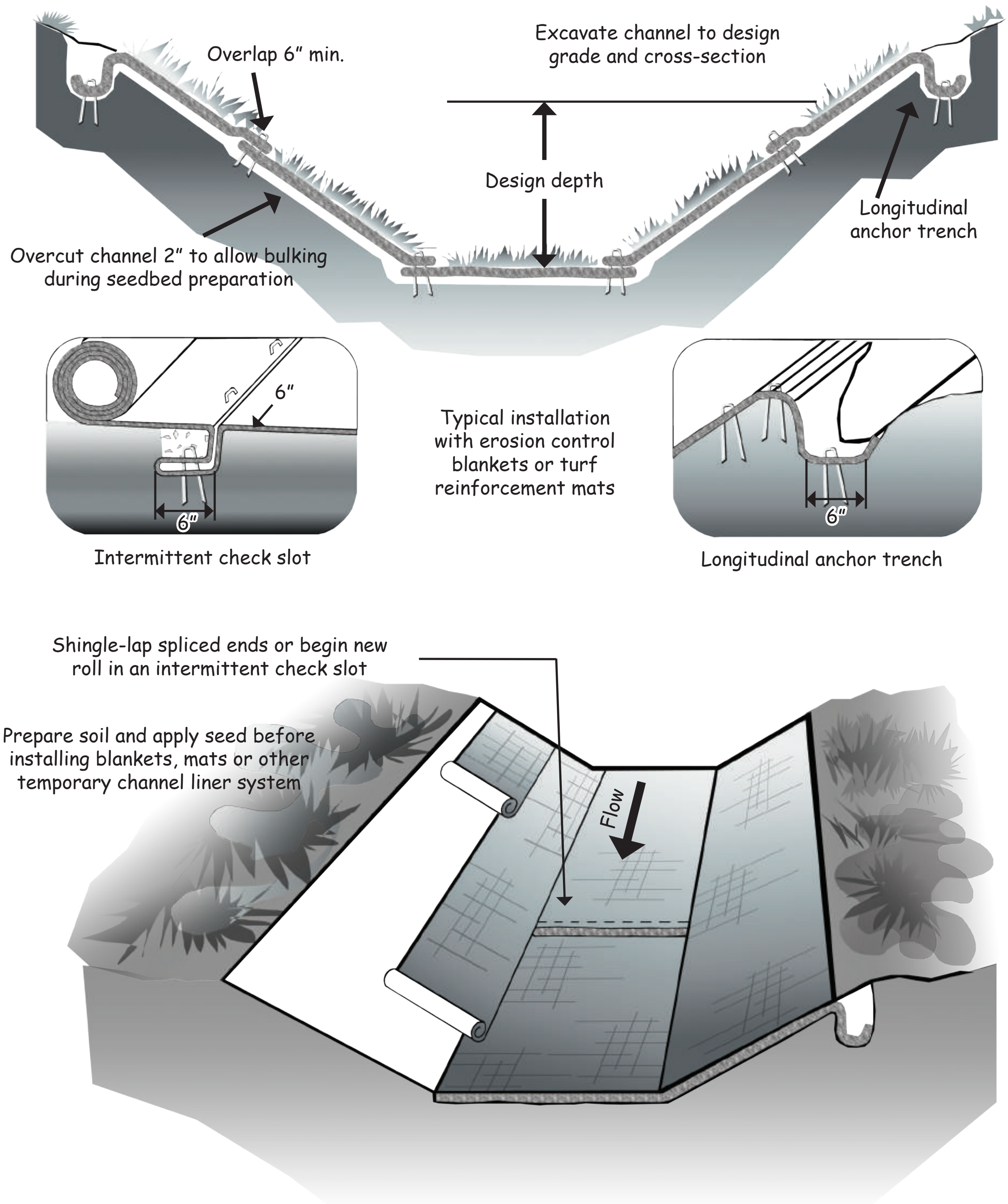
Then pin the RECP (two layers) to the bottom of the trench, backfill, and compact. Continue up the channel (wrapping over the top of the intermittent trench) repeating this step at other intermittent trenches, until reaching the upper terminal trench.

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.

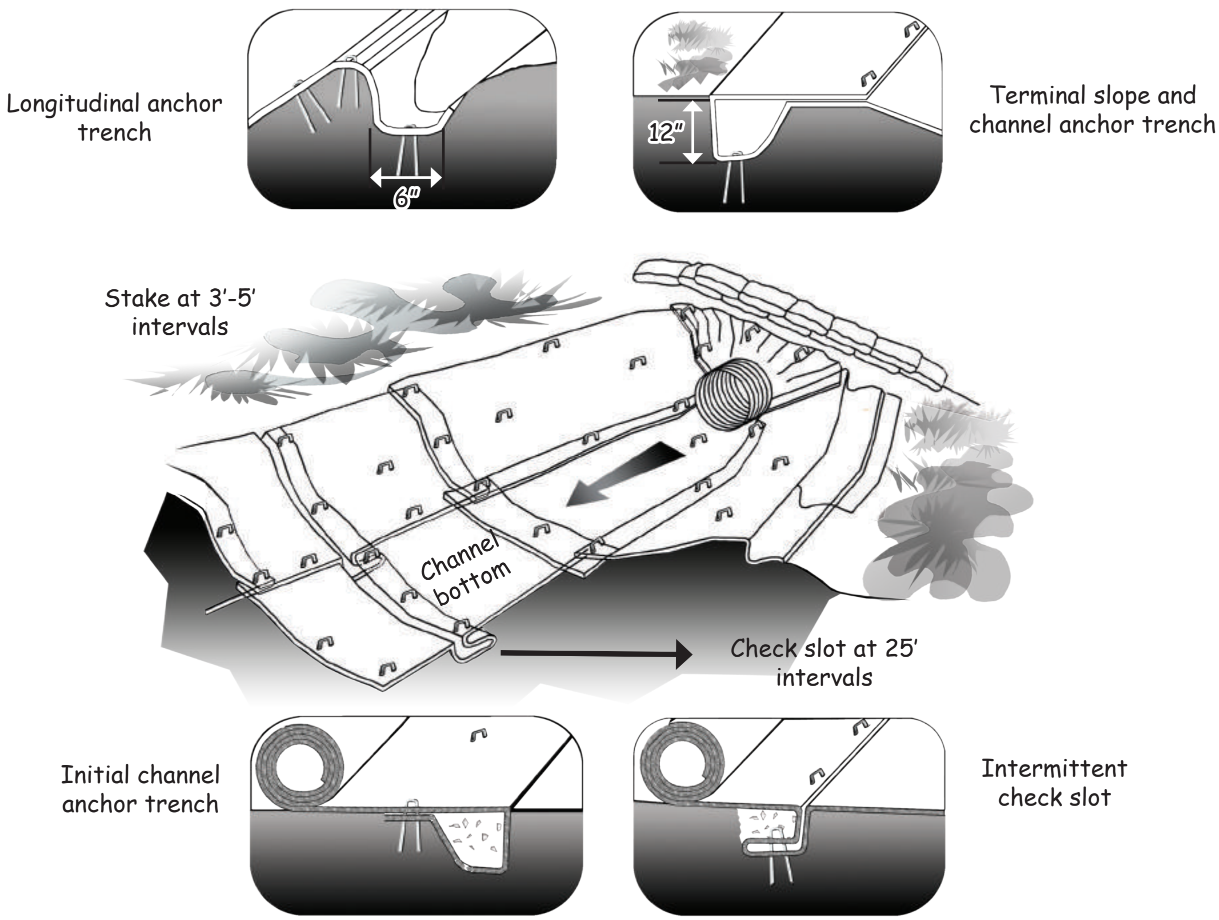
Drive staples or pins so that the top of the staple or pin is flush with the ground surface. Anchor each RECP every 3 feet along its center. Longitudinal overlaps must be sufficient to accommodate a row of anchors and uniform along the entire length of overlap and anchored every 3 feet along the overlap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

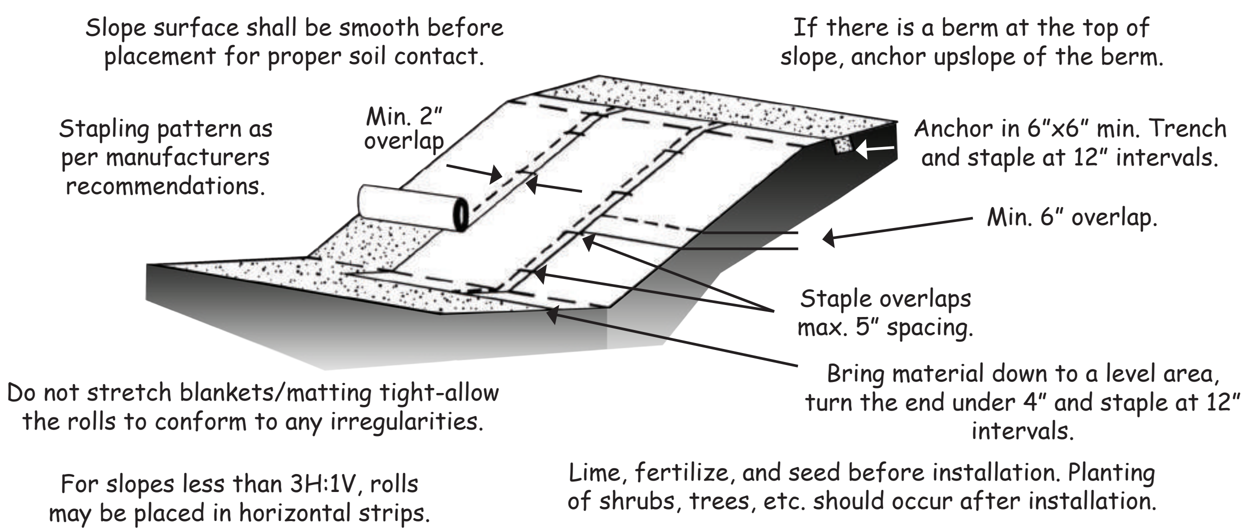


NOTES:
1. Design velocities exceeding 2 ft/sec require temporary blankets, mats or similar liners to protect seed and soil until vegetation becomes established.
2. Grass-lined channels with design velocities exceeding 6 ft/sec should include turf reinforcement mats

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



NOTE:
1. Check slots to be constructed per manufacturers specifications.
2. Staking or stapling layout per manufacturers specifications.



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 COMPOST BLANKETS

C
BLK

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.

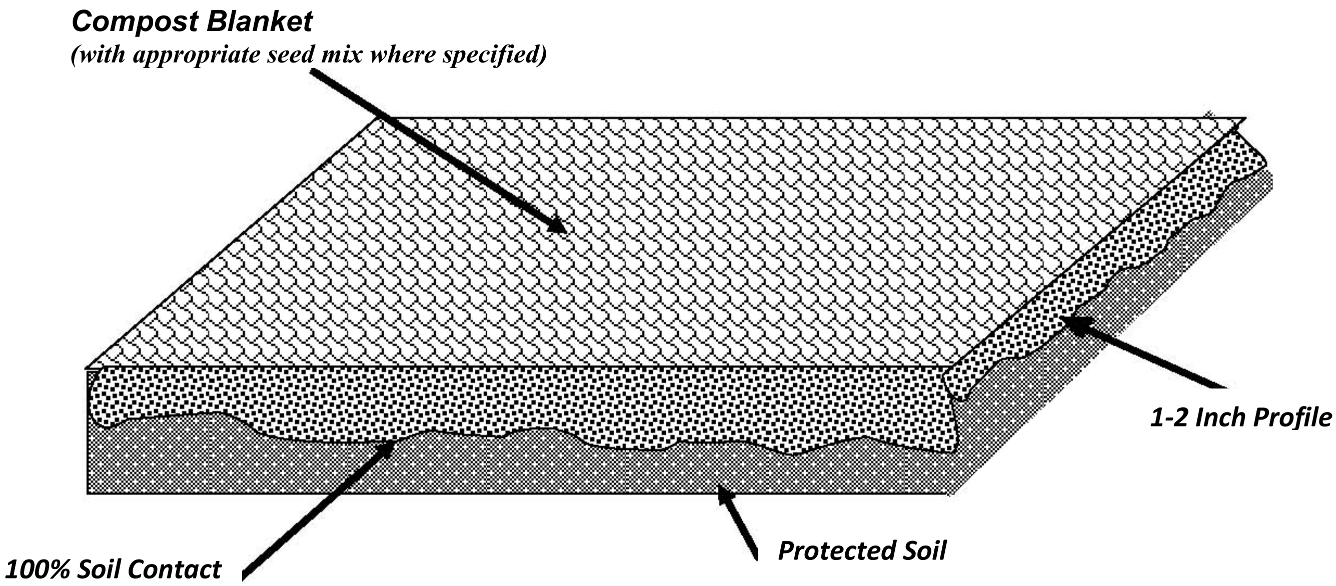


Figure 6.18a Compost Blanket Installation

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/

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INDEX

RUNOFF CONTROL MEASURES

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

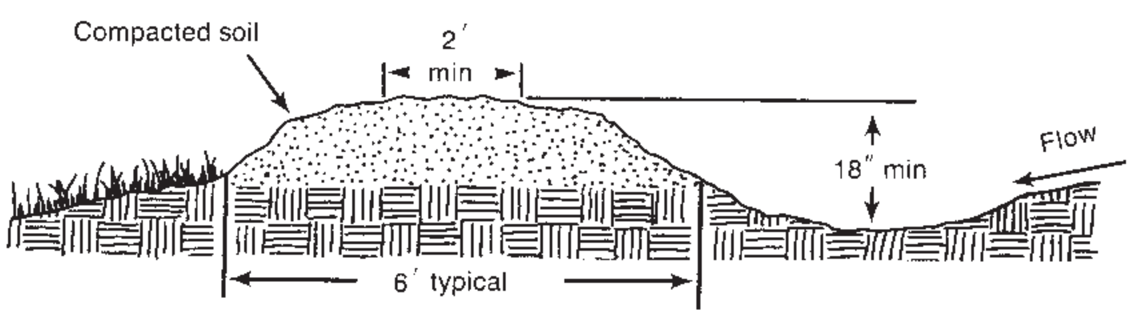

Figure 6.20a Temporary earthen diversion dike.

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).

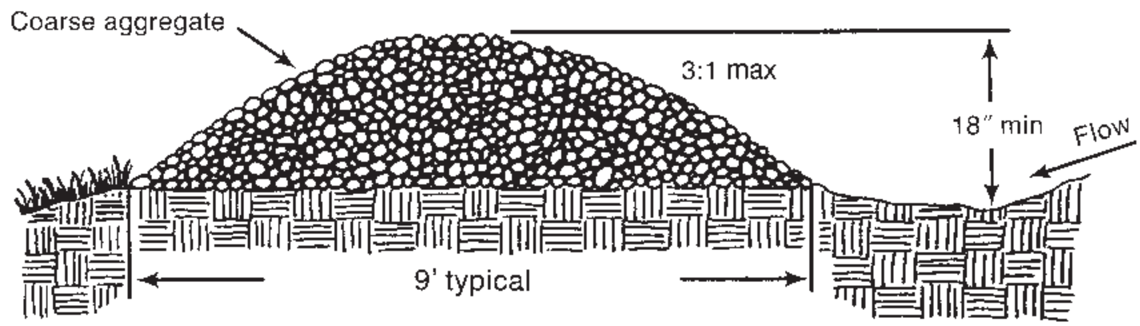

Figure 6.20b Temporary gravel diversion dike for vehicle crossing (modified from Va SWCC).

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

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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

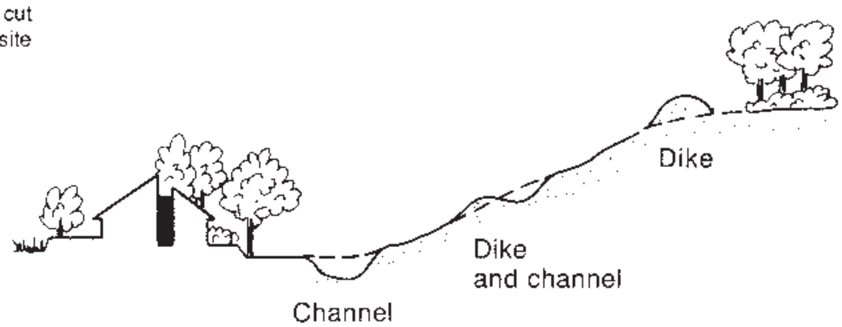
This permanent site development practice applies to construction areas where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sedimentation damage. Specific locations and conditions include:

- 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

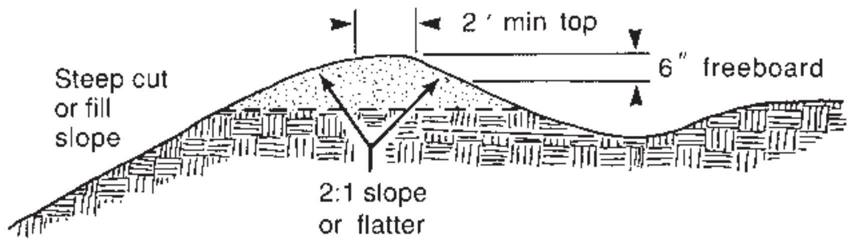
Construction Specifications

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

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).

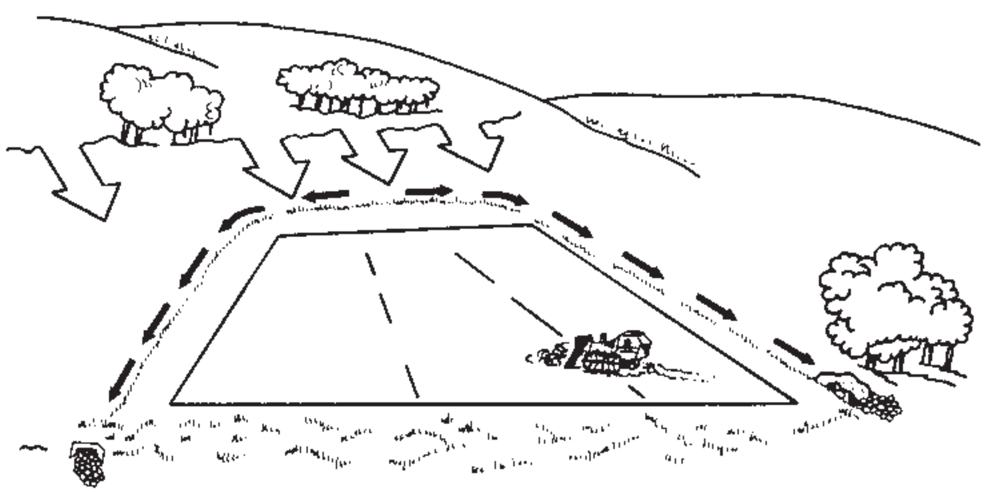


Figure 6.22a Perimeter dikes prevent surface runoff from entering construction sites.

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.

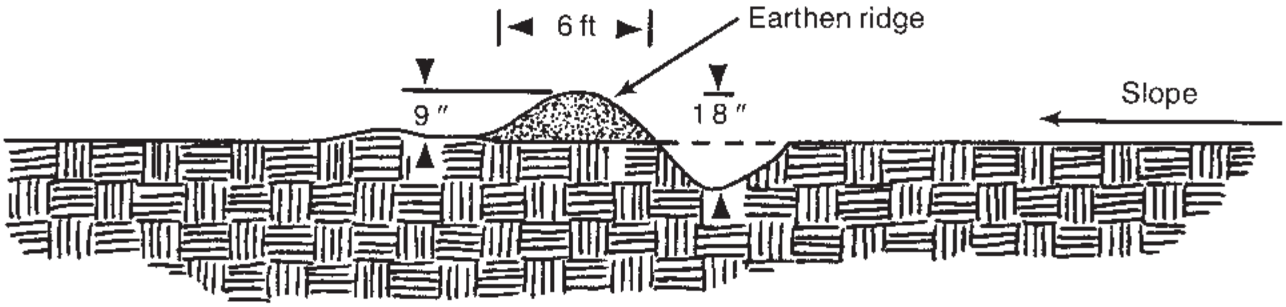


Figure 6.23b Section view of a water bar.

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.

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INDEX

RUNOFF CONVEYANCE MEASURES

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

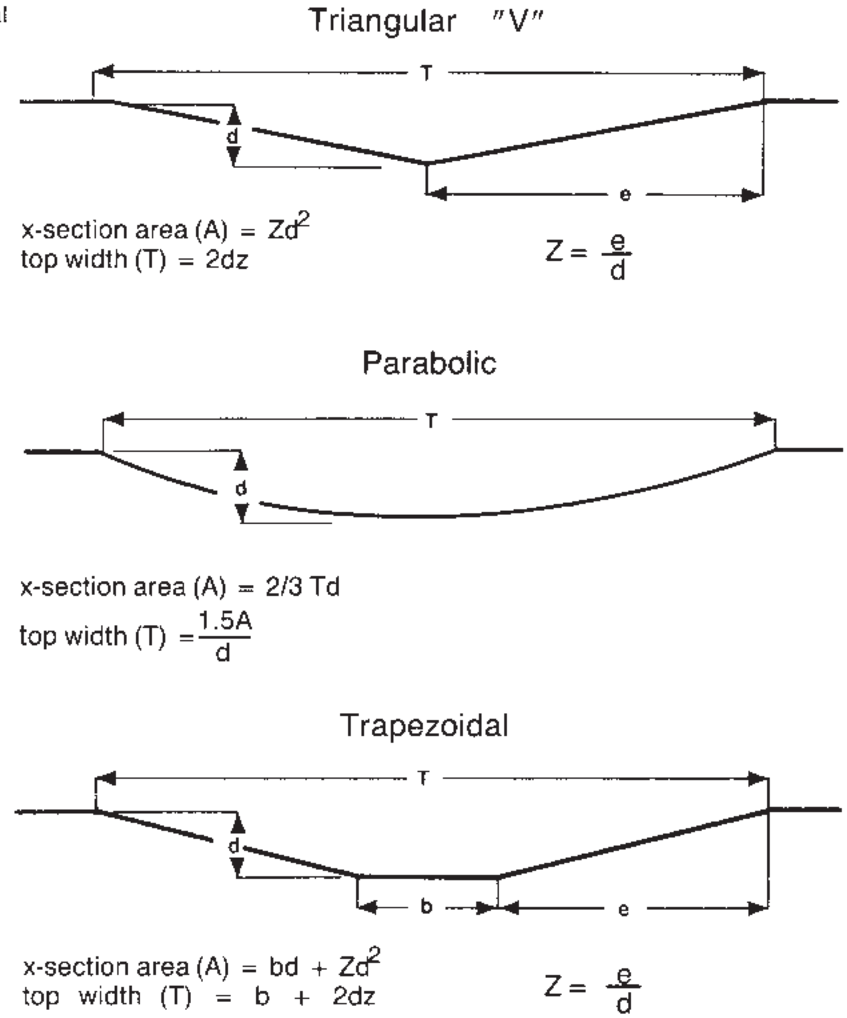
Capacity—At a minimum, grass-lined channels should carry peak runoff from the 10-year storm without eroding. Where flood hazard exists, increase the capacity according to the potential damage. Channel dimensions may be determined by using design tables with appropriate retardance factors or by Manning's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

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).

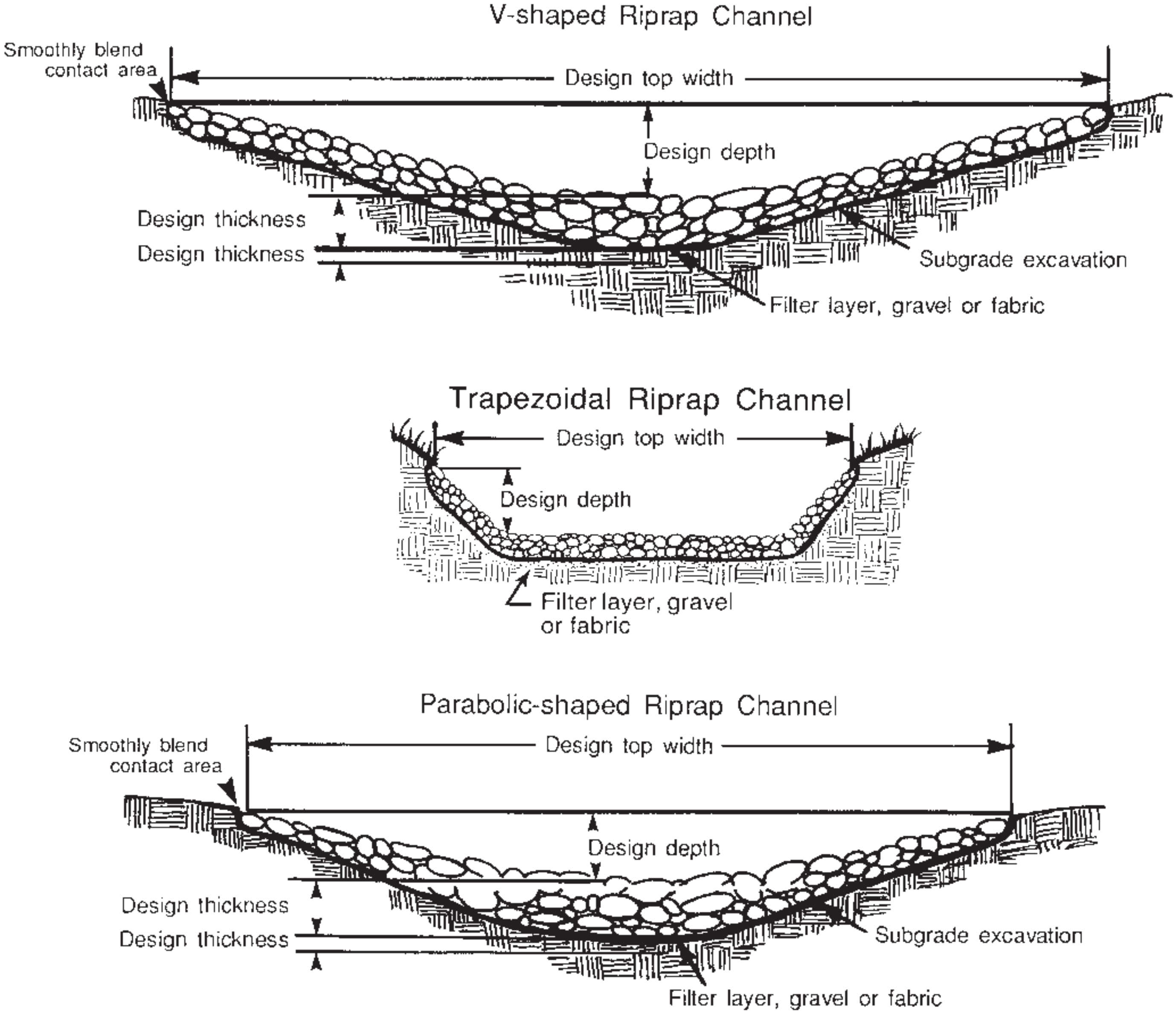


Figure 6.31a Construction detail of riprap channel cross sections.

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

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.

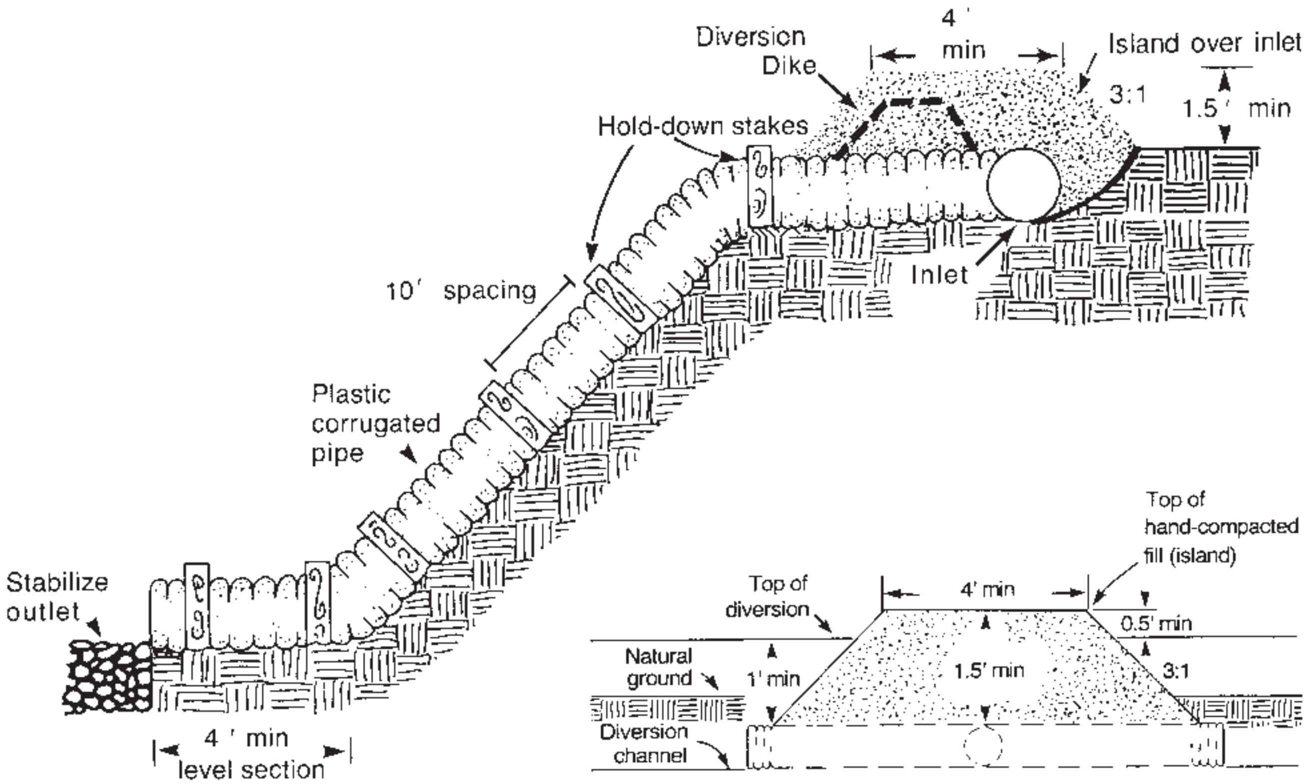


Figure 6.32a Cross section of temporary slope drain.

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.

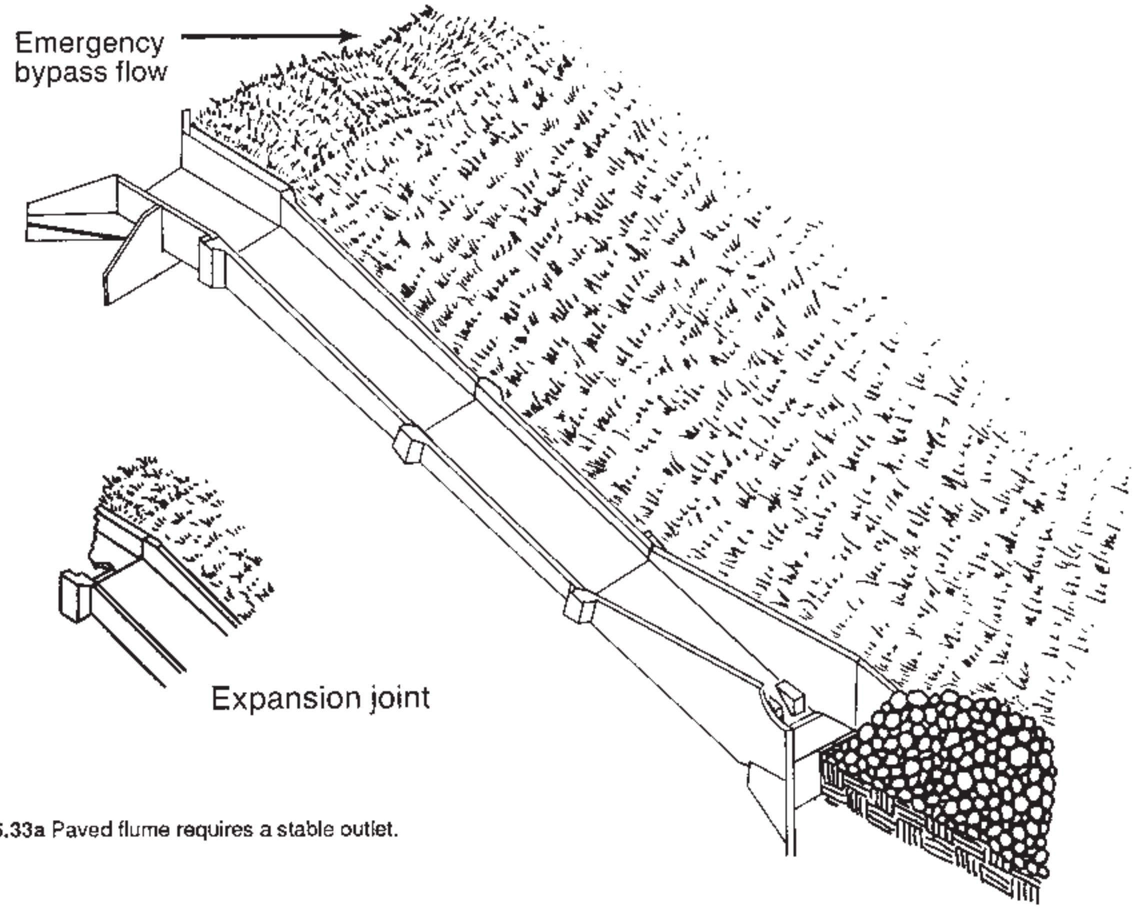


Figure 6.33a Paved flume requires a stable outlet.

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)

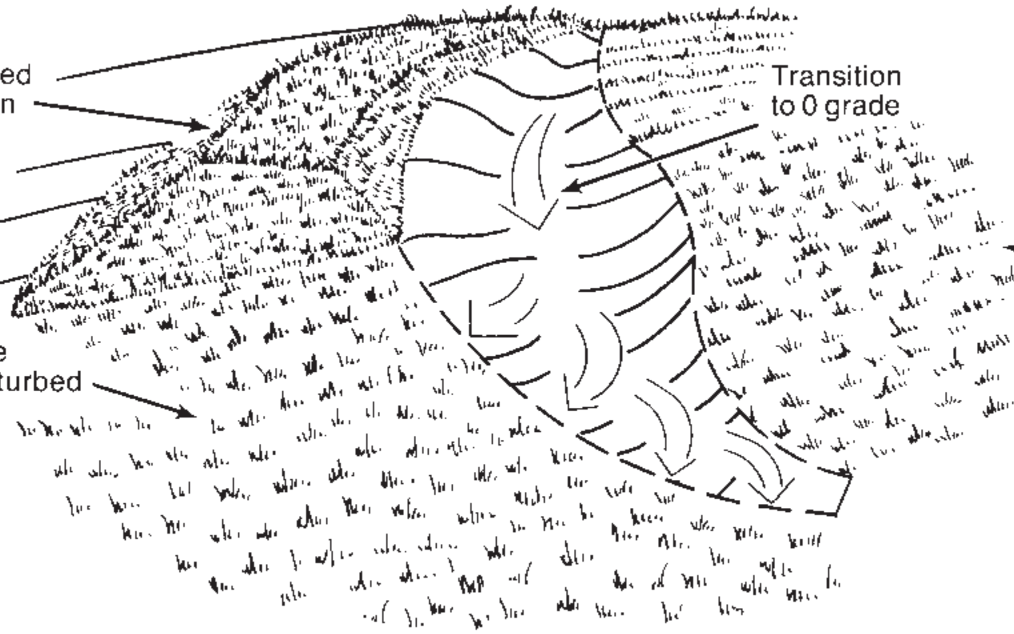


Figure 6.40a Level spreader is designed to disperse small volumes of concentrated flow across stable slopes.

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.

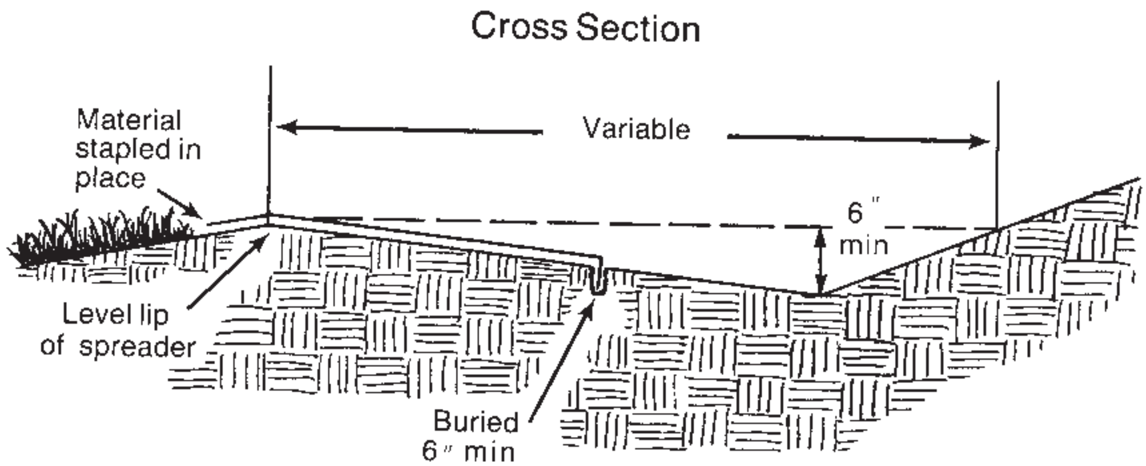


Figure 6.40b Detail of level spreader cross section.

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.

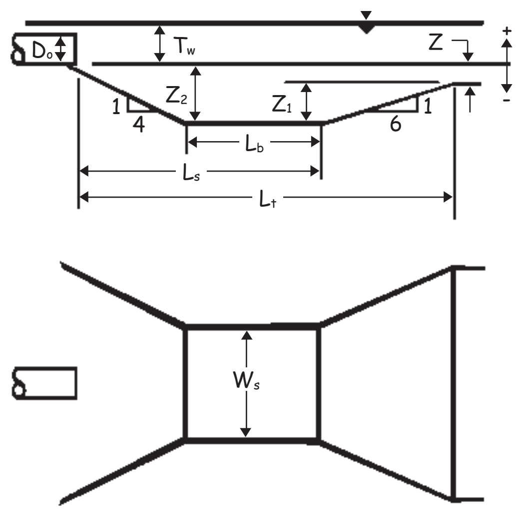
Design Criteria

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.

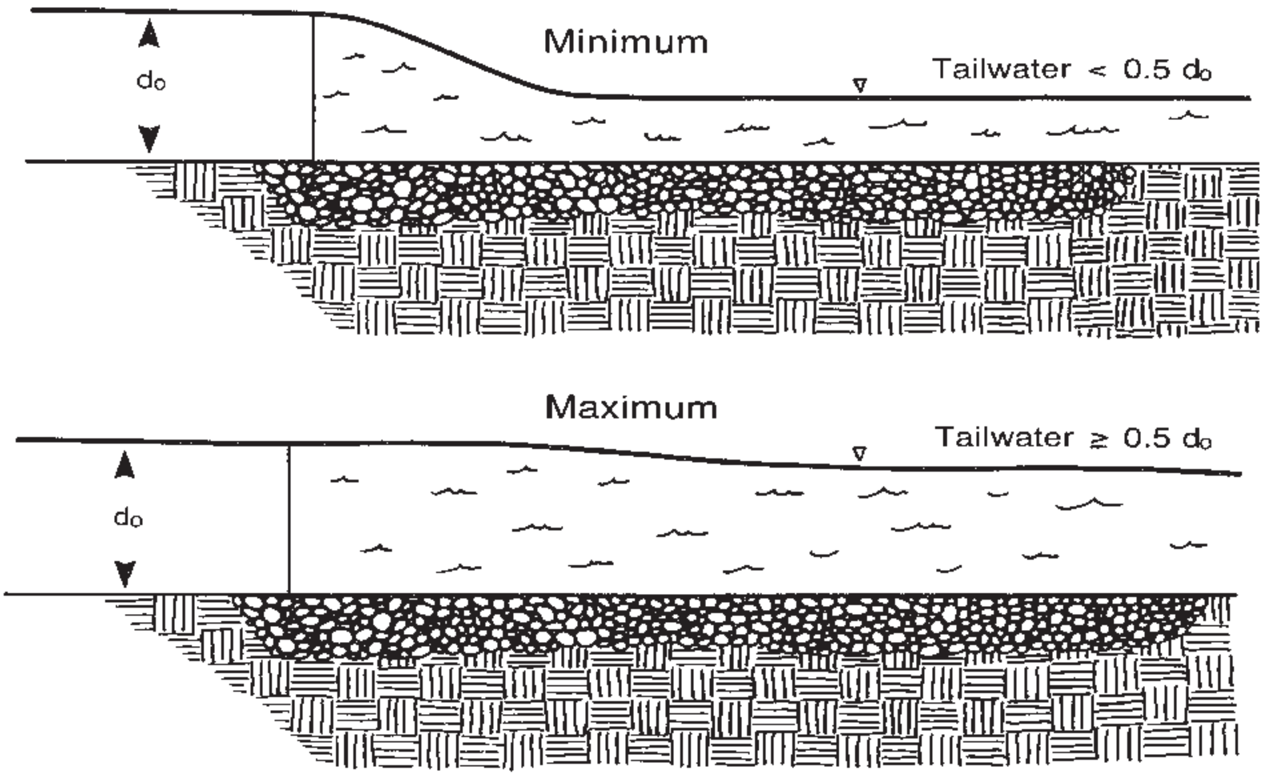


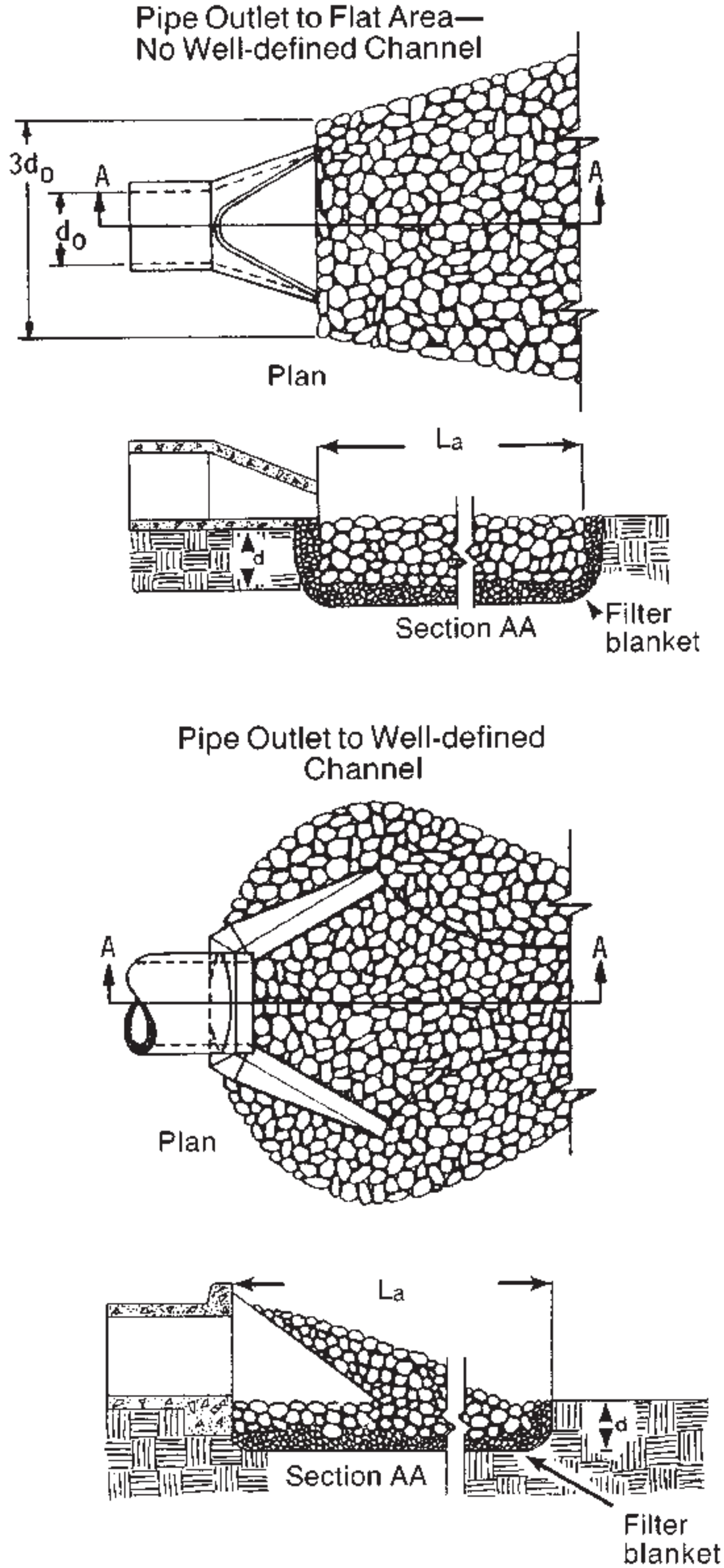
Figure 6.41b Stage showing maximum and minimum tailwater condition.

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*.



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.

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

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 $-1 \le TW/D \le 0.7$" 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*.

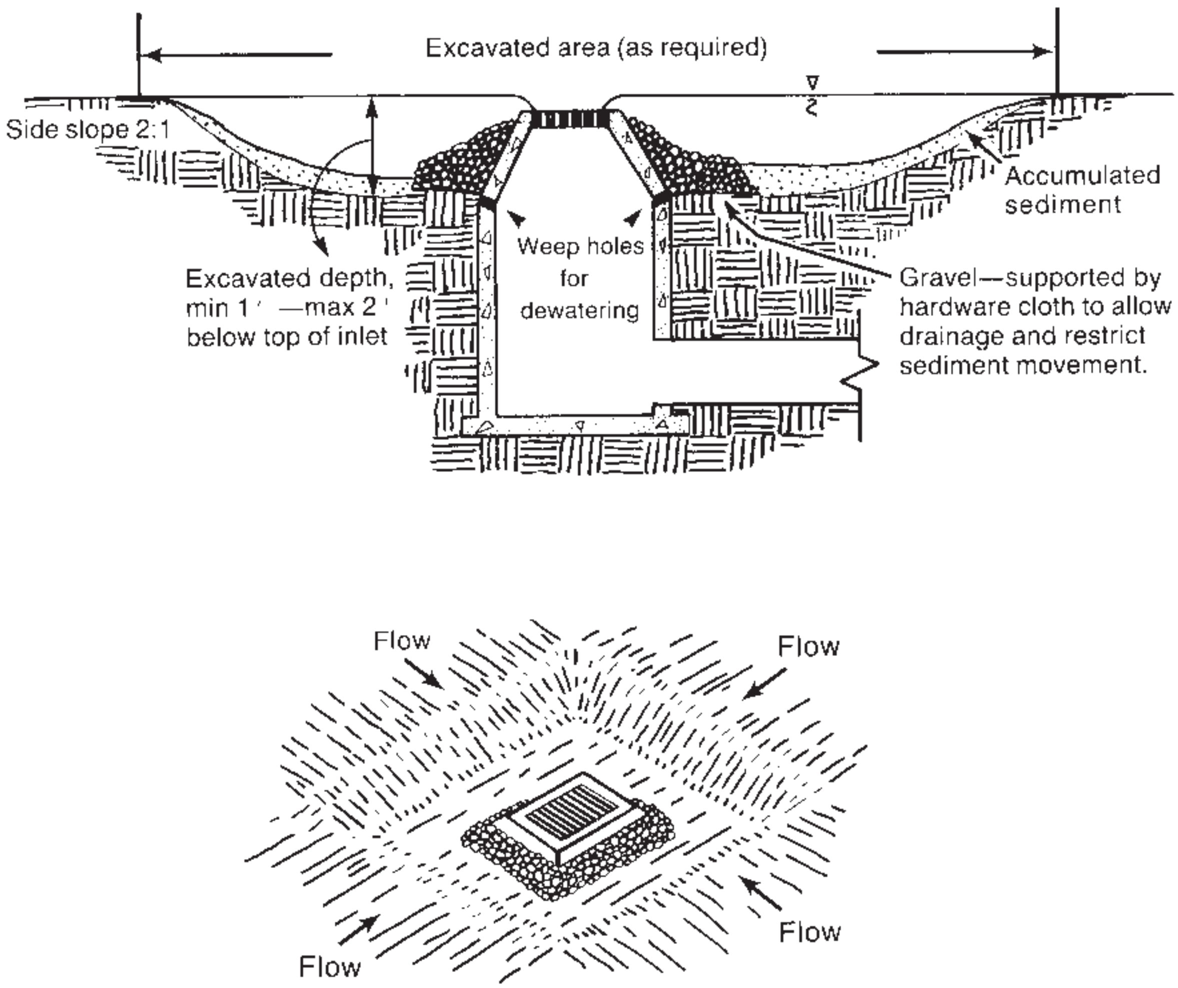


Figure 6.50a Excavated drop inlet protection.

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).

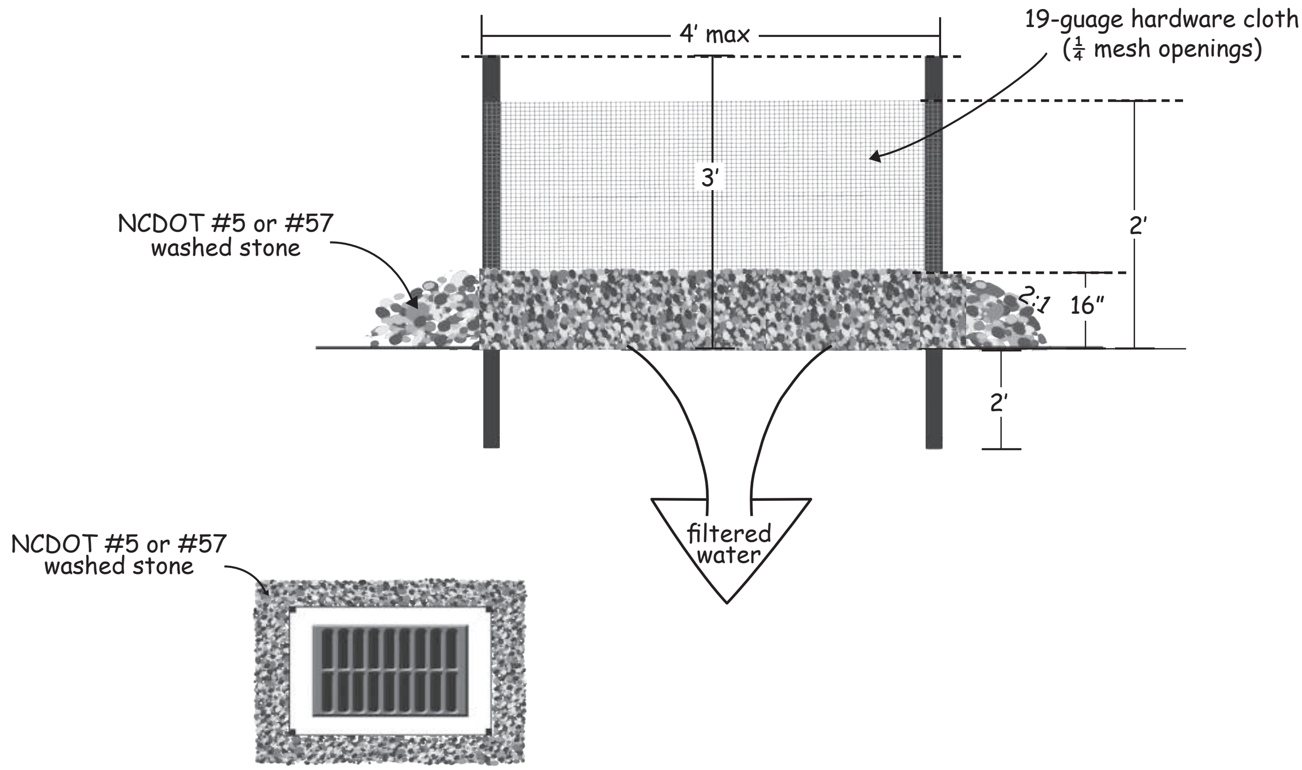


Figure 6.51a Hardware cloth and gravel inlet protection

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

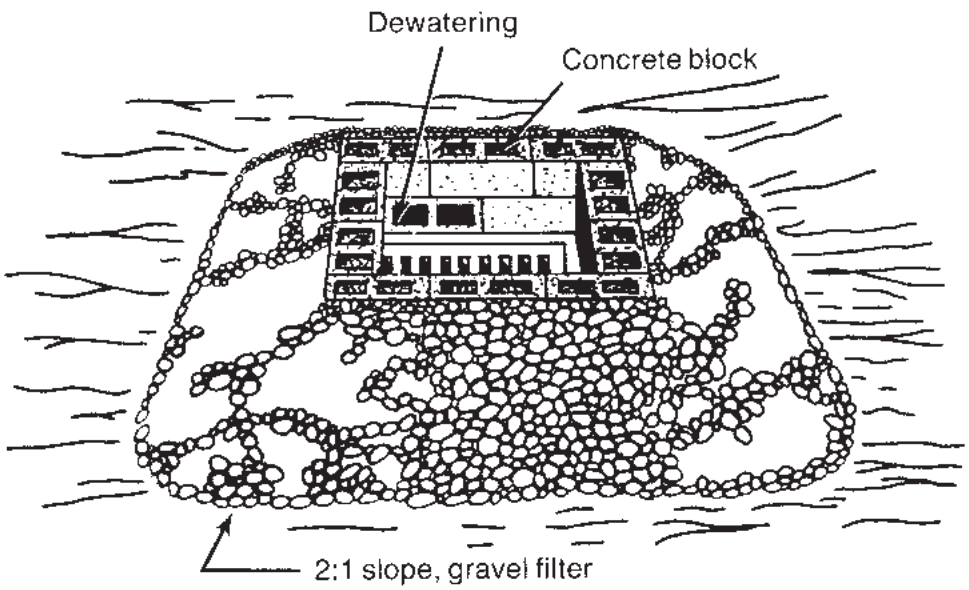
Keep the drainage area no greater than 1 acre unless site conditions allow for frequent removal and adequate disposal of accumulated sediment.

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.



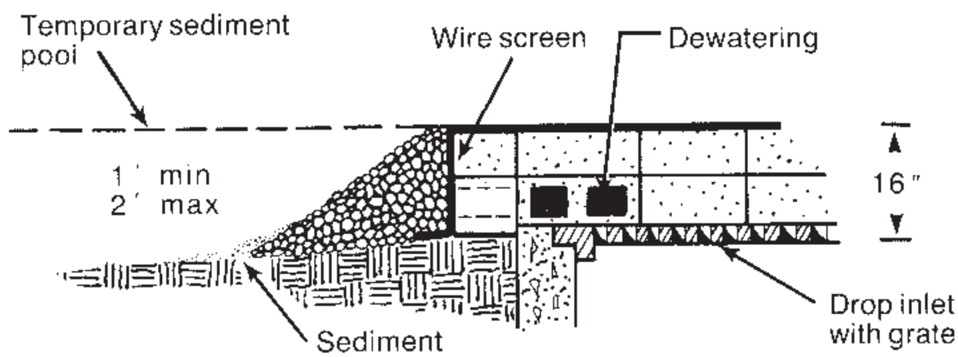


Figure 6.52a Block and gravel drop inlet protection.

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.

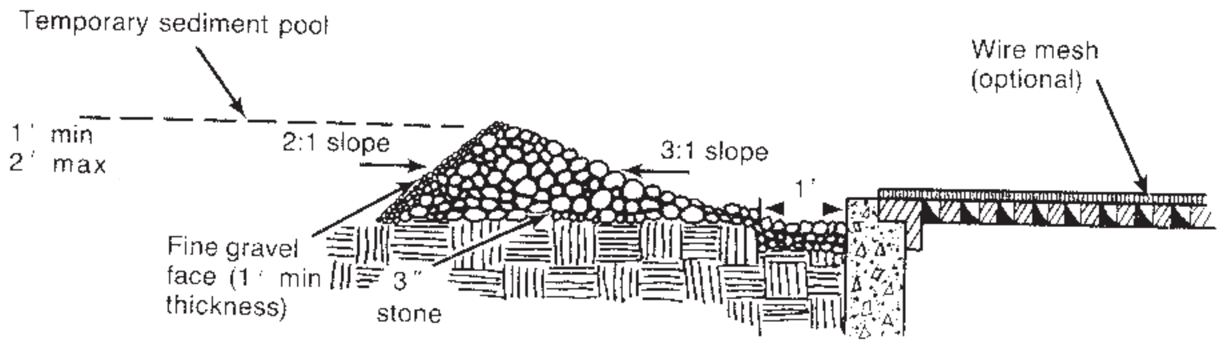


Figure 6.52b Gravel drop inlet protection (gravel donut).

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.

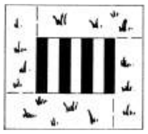
References

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

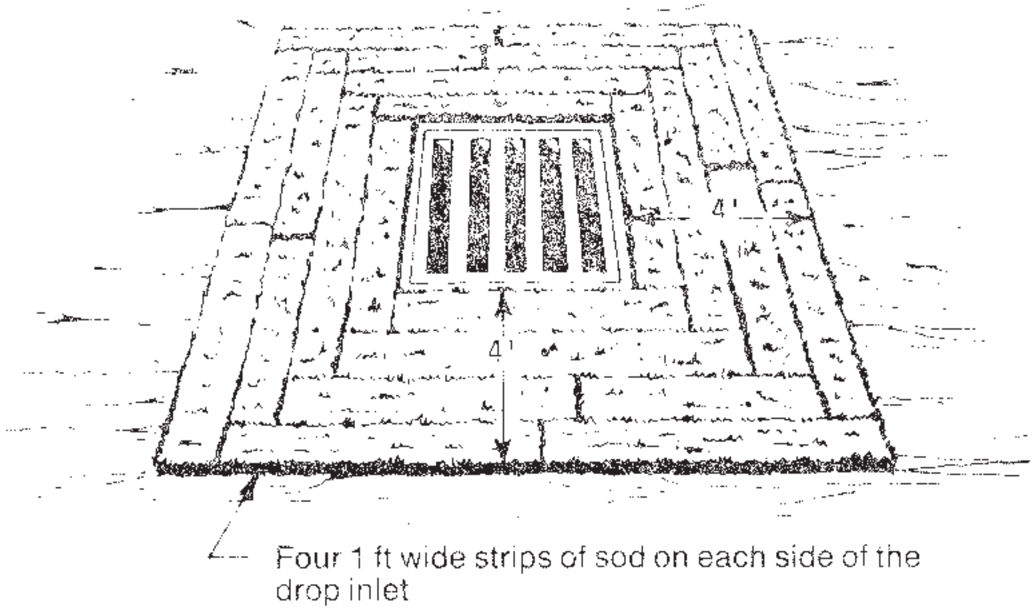


Figure 6.53a Sod strips protect inlet area from erosion (source: Va SWCC)

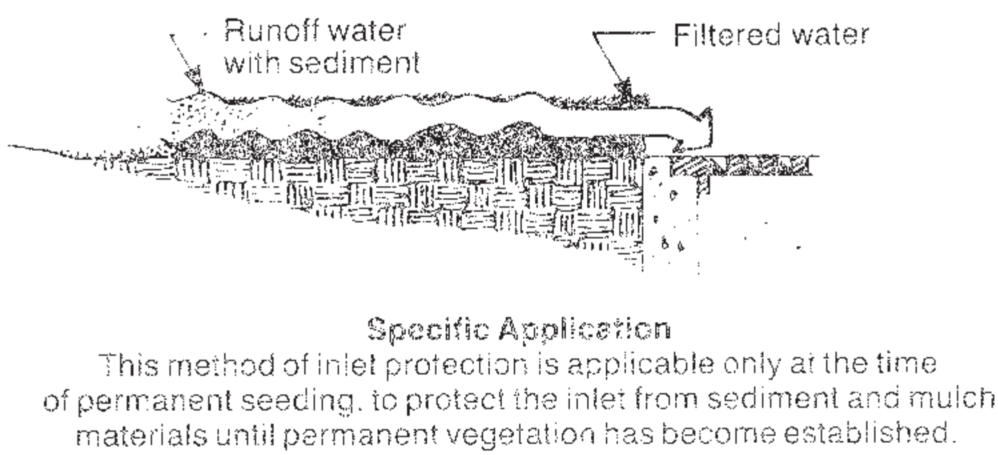


Figure 6.53b Sod drop inlet sediment filter (source: Va SWCC)

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.

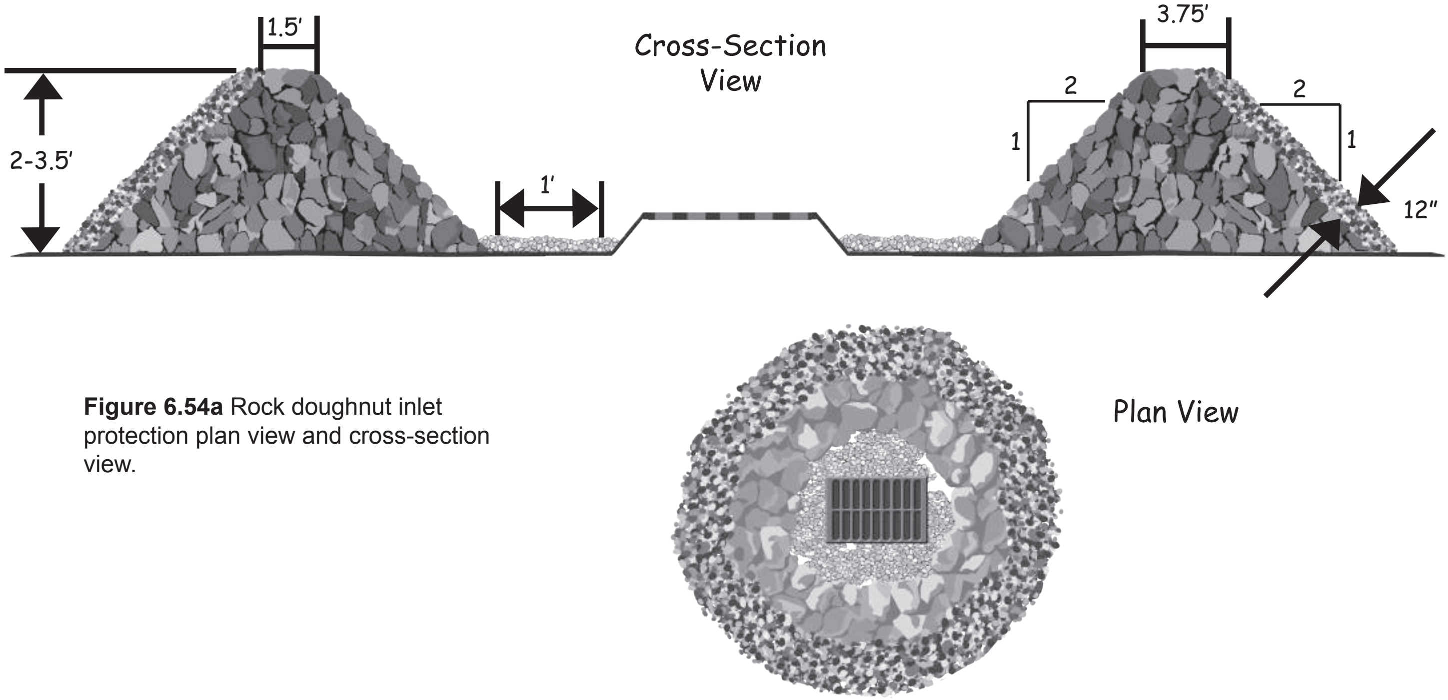


Figure 6.54a Rock doughnut inlet protection plan view and cross-section view.

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.

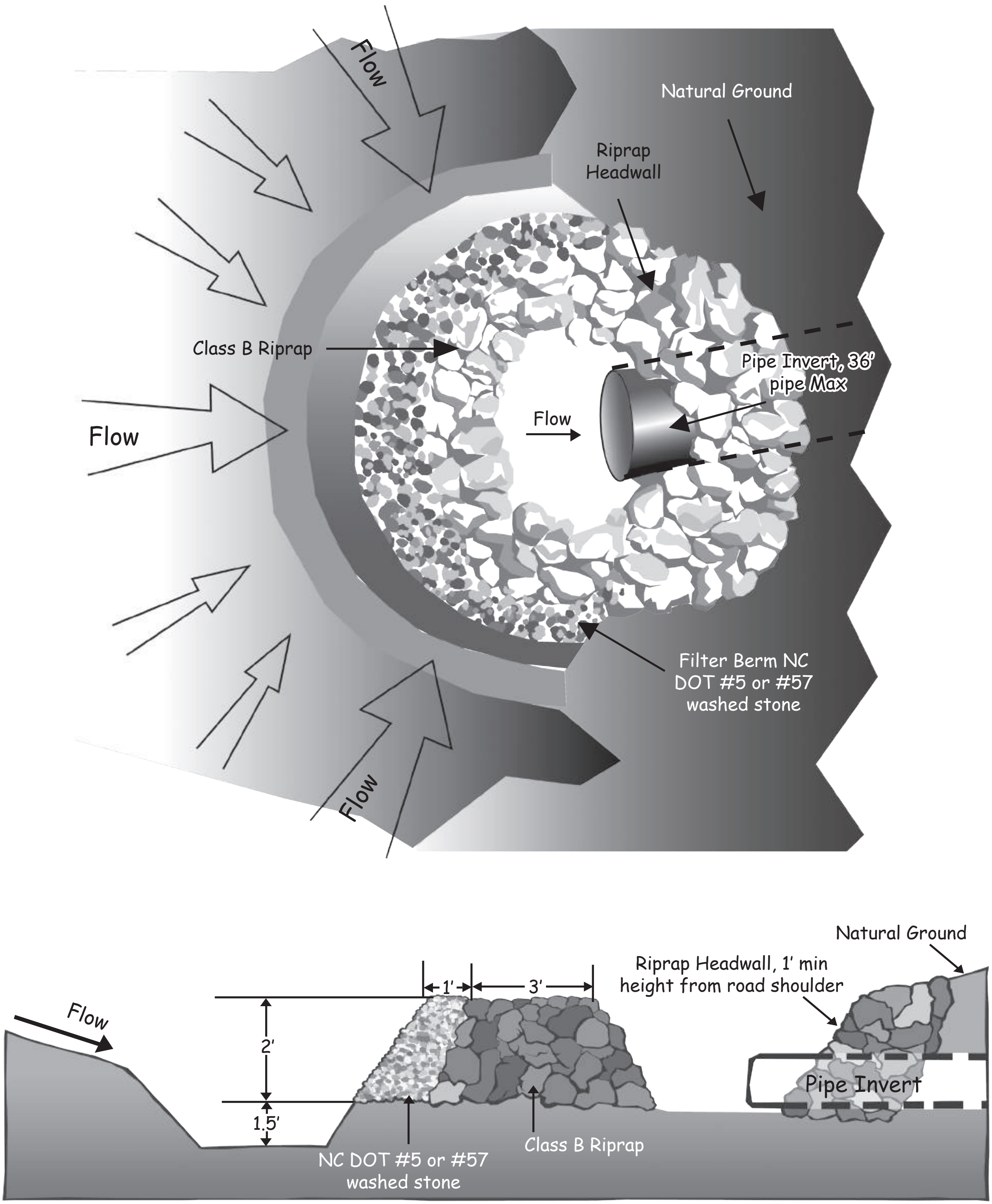


Figure 6.55a Rock pipe inlet protection plan view and cross-section view

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

6.60

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.

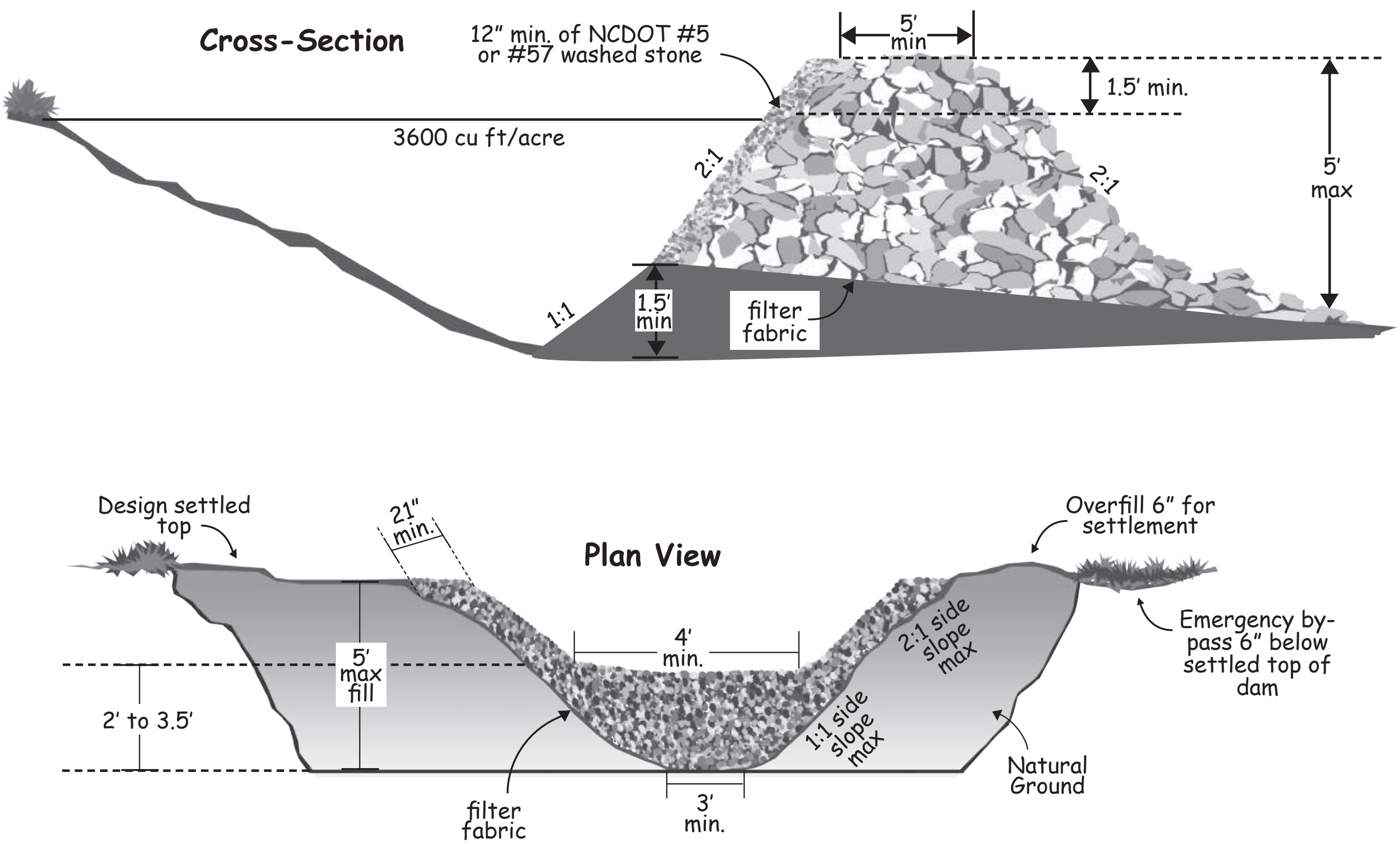


Figure 6.60a Plan view and cross-section view of a temporary sediment trap.

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

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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.

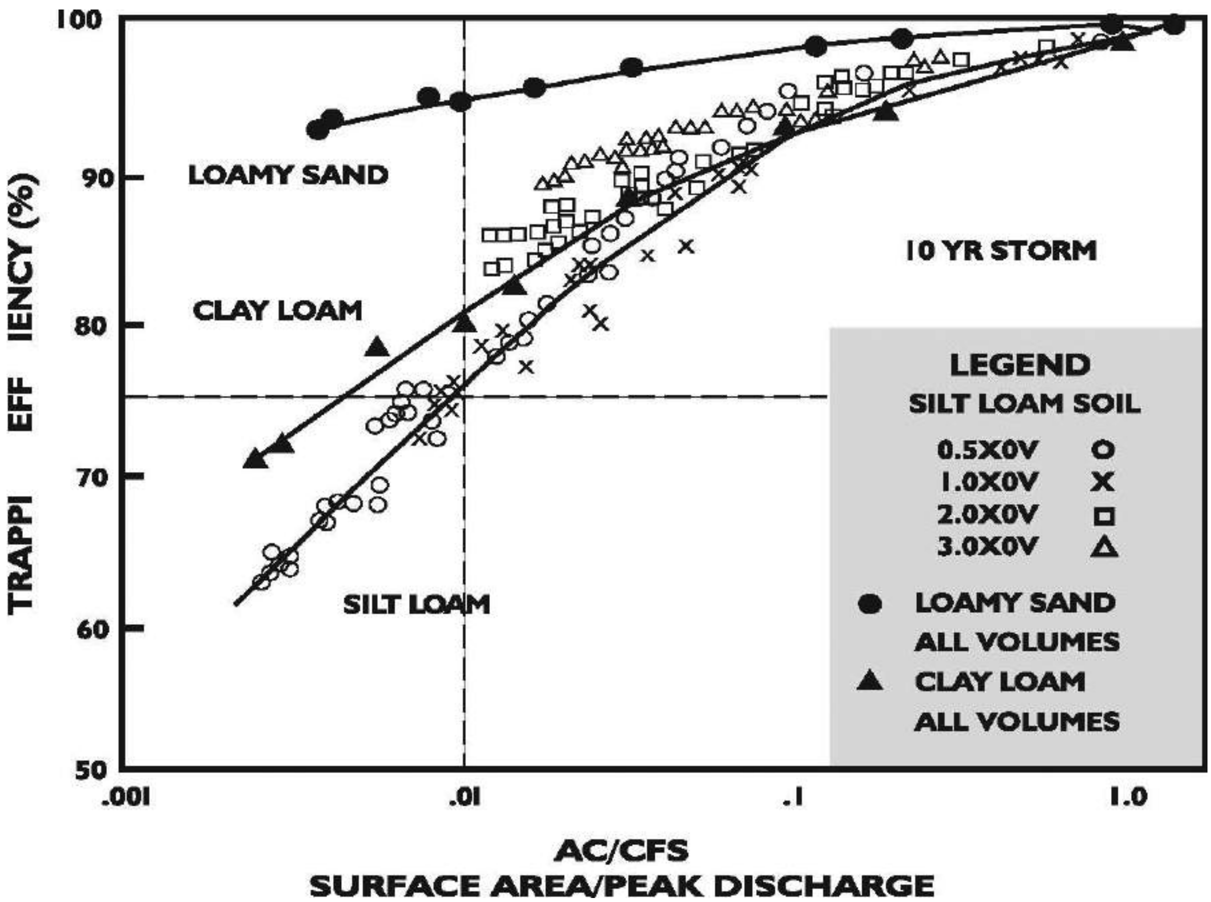


Figure 6.61a Relationship between the ratio of surface area to peak inflow rate and trap efficiency.

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*).

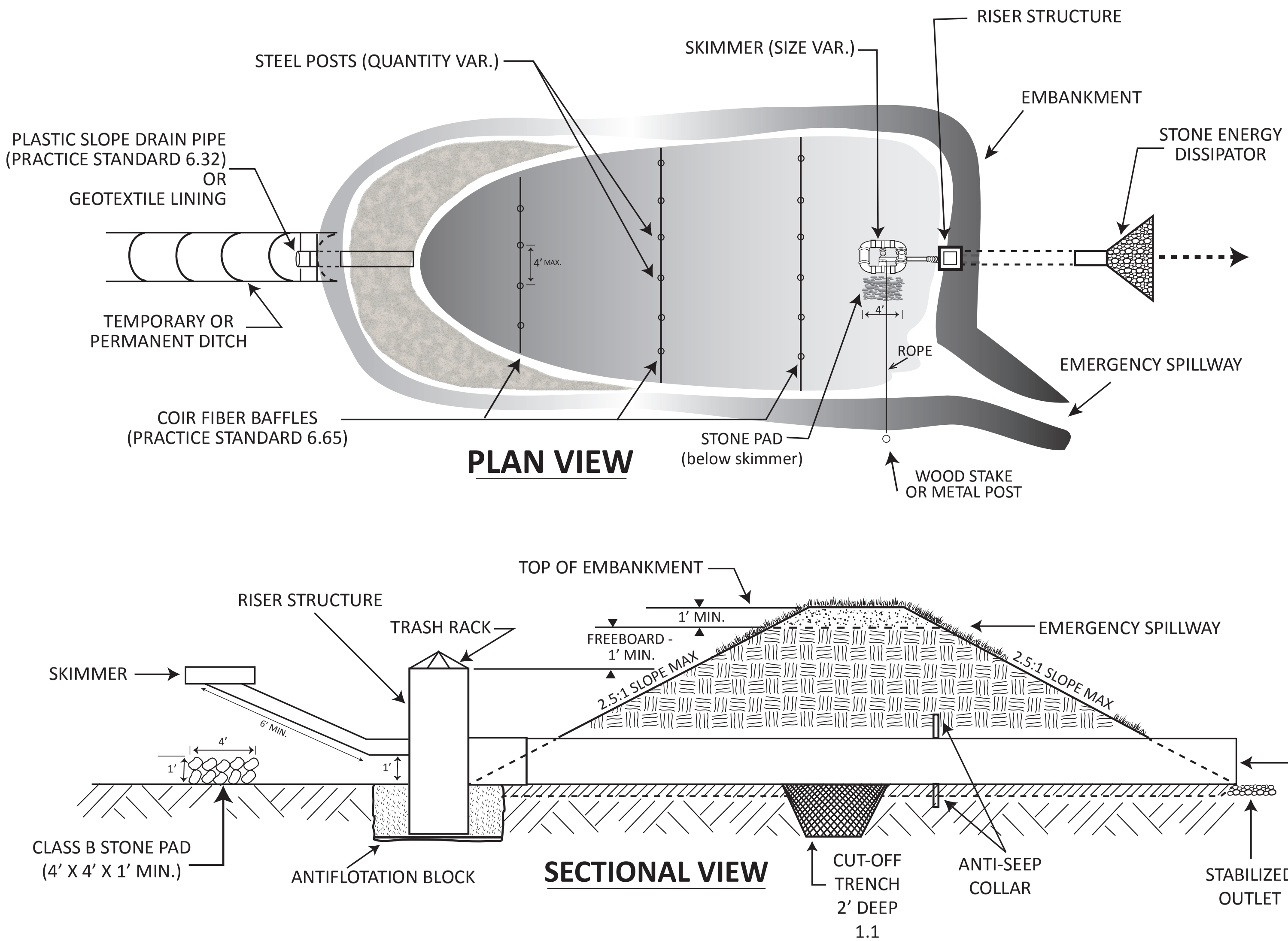
8. Install porous baffles as specified in Practice 6.65, Porous Baffles.

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.

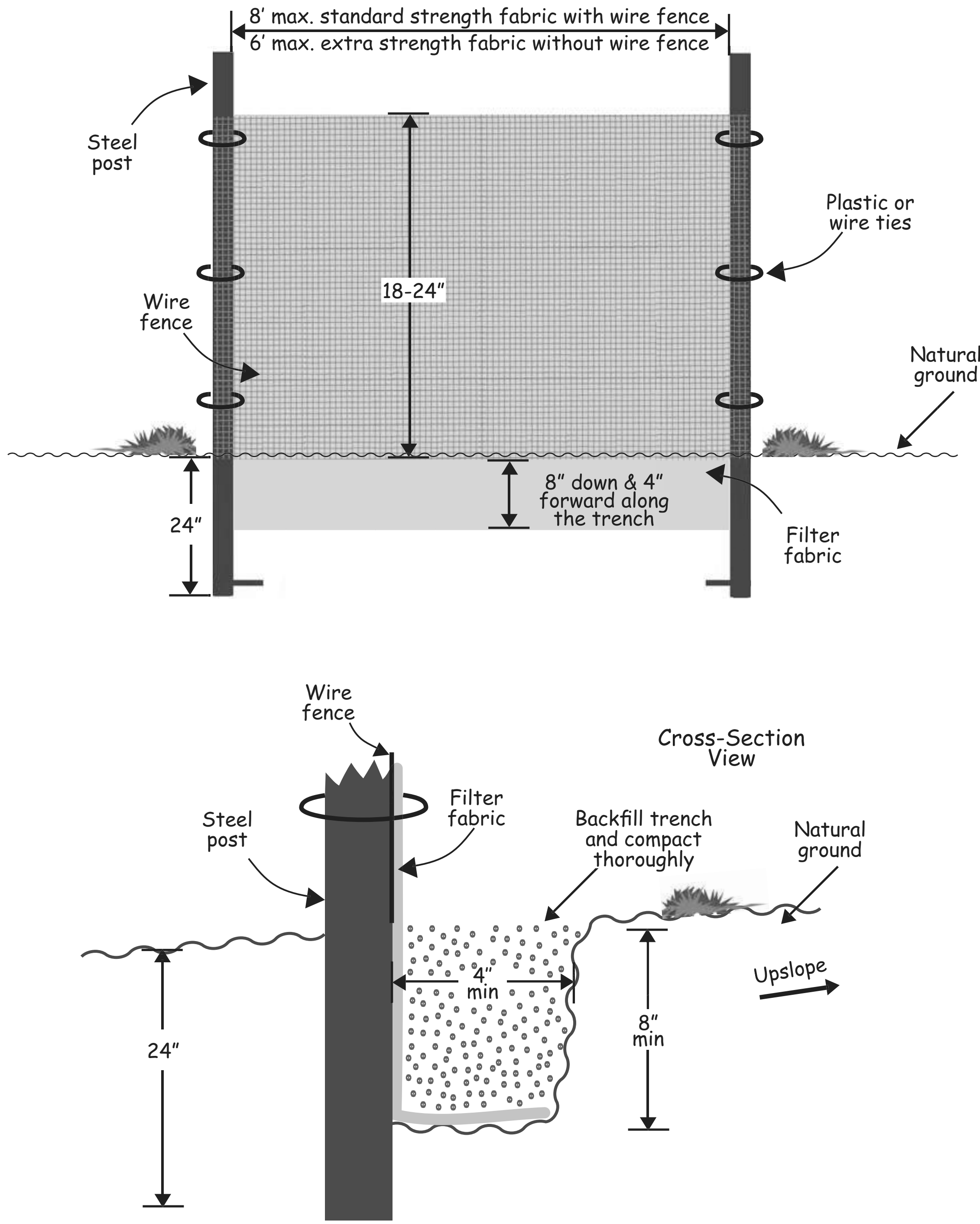


Figure 6.62a Installation detail of a sediment fence.

The Slicing Method

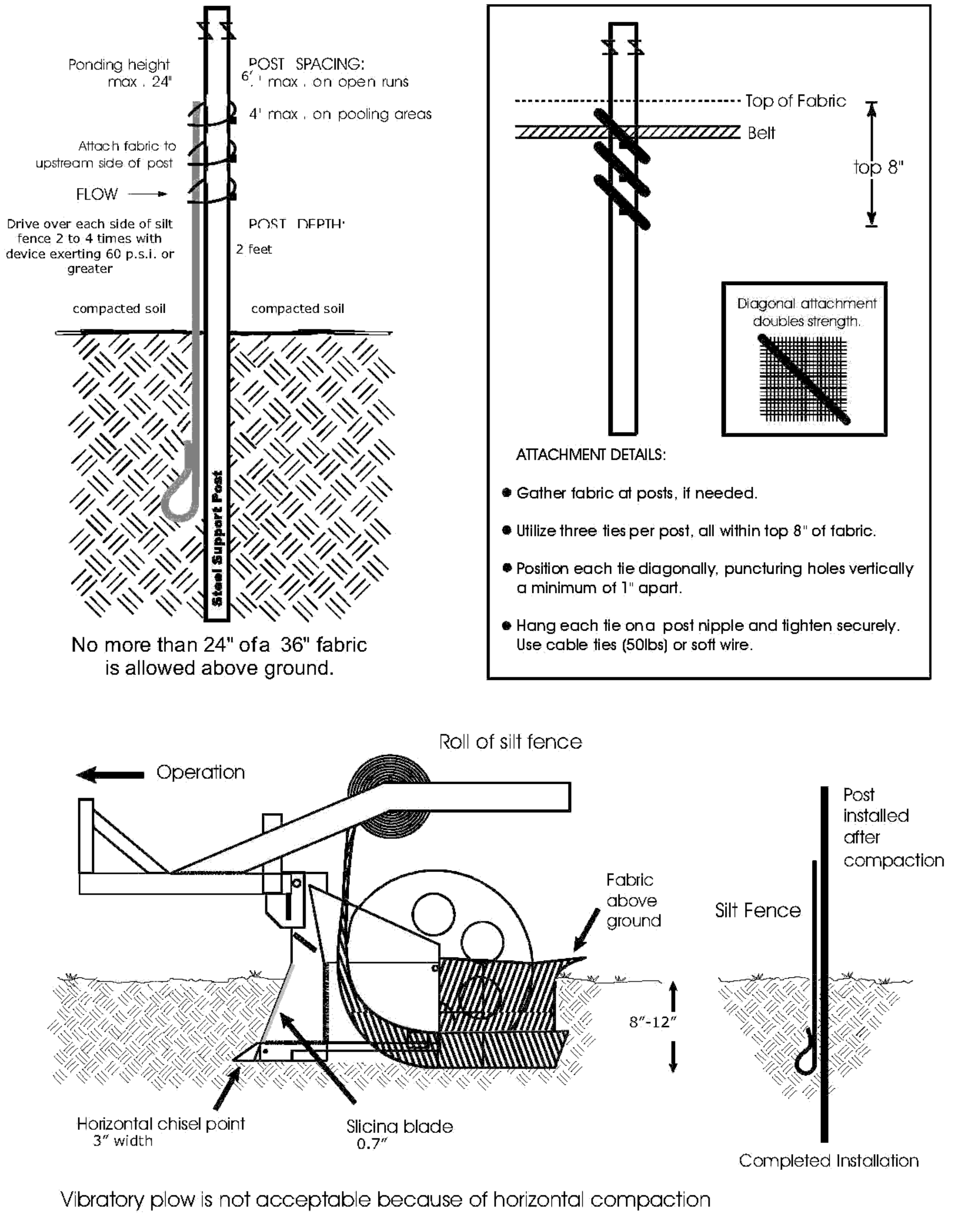


Figure 6.62b Schematics for using the slicing method to install a sediment fence. Adapted from *Silt Fence that Works*

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.

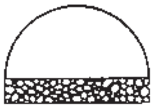
Runoff Control Measures
6.20, Temporary Diversions

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.

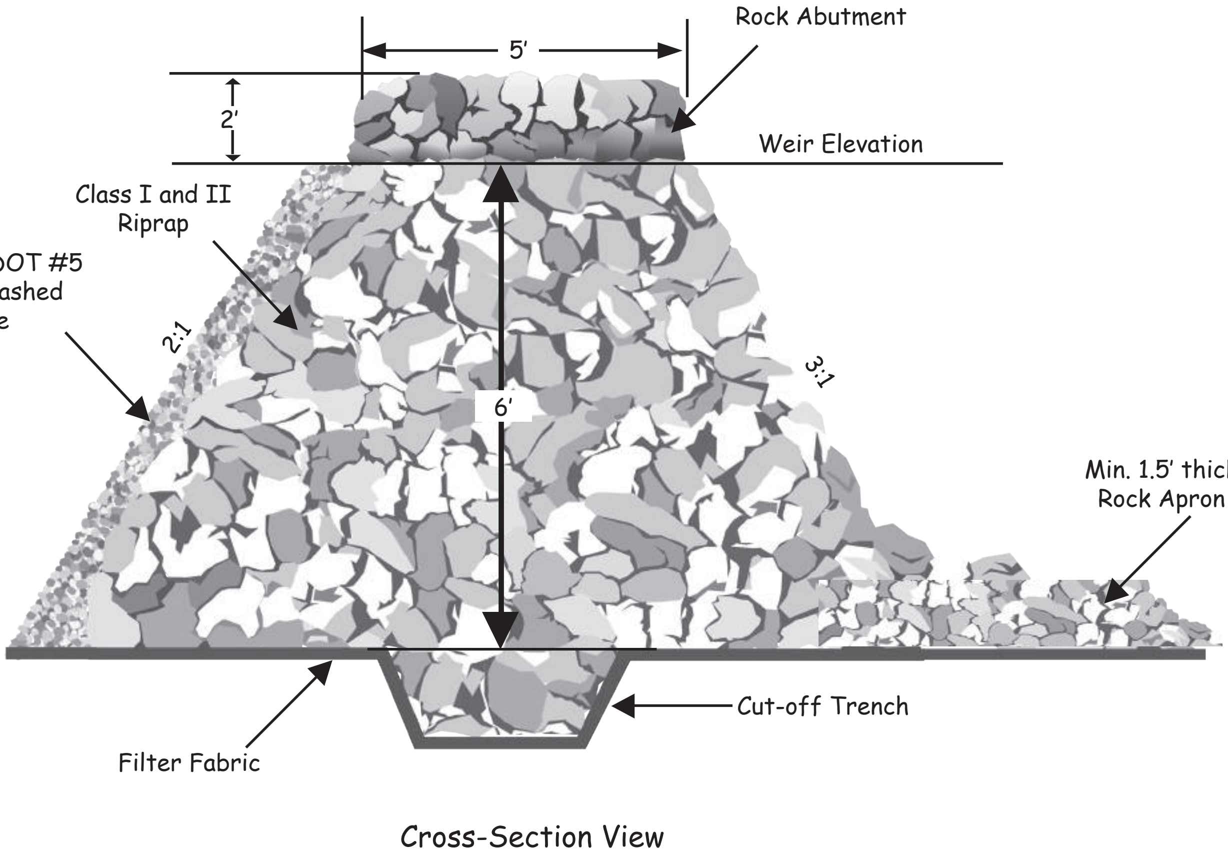


Figure 6.63a Rock Dam cross section

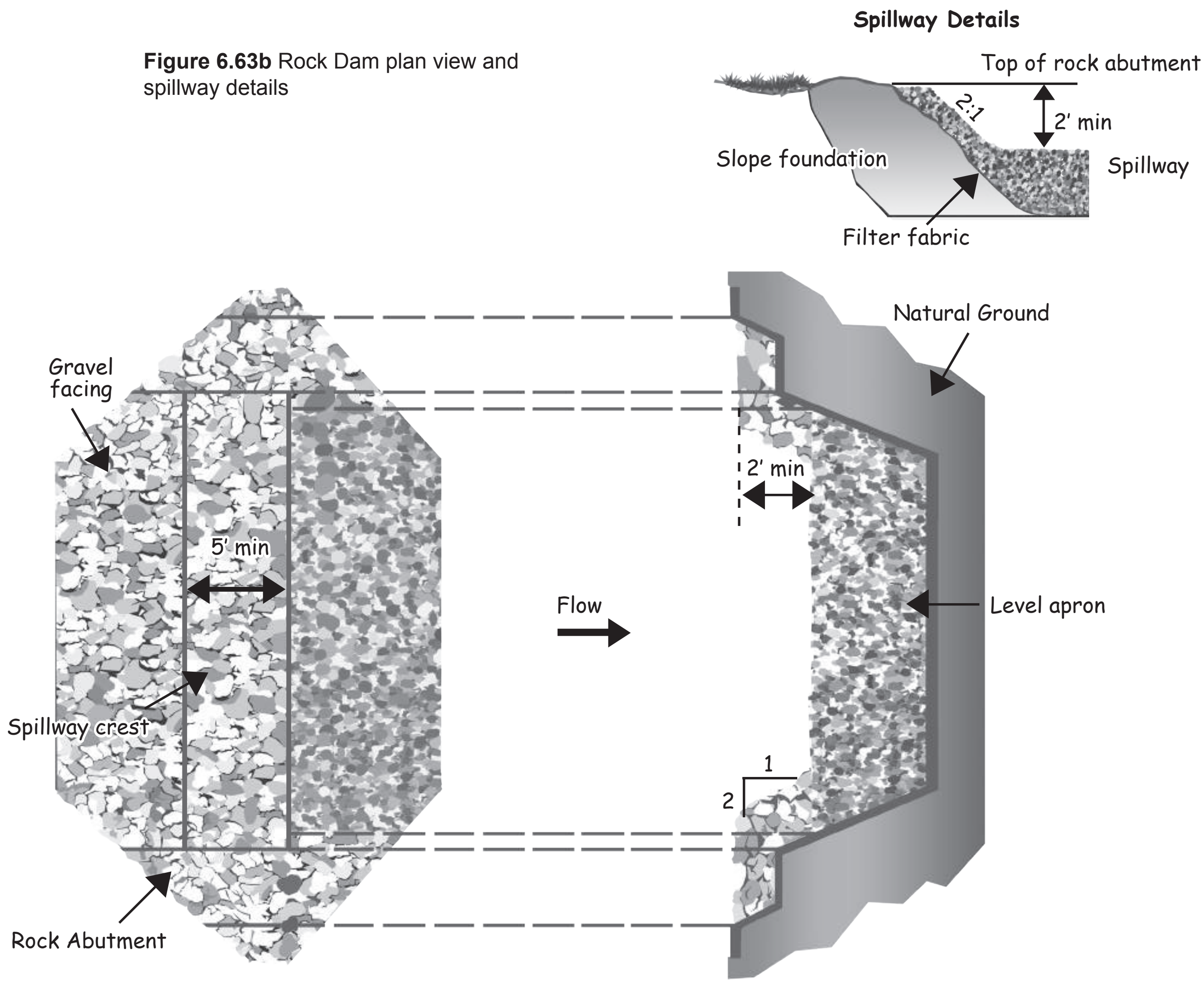
Construction Specifications

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.**

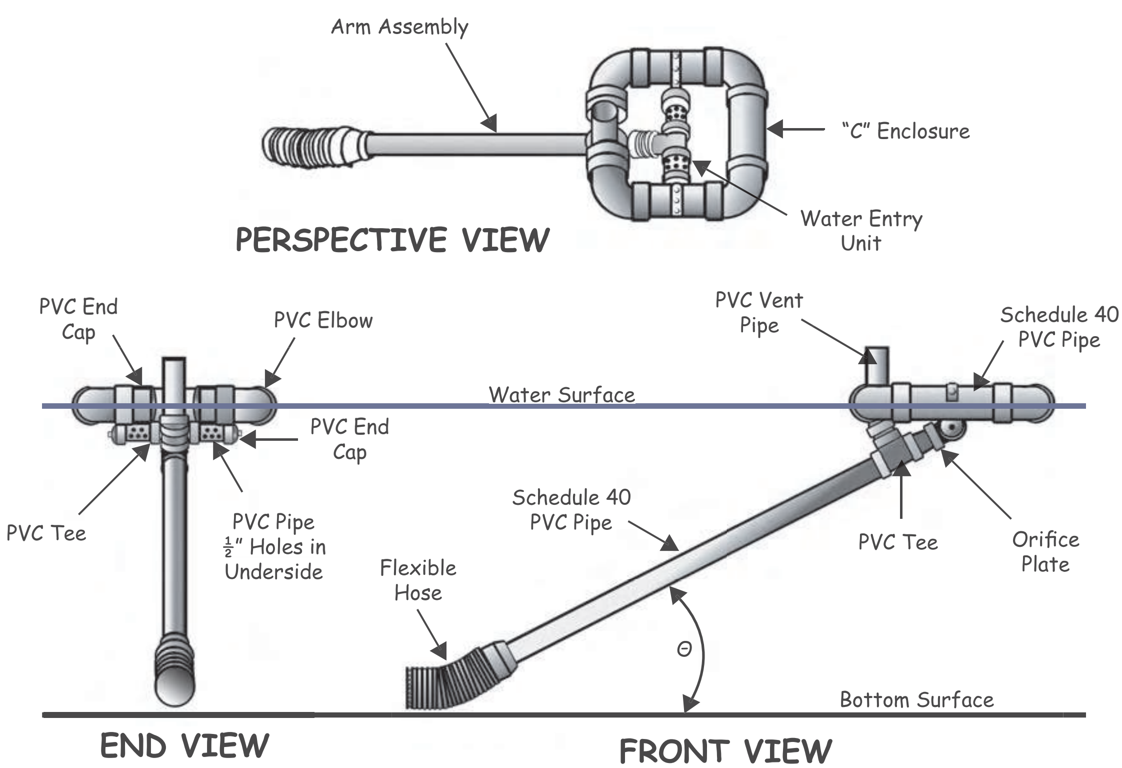


Figure 6.64a Schematic of a skimmer, from Pennsylvania Erosion and Sediment Pollution Control Manual, March, 2000.

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.

$$Q_d = V / t_d \quad (\text{ft}^3/\text{day})$$

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.

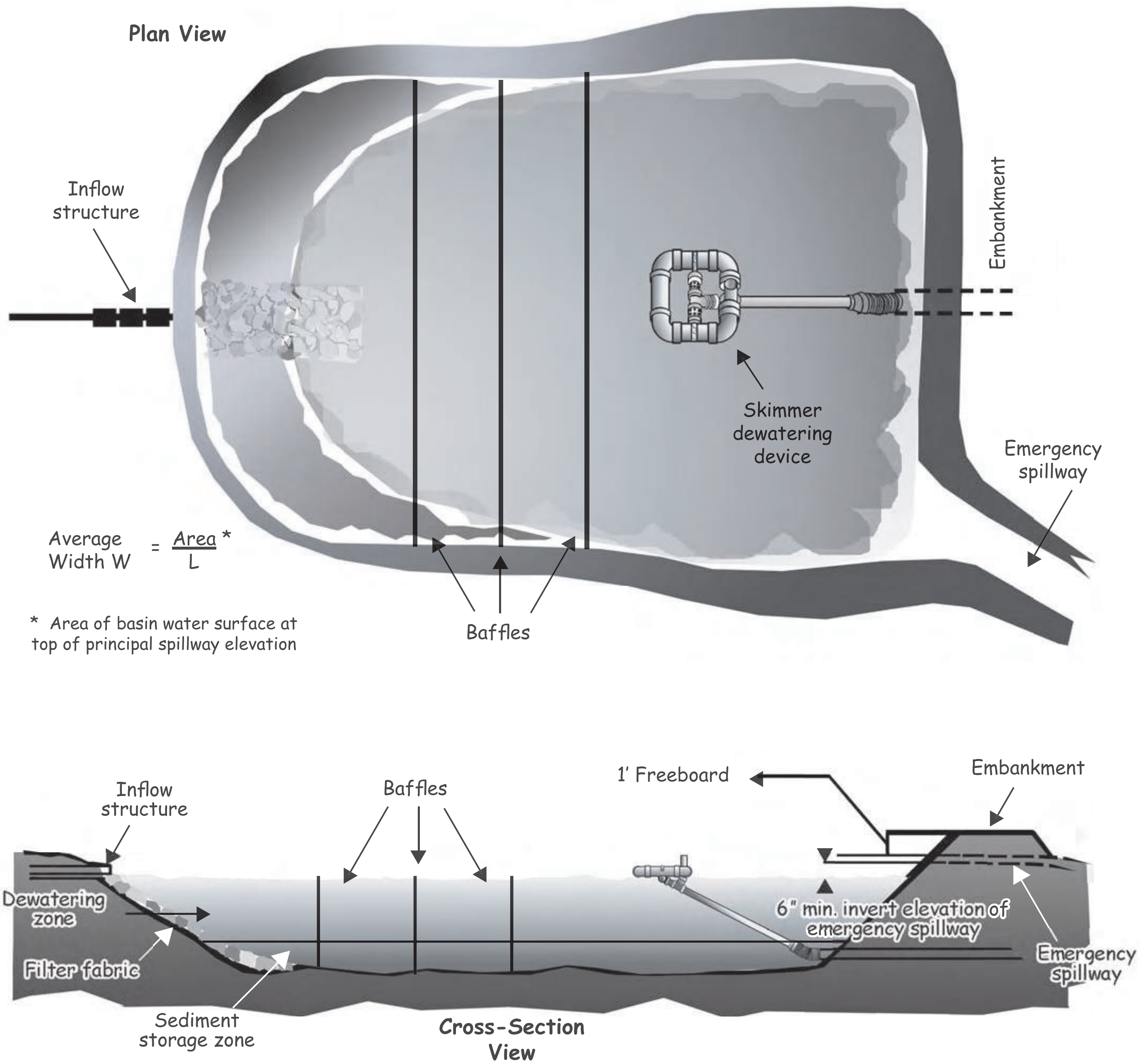


Figure 6.64c Example of a sediment basin with a skimmer outlet and emergency spillway. From Pennsylvania Erosion and Sediment Pollution Control Manual, March, 2000.

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

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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.

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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.

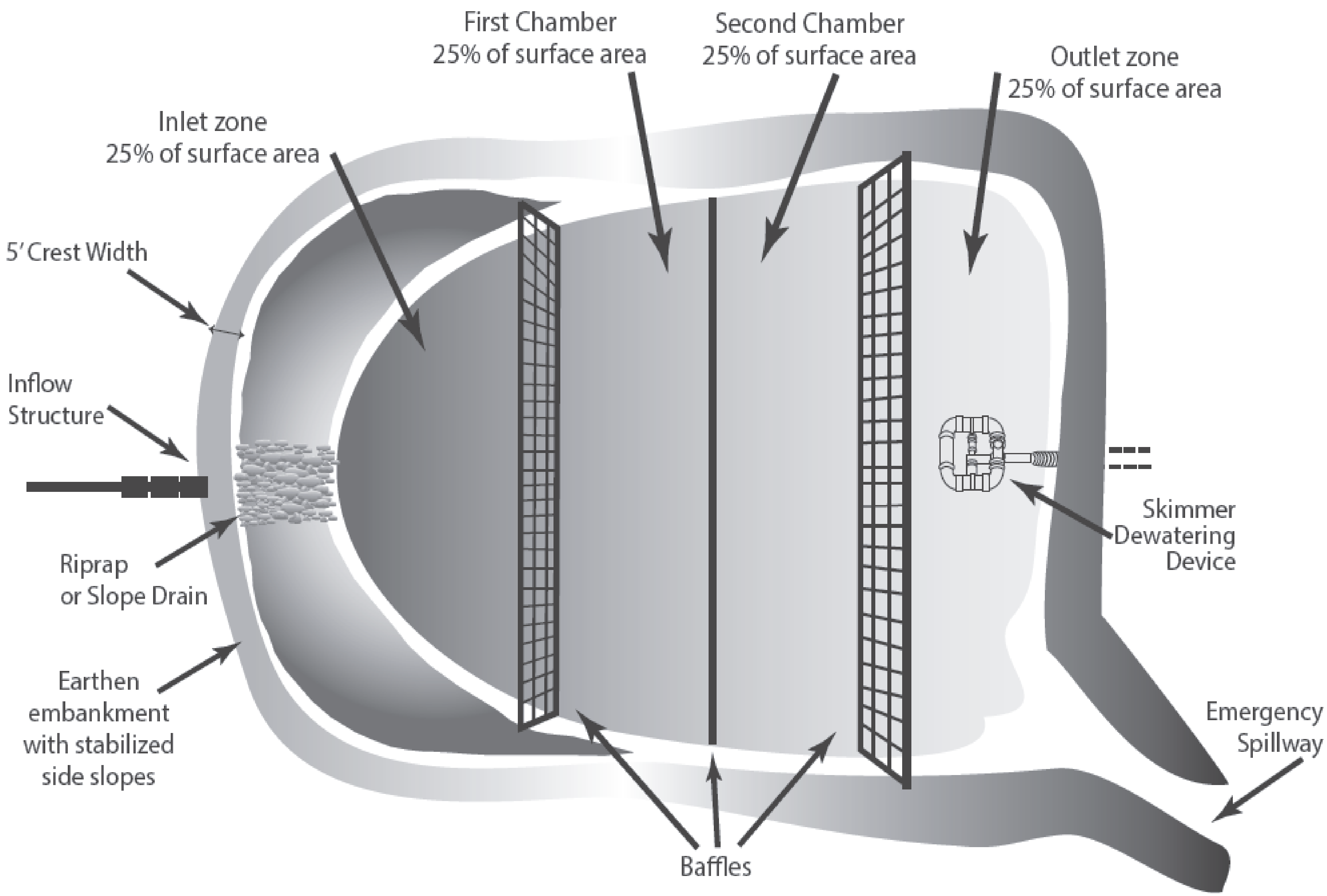

Figure 6.65a Porous baffles in a sediment basin. The flow is distributed evenly across the basin to reduce flow rates and turbulence, resulting in greater sediment retention.

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.

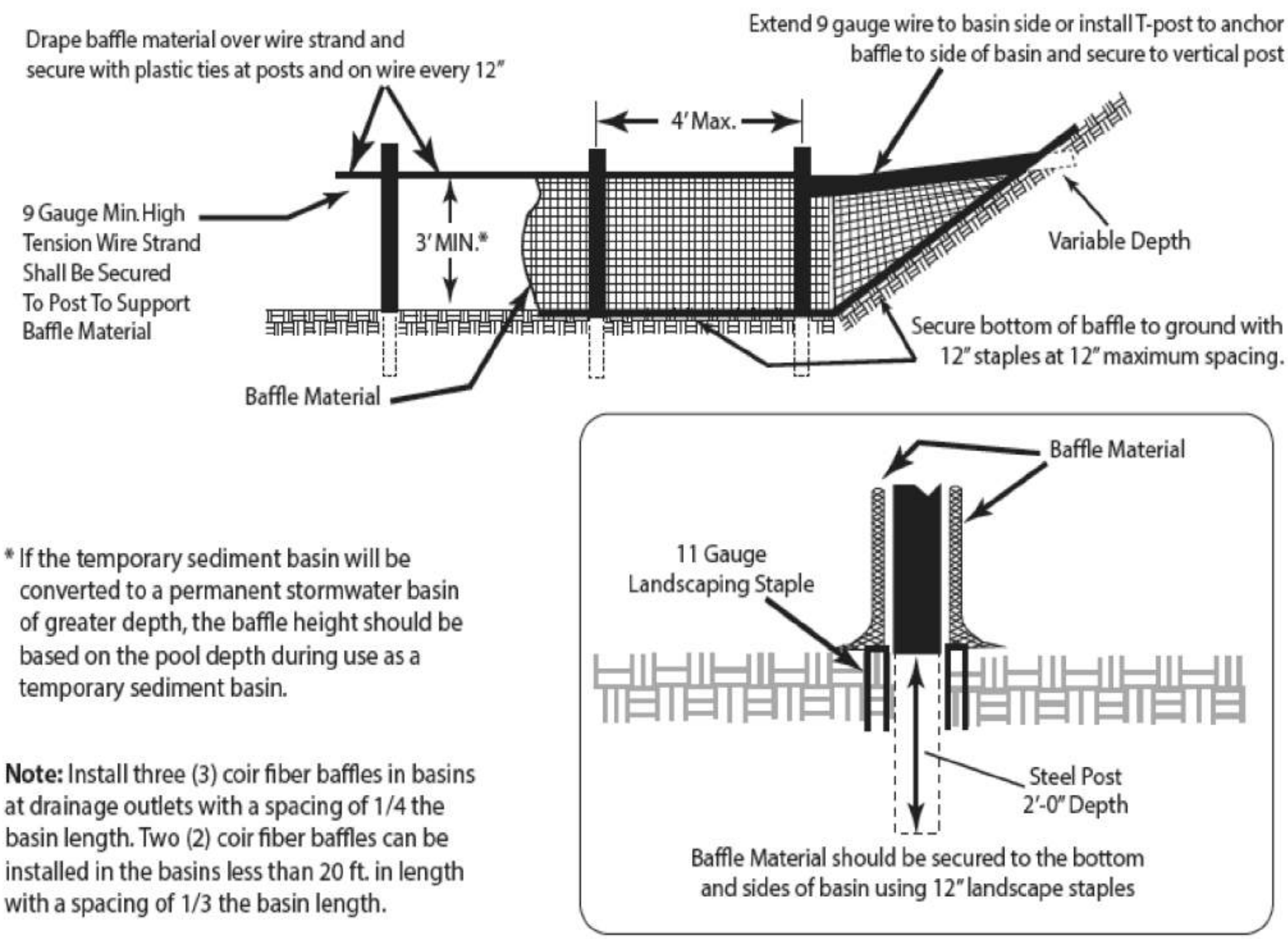

Figure 6.65b Coir Fiber Baffle Detail
Cross section of a porous baffle in a sediment basin.

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

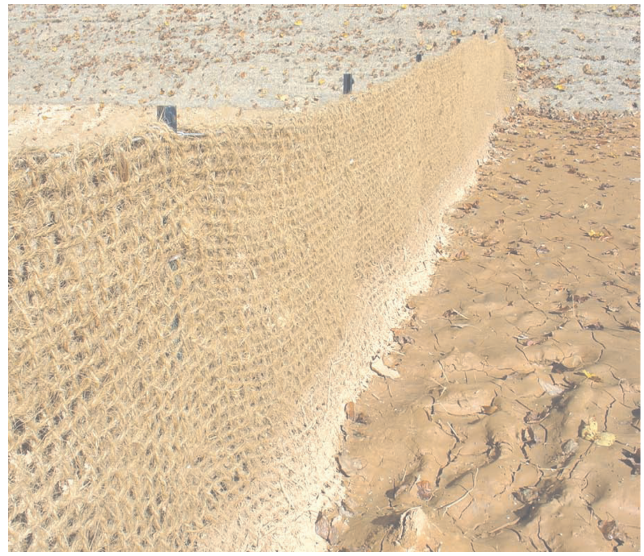

Figure 6.65d Close-up of a porous baffle.

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

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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.

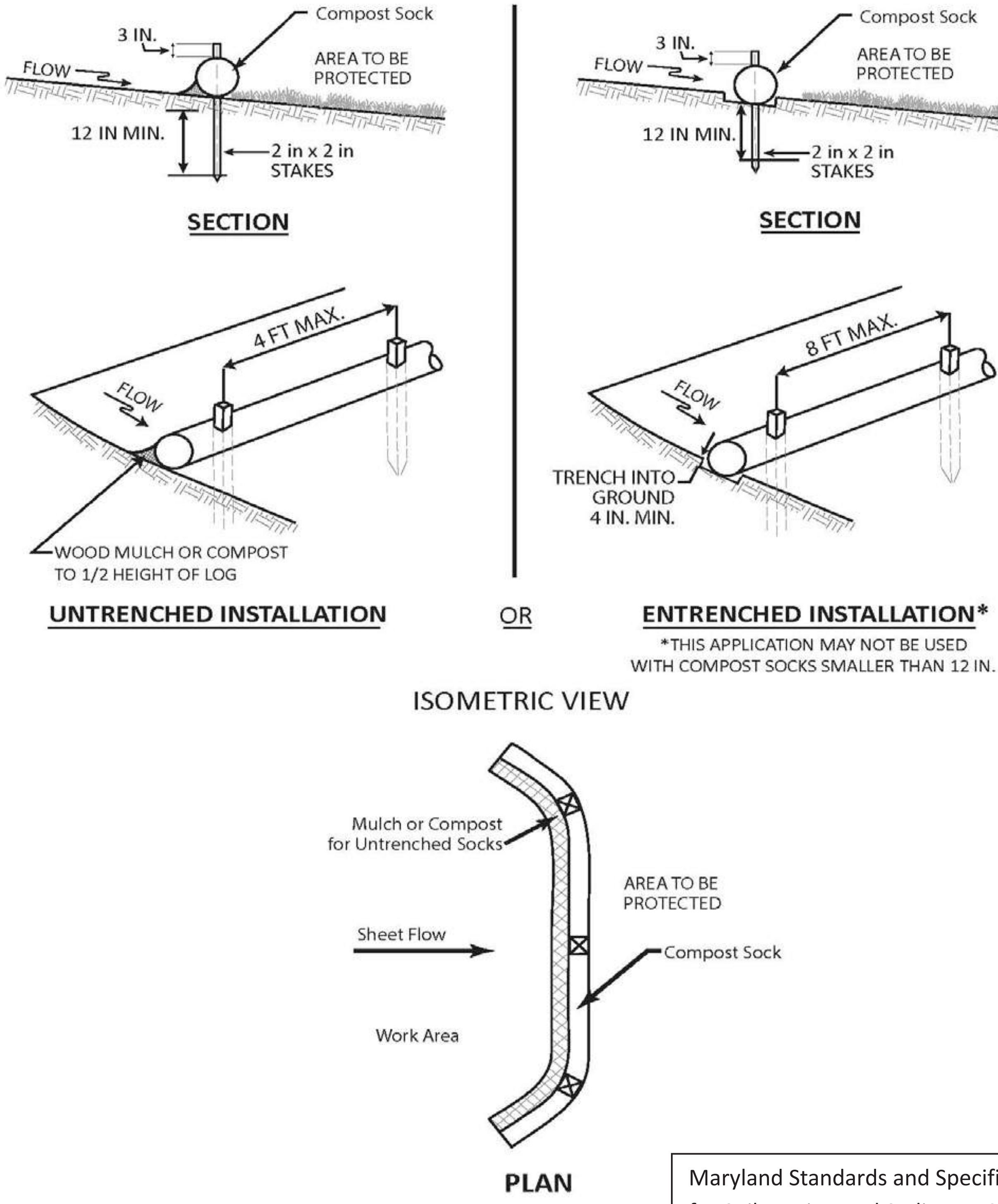

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Figure 6.66b Compost Sock Installation

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

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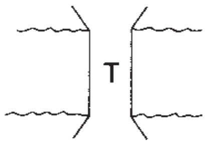
INDEX

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.

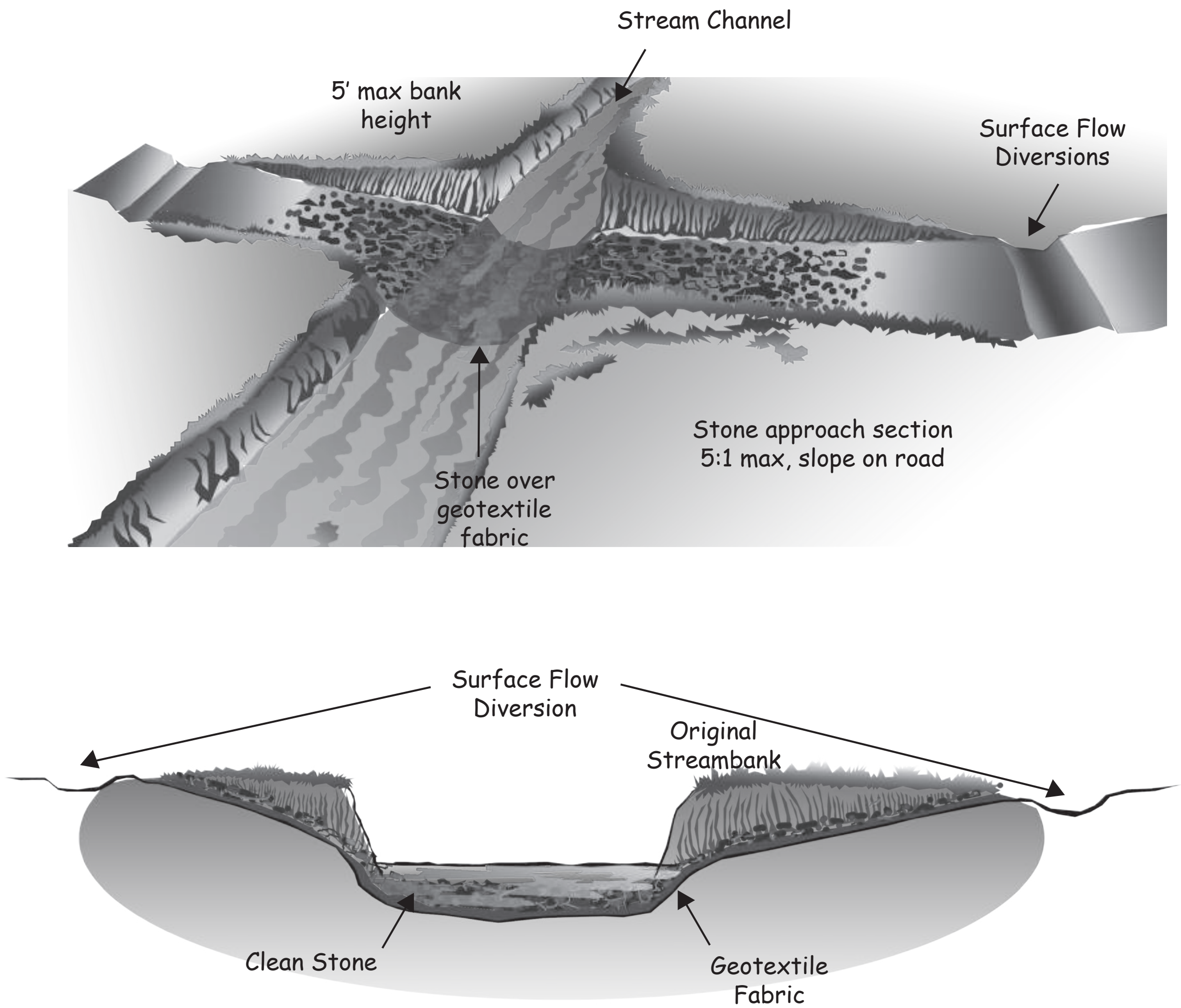


Figure 6.70a A well constructed ford offers little obstruction to flow while safely handling heavy loading.

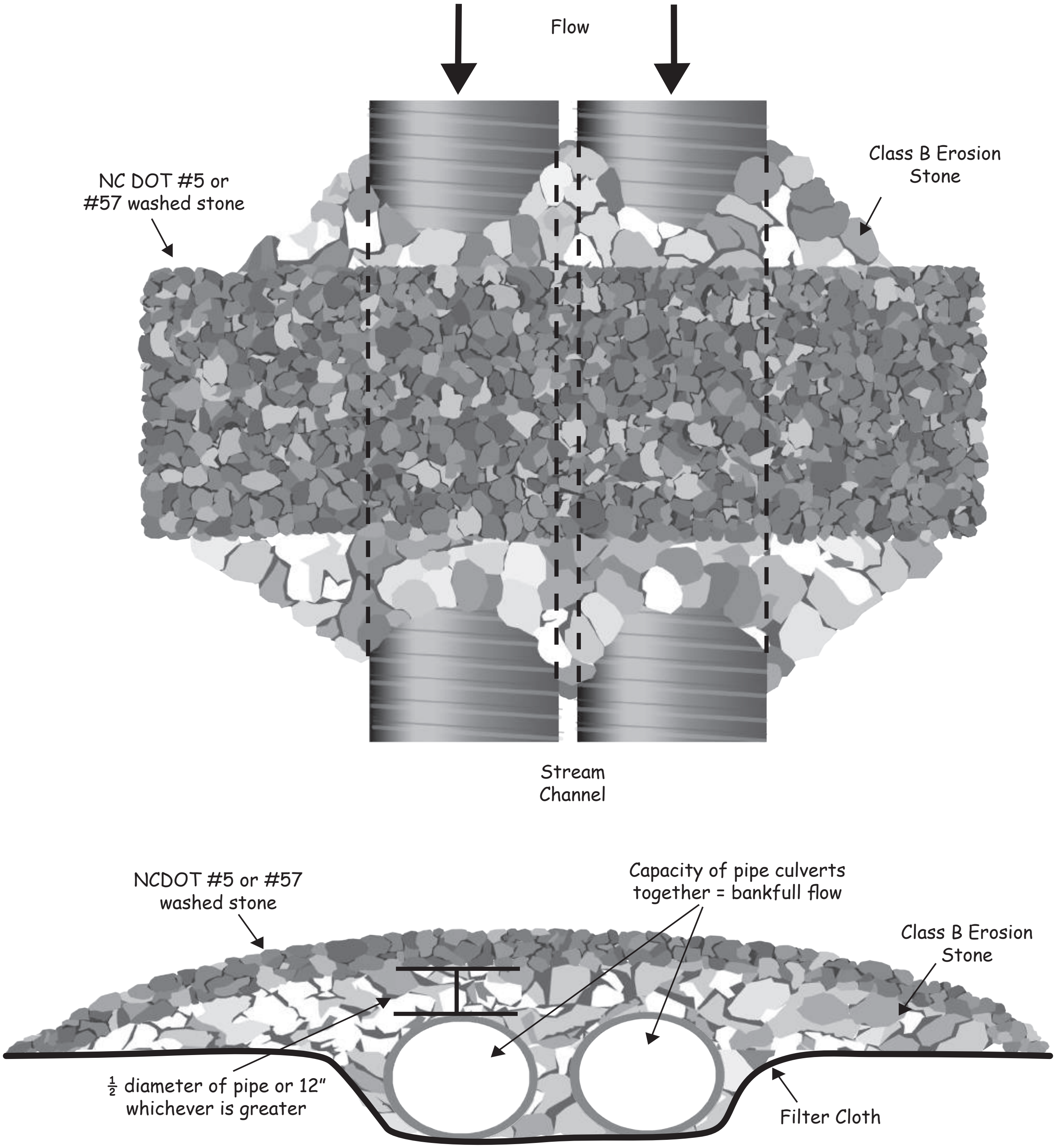


Figure 6.70b Temporary culvert backfilled with stone.

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.

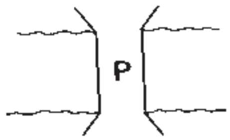
References

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.

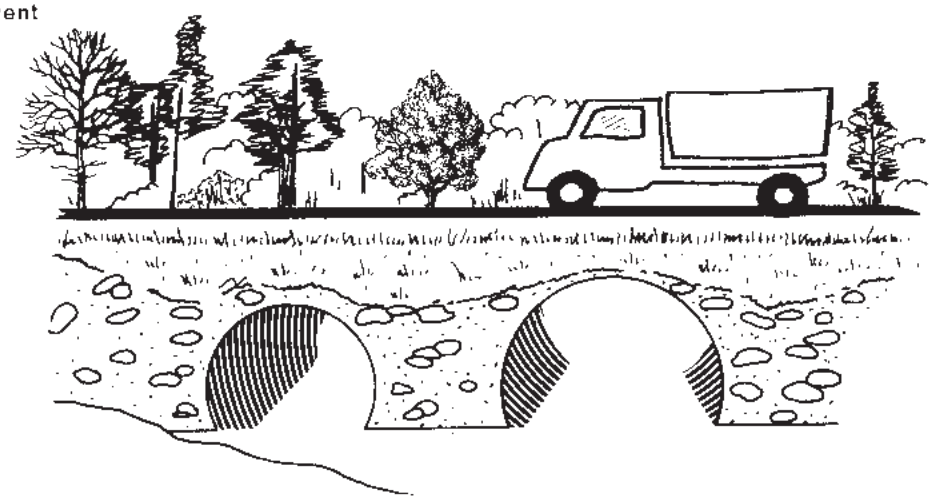
Purpose To provide a suitable means for construction and post-construction traffic to cross a watercourse.

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.

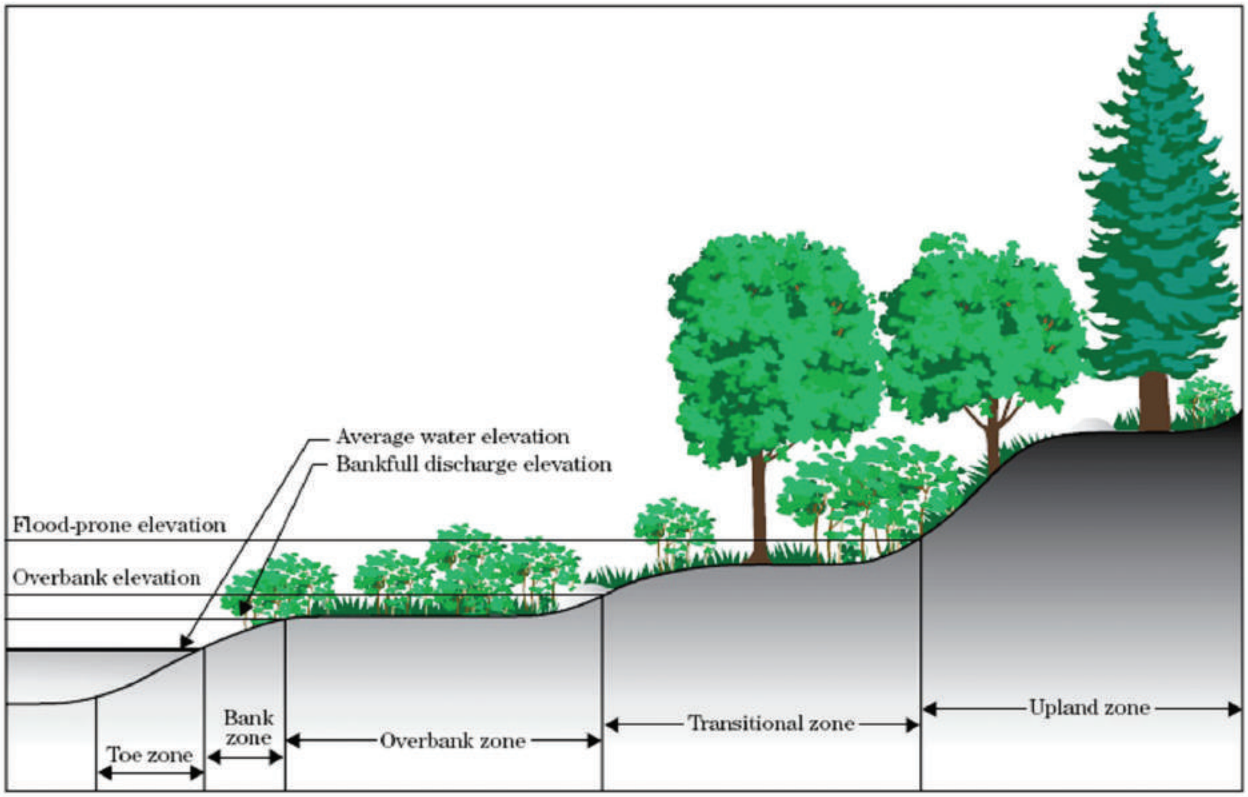
Bankfull channel elevation—Bankfull stage is typically defined at a point where the width-to-depth ratio is at a minimum. Practitioners use other consistent morphological indices to aid in its identification. Often, the flow at the bankfull stage has a recurrence interval of 1.5 years. Due to the high 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)
Sf = 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

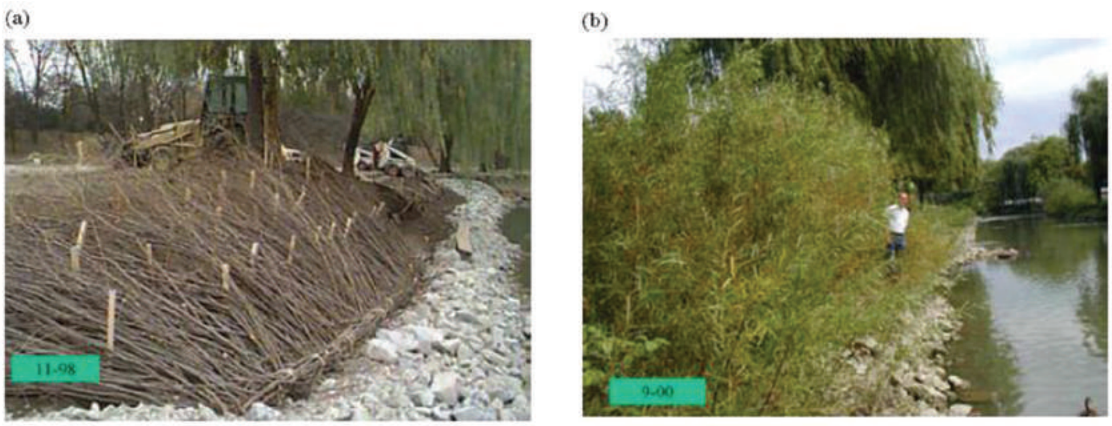
Installation

• 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



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.

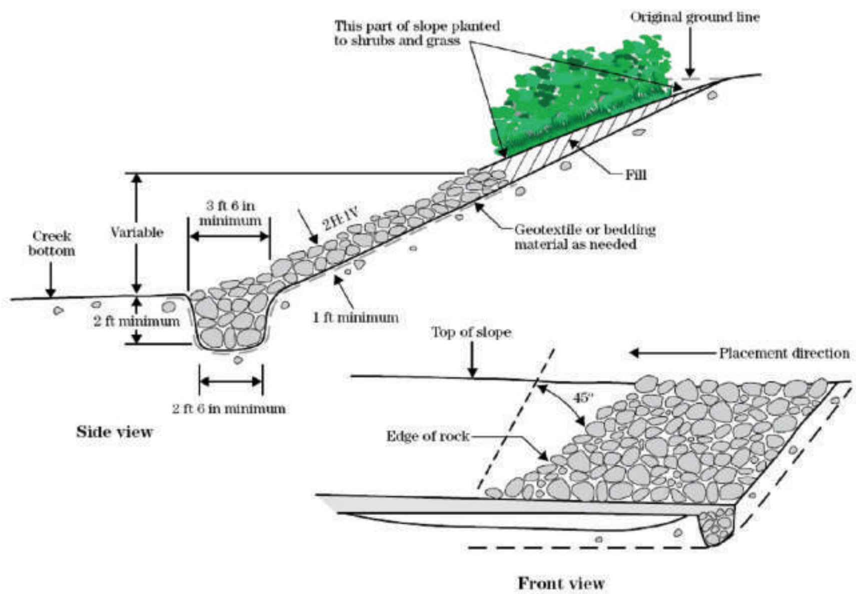
Dumped rock riprap

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.

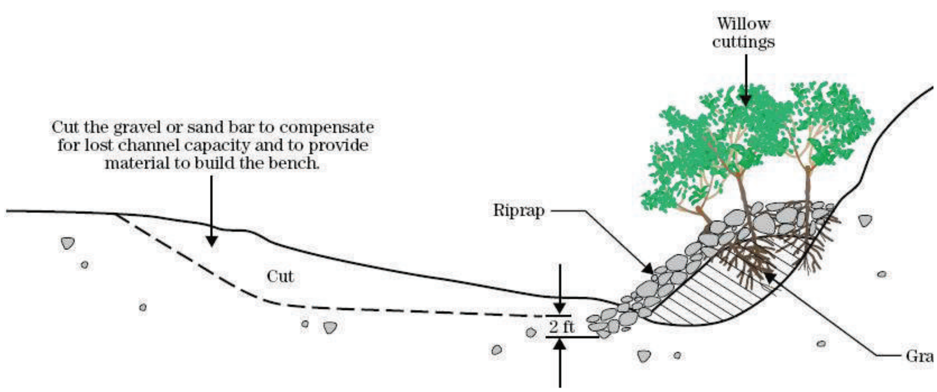


Figure 6.73b Embankment bench method

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.

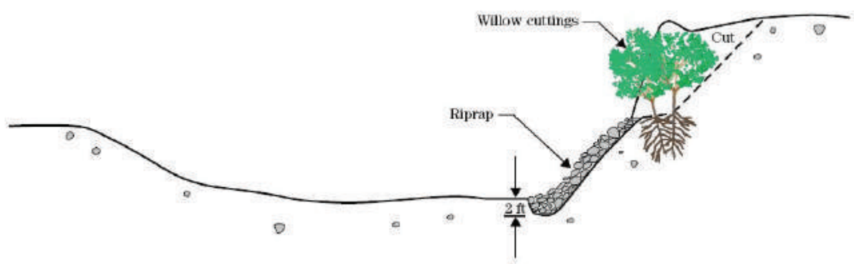


Figure 6.73c Excavated bench method

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.

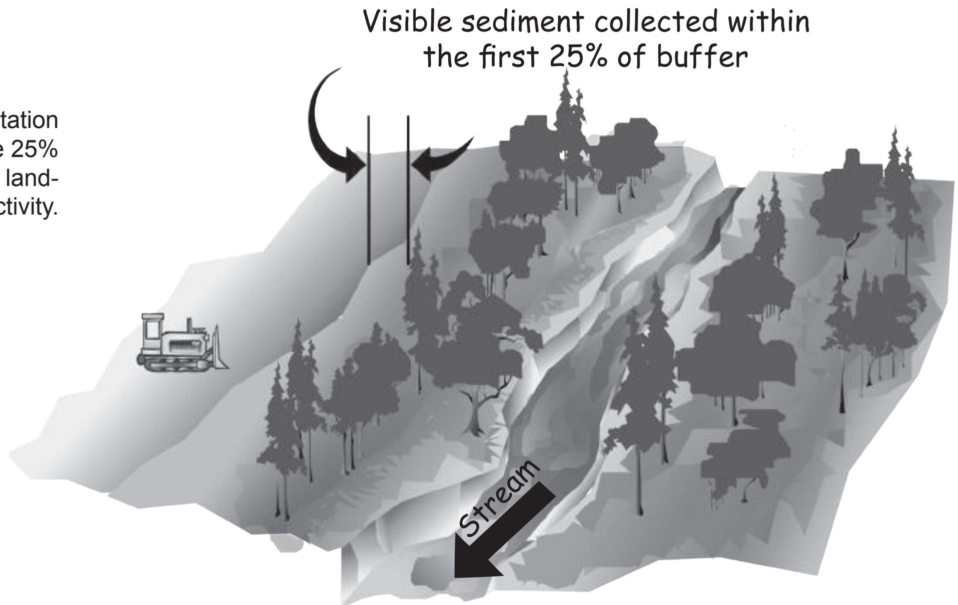


Figure 6.74a Visible siltation should be kept within the 25% buffer zone nearest the land-disturbing activity.

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.

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.

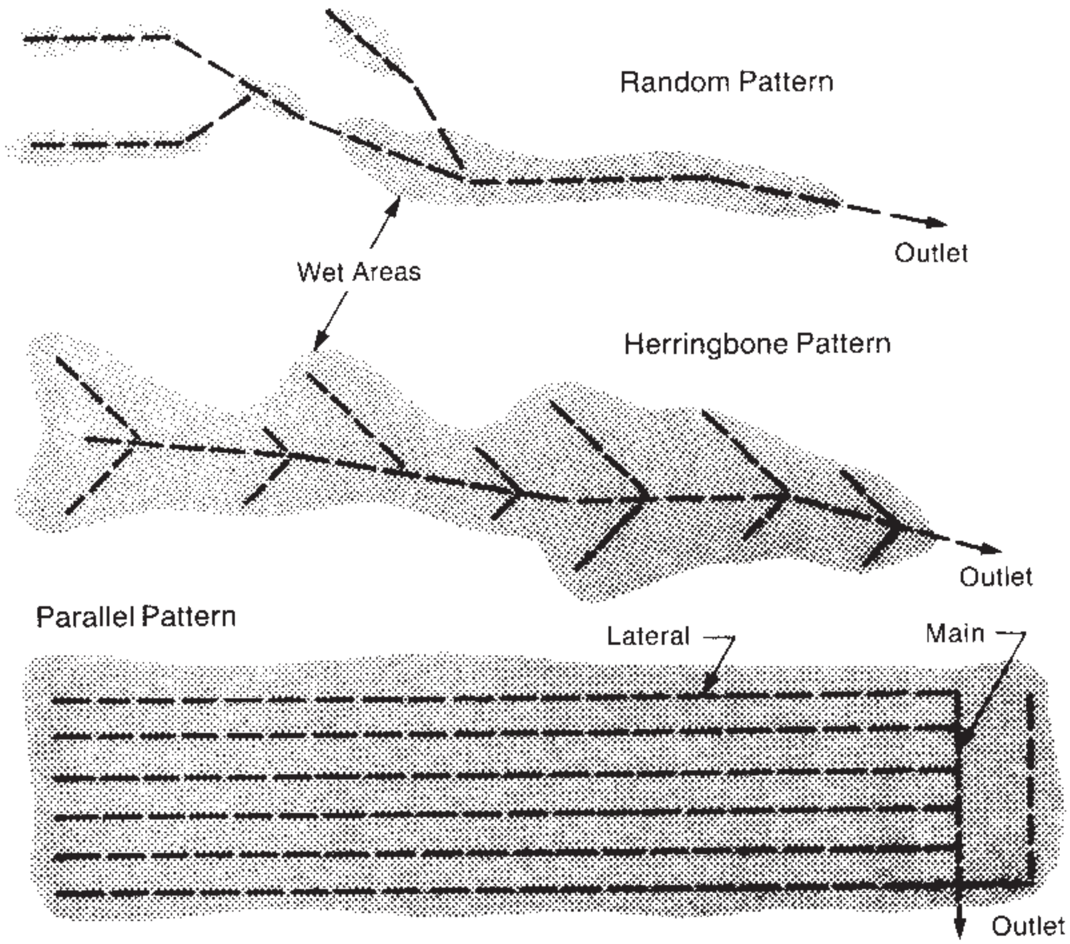


Figure 6.81a Subsurface relief drain layouts (source: USDA-SCS).

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.

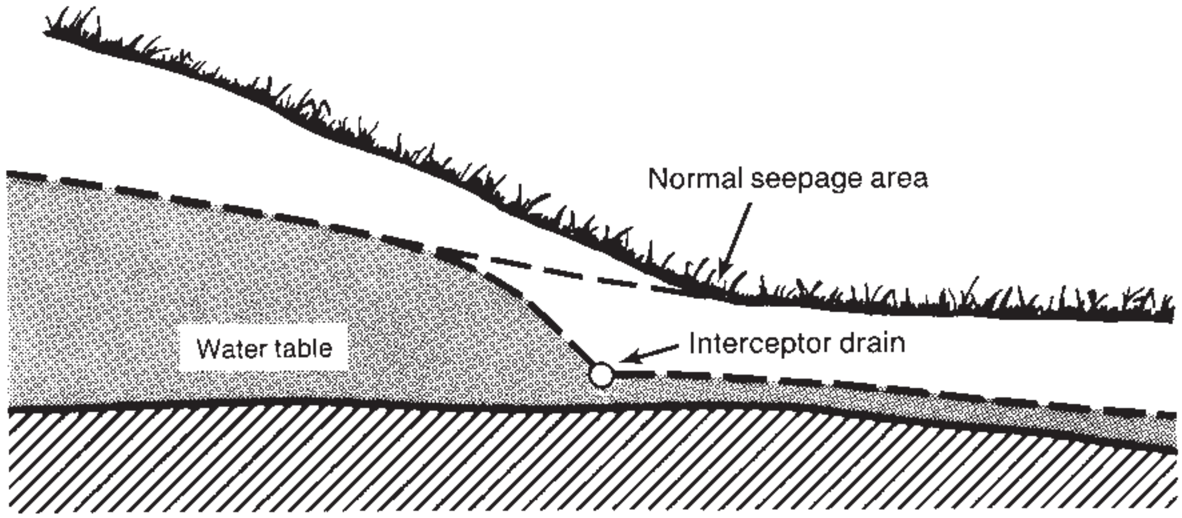


Figure 6.81b Interceptor drain to control seepage.

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.

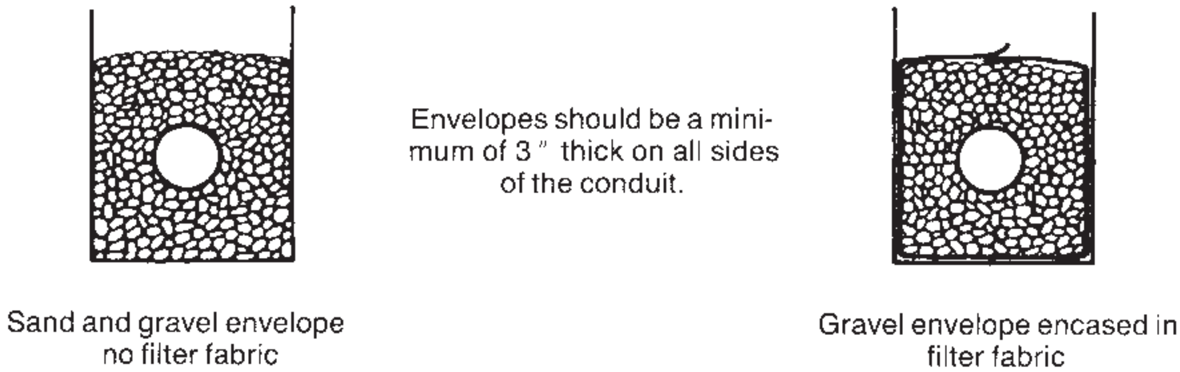


Figure 6.81c Drainage envelopes and filters (modified from USDA-SCS).

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.

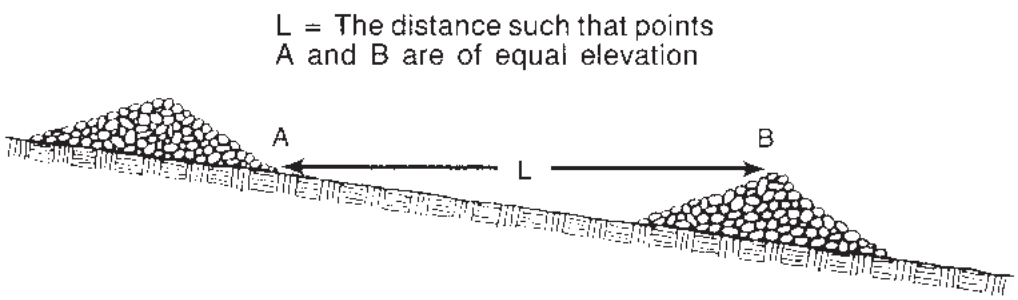


Figure 6.83a Space check dams in a channel so that the crest of downstream dam is at elevation of the toe of upstream dam.

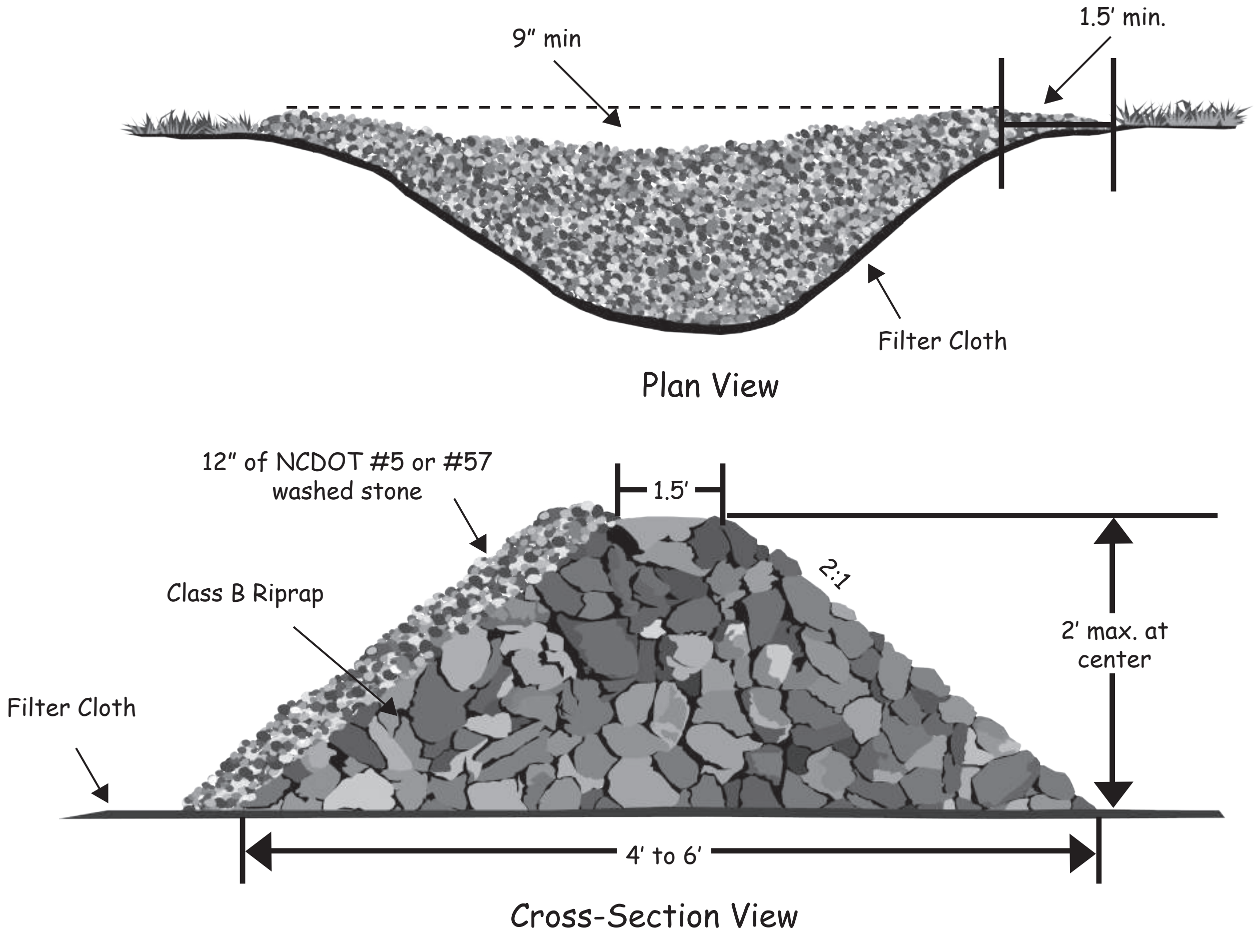


Figure 6.83b Stone check dam stone should be placed over the channel banks to keep water from cutting around the dam.

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).

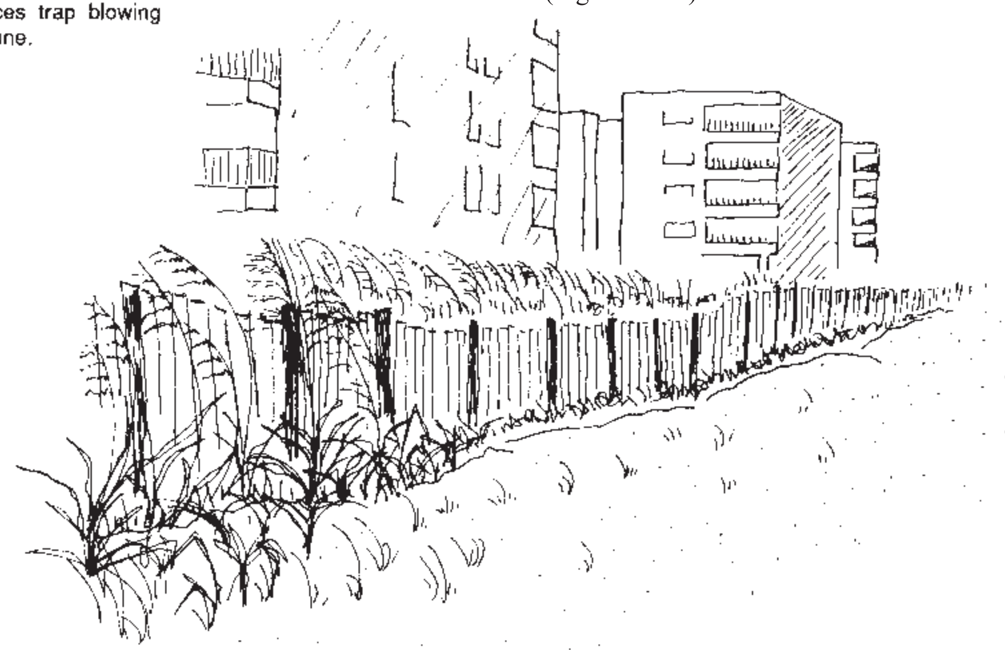


Figure 6.85a Sand fences trap blowing sand to rebuild frontal dune.

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

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

7

Sample Erosion and Sedimentation Control Plan

Attached is a sample erosion and sedimentation control plan based on one from the files of the state of North Carolina. The site is located in the Piedmont region. The plan was modified to demonstrate the application of a variety of erosion and sedimentation control practices commonly used through out the State.

This sample plan was developed in detail for instructive purposes. The specific number of maps, practices, drawings, specifications, and calculations required depends on the size and complexity of the development. The designer should select the most practical and effective practices to control erosion and prevent sediment from leaving the site. The plan should be organized and presented in a clear, concise manner. Sufficient design and background in formation should be included to facilitate review by erosion control personnel. Construction details should be precise and clear for use by an experience general contractor.

An acceptable erosion and sedimentation control plan must contain:

1. brief narrative
2. construction schedule
3. maintenance plan
4. vicinity map
5. site topographic map
6. site development plan
7. erosion and sedimentation control plan drawing
8. detail drawings and specifications
9. vegetative plan
10. supporting calculations
11. financial responsibility/ownership form
12. checklist

SAMPLE

EROSION AND SEDIMENTATION CONTROL PLAN

ABC INDUSTRIES, INC.

DEAL, N.C.

SEPTEMBER 1988

TABLE OF CONTENTS

NARRATIVE

Project Description

The purpose of the project is to construct two large commercial buildings with associated paved roads and parking area. Another building will be added in the future. Approximately 6 acres will be disturbed during this construction period. The site is 11.1 acres located in Granville county, 2 miles north of Deal, NC, off Terri Road (see Vicinity Map).

Site Description

The site has rolling topography with slopes generally 4 to 6%. Slopes steepen to 10 to 20% in the northwest portion of the property where a small, healed-over gully serves as the principal drainageway for the site. The site is now covered with volunteer heavy, woody vegetation, predominantly pines, 15 to 20 ft high. There is no evidence of significant erosion under present site conditions. The old drainage gully indicates severe erosion potential and receives flow from 5 acres of woods off-site. There is one large oak tree, located in the western central portion of the property, and a buffer area, fronting Terri Road, that will be protected during construction.

Adjacent Property

Land use in the vicinity is commercial/industrial. The land immediately to the west and south has been developed for industrial use. Areas to the north and east are undeveloped and heavily wooded, primarily in volunteer pine. Hocutt Creek, the off-site outlet for runoff discharge, is presently a well-stabilized, gently-flowing perennial stream. Sediment control measures will be taken to prevent damage to Hocutt Creek. Approximately 5 acres of wooded area to the east contribute runoff into the construction area.

Soils

The soil in the project area is mapped as Creedmore sandy loam in B and C slope classes. Creedmoor soils are considered moderately well to somewhat poorly drained with permeability rates greater than 6 inches/hour at the surface but less than 0.1 inches/hour in the subsoil. The subsurface is pale brown sandy loam, 6 inches thick. The subsoil consists of a pale brown and brownish yellow sandy clay loam ranging to light gray clay, 36 inches thick. Below 36 inches is a layer of fine sandy loam to 77 inches. The soil erodibility factor (K value) ranges from 0.20 at the surface to 0.37 in the subsoil.

Due to the slow permeability of the subsoil that will be exposed during grading, a surface wetness problem with high runoff is anticipated following significant rainfall events. No groundwater problem is expected. The tight clay in the subsoil will make vegetation difficult to establish. A small amount of topsoil exists on-site and will be stockpiled for use in landscaping.

Planned Erosion and Sedimentation Control Practices

1. Sediment Basin -- Practice 6.61
   A sediment basin will be constructed in the northwest corner of the property. All water from disturbed areas, about 6 acres, will be directed to the basin before leaving the site. (NOTE: The undisturbed areas to the east and north could have been diverted, but this was not proposed because it would have required clearing to the property line to build the diversion and the required outlet structure.) See pages 7.11 - 7.13 for details and pages 7.35 - 7.37 for supporting calculations.

2. Temporary Gravel Construction Entrance/Exit -- Practice 6.06
   A temporary gravel construction entrance will be installed near the north-west corner of the property. During wet weather it may be necessary to wash vehicle tires at this location. The entrance will be graded so that runoff water will be directed to an inlet protection structure and away from the steep fill area to the north. See page 7.13 for specifications.

3. Temporary Block and Gravel Drop Inlet Protection -- Practice 6.52
   A temporary block and gravel drop inlet protection device will be installed at the drop inlet located on the south side of the construction entrance. Runoff from the device will be directed into the sediment basin. (NOTE: The presence of this device reduces the sediment load on the sediment basin and provides sediment protection for the pipe. In addition, sediment removal at this point is more convenient than from the basin.) See page 7.14 for specifications.

4. Temporary Diversions -- Practice 6.20
   Temporary diversions will be constructed above the 3:1 cut slopes south of Buildings A and B to prevent surface runoff from eroding these banks. (NOTE: Sediment-free water may be diverted away from the project sediment basin.) A temporary diversion will be constructed near the middle of the disturbed area to break up this long, potentially erosive slope should the grading operation be temporarily discontinued. A temporary diversion will be constructed along the top edge of the fill slope at the end of each day during the filling operation to protect the fill slope. This temporary diversion will outlet to the existing undisturbed channel near the north edge of the construction site and/or to the temporary inlet protection device at the construction entrance as the fill elevation increases. See page 7.15 for specifications and pages 7.49 - 7.50 for supporting calculations.

5. Level Spreader -- Practice 6.40
   A level spreader will serve as the outlet for the diversion east of Building A and south of Building B. The area below the spreader is relatively smooth and heavily vegetated with a slope of approximately 4%. See page 7.16 for specifications.

6. Tree Preservation and Protection -- Practice 6.05
   A minimum 2.0 ft high protective fence will be erected around the large oak tree at the dripline to prevent damage during construction. Sediment fence materials

may be used for this purpose. See page 7.17 for specifications.

7. <u>Land Grading -- Practice 6.02</u>
Heavy grading will be required on approximately 6 acres. The flatter slope after grading will reduce the overall erosion potential of the site. The buildings will be located on the higher cut areas, and the access road and open landscaped areas will be located on fill areas. See pages 7.17 - 7.18 for specifications.

All cut slopes will be 3:1 or flatter to avoid instability due to wetness, provide fill material, give an open area around the buildings, and allow vegetated slopes to be mowed. Cut slopes will be fine graded immediately after rough grading; the surface will be disked and vegetated according to the Vegetation Plan (pages 7.30 - 7.32).

Fill slopes will be 2:1 with fill depths as much as 12 to 15 ft. Fill will be placed in layers not to exceed 9 inches in depth and compacted. (NOTE: Fills of this depth should have detailed compaction specifications in the general construction contract. These specifications are not part of the erosion and sedimentation control plan.)

The fill slope in the north portion of the property is the most vulnerable area to erosion on the site. Temporary diversions will be maintained at the top of this fill slope at all times, and the filling operation will be graded to prevent overflow to the north. Filling will be done as a continuous operation until final grade is reached. The paved road located on the fill will be sloped to the south and will function as a permanent diversion. The area adjacent to the roads and parking area will be graded to conduct runoff to the road culverts. Runoff water from the buildings will be guttered to the vegetated channels. The finished slope face to the north will not be back-bladed. The top 2 to 6 inches will be left in a loose and roughened condition. Plantings will be protected with mulch, as specified in the Vegetation Plan.

A minimum 15-ft undisturbed buffer zone will be maintained around the perimeter of the disturbed area. (NOTE: This will reduce water and wind erosion, help contain sediment, reduce dust, and reduce final landscaping costs.)

8. <u>Temporary Sediment Trap -- Practice 6.60</u>
A small sediment trap will be constructed at the intersection of the existing road ditch and channel number 3 to protect the road ditch. Approximately 2 acres of disturbed area will drain into this trap. See pages 7.19 - 7.20 for specifications and pages 7.48 - 7.49 for calculations.

9. <u>Sediment Fence -- Practice 6.62</u>
A sediment fence will be constructed around the topsoil stockpile and along the channel berm adjacent to the deep cut area as necessary to prevent sediment from entering the channels. See page 7.20 - 7.21 for specifications.

10. <u>Sod Drop Inlet Protection -- Practice 6.53</u>
Permanent sod drop inlet protection will replace the temporary block and gravel

structure when the contributing drainage area has been permanently seeded and mulched. See pages 7.21 - 7.22 for specifications.

11. <u>Grass-Lined Channel -- Practice 6.30</u>
    Grass-lined channels with temporary straw-net liners will be constructed around Buildings A and B to collect and convey site water to the project's sediment basin. See pages 7.22 - 7.24 for specifications and pages 7.37 - 7.41 for calculations.

    Should the disturbed areas adjoining the channels not be stabilized at the time the channels are vegetated, a sediment fence will be installed adjacent to the channel to prevent channel siltation.

12. <u>Riprap-Lined and Paved Channels -- Practice 6.31</u>
    A riprap channel will be constructed in the old gully along the north side of the property starting in the northwest corner after all other construction is complete. This channel will replace the old gully as the principal outlet from the site. See pages 7.25 7.26 for specifications and pages 7.41 - 7.43 for calculations.

13. <u>Construction Road Stabilization -- Practice 6.80</u>
    As soon as final grade is reached on the entrance road, the subgrade will be sloped to drain to the south and stabilized with a 6-inch course of NC DOT standard size ABC stone. The parking area and its entrance road will also be stabilized with ABC stone to prevent erosion and dust during the construction of the buildings prior to paving. See pages 7.26 - 7.27 for specifications.

14. <u>Outlet Stabilization Structure -- Practice 6.41</u>
    A riprap apron will be located at the outlet of the three culverts to prevent scour. See pages 7.27 - 7.28 for specifications and page 7.48 for calculations.

15. <u>Surface Roughening -- Practice 6.03</u>
    The 3:1 cut slopes will be lightly roughened by disking just prior to vegetating, and the surface 4 to 6 inches of the 2:1 fill slopes will be left in a loose condition and grooved on the contour. See page 7.29 for specifications.

16. Surface stabilization will be accomplished with vegetation and mulch as specified in the vegetation plan. One large oak tree southwest of Building A and a buffer area between the parking lot and Terri Road will be preserved. Roadway and parking lot base courses will be installed as soon as finished grade is reached.

17. Dust control is not expected to be a problem due to the small area of exposure, the undisturbed perimeter of trees around the site, and the relatively short time of exposure (not to exceed 9 months). Should excessive dust be generated, it will be controlled by sprinkling.

CONSTRUCTION SCHEDULE

1. Obtain plan approval and other applicable permits.

2. Flag the work limits and mark the oak tree and buffer area for protection.

3. Hold preconstruction conference at least one week prior to starting construction.

4. Install sediment basin as the first construction activity.

5. Install storm drain with block and gravel inlet protection at construction entrance/exit.

6. Install temporary gravel construction entrance/exit.

7. Construct temporary diversions above proposed building sites. Install level spreader and sediment trap and vegetate disturbed areas.

8. Complete site clearing except for the old gully channel in the northwest portion of the site. This area will be cleared during last construction phase for the installation of the riprap channel liner.

9. Clear waste disposal area in northeast corner of property, only as needed.

10. Rough grade site, stockpile topsoil, construct channels, install culverts and outlet protection, and install sediment fence as needed. Maintain diversions along top of fill slope daily. NOTE: A temporary diversion will be constructed across the middle of the graded area to reduce slope length and the bare areas mulched should grading be discontinued for more than 3 weeks.

11. Finish the slopes around buildings as soon as rough grading is complete. Leave the surface slightly roughened and vegetate and mulch immediately.

12. Complete final grading for roads and parking and stabilize with gravel.

13. Complete final grading for buildings.

14. Complete final grading of grounds, topsoil critical areas, and permanently vegetate, landscape, and mulch.

15. Install riprap outlet channel and extend riprap to pipe outlet under entrance road.

16. All erosion and sediment control practices will be inspected weekly and after rainfall events. Needed repairs will be made immediately.

17. After site is stabilized, remove all temporary measures and install permanent vegetation on the disturbed areas.

18. Estimated time before final stabilization--9 months.

MAINTENANCE PLAN

1. All erosion and sediment control practices will be checked for stability and operation following every runoff-producing rainfall but in no case less than once every week. Any needed repairs will be made immediately to maintain all practices as designed.

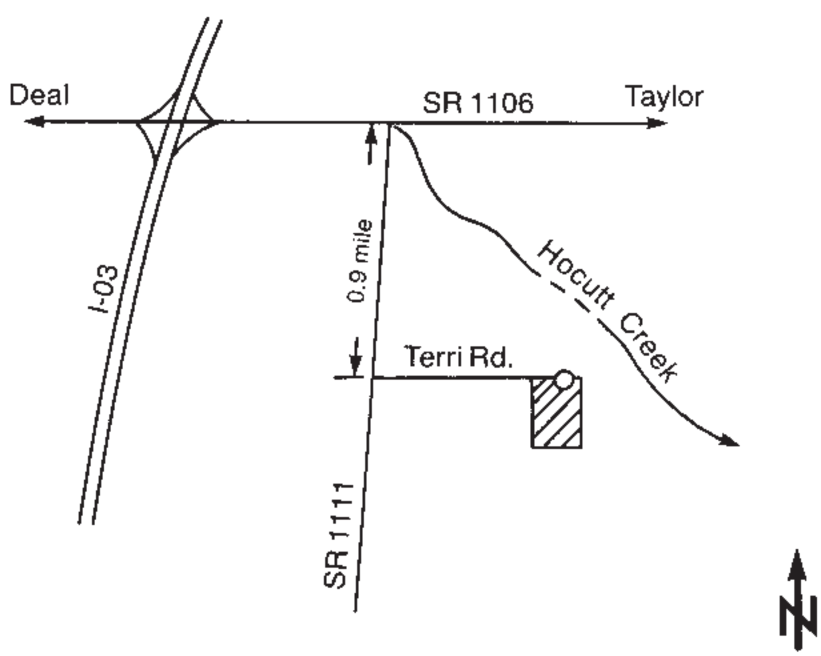
2. The sediment basin will be cleaned out when the level of sediment reaches 2.0 ft below the top of the riser. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.

3. Sediment will be removed from the sediment trap and block and gravel inlet protection device when storage capacity has been approximately 50% filled. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.

4. Sediment will be removed from behind the sediment fence when it becomes about 0.5 ft deep at the fence. The sediment fence will be repaired as necessary to maintain a barrier.

5. All seeded areas will be fertilized, reseeded as necessary, and mulched according to specifications in the vegetative plan to maintain a vigorous, dense vegetative cover.

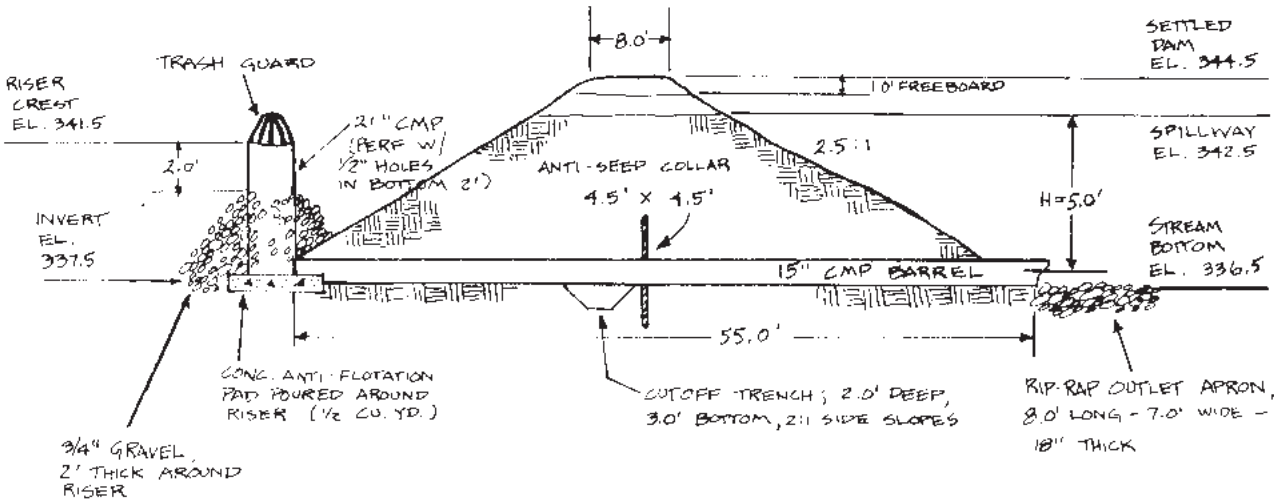
VICINITY MAP

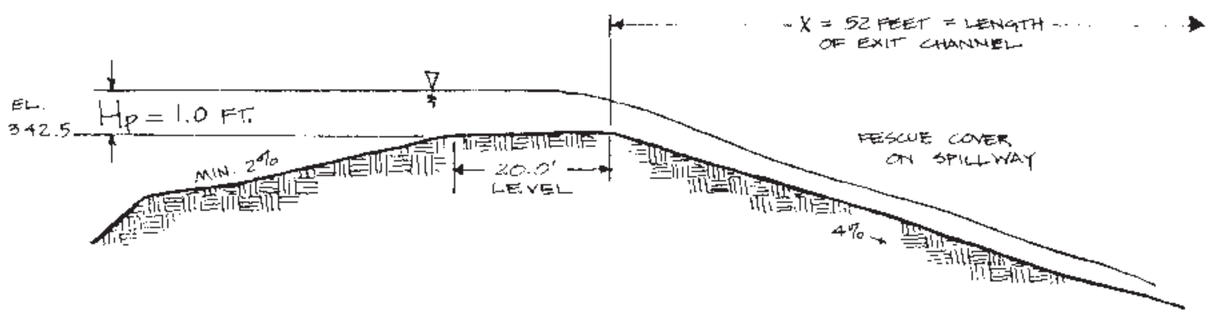


Granville, N.C.

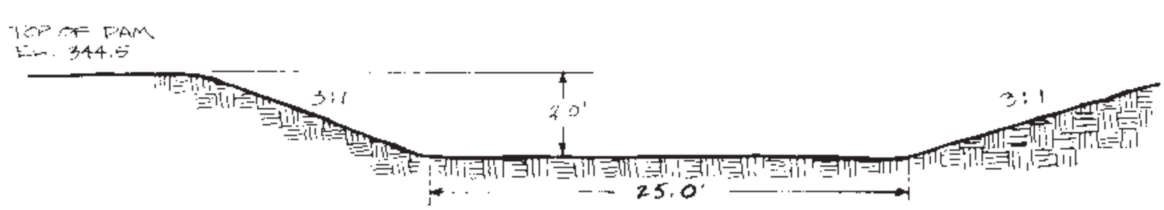
DETAIL DRAWINGS AND SPECIFICATIONS

1. SEDIMENT BASIN





SPILLWAY PROFILE



SPILLWAY: CROSS SECTION AT CONTROL SECTION

(1) CONSTRUCTION SPECIFICATIONS:

1. CLEAR AND GRUB FOUNDATION FOR EMBANKMENT AND EXCAVATE THE AREA FOR THE RIPRAP OUTLET PAD. AREA TO BE 8.0' LONG, 7.0' WIDE AND 1.5' DEEP. (NOTE: THIS EXCAVATION WILL SERVE AS A SEDIMENT TRAP WHILE STRUCTURE IS BEING BUILT.)

2. EXCAVATE CUTOFF TRENCH ALONG EMBANKMENT CENTERLINE AND UP ABUTMENTS TO ELEVATION 344.0 AS SHOWN. KEEP TRENCH DRY WHEN BACKFILLING AND COMPACTING.

3. USE SEDIMENT POOL AREA AS SOURCE OF FILL MATERIAL FOR THE DAM. MATERIAL SHOULD BE CLEAN MINERAL SOIL, FREE OF ROOTS, WOODY MATERIAL, ROCKS OR OTHER OBJECTIONABLE MATERIAL. SCARIFY FOUNDATION AND PLACE FILL IN LAYERS NOT TO EXCEED 8" OVER THE ENTIRE LENGTH OF DAM. COMPACT BY HEAVY WHEEL EQUIPM NT. THE ENTIRE SURFACE OF EACH LAYER MUST BE TRAVERSED BY AT LEAST ONE WHEEL OF THE COMPACTION EQUIPMENT. THE FILL MATERIAL MUST BE MOIST BUT NOT SO WET THAT WATER CAN BE SQUEEZED FROM IT.

4. PERFORATE 24" CMP RISER WITH ½" HOLES SPACED 3" APART IN EACH OUTSIDE VALLEY TO WITHIN 2.0' OF THE TOP. SECURE TRASH RACK TO RISER TOP. MAXIMUM OPENING BETWEEN BARS OF RACK NOT TO EXCEED 3".

5. SECURELY ATTACH THE RISER TO THE BARREL AND ALL OTHER PIPE JOINTS WITH ROD AND LUG CONNECTOR BANDS WITH RUBBER GASKETS TO ASSURE WATER TIGHTNESS. PLACE THE BARREL AND RISER ON A SMOOTH, FIRM FOUNDATION. PLACE FILL AROUND THE PIPE IN 4" LAYERS AND HAND COMPACT. TAKE CARE NOT TO RAISE THE PIPE FROM FIRM CONTACT WITH ITS FOUNDATION WHEN COMPACTING UNDER PIPE HAUNCHES.

6. SECURE ONE STANDARD CORRUGATED METAL ANTI-SEEP COLLAR AROUND BARREL. MAKE SURE CONNECTION IS WATERTIGHT. HAND COMPACT AROUND ANTI-SEEP COLLAR.

7. PLACE A MINIMUM OF 2 FT. OF HAND COMPACTED BACKFILL OVER PIPE BEFORE CROSSING IT WITH CONSTRUCTION EQUIPMENT.

8. ANCHOR RISER IN PLACE WITH ½ YD^3 CONCRETE PAD POURED AROUND RISER.

9. PLACE ¾" GRAVEL (D.O.T. #5 WASHED STONE) OVER THE PERFORATED HOLES APPROXIMATELY 2" THICK.

10. INSTALL EMERGENCY SPILLWAY IN UNDISTURBED SOIL TO THE LINES AND GRADES SHOWN IN DRAWINGS.

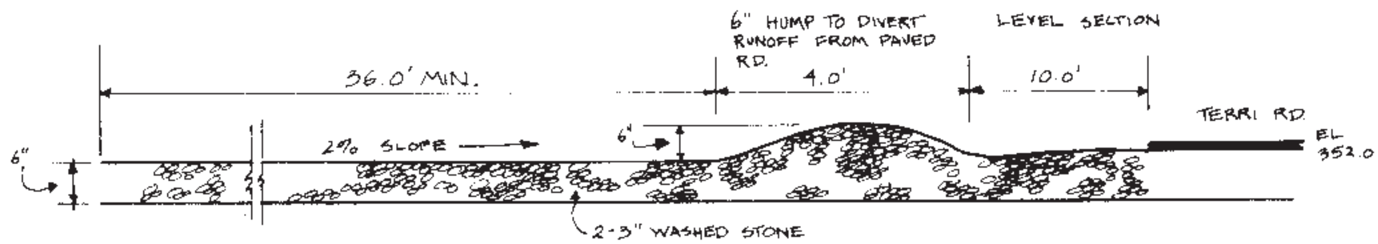
11. PLACE CLASS A EROSION CONTROL STONE OVER FILTER FABRIC ON LEVEL GRADE FOR RIPRAP APRON AT PIPE OUTLET, TOP OF RIPRAP TO BE SAME ELEVATION AS OUTLET CHANNEL BOTTOM. NO OVERFALL.

12. CLEAR SEDIMENT POOL AREA TO ELEVATION 341.5 AFTER THE EMBANKMENT IS COMPLETE.

13. VEGETATE ALL DISTURBED AREAS (EXCEPT THE SEDIMENT POOL) IN ACCORDANCE WITH THE VEGETATIVE PLAN.

14. SEDIMENT TO BE REMOVED FROM BASIN WHEN THE LEVEL IS WITHIN 2.0' OF THE TOP OF THE RISER. (SAME LEVEL AS TOP OF GRAVEL.)

2. TEMPORARY GRAVEL CONSTRUCTION ENTRANCE



GRAVEL ENTRANCE / EXIT : WIDTH — 15.0', FLARED TO 25.0' AT ROAD
LENGTH — 50.0'
GRADE — 2.0%

(2) CONSTRUCTION SPECIFICATIONS

1. CLEAR THE ENTRANCE / EXIT AREA OF ALL VEGETATION, ROOTS, AND OTHER OBJECTIONABLE MATERIAL.

2. GRADE THE ROAD FOUNDATION SO THAT THE ENTRANCE / EXIT WILL

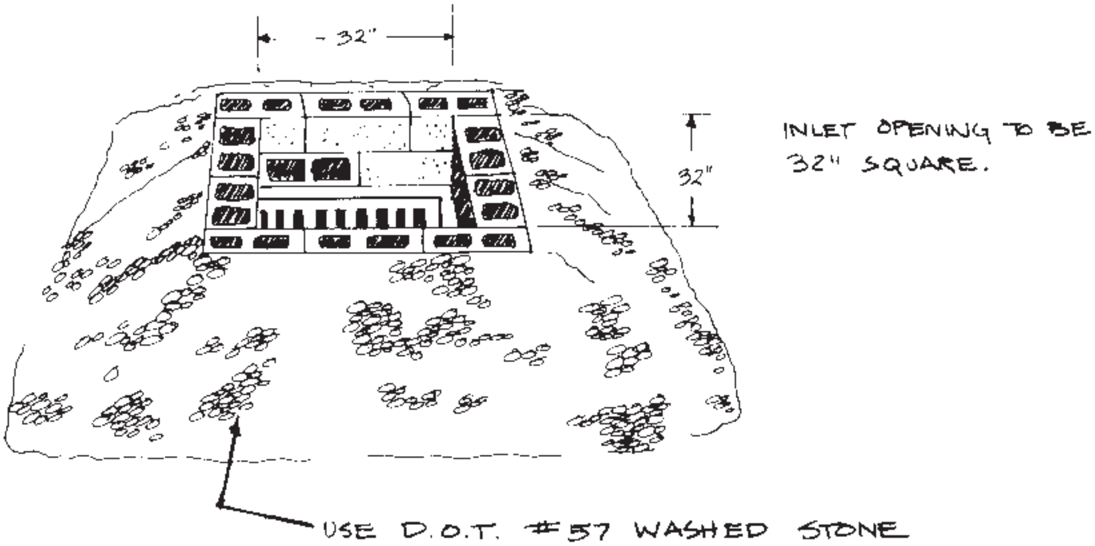
   HAVE A CROSS SLOPE TO THE SOUTH AND ALL RUNOFF WILL DRAIN TO THE BLOCK AND GRAVEL DROP INLET PROTECTION STRUCTURE.

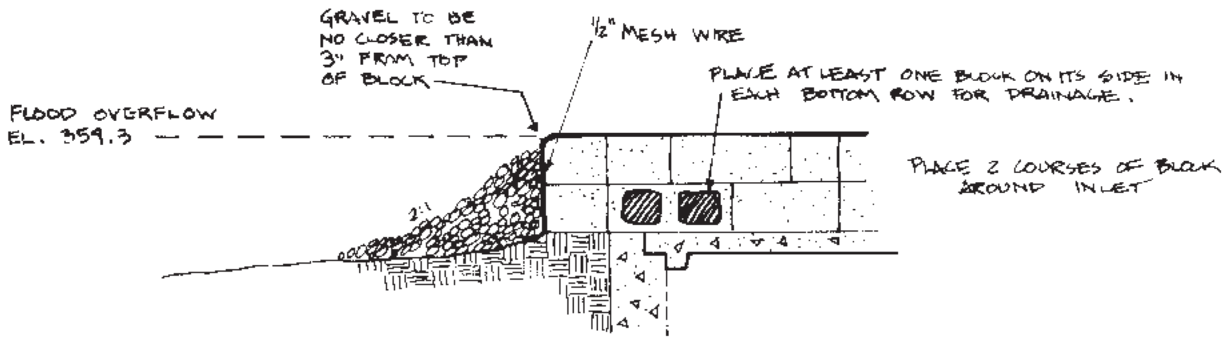
3. PLACE STONE TO THE DIMENSIONS, GRADE AND ELEVATION SHOWN.

4. USE WASHED STONE 2" TO 3" IN SIZE.

NOTE: MAINTAIN THE GRAVEL PAD IN A CONDITION TO PREVENT MUD OR SEDIMENT FROM LEAVING THE SITE. SHOULD MUD BE TRACKED OR WASHED ONTO TERRI ROAD, IT MUST BE REMOVED IMMEDIATELY.

3. TEMPORARY BLOCK AND GRAVEL DROP INLET PROTECTION





(3.) CONSTRUCTION SPECIFICATIONS

1. LAY CONCRETE BLOCKS ON FIRM, SMOOTH FOUNDATION EXCAVATED 3" BELOW STORM DRAIN TOP. PLACE BLOCKS AGAINST DRAIN INLET FOR LATERAL SUPPORT.

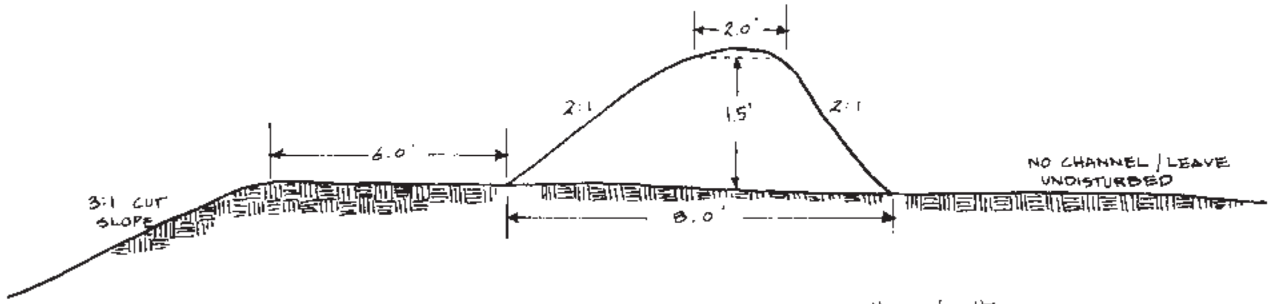
2. PLACE AT LEAST ONE CONCRETE BLOCK ON ITS SIDE IN EACH BOTTOM ROW OF BLOCKS.

3. PLACE WIRE MESH WITH ½" OPENINGS OVER ALL BLOCK OPENINGS USED FOR DRAINAGE.

4. USE D.O.T. #57 WASHED STONE TO REDUCE FLOW RATE BUT ALLOW DRAINAGE. PLACE STONE ON 2:1 SLOPE TO WITHIN 3" OF TOP OF BLOCK.

5. ANY SOIL LEFT EXPOSED BETWEEN THE BLOCK AND CONCRETE DRAIN INLET SHOULD BE FILLED WITH 3" DIAMETER STONE TO PREVENT WASHING WHEN WATER FLOWS OVER BLOCKS INTO DRAIN.

4. TEMPORARY DIVERSIONS



TYPICAL X-SECTION DIVERSION #1 & #2

DIVERSION #1 — GRADE = 2%
LENGTH = 450'

DIVERSION #2 — GRADE = 0.5%
LENGTH = 400'

(4.) CONSTRUCTION SPECIFICATIONS

1. REMOVE ALL TREES, BRUSH & STUMPS FROM DIVERSION FOUNDATION.

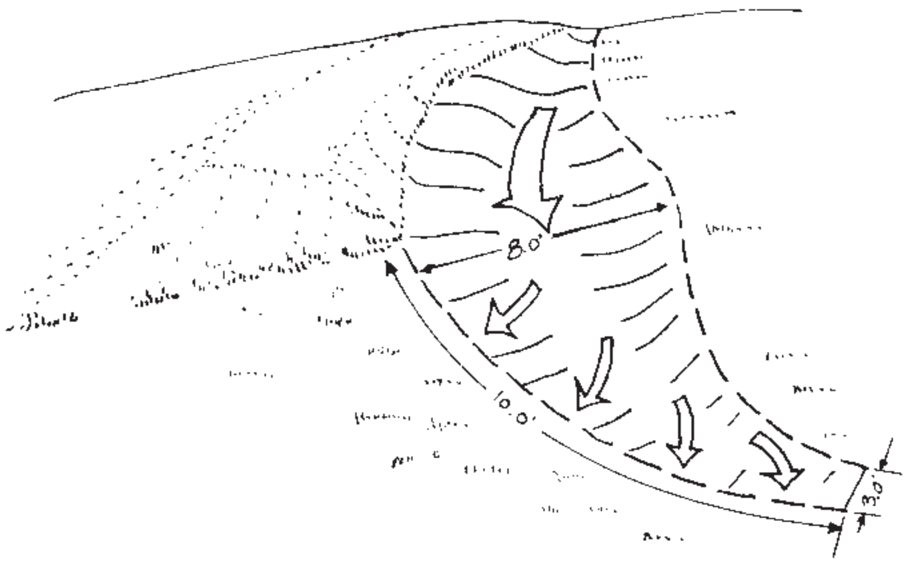
2. CONSTRUCT RIDGE TO FULL DIMENSIONS SHOWN — ALLOW 10% FOR SETTLING.

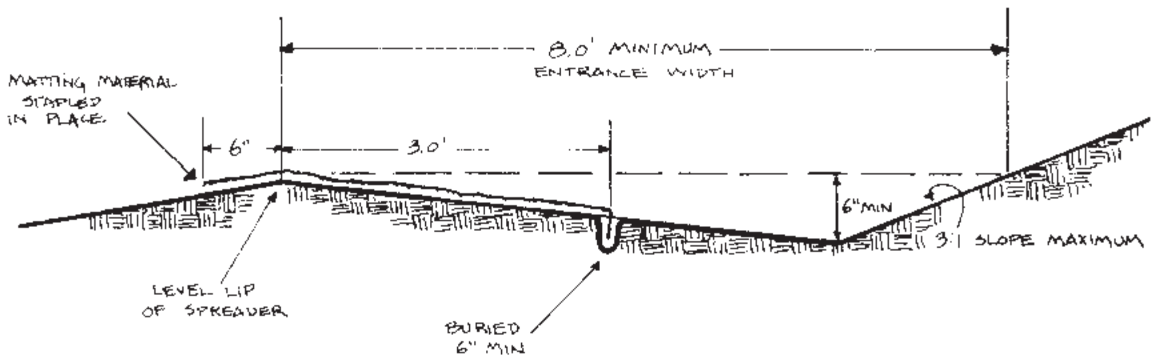
3. COMPACT RIDGE BY WHEELS OF CONSTRUCTION EQUIPMENT.

4. ENSURE THAT THE TOP OF THE DIVERSION IS ON DESIGN GRADE OR HIGHER AT ALL POINTS.

5. SEED AND MULCH IMMEDIATELY AFTER CONSTRUCTION. SEE VEGETATIVE PLAN.

5. LEVEL SPREADER





CROSS SECTION

(5.) CONSTRUCTION SPECIFICATIONS

1. FIBERGLASS MATTING, 4.0 FT. WIDE, SHOULD EXTEND 6" OVER THE LEVEL LIP AND BE BURIED 6" DEEP AT THE LOWER EDGE.

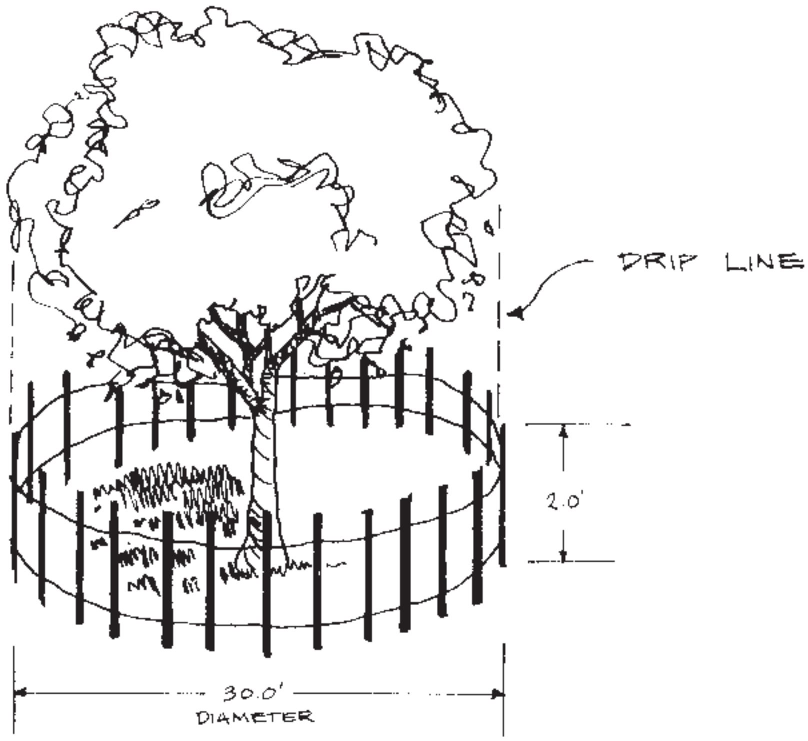
2. ENSURE THAT THE SPREADER LIP IS LEVEL THROUGHOUT IT'S LENGTH.

3. CONSTRUCT THE LEVEL SPREADER ON UNDISTURBED SOIL (NOT ON FILL.)

4. CONSTRUCT A TRANSITION SECTION FROM THE DIVERSION TO BLEND SMOOTHLY TO THE WIDTH AND DEPTH OF THE SPREADER.

5. IMMEDIATELY AFTER CONSTRUCTION, APPROPRIATELY SEED AND MULCH THE ENTIRE DISTURBED AREA OF THE SPREADER. SEE VEGETATIVE PLAN.

6. TREE PRESERVATION & PROTECTION



NOTE: SEDIMENT FENCE MATERIAL MAY BE USED TO BUILD FENCE.

- DRIVE STAKES FIRMLY INTO GROUND – AT LEAST 12"

7. LAND GRADING

1. FINISHED LAND SURFACES WILL BE GRADED AS SHOWN ON SITE DEVELOPMENT PLAN.
2. CUT SLOPES WILL BE 3:1 OR FLATTER FOR MAINTENANCE BY MOWING AND ROUGHENED FOR VEGETATIVE ESTABLISHMENT.
3. THE HIGH FILL SLOPE ON THE NORTH WILL NOT BE STEEPER THAN 2:1 AND ROUGHENED BY GROOVING ACROSS THE SLOPE.
4. TOPSOIL WILL BE REMOVED FROM AREAS TO BE GRADED AND FILLED AND IT WILL BE STOCKPILED IN LOCATIONS SHOWN.
5. AREAS TO BE FILLED WILL BE CLEARED AND GRUBBED.
6. FILL WILL BE PLACED IN LAYERS NOT TO EXCEED 9" AND COMPACTED AS REQUIRED IN THE SPECIFICATIONS FOR THE DEVELOPMENT PLAN (NOT A PART OF SEDIMENT CONTROL PLAN.)

7. FROZEN MATERIAL OR SOFT, HIGHLY COMPRESSIBLE MATERIAL WILL NOT BE USED AS FILL.

8. FILL WILL NOT BE PLACED ON A FROZEN SURFACE.

9. ROAD AND PARKING SURFACES WILL BE SLOPED AS SHOWN ON SITE DEVELOPMENT PLAN TO CONTROL RUNOFF.

10. LAND ADJOINING PAVED AREAS WILL BE SLOPED NO STEEPER THAN 6:1 AND GRADED TO DRAIN AS SHOWN.

11. SURFACE RUNOFF FROM BUILDINGS WILL BE COLLECTED IN GUTTERS AND PIPED TO CHANNELS 1, 2, 3 AND 4.

12. DIVERSIONS WILL BE INSTALLED ABOVE CUT SLOPES PRIOR TO LAND CLEARING AND GRADING.

13. A DIVERSION WILL BE MAINTAINED AT ALL TIMES ABOVE THE FILL SLOPE TO PREVENT OVERFLOW ON THIS STEEP AREA.

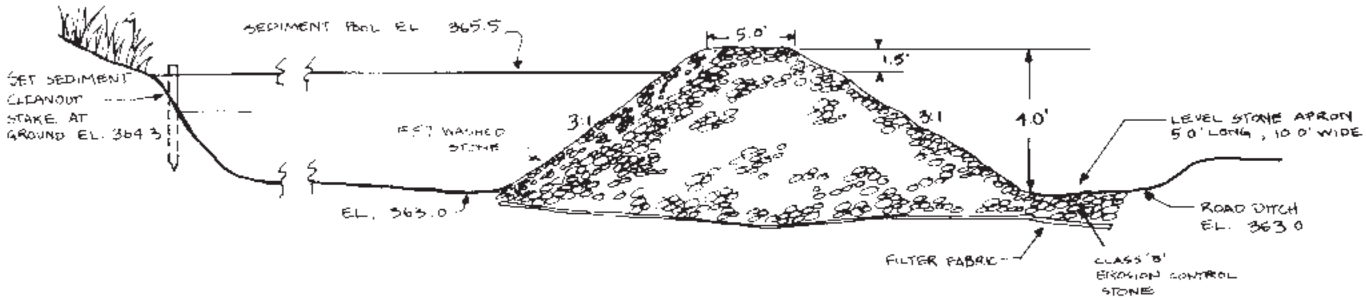
14. CUTTING AND FILLING WILL BE DONE AS A CONTINUOUS OPERATION UNTIL FINAL GRADE IS REACHED. SHOULD GRADING BE TEMPORARILY DISCONTINUED, A TEMPORARY DIVERSION WILL BE CONSTRUCTED ACROSS THE MIDDLE OF THE DISTURBED AREA TO BREAK UP THE LONG SLOPE TO THE NORTH.

15. AS SOON AS FINAL GRADES ARE REACHED THE GRADED AREAS WILL BE STABILIZED IN ACCORDANCE WITH THE VEGETATIVE PLAN.

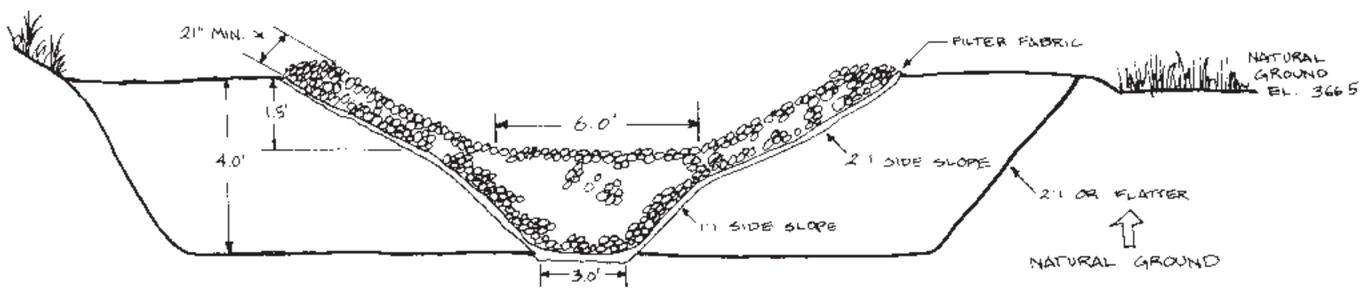
16. AN UNDISTURBED AREA WILL BE LEFT AS A BUFFER AROUND THE ENTIRE GRADED SITE EXCEPT AT ROAD ENTRANCE AND CHANNEL #3 OUTLET.

17. WHEN THE DEVELOPED SITE HAS BEEN PROPERLY STABILIZED, ALL THE TEMPORARY SEDIMENT AND EROSION CONTROL MEASURES WILL BE REMOVED, THE DISTURBED AREA GRADED TO BLEND WITH THE SURROUNDING AREA, AND VEGETATED.

8. TEMPORARY SEDIMENT TRAP



CROSS SECTION



STONE SECTION

(8.) CONSTRUCTION SPECIFICATIONS

1. CLEAR, GRUB AND STRIP THE AREA UNDER THE EMBANKMENT OF ALL VEGETATION AND ROOT MAT.

2. CLEAR POND AREA BELOW ELEVATION 365.5'

3. USE FILL MATERIAL FREE OF ROOTS, WOODY VEGETATION AND ORGANIC MATTER. PLACE FILL IN LIFTS NOT TO EXCEED 9" AND MACHINE COMPACT.

4. CONSTRUCT DAM AND STONE SPILLWAY TO DIMENSIONS, SLOPES AND ELEVATIONS SHOWN.

5. ENSURE THAT THE SPILLWAY CREST IS LEVEL AND AT LEAST 1.5' BELOW THE TOP OF THE DAM AT ALL POINTS.

6. STONE USED FOR SPILLWAY SECTION — CLASS "B" EROSION CONTROL STONE.

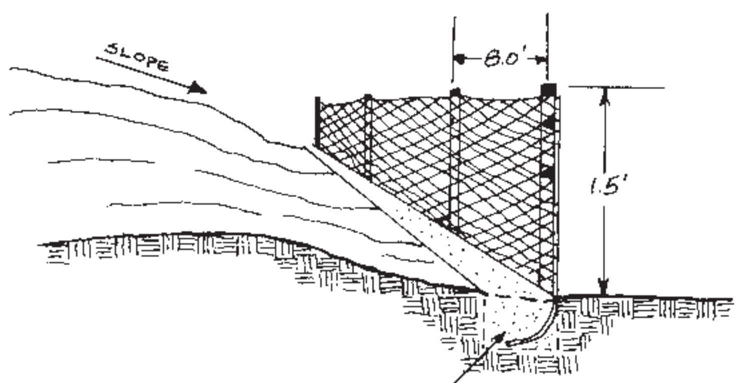
7. STONE USED ON INSIDE SPILLWAY FACE TO CONTROL DRAINAGE — D.O.T. # 57 WASHED STONE.

8. EXTEND STONE OUTLET SECTION TO VEGETATED ROAD DITCH ON ZERO GRADE WITH TOP ELEVATION OF STONE LEVEL WITH BOTTOM OF DRAIN.

9. ENSURE THAT THE TOP OF THE DAM AT ALL POINTS IS 0.5' ABOVE NATURAL SURROUNDING GROUND.

10. STABILIZE THE EMBANKMENT AND ALL DISTURBED AREA ABOVE THE SEDIMENT POOL AS SHOWN IN THE VEGETATION PLAN.

9. SEDIMENT FENCE



(9.) CONSTRUCTION SPECIFICATIONS

1. CONSTRUCT SEDIMENT FENCE ON LOW SIDE OF TOPSOIL STOCKPILE TO PREVENT SEDIMENT FROM BEING WASHED INTO THE DRAINAGE SYSTEM. FENCE TO EXTEND AROUND APPROXIMATELY 70% OF THE PERIMETER OF THE STOCKPILE.

2. LOCATE POSTS DOWNSLOPE OF FABRIC TO HELP SUPPORT FENCING.

3. BURY TOE OF FENCE APPROXIMATELY 8" DEEP TO PREVENT UNDERCUTTING

4. WHEN JOINTS ARE NECESSARY, SECURELY FASTEN THE FABRIC AT A SUPPORT POST WITH OVERLAP TO THE NEXT POST.

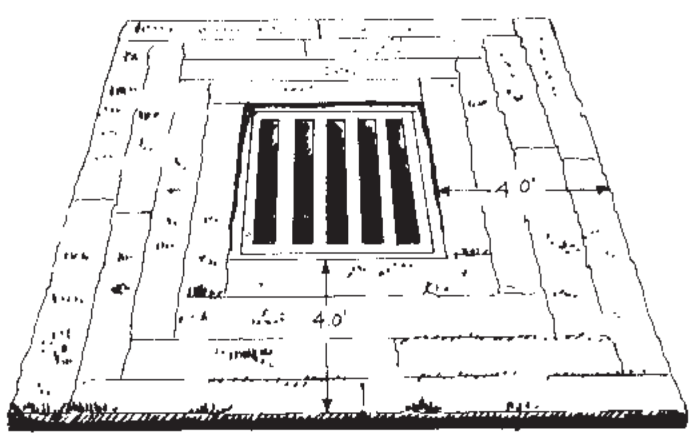
5. FILTER FABRIC TO BE OF NYLON, POLYESTER, PROPYLENE OR ETHYLENE YARN WITH EXTRA STRENGTH — 50 LB/LIN. IN. (MINIMUM) — AND WITH A FLOW RATE OF AT LEAST 0.3 GAL./FT² / MINUTE. FABRIC SHOULD CONTAIN ULTRAVIOLET RAY INHIBITORS AND STABILIZERS.

6. POST TO BE 4" DIAMETER PINE WITH A MIMUMUM LENGTH OF 4' FEET.

NOTE: IF HIGH CUT SLOPES ADJOINING CHANNELS 1, 2, AND 3 ARE NOT ADEQUATELY STABILIZED BEFORE CHANNEL IS CONSTRUCTED, A SEDIMENT FENCE SHOULD BE LOCATED ON THE CHANNEL BERM TO PREVENT SEDIMENT FROM ENTERING THE CHANNEL SYSTEM. THE FENCE SHOULD BE INSTALLED AS SHOWN ABOVE ALONG THE ENTIRE UNSTABLE AREA ADJOINING THE CHANNEL.

10. SOD DROP INLET PROTECTION

AFTER THE CONTRIBUTING DRAINAGE AREA HAS BEEN PERMANENTLY STABILIZED, THE BLOCK AND GRAVEL STRUCTURE WILL BE REMOVED AND PERMANENT SOD LAID AROUND THE DROP INLET.



FOUR 1-FOOT WIDE STRIPS OF TALL FESCUE SOD ON EACH SIDE OF THE DROP INLET

(10.) CONSTRUCTION SPECIFICATIONS

1. RAKE SOIL SURFACE TO BREAK GROUND CRUST; LEAVE SURFACE UNIFORM AND WATER LIGHTLY.

2. LAY SOD IN A STAGGERED PATTERN AS SHOWN WITH STRIPS BUTTED TIGHTLY AGAINST EACH OTHER.

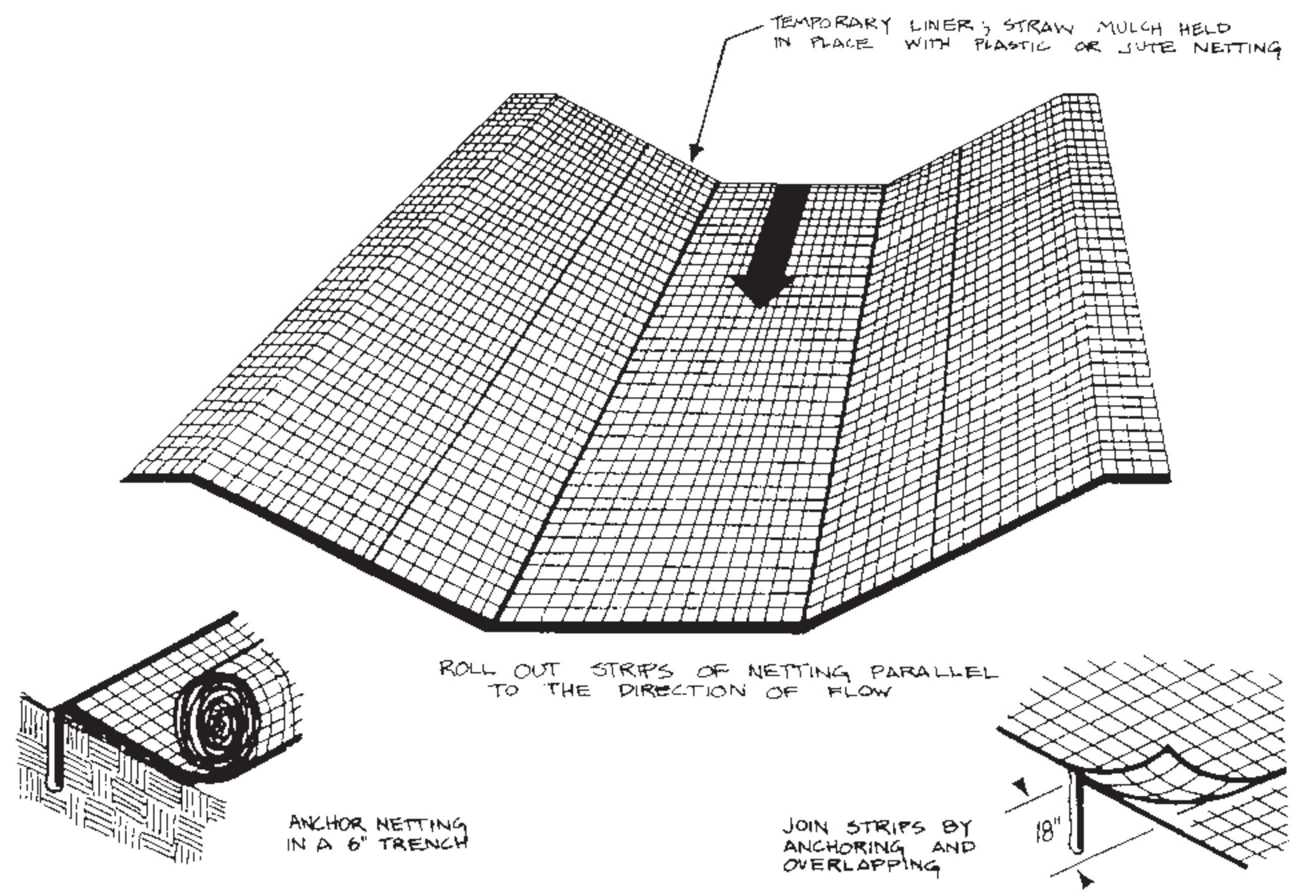
3. BUTTING — ANGLED ENDS CAUSED BY CUTTING MUST BE MATCHED CORRECTLY.

4. ROLL SOD TO PROVIDE FIRM SOIL CONTACT.

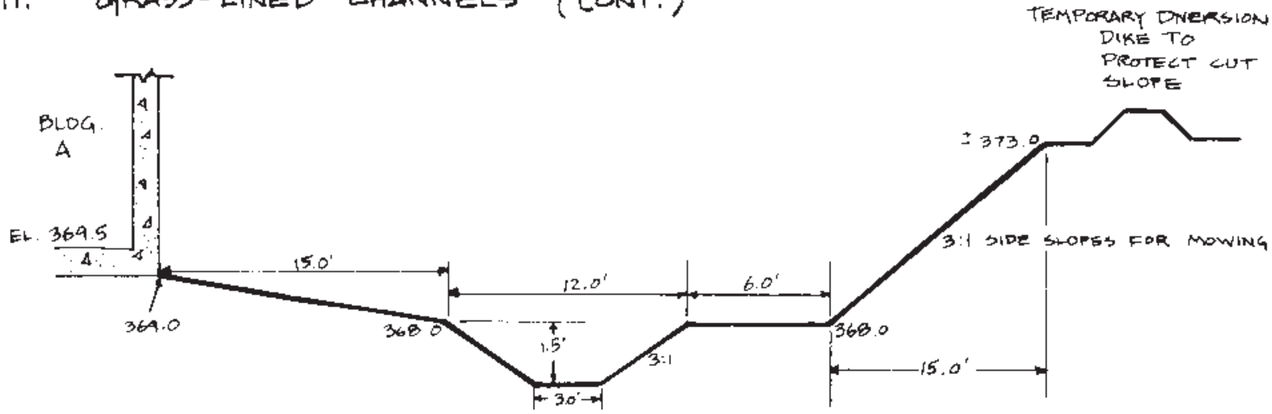
5. IRRIGATE UNTIL SOIL IS WET TO ABOUT 4" BELOW THE SOD.

6. KEEP SOD MOIST UNTIL SOD TAKES ROOT.

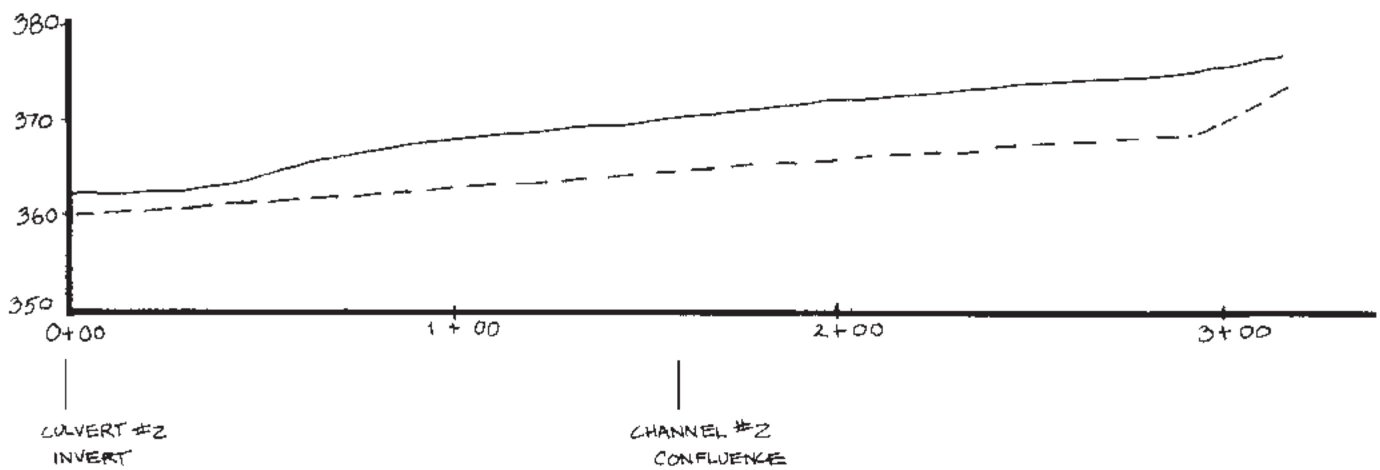
11. GRASS—LINED CHANNELS



11. GRASS-LINED CHANNELS (CONT.)



TYPICAL CROSS SECTION;
ALL CHANNELS (DEPTH AND TOP WIDTH WILL VARY BASED ON GROUND ELEVATION)



PROFILE — CHANNEL #1

CHANNEL #1

GRADE : 2%

LENGTH : 350'

BEGINNING GRADE EL: 359.5
- AT OUTLET- INVERT OF CULVERT #2

CHANNEL #2

GRADE : 1.75%

LENGTH : 230'

BEGINNING GRADE EL : 362.7
- AT INTERSECTION W/ CHANNEL #1

CHANNEL #3

GRADE : 1%

LENGTH : 450'

BEGINNING GRADE ELEVATION : 362.0
- CULVERT INVERT UNDER TERRI ROAD

CHANNEL #4

GRADE : 1.1%

LENGTH : 160'

BEGINNING GRADE EL. : 364.8
- AT OUTLET - EXISTING STABLE CHANNEL BOTTOM

(11.) CONSTRUCTION SPECIFICATIONS

1. EXCAVATE THE CHANNEL AND SHAPE IT TO AN EVEN CROSS-SECTION AS SHOWN. WHEN STAKING INDICATE A 0.2' OVERCUT AROUND THE CHANNEL PERIMETER FOR SILTING AND BULKING.

2. GRADE SOIL AWAY FROM CHANNEL SO THAT SURFACE WATER MAY ENTER FREELY.

3. APPLY LIME, FERTILIZER AND SEED TO THE CHANNEL AND ADJOINING AREAS IN ACCORDANCE WITH THE VEGETATION PLAN.

4. SPREAD STRAW MULCH AT THE RATE OF 100 LB/1000 FT^2.

5. HOLD MULCH IN PLACE IMMEDIATELY AFTER SPREADING WITH A PLASTIC NETTING INSTALLED AS SHOWN.

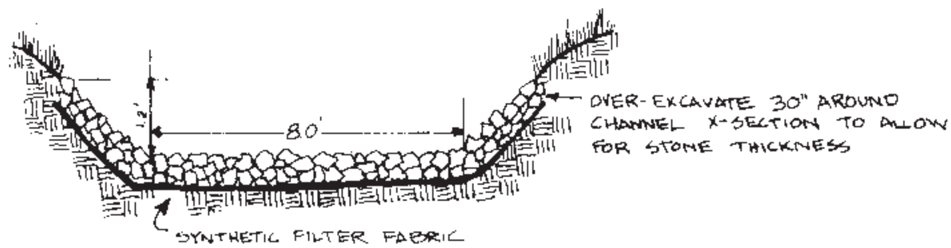
6. START LAYING THE NET FROM THE TOP OF THE UPSTREAM END OF THE CHANNEL AND UNROLL IT DOWN GRADE. DO NOT STRETCH NETTING.

7. BURY THE UPSLOPE END AND STAPLE THE NET EVERY 12" ACROSS THE TOP END, EVERY 3 FT. AROUND THE EDGES AND ACROSS THE NET SO THAT THE STRAW IS HELD CLOSELY AGAINST THE SOIL, HOWEVER, DO NOT STRETCH THE NETTING WHEN STAPLING.

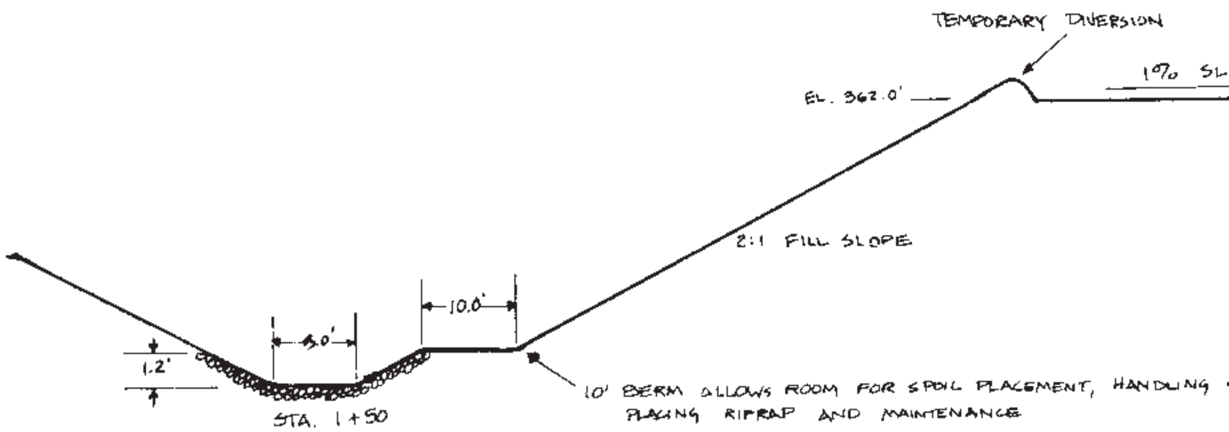
8. NETTING STRIPS SHOULD BE JOINED TOGETHER ALONG THE SIDES WITH A 3" OVERLAP AND STAPLED TOGETHER.

9. TO JOIN ENDS OF STRIPS, INSERT THE NEW ROLL OF NET IN A TRENCH AS WITH UPSLOPE END AND OVERLAP IT 18" WITH THE PREVIOUSLY LAID UPPER ROLL. TURN UNDER 6" OF THE 18" OVERLAP AND STAPLE EVERY 12" ACROSS THE END.

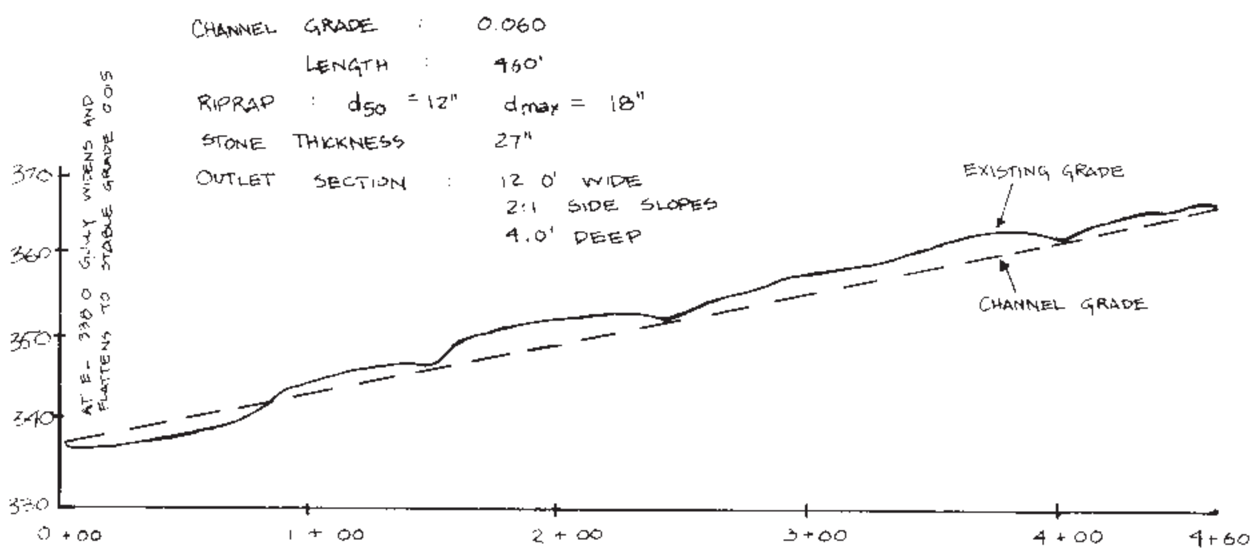
12. RIPRAP CHANNEL



TYPICAL CROSS SECTION



TYPICAL CROSS SECTION



CHANNEL PROFILE

(12.) CONSTRUCTION SPECIFICATIONS

(1). CLEAR THE FOUNDATION OF ALL TREES, STUMPS, AND ROOTS.

2. EXCAVATE THE BOTTOM AND SIDES OF THE CHANNEL 30" BELOW GRADE AT ALL POINTS TO ALLOW FOR THE PLACEMENT OF RIPRAP AS SHOWN IN THE TYPICAL X-SECTION.

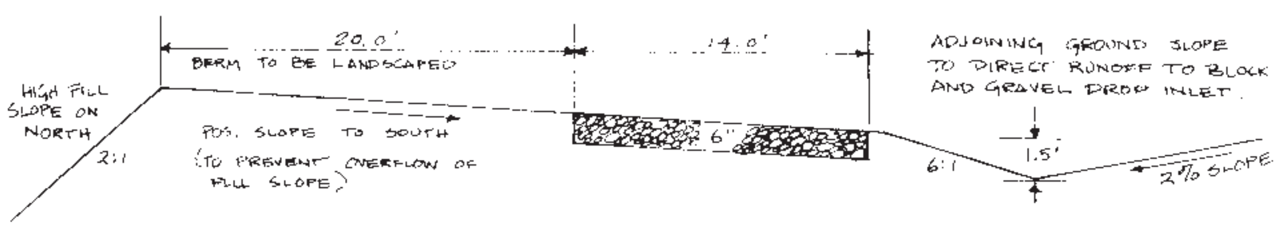
3. INSTALL EXTRA STRENGTH FILTER FABRIC ON THE BOTTOM AND SIDES OF THE CHANNEL FOUNDATION, PLACING THE UPSTREAM FABRIC OVER THE DOWNSTREAM FABRIC WITH AT LEAST A 1.0' OVERLAP ON ALL JOINTS. THE FABRIC IS TO BE SECURELY HELD IN PLACE WITH METAL PINS.

4. PLACE RIPRAP EVENLY TO THE LINES AND GRADES SHOWN ON THE DRAWINGS AND STAKED IN THE FIELD. RIPRAP TO BE PLACED IMMEDIATELY FOLLOWING THE INSTALLATION OF THE FILTER FABRIC.

5. RIPRAP TO MEET SPECIFICATION FOR D.O.T. CLASS 2 RIPRAP.

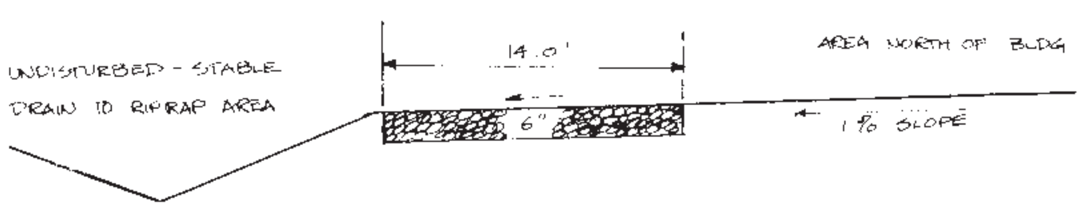
6. VEGETATE ALL DISTURBED AREAS FOLLOWING SPECIFICATIONS SHOWN IN THE VEGETATIVE PLAN.

13. CONSTRUCTION ROAD STABILIZATION



TYPICAL X-SECTION ENTRANCE ROAD

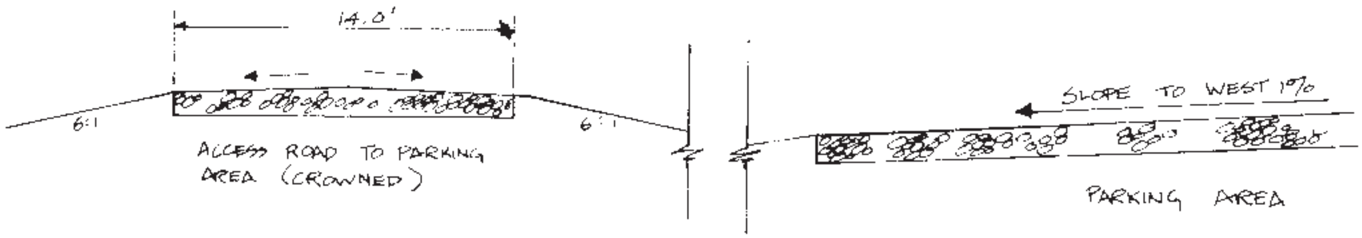
(TERRI RD. EAST TO CHANNEL #1)



TYPICAL X-SECTION ENTRANCE ROAD

(FROM CHANNEL #1 EAST TO EAST END OF BLDG. B)

13. CONST. RD. STABILIZATION (CONT.)



TYPICAL CROSS-SECTION ACCESS ROAD

(13) CONSTRUCTION SPECIFICATIONS

1. CLEAR ROAD BED AND PARKING AREAS OF ALL VEGETATION, ROOTS AND OTHER OBJECTIONABLE MATERIAL.

2. PROVIDE SURFACE DRAINAGE AS SHOWN.

3. SPREAD 6" COURSE OF D.O.T. "ABC" CRUSHED STONE EVENLY OVER THE FULL WIDTH OF ROAD AND PARKING AREA AND SMOOTH TO AVOID DEPRESSIONS.

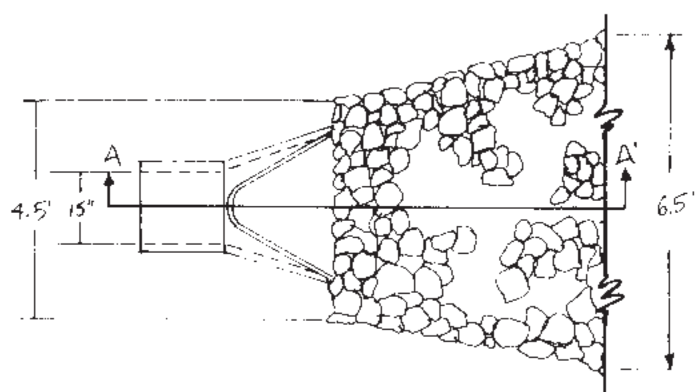
4. VEGETATE ALL DISTURBED AREAS ADJOINING ROADS AND PARKING AS SOON AS GRADING IS COMPLETE IN ACCORDANCE WITH THE VEGETATION PLAN.

14. OUTLET STABILIZATION STRUCTURES

OUTLET PROTECTION FOR CULVERT #1

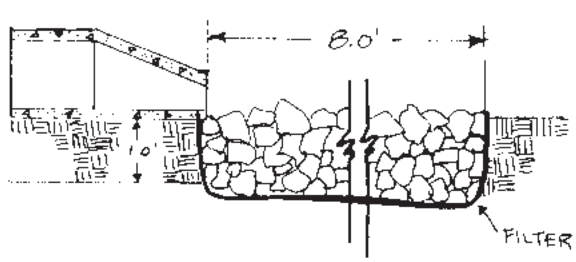
(FOR RIPRAP PROTECTION USE CLASS A OR CLASS B EROSION CONTROL STONE)

PLAN



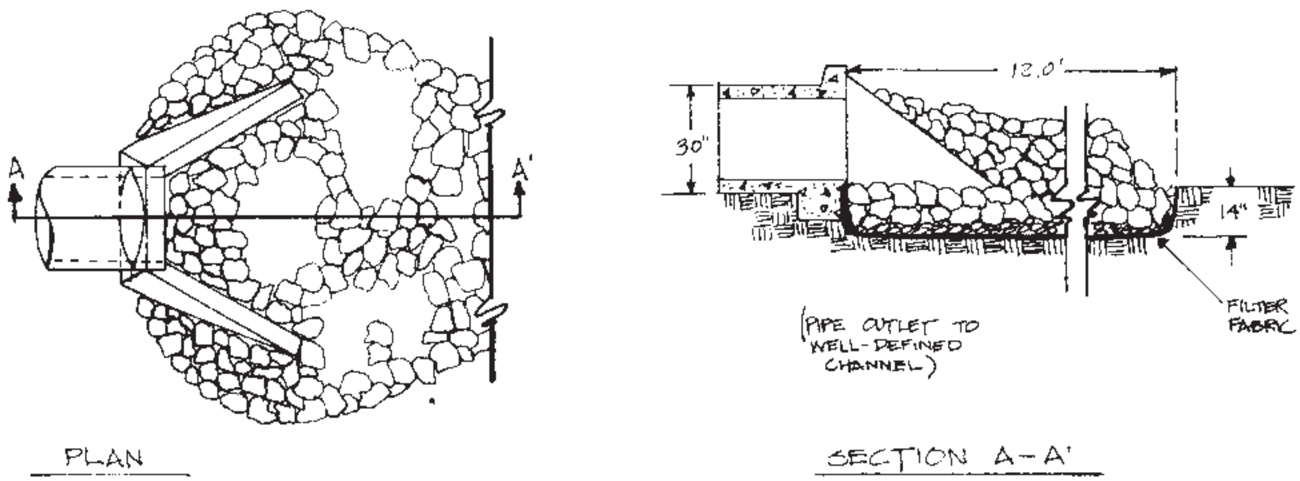
NOTE: APRON TO BE PLACED LEVEL WITH THE TOP SURFACE OF RIPRAP AT SAME LEVEL AS SURROUNDING LAND SURFACE — NO OVERFALL SHOULD EXIST.

SECTION A-A'



OUTLET PROTECTION FOR CULVERT #2

(LINE CHANNEL TO TOP OF BANKS FOR A DISTANCE OF 12.0' DOWNSTREAM. USE CLASS B EROSION CONTROL STONE.)



NOTE: APRON TO BE PLACED LEVEL WITH THE TOP SURFACE OF RIPRAP AT SAME ELEVATION AS SIDES AND BOTTOM OF CHANNEL. NO CHANNEL OVERFALL OR RESTRICTION IN CHANNEL CROSS-SECTION SHOULD EXIST.

(14.) CONSTRUCTION SPECIFICATIONS

1. EXCAVATE BELOW CHANNEL OUTLET AND WIDEN CHANNEL TO THE REQUIRED RIPRAP THICKNESS FOR EACH APRON. FOUNDATION TO BE CUT TO ZERO GRADE AND SMOOTHED.

2. PLACE FILTER CLOTH ON BOTTOM AND SIDES OF PREPARED FOUNDATION. ALL JOINTS TO OVERLAP A MINIMUM OF 1.0'.

3. EXERCISE CARE IN RIPRAP PLACEMENT TO AVOID DAMAGE TO FILTER FABRIC.

4. PLACE RIPRAP ON ZERO GRADE — TOP OF RIPRAP TO BE LEVEL WITH EXISTING OUTLET — NO OVERFALL AT ENDS.

5. RIPRAP TO BE HARD, ANGULAR, WELL GRADED CLASS B EROSION CONTROL STONE.

6. IMMEDIATELY AFTER CONSTRUCTION STABILIZE ALL DISTURBED AREAS WITH VEGETATION AS SHOWN IN VEGETATIVE PLAN.

15. SURFACE ROUGHENING

A. – 2:1 FILL SLOPE

1. PLACE FILL IN LIFTS NOT TO EXCEED 9" AND COMPACT.
2. LEAVE FACE OF FILL SLOPE LOOSE AND UNCOMPACTED — 4-6" DEEP — DO NOT BACK BLADE IN FINAL GRADING.
3. GROOVE ON CONTOUR – GROOVES APPROX. 3" DEEP + 12" APART.
4. VEGETATE IMMEDIATELY AFTER GROOVING.

B. – 3:1 CUT SLOPE

1. GROOVE BY DISCING TO EVEN SURFACE FOR MAINTENANCE BY MOWING.
2. GROOVES APPROX. 1" – 2" DEEP AND 10" APART.
3. VEGETATE IMMEDIATELY AFTER DISCING. SEE VEGETATIVE PLAN.

VEGETATIVE PLAN

Seedbed Preparation (SP)

SP-1 Fill slopes 3:1 or steeper to be seeded with a hydraulic seeder (permanent seedings)

1) Leave the last 4-6 inches of fill loose and uncompacted, allowing rocks, roots, large clods and other debris to remain on the slope.

2) Roughen slope faces by making grooves 2-3 inches deep, perpendicular to the slope.

3) Spread lime evenly over slopes at rates recommended by soil tests.

SP-2 Fill slopes 3:1 or steeper (temporary seedings)

1) Leave a loose, uncompacted surface. Remove large clods, rocks, and debris which might hold netting above the surface.

2) Spread lime and fertilizer evenly at rates recommended by soil tests.

3) Incorporate amendments by roughening or grooving soil surface on the contour.

SP-3 High-maintenance turf

1) Remove rocks and debris that could interfere with tillage and the production of a uniform seedbed.

2) Apply lime and fertilizer at rates recommended by soil tests; spread evenly and incorporate to a depth of 2-4” with a farm disk or chisel plow.

3) Loosen the subgrade immediately prior to spreading topsoil by disking or scarifying to a depth of at least 2 inches.

4) Spread topsoil to a depth of 2-4 inches and cultipack.

5) Disk or harrow and rake to produce a uniform and well-pulverized surface.

6) Loosen surface just prior to applying seed.

SP-4 Gentle or flat slopes where topsoil is not used.

1) Remove rocks and debris.

2) Apply lime and fertilizer at rates recommended by soil tests; spread evenly and incorporate into the top 6” with a disk, chisel plow, or rotary tiller.

3) Break up large clods and rake into a loose, uniform seedbed.

4) Rake to loosen surface just prior to applying seed.

Seeding Methods (SM)

SM-1 Fill slopes steeper than 3:1 (permanent seedings)

Use hydraulic seeding equipment to apply seed and fertilizer, a wood fiber mulch at 45 lb/1,000 ft^2, and mulch tackifer.

SM-2 Gentle to flat slopes or temporary seedings

1) Broadcast seed at the recommended rate with a cyclone seeder, drop spreader, or cultipacker seeder.

2) Rake seed into the soil and lightly pack to establish good contact.

Mulch (MU)

MU-1 Steep slopes (3:1 or greater)

In mid-summer, late fall or winter, apply 100 lb/1,000 ft^2 grain straw, cover with netting and staple to the slope. In spring or early fall use 45 lb/1,000 ft^2 wood fiber in a hydroseeder slurry.

MU-2 High-maintenance vegetation and temporary seedings

Apply 90 lb/1,000 ft^2 (4,000 lb/acre) grain straw and tack with 0.1 gal/yd^2 asphalt (11 gal/1,000 ft^2).

MU-3 Grass-lined channels

Install excelsior mat in the channel, extend up the channel banks to the highest calculated depth of flow, and secure according to manufacturer's specifications.

On channel shoulders, apply 100 lb/1,000 ft^2 grain straw and anchor with 0.1 gal/yd^2 (11 gal/1,000 ft^2) asphalt.

Maintenance (MA)

MA-1 Refertilize in late winter or early spring the following year. Mow as desired.

MA-2 Keep mowed to a height of 2-4 inches. Fertilize with 40 lb/acre (1 lb/1,000 ft^2) nitrogen in winter and again the following fall.

MA-3 Inspect and repair mulch and lining. Refertilize in late winter of the following year with 150 lb/acre 10-10-10 (3.5 lb/1,000ft^2). Mow regularly to a height of 3-4 inches.

MA-4 Topdress with 10-10-10 fertilizer if growth is not fully adequate.

MA-5 Topdress with 50 lb/acre (1 lb/1,000 ft^2) nitrogen in March. If cover is needed through the following summer, overseed with 50 lb/acre Kobe lespedeza.

TABLE 1: VEGETATIVE PLAN[1]

Area No.[2]	Description	Season[3]	Seeding Mixture: Permanent lb/ac	Seeding Mixture: Temporary lb/ac	Seedbed Preparation	Seeding Method	Mulch	Maintenance	Notes
1	Steep slopes (3:1); low maintenance	Spring or fall	Tall fescue 100 Kobe lespedeza 10 Bahiagrass 25 Rye grain 40		SP-1	SM-1	MU-1	MA-1	Permanent mixture also used for low-maint. areas (4). Overseed winter plantings of rye with Kobe lespedeza in March if grading is not complete.
		Summer		German millet 40	SP-2	SM-2		MA-5	
		Winter		Rye grain 120					
2	High-maintenance turf	Spring		Rye grain 120 Kobe lespedeza 50	SP-3	SM-2	MU-2	MA-4	Tall fescue can be seeded in spring - increase rate to 250 lb/ac. Temp. seeding for fall is the same as for winter.
		Summer		German millet 40					
		Fall	Tall fescue blend 200					MA-2	
		Winter		Rye grain 120				MA-5	
3	Grassed channels with side slopes 3:1	Fall-Spring	Tall fescue 200 Rye grain 40		SP-4	SM-2	MU-3	MA-3	
		Summer	Tall fescue 200 German millet 10						
4	Low-maintenance areas	Spring or Fall	Tall fescue 100 Kobe lespedeza 10 Bahiagrass 25 Rye grain 40		SP-4	SM-2	MU-2	MA-1	For temporary seeding in spring or fall see 5 below.
		Summer	Tall fescue 100 Kobe lespedeza 10 Bermudagrass 15 German millet 10					MA-5	Use these specs for temporary diversions.
		Winter		Rye grain 120					
5	Areas requiring cover for less than 1 year	Spring		Rye grain 120 Kobe lespedeza 50	SP-4	SM-2	MU-2	MA-4	Treat temporary diversions as low-maintenance, permanent (area 4)
		Summer		German millet 40					
		Fall & Winter		Rye grain 120 Kobe lespedeza 50				MA-5	Include topsoil stockpiles here

[1] Column entries for seedbed preparation, seeding method, mulch, and maintenance refer to Attachment 1.

[2] Area numbers are designated on map.

[3] Spring (Feb. 1 - Apr. 15), Summer (Apr. 15 - Aug. 20), Fall (Aug. 20 - Oct. 25), Winter (Oct. 25 - Jan.).

SUPPORTING CALCULATIONS

RUNOFF CALCULATIONS

Method: Peak Discharge Method SCS Technical Release No. 55, Urban Hydrology for Small Watersheds

NOTE: Other acceptable methods such as Rational Method may also be used.

Calculate peak runoff rate for site during development--Design point outlet at northwest property corner.

Site information:

1) Site location: South Granville County
2) Hydrologic soil group for Creedmore sandy loam: C
3) Approximate hydraulic length: 650 feet
4) Average watershed slope: 5%
5) 11 acres in site; 9.6 acres contributing runoff to construction area at outlet in N.W. corner
6) Off-site runoff into project area: 5 acres woods and open land.

1. Weighted curve number (CN) (Table 8.03b)

Land Use	Percent	CN	Product
Newly graded	62.5	93	58.13
Woods or forest, good cover	37.5	70	26.25
	100.0		84.38

Weighted CN = 84.38, use 85.

2. Rainfall (Figures 8.03h and 8.03j):
   2-yr, 24-hr. storm: 3.6 in.
   10-yr, 24-hr. storm: 5.6 in.

3. Calculate Runoff Depth (Table 8.03c):

   Runoff depth 2,24 = 2.06 in.
   Runoff depth 10,24 = 3.87 in.

4. Calculate Peak Discharge Rate

   a. No adjustment for watershed shape, impervious area, channel improvements, or ponding are required. Adjustment for slope will be made.

   b. Peak runoff rate moderate slope = 12.5 cfs/inch of runoff from D.A. = 9.6 acs (Figure 8.03p):

   c. Multiply discharge/ inch of runoff by runoff depth

   $Q_{2,24}$ = 12.5 cfs/inch runoff x 2.06 in = 26 cfs

   $Q_{10,24}$ = 12.5 cfs/inch runoff x 3.87 in = 48 cfs

--A graph of peak discharge rate vs. area was developed from Figures 8.03o and 8.03p to facilitate the design of waterways, diversions and other practices whose design specifications are based on peak flows from areas less than the entire site (Exhibit 4).

d. Adjust peak discharge rate for actual watershed slope (Table 8.03d):

$Q_{2,24}$ = 26 cfs x 1.04 = 27.0 cfs

$Q_{10,24}$ = 48 cfs x 1.04 = 50.0 cfs

e. Add off-site runoff that will enter site from the east from woods and open land.

5 acres - $Q_{10,24}$ = 21 cfs

Total$Q_{10,24}$ = 50 + 21 = 71 cfs

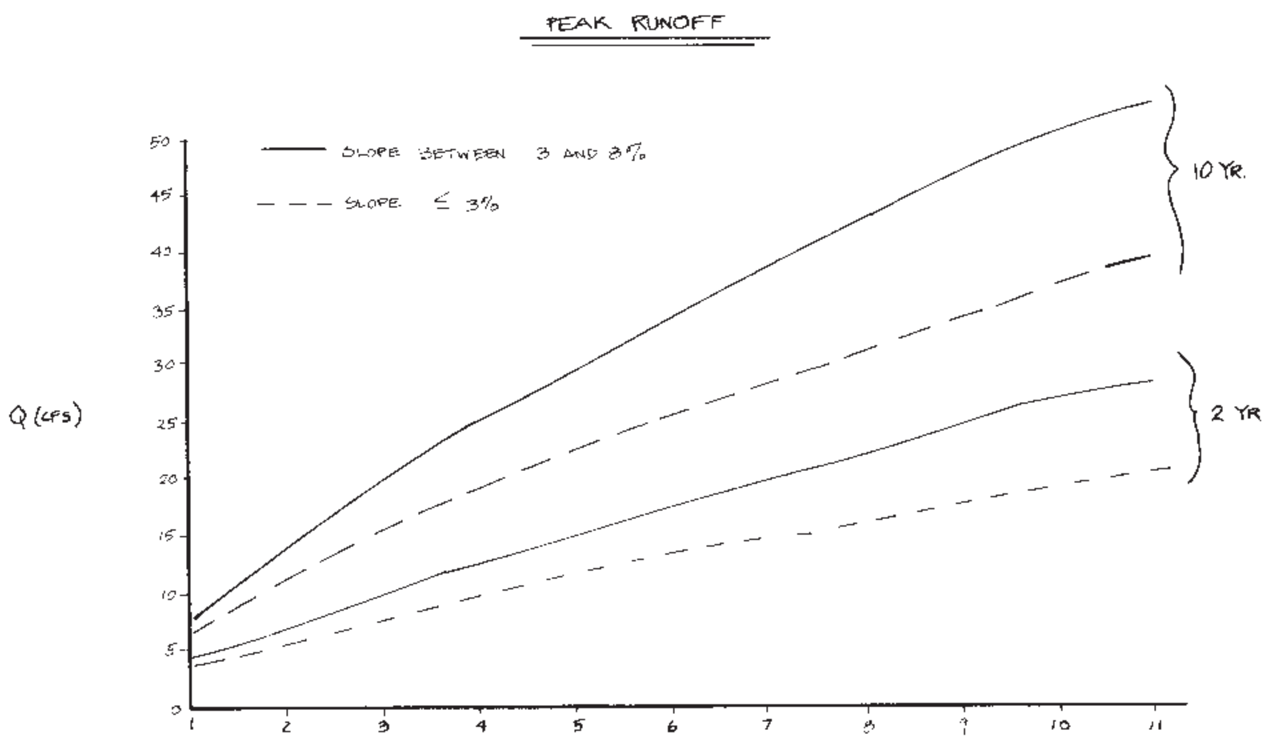


EXHIBIT 4

SEDIMENT BASIN DESIGN

1. All runoff from subwatersheds 1, 2, and 3 (9.6 acres) will enter the basin. Determine the peak flows of the 10-year, 24 hour storm $Q_{10,24}$.

   a) Peak flow (See Sheet 1, Runoff calculations): $Q_{10,24}$ = 50.0 cfs
   Add in off-site contributions that must pass through basin = 21.0 cfs
   71.0 cfs total

2. Determine basin volume:

   a) Minimum required sediment volume (Std. and Spec. 6.61):
   V = 1800 ft^3/acre x (9.6 + 5) acres = 26,280 ft^3.

3. Determine shape of basin:

   a) By examining contours on site map before channel installation or other modification:

Elevation (ft)	Area (ft^2)	Depth (ft)	Storage (ft^3)
338	3200	0.5	800
339	5400	1.5	5,100
340	9000	2.5	12,300
341	9600	3.5	21,600
342	11400	4.5	32,100
343	13300	5.5	44,450

   Elevation 341.5 yields 26,850 ft^3 of storage for sediment--meets design requirement.

4. Principal spillway design (cmp pipe spillway) for temporary basin:
   Set principal spillway crest at top of required sediment pool, elev. 341.5.

   a) The minimum capacity of principal spillway should be 0.2 cfs per acre of drainage area (Std. & Spec. 6.61, principal spillway).

   Q_{min} = 9.6 acres + 5 acres x 0.2 cfs = 2.9 ~3 cfs

   NOTE: Developer had 15” cm pipe available - larger than minimum pipe sizes are preferred when practical to reduce frequency of emergency spillway operation.

   Pipe flow is determined for water at the crest of the emergency spillway 1 ft above the riser inlet. Tailwater assumed at middle of pipe.

   H = 5.0 ft -- See sketch (page 7.11)
   barrel length = 55 ft
   Q_{pipe} = 7.78 cfs x 1.10 = 8.6 cfs (Table 8.07a)

   Determine riser requirement. From Figure 8.07b, riser: 21 in. diameter matches 15” pipe barrel.

   Determine capacity of cmp riser. From Figure 8.07b for h = 1.0 ft, Q_{riser} = 17 cfs; $Q_{riser} > Q_{pipe}$ pipe flow governs.

5. Emergency Spillway Design

Set emergency spillway elevation 1.0 ft above principal spillway or elev. 342.5

a) Capacity

Q_e = $Q_{10,24} - Q_p$

Q_e = 71.0cfs - 9.4 cfs = 61.6 cfs (9.4 = principal spillway discharge at H = 6.0 ft = design stage for emergency spillway flow.)

b) Dimensions for earth spillway from Table 8.07c. Soil borings indicate that soil of the spillway is resistant to erosion.

NOTE: For site desirable stage in spillway 1.0 ft.

Q= 60 cfs
H_p =1.05 ft
b= 24 ft

Use 25 ft bottom.

Add 1 ft freeboard minimum.
Set top of dam 1.0 ft above design stage of emergency spillway or elev. 344.5.

c) Antiseep collars
1) not closer than 2 feet to a pipe joint
2) 1 collar 4.5' x 4.5' (Std. & Spec. 6.61, sediment basin)

6. Anchor principal spillway

Downward force = 1.1 x upward force

Required net $1.1 \times 5 \text{ ft} \times \frac{(24 \text{ inches}/12 \text{ inches/ft})^2}{4} \times \prod \times 62.4 \text{ lb/ft}^3 = 1078 \text{ lb}$

Use concrete [1] = 13 ft^3 or approx. 1/2 yd^3 = 1140 lbs.

[1] Use buoyant weight of concrete for net downward force it exerts.

7. Dewatering the basin:

Perforate the riser with ¼ to ½ inch holes spaced 3 inches apart. Cover the perforated section with a ¾ inch gravel filter 2 feet thick

8. Trash guard to be firmly fastened to the top of the riser.

9. Embankment design:

8 foot top width, 2.5:1 side slopes, settled top elevation = 344.5
Constructed top elevation 344.5 + 0.7 ft (10% settlement) = 345.2 at center grading to 344.5 at abutments.

From soil borings--cut off trench should be excavated into the tight gray subsoil. Trench dimensions 2.0 to 3.0 ft deep; 3.0 ft wide with 1:1 side slopes.

GRASS LINED CHANNELS

Procedure given in Appendices 8.05 used in design.

1. Channel #1

Although channel #1 receives flow from channel #2 midway in its length, it will be designed as a single reach instead of 2 separate reaches. The flow in the upper reach will be considerably less than the design flow, but for consistency in dimensions, grade, and appearance the upper reach will not be designed separately. Final design is based on the removal of the temporary diversions.

a) Estimate drainage area and determine peak flow into channel #1.

Area = 1.9 acre
Average slope of drainage area: 3%
$Q_{10,24}$ = 10.0 cfs (Exhibit 4)

Off-site contributions : Flow from channel #2 = 7.4 cfs

For design purpose $Q_{10,24}$ = 10.0 cfs + 7.4 cfs = 17.4 cfs

b) Proposed channel grade = 2%
c) Proposed vegetation: Tall Fescue
d) Soil: Creedmore (easily erodible)
e) Permissible velocity: (V_p) 4.5 ft/s (Table 8.05a)
f) Retardance class: "B" unmowed, "D" mowed (Table 8.05c).
g) Trapezoidal Channel dimensions:
designing for low retardance condition (retardance class D) design to meet V_p

$A = Q/V$; 17.4 cfs/4.5 ft/sec = 3.87 ft^2

Try bottom width = 3.0 ft

$Z = 3$
$A = bd + Zd^2$
$P = b + 2d\sqrt{z^2+1}$
An iterative solution using Figure 8.05c to relate hydraulic radius depth to Manning's n proceeds as follows: Manning's equation is used to check velocities.

d (ft)	A (ft^2)	R (ft)	n	V (fps)	Q (cfs)	Comments
0.8	4.32	0.54	0.043	3.25	14.0	$V<V_p$ OK, $Q<Q_{10}$, too small, try deeper channel
0.9	5.13	0.59	0.042	3.53	18.1	$V<V_p$ OK, $Q>Q_{10}$, OK

now design for high retardance (class B)

Try d = 1.5 ft and trial V = 3.0 ft/sec

d (ft)	A (ft^2)	R (ft)	V_t (fps)	n	V (fps)	Q (cfs)	Comments
1.5	11.25	0.90	3.0	0.08	2.5		
	reduce trial V		2.0	0.11	1.8		
			1.6	0.12	1.6	18.4	$Q>Q_{10}$ OK

h) Evaluate need for temporary liner:

The channel will be protected from upland flow by a diversion during construction. This reduces the contributing drainage area when evaluating the need for temporary liners.

Area = 1.4 acre
Average Slope = 1%
V_p = 2.0 ft/sec

$Q_{2,24}$ = 4.1 cfs (Exhibit 4)

Off-site contribution: Flow from channel #2 = 3.5 cfs for $Q_{2,24}$

For design of temporary liner: $Q_{2,24}$ = 4.1 cfs + 3.5 cfs = 7.6 cfs

Use basic "n" value for channels cut in earth = 0.02 (Table 8.05b).

Using Manning's equation:

b (ft)	d (ft)	A (ft^2)	P (ft)	R (ft)	V (fps)	Q (cfs)	Comments
3	0.40	1.68	5.53	0.304	4.76	8.00	$Q > Q_2$, OK, $V > V_p$, needs protection

Velocity > 2.0 fps channel requires temporary liner.

i) Calculate shear stress for Q_2

T = yds where y = unit weight of water (62.4 lb/ft^3)
d = flow depth (ft)
s = channel gradient (ft/ft)

T = (62.4) (0.40) (.02) = 0.50 lb/ft^2

Fiberglass roving is an acceptable lining; however, use straw with net to provide additional protection as well as mulch for seeding. n = 0.033 (Table 8.05e); T_d = 1.45 (Table 8.05g)

b (ft)	d (ft)	A (ft^2)	R (ft)	V (fps)	Q (cfs)	T (lbs/ft^2)	Comments
3	0.6	2.88	0.42	3.6	10.3	0.75	$T<T_d$ $Q>Q_2$ OK where T_d = allowable shear stress

Channel Summary:
Trapezoidal shape, z=3, b=3 ft, d=1.5 ft, grade=2%
Temporary liner: straw with net

2. **Channel #3**

Channel design capacity to include flow that will be diverted from south during construction because diversion may be removed when construction is complete.

a) Estimate drainage area and determine peak flows in ditch #3.

Area ~ 2 acres
Avg. slope of drainage area = 4%

$Q_{10,24}$ = 13.5 cfs (Exhibit 4)

Off-site contribution: none

b) Proposed channel grade: = 1%
c) Proposed vegetative cover: Tall Fescue
d) Soil: Creedmore (easily erodible)
e) Permissible velocity for established vegetation: 4.5 ft/s (Table 8.05a)
f) Retardance class "B" unmowed, "D" mowed (Table 8.05c)
g) Trapezoidal Channel: z=3

By the same method as channel #1:

Description	b (ft)	d (ft)	A (ft^2)	R (ft)	V (fps)	Q (cps)	Comments
cut (D)	3.0	1.2	7.42	0.748	2.7	21.1	$Q > Q_{10}$, $V < V_p$
uncut (B)	3.0	1.7	13.77	1.00	1.0	13.8	$Q > Q_{10}$

h) Evaluate Temporary Liner Requirements:

Determine velocity and depth of flow for 2-yr, 24-hr storm. Because the channel will be protected by a temporary diversion, the drainage area contributing the flow during construction is reduced to 1.15 acre $Q_{2,24}$ = 3.7 cfs.

Using Manning's equation with "n" = 0.02 (Table 8.05b)

d (ft)	A (ft^2)	R (ft)	V (fps)	Q (cfs)	Comments
0.32	1.27	0.25	2.96	3.76	$Q>Q_2$, $V>V_p$, needs protection

Velocity >2.0 fps is excessive for bare soil conditions, requires temporary liner.

i. Calculate shear stress in channel at depth associated with $Q_{2,24}$.

T = yds = (62.4) (0.32) (0.01) = 0.20 lb/ft^2

Jute net is an acceptable temporary liner (Table 8.05g), however straw with net will provide additional protection as well as mulch for seeding.

Channel #3 Summary:
Trapezoidal channel, z=3, b=3 ft, d=1.7 ft, grade=1%
Temporary liner: straw with net

3. Channel #2

a) Estimate drainage area and determine peak flows into channel #2

Area = 0.8 acres

Average slope of drainage area ~ 3.5% (moderate)
$Q_{10,24}$ = 3.6 cfs (Exhibit 4)

Offsite contribution: None
Because diversion will protect entire channel during construction, overland flow contributing to $Q_{2,24}$ peak flow will be negligible.

$Q_{10,24}$ = 3.6 cfs

b) Proposed channel grade = 1.75%
c) Proposed vegetative cover = Tall Fescue
d) Soil: Creedmore (easily erodible)
e) Permissible velocity: 4.5 ft/s (Table 8.05a)
f) Retardance class: "B" unmowed, "D" mowed (Table 8.05c).
g) Trapezoidal channel, b=2 ft, z=3

Description	b (ft)	d (ft)	A (ft^2)	R (ft)	Q (cfs)	V (fps)	Comments
cut (D)	2.0	1.0	5.00	0.60	14.5	2.90	$Q > Q_{10}$, $V < V_p$
uncut (B)	2.0	1.4	8.68	0.80	8.19	0.94	$Q > Q_{10}$

h) Evaluate temporary liner requirements: Not necessary, negligible Q_2 flow.

Channel #2 Summary:
Trapezoidal channel: b = 2 ft, z = 3, d = 1.25 ft, grade = 1.75%
Temporary liner: none required.
Straw mulch tacked with asphalt could be used to facilitate vegetative establishment. However, since all other channels need temporary liner (mulch with netting) use the same materials for channel #2.

4. Channel #4

a) Estimate drainage area and determine peak flow into ditch #4.

Area = 0.75 acre
Average slope of drainage area: 0.5%

$Q_{10,24}$ = 5.8 cfs (Exhibit 4)

b) Proposed channel grade = 1.1%
c) Proposed vegetative cover = Tall fescue
d) Soil: Creedmore (easily erodible)
e) Permissible velocity: 4.5 ft/s (Table 8.05a)

f) Retardance Class: "B" unmowed, "D" mowed (Table 8.05c)

g) Trapezoidal channel dimensions: z = 3

By same method as channel #1:

Description	b (ft)	d (ft)	A (ft^2)	R (ft)	V (fps)	Q (cps)	Comments
cut (D)	2.0	1.00	5.00	0.60	1.95	9.75	$Q>Q_{10}$, V_p, OK
uncut (B)	2.0	1.7	12.1	0.95	0.60	7.3	$Q>Q_{10}$, OK

h) Evaluate temporary liner requirements:

Using Manning's equation with "n" = 0.02 (Table 8.05b)
$Q_{2,24}$ = 3.1 cfs

d (ft)	A (ft^2)	R (ft)	V (fps)	Q (cfs)	Comments
0.35	1.07	0.25	3.10	3.32	$Q>Q_2$, $V>V_p$, needs protection

Velocity > 2 fps: requires temporary liner.

i) Calculate shear stress for $Q_{2,24}$ conditions.

T = yds = (62.4) (0.35) (0.011) = 0.24 lb/ft^2

Jute net is an appropriate temporary channel liner (Table 8.05e); however, straw with net will provide more erosion protection, better mulch for seeding, and will be consistent with channels #1 and #3.

Channel #4 Summary: z = 3, b = 3, d = 1.5 ft, grade = 1.1%
Temporary liner: straw with net

[1]**NOTE:** For uniformity of construction make channel bottom 3.0' wide same as all other channels even though design only requires a 2.0' bottom width.

RIPRAP CHANNELS

a) Estimate on-site direct runoff from drainage area and calculate peak flow, add flow from channels #2, #1, #4.

Area = 3.74 acres
Average slope of drainage area: 4% moderate

$Q_{10,24}$ = 23.2 cfs (Exhibit 4)

Channels	$Q_{10,24}$
2	7.4 cfs
1	9.2 cfs
4	5.8 cfs
	22.4 cfs

Other flow contributions:
Off-site contribution: 21 cfs

Design flow: $Q_{10,24}$ = 23.2 cfs + 22.4 cfs + 21 cfs = 66.6 cfs

b) Proposed channel grade: 6%

c) Proposed liner: riprap

d) Trapezoidal channel is designed with capacity to meet design flow. Riprap liner requirements are then analyzed. First estimate a trial riprap size of 6 inches. For flow of the expected depth range of 1 to 2 ft, n = 0.044 (Table 8.05f) and T_d = 2.5 (Table 8.05g); z=2

Channel dimensions:

b (ft)	d (ft)	A (ft^2)	n	S	V (fps)	Q (cfs)
6	1.2	10.1	0.044	0.06	7.6	77.3

e) Determine riprap requirements

T = yds = (62.4) (1.2) (0.06) = 4.49

where y = unit weight of water (62.4 lb/ft^3)

d = flow depth (ft)

s = channel gradient (ft/ft)

Since T_d < T, select a larger stone size and a larger bottom width. Try b = 8 ft, d_{50}, = 12 in. From Table 8.05g T_d = 5.00; from Table 8.05f n = 0.060.

b (ft)	d (ft)	A (ft^2)	R (ft)	Q (cfs)	T (lb/ft^2)	Comment
8	1.2	12.48	0.93	72.3	4.5	$Q>Q_{10}$, $T<T_d$, OK

Since the side slopes are steeper than 3:1, the d_{50} must be adjusted:

-- Determine boundary shear from Figure 8.05h: B/d = 6.67, z = 2, K = 0.78.

-- Determine angle of respose from Figure 8.05g: for crushed rock d_{50} = 1.00 ft angle of repose = 42.4 degrees.

-- Determine critical shear on side to shear on bottom from Figure 8.05i: for angle of repose = 42.4 degrees and z = 2, K_2 = 0.74.

Adjustment:

$d_{50} = d_{50} \times K_1/K_2$ = (12 inches) 0.78/0.74 = 12.65 inches

-- $d_{max} = 1.5 \times d_{50}$ = (1.5) (12.65) ~ 19.0 inches--Use DOT class 2 riprap

Thickness of riprap (installed below finished grade)

1.5 x d_{max} = (1.5) (19.0) = 28.5--Use 30 inches

Straight channel, therefore bend stability doesn't need to be evaluated.

f) Filter blanket: Use synthetic filter fabric, overlap edges 12 inches and anchor overlap with pins spaced 3 feet.

Outlet Stability Evaluation:

Velocity at the end of the riprap channel on 6% of grade is 3.8 ft/sec. A natural run serves as the outlet for the riprap channel. The drainageway is approximately 12 ft wide with gradually sloping banks and is well stabilized with natural vegetation. It empties into Hocutt Creek on an average grade of 1.5 % for a distance of approximately 500 ft. The riprap channel will be widened to 12.0 ft and terminate on a nearly level grade for a distance of 10.0 ft. Exit velocity will be less than 3.0 ft/sec for the 10-yr storm flow due to flat grade and estimated tailwater depth of 2 ft. Estimated allowable exit velocity based on soils and vegetation is 4.0 ft/sec.

CULVERT DESIGNS

1) Culvert #2--under roadway between buildings A&B

a) Design information:
Q_{25} (design discharge to protect road from flooding) = 36 cfs
Length (L) = 40 ft
Slope (S_o) = 0.013 ft/ft
Allowable Headwater Depth (AHW) = 4 ft
Culvert type: RCP Groove end headwall
Ke = 0.2
n = 0.012

Receiving watercourse: trapezoidal, riprap lined channel

Side slope (z) = 2:1
n = 0.07
Channel slope (S_o) = 0.06 ft/ft

Tailwater (TW_{25}) = 1.7 ft

b) Using the method in "Design of Culverts" NRCD-Land Quality Section, complete Exhibit 5. Select a 30-inch culvert. To improve hydraulics at 90 degree intersection of culvert and channel, recess culvert outlet a minimum of 5.0 ft so that the culvert does not discharge directly into the channel bank.

2) Culvert #1 – under road to parking lot

a) Design information:
Q_{25} = 6.2 cfs
Length (L) =40 ft
Slope (S_o) = 0.0125 ft/ft
Allowable Headwater Depth (AHW) = 2 ft
Culvert type: RCP Groove end headwall
Ke = 0.2
n = 0.012
Tailwater (TW_{25}) = 0.4 ft

b) Using the method referenced above complete Exhibit 6. Select a 15-inch culvert.

3) Culvert #3 – under entrance road

a) Design information:

Q_{25} = 20 cfs
Length (L) =75 ft
Slope (S_o) = 0.013 ft/ft
Allowable Headwater Depth (AHW) = 5 ft
Culvert type:RCP Groove end headwall
Ke = 0.2
n = 0.012
Tailwater (TW_{25}) = 1.3 ft

b) Using the method referenced above complete Exhibit 7. Select a 21-inch culvert.

[1]**NOTE:** There are a number of acceptable culvert design procedures available.

PROJECT: ABC INDUSTRIES

DESIGNER: D. M.

DATE: 1 · 4 · 88

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = ______

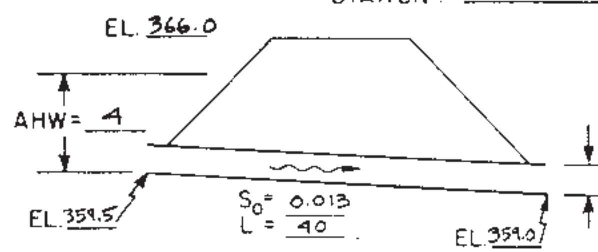
Q_2 = 36 C.F.S.

TW_1 = ______

TW_2 = 1.7 FT.

SKETCH

STATION : CULVERT #2 BTWN. BLDGS. A + B



MEAN STREAM VELOCITY = ______

MAX. STREAM VELOCITY = ______

CULVERT DESCRIPTION (ENTRANCE TYPE)	Q	SIZE	HEADWATER COMPUTATION: INLET CONT. $\frac{HW}{D}$	INLET CONT. HW	OUTLET CONTROL $HW = H + h_o - LS_o$: K_e	H	d_c	$\frac{d_c+D}{2}$	TW	h_o	LS_o	HW	CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
GROOVE END w/ HEADWALL RCP	36	30"	1.4	3.5	0.2	1.2	2.0	2.3	1.7	2.3	0.5	3.0	3.5	11.2		INLET CONTROL
	36	27"	1.85	4.16	0.2				1.7							HW TOO HIGH
																USE 30"

SUMMARY & RECOMMENDATIONS: OUTLET STABILIZATION STRUCTURE NEEDED TO REDUCE VELOCITY AND CONTROL EROSION.

EXHIBIT 5

PROJECT: ABC INDUSTRIES

DESIGNER: D.M.

DATE: 1 · 4 · 88

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = ______

Q_2 = 6.2 CFS

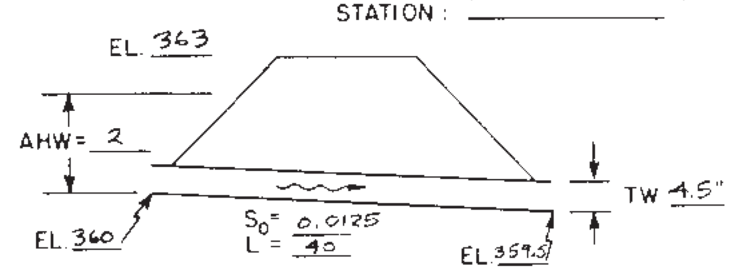
TW_1 = ______

TW_2 = ______

SKETCH

CULVERT #1 UNDER ROAD TO PARKING LOT

STATION: ______



MEAN STREAM VELOCITY = ______

MAX. STREAM VELOCITY = ______

CULVERT DESCRIPTION (ENTRANCE TYPE)	Q	SIZE	HEADWATER COMPUTATION: INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$								CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c+D}{2}$	TW	h_o	LS_o	HW				
GROOVE END W/ HEADWALL	6.2	15"	1.33	1.66	0.2	0.9	0.9	1.1	0.4	1.1	0.5	1.5	1.66	5.0		INLET CONTROL
	6.2	12"	2.3	2.3												HW TOO HIGH – USE 15"

SUMMARY & RECOMMENDATIONS: OUTLET STABILIZATION STRUCTURE NEEDED TO REDUCE VELOCITY AND CONTROL EROSION.

EXHIBIT 6

PROJECT: ABC INDUSTRIES

DESIGNER: D.M.

DATE: 1·4·88

HYDROLOGIC AND CHANNEL INFORMATION

Q_1 = ____

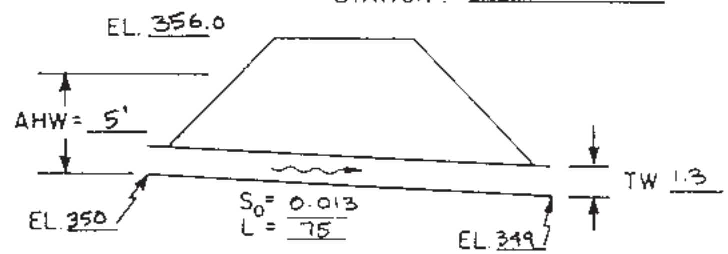
Q_2 = 20

TW_1 = ____

TW_2 = 1.3

SKETCH

STATION: CULVERT #3 UNDER ENTRANCE ROAD



MEAN STREAM VELOCITY = ____

MAX. STREAM VELOCITY = ____

CULVERT DESCRIPTION (ENTRANCE TYPE)	Q	SIZE	HEADWATER COMPUTATION: INLET CONT.		OUTLET CONTROL $HW=H+h_o-LS_o$								CONTROLLING HW	OUTLET VELOCITY	COST	COMMENTS
			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c+D}{2}$	TW	h_o	LS_o	HW				
GROOVE END W/ HEADWALL	20	24"	1.3	2.6	0.2	1.4	1.6	1.8	1.3	1.8	1.0	2.2	2.6	9.2		INLET CONDITION GOVERNS—
	20	21"	1.9	3.3	0.2	2.3	1.6	1.7	1.3	1.7	1.0	3.0	3.3	8.0		USE 21"

SUMMARY & RECOMMENDATIONS: OUTLET PIPE TO EXTEND INTO SEDIMENT BASIN AND CONNECT TO RIPRAP CHANNEL WHEN IT IS INSTALLED. USE TEMPORARY RIPRAP PAD TO PREVENT SCOUR HOLE IN SEDIMENT BASIN. INLET TO HAVE POURED CONC. RISER & GRATE W/ INLET ELEVATION OF 353.0.

EXHIBIT 7

RIPRAP OUTLET PROTECTION

Riprap Outlet Protection for Culvert #1

Q_{Design} = 6.2 cfs
Pipe diameter = 15 inches
Tailwater = 0.4', no defined channel, minimum tailwater conditions
Length of apron = 8 feet (Figure 8.06a)
d_{50} = 4 inches (Figure 8.06a)
d_{max} = 1.5 x d_{50} = 6 inches
Depth of riprap (laid flush with ground surface) = 1.5 x d_{max} = 9 inches = Use 1.0'
Upstream apron width = 3.0 x pipe diameter = 4.5 ft
Downstream apron width = apron length + pipe diameter = 6.5 ft
Use Class A erosion stone – (Note Class B may be used to be same as riprap for culvert #2)

Riprap Outlet Protection for Culvert #2

Q_{Design} = 36 cfs
Pipe diameter = 30 inches
Tailwater = 1.7 feet
Length of apron = 12 feet (Figure 8.06b)
d_{50} = 6 inches (Figure 8.06b)
d_{max} = 1.5 x d_{max} = 9 inches
Depth of riprap (laid flush with ground surface) = 1.5 x d_{max} ~ 14 inches
Upstream apron width = 3.0 x pipe diameter = 7.5 ft
Downstream apron width = apron length + pipe diameter = 12.5 ft

Riprap Outlet Protection for Culvert #3

Q_{Design} = 20 cfs
Pipe diameter = 24 inches
Use Class B erosion stone 18" thick
Riprap apron to extend to riprap channel to prevent erosion on steep fill slope.
Install temporary riprap outlet pad 6' wide and 10' long at end of pipe in sediment basin. Use Class B erosion control stone or D.O.T. class 2 riprap. (Same as riprap channel)

NOTE: Filter fabric to be placed under all riprap outlet structures to prevent soil movement.

SEDIMENT TRAP

a) Location: intersection of channel #3 and roadside ditch

b) Drainage areas: ~ 2 acres

c) Trap capacity:

Required sediment volume = 1800 ft^3 x 2 acre = 3600 ft^3 (Practice Standard 6.61)

Excavate so that pool bottom elevation = 363 ft (the same elevation as the roadside ditch). This gives a pool 2.5 feet deep fits site provides the required volume and allows the pool to drain.

Using trapezoidal rule approximation, surface area = volume / (0.4 x max. pool depth)

Area = 3.600 / (0.4 x 2.5) = 3600 ft^3

d) Embankment:

4.0 ft high
5 ft top width
3:1 side slopes; machine compacted and keyed into ground surface under dam and abutments

e) Stone outlet section:

Bottom width: 6 ft.
Spillway depth: 1.5 ft.
Side slopes: 2:1 and 21 inches thick
Stone size: d_{50} = 9 inches, d_{max} = 14 inches; 1 foot thick layer of 3/4 inch gravel placed on inside (upstream) face of stone section
Synthetic filter cloth to be placed under the entire stone outlet section to the top of the dam.

TEMPORARY DIVERSIONS

Diversion #1

Drainage area: 1.8 acres
Land use: woods
Soil hydrology group: C
$Q_{10,24}$: 8 cfs

Land slope toward diversion ~4%

Try minimal practical dike cross section; 1.5 ft high ridge; 2:1 slope
Estimated capacity at depth = 1.0 ft; area = 13 ft^2;
grade = 2%; "C" retardance; V = 1.2 fps;
Q_A = 16 cfs
$Q_A > Q_{10,24}$ selected cross section is ok

Diversion #2

Drainage area: 1.2 acres
Land use: woods
Soil hydrologic group: C
$Q_{10,24}$: 5 cfs

Land slope toward diversion ~4%

Use same minimum cross section as diversion #1.

Estimated capacity at depth = 1.0 ft; area = 13 ft^2;
grade = 0.5%; “C” retardance; V = 0.8 fps;
Q_A = 10 cfs
$Q_A > Q_{10,24}$ selected cross section is ok

FINANCIAL RESPONSIBILITY/OWNERSHIP FORM
SEDIMENTATION POLLUTION CONTROL ACT

No person may initiate any land-disturbing activity on one or more contiguous acres as covered by the Act before this form and an acceptable erosion and sedimentation control plan haved been completed and approved by the Land Quality Section, N.C. Department of Environment, Health and Natural Resources. (Please type or print and, if question is not applicable, place N/A in the blank.)

Part A.

1. Project Name ABC Industries, Inc. -- Home Office and Warehouse

2. Location of land-disturbing activity: County Granville, City or Township Deal, NC, and Highway / Street Terri Road

3. Approximate date land-disturbing activity will be commenced: 10/28/87

4. Purpose of development (residential, commercial, industrial, etc.) : commercial

5. Approximate acreage of land to be disturbed or uncovered : 6 acres

6. Has an erosion and sedimentation control plan been filed ?Yes xx No ______

7. Person to contact should sediment control issues arise during land-disturbing activity.

   Name John A. Jones Telephone (919) 100-0000

8. Landowner (s) of Record (Use blank page to list additional owners.):

   Name (s): ABC Industries, Inc.

   Current Mailing Address: P.O. Box 1111 — Current Street Address: 666 Woodhouse Way

City	State	Zip	City	State	Zip
Deal	NC	20000	Deal	NC	20000

9. Recorded in Deed Book No. 010 Page No. 001

Part B.

1. Person (s) or firms (s) who are financially responsible for this land-disturbing activity (Use the blank page to list additional persons or firms):

   Name of Person (s) or Firm (s): ABC Industries, Inc.

   Mailing Address: P.O. Box 1111 — Street Address: 666 Woodhouse Way

City	State	Zip	City	State	Zip
Deal	NC	20000	Deal	NC	20000

   Telephone (919) 000-0000 Telephone ______

2. (a) If the Financially Responsible Party is a Corporation give name and street address of the Registered Agent.

John A. Jones
Name

Mailing Address: ______ | Street Address: 1111 Clay Street

City ______ State ______ Zip ______ | City: Deal State: NC Zip: 20000

Telephone: ______ | Telephone: 919-100-0000

(b) If the Financially Responsible Party is a Partnership give the name and street address of each General Partner (Use blank page to list additional partners.):

Name ______

Mailing Address ______ | Street Address ______

City ______ State ______ Zip ______ | City ______ State ______ Zip ______

Telephone ______ | Telephone ______

The above information is true and correct to the best of my knowledge and belief and was provided by me under oath. (This form must be signed by the financially responsible person if an individual or his attorney-in-fact or if not an individual by an officer, director, partner, or registered agent with authority to execute instruments for the finanacially responsible person). I agree to provide corrected information should there be any change in the information provided herein.

Type or print name: John A. Jones | Title or Authority: Registered Agent

Signature: John A. Jones | Date: September 1, 1987

I, Sam B. Smith, a Notary Public of the County of Granville

State of North Carolina, hereby certify that John A. Jones appeared personally before me this day and being duly sworn acknowledged that the above form was executed by him.

Witness my hand and notarial seal, this 1st day of September, 19 87.

Seal

Sam B. Smith
Notary

My commission expires 10/1/88

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT & NATURAL RESOURCES
LAND QUALITY SECTION

EROSION and SEDIMENTATION CONTROL PLAN PRELIMINARY REVIEW CHECKLIST

The following items shall be incorporated with respect to specific site conditions, in an erosion & sediment control plan

LOCATION INFORMATION

______ Project location (roads, streets, landmarks)
______ North arrow and scale

GENERAL SITE FEATURES (Plan elements)

______ Legend: North arrow, scale, etc.
______ Property lines
______ Existing contours (topographic lines)
______ Proposed contours
______ Limits of disturbed area (provide acreage total, delineate limits, and label)
______ Planned and existing building locations and elevations
______ Planned & existing road locations & elevations
______ Lot and/or building numbers
______ Geologic features: rock outcrops, seeps, springs, wetland and their limits, streams, lakes, ponds, dams, etc.
______ Easements and drainage ways
______ Profiles of streets, utilities, ditch lines, etc.
______ Stockpiled topsoil or subsoil locations
______ If the same person conducts the land-disturbing activity & any related borrow or waste activity, the related borrow or waste activity shall constitute part of the land-disturbing activity unless the borrow or waste activity is regulated under the Mining Act of 1971, or is a landfill regulated by the Division of Waste Management. If the land-disturbing activity and any related borrow or waste activity are not conducted by the same person, they shall be considered separate land-disturbing activities and must be permitted either thru the Sedimentation Pollution Control Act as a **one-use borrow site** or through the Mining Act.
______ Required Army Corps 404 permit and Water Quality 401 certification (e.g. stream disturbances over 150 linear feet)

EROSION CONTROL MEASURES (on plan)

______ Legend
______ Location of temporary measures
______ Location of permanent measures
______ Construction drawings and details for temporary and permanent measures
______ Maintenance requirements of measures
______ Contact person responsible for maintenance

SITE DRAINAGE FEATURES

______ Existing and planned drainage patterns (include off-site areas that drain through project)
______ Method of determination of and calculations for Acreage of land being disturbed
______ Size and location of culverts and sewers
______ Soil information: type, special characteristics
______ Soil information below culvert storm outlets

STORMWATER CALCULATIONS

______ Pre-construction runoff calculations for each outlet from the site (at peak discharge points)
______ Design calculations for peak discharges of runoff (including the construction phase & the final runoff coefficients of the site)
______ Design calcs of culverts and storm sewers
______ Discharge and velocity calculations for open channel and ditch flows (easement & right-of-ways)
______ Design calcs of cross sections and method of stabilization of existing and planned channels (include temporary linings)
______ Design calcs and construction details of energy dissipators below culvert and storm sewer outlets (diameters & apron dimensions)
______ Design calcs and dimension of sediment basins
______ Surface area and settling efficiency information for proposed sediment traps and/or basins

VEGETATIVE STABILIZATION

______ Area & acreage to be vegetatively stabilized
______ Method of soil preparation
______ Seed type & rates (temporary & permanent)
______ Fertilizer type and rates
______ Mulch type and rates

NOTE: **Plan should include provisions for groundcover on exposed slopes within 21 calendar days following completion of any phase of grading; permanent groundcover for all disturbed areas within 15 working days or 90 calendar days (whichever is shorter) following completion of construction or development.**

FINANCIAL RESPONSIBILITY/OWNERSHIP FORM

______ Completed, signed & notarized FR/O Form
______ Accurate application fee ($50.00 per acre rounded up the next acre with no ceiling amount)
______ Certificate of assumed name, if the owner is a partnership
______ Name of Registered Agent (if applicable)
______ Copy of the most current Deed for the site

NOTE: **For the Express Permitting Option, inquire at the local Regional Office for availability.**

NARRATIVE AND CONSTRUCTION SEQUENCE

______ Narrative describing the nature & purpose of the construction activity
______ Construction sequence related to erosion and sediment control (including installation of critical measures prior to the initiation of the land-disturbing activity & removal of measures after

8

Appendices

8

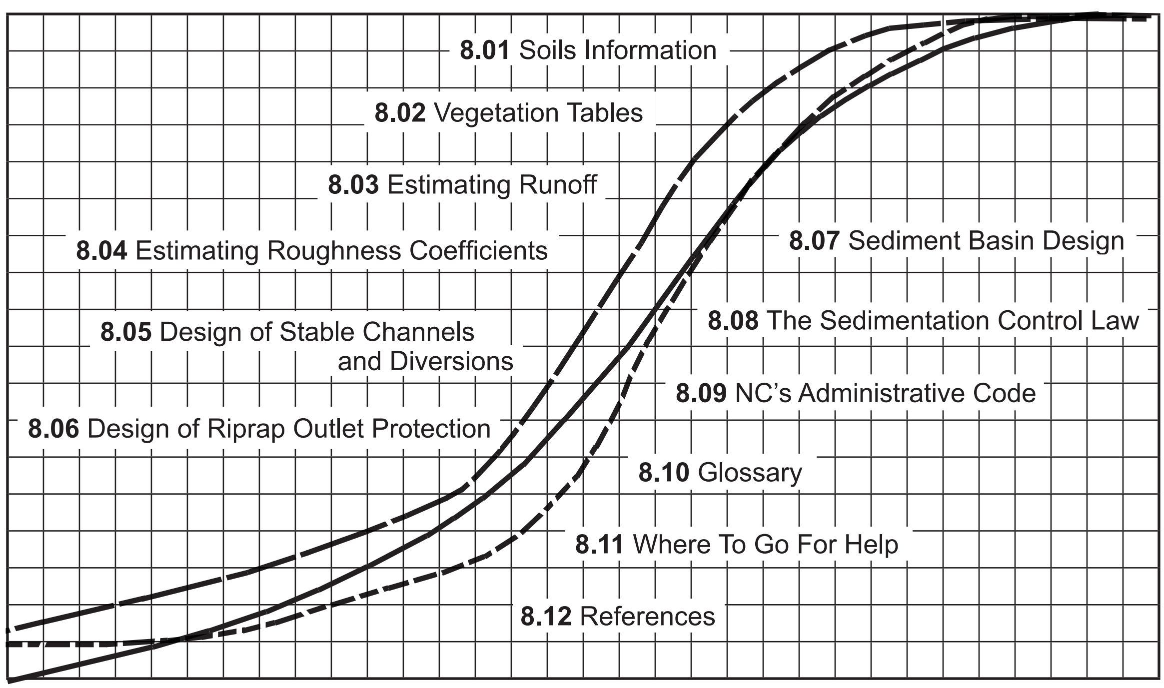
INDEX

APPENDICES

8

Appendices

The following appendices supplement material presented in earlier sections of the manual. The first seven appendices provide technical information to aid in the design and installation of structural and vegetative practices. These appendices include general information on soil properties and on the selection of vegetation as well as detailed guidelines on estimating runoff rates and roughness coefficients and on the design of channels and diversions, sediment basins and stable outlets. The final four appendices are less technical in nature and include the text of the law and regulations governing sediment control in North Carolina, a glossary, a list of offices readers may contact to obtain additional information, and a list of references.



8.01

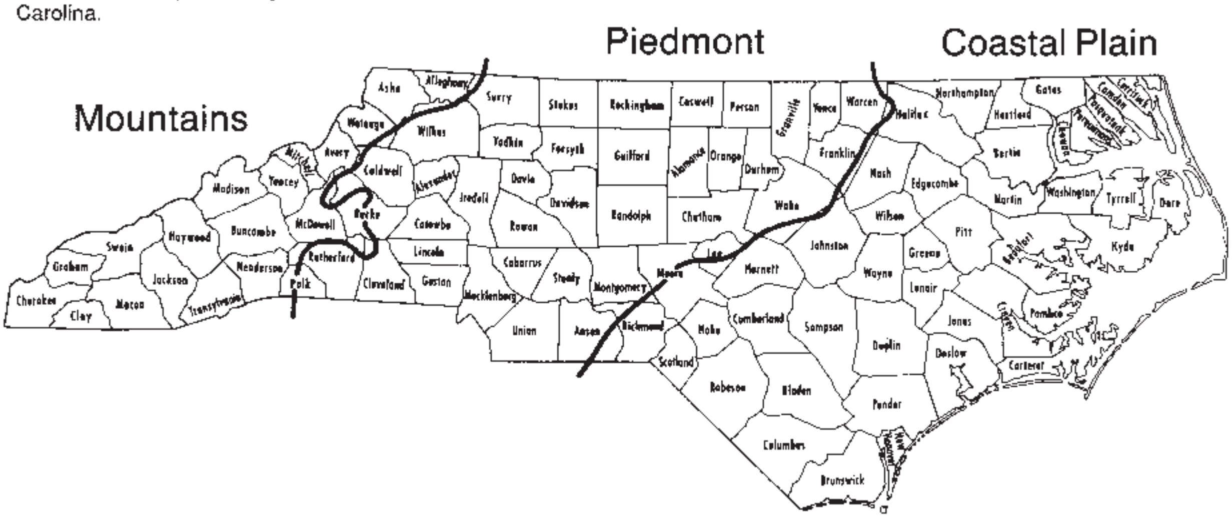
SOILS INFORMATION

A basic knowledge of soils can aid in preparing development plans. Selection of vegetation to be grown on the site for landscaping and erosion control also requires knowledge of the soils, and selection of other erosion control practices may depend on soil characteristics. In general, erosion control can be designed more cost effectively if soils are considered.

North Carolina is divided into three major soil regions (Coastal Plain, Piedmont, and Mountains) in which geology, geomorphology, and climate are the major factors determining soil characteristics (Figure 8.01a). Other site-specific factors such as moisture, temperature, organic matter, and vegetation also influence these characteristics.

About 45% of the land area of North Carolina is in the Coastal Plain. Elevations range from sea level to about 650 feet. Topography is flat to rolling, with soils that vary from sandy, droughty sandhills to large, wet pocosins, which are composed of sandy to clayey unconsolidated marine and fluvial deposits. About 39% of the state is in the Piedmont, in a rolling to hilly area between the Coastal Plain and the Mountains. Elevations range from 300 feet to 1500 feet. About 16% of the state is in the Mountains, with elevations ranging from 1500 to 6680 feet. Within each region the soils are numerous and often complex. Transition zones between the major regions are composed of mixed soils with variable characteristics.

Figure 8.01a Major soil regions of North Carolina.



USING SOIL SURVEYS

Information on soils may be obtained from soil surveys, but should be verified by on-site investigation. Soil surveys are available for most counties and can be obtained from the local Soil Conservation Service. The survey includes soil maps, soil descriptions, and soil interpretations.

A soil survey map is shown in Figure 8.01b. Boundaries of the different kinds of soils are delineated, showing their location and extent in relation to streams, roads, buildings, and other landscape features. Soil properties are determined from soil samples taken throughout the survey area and from laboratory analyses of selected samples.

Soils are named according to a nationwide uniform procedure. The classification system discussed here is that developed by the Soil Survey Staff of the U.S. Department of Agriculture (1975), published as Soil Taxonomy. The primary bases for identifying different classes in this system are the properties of soils as found in the field–properties that can be measured quantitatively. Another significant feature of this system is the nomenclature employed. The family names, for instance, define the major soil characteristics. Families are divided into lower-level groups called series. Soil series are commonly named for towns, or other geographic features near the place where they were first observed and mapped. A soil series is made up of soils that have similar profiles, major horizons, or layers that are similar in thickness, arrangement, and other important characteristics. A description of each soil type commonly found in North Carolina is given in Table 8.01d (found at the end of this appendix).

A series is divided into phases based on differences in surface layer texture, slope, stoniness, and other characteristics that affect use of the soils. The phase name indicates a feature that affects management. A Cecil sandy loam, 3 to 5% slope, and a Wedowee sandy loam, 8 to 15% slope, stony, are examples of soils in which phase distinctions are made.

Figure 8.01b Detail of soil survey map of Craven County.

NC0069 SOIL INTERPRETATIONS RECORD

MLRA(S): 133A, 136, 153A, 148, 153B, 153C
REV. RAG,WEH, 7-87
TYPIC HAPLUDULTS, FINE-LOAMY, MIXED, THERMIC

WICKHAM SERIES

THE WICKHAM SERIES CONSISTS OF NEARLY LEVEL TO MODERATELY STEEP, WELL DRAINED SOILS ON STREAM TERRACES IN THE PIEDMONT AND STREAM TERRACES AND LOW MARINE TERRACES IN THE COASTAL PLAIN. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS BROWN SANDY LOAM ABOUT 9 INCHES THICK. THE SUBSOIL IS YELLOWISH RED AND STRONG BROWN. IT EXTENDS TO 51 INCHES AND IS SANDY CLAY LOAM IN THE UPPER PART; SANDY CLAY LOAM AND SANDY LOAM IN THE MIDDLE PART; SANDY LOAM AND LOAMY SAND IN THE LOWER PART. THE UNDERLYING LAYER TO 70 INCHES IS GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 25 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT 3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-9	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-4	0	95-100	90-100	70-100	45-80	25	NP-7
0-9	LS, LFS	SM	A-2	0	95-100	90-100	55-80	15-30	-	NP
0-9	SCL, CL	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7-6	0	95-100	90-100	75-100	30-70	20-41	5-15
9-40	SCL, CL, L	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7-6	0	95-100	90-100	75-100	30-70	20-41	5-15
40-70	VAR									

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-9	8-15	1.45-1.65	2.0-6.0	0.11-0.16	4.5-6.0	-	LOW	.24	5	-	.5-2	MODERATE	HIGH
0-9	4-10	1.60-1.70	2.0-6.0	0.05-0.08	4.5-6.0	-	LOW	.15	5	-	.5-1		
0-9	18-35	1.30-1.50	0.6-2.0	0.12-0.17	4.5-6.0	-	LOW	.24	4	-	.5-1		
9-40	18-35	1.30-1.50	0.6-2.0	0.12-0.17	4.5-6.0	-	LOW	.24					
40-70													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE-RARE			6.0			-		60		-		B	-

SANITARY FACILITIES (B)		CONSTRUCTION MATERIAL (B)	
SEPTIC TANK ABSORPTION FIELDS	0-8% NONE: MODERATE-PERCS SLOWLY 8-15% NONE: MODERATE-SLOPE,PERCS SLOWLY 0-8% RARE: MODERATE-FLOODING,PERCS SLOWLY 8-15% RARE: MODERATE-FLOODING,PERCS SLOWLY 15+%: SEVERE-SLOPE	ROADFILL	0-15%: GOOD 15+%: FAIR-SLOPE
SEWAGE LAGOON AREAS	0-2%: MODERATE-SEEPAGE 2-7%: MODERATE-SEEPAGE,SLOPE 7+%: SEVERE-SLOPE	SAND	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (TRENCH)	0-8% NONE: MODERATE-TOO CLAYEY 8-15% NONE: MODERATE-SLOPE,TOO CLAYEY 0-8% RARE: MODERATE-FLOODING,TOO CLAYEY 8-15%RARE:MODERATE-FLOODING,SLOPE,TOO CLAYEY 15+%: SEVERE-SLOPE	GRAVEL	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (AREA)	0-8% NONE: SLIGHT 8-15% NONE: MODERATE-SLOPE 0-8% RARE: MODERATE-FLOODING 8-15% RARE: MODERATE-FLOODING,SLOPE 15+%: SEVERE-SLOPE	TOPSOIL	0-8%: FAIR-TOO CLAYEY,SMALL STONES 8-15%: FAIR-TOO CLAYEY,SMALL STONES,SLOPE 15+%: POOR-SLOPE

Figure 8.01c Typical soil interpretation sheet describing soil properties and suitability for various uses.

Each soil series is described on an interpretation sheet, such as that shown in Figure 8.01c. Interpretation sheets list properties and typical site conditions that are important in erosion and sedimentation control planning for construction sites: texture, erodibility, slope, plasticity, permeability, and depth to and hardness of bedrock. The interpretation sheet also lists other ratings and limitations that are important for site selection and development, such as shrink-swell potential, risk of corrosion, engineering properties, and hydrologic soil group.

Limitations of the survey must also be understood to make accurate interpretations. First, data generally do not represent soil material below 5 or 6 feet. Also, small soil areas that differ from the dominant soil may not be delineated in the map because the map scale limits the size of areas that can be shown. The ranges given for soil properties are often too wide for the design needs of a small development. Therefore, on-site investigation is needed in conjunction with a soil survey to evaluate many specific soil characteristics.

Properties included on the soils interpretation sheet that affect erosion most are soil texture, soil erodibility factor, slope, plasticity index, liquid limit, permeability, depth to bedrock, soil reaction, seasonal high water table, hydrologic group, and engineering classification. A description of each follows.

Soil Texture

Soil survey interpretation sheets indicate the USDA texture class for each soil, expressed as a relative proportion by weight of soil particle size classes finer than 2 mm. The basic texture classes, in decreasing particle size are sands, loams and clays. On the basis of these classes, additional class names are used such as loamy sand, sandy clay, and silty clay. Sands, loamy sands, and sandy loams may be further subdivided as very coarse, coarse, fine, or very fine. Soil description by particle size analysis, which is used by USDA as a guide to textural classifications, is shown in Figure 8.01d. Symbols used in classifying soils according to texture are provided at the bottom of the figure with corresponding descriptions.

Soil texture is defined by the proportions of different size groups of particles. The size limits of different soil particles are listed in Table 8.01a.

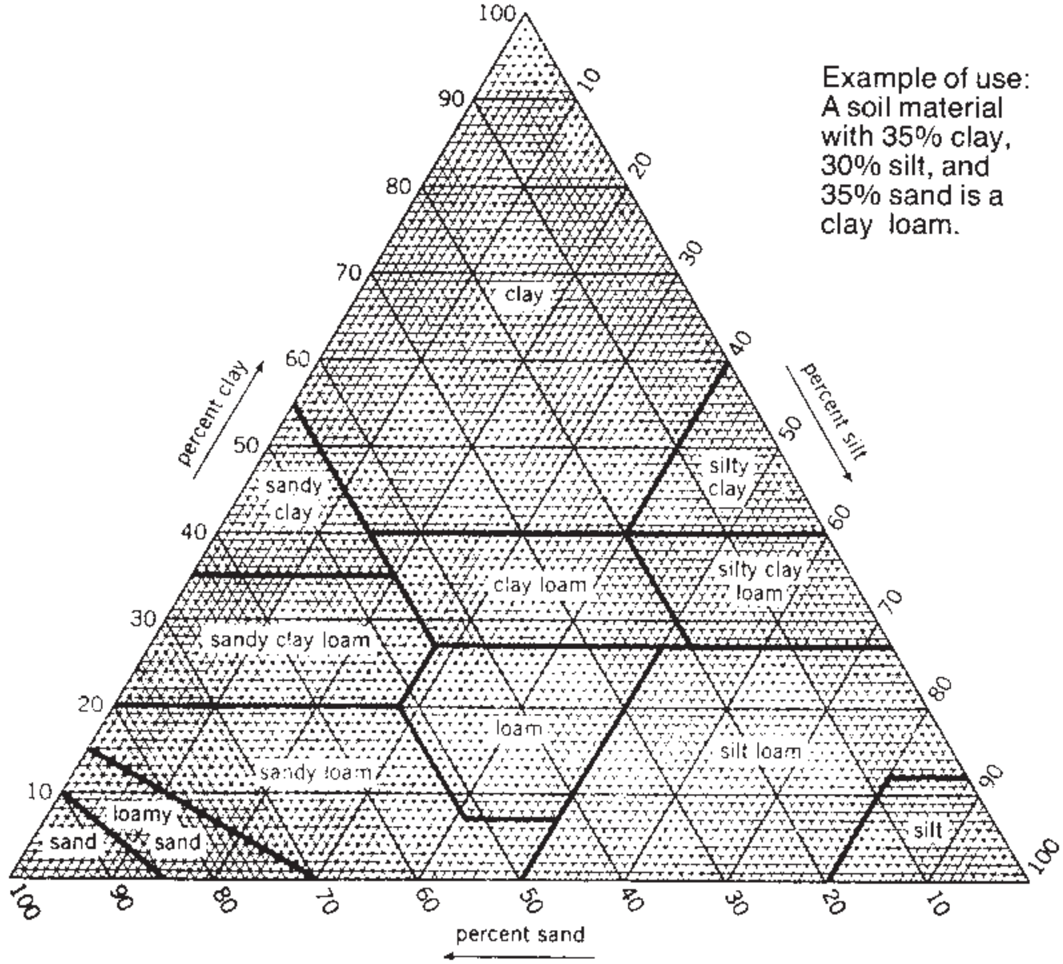
Table 8.01a
Size Limits
of Soil Particles

Soil Particle	Size
Cobble	0.3 - 0.15m
Gravel	0.15 - 2.0 mm
Sand	2.0 - 0.05 mm
Silt	0.05 - 0.002 mm
Clay	<0.002 mm

The physical properties and chemical composition of large soil particles differ from small soil particles. Since most physical and chemical reactions occur on the surface of small particles, clay (which has much more surface per unit mass than silt or sand) affects soil properties to a much greater extent than do coarser particles. Sand and rock fragments retain water and nutrients poorly because the voids between particles allow water and air to move freely. Therefore, soils with a large percentage of sand-size particles are generally poorly aggregated, well-drained, and well-aerated.

Silt particles are barely visible to the naked eye and are intermediate in many properties between sand and clay. Silt is characterized by its plasticity and stickiness. Silt content is an important characteristic for determining erodibility because silt-sized particles are small enough to reduce the water intake or infiltration rate, and because they are easily detached and transported in runoff. The small particle size makes silt difficult to capture in traps or basins.

There are two major types of clays, kaolinite and montmorillonite. Kaolinite (referred to as a 1:1 clay) is the most common clay in North Carolina soils. It is relatively inactive and fairly stable. Montmorillonite (referred to as a 2:1 clay) is a very active clay that shrinks when dry and swells when wet. These characteristics affect the permeability of soils and are very important to their use and management. Clayey soils retain water that is available for plant



Texture modifier:

CB	Cobbly
CBA	Angular Cobbly
CBV	Very Cobbly
CBX	Extremely cobbly
CN	Channery
CNV	Very channery
CNX	Extremely channery
GR	Gravelly
GRC	Coarse gravelly
GRF	Fine gravelly
GRV	Very gravelly
GRX	Extremely gravelly
MK	Mucky
PT	Peaty
SH	Shaly
SHV	Very shaly
SHX	Extremely shaly
SHR	Stratified
ST	Stony
STV	Very Stony
STX	Extremely Stony

Texture terms:

COS	Coarse sand
S	Sand
FS	Fine Sand
VFS	Very fine sand
LCOS	Loamy coarse sand
LS	Loamy sand
LFS	Loamy fine sand
LVFS	Loamy very fine sand
COSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
SI	Silt
SCL	Sandy clay loam
CL	Clay loam
SICL	Silty clay loam
SC	Sandy clay
SIC	Silty clay
C	Clay

Terms used in lieu of texture:

G	Gravel
MARL	Marl
MPT	Mucky-peat
MUCK	Muck
PEAT	Peat
SG	Sand and gravel
UWB	Unweathered bedrock
VAR	Variable
WB	Weathered bedrock

Note: These are boundary classifications. Soils possessing characteristics of two or more groups are designated by combinations of group symbols. For example, SR-S-FS is a stratified sand fine sand.

Figure 8.01d Guide for USDA Textural Classification and symbols (source: National Soils Handbook).

growth, but these soils are often dense, hard, wet, airtight, acidic and infertile. They may restrict root growth even though water holding capacity and potential rooting depth are adequate. Urban uses of clayey soils may be limited due to cracking of foundations and failure of septic drain fields.

Soil texture information for soils commonly found in North Carolina is given in Table 8.01

Soil Erodibility Factor, (K)

The soil erodibility factor, K, provides a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The principal factors affecting K are texture, organic matter, structure, and permeability. If minimal grading or compaction is expected, K from the soil interpretation sheet, which provides K for a range of depths, can be used (Table 8.01d). Erodibility increases with increasing K. Subsoils exposed during construction, however, may be too deep to be included on the survey. In this case, an on-site investigation is necessary to flag erosion-prone areas. The soil erodibility nomograph, in Figure 8.01e, can be used to estimate K from the percentage of sand, percentage of organic matter, soil structure, and soil permeability.

Slope

The erosion potential increases with slope length and gradient. Long and steep slopes have high potential for soil loss due to surface runoff.

Plasticity Index and Liquid Limit

Both the plasticity index and the liquid limit indicate the effect of water on the strength and consistency of soil and are most important in fine-grained soils. Soils with greater plasticity generally have higher cohesion and resistance to erosion than soils with lower plasticity. These indexes are used in both the Unified and the American Association of State Highway and Transportation Officials (AASHTO) soil classification systems, which are described in more detail later. They are also used as indicators in making general predictions of soil behavior.

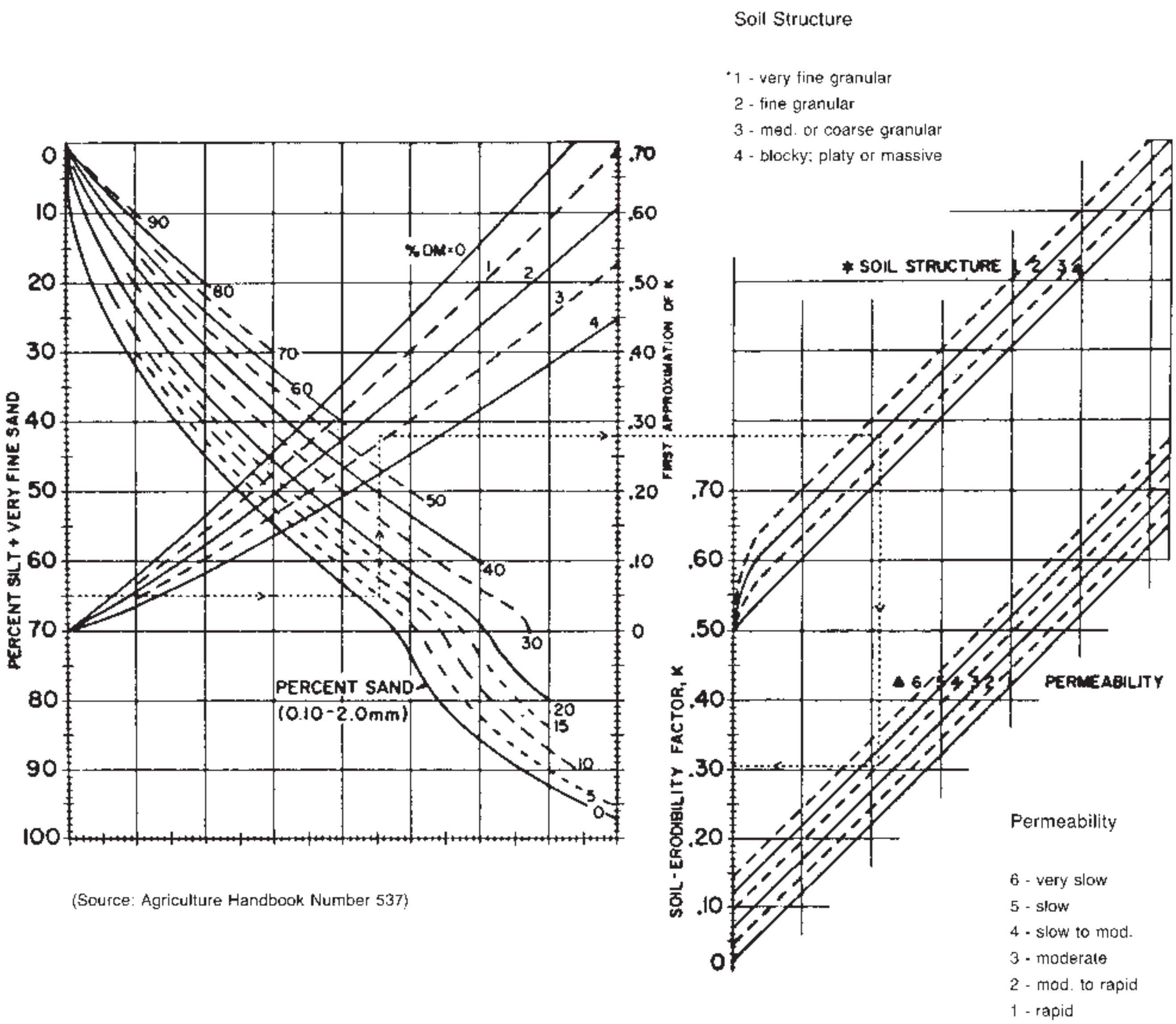
Information on plasticity of soils commonly found in North Carolina is given in Table 8.01d

Permeability

Permeability is a major factor influencing erosion. It refers to the soil's ability to transmit water or air and depends on both the size and volume of pores. Deep, permeable soils are less erodible because more rainfall soaks in, reducing surface runoff. Because permeability varies with depth, excavation may expose layers that are more or less permeable than the original surface. Compaction reduces permeability.

Depth to Bedrock

Soil survey interpretation sheets generally provide an estimate of depth to and hardness of bedrock, the solid (fixed) rock underlying soil. This information is helpful in determining time and cost of excavation as well as potential erodibility of the subsoil material. Hardness classes, "soft" and "hard", indicate the ease of excavating into the bedrock. "Soft" rock is likely to be sufficiently soft, thinly bedded, or fractured so that excavation can be made with trenching machines, backhoes, small ripper, or other equipment common in construction of pipelines, sewer lines, cemeteries, dwellings, or small buildings.



Procedure: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0mm), % organic matter, structure and permeability, **in that sequence**. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: silt + vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Figure 8.01e Soil-erodibility nomograph

"Hard" rock is likely to require blasting or special equipment beyond what is considered normal in this type of construction.

Bedrock at shallow depths limits plant growth by restricting root penetration. There is frequently a correlation between bedrock depth and water holding capacity.

Soil Reaction, (pH)

Soil reaction represents the degree of acidity or alkalinity of a soil, expressed as pH. The pH in soils is directly related to parent material. The principal value of soil pH measurement is the knowledge it gives about associated soil characteristics, such as phosphorus availability or base saturation. A pH of approximately 6 to 7 indicates readily available plant nutrients.

Leaching removes bases, causing a pH decline. Therefore, the amount of rainfall, rate of percolation, return movement of moisture by capillary action, and evaporation affect pH. The pH is higher in soils of arid regions than in humid regions, higher in younger soils than older soils, higher on steep slopes than on flap topography, and higher under prairie than under timber.

Soil reaction is also used as an indicator of corrosivity or dispersivity. In general, soils that are either very alkaline or very acid are likely to be highly corrosive to steel. Soils that are acid are likely to be corrosive to concrete.

The range of pH for soils commonly found in North Carolina is given in Table 8.10d.

Seasonal High Water Table

A seasonal high water table is a zone of saturation at the highest average depth during the wettest season of the year. It is at least 6 inches thick, persists in the soil for more than a few weeks, and is within 6 feet of the soil surface. Soils that have a seasonal high water table are classified according to depth to the water table, kind of water table, and time of year when the water table is highest. Depth and duration of high water may limit soils for uses, such as septic tank absorption fields, roadfill, and topsoil. A water table near the surface during the growing season is detrimental to many plants and must be considered in vegetation plans.

Hydrologic Group

Hydrologic group identifies soils as having the same runoff potential under similar storm and cover conditions. Soil properties that determine the hydrologic groups include the following: seasonal high water table, water intake rate and permeability after prolonged wetting, and depth to the slowly permeable layer. The influence of ground cover is not considered. The soils in the U.S. and Caribbean area are placed into four groups (A, B, C, and D) and three dual classes (A/D, B/D, C/D). In the definition of classes, infiltration rate is the rate at which water enters the soil at the surface, controlled by surface conditions. Transmission rate is the rate water moves in the soil, controlled by the permeability of deeper horizons. The hydrologic group for soils commonly found in North Carolina is given in Table 8.01d. Definitions of the groups are listed below.

- **Group A** (low runoff potential)—Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

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

- **Group C**—Soils having slow infiltration rates when thoroughly wetted. Group C soils often have a layer that impedes downward movement of water, or may consist of moderately fine to fine-textured particles. These soils have a slow rate of water transmission.

- **Group D** (high runoff potential)—Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of clay soils with high swelling potential. These soils frequently have a permanent high water table, or a claypan or clay layer at or near the surface. Other soils in this group consist of shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

- **Dual hydrologic groups**, A/D, B/D, and C/D, are indicated for certain wet soils that can be drained. The first letter applies to the drained condition, the second to the undrained condition. Only soils that are rated D in their natural condition are assigned to a group.

Engineering Classification

Soils are classified according to engineering properties by two classification systems in the soil survey: (1) the AASHTO system and (2) the Unified Soil Classification System. Engineering classification for soils commonly found in North Carolina is given in Table 8.01d.

AASHTO System

The AASHTO system classifies soils according to the properties that affect roadway construction and maintenance. The fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of grain-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in silt and clay. Soils in group A-7 are fine grained. Highly organic soils in Group A-8 are classified on the basis of visual inspection. The AASHTO classification system is summarized in Table 8.01b.

Unified System

The Unified System classifies soils according to suitability for construction material: grain-size distribution, plasticity index, liquid limit, and organic matter content. This classification is based on that portion of soil having particles smaller than 3 inches in diameter. Classes include coarse-grained soils (GW, GP, GM, GC, SW, SP, SM, SC), fine-grained soils (ML, CL, OL, MH, CH, OH), and highly organic soils (PT). Borderline soils require a dual classification symbol. Table 8.01c provides classification descriptions for each class in the Unified System.

Table 8.01b
AASHTO Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or less passing 0.075 mm)							Silt-Clay Materials (More than 35% passing 0.075 mm)			
Group Classification	A - 1		A - 3	A - 2				A - 4	A - 5	A - 6	A - 7 A - 7 - 5 A - 7 -6
	A - 1- a	A - 1 - b		A - 2 - 4	A - 2 - 5	A - 2 - 6	A - 2 - 7				
Sieve Analysis, Percent Passing:											
2.00 mm (No. 10)	50 max										
0.425 mm (No. 40)	30 max	50 max	51 min								
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of Fraction Passing 0.425 mm (No. 40)											
Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		N.P.	10 max	10 max	11 min	11min	10 max	10 max	11 min	11 min[a]
Usual Types of Significant Constituent Materials	Stone Fragments Gravel and Sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
General Ratings as Subgrade	Excellent to Good							Fair to Poor			

[a] Plasticity index of A - 7 -5 subgroup is equal to or less than LL minus 30.
Plasticity index of A-7-6 subgroup is greater than LL minus 30.

FIELD TESTS

Although soil textures are defined in terms of the particle-size distribution determined by mechanical analysis in the laboratory, it is often desirable and necessary to estimate the textural class in the field. Field estimates of texture are influenced by consistency, structure, organic matter content, kind of clay and absorbed cations, and particle size.

Classification of soils in the field involves several different tests. Screening and weighing the samples are not necessary. Field tests described here include tests to (1) determine texture as coarse- or fine-grained, (2) classify coarse-grained materials, (3) classify fine-grained materials, and (4) determine if the soil has high organic matter content, high plasticity, or high clay content.

Determining Texture as Coarse- or Fine-grained

TEST 1
Spread the sample on a flat surface, and examine the particles to determine approximate grain size by visual inspection. If more than 50% of the sample has individual grains that are visible to the naked eye, the material is coarse; if less than 50%, it is fine.

Aggregated dry particles may appear to be sand-sized. Saturating the sample will break these aggregated particles down. By rubbing the wetted soil between the thumb and forefinger, sand-sized grains can be detected as they will feel rough and gritty. Practice with samples with known percentages of sand is helpful in establishing sand content.

TEST 2
Fill a straight-sided glass bottle to approximately 0.4 of its height with the sample, then nearly fill the bottle with water. Shake until all the material is in suspension. Estimate the percentage that settles in 25 seconds. If more than 50%

Table 8.01c
Classification of Materials for the Unified System

Group Symbol	Description of Material Classification
Coarse-grained	
GW	Well-graded gravels and gravel-sand mixture little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
GM	Silty gravels, gravel-sand-silt mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.
GC	Clayey gravels, gravel-sand clay mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.
SW	Well-graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
SP	Poorly graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
SM	Silts sands, sand-silt mixtures. More than 50% passes No. 4 sieve. More than 50% retained on No. 200 sieve.
SC	Clayey sands, sand-clay mixtures. More than 50% passes No. 4 sieve. More than 50% retained on No. 200 sieve.
Fine-grained	
OL	Organic silts and organic silty clays of low plasticity. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
CH	Inorganic clays of high plasticity, fat clays. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
OH	Organic clays of medium to high plasticity. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
Highly organic	
PT	Peat, muck, and other highly organic soils.

NOTE: These are boundary classifications. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC is a well-graded, gravel-sand mixture with clay binder.
All sieve sizes on this table are U.S. Standard.

of the material settles in 25 seconds, the material is coarse-grained; if less than 50% of the material settles in 25 seconds, the material is fine-grained.

Classifying Coarse-Grained Materials

Spread a representative sample on a flat surface. Determine whether more than one-half of the visible grains by weight are pea size or larger. If they are, it is a gravel; if not, it is a sand.

After determining if the material is a gravel of a sand, it is further classified according to the properties of the fine content of the material. Remove the coarse material by spreading a thin layer of material on a sheet of paper and tapping the coarse material to the edge. Saturate the remaining material, and work it into the hands. The hands will not be stained if there is less than 5% fines. It will be GW or GP if the material is a gravel, or SW or SP if the material is a sand. The hands will be stained if there is more than 12% fines. Weak casts can be formed from moist material. It will be GM or GC if the material is a gravel, SM, or SC if the material is a sand.

Dual symbol materials (5 to 12% fines) cannot be readily classified by field procedures.

Use a second sample if there is less than 5% fines. Spread it out an observe the grain size distribution. If the coarse material consists of fairly well-distributed particles, the material is a well-graded gravel or sand (GW or SW). If the coarse material consists chiefly of single-sized particles or of large and small particles with in-between sizes missing, the material is a poorly graded gravel or sand (GP or SP).

When there are more than 12% fines in a coarse-grained material, make the plasticity tests on the fines described below under **Classifying Fine-grained Materials** to determine whether the material is clayey or silty.

The material will be GC or SC if clayey and GM or SM if silty.

Classifying Fine-Grained Materials

TEST 1
Prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water to make the soil soft, but not sticky. Place pat in the open palm of the hand and shake it horizontally. Presence of fine-grained material is indicated by the appearance of water on the surface of the pat, giving the sample a glossy appearance. The water and gloss will disappear from the surface when the pat is squeezed between the thumb and forefinger. The rapidity of the appearance of water during shaking and its disappearance when squeezed identifies the character of the fines. An ML will have a rapid reaction; an MH and CL, a slow reaction; and a CH, no reaction.

TEST 2
Dry crushing strength is estimated by crushing a dry clod between the fingers. A block of soil at least 3/4 inch in smallest dimension should be used, as smaller samples may give erroneous results. CH material is almost impossible to break. Easily crushed material of low strength is classified ML. Medium strength material is either CL or MH.

TEST 3
The toughness test uses the same procedures that are used in the laboratory to determine the plastic limit (PL). Wet and mold a soil sample so that it can be rolled into a thread without crumbling. The material will not stick to the hands if the correct amount of water is added. Roll the moist soil with the palm of the hand on any clean, smooth surface such as a piece of paper, to form a 1/8 inch diameter thread. Gradually reduce the moisture content by breaking up the sample and remolding and rolling it until the 1/8 inch thread breaks into approximately 3/4 inch long pieces. The material is then at its plastic limit. Circumferential breaks in the thread indicate a CH or CL material. Longitudinal cracks and diagonal breaks indicate an MH material.

Remold the sample into a coarse thread and pull it apart. A tough thread indicates high plasticity (CH or CL). A medium tough thread indicates an MH material. A weak thread indicates an ML material.

TEST 4
The ribbon test uses a sample with moisture content at or slightly below the plastic limit. The ribbon is formed by squeezing and working the sample between thumb and forefinger.

A weak ribbon that breaks easily indicates an ML soil. A hard ribbon that breaks fairly readily indicates an MH soil. A flexible ribbon with medium strength indicates a CL soil. A strong, flexible ribbon indicates a CH soil.

TEST 5
A test for stickiness can be made by saturating the material and letting it dry on the hands. An ML soil will brush off with little effort. A CL or MH soil rubs off with moderate effort when dry. A CH soil requires rewetting to completely remove it from the hands.

TEST 6
The Liquid Limit (LL) test takes a pat of moist soil with volume about one-half cubic inch and enough water to make the soil soft, but not sticky. Rapidly add enough water to cover the surface. Break the pat open immediately. If water penetrates, the LL is low. If water does not penetrate, LL is high. Visual observation of this phenomenon is much easier in direct sunlight.

Determining Other Conditions

Tests are also available to identify high organic matter content, plasticity, and clay content, as described below.

- **Odor test**—to determine high organic matter content. Fresh, damp organic soils have a distinctive, pungent, musty odor.

- **Shine test**—to determine plasticity. In making the shine test, be sure soil is not micaceous. Rub a small clod of air-dry soil with a knife blade. A shiny surface indicates high plasticity. You are seeing the shine of the dry, highly plastic fines.

- **Malachite-green test**—to determine clay content. The staining agent used is a saturated nitrobenzene solution of malachite green. Clay minerals of the kaolinite group merely absorb the dye, becoming blue to green-blue after application of this solution. Montmorillonite becomes yellow-red, and illite becomes purple-red to purple.

Table 8.01d
Soil Characteristics for Common Soils in North Carolina.

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
ALAGA	0-6	4.5-6.0	0.17	A	NP	LS, LFS, FS	SM, SW-SM, SP-SM	A-2, A-1-B
	6-80	4.5-6.0	0.17	A	NP-4	LS, LFS, FS	SM, SW-SM, SP-SM	A-2
ALAMANCE	0-11	4.5-7.3	0.43	B	NP-10	L, SIL,VFSL	ML	A-4
	0-11	4.5-7.3	0.28	B	NP-5	GR-L, GR-SIL, GR-VFSL	ML	A-4
	11-35	4.5-5.5	0.43	B	7-20	CL, SICL, SIL	CL, ML	A-4, A-6, A-7
	35-46	4.5-5.5	0.43	B	5-15	L, SIL, VFSL	CL, ML, CL-ML	A-4, A-6, A-7
	46-84	4.5-6.0	0.32	B	NP-12	VFSL	ML	A-4, A-6
	64-80			B		Var		
ALBANY	0-48	3.6-6.5	0.10	C	NP	S, FS	SM	A-2
	0-48	3.6-6.5	0.10	C	NP	LS	SM	A-2
	48-56	4.5-6.0	0.20	C	NP	SL	SM	A-2
	56-88	4.5-6.0	0.24	C	NP-17	SCL, SL, FSL	SC, SM, SM-SC	A-2, A-4, A-6
ALTAVISTA	0-12	4.5-6.0	0.20	C	NP	LS, SL	SM	A-2
	0-12	4.5-6.0	0.24	C	NP-7	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	12-42	4.5-6.0	0.24	C	5-28	CL, SCL, L	CL, CL-ML, SC, SM-SC	A-4, A-6, A-7
	42-60			C	NP	Var		
AMERICUS	0-7	4.5-5.5	0.10	A	NP	LS, S, LFS	SM, SP-SM	A-2
	7-47	4.5-5.5	0.17	A	NP	LS, LFS	SM	A-2
	47-72	4.5-5.5	0.20	A	NP-7	SL, LS, FSL	SM, SM-SC	A-2
APPLING	0-9	4.5-5.5	0.24	B	NP-5	FSL, SL, LS	SM, SM-SC	A-2
	0-9	4.5-5.5	0.15	B	NP	GR-SL, GR-COSL	GM, GP-GM, SM, SP-SM	A-1
	0-9	4.5-5.5	0.20	B	6-20	SCL	CL, SC, CL-ML, SM-SC	A-6, A-4
	9-35	4.5-5.5	0.20	B	15-30	SC, CL, C	MH, ML	A-7
	35-46	4.5-5.5	0.24	B	8-22	SC, CL,SCL	SC, CL	A-4, A-6, A-7
	45-65			B	NP	Var		
ARAPAHOE	0-17	3.6-5.5	0.15	B/D	NP	LFS, LS	SM	A-2, A-4
	0-17	3.6-5.5	0.15	B/D	NP-4	FSL, L	SM	A-2, A-4
	17-42	3.6-7.8	0.15	B/D	NP	FSL, L, SL	SM	A-2, A-4
	42-80	5.6-7.8	0.10	B/D	NP-4	SR,-LS-S	SM, SP-SM	A-2, A-3, A-4
ASHE	0-7	4.5-6.0	0.24	B	NP-7	L, SL, FSL	SM, SM-SC, ML, CL-ML	A-4
	0-7	4.5-6.0	0.17	B	NP-7	GR-L, GR-SL, GR-FSL	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.17	B	NP-7	ST-L, ST-SL, ST-FLS	SM, SM-SC	A-2, A-4
	7-25	4.5-6.0	0.17	B	NP-7	L, SL, FSL	SM, SM-SC	A-4
	25-30	4.5-6.0	0.17	B	NP	SL	SM	A-2, A-4
	30			B		UWB		
AUGUSTA	0-9	4.5-6.0	0.24	C	NP-10	SIL, L	ML, CL-ML	A-4
	9-60	4.5-6.0	0.24	C	5-25	SCL, CL, L	CL, CL-ML	A-4, A-6, A-7
	60-70	4.5-6.0	0.24	C	NP-5	COSL, L, GR-LS	SM,SP-SM, ML, SM-SC	A-2, A-4, A-1
AUTRYVILLE	0-26	4.5-6.5	0.10	A	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	26-41	4.5-5.5	0.10	A	NP-3	SL, SCL, FSL	SM	A-2
	41-58	4.5-5.0	0.10	A	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	58-85	4.5-5.5	0.17	A	NP-10	SL, SCL, FSL	SM, SC, SM-SC	A-2, A-4
AYCOCK	0-12	4.5-6.0	0.37	B	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-80	4.5-5.5	0.43	B	8-30	CL. SICL, L	CL	A-4, A-6, A-7

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
AYERSVILLE	0-8	4.5-6.0	0.32	B	NP-11	L, SIL, SICL	ML, CL-ML, CL, SC	A-4, A-6
	0-8	4.5-6.0	0.28	B	4-25	GR-L, GR-SIL, GR-SICL	SM, SM-SC, ML, SC	A-4, A-6
	8-22	4.5-5.5	0.28	B	4-25	GR-SIL, GR-L, L	CL, CL-ML, ML	A-4, A-6, A-7
	22-26	4.5-5.5	0.28	B	NP-10	GR-SIL, GR-L	CL, CL-ML, ML	A-4
	26-30			B	NP			
	30			B	NP			
BADIN	0-6	3.6-6.5	0.24	C	NP-10	CN-SIL, CN-VFSL, CN-L	ML, CL, CL-ML, GM	A-4
	6-25	3.6-5.5	0.24	C	15-35	SIC, SICL, CN-SICL	CL, CH	A-6, A-7
	25-40			C	NP	WB		
	40			C	NP	UWB		
BALLAHACK	0-9	4.5-5.5	0.10	D	NP-10	FSL, SL, L	SM, SC. CL, ML	A-4
	9-35	4.5-5.5	0.10	D	8-20	SCL, L	SC, CL	A-4, A-6
	35-74	4.5-5.5	0.17	D	NP-10	SR-S-SC	SM, SC, ML, CL	A-2, A-4
BARCLAY	0-57	4.5-6.0	0.43	C	NP-7	L, SIL, VFSL	CL-ML, ML	A-4
	57-72	4.5-6.0	0.43	C	NP	FS, LS, FSL	SM, SP-SM	A-2
BAYBORO	0-14	4.5-5.5	0.15	D	NP-7	FSL	SM-SC, SM, CL-ML, ML	A-4
	0-14	4.5-5.5	0.17	D	4-20	L, CL	CL, ML, CL-ML	A-6, A-7
	14-64	4.5-5.5	0.32	D	20-40	CL, SC, C	CL, CH	A-7
BAYMEADE	0-36	4.5-6.5	0.10	A	NP	FS, S	SM, SP-SM	A-2, A-3
	0-36	4.5-6.5	0.10	A	NP	LS, LFS	SM	A-2-4
	36-49	4.5-6.5	0.10	A	2-9	FSL, SCL, SL	SC, SM, SM-SC	A-2, A-4
	49-78	4.5-6.5	0.10	A	NP	LFS, S, LS	SM, SP-SM	A-2, A-3
BELHAVEN	0-26	4.5		D	NP	MUCK	PT	
	26-32	3.6-5.5	0.24	D	NP-10	SL, FSL	SM, SC, SM-SC	A-2, A-4
	32-65	3.6-6.5	0.24	D	4-15	L, CL, SCL	CL, CL-ML, SC, SM-SC	A-4, A-6
	65-72	3.6-6.5	0.15	D	NP	SR-S, FS	SM, SP-SM	A-2, A-3
BERTIE	0-17	4.5-6.5	0.17	B	NP-4	LS, LFS	SM	A-2
	0-17	4.5-6.5	0.20	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	17-42	4.5-6.5	0.24	B	4-16	SCL, CL, SL	SC, CL, SM-SC, CL-ML	A-2, A-4,A-6
	42-57	4.5-6.0	0.24	B	NP-8	FSL, SL, SCL	SM, SM-SC	A-2, A-4
	57-85	4.5-6.0	0.17	B	NP-6	SL, LFS, FS	SM, SM-SC, SP-SM	A-2, A-4
BIBB	0-12	4.5-5.5	0.20	C	NP-7	SL, FSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	0-12	4.5-5.5	0.28	C	NP-7	L, SIL	ML, CL-ML	A-4
	0-12	4.5-5.5	0.15	C	NP	S, LS	SM, SP-SM	A-2, A-3
	12-60	4.5-5.5	0.37	C	NP-7	SL, L, SIL	SM, SM-SC, ML, CL-ML	A-2, A-4
BILTMORE	0-10	5.1-7.8	0.15	A	NP-4	FSL, SL, LFS	SM	A-2, A-4
	10-60	5.1-7.8	0.10	A	NP	LS, LFS, S	SM, SP-SM	A-2
BLADEN	0-14	3.6-5.5	0.24	D	NP	FSL, SL	SM	A-2, A-4
	0-14	3.6-5.5	0.37	D	NP-10	L, SIL	CL, ML, CL-ML	A-4
	14-41	3.6-5.5		D	23-45	C, SC	CL, CH	A-7
	41-62	3.6-5.5		D	8-35	C, SC, CL	CL, CH, SC	A-4, A-6, A-7
	62-80			D	NP	Var		
BLANEY	0-25	4.5-6.0	0.15	B	NP	S, LS	SM, SP-SM	A,2, A-3
	0-25	4.5-6.0	0.10	B	NP	COS, LCOS	SM, SP-SM	A-2, A-3, A-1-B
	25-50	4.5-5.5	0.28	B	NP-20	SCL, SL	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B
	50-65	4.5-5.5	0.28	B	NP-14	SL, SCL, LS	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
BLANTON	0-58	4.5-6.0	0.10	A	NP	S, FS, COS	SP-SM	A-3, A-2-4
	0-58	4.5-6.0	0.15	A	NP	LS, LFS	SM	A-2-4
	0-58	4.5-6.0	0.05	A	NP	GR-S	SP-SM	A-1, A-2-4, A-3
	58-62	4.5-5.5	0.15	A	NP-3	SL, LS, LCOS	SM	A-2-4
	62-80	4.5-5.5	0.20	A	3-22	SCL, SL, FSL	SM, SM-SC, SM	A-4, A-2-4, A-2-6, A-6
BOWIE	0-12	5.1-6.5	0.32	B	NP-6	FSL	SM, SM-SC, ML	A-2-4, A-4
	12-42	4.5-5.5	0.32	B	8-25	SCL, CL, FSL	SC, CL	A-4, A-6
	42-78	4.5-5.5	0.28	B	8-30	SCL, CL, FSL	SC, CL	A-4, A-6, A-7
BRADDOCK	0-9	3.6-5.5	0.32	B	NP-10	L, FSL, SL	CL, SM, ML, SC	A-2, A-4
	0-9	4.5-5.5	0.32	B	15-25	CL, SICL, GR-CL	ML, CL	A-6, A-7
	9-48	4.5-5.5	0.24	B	15-23	CL, GR-SC, C	MH, CH, CL, SC	A-7, A-2
	48-80	4.5-5.5	0.24	B	8-28	L, SCL, CBV-C	SC, CL	A-2, A-4, A-6, A-7
BRADSON	0-6	4.5-6.0	0.20	B	NP-15	L, FSL, SL	SC, SM, ML	A-4, A-6
	0-6	4.5-6.0	0.15	B	NP-15	GR-L, GR-FSL, GR-SL	SM, SM-SC, SC	A-2
	6-65	4.5-6.0	0.24	B	11-25	CL, SC, C	ML, MH	A-7
	65-75	4.5-6.0	0.32	B	NP-10	L, SCL, SL	ML, CL-ML, CL	A-4
BRAGG	0-6	4.5-5.5	0.20	C	NP-4	LS, SL, SCL	SM	A-2, A-4
	6-30	4.5-5.5	0.28	C	3-25	SR-SL, CL	SM-SC, SC, CL	A-2, A-4, A-6, A-7-6
	30-72	4.5-5.5	0.28	C	3-18	SL, SCL, SC	SM, SC, ML, CL	A-4, A-6
	72-80			C	NP	Var		
BRANDYWINE	0-8	3.6-5.5	0.24	C	2-11	L	ML, SM	A-4, A-6
	0-8	3.6-5.5	0.20	C	2-11	GR-L	ML, SM, GM	A-2, A-4, A-6
	8-12	3.6-5.5	0.28	C	NP-10	GR-L, L	SM, ML, GM, GL-ML	A-2, A-4
	12-60	3.6-5.5	0.17	C	NP	GR-VCOS, GR-LS	GW, GP, GM-SP	A-1
BREVARD	0-4	4.5-6.0	0.24	B	NP-10	L, SIL	ML, CL, CL-ML	A-4
	0-4	4.5-6.0	0.15	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	4-76	4.5-6.0	0.24	B	5-15	SCL, CL, SICL	CL, CL-ML	A-4, A-6
	76-80	4.5-6.0		B	NP	GR-L	GM	A-1
BUCKS	0-15	4.5-5.5	0.32	B	3-10	SIL	ML, CL, CL-ML	A-4
	15-35	4.5-5.5	0.37	B	3-15	SIL, SICL, SH-L	ML, CL, SM, SC	A-4, A-6
	35-44	4.5-5.5	0.32	B	NP-10	SH-SIL, SIL, SICL	ML, CL, GM, SM	A-4, A-2
	44			B	NP	UWB		
BUNCOMBE	0-10	6.1-6.5	0.10	A	NP	LS, S	SM, SP-SM	A-2, A-3
	10-55	4.5-6.0	0.10	A	NP	LS, S	SM, SP-SM	A-2, A-3
	55-65			A	NP	Var		
BURTON	0-12	3.6-6.0	0.24	B	NP-7	L, FSL, SL	SM, SM-SC	A-2, A-4
	12-21	3.6-6.0	0.15	B	NP-7	L, FSL, SL	SM, SM-SC	A-2, A-4
	21-28	3.6-6.0	0.15	B	NP-3	FSL, SL	SM, GM, SP-SM	A-2, A-1-B
	28-29			B	NP	UWB		
BYARS	0-13	3.6-5.5	0.20	D	NP-7	SL, FSL	SM, ML	A-4
	0-13	3.6-5.5	0.28	D	11-23	SICL, CL, L	CL	A-6, A-7-6
	0-13	3.6-5.5	0.37	D	11-23	SIL	CL	A-6, A-7-6
	13-43	3.6-5.5	0.32	D	17-42	C, CL, SC	CL, CH	A-7-5, A-7-6, A-6
	43-73	3.6-5.5	0.32	D	8-20	C, SICL, SIC	CL	A-6, A-7, A-4
	73-79			D		Var		
CAHABA	0-9	4.5-6.0	0.24	B	NP	SL, FSL	SM	A-4, A-2-4
	0-9	4.5-6.0	0.15	B	NP	LS, LFS	SM	A-2
	0-9	4.5-6.0	0.28	B	NP-7	L	ML, CL-ML	A-4
	9-53	4.5-6.0	0.28	B	8-15	SCL, L, CL	SC, CL	A-4, A-6
	53-80	4.5-6.0	0.24	B	NP	S, LS, SL	SM, SP-SM	A-2-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
CAPE FEAR	0-16	4.5-6.5	0.15	D	3-15	L, SIL	ML. CL-ML, CL	A-4, A-6
	0-16	4.5-6.5	0.17	D	NP-10	FSL, VFSL	SM, SC, SM-SC	A-4
	16-52	4.5-6.0	0.32	D	15-35	CL, C, SIC	ML, CL, MH, CH	A-7
	52-62			D	NP	Var		
CAROLINE	0-9	3.6-5.5	0.43	C	NP-5	FSL, SL	SM, ML, CL-ML, SM-SC	A-2, A-4
	0-9	3.6-5.5	0.43	C	NP-7	L, SIL	ML, CL-ML	A-4
	0-9	3.6-5.5	0.43	C	15-40	CL, SCL	CL, CH	A-6, A-7
	9-84	3.6-5.5	0.32	C	18-40	CL, C, SIC	CL, CH	A-7
	84-99	3.6-5.5	0.32	C	5-40	CL, C, GR-FSL	SM-SC, SC, CL, CH	A-4, A-6, A-7
CARTECAY	0-9	5.1-6.5	0.24	C	NP	SL, LS	SM	A-2, A-4
	0-9	5.1-6.5	0.32	C	NP-15	L, SIL, SICL	ML, CL, CL-ML	A-4, A-6
	0-9	5.1-6.5	0.24	C	NP-5	VFSL, FSL	SM, SM-SC, ML	A-2, A-4
	9-40	5.1-6.5	0.24	C	NP-10	SL, FSL, L	SM, SC, SM-SC	A-2, A-4
	40-60	5.1-6.5	0.15	C	NP	LS, S, SL	SM, SP-SM	A-2, A-1
CARTERET	0-80	5.6-8.4	0.15	D	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-80	5.6-8.4	0.15	D	NP	S, FS	SP, SP-SM	A-3
CATAULA	0-7	5.1-6.5	0.17	B	NP-7	LS	SM, SM-SC	A-2
	0-7	5.1-6.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-7	5.1-6.5	0.32	B	NP-20	SCL, CL	CL, ML, SC, SM	A-4, A-6, A-7
	7-27	4.5-6.0	0.24	B	11-30	C, CL,SC	MH, ML, CL	A-7, A-6
	27-55	4.5-6.0	0.24	B	2-30	SCL, SC, CL	MH, ML	A-5, A-7
	55-75	4.5-6.0	0.32	B	20	SCL, CL, L	CL, ML, CL-ML, SC	A-4, A-6
CECIL	0-7	4.5-6.0	0.28	B	NP-6	SL, FSL, L	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.15	B	NP-4	GR-SL	GM, GM-GC, SM, SM-SC	A-2, A-1
	0-7	4.5-6.0	0.28	B	3-15	SCL, CL	SM, SC, CL, ML	A-4, A-6
	7-11	4.5-6.0	028	B	3-15	SCL, CL	SM, SC, ML, CL	A-4, A-6
	11-50	4.5-5.5	0.28	B	9-37	C	MH, ML	A-7, A-5
	50-75			B	NP	Var		
CHANDLER	0-4	4.5-6.0	0.15	B	12-26	L, FSL, SIL	ML, MH	A-7
	0-4	4.5-6.0	0.17	B	NP-7	ST-L, ST-FSL, ST-SIL	SM	A-4
	4-66	4.5-6.0	0.15	B	12-26	L, FSL, SIL	ML, MH	A-7
CHAPANOKE	0-6	3.6-6.5	0.43	C	NP-7	SIL, L	ML, CL-ML	A-4
	0-6	3.6-6.5	0.37	C	NP-7	FSL, VFSL	SM, ML, CL-ML, SM-SC	A-4
	6-50	3.6-6.5	0.43	C	6-30	SICL, L, CL	CL, CL-ML, ML	A-4, A-6, A-7
	50-62	3.6-6.5	0.37	C	NP-7	FSL, LFS	SM, SM-SC, ML	A-2, A-4
	62-80	3.6-6.5	0.20	C	NP-7	SR-S-L	SM, ML, SM-SC, CL-ML	A-2, A-4
CHASTAIN	0-5	4.5-6.0	0.32	D	3-18	SICL, SIL, L	ML, CL, CL-ML	A-4, A-6, A-7
	0-5	4.5-6.0	0.28	D	12-40	SIC, CL, C	ML, CL, MH, CH	A-6, A-7
	5-52	4.5-6.0	0.37	D	12-40	SICL, SIC, C	CL, CH, ML, MH	A-6, A-7
	52-72	4.5-6.0	0.10	D	NP	LS, S.FS	SP, SM, SP-SM	A-2, A-3
CHESTER	0-15	4.5-5.5	0.32	B	8-12	SIL, L	ML, CL	A-4, A-6, A-7
	0-15	4.5-5.5	0.28	B	8-12	CN-L, CN-SIL	ML, CL	A-4, A-6, A-7
	15-36	4.5-5.5	0.43	B	8-17	SICL, SIL, CN-L	ML, CL, SM, SC	A-4, A-6, A-7
	36-62	4.5-5.5	0.49	B	16	L	SM, SC, ML	A-2, A-4, A-7
CHEWACLA	0-8	4.5-6.5	0.24	C	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-8	4.5-6.5	0.28	C	4-20	SIL, L	ML, CL, CL-ML	A-4, A-6, A-7
	8-24	4.5-6.5	0.32	C	4-22	SIL, SICL, CL	ML, CL	A-4, A-6, A-7
	24-34	4.5-6.5	0.28	C	NP-7	SCL, L, SL	SM, CL-ML, SM-SC, ML	A-4
	34-58	4.5-6.5	0.32	C	4-28	SIL, CL, SICL	ML, MH	A-4, A-6, A-7
	58-70			C	NP	Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
CHIPLEY	0-6	3.6-6.0	0.10	C	NP	S, FS	SP-SM	A-3, A-2-4
	6-77	4.5-6.5	0.10	C	NP	S, FS	SP-SM	A-3, A-2-4
CHOWAN	0-6	3.6-6.0	0.32	D	4-24	L, SIL, SICL	CL-ML, ML, MH	A-7-5, A-4, A-6
	6-27	3.6-6.0	0.32	D	6-30	S, SIL, SICL	CL, MH, ML	A-7-5, A-4, A-6
	27-80	3.6-5.0		D	NP	SP	PT	
CLIFTON	0-5	4.5-6.5	0.17	B	NP-10	L, FSL	ML, CL, CL-ML	A-4
	0-5	4.5-6.5	0.17	B	5-12	CL	ML, CL, CL-ML	A-4, A-6
	0-5	4.5-6.5	0.17	B	NP-7	ST-L, ST-FSL	SM, CL-ML, SM-SC	A-4
	5-10	4.5-6.5	0.17	B	12-20	L, CL, SCL	SC, SM-SC	A-4, A-6
	10-45	4.5-6.5	0.17	B	12-25	C, CL	ML, MH	A-7
	45-65	4.5-6.5	0.17	B	NP-18	FSL, L	SM, ML, CL, SC	A-4
CODORUS	0-18	4.5-6.0	0.49	C	2-12	SIL, L	ML, CL, CL-ML	A-4, A-6
	18-54	5.1-6.5	0.37	C	2-12	SIL, L, SICL	ML, CL, CL-ML	A-4, A-6
	54-60	5.1-6.5	0.24	C	NP-7	SR-S-SI	SM, GM, ML	A-1, A-2, A-4
COLFAX	0-12	4.5-5.5	0.37	C	NP-10	L, SIL	ML, CL, CL-ML	A-4
	0-12	4.5-5.5	0.28	C	NP-10	SL, FSL	SM, SM-SC	A-2, A-4
	12-30	4.5-5.5	0.28	C	7-25	SCL, CL, L	SC, CL	A-4, A-6, A-7-6
	30-46	4.5-5.5	0.28	C	NP-20	SL, FSL, CL	ML, CL, SM, SC	A-2, A-4, A-6
	46-50	4.5-5.5	0.28	C	NP-10	SL	SM, SC, SM-SC	A-2, A-4
	50			C	NP	WB		
COMUS	0-30	4.5-6.0	0.43	B	6-15	SIL, L, FSL	ML, SM, CL, SC	A-2, A-4, A-6
	30-60	4.5-6.0	0.28	B	NP-20	SR-GR, SL-SICL	GM, SM, ML, CL	A-1, A-2, A-4, A-6
CONABY	0-13	3.6-5.5		B/D	NP	MUCK	PT	
	13-21	3.6-5.5	0.10	B/D	NP	S, LS, LFS	SM, SP-SM	A-2, A-3
	21-33	3.6-5.5	0.15	B/D	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-4
	33-74			B/D	NP	Var		
CONETOE	0-25	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-25	4.5-6.0	0.15	A	NP	S, FS	SM, SP-SM	A-2, A-3
	25-41	4.5-6.0	0.15	A	NP-10	SL, SCL	SM, SC, SM-SC	A-2, A-4
	41-80	4.5-6.0	0.10	A	NP	LS, S	SM, SP, SP-SM	A-2, A-3, A-1
CONGAREE	0-8	4.5-7.3	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-8	4.5-7.3	0.37	B	3-10	L, SIL	CL-ML, ML, CL	A-4
	8-38	4.5-7.3	0.37	B	3-22	SICL, FSL, L	SC, ML, CL, SM	A-4, A-6, A-7
	38-80			B	NP	Var		
COROLLA	0-72	5.6-7.8	0.10	D	NP	S, FS	SW, SP-SM, SP	A-2, A-3
COWARTS	0-8	4.5-5.5	0.15	C	NP	LS, LFS	SM	A-2
	0-8	4.5-5.5	0.24	C	NP-5	FSL, SL	SM, SM-SC	A-2, A-4
	8-19	4.5-5.5	0.28	C	NP-15	FSL, SL, SCL	SM-SC, SC, SM	A-2, A-4, A-6
	19-25	4.5-5.5	0.28	C	11-23	SCL, SC, CL	SM-SC, SM, SC	A-6, A-7
	25-60	4.5-5.5	0.24	C	5-20	SL, SCL, CL	SM-SC, SC, CL-ML, CL	A-2, A-4, A-6, A-7
COXVILLE	0-11	3.6-5.5	0.24	D	3-15	FSL, SL, L	SM, ML, CL-ML, CL	A-4, A-6, A-7
	11-72	3.6-5.5	0.32	D	12-35	CL, SC, C	CL, CH	A-6, A-7
	72-80			D	NP	Var		
CRAVEN	0-9	4.5-6.5	0.37	C	NP-7	L, FSL, SIL	ML, CL-ML, SM, SM-SC	A-4
	9-54	3.6-5.5	0.32	C	24-43	C, SIC, SICL	CH	A-7
	54-80	3.6-5.5	0.32	C	NP-15	SCL, LS, SL	SM, SM-SC, SC	A-2, A-4, A-6
CREEDMOOR	0-8	3.6-5.5	0.28	C	NP-7	SL, FSL, L	SM, SM-SC	A-4, A-2
	0-8	3.6-5.5	0.20	C	NP	LS	SM	A-2
	8-19	3.6-5.5	0.32	C	20-30	SCL, CL	CL	A-7
	19-56	3.6-5.5	0.32	C	25-49	C, SIC, SC	CH	A-7
	56-77	3.6-5.5	0.37	C	4-21	SL, SCL, L	ML, CL-ML, SM, SM-SC	A-7, A-6, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
CROATAN	0-28	4.5		D	NP	MUCK	PT	
	28-38	3.6-6.5	0.17	D	NP-10	SL, FSL, MK-SL	SM, SC, SM-SC	A-2, A-4
	38-60	3.6-6.5	0.24	D	4-15	L, CL, SCL	CL, CL-ML, SC, SM-SC	A-4, A-6
	60-80			D	NP	Var		
CURRITUCK	0-14	4.5-5.5		D	NP	MUCK, MPT	PT	A-8
	14-28	3.6-5.5		D	NP	MUCK	PT	A-8
	28-60	3.6-5.5		D	NP	LS, S	SM, SP-SM	A-2, A-3
DARE	0-70	3.6-4.4		D	NP	MUCK	PT	
	70-80	3.6-6.0	0.15	D	NP	SR-FS, LS	SM, SP-SM	A-2, A-3
DAVIDSON	0-7	4.5-6.5	0.28	B	3-15	L	CL, CL-ML, ML	A-4, A-6
	0-7	4.5-6.5	0.28	B	5-18	CL, SCL	CL, SC, CL-ML, SM-SC	A-6, A-4
	7-12	4.5-6.0	0.32	B	11-25	CL	CL	A-6
	12-53	4.5-6.0	0.24	B	12-33	C	CL, CH, ML, MH	A-7, A-6
	53-72	4.5-6.0	0.28	B	7-30	C, CL, SCL	CL, ML, MH	A-4, A-6, A-7
DELANCO	0-11	3.6-5.5	0.37	C	NP-15	SIL, FSL	ML, CL, SM ,SC	A-4, A-6
	11-36	3.6-5.5	0.32	C	10-25	SICL, CL, L	CL, ML	A-6, A-7
	36-50	3.6-5.5	0.28	C	NP-15	SR-GR-SL-SICL	ML, CL, SM, SC	A-2, A-4, A-6
DELOSS	0-18	4.5-6.5	0.15	B/D	NP-4	LFS	SM	A-2
	0-18	4.5-6.5	0.24	B/D	NP-7	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-2, A-4
	18-56	4.5-5.5	0.24	B/D	4-22	SCL, CL, FSL	SM-SC, SC, CL-ML, CL	A-4, A-6, A-7
	56-80			B/D	NP	Var		
DOROVAN	0-3	3.6-4.4		D	NP	MPT, MUCK	PT	
	3-74	3.6-4.4		D	NP	MUCK	PT	
	74-99	4.5-5.5		D	NP-7	S, LS,L	SP-SM, SM-SC, SM	A-1, A-3, A-4, A-2-4
DOTHAN	0-13	4.5-5.5	0.15	B	NP	LFS, LS	SM	A-2
	0-13	4.5-5.5	0.24	B	NP-5	FSL, SL	SM, SM-SC	A-2, A-4
	13-33	4.5-5.5	0.28	B	NP-16	SCL, SL, FSL	SM-SC, SC, SM	A-2, A-4, A-6
	33-60	4.5-5.5	0.28	B	4-23	SCL, SC	SM-SC, CL-ML, CL	A-2, A-4, A-6, A-7
DRAGSTON	0-9	4.5-5.5	0.20	C	NP-8	FSL, SL, L	SM, SC, SM-SC, CL-ML	A-2, A-4
	0-9	4.5-5.5	0.17	C	NP-7	LFS, LS	SM, SM-SC	A-2
	9-37	4.5-5.5	0.17	C	NP-10	FSL, SL, L	SM, SC, SM-SC, CL-ML	A-2, A-4
	37-66	4.5-6.5	0.17	C	NP-7	S, LS, FSL	SM, SP-SM, SM-SC	A-1, A-2, A-3
DUCKSTON	0-72	3.6-8.4	0.10	A/D	NP	S, FS	SP-SM, SP	A-3
DUNBAR	0-8	4.5-5.5	0.32	D	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-4
	8-80	3.6-5.5	0.32	D	18-35	SC, CL, C	CL, CH	A-6, A-7
DUPLIN	0-8	5.1-7.3	0.24	C	NP-7	SL, FSL, LS	SM, SM-SC	A-2, A-4
	8-80	4.5-5.5	0.28	C	13-35	SC, CL, C	CL, CH, SC	A-6, A-7
DURHAM	0-16	4.5-6.0	0.17	B	NP-3	LCOS, LS	SM	A-2
	0-16	4.5-6.0	0.24	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	16-36	4.5-5.5	0.20	B	10-25	SCL, CL	SC, CL	A-2, A-6, A-7
	36-42	4.5-5.5	0.20	B	13-28	CL, SC, SCL	SC, CL	A-6, A-7
	42-48	4.5-5.5	0.20	B	NP-10	SCL, SL	SM, SC, SM-SC	A-2, A-4
	48-60	4.5-5.5	0.17	B	NP-7	LS, SL, SCL	SM, SM-SC	A-2, A-4
EDNEYVILLE	0-10	4.5-6.0	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-10	4.5-6.0	0.28	B	NP-10	L, SIL	ML, CL-ML, CL	A-4
	10-60	4.5-6.0	0.20	B	6-15	FSL, SL, L	SM, SM-SC	A-2, A-4, A-6

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
ELBERT	0-11	4.5-5.5	0.49	D	14.20	SIL, L, SICL	CL	A-6
	11-41	4.5-5.5	0.24	D	55-65	C	CH	A-7
	41-52	6.1-7.3	0.24	D	26-32	SC, CL, C	MH, CH, SC, SM	A-7
	52-61	6.1-7.3	0.24	D	12-18	SL, GR-SL	SCL, SC	A2
	61			D	NP	WB		
ELIOAK	0-15	4.5-6.0	0.32	C	5-20	SIL, CL, FSL	ML, CL, SM	A-4, A-6, A-7
	15-42	4.5-5.5	0.28	C	11-26	SICL, CL, SIC	CL, CH, MH, ML	A-6, A-7
	42-60	4.5-5.5	0.49	C	NP-10	SIL, L, GR-FSL	ML, SM, GM	A-4, A-5, A-2
ELSINBORO	0-15	4.5-5.5	0.37	B	5-10	SIL, L, SL	ML, CL, SM, SC	A-2, A-4
	15-36	4.5-5.5	0.28	B	2-20	SICL, SIL, L	ML, CL	A-4, A-6, A-7
	36-60	4.5-5.5	0.17	B	2-20	SR, GR-SL, SCL	SM, SC, ML, CL	A-2, A-4, A-6, A-7
ENGLEHARD	0-72	3.6-5.5	0.49	B/D	NP-4	SI, SIL,VFSL	ML	A-4
ENON	0-8	5.1-6.5	0.28	C	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	0-8	5.1-6.5	0.24	C	4-20	L, CL, SCL	CL, CL-ML	A-4, A-6
	8-33	5.1-7.8	0.28	C	25-52	CL, C	CH	A-7-6
	33-75			C	NP	WB		
EUSTIS	0-6	4.5-5.5	0.10	A	NP	S, FS	SP-SM, SM	A-3, A-2-4
	0-6	4.5-5.5	0.10	A	NP	LS, LFS	SP-SM, SM	A-3, A-2-4
	6-24	4.5-5.5	0.17	A	NP	S, FS, LFS	SP-SM, SM	A-3, A-2-4
	24-76	4.5-5.5	0.17	A	NP	LFS, LS	SM	A-2-4
	76-98	4.5-5.5	0.17	A	NP	S, FS	SP-SM	A-3, A-2-4
EXUM	0-12	4.5-6.0	0.37	C	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-80	4.5-5.5	0.37	C	8-30	L, CL, SICL	CL	A-4, A-6, A-7
FACEVILLE	0-5	4.5-5.5	0.17	B	NP	LS, LFS	SM	A-2
	0-5	4.5-5.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-5	4.5-5.5	0.32	B	NP-7	SCL	SM, CL-ML, ML, SM-SC	A-4
	5-11	4.5-5.5	0.37	B	NP-13	SCL, SC	SC, ML, CL, SM	A-4, A-6
	11-72	4.5-6.0	0.37	B	11-25	SC, C, CL	CL, SC, CH	A-6, A-7
FANNIN	0-7	4.5-6.0	0.24	B	8-18	L, SIL, FSL	CL, SC	A-4, A-6
	0-7	4.5-6.0	0.24	B	NP-10	CB-L, CB-SIL, CB-FSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	7-32	4.5-6.0	0.24	B	5-23	CL, SCL, SICL	ML, MH, SM	A-4, A-7
	32-60	4.5-6.0	0.24	B	NP-10	L, SL, FSL	SM, ML	A-2, A-4
FLETCHER	0-11	4.5-5.5	0.43	B	3-8	SIL	ML, CL-ML, CL	A-4
	11-32	4.5-5.5	0.43	B	5-15	SIL, SICL	CL, CL-ML	A-4, A-6
	32-44	4.5-5.5	0.43	B	3-8	SIL	CL, CL-ML, CL	A-4
	44			B	NP	UWB		
FRENCH	0-12	5.1-6.5	0.28	C	4-18	L	CL-ML, SM-SC, CL	A-4, A-6
	0-12	5.1-6.5	0.24	C	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	12-30	5.1-6.5	0.32	C	7-25	FSL, SCL, CL	SM, SM-SC, SC, CL	A-4, A-6, A-7
	30-60			C	NP	SR-S-G		
FUQUAY	0-34	4.5-6.0	0.15	B	NP	LS, LFS	SP-SM, SM	A-2, A-3
	0-34	4.5-6.0	0.10	B	NP	S, FS	SP-SM, SM	A-1, A-2, A-3
	34-45	4.5-6.0	0.20	B	NP-13	SL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	45-96	4.5-6.0	0.20	B	4-12	SCL	SC, SM-SC, CL-ML	A-2, A-4, A-6, A-7-6
	96-99			B	NP	Var		
GEORGEVILLE	0-6	4.5-6.0	0.32	B	NP-10	SIL, L, VFSL	ML	A-4
	0-6	4.5-6.0	0.32	B	11-20	SICL, CL	CL, ML	A-6, A-7
	6-10	4.5-5.5	0.32	B	8-20	SICL, CL	CL, ML	A,6, A-7, A-4
	10-53	4.5-5.5	0.28	B	15-35	C, SIC, SICL	MH, ML	A-7
	53-63	4.5-5.5	0.32	B	NP-12	SICL, L, SIL	ML, CL, CL-ML	A-4, A-6

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
GILEAD	0-5	4.5-5.5	0.17	C	NP	LS, GR-LS	SP-SM, SM	A-2
	0-5	4.5-5.5	0.20	C	NP-4	SL, GR-SL	SM	A-2, A-4
	5-8	4.5-5.5	0.24	C	4-16	SL, SCL	SM-SC, SC	A-2, A-4, A-6
	8-42	4.5-5.5	0.28	C	18-30	SC, CL, C	SC, CL	A-6, A-7
	42-72	4.5-5.5	0.24	C	11-20	SL, SCL	SC, CL	A-2, A-6
	72-82	4.5-5.5		C		Var		
GOLDSBORO	0-15	4.5-6.0	0.20	B	NP-14	LS, SL, FSL	SM, SM-SC, SC	A-2, A-4, A-6
	15-45	4.5-5.5	0.24	B	4-18	SCL, SL	SM-SC, SC, CL-ML, CL	A-2, A-4, A-6
	45-65	4.5-5.5	0.24	B	6-32	SCL, CL, SC	SC, CL, CL-ML, CH	A-4, A-6, A-7-6
	65-76			B	NP	Var		
GOLDSTON	0-16	3.6-5.5	0.15	C	NP-10	CN-SIL, CN-VFSL	GM, GM-GC, SM,ML	A-2-4, A-4
	0-16	3.6-5.5	0.20	C	NP-7	CNV-SIL, CNV-VFSL	GM, GM-GC, SM, ML	A-2-4, A-4
	16-36			C	NP	WB		
	36			C	NP	UWB		
GRANTHAM	0-11	4.5-5.5	0.37	D	NP-7	VFSL, L, SIL	ML, CL-ML	A-4
	11-80	3.6-5.5	0.43	D	8-30	L, CL, SICL	CL	A-4, A-6, A-7
GRANVILLE	0-16	4.5-5.5	0.17	B	NP	LS, COSL	SM	A-2, A-1
	0-16	4.5-5.5	0.24	B	NP-3	SL, FSL	SM	A-2, A-4, A-1
	16-45	4.5-5.5	0.20	B	9-25	CL, SCL	SC	A-4, A-6, A-7
	45-60	4.5-5.5	0.17	B	NP-7	SL, L, SCL	SM, SM-SC	A-2, A-4
GRIFTON	0-15	4.5-6.5	0.20	D	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-15	4.5-6.5	0.17	D	NP-4	LS, LFS	SM, SP-SM	A-2
	15-58	4.5-6.5	0.24	D	8-15	SL, SCL, CL	SC, CL	A-4, A-6
	58-70			D	NP	Var		
GROVER	0-9	4.5-6.5	0.24	B	NP-10	SL, FSL, COSL	SM, SM-SC, SC	A-4
	0-9	4.5-6.5	0.28	B	7-20	SCL	SC, CL	A-4, A-6
	9-38	4.5-5.5	0.32	B	12-30	SCL, CL	SM, ML, MH	A-6, A-7
	38-68	4.5-5.5	0.32	B	NP-7	SL, L, SCL	SM, SM-SC	A-4
GWINNETT	0-7	5.1-6.5	0.28	B	NP-15	SL, L	SM, SC, SM-SC, ML	A-2, A-4, A-6
	0-7	5.1-6.5	0.28	B	4-12	SCL, CL	SC, ML, SM-SC, CL-ML	A-4, A-6
	0-7	5.1-6.5	0.17	B	NP-15	GR-SL, GR-SCL	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B
	7-35	5.1-6.5	0.28	B	16-30	C, SC	MH, ML, CL, CH	A-7, A-6
	35-45			B	NP	WB		
HARTSELLS	0-13	3.6-5.5	0.28	B	NP-7	FSL, L	SM, ML, SM-SC, CL	A-4
	13-30	3.6-5.5	0.32	B	NP-15	FSL, L, SCL	SM-SC, SC, CL-ML, CL	A-4, A-6
	30-36	3.6-5.5	0.32	B	NP-15	SL, L, SCL	SM-SCSC, CL-MLCL	A-2, A-4, A-6
	36			B	NP	UWB		
HATBORO	0-9	4.5-7.3	0.49	D	2-12	SIL, L, SL	ML, CL, SC, SM	A-4, A-6
	9-44	4.5-7.3	0.32	D	2-12	SIL, SICL, SCL	ML, CL, CL-ML	A-4, A-6
	44-56	5.6-6.5	0.20	D	2-10	SCL, SL, SIL	ML, CL, SC, SM	A-4
	56-70	5.6-6.5	0.20	D	NP-14	SR-C-GS	SM, SC, GM,GC	A-1, A-2
HAYESVILLE	0-5	4.5-6.0	0.20	B	NP-10	L, FSL, VFSL	SM, SC, ML, CL	A-4
	5-38	4.5-6.0	0.24	B	11-35	CL, C	ML, MH, CH, CL	A-6, A-7
	38-48	4.5-6.0	0.20	B	11-25	SCL, CL	SM, ML, MH, CL	A-6, A-7
	48-60	4.5-6.0	0.17	B	NP-12	FSL, L, SCL	SM, ML, CL, SC	A-4, A-6
HAYWOOD	0-60	5.1-6.5	0.24	B	NP-10	SL, FSL, L	SM, ML, SC, CL	A-4
	0-60	5.1-6.5	0.15	B	NP-7	GR-L, GR-FSL, GR-SL	SM, ML, SM-SC, CL-ML	A-2-4, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1]		
						USDA	Unified	AASHTO
HELENA	0-12	4-5-6.0	0.15	C	NP-9	SL, FSL, L	SM, SM-SC, SC	A-2, A-4
	0-12	4.5-6.0	0.20	C	NP	LS, LCOS	SM	A-2, A-1-B
	0-12	4.5-6.0	0.28	C	15-25	SCL, CL	CL	A-6, A-7
	12-19	4.5-5.5	0.28	C	15-26	SCL, CL, SL	CL, SC	A-6, A-7
	19-43	4.5-5.5	0.28	C	24-50	CL, SC, C	CH	A-7
	43-60			C	NP	Var		
HERNDON	0-9	4.5-6.5	0.24	B	NP-5	ST-L, ST-SIL, ST-VFSL	ML	A-4
	0-9	4.5-6.5	0.43	B	NP-12	L, SIL, VFSL	ML, CL, CL-ML	A-4, A-6
	0-9	4.5-6.5	0.49	B	11-20	SICL	CL, ML	A-6, A-7
	9-48	3.6-5.5	0.28	B	13-30	SICL, SIC, C	MH, ML	A-7
	48-68	3.6-5.5	0.32	B	9-36	SIL, L, FSL	MH, ML	A-7, A-5
HIBRITEN	0-8	4.5-5.5	0.20	C	NP-10	CBV-SL, CB-SL	GM	A-2, A-1-B
	0-8	4.5-5.5	0.20	C	NP-10	CBV-FSL, CB-FSL	GM	A-2
	8-12	4.5-5.5	0.20	C	NP-18	CBV-FSL, CBV-SL, CBV-SCL	GM, GC, SM	A-2, A-1-B
	12-22	4.5-5.5	0.20	C	NP-18	CBV-CL, CBV, SCL	GC, SM	A-2, A-2-4
HIWASSEE	0-7	4.5-6.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-4, A-2
	0-7	4.5-6.5	0.32	B	NP-7	SIL	ML	A-4, A-2
	0-7	4.5-6.5	0.28	B	5-23	CL, SCL, L	CL, ML, CL-ML	A-7-6, A-6, A-4
	7-61	4.5-6.5	0.28	B	12-36	C, SIC, CL	CL, ML, MH	A-7-5, A-7-6, A-6
	61-70	4.5-6.5	0.28	B	4-20	SL, L, SCL	SM, ML, SM-SC, ML	A-4, A5, A-6, A-7
HULETT	0-13	4.5-6.0	0.32	B	NP-7	FSL, SL, L	SM, SM-SC, ML	A-2, A-4
	0-13	4.5-6.0	0.15	B	NP-7	GR-FSL, GR-SL, GR-L	SM, SM-SC, ML	A-2, A-4
	0-13	4.5-6.0	0.32	B	4-17	SCL, CL	ML, CL, CL-ML	A-4
	36-60			B	NP	WB		
HYDE	0-17	3.6-5.5	0.17	B/D	NP-7	L, SIL, VFSL	CL-ML, ML	A-4
	17-54	3.6-5.5	0.43	B/D	7-20	CL, L, SICL	CL	A-6, A-4, A-7
	54-72			B/D	NP	Var		
IOTLA	0-10	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	10-31	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	31-35	5.1-7.3	0.10	B	NP	LS, S	SM, SP-SM	A-2
	35-60	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
IREDELL	0-7	5.1-7.3	0.24	C/D	2-10	GR-L, ST-L	SM, SC, ML, GM	A-2-4, A-4
	0-7	5.1-7.3	0.28	C/D	NP-9	FSL, SL	SM, SM-SC, SC	A-2-4, A-4
	0-7	5.1-7.3	0.32	C/D	5-12	L, SIL, CL	ML, CL-ML, CL	A-4, A-6
	7-24	6.1-7.3	0.20	C/D	29-85	C	CH	A-7
	24-27	6.1-7.8	0.28	C/D	20-39	L, SCL, CL	CL, CH, SC	A-7
	27-62			C/D	NP	Var		
IUKA	0-13	5.1-6.0	0.17	C	NP	LS, LFS	SM	A-2
	0-13	5.1-6.0	0.24	C	NP-7	FSL, SL	SM, SM-SC, ML, CL-ML	A-4, A-2
	0-13	5.1-6.0	0.37	C	NP-7	L, SIL	ML, CL-ML	A-4
	13-22	4.5-5.5	0.28	C	NP-7	FSL, L, SL	SM, SM-SC, ML, CL-ML	A-4
	22-60	4.5-5.5	0.20	C	NP-7	SL, FSL, L	SM, ML	A-2, A-4
IZAGORA	0-11	3.6-6.0	0.28	C	NP-5	VFSL, FSL, SL	SM, SM-SC, ML, CL-ML	A-4
	0-11	3.6-6.0	0.20	C	NP	LS, LFS	SM, SP-SM	A-2, A-4
	0-11	3.6-6.0	0.37	C	NP-10	L, SIL	CL, CL-ML, ML	A-4
	11-46	3.6-5.5	0.32	C	8-25	L, CL, SICL	CL	A-4, A-6, A-7
	46-91	3.6-5.5	0.32	C	20-40	CL, C	CL, CH	A-6, A-7
JOHNS	0-15	4.5-5.5	0.15	C	NP	LS, LFS	SM, SM-SC	A-2, A-4
	0-15	4.5-5.5	0.20	C	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	15-32	4.5-5.5	0.24	C	5-25	SCL, SL, CL	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6, A-7
	32-60	4.5-5.5	0.10	C	NP	S, LS	SM, SP-SM, SP	A-2, A-3

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
JOHNSTON	0-30	4.5-5.5	0.17	D	2-14	MK-L	OL, ML, CL-ML	A-8, A-4,A-5
	0-30	4.5-5.5	0.20	D	NP-10	L, SL, FSL	ML, SM	A-2, A-4
	30-34	4.5-5.5	0.17	D	NP	SR-S-S	SM, SP-SM	A-2, A-3
	34-60	4.5-5.5	0.17	D	NP-10	SR-FSL-SL	SM	A-2, A-4
KALMIA	0-14	4.5-6.0	0.15	B	NP	LS, LFS	SM, SM-SC, SC	A-2
	0-14	4.5-6.0	0.20	B	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	14-32	4.5-5.5	0.24	B	4-15	SCL	SC, SM-SC	A-2, A-4, A-6
	32-60	4.5-5.5	0.10	B	NP	LS, S	SM, SP-SM, SP	A-2, A-3
KENANSVILLE	0-24	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-1, A-2
	0-24	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM	A-2, A-2
	24-36	4.5-6.0	0.15	A	NP-10	SL, FSL	SM, SC, SM-SC	A-2, A-4
	36-80	4.5-6.0	0.10	A	NP	S, LS	SP-SM, SM	A-1, A-2, A-3
KERSHAW	0-80	4.5-6.0	0.10	A	NP	S, COS, FS	SP, SP-SM, SW	A-2, A-3
KINSTON	0-12	4.5-6.0	0.24	B/D	NP-10	FSL	SM, SC SM-SC	A-2, A-4
	0-12	4.5-6.0	0.37	B/D	4-15	L, SIL	ML, CL, CL-ML	A-4, A-6
	12-60	4.5-5.5	0.32	B/D	8-22	L, CL, SCL	CL	A-4, A-6, A-7
	60-72			B/D	NP	Var		
KUREB	0-80	4.5-7.3	0.10	A	NP	S, COS, FS	SP, SP-SM	A-3
LAKELAND	0-43	4.5-6.0	0.10	A	NP	S, FS	SP-SM	A-3, A-2-4
	43-80	4.5-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3, A-2-4
LEAF	0-9	3.6-5.5	0.32	D	5-15	SIL, VFSL	ML, CL	A-4, A-6
	0-9	3.6-5.5	0.28	D	5-12	FSL, L	ML	A-4, A-6
	9-72	3.6-5.5	0.32	D	20-38	SICL, SIC, C	CL, CH	A-7
LEAKSVILLE	0-9	5.1-6.5	0.43	D	6-16	SIL, L, SICL	ML, CL-ML	A-4, A-6
	9-18	6.1-7.8	0.24	D	35-75	CL, C, SIC	CH	A-7
	18-24	6.1-7.8	0.24	D	20-45	CL, SICL	CL, CH	A-7
	24-30			D		WB		
	30			D		UWB		
LENOIR	0-8	4.5-5.5	0.37	D	4-10	L, SIL, VFSL	ML, CL, CL-ML	A-4
	8-75	4.5-5.5	0.32	D	11-35	C, SIC, CL	CL, CH	A-6, A-7
LEON	0-15	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
	15-30	3.6-5.5	0.15	B/D	NP	S, FS, LS	SM, SP-SM, SP	A-3, A-2-4
	30-80	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
LIDDELL	0-8	4.5-5.5	0.43	B/D	2-10	L, SIL, VFSL	ML, CL-ML	A-4
	8-65	4.5-5.5	0.43	B/D	2-10	L, SIL, VFSL	ML, CL-ML	A-4
LILLINGTON	0-16	4.5-6.0	0.15	B	NP	GR-LS, GR-SL	GM, GP-GM, SM, SP-SM	A-1, A-2
	16-44	4.5-5.5	0.15	B	NP-10	GR-SCL, GR-CL	GM, GC, SM, SC	A-1, A-2, A-4
	44-80	4.5-5.5	0.10	B	NP	SR-GRV-LS-GRV-SCL	GM, SM	A-1, A-2
LOCKHART	0-6	5.1-6.5	0.15	B	NP	GR-LS, GR-SL	GM, GP-GM, SM, SP-SM	A-1, A-2
	6-54	5.1-6.5	0.17	B	5-15	GR-SCL, GR-L	GC, GM-GC, SC, SM-SC	A2, A-4, A-6
	54-72			B		Var		
LOUISA	0-4	4.5-6.0	0.17	B	NP	GR-L, GR-SL, GR-FSL	SM	A-1, A-2, A-4
	0-4	4.5-6.0	0.28	B	NP	L, SL, FSL	SM, ML	A-2, A-4
	4-15	4.5-6.0	0.24	B	NP	GR-L, GR-SL	SM	A-2, A-4
	15-60			B		WB		
LOUISBURG	0-7	4.5-6.0	0.10	B	NP	LS, LCOS	SM	A-2, A-1-B
	0-7	4.5-6.0	0.24	B	NP-6	SL, FSL	SM, SM-SC	A-2
	7-24	4.5-6.0	0.24	B	NP-7	SL	SM, SM-SC	A-2, A-4
	24-60			B		WB		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	----Textural Classification[1]---- USDA	Unified	AASHTO
LUCY	0-24	5.1-6.0	0.15	A	NP	LS, S, LFS	SM, SP-SM	A-2
	24-35	4.5-5.5	0.24	A	NP-15	SL, FSL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	35-70	4.5-5.5	0.28	A	3-20	SL, SCL, CL	SC, SM-SC, SM	A-2, A-6, A-4
LUMBEE	0-14	4.5-5.5	0.24	B/D	NP-7	LS, SL, FSL	SM, SM-SC	A-2, A-4
	14-36	4.5-5.5	0.32	B/D	7-25	SCL, SL, CL	SC, CL	A-4, A-6, A-7
	36-60	4.5-5.5	0.10	B/D	NP	LS, S. FS	SP, SM, SP-SM	A-2, A-3
LYNCHBURG	0-10	3.6-5.5	0.15	C	NP-4	LS, LFS	SM, SP-SM	A-2
	0-10	3.6-5.5	0.20	C	NP-7	SL, FSL, L	SM, ML, SM-SC, CL-ML	A-2, A-4
	10-62	3.6-5.5	0.20	C	4-18	SCL, SL, CL	SM-SC, SC, CL, CL-ML	A-2, A-4, A-6
LYNN HAVEN	0-16	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM, SM	A-3, A-2-4
	16-30	3.6-5.5	0.15	B/D	NP	S, FS, LS	SM, SP-SM	A-3, A-2-4
	30-75	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
MADISON	0-6	4.5-6.0	0.24	B	NP-8	FSL, SL	SM, SM-SC	A-2, A-4
	0-6	4.5-6.0	0.15	B	NP-7	GR-FSL, GF-SL	SM, SM-SC	A-2, A-4
	0-6	4.5-6.0	0.28	B	7-20	CL, SCL	CL	A-4, A-6
	6-30	4.5-5.5	0.32	B	12-43	C, CL, SC	MH, ML	A-7
	30-35	4.5-6.0	0.28	B	7-20	L, SCL, CL	CL	A-4, A-6
	35-66			B		WB		
MANTACHIE	0-11	4.5-5.5	0.37	C	NP-10	SIL	ML, CL-ML, CL	A-4
	0-11	4.5-5.5	0.28	C	5-15	CL	CL-ML, CL	A-4, A-6
	0-11	4.5-5.5	0.28	C	NP-5	FSL, SL, L	CL-ML, SM-SC, SM, ML	A-4
	11-61	4.5-5.5	0.28	C	5-15	L, CL, SCL	CL, SC, SM-SC, CL-ML	A-4, A-6
MANTEO	0-6	3.6-5.5	0.28	C/D	2-15	CN-SIL, CN-L	GM, ML, CL, GC	A-4
	0-6	3.6-5.5	0.28	C/D	2-15	CN-VSIL, CN-VL	GM, ML, CL, GC	A-1, A-2, A-4, A-6
	6-15	3.6-5.5	0.28	C/D	2-20	CN-VSIL, CN-SIL, CN-CL	GM GC , ML, CL	A-1, A-2, A-4, A-6
	15			C/D		UWB		
MARLBORO	0-9	5.1-6.5	0.15	B	NP-4	LS, LFS	SM	A-2
	0-9	5.1-6.5	0.20	B	NP-7	SL, FSL, VFSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	9-60	4.5-6.0	0.20	B	6-20	SC, CL,C	CL, ML, CL-ML	A-4, A-6, A-7
	60-72	4.5-6.0	0.20	B	6-20	SCL, SC, C	CL, ML, SM-SC	A-4, A-6, A-7
MASADA	0-10	4.5-5.5	0.32	C	NP-8	FSL, L	ML, SM, SC, CL	A-4, A-6
	10-55	4.5-5.5	0.24	C	20-35	CL, C, GR-C	CH, CL	A-7, A-6
	55-72	4.5-5.5	0.24	C	15-25	L, CL, GR-SCL	CL, ML	A-6, A-7, A-4
MATTAMUSKEET	0-22	4.5		D	NP	MUCK	PT	
	22-72	3.6-5.5		D	NP	LS, S, FS	SM, SP-SM	A-2, A-3
MAXTON	0-12	4.5-6.0	0.20	B	NP-7	SL, FSL	SM, SM-SC	A-2
	0-12	4.5-6.0	0.15	B	NP	LS, LFS	SM, SP-SM	A-2
	12-33	4.5-5.5	0.24	B	4-15	SCL, SL	SC, SM-SC	A-4, A-6, A-2
	33-60	4.5-5.5	0.10	B	NP	SR-LS-S	SM, SP-SM, SP	A-2, A-3
MAYODAN	0-12	4.5-6.0	0.24	B	NP-5	SL, FSL, SIL	SM, ML, SM-SC	A-2, A-4
	0-12	4.5-6.0	0.15	B	NP-4	GR-SL, GR-FSL	GP-GM, GM ,SM, SP-SM	A-1
	0-12	4.5-6.0	0.32	B	7-26	CL, SCL	CL, SC	A-4, A-6, A-7-6
	12-18	4.5-6.0	0.32	B	7-26	SICL, CL, SCL	CL, ML, SC	A-4, A-6, A-7-6
	18-47	4.5-5.5	0.28	B	15-45	C, SC, SIC	MH, CH, CL, ML	A-7
	47-60	4.5-5.5		B		Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
MCCOLL	0-9	4.5-7.3	0.24	D	4-12	SL, FSL	SC, SM-SC	A-2
	0-9	4.5-7.3	0.24	D	5-20	SCL, CL, L	SC, CL-ML, CL, SM-SC	A-4, A-6
	9-13	4.5-5.5	0.24	D	8-23	CL, SC, C	SC, CL	A-4, A-6, A-7
	13-42	4.5-5.5	0.24	D	3-15	SCL, CL, SC	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6
	42-80	4.5-5.5	0.32	D	3-22	SCL, SL, SC	SM, SC, SM-SC	A-2, A-4, A-6, A-7
MECKLENBURG	0-8	5.6-7.3	0.24	C	NP-15	L, FSL, SL	ML, SM	A-4, A-6, A-7-6
	0-8	5.6-7.3	0.17	C	NP-12	GR-L, GR-SL, GR-FSL	GM, SM, GP-GM, SP-SM	A-2, A-1
	0-8	5.6-7.3	0.28	C	11-25	CL, SCL	CL	A-6, A-7-6
	8-25	5.6-7.3	0.32	C	24-45	C	CH, MH	A-7
	25-36	5.6-7.3	0.32	C	11-25	L, SCL, CL	CL, ML	A-4, A-6, A-7
	36-60			C		WB		
MEGGETT	0-8	4.5-6.5	0.24	D	NP	FSL, SL, LS	SM	A-2, A-4
	0-8	4.5-6.5	0.28	D	NP-10	L, CL	ML, CL-ML	A-4
	8-16	5.1-8.4	0.32	D	20-30	C, SC, CL	CH, MH, CL	A-6, A-7
	16-52	6.1-8.4	0.32	D	20-30	C, SC, CL	CH, MH, CL	A-6, A-7
	52-65	6.1-8.4	0.28	D	NP-25	SC, CL, SCL	CL, SC, SM	A-4, A-6
MISENHEIMER	0-14	3.6-5.5	0.20	B	NP-10	CN-SIL, CN-L	GM, SM, ML	A-4
	14-25			B		WB		
	25			B		UWB		
MOLENA	0-7	4.5-6.5	0.10	A	NP	S, LS	SM, SP-SM	A-2, A-3
	7-51	4.5-6.0	0.17	A	NP	LFS, LS	SM, SP-SM	A-2, A-3
	51-60	4.5-6.0	0.15	A	NP	S, COS, GR-S	SP, SP-SM	A-2, A-3
MURVILLE	0-8	3.6-5.5	0.10	A/D	NP	FS, S, LFS	SP-SM, SM	A-2, A-3
	8-45	3.6-5.5	0.10	A/D	NP	FS, S, LFS	SM, SP-SM	A-2
	45-56	3.6-5.5	0.10	A/D	NP	FS, S	SP-SM, SP	A-2, A-3
	56-70			A/D		Var		
MUSELLA	0-4	5.1-6.5	0.20	B	NP-10	GR-CL, GR-SCL	SM, SC, SM-SC	A-2, A-4
	0-4	5.1-6.5	0.32	B	NP-10	CL, SCL	SM, SC, SM-SC, ML	A-4
	4-14	5.1-6.5	0.32	B	11-20	GR-CL, CL	ML, CL, SM, SC	A-6, A-7
	14-18	5.1-6.5	0.28	B	8-15	CRV-CL	SM, SC, GC	A-4, A-6
	18-60			B		WB		
MYATT	0-10	4.5-6.0	0.28	D	NP-5	FSL, SL, VFSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	0-10	4.5-6.0	0.32	D	NP-5	SIL, L	ML, CL-ML	A-4
	0-10	4.5-5.5	0.20	D	NP-4	LS, LFS	SM, SM-SC, CL-ML	A-2
	10-50	3.6-5.5	0.28	D	NP-10	L, SCL, CL	SM, SC, ML, CL	A-4
	50-72	3.6-5.5	0.24	D	5-20	GR, FSL, SCL, CL	SM-SC, SC, CL-ML, CL	A-6, A-4, A-2
NAHUNTA	0-12	4.5-6.0	0.43	C	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-79	3.6-5.5	0.43	C	8-30	L, CL, SICL	CL	A-4, A-6, A-7
NASON	0-9	4.5-6.5	0.37	C	NP-10	L, SIL, FSL	ML, CL-ML, SM	A-4
	0-9	4.5-6.5	0.37	C	11-20	SICL	CL	A-6, A-7
	9-38	4.5-5.5	0.28	C	15-30	SICL, SIC, C	CL, CH, MH	A-7
	38-50	4.5-5.5	0.28	C	4-12	CN-SIL, SIL, L	CL-ML, SC, GM-GC	A-2, A-4, A-6
	50			C		WB		
NEWHAN	0-64	3.6-7.8	0.10	A	NP	FS, S	SP	A-3
NIXONTON	0-34	5.1-6.5	0.37	B	NP-7	VFSL, L, SIL	CL-ML, ML	A-4
	34-80	5.1-6.5	0.32	B	NP	LFS, LS, FS	SM, SP-SM	A-2

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
NORFOLK	0-17	4.5-6.0	0.17	B	NP-14	SL, FSL	SM, SM-SC, SC	A-2
	0-17	4.5-6.0	0.20	B	NP	LS, LFS	SM	A-2
	17-38	4.5-5.5	0.24	B	4-15	SL, SCL, CL	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6
	38-70	4.5-5.5	0.24	B	4-23	SCL, SC, CL	SC, SM-SC, CL, CL-ML	A-4, A-6, A-7-6
	70-99			B		Var		
OAKBORO	0-10	4.5-6.5	0.28	C	NP-10	SIL, L	ML, CL-ML, CL	A-4, A-6
	10-46	4.5-6.5	0.28	C	NP-15	L, SIL, SICL	ML, CL-ML, CL	A-4, A-6
	46			C		UWB		
OCHLOCKONEE	0-6	4.5-5.5	0.20	B	NP-5	FSL, SL	SM, ML, SM-SC, CL-ML	A-4, A-2
	0-6	4.5-5.5	0.24	B	NP-7	SIL, L	ML, CL-ML	A-4
	0-6	4.5-5.5	0.17	B	NP	LS, LFS	SM	A-2, A-4
	6-44	4.5-5.5	0.20	B	NP-9	FSL, SL, SIL	SM, SL, SC, CL	A-4
	44-72	4.5-5.5	0.17	B	NP-9	LS, SL, SIL	SM, ML, CL, SC	A-4, A-2
OCILLA	0-28	4.5-5.5	0.10	C	NP	LS, LFS, S	SM, SP-SM	A-2, A-3
	28-67	4.5-5.5	0.24	C	NP-18	SL, SCL	SM, CL, SC	A-2, A-4, A-6
OLUSTEE	0-8	3.6-5.5	0.10	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	8-21	3.6-5.5	0.15	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	21-35	4.5-5.5	0.10	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	35-62	4.5-5.5	0.24	B/D	8-15	SCL, SL	SC	A-2, A-4, A-6
	62-74	4.5-5.5	0.28	B/D	15-25	SC	SC, CL	A-6, A-7
ONSLOW	0-17	3.6-5.5	0.17	B	NP	LFS, LS	SM-SP-SM	A-2, A-3, A-4
	0-17	3.6-5.5	0.20	B	NP-10	FSL, SL	SM, ML, SC, CL	A-2, A-4
	17-53	3.6-5.5	0.24	B	NP-14	SCL, SL, CL	SM, CL, SM-SC, SC	A-2, A-4, A-6
	53-80			B		Var		
ORANGE	0-10	5.1-6.5	0.49	D	NP-10	SIL, L	SM, ML, CL-ML, SM-SC	A-4
	0-10	5.1-6.5	0.32	D	NP-7	FSL, SL	SM, ML, CL-ML, SM-SC	A-4
	10-38	5.1-6.5	0.28	D	45-70	C, SLC, SICL	CH	A-7
	38-58	5.6-7.8	0.28	D	10-25	SIL, CNV-SIL, SCL	SC, CL, GC	A-6, A-7
	58			D		UWB		
ORANGEBURG	0-7	4.5-6.0	0.10	B	NP	LS, LFS, S	SM	A-2
	0-7	4.5-6.0	0.20	B	NP	SL, FSL	SM	A-2
	0-7	4.5-6.0	0.24	B	3-16	SCL	SM, SM-SC, SC	A-4, A-6
	7-12	4.5-6.0	0.20	B	NP-4	SL	SM	A-2
	12-54	4.5-5.5	0.24	B	3-19	SCL, SL	SC, CL, SM, SM-SC	A-6, A-4
	54-64	4.5-5.5	0.24	B	8-21	SCL, SC, SL	SC, CL	A-6, A-4, A-7
OSIER	0-8	3.6-6.0	0.10	A/D	NP	S, LS, FS	SP-SM	A-2, A-3
	0-8	3.6-6.0	0.15	A/D	NP	FSL, LFS	SM	A-2
	8-48	3.6-6.0	0.10	A/D	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	48-75	3.6-6.0	0.05	A/D	NP	COS, S, FS	SP, SP-SM	A-1, A-3, A-2-4
OTEEN	0-6	5.1-7.3	0.24	C	NP-7	FSL, SL, L	ML, CL-ML, SM-SC, SM	A-2, A-4
	0-6	5.1-7.3	0.17	C	NP-7	GR-FSL, GR-L, GR-SL	SM, SM-SC	A-2, A-4, A-1
	6-17	5.1-7.3	0.32	C	11-30	L, CL, C	CL	A-6, A-7
	17-60			C		WB		
PACOLET	0-3	4.5-6.5	0.20	B	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-1-B
	0-3	4.5-6.5	0.24	B	4-17	CL, SCL	SM-SC, SC	A-4, A-6
	0-3	4.5-6.5	0.15	B	NP-3	LS	SM	A-2
	3-29	4.5-6.0	0.28	B	11-30	SC, CL, C	ML, MH	A-6, A-7
	29-52	4.5-6.0	0.28	B	5-15	CL, SCL, SL	CL, CL-ML, SM-SC, SC	A-2, A-4, A-6
	52-70	4.5-6.0	0.28	B	NP-6	SL, FSL, L	SM, SM-SC	A-4, A-2-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
PACTOLUS	0-40	4.5-6.0	0.10	A/C	NP	LS, LFS, S	SM	A-2
	40-80	4.5-5.5	0.10	A/C	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
PAMLICO	0-30	3.6-4.4		D	NP	MUCK	PT	
	30-60	3.6-5.5	0.10	D	NP	LS, S, LFS	SM, SP-SM	A-2, A-3
PANTEGO	0-18	3.6-5.5	0.10	B/D	NP-10	MK-L	CL, SM, ML, SM-SC	A-2, A-4
	0-18	3.6-5.5	0.15	B/D	NP-10	L, FSL, SL	SM, SM-SC, CL, ML	A-2, A-4
	0-18	3.6-5.5	0.10	B/D	NP	LFS, LS	SM	A-2
	18-42	3.6-5.5	0.28	B/D	4-16	SCL, SL, CL	SC, CL, SM-SC, CL-ML	A-4, A-6, A-2
	42-65	3.6-5.5	0.28	B/D	11-24	CL, SC, SCL	CL, SC	A-6, A-7
PASQUOTANK	0-17	4.5-6.0	0.43	B/D	NP-7	SIL, L, VFSL	CL-ML, ML	A-4
	17-56	4.5-5.5	0.43	B/D	NP-7	L, VFSL, SIL	CL-ML, ML	A-4
	56-80	4.5-5.5	0.32	B/D	NP	LS, LFS, FS	SM, SP-SM	A-2
PELHAM	0-27	4.5-5.5	0.10	B/D	NP	LS	SM	A-2
	0-27	4.5-5.5	0.10	B/D	NP	S, FS	SM	A-2
	27-56	4.5-5.5	0.24	B/D	2-12	SCL, SL	SM, SC, SM-SC	A-2, A-4, A-6
	56-68	4.5-5.5	0.24	B/D	5-20	SCL, SL, SC	SC, SM-SC, ML, CL	A-2, A-4, A-6, A-7
PENDER	0-13	4.5-6.5	0.24	C	NP-14	SL, FSL	SM, SM-SC, SC	A-2
	0-13	4.5-6.5	0.15	C	NP-10	LS, LFS	SM, SP-SM	A-2
	13-54	5.6-7.3	0.24	C	4-20	SL, SCL, CL	SC, SH-SC, CL, CL-ML	A-2, A-4, A-4
	54-62			C		Var		
PENN	0-8	3.6-5.5	0.32	C		SIL, L	ML	A-4
	0-8	3.6-5.5	0.28	C		SH-SIL, SH-L	ML, GM	A-4
	8-21	3.6-6.0	0.24	C	1-10	SH-SIL, SH-L, SH-SICL	ML, SM, GM	A-4, A-2
	21-34	5.1-6.5	0.24	C	3-10	SH-SIL, SHVL	ML, CL, SM, GM	A-4, A-2, A-1
	34			C		UWB		
PERQUIMANS	0-8	4.5-6.5	0.37	D	NP-7	SIL, L, VFSL	ML, CL-ML	A-4
	8-50	4.5-6.0	0.43	D	8-30	L, SICL, CL	CL	A-4, A-6, A-7
	50-62	4.5-6.0	0.37	D	NP-7	SIL, L, SL	ML, CL-ML	A-4
PETTIGREW	0-15	3.6-5.5		B/D	NP	MUCK	PT	
	15-26	3.6-5.5	0.17	B/D	11-25	L, CL, SICL	CL	A-6, A-7
	26-50	3.6-5.5	0.32	B/D	20-40	CL, C, SIC	CL, CH	A-7
	50-74	5.6-7.8		B/D		Var		
PINKSTON	0-8	4.5-6.5	0.32	B	NP-10	FSL, SL	CL, ML, SM, SC	A-2, A-4
	0-8	4.5-6.5	0.32	B	NP-10	SIL, L, VFSL	CL, ML, SM-SC	A-4
	8-19	4.5-5.5	0.24	B	NP-10	L, SL, SIL	SC, CL, ML, SM	A-2, A-4, A-1
	19-26	4.5-5.5	0.24	B	3-15	GR-SL, L, SIL	CL, GM, GP-GM, ML	A-1, A-2, A-4, A-6
	26			B		WB		
PLUMMER	0-50	3.6-5.5	0.10	B/D	NP	S, FS, LS	SM, SP-SM	A-2-4, A-3
	50-72	3.6-5.5	0.15	B/D	NP-10	SL, SCL, FSL	SM, SC, SM-SC	A-2-4, A-2-6, A-4
POCALLA	0-23	4.5-6.5	0.15	A	NP	S, LS	SP-SM, SM	A-2, A-3
	23-36	4.5-5.5	0.10	A	NP-4	SL	SM	A-2
	36-46	4.5-5.5	0.10	A	NP	S, LS	SP-SM, SM	A-2, A-3
	46-72	4.5-5.5	0.15	A	3-15	SCL, SL	SM-SC, SC, SM	A-2, A-4, A-6
POCOMOKE	0-28	3.6-5.5	0.28	B/D	3-10	SL, FSL, LS	SM, SC, CL-ML	A-2, A-4
	28-40	3.6-5.5	0.20	B/D	NP-8	LS, S	SM, SP-SM	A-2, A-3
POMELLO	0-42	4.5-6.0	0.10	C	NP	COS, S, FS	SP, SP-SM	A-3
	42-64	4.5-6.0	0.15	C	NP	COS, S, FS	SP- SM, SM	A-3, A-2-4
	64-80	4.5-6.0	0.10	C	NP	COS, S, FS	SP, SP-SM	A-3
PONZER	0-24	3.6-4.4		D	NP	MUCK	PT	
	24-52	3.6-6.5	0.24	D	NP-20	L, SCL, SIL	SM, ML, SC, CL	A-2, A-4, A-6
	52-72			D		Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
PORTERS	0-7	4.5	0.24	B	NP-10	FSL, SL	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.28	B	NP-10	L, SIL	ML, CL, CL-ML	A-4
	7-42	4.5-6.0	0.24	B	NP-7	L, SL, FSL	SM, SM-SC	A-2, A-4
	42-60			B		UWB		
PORTSMOUTH	0-19	3.6-5.5	0.24	B/D	NP-7	SL, FSL, L	SM, SM-SC, ML	A-2, A-4
	19-35	3.6-5.5	0.28	B/D	7-18	L, SCL, CL	SC, CL-ML, CL	A-4, A-6
	35-38	3.6-5.5	0.17	B/D	NP-4	LS, SL	SM	A-2
	38-72	3.6-6.0	0.17	B/D	NP	SR-COS-LS	SP-SM, SP, SM	A-1, A-2, A-3
PUNGO	0-72	4.5		D	NP	MUCK	PT	
	72-84	3.6-7.3	0.24	D	15-35	C, SIC, SC	CH, CL,SC	A-7, A-6
RABUN	0-9	5.1-6.5	0.32	B	3-20	L, CL, SIL	ML, CL, SM, SC	A-6, A-7, A-4
	0-9	5.1-6.5	0.20	B	3-12	GR-L, GR-CL	SM, SC, SM-SC	A-6, A-4
	9-37	5.1-6.5	0.28	B	12-30	CL, C, SIC	ML, CL, MH, CH	A-7
	37-48	5.1-6.5	0.28	B	11-23	C, CL, SICL	ML, CL	A-7, A-6
	48-62			B		WB		
RAINS	0-12	4.5-6.5	0.10	B/D	NP	S, FS	SP-SM	A-3, A-2-4
	12-62	4.5-5.5	0.24	B/D	8-18	SCL	SC	A-2-6, A-2-4
	62-85	4.5.5	0.20	B/D	NP-7	LS, LFS, SL	SM, SM-SC	A-2-4
RAMSEY	0-5	4.5-5.5	0.24	D	NP-7	L, SL, FSL	SM, CL-ML, ML, SM-SC	A-4, A-2
	5-18	4.5-5.5	0.17	D	NP-7	L, SL, FSL	SM, CL-ML, ML, SM-SC	A-4, A-2
	18			D		UWB		
RANGER	0-6	4.5-5.5	0.24	C	2-8	CN-SIL	ML, CL-ML, CL	A-4
	6-26	4.5-5.5	0.24	C	2-10	CN-SIL, CN-SICL, CNV-SIL	GM,CG, GM-GC	A-4, A-2
RIDGELAND	0-8	3.6-6.5	0.10	B/D	NP	S, FS, LFS	SP-SM, SM	A-2, A-3
	8-15	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP-SM, SP, SM	A-2, A-3
	15-35	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP, SM, SP, SM	A-2, A-3
	35-80	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP-SM, SP, SM	A-2, A-3
RIMINI	0-58	3.6-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	58-70	3.6-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	70-80	36.-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
ROANOKE	0-7	3.6-5.5	0.28	D	NP-7	FSL	SM, ML, CL-ML, SM-SC	A-2, A-4
	0-7	3.6-5.5	0.37	D	5-16	SIL, L	SM-SC, CL-ML, CL, SC	A-4, A-6
	0-7	3.6-5.5	0.37	D	14-20	SICL, CL	CL	A-6, A-7
	7-12	3.6-5.5	0.24	D	14-20	CL, SICL	CL	A-6, A-7
	12-50	3.6-5.5	0.24	D	22-40	C, SIC, CL	CH, CL	A-7
	50-72	3.6-6.5	0.24	D	NP-40	SR, SC-C	CL-ML, GM-GC, CL, ML	A-2, A-4, A-6, A-7
ROPER	0-15	3.6-5.5		B/D	NP	MUCK	PT	
	15-42	3.6-5.5	0.43	B/D	8-25	SIL, SICL, L	CL	A-4, A-6
	42-55	5.6-7.8	0.43	B/D	8-25	SIL, SICL, L	CL	A-4, A-6
	55-72	5.6-7.8		B/D		Var		
ROSMAN	0-50	5.1-6.5	0.24	B	4-15	L, FSL, SIL	ML, CL-ML	A-4
	50-60	5.1-6.5	0.10	B	NP-7	SR-GR-S-GR-C	SM, ML, CL-ML, SM-SC	A-4
RUMFORD	0-17	3.6-5.5	0.17	B	NP	LFS, LS	SM	A-2, A-1
	0-17	3.6-5.5	0.24	B	NP-6	FSL, SL	SM, SM-SC	A-2, A-4
	17-37	3.6-6.0	0.17	B	NP-12	FSL, SL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	37-60	3.6-6.5	0.17	B	NP-6	SR-SL-GR-S	SM, SP, GP, GM	A-1, A-2, A-3, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
RUSTON	0-16	4.5-6.5	0.15	B	NP-3	GR-FSL, GR-SL, GR-L	SM	A-2, A-1-B
	0-16	4.5-6.5	0.28	B	NP-3	FSL, SL	SM, ML	A-4, A-2-4
	0-16	4.5-6.5	0.20	B	NP-3	LFS	SM	A-2-4
	41-47	4.5-6.0	0.32	B	NP-7	FSL, SL, LS	SM, ML, CL-ML, SM-SC	A-4, A-2-4
	47-80	4.5-6.0	0.28	B	11-20	SCL, L, CL	SC, CL	A-6
SCRANTON	0-7	4.5-6.5	0.15	A/D	NP	LS, LFS	SM, SP-SM	A-2, A-4
	0-7	4.5-6.5	0.10	A/D	NP	S, FS	SP-SM, SM	A-2, A-3
	7-41	4.5-5.5	0.10	A/D	NP	LS, S, FS	SP-SM, SM	A-2, A-3
	41-72	4.5-5.5	0.10	A/D	NP	S, FS	SP-SM, SM	A-2, A-3
SEABROOK	0-9	4.5-6.5	0.10	C	NP	LFS, LS, FS	SM, SP-SM	A-2, A-3
	9-60	4.5-6.5	0.10	C	NP	LFS, FS, S	SM, SP-SM	A-2, A-3
SEAGATE	0-12	3.6-6.0	0.10	A/D	NP	FS, S	SM, SP-SM	A-2, A3
	12-28	3.6-6.0	0.15	A/D	NP	FS, LFS, S	SM, SP-SM	A-2
	28-36	3.6-6.0	0.10	A/D	NP	FS, S	SM, SP-SM	A-2, A-3
	36-40	3.6-6.0	0.28	A/D	NP-7	SL, SCL	SM- SM-SC	A-2, A-4
	40-64	3.6-6.0	0.32	A/D	16-27	CL, SCL	CL	A-6, A-7
SEDGEFIELD	0-13	4.5-6.5	0.17	C	NP	LS	SM	A-2
	0-13	4.5-6.5	0.28	C	5-20	FSL, SL, SCL	SM, SM-SC, CL	A-2, A-4, A-6
	13-33	4.5-6.5	0.28	C	25-60	SC, CL, C	CL, CH	A-7
	33-37	5.6-8.4	0.28	C	8-25	SL, SCL, CL	SC, CL	A-6, A-7, A-4
	37-65			C		UWB		
STALLINGS	0-12	3.6-5.5	0.10	C	NP	LS, LFS, FS	SM	A-2
	0-12	3.6-5.5	0.20	C	NP-3	SL, FSL	SM	A-2, A-4
	12-42	3.6-5.5	0.17	C	NP-3	SL, FSL	SM	A-2, A-4
	42-80	3.6-5.5	0.17	C	NP-4	SL, LS, LFS	SM, SP-SM, SM-SC	A-2, A-4
STARR	0-10	5.1-6.5	0.24	C	NP-7	SL, FSL	SM, SM-SC	A-4, A-2
	0-10	5.1-6.5	0.28	C	3-12	L	ML, CL-ML, CL	A-4, A-6
	0-10	5.1-6.5	0.28	C	3-23	SIL, SICL, SCL	ML, CL-ML, CL	A-4, A-6, A-7
	10-53	5.1-6.5	0.28	C	3-23	CL, SCL, SICL	ML, CL-ML, CL	A-4, A-6, A-7
	53-70	5.1-6.5	0.28	C	NP-15	GR-SL, SCL, CL	SM, SM-SC, SC	A-2, A-4, A-6
STATE	0-10	4.5-5.5	0.28	B	NP-7	FSL, SL	SM, ML CL-ML, SM-SC	A-2, A-4
	0-10	4.5-5.5	0.38	B	NP-15	SIL, L	L, SM, SC, ML, CL	A-4, A-6
	0-10	4.5-5.5	0.28	B	NP-6	LS, LFS	SM, SM-SC	A-2, A-1
	10-45	4.5-5.5	0.28	B	8-22	L, CL, SCL	CL, SC	A-4, A-6
	45-60	4.5-6.0	0.17	B	NP-7	SR-S-FSL	SM, SM-SC, SP-SM	A-1, A-2, A-3, A-4
STONEVILLE	0-5	4.5-6.0	0.32	B	6-16	L, SIL, CL	SM-SC, CL, ML, CL-ML	A-4, A-6
	5-13	4.5-6.0	0.32	B	11-25	CL, SICL, L	CL	A-6, A-7-6
	13-38	4.5-6.0	0.28	B	20-50	C, CL, SIC	CL, CH, MH	A-6, A-7
	38-48	4.5-6.0	0.24	B	11-31	CL, SICL, L	CL, MH, ML	A-6, A-7
	48-72			B		WB		
SUNCOOK	0-7	4.5-6.5	0.17	A	NP	LFS, LS, SL	SM	A-2
	7-42	4.5-6.5	0.17	A	NP	SR-LFS-COS	SP, SM	A-2, A-3
	42-60	4.5-6.5	0.10	A	NP	SR-LFS-GR-COS	SP, SM	A-1, A-2, A-3
TALLADEGA	0-9	4.5-5.5	0.28	C	NP-10	CN-SIL, CN-L	SM, SC, SM-SC, GM	A-4, A-2, A-1
	0-9	4.5-5.5	0.32	C	NP-10	SIL, L	SM, SC, ML, SM-SC	A-4
	9-22	4.5-5.5	0.28	C	8-15	CN-CL, CN-SIL, CN-SICL	GM, GC, SC, SM	A-4, A-6, A-2
	22-26			C		Var		
	26			C		WB		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
TALLAPOOSA	0-4	4.5-5.0	0.32	C	1-9	L, SIL	SM, ML	A-4, A-5
	0-4	4.5-5.0	0.28	C	NP-7	FSL, SL	SM, ML	A-4, A-2
	4-10	4.5-5.0	0.37	C	8-14	SICL, CL, L	ML, CL	A-4, A-6
	10-19	4.5-5.0	0.20	C	NP-6	L	ML, SM	A-4
	19-60			C	NP	WB		
TARBORO	0-40	5.1-6.5	0.10	A	NP	LS, S	SM, SP-SM, SW-SM	A-2, A-3, A-1
	40-80	5.1-6.5	0.10	A	NP	S, COS, LS	SP, SP-SM, SW-SM, SM	A-2, A-3, A-1
TATE	0-7	5.1-6.0	0.24	B	NP-13	L, FSL	CL, ML, SM, SC	A-4, A-6
	0-7	5.1-6.0	0.24	B	NP-13	ST-L, ST-FSL	CL, ML, SM, SC	A-4, A-6
	7-46	5.1-6.0	0.28	B	2-12	CL, SCL, L	CL, ML, CL-ML	A-4, A-6
	46-72	5.1-5.5	0.17	B	NP-7	GR-FSL	GM, GM-GC	A-4, A-2-4
TATUM	0-8	4.5-5.5	0.37	C	NP-10	SIL, L, VFSL	ML, CL, SM	A-4
	0-8	4.5-5.5	0.37	C	12-20	SICL	CL	A-6, A-7
	8-45	4.5-5.5	0.28	C	10-36	SICL, SIC, C	MH	A-7
	45-47	4.5-5.5	0.28	C	12-20	SIL, L, SICL	CL	A-6, A-7
	47			C		WB		
THURMONT	0-9	4.5-5.5	0.24	B	NP-10	GR-SL, GR-FSL, GR-L	SM, SC, SM-SC, CL	A-1, A-2, A-4
	0-9	4.5-5.5	0.24	B	NP-10	CB-SL, CB-FSL, CB-L	SM, SC, SM-SC, CL	A-1, A-2, A-4
	9-36	4.5-5.5	0.20	B	12-20	CL, L, GR-SCL	SC, CL	A-2, A-6, A-7
	36-48	4.5-5.5	0.20	B	12-25	SL, SCL, GR-SCL	SC	A-2, A-6, A-7
	48-60	4.5-5.5	0.20	B	NP-7	CB-SL, GR-SCL	SM, SM-SC	A-1, A-2
TOCCOA	0-10	5.1-6.5	0.24	B	NP-4	FSL, L, SIL	SM, ML	A-2, A-4
	0-10	5.1-6.5	0.10	B	NP-4	SL, LS	SM	A-2, A-4
	10-60	5.1-6.5	0.10	B	NP-4	SL, L	SM, ML	A-2, A-4
TOISNOT	0-13	4.5-5.5	0.28	B/D	5-15	L, SIL	CL-ML, CL, ML	A-4, A-6
	0-13	4.5-5.5	0.10	B/D	NP-10	LS, SL	SM, SM-SC, SC	A-2, A-4
	13-28	4.5-5.5	0.32	B/D	NP-10	SL, FSL, SIL	SM, SM-SC, SC, ML	A-2, A-4
	28-45	4.5-5.5	0.43	B/D	NP-7	LS, SL	SM, SM-SC	A-2, A-4
	45-80	4.5-5.5	0.37	B/D	4-20	SCL, SC, L	CL, SC, CL-ML	A-4, A-6
TOMAHAWK	0-24	4.5-5.5	0.10	A	NP	LS, LFS, S	SM-SP-SM	A-2-4, A-1-B
	24-42	4.5-5.5	0.15	A	NP-10	SL, FSL	SM, SC, SM-SC	A-2-4, A-4
	42-80	4.5-6.5	0.10	A	NP	FS, S, LS	SM, SP-SM	A-2-4, A-1-B, A-3
TORHUNTA	0-15	3.6-5.5	0.10	C	NP-4	MK-L, MK-FSL	SM	A-2-4, A-4
	0-15	3.6-5.5	0.15	C	NP-4	FSL, L, LFS	SM	A-2, A-4
	15-40	3.6-5.5	0.15	C	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	40-80	3.6-6.5	0.10	C	NP-4	LS, S, SL	SM, SP-SM	A-2, A-3
TOXAWAY	0-36	5.1-6.5	0.17	B/D	6-22	SIL, L	CL, ML, CL-ML	A-4, A-6, A-7
	36-72	5.1-6.5	0.17	B/D	NP-15	SR-SCL-S	CL, ML, SM, SC	A-2, A-4, A-6
TRANSYLVANIA	0-27	4.5-6.0	0.37	B	7-20	SIL, L	ML, MH	A-4, A-6
	27-60	4.5-6.0	0.32	B	7-20	SICL, CL, L	ML, MH	A-4, A-6, A-7
	60-70			B		Var		
TROUP	0-53	4.5-6.0	0.17	A	NP	LS, LFS	SM, SP-SM	A-2, A-3, A-4
	0-53	4.5-6.0	0.10	A	NP	S, FS	SM, SP-SM	A-2
	53-80	4.5-5.5	0.20	A	4-13	SCL, SL, FSL	SC, SM-SC, CL-ML, CL	A-4, A-2
TUCKERMAN	0-9	4.5-6.0	0.24	D	NP-3	FSL	ML, SM	A-4, A-2
	9-18	4.5-6.0	0.24	D	NP-5	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	18-34	4.5-6.0	0.32	D	5-15	SCL, L	CL, CL-ML, SC, SM-SC	A-4, A-6
	34-52	4.5-6.0	0.24	D	NP-5	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	52-62	4.5-6.0	0.20	D	NP-3	LFS, FSL, SL	SM-ML	A-2, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
TUSQUITTEE	0-10	4.5-6.0	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-10	4.5-6.0	0.28	B	NP-7	L, SIL	ML, CL-ML, CL, SM	A-4, A-5
	10-48	4.5-6.0	0.20	B	6-15	L, SL, FSL	SM-SC, SM	A-4
	48-60	4.5-6.0	0.20	B	NP-7	GR-SL, GR-FSL	GM, SM-SC, SM, GM-GC	A-4, A-1, A-2
UNISON	0-9	4.5-6.0	0.32	B	2-15	L, SIL, FSL	CL, ML, CL-ML, SM	A-4, A-6
	9-50	4.5-6.0	0.24	B	15-35	CL, C, GR-SIC	CL, CH	A-6, A-7
	50-72	4.5-6.0	0.28	B	5-20	CB-CL, SICL, GRV-L	CL-ML, CL, ML, GM-GC	A-1, A-2, A-6, A-7
VALHALLA	0-21	4.5-6.0	0.15	A	NP	LFS, LS	SM	A-2
	0-21	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM, SP	A-2, A-3
	21-30	4.5-6.0	0.24	A	NP-10	FSL, SL, SCL	SM, SC, SM-SC	A-2, A-4
	30-99	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM	A-2, A-3
VANCE	0-5	4.5-6.0	0.24	C	NP-7	FSL, SL, COSL	SM, SM-SC	A-2, A-4
	0-5	4.5-6.0	0.15	C	NP-7	GR-SL, GR-COSL	SM, GM, GM-GC	A-1, A-2, A-4
	0-5	4.5-6.0	0.28	C	8-20	SCL, CL	CL, SC	A-6, A-4
	5-29	4.5-5.5	0.37	C	25-48	CL, SC, C	CH	A-7
	29-72			C		WB		
VARINA	0-14	4.5-6.5	0.15	C	NP-3	LS	SM, SP-SM	A-2
	0-14	4.5-6.5	0.17	C	NP-7	SL	SM, SM-SC	A-2, A-4
	14-38	4.5-5.5	0.28	C	11-25	SC, CL, C	SC, MH, ML, SM	A-6, A-7
	38-80	4.5-5.5	0.28	C	8-26	SC, CL, C	SC, CL, CH	A-4, A-6, A-7
VAUCLUSE	0-15	4.5-6.0	0.15	C	NP	LS, S. LCOS	SM, SP-SM	A-2,A-3
	0-15	4.5-6.0	0.24	C	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-15	4.5-6.0	0.32	C	NP-7	SCL	SM, CL-ML, ML, SM-SC	A-4
	15-29	3.6-5.5	0.24	C	5-18	SCL, SL	SC, SM-SC	A-2, A-4, A-6
	29-58	3.6-5.5	0.24	C	NP-20	SCL, SL, SC	SC, SM-SC, SM	A-2, A-4, A-6
	58-72	3.6-5.5	0.17	C	NP-12	SL, SCL, LS	SM, SC, SM-SC	A-2, A-4, A-6
WAGRAM	0-24	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-24	4.5-6.0	0.10	A	NP	FS, S	SP-SM, SM	A-1, A-2, A-3
	24-75	4.5-6.0	0.20	A	8-25	SCL, SL	SC	A-2, A-4, A-6, A-7
WAHEE	0-11	4.5-6.0	0.24	D	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-11	4.5-6.0	0.28	D	2-10	L, SIL, VFSL	ML, CL-ML, CL	A-4
	11-56	3.6-5.5	0.28	D	18-42	S, CL, SIC	CL, CH	A-6,A-7
	56-65	3.6-5.5	0.28	D		Var		
WAKE	0-15	4.5-6.0	0.20	D	NP	GR-LCOS, GR-LS, LS	SP-SM, SM, GM, GP-GM	A-2, A-3, A-1
WAKULLA	0-24	4.5-6.0	0.10	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-24	4.5-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	24-42	4.5-6.0	0.10	A	NP	LS, LFS	SM, SP-SM	A-2
	42-80	4.5-6.0	0.10	A	NP	S, FS	SM, SP-SM	A-2, A-3
WANDO	0-8	5.6-7.3	0.10	A	NP	LFS, FS	SP-SM, SM	A-2, A-3
	8-99	5.6-7.3	0.10	A	NP	S, FS	SP, SP-SM, SM	A-2, A-3
WASDA	0-14	3.6-5.5		B/D	NP	MUCK	PT	
	14-42	4.5-5.5	0.20	B/D	NP-10	CL, SCL, SL	ML, CL, CL-ML	A-4
	42-60	5.6-7.8	0.24	B/D	NP-7	SL, L	ML, SM, CL-ML, SM-SC	A-4
	60-74	5.6-7.8	0.15	B/D		S	SP-SM, SM	A-2, A-3

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
WATAUGA	0-7	4.5-6.0	0.24	B	NP-10	L, FSL, SIL	SM, SM-SC, SC, ML	A-4
	0-7	4.5-6.0	0.17	B	NP-7	CB-L, CB-FSL, CB-SIL	SM, SM-SC, ML, CL-ML	A-2, A-4
	7-28	4.5-6.0	0.28	B	12-25	CL, L, SCL	SC, CL	A-6, A-7
	28-72	4.5-6.0	0.24	B	NP	L, SL, FSL	SM	A-2, A-4
WEDOWEE	0-10	4.5-5.5	0.24	B	NP-6	SL, FSL, L	SM, SM-SC	A-4, A-2-4
	0-10	4.5-5.5	0.15	B	NP-6	GR-SL, GR-FSL, GR-L	SM, SM-SC	A-4, A-2, A-1
	0-10	4.5-5.5	0.28	B	5-15	SCL, CL	SC, CL	A-4, A-6
	10-14	4.5-5.5	0.28	B	NP-15	L, SCL	SM, SC, CL, ML	A-4, A-6
	14-32	4.5-5.5	0.28	B	10-25	SC, CL, C	SC, ML, CL, SM	A-6, A-7
	32-60	4.5-5.5	0.28	B	5-15	SCL, CL, SL	SC, SM-SC, CL	
WEEKSVILLE	0-42	4.5-5.5	0.43	B/D	NP-7	SIL, VFSL, L	CL-ML, ML	A-4
	42-56	4.5-5.5	0.43	B/D	NP-3	FSL, SL	SM	A-2, A-4
	56-72	4.5-5.5	0.32	B/D	NP	S, LS, LFS	SM, SP-SM	A-2
WEHADKEE	0-8	4.5-6.5	0.24	D	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	0-8	4.5-6.5	0.32	D	10-24	SIL, SICL	CL, MH, ML	A-6, A-7
	8-40	4.5-6.5	0.32	D	7-25	L, SCL, CL	ML, CL, CL-ML	A-6, A-7, A-4
	40-50			D		Var		
WESTON	0-9	4.5-6.0	0.24	D	NP-3	FSL, SL	ML, SM	A-4
	0-9	4.5-6.0	0.20	D	NP-3	LFS	SM	A2, A-4
	9-44	4.5-5.0	0.24	D	NP-5	SL, L, FSL	SM, SM-SC, ML, CL-ML	A-4
	44-54	4.5-5.0	0.32	D	NP-15	SR-S-C	SM, ML, CL, CL-ML	A-4, A-6
WHITE STORE	0-6	5.6-6.0	0.28	D	NP-7	SL, FSL	ML, CL-ML	A-4
	0-6	5.6-6.0	0.43	D	NP-7	L, SIL	ML, CL-ML	A-4
	0-6	4.5-5.5	0.37	D	25-45	CL, C	CH, CL	A-7
	6-35	4.5-5.5	0.37	D	45-65	C	CH	A-7
	35-60			D		Var		
WICKHAM	0-9	4.5-6.0	0.24	B	NP-7	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-4
	0-9	4.5-6.0	0.15	B	NP	LS	SM	A-2
	9-40	4.5-6.0	0.24	B	5-15	SCL, CL, L	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7
	40-70			B		Var		
WICKSBURG	0-26	4.5-6.0	0.10	B	NP	GR-COS	SP, SP-SM	A-1
	0-26	4.5-6.0	0.17	B	NP	LS, LFS	SM	A-2
	0-26	4.5-6.0	0.15	B	NP	S, FS	SM, SP-SM	A-2, A-3
	26-30	4.5-5.5	0.20	B	NP-15	SCL, CL	SC, SM-SC, CL, CL-ML	A-4, A-6
WILBANKS	0-5	3.6-5.5	0.20	D	6-20	FSL, SIL, L	ML, CL-ML, CL	A-4
	5-39	3.6-5.5	0.24	D	18-35	SIC, C, CL	CH, MH	A-7
	39-78			D		Var		
WILKES	0-6	5.1-6.5	0.24	C	NP-7	SL, L	ML, SM, SM-SC	A-2, A-4
	0-6	5.1-6.5	0.28	C	10-25	SCL, CL	CL, SC	A-6, A-7
	0-6	5.1-6.5	0.17	C	NP-7	GR-SL, GR-L	SM, SM-SC	A-2, A-4, A-1-B
	6-13	6.1-7.8	0.32	C	11-35	CL, C, SCL	CL, CH	A-6, A-7
	13-48			C		WB		
WOODINGTON	0-12	3.6-5.5	0.10	B/D	NP	LS, LFS	SM	A-2
	0-12	3.6-5.5	0.20	B/D	NP-3	SL, FSL	SM	A-2, A-4
	12-47	3.6-5.5	0.20	B/D	NP-3	SL, FSL	SM	A-2, A-4
	47-85	3.6-5.5	0.10	B/D	NP-3	SL, LS, LFS	SM, SP-SM	A-2, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
WORSHAM	0-8	4.5-5.5	0.28	D	NP-9	FSL, SL	SM, SC, ML, CL	A-2, A-4
	0-8	4.5-5.5	0.37	D	4-12	L, SIL	CL, CL-ML	A-4, A-6
	8-50	4.5-5.5	0.28	D	22-40	SCL, SC, C	SC, CH, CL	A-2, A-7
	50-70	4.5-5.5	0.28	D	8-30	SL, SCL, CL	SC, CL	A-2, A-4, A-6, A-7
WRIGHTSBORO	0-9	4.5-6.0	0.17	C	NP	LS, LFS	SM	A-2
	0-9	4.5-6.0	0.28	C	NP-3	SL, FSL	SM	A-2, A-4
	9-48	4.5-6.0	0.32	C	11-25	SCL, CL, L	SC, CL	A-6, A-7
	48-65	4.5-6.0	0.43	C	25-45	C	CH	A-7

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

8.02 VEGETATION TABLES

Table 8.02a is a listing of grasses and legumes referred to in this manual, along with characteristics useful in their selection. Most of these plants are discussed in detail in *Chapter 3, Vegetative Considerations*. This table is intended for use as a reference and should not be used as a substitute for seeding mixture specifications given in *Practice Standards and Specifications 6.10, Temporary Seeding,* and *6.11, Permanent Seeding*.

Table 8.02b is a reference for selecting trees and shrubs native to North Carolina. It is the master list developed by the NC DENR Ecosystem Enhancement Program. Appropriate riparian species may be selected from this list for reforestation of stream buffers. These plants are considered separately from grasses and herbaceous legumes because of the longer time required to produce effective cover and the different planting methods used in their establishment. Light and moisture requirements are given for each plant to assist in fitting it to a specific use and site. Region refers to the physiographic provinces of the state where a plant is climatically suited.

There are many excellent sources of information on plant materials. The USDA Natural Resources Conservation Service maintains a Plants Database at http://plants.usda.gov/index.html. The Federal Highway Administration maintains a list of Native Plants for Landscape Use in North Carolina at http://www.fhwa.dot.gov/environment/rdsduse/nc.htm. Appendix Three of this reference lists 129 dominant plant communities within the United States, with a species list for each plant community at http://www.fhwa.dot.gov/environment/rdsduse/rdus3_20.htm This is a valuable tool in selecting appropriate species to plant together to recreate a natural plant community.

Table 8.02a
Grasses and Legumes for Use in Stabilization of Disturbed Soils In North Carolina

Grasses

Common name:	AMERICAN BEACHGRASS
Botanical name:	*Ammophila breviligulata* Fernald
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	20-60 inches
pH range:	—
Seeds per lb (x 1000):	Not seeded
Applications:	Dune building
Adaptations:	Excessively drained soils
Recommended variety:	Hatteras
Notes:	Transplant sprigs or potted plants in spring Native

Common name:	BAHIAGRASS
Botanical name:	*Paspalum notatum* Flugge
Life cycle:	Perennial
Growth form:	Spreads by rhizomes and stolons
Season of growth:	Warm
Height:	15-30 inches
pH range:	4.5-7.0
Seeds per lb (x 1000):	273
Applications:	Fine turf, waterways and critical areas, Coastal Plain and Southern Piedmont
Adaptations:	Traffic, heat, drought
Recommended varieties:	Pensacola and Wilmington
Notes:	Tall seed heads may be aesthetically objectionable

Common name:	BERMUDAGRASS
Botanical name:	*Cynodon dactylon* (L.) Pers
Life cycle:	Perennial
Growth form:	Spreads by rhizomes and stolons
Season of growth:	Warm
Height:	4-16 inches
pH range:	4.5-7.5
Seeds per lb (x 1000):	1,586 (unhulled), 2,071 (hulled)
Applications:	Waterways and other critical areas in the Coastal Plain and Southern Piedmont; hybrids used for fine turf
Adaptations:	Traffic, drought, flooding, salinity
Recommended varieties:	Coastal in the Coastal Plain; Tifway, Tifway II, and Tifton-44 for fine turf in the Piedmont and Coastal Plain; Vamont and Midiron for Piedmont lawns.
Notes:	Common Bermudagrass is an agressive invader and potential pest.

Common name:	BIG BLUESTEM
Botanical name:	*Andropogon geradii*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer
Height:	6 feet
pH range:	6-7.5
Seeds per lb (x 1000):	144
Applications:	Riparian areas, erosion control, prairie restoration
Adaptations:	Full sun, well drained soils
Recommended varieties:	Roundtree, Kaw, Earl
Notes:	Native

Common name:	BITTERPANICUM
Botanical name:	*Panicum amarum* Ell.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	3-4 feet
pH range:	5.0-7.5
Seeds per lb (x 1000):	Does not produce viable seed
Applications:	Dune building
Adaptations:	Excessively drained soils
Notes:	Transplants better than sea oats; spreads slowly. Should not be confused with *P. amarulum*, a seed-producing bunchgrass

Common name:	CENTIPEDEGRASS
Botanical name:	*Eremochloa ophiuroides* (Munro.) Hack.
Life cycle:	Perennial
Growth form:	Spreads by stolons
Season of growth:	Warm
Height:	4-12 inches
pH range:	5-5-6.0
Seeds per lb (x 1000):	800
Applications:	Dry sites—Coastal Plains and Piedmont
Adaptations:	Drought

Common name:	CORDGRASS, GIANT
Botanical name:	*Spartina cynosuroides* (L.) Roth
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	To 9 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Irregularly flooded estuarine areas of moderate salinity
Notes:	Transplant nursery-grown potted plants in spring Native

Common name:	CORDGRASS, SALTMEADOW(MARSHHAY CORDGRASS)
Botanical name:	*Spartina patens* (Ait.) Muhl.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	1-4 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Dunes, sand flats, and channel banks along the coast
Adaptations:	Poor drainage; salinity
Notes:	Transplanted by sprigs or potted plants Native

Common name:	CORDGRASS, SMOOTH
Botanical name:	*Spartina alterniflora* Loisel
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	1-6 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Salt marsh restoration
Adaptations:	Regularly flooded, organic and mineral soils along the coast
Notes:	Transplant sprigs or potted plants in spring Native

Common name:	CREEPING BENTGRASS
Botanical name:	*Agrostis stolonifera*
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Cool
Height:	2 feet
pH range:	5.1-7.5
Seeds per lb (x 1000):	6,130
Applications:	Works well in mixtures; waterways
Adaptations:	Drought, acid soils, flooding
Notes:	Native

Common name:	DEERTONGUE
Botanical name:	*Dichanthelium clandestinum*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring, Summer
Height:	2 feet
pH range:	4-7.5
Seeds per lb (x 1000):	350
Applications:	Mine reclamation, erosion control
Adaptations:	Full sun, drought tolerant, acidic soils
Recommended varieties:	
Notes:	Native

Common name:	EASTERN BOTTLEBRUSH GRASS
Botanical name:	*Elymus hystrix*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring, Summer
Height:	2-5 feet
pH range:	--
Seeds per lb (x 1000):	--
Applications:	Riparian areas, erosion control, moist woods
Adaptations:	Partial sun to shade, moist soils
Recommended varieties:	
Notes:	Native

Common name:	FESCUE, CHEWINGS RED
Botanical name:	*Festuca rubra* var. *commutata* Gaud.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	1-2 feet
pH range:	4.5-7.5
Seeds per lb (x 1000):	449
Applications:	Waterways
Adaptations:	Shade, traffic, and flooding
Notes:	Stands thin with age

Common name:	FESCUE, HARD
Botanical name:	*Festuca brevipila*
Life cycle:	Perennial
Growth form:	Bunchgrass
Season of growth:	Cool
Height:	1-2 feet
pH range:	4.5-8.0
Seeds per lb (x 1000):	592
Applications:	Shaded, high maintenance areas in the Mountains and Upper Piedmont
Adaptations:	Partial shade

Common name:	FESCUE, RED, (CREEPING RED FESCUE)
Botanical name:	*Festuca rubra* L.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	To 18 inches
pH range:	4.5-7.5
Seeds per lb (x 1000):	365
Applications:	Waterways; used in turf grass mixtures for the Mountains and Piedmont
Adaptations:	Shade, traffic, and flooding
Recommended varieties:	Fortress and Pennlawn for fine turf

Common name:	FESCUE, TALL
Botanical name:	*Festuca arundinacea* Schreb.
Life cycle:	Perennial
Growth form:	Bunch
Season of growth:	Cool
Height:	3-4 feet
pH range:	4.8-8.2
Seeds per lb (x 1000):	200
Applications:	Waterways and lawns
Adaptations:	Shade, traffic, drought, and flooding
Recommended varieties:	KY-31; for fine turf: Rebel, Falcon and many others

Common name:	FOX SEDGE
Botanical name:	*Carex vulpinoidea*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	3.2 feet
pH range:	6.8-8.9
Seeds per lb (x 1000):	1297
Applications:	Riparian areas, wetlands
Adaptations:	Full sun to partial shade, wet soils
Recommended varieties:	--
Notes:	Native

Common name:	INDIAN GRASS
Botanical name:	*Sorghastrum nutans*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer, Fall
Height:	6 feet
pH range:	4.8-7.5
Seeds per lb (x 1000):	175
Applications:	Riparian Areas
Adaptations:	Full sun, tolerant of poorly to excessively drained soils
Recommended varieties:	Rumsey, Osage, Cheyenne, Lomenta
Notes:	Native

Common name:	INDIAN SEAOATS (INDIAN WOODOATS)
Botanical name:	*Chasmanthium latifolium*
Life Cycle:	Perennial
Growth habit:	Rhizomatous
Season of growth:	Spring
Height:	4.6 feet
pH range:	5-7

Seeds per lb (x 1000):	900
Applications:	Riparian areas
Adaptations:	Shade tolerant, streambanks, shaded slopes and bottomland forests
Recommended varieties:	--
Notes:	Native

Common name:	KENTUCKY BLUEGRASS
Botanical name:	*Poa pratensis* L.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	4-32 inches
pH range:	5.0-8.0
Seeds per lb (x 1000):	1,022-1,758
Applications:	Waterways and turf—Western Piedmont and Mountains
Adaptations:	Flooding
Recommended varieties:	Many varieties available

Common name:	LITTLE BLUESTEM
Botanical name:	*Schizachyrium scoparium*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer, Fall
Height:	3 feet
pH range:	5-8.4
Seeds per lb (x 1000):	241
Applications:	Riparian areas, erosion control, prairie restoration
Adaptations:	Full sun, well drained, infertile soils
Recommended varieties:	Aldous, Cimmaron, Common
Notes:	Native

Common name:	MAIDENCANE
Botanical name:	*Panicum hemitomon* Shultes
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	2-6 feet
pH range:	6-7.5
Seeds per lb (x 1000):	—
Applications:	Shoreline stabilization, wetlands
Adaptations:	Shallow water, periodically flooded sites
Recommended varieties:	Halifax
Notes:	Transplant dormant rhizomes from existing beds. Very sensitive to salinity; excellent forage for livestock. Native

Common name:	MILLET, GERMAN (FOXTAIL MILLET)
Botanical name:	*Setaria italica* (L.) Beauvois
Life cycle:	Annual
Season of growth:	Warm
Height:	2-3 feet
pH range:	4.5-7.0
Seeds per lb (x 1000):	184-249
Applications:	Temporary seedings in spring and summer on the Coastal Plain
Adaptations	—
Notes:	Watch List of Exotic Invasive Plants

Common name:	PARTRIDGE PEA
Botanical name:	*Chamaecrista fasciculata*
Life Cycle:	Annual

Growth form:	Bunch
Season of growth:	Spring
Height:	2.4 feet
pH range:	5.5-7.5
Seeds per lb (x 1000):	65
Applications:	Native legume for erosion control on disturbed areas
Adaptations:	Partial shade, well drained soils
Recommended varieties:	--
Notes:	Native, Not suitable for pasture or hay

Common name:	CREEPING BENTGRASS
Botanical name:	*Agrostis stolonifera*
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Cool
Height:	2 feet
pH range:	5.1-7.5
Seeds per lb (x 1000):	6,130
Applications:	Works well in mixtures; waterways
Adaptations:	Drought, acid soils, flooding
Notes:	Native

Common name:	REED CANARYGRASS
Botanical name:	*Phalaris arundinacea* L.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Spring, Summer, Fall
Height:	To 5 feet
pH range:	5.5-8
Seeds per lb (x 1000):	538
Applications:	Stabilization of pond shorelines, drainage ditches and streambanks, Mountains and Western Piedmont
Adaptations:	Low, wet areas to upland sites; drought resistant
Notes:	Plant freshly cut stem slips or rhizome fragments; stems root at the nodes. Native

Common name:	RICE CUTGRASS
Botanical name:	*Leersia oryzoides (Persia oryzoides)*
Life Cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Summer
Height:	4.9 feet
pH range:	5.1-8.8
Seeds per lb (x 1000):	--
Applications:	Wetland restoration, shoreline stabilization
Adaptations:	Sun to partial shade, wet soil, mud flats, low pH
Recommended varieties:	--
Notes:	Native

Common name:	RYE(WINTER RYE, CEREAL RYE GRAIN)
Botanical name:	*Secale cereale* L.
Life cycle:	Annual
Season of growth:	Cool
Height:	To 4 feet
pH range:	5-5-7.0
Seeds per lb (x 1000):	18
Applications:	Temporary fall and winter seedings; nurse plant
Adaptations:	Cold, drought

Common name:	SAINT AUGUSTINE GRASS
Botanical name:	*Stenotaphrum secundatum* (Walter) Kuntze
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Warm
Height:	4-5 inches (seedheads)
pH range:	6.5-7.0
Seeds per lb (x 1000):	Propagated vegetatively
Applications:	High maintenance turf, Coastal Plain, and Southern Piedmont
Adaptations:	Sun or shade and close mowing; not cold hardy; withstands salt spray.
Recommended variety:	Raleigh
Notes:	Not seeded; sod or plug on 12-inch centers

Common name:	SEA OATS
Botanical name:	*Uniola paniculata* L.
Life cycle:	Perennial
Growth habit:	Rhizomatous
Season of growth:	Warm
Height:	3-4 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Dune stabilization
Adaptations:	Salinity; dune sands
Notes:	Transplant by sprigs or potted plants; flourishes in drifting and accumulating sand. Native

Common name:	SHALLOW SEDGE
Botanical name:	*Carex lurida*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	3.2 feet
pH range:	4.9-6.8
Seeds per lb (x 1000):	--
Applications:	Riparian areas, wetlands
Adaptations:	Full sun to partial shade, wet soils
Recommended varieties:	--
Notes:	Native

Common name:	SOFT RUSH (COMMON RUSH)
Botanical name:	*Juncus effusus*
Life Cycle:	Perennial
Growth form:	Bunch, Rhizomatous
Season of growth:	Spring
Height:	6.6 feet
pH range:	5.5-7.0
Seeds per lb (x 1000):	--
Applications:	Freshwater marshes, swamps, seasonal wetlands
Adaptations:	Full sun, shallow water, low pH
Recommended varieties:	--
Notes:	Native

Common name:	SUDANGRASS
Botanical name:	*Sorghum bicolor* (L.) Moench *(previously S. sudanense)*
Life cycle:	Annual
Season of growth:	Warm
Height:	3-6 feet
pH range:	4.5-7.5
Seeds per lb (x 1000):	38-51
Applications:	Temporary seedings; nurse plant

Adaptations:	Acidity; fine soils
Notes:	Use only small-stemmed varieties; do not substitute sorghum-Sudan hybrids

Common name:	SWEET WOODREED
Botanical name:	*Cinna arundinacea*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	4.9 feet
pH range:	4-8.5
Seeds per lb (x 1000):	--
Applications:	Riparian areas, moist woodlands, floodplains
Adaptations:	Shade tolerant, wet soils
Recommended varieties:	
Notes:	Native

Common name:	SWITCHGRASS
Botanical name:	*Panicum virgatum*
Life Cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Summer
Height:	5 feet
pH range:	4.5-8
Seeds per lb (x 1000):	259
Applications:	Riparian areas, erosion control
Adaptations:	Full sun, somewhat dry to poorly drained soils
Recommended varieties:	Cave-in-Rock, Blackwell, Shelter, Carthage, Kanlow, Alamo
Notes:	Native

Common name:	VIRGINIA WILD RYE
Botanical name:	*Elymus virginicus*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	2.5 feet
pH range:	5-7
Seeds per lb (x 1000):	100
Applications:	Riparian areas, moist woods
Adaptations:	Shade tolerant, moist soils
Recommended varieties:	--
Notes:	Native

Common name:	WEEPING LOVE GRASS
Botanical name:	*Eragrostis curvula* (Schrader) Nees.
Life cycle:	Perennial
Growth form:	Bunch
Season of growth:	Warm
Height:	3 feet
pH range:	4.5-8.0
Seeds per lb (x 1000):	1,482
Applications:	Steep, dry slopes
Adaptations:	Drought
Notes:	Quick summer cover; frequently short-lived, and best used with sericea lespedeza. Bunch growth is a problem in pure stands.

Common name:	ZOYSIAGRASS (MANILAGRASS)
Botanical name:	*Zoysia matrella* L. Merrill
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Warm

Height: 4 inches (leaves)
pH range: 6.5-7.0
Seeds per lb (x 1000): 601
Applications: Fine turf, Coastal Plain and Piedmont
Adaptations: Drought
Notes: High-maintenance lawn grass. Not seeded; sod or plug on 12-inch centers

Legumes

Common name: CROWN VETCH
Botanical name: *Coronilla varia* L.
Life cycle: Perennial
Growth form: Low, spreading
Season of growth: Cool
Height: To 3 feet
pH range: 5.5-7.5
Seeds per lb (x 1000): 138
Applications: Steep roadbanks and other low-maintenance areas in the Mountains and on cool slopes in the Western Piedmont
Adaptations: Low pH, low fertility, and drought
Notes: Not very aggressive in the seedling stage, but a strong grower after establishment and very persistent. Does not compete well. Good in mixtures with tall fescue. Significant Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, KOBE (JAPANESE CLOVER)
Botanical name: *Lespedeza striata* (Thumb) H. & A.
Life cycle: Annual
Growth habit: Upright
Season of growth: Warm
Height: 4-16 inches
pH range: 5-7
Seeds per lb (x 1000): —
Applications: Nurse plant (Coastal Plain and Piedmont)
Adaptations: Drought
Notes: Heavy seeder and volunteer plant, Lesser Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, KOREAN
Botanical name: *Lespedeza stipulacea* Maxim.
Life cycle: Annual
Growth habit: Upright
Season of growth: Warm
Height: 4-12 inches
pH range: 5.5-7.5
Seeds per lb (x 1000): 238
Applications: Nurse plant (Mountains)
Adaptations: —
Notes: Volunteers, Lesser Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, SERICEA (CHINESE LESPEDEZA)
Botanical name: *Lespedeza cuneata* (Dumont) G. Don
Life cycle: Perennial
Growth habit: Upright
Season of growth: Warm
Height: 2-4 feet
pH range: 5.0-7.0
Seeds per lb (x 1000): 372
Applications: Low maintenance slopes; works well in mixtures with tall fescue

Adaptations: Low pH
Recommended varieties: Appalow, Ambro, Caricea, Interstate, and Serala
Notes: Severe Threat List of Exotic Invasive Species

Common name: ROUNDHEAD LESPEDEZA
Botanical name: *Lespedeza capitata*
Life Cycle: Perennial
Growth form: Multiple Stem
Season of growth: Summer
Height: 2.6 feet
pH range: 5.7-8.2
Seeds per lb (x 1000): 275
Applications: Native legume for use in upland seed mixes
Adaptations: Full sun, drought tolerant
Recommended varieties: --
Notes: Native

Table 8.02b
Guide to the Selection of Native Trees and Shrubs

Adapted from the NC DENR Ecosystem Enhancement Program Publication *Guidelines for Riparian Buffer Restoration,* October, 2004

Master List of Native Plants

Native Regions
M= Mountains
P= Piedmont
C= Coastal Plain

Light Requirements
S= Shade
P= Partial Sun
F= Full Sun

Moisture Requirements
L= Low Moisture
M= Moderate Moisture
H= High Moisture
A= Aquatic

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Medium to Large Trees											
Acer barbatum	Southern sugar maple		X	X	X	X			X		
Acer saccharinum	silver maple		X		X	X	X		X		
Acer saccharum	sugar maple	X				X	X		X		
Betula alleghaniensis	yellow birch	X			X	X			X		
Betula lenta	cherry birch, sweet birch	X			X	X			X		
Betula nigra	river birch	X	X	X		X	X		X	X	
Carya aquatica	water hickory			X		X	X			X	
Carya cordiformis	bitternut hickory	X	X	X	X	X	X		X	X	
Carya glabra	pignut hickory	X	X	X	X	X	X	X	X		
Carya ovata	shagbark hickory	X	X	X	X	X	X		X		
Carya tomentosa	mockernut hickory	X	X	X	X	X	X	X	X		
Celtis laevigata	sugarberry, hackberry		X	X	X	X			X		
Chamaecyparis thyoides	Atlantic white cedar			X		X	X		X	X	
Cladrastis kentuckea	yellowwood	X			X	X			X		
Diospyros virginiana	persimmon	X	X	X	X	X	X	X	X		
Fagus grandifolia	American beech	X	X	X	X	X			X		
Fraxinus americana	white ash	X	X	X	X	X			X		
Fraxinus pennsylvanica	green ash	X	X	X	X	X			X	X	
Fraxinus profunda	pumpkin ash, red ash		X	X		X				X	
Juglans nigra	black walnut	X	X	X	X	X			X		
Liriodendron tulipifera	tulip poplar, yellow poplar	X	X	X	X	X	X		X		
Magnolia acuminata	cucumber magnolia	X	X		X	X			X		
Magnolia fraseri	Fraser magnolia	X				X			X		
Nyssa aquatica	water tupelo			X	X	X	X			X	X
Nyssa sylvatica	black gum	X	X	X	X	X	X	X	X		

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Nyssa sylvatica var. biflora	swamp black gum			X	X	X	X			X	
Oxydendrum arboreum	sourwood	X	X	X		X	X	X	X		
Picea rubens	red spruce	X			X	X	X		X		
Pinus echinata	shortleaf pine	X	X	X		X	X	X			
Pinus palustris	longleaf pine		X	X			X	X	X		
Pinus rigida	pitch pine	X					X	X			
Pinus serotina	pond pine			X				X	X	X	
Pinus strobus	white pine	X	X			X	X		X		
Platanus occidentalis	sycamore	X	X	X		X	X		X	X	
Populus deltoides	eastern cottonwood		X	X			X			X	
Populus heterophylla	swamp cottonwood			X		X	X			X	
Prunus serotina	black cherry	X	X	X	X	X	X	X	X		
Quercus alba	white oak	X	X	X		X	X	X	X		
Quercus bicolor	swamp white oak		X		X	X				X	
Quercus coccinea	scarlet oak	X	X		X	X		X			
Quercus falcata	Southern red oak	X	X	X	X	X		X	X		
Quercus pagoda	cherrybark oak		X	X	X	X			X	X	
Quercus laurifolia	laurel oak			X	X	X	X		X	X	
Quercus lyrata	overcup oak		X	X	X	X				X	
Quercus margaretta	sand post oak			X		X	X	X			
Quercus marilandica	black jack oak	X	X	X	X	X		X			
Quercus michauxii	swamp chestnut oak		X	X	X	X	X		X	X	
Quercus nigra	water oak		X	X	X	X	X	X	X		
Quercus phellos	willow oak		X	X	X	X	X		X	X	
Quercus prinus	chestnut oak	X	X		X	X		X			
Quercus rubra	Northern red oak	X	X		X	X		X	X		
Quercus shumardii	shumard oak		X	X	X	X			X	X	
Quercus stellata	post oak	X	X	X	X	X		X			
Quercus velutina	black oak	X	X	X	X	X		X			
Quercus virginiana	live oak			X		X	X	X			
Robinia pseudoacacia	black locust	X	X	X		X	X		X		
Taxodium ascendens	pond-cypress			X		X	X				X
Taxodium distichum	bald-cypress			X		X	X				X
Tilia americana var. heterophylla	basswood	X	X		X	X			X		
Tsuga canadensis	Eastern hemlock	X	X		X	X	X		X		
Tsuga caroliniana	Carolina hemlock	X	X			X	X	X			
Ulmus alata	winged elm		X	X	X	X	X	X	X		
Ulmus americana	American elm	X	X	X	X	X			X		
Small Trees											
Amelanchier arborea	downy serviceberry, shadbush	X	X	X	X	X			X		
Amelanchier canadensis	Canada serviceberry			X			X		X	X	
Amelanchier laevis	smooth serviceberry	X				X	X	X	X		
Asimina triloba	pawpaw		X	X	X	X	X				X
Carpinus caroliniana	ironwood, American hornbeam	X	X	X	X	X			X	X	
Cercis canadensis	eastern redbud	X	X	X	X	X			X		
Chionanthus virginicus	white fringetree, old man's beard	X	X	X		X	X		X		
Cornus alternifolia	alternate-leaf dogwood	X			X	X			X		
Cornus florida	flowering dogwood	X	X	X	X	X		X	X		
Crateagus crus-galli	cockspur hawthorn	X	X	X		X	X	X	X		
Crateagus flabellata	fanleaf hawthorn	X	X			X			X		
Crateagus flava	October haw	X	X	X		X	X		X		
Cyrilla racemiflora	titi			X		X	X		X	X	
Fraxinus caroliniana	water ash			X	X	X				X	
Gordonia lasianthus	loblolly bay			X	X	X	X		X	X	
Halesia tetraptera (H. carolina)	common silverbell		X	X		X	X			X	
Ilex opaca	American holly		X	X	X	X	X		X	X	X
Juniperus virginiana	Eastern red cedar		X	X	X		X	X	X	X	

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Magnolia tripetala	umbrella tree		X	X		X				X	
Magnolia virginiana	sweetbay magnolia			X	X	X	X	X		X	X
Morus rubra	red mulberry		X	X	X	X	X			X	
Osmanthus americana	wild olive, devilwood				X	X	X			X	
Ostrya virginiana	Eastern hop-hornbeam		X	X		X	X			X	
Persea borbonia	red bay				X	X	X	X	X	X	
Persea palustris	swamp bay				X	X	X	X		X	X
Pinus pungens	table mountain pine		X					X	X		
Prunus americana	American wild plum		X	X			X			X	
Prunus caroliniana	Carolina laurel-cherry				X		X	X	X	X	
Quercus incana	bluejack oak				X		X	X	X		
Quercus laevis	turkey oak			X		X	X	X			
Rhus glabra	smooth sumac	X	X				X	X	X		
Rhus hirta (Rhus typhina)	staghorn sumac	X					X	X			
Salix caroliniana	swamp willow	X	X	X		X	X		X	X	
Salix nigra	black willow	X	X	X		X	X		X	X	
Sassafras albidum	sassafras	X	X	X		X	X	X	X		
Staphylea trifolia	bladdernut		X		X				X	X	
Symplocos tinctoria	horse-sugar, sweetleaf	X	X	X	X	X		X	X		
Ulmus rubra	slippery elm	X	X		X	X			X		
Shrubs											
Aesculus sylvatica	painted buckeye	X	X		X	X			X		
Alnus serrulata*	common alder	X	X	X	X	X	X			X	X
Aronia arbutifolia	red chokeberry	X	X	X	X	X			X	X	
Baccharis halimifolia	silverling		X	X			X	X	X	X	
Callicarpa americana	American beautyberry		X	X	X	X	X		X		
Calycanthus floridus	sweet-shrub	X	X		X	X			X		
Castanea pumila	Allegheny chinkapin	X	X	X	X	X	X	X			
Ceanothus americanus	New Jersey tea	X	X	X		X	X	X			
Cephalanthus occidentalis	buttonbush	X	X	X		X	X				X
Clethra acuminata	mountain sweet pepperbush	X			X	X			X		
Clethra alnifolia	sweet pepperbush			X	X	X			X	X	
Comptonia peregrina	sweet fern	X	X			X	X				
Cornus amomum	silky dogwood	X	X	X	X	X				X	X
Cornus stricta	swamp dogwood			X	X	X				X	
Corylus americana	American hazel, hazelnut	X	X		X	X			X		
Euonymus americanus	hearts-a-bustin', strawberry bush	X	X	X	X	X		X	X		
Fothergilla gardenii	witch-alder			X		X			X	X	
Gaylussacia frondosa	dangleberry			X	X	X	X		X	X	
Hamamelis virginiana	witch hazel	X	X	X	X	X		X	X		
Hydrangea arborescens	wild hydrangea	X	X		X	X			X		
Ilex coriacea	gallberry			X	X	X			X	X	
Ilex decidua	deciduous holly, possumhaw		X	X	X	X			X		
Ilex glabra	inkberry			X	X	X	X		X	X	
Ilex verticillata	winterberry	X	X	X	X	X	X		X	X	
Ilex vomitoria	yaupon holly			X	X	X	X	X			
Itea virginica	Virginia willow		X	X	X	X				X	
Kalmia angustifolia var. caroliniana	lamb-kill, sheep-kill			X		X	X		X	X	
Kalmia latifolia	mountain laurel	X	X		X	X		X	X		
Leucothoe axillaris	coastal dog-hobble			X	X	X			X		
Leucothoe fontanesiana	dog-hobble	X	X		X				X		
Leucothoe racemosa	fetterbush		X	X	X	X			X	X	
Lindera benzoin	spicebush	X	X		X				X		
Lyonia ligustrina	northern maleberry	X	X	X		X			X	X	
Lyonia lucida	shining fetterbush			X	X	X			X		
Myrica cerifera*	Southern wax-myrtle		X	X	X	X	X	X	X	X	

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Myrica cerifera var. pumila*	dwarf Southern wax-myrtle			X		X	X	X	X		
Myrica heterophylla*	bayberry, evergreen bayberry			X	X	X			X		
Pieris floribunda	evergreen mountain fetterbush	X					X	X	X		
Rhododendron atlanticum	dwarf azalea			X		X			X		
Rhododendron calendulaceum	flame azalea	X			X	X			X		
Rhododendron catawbiense	Catawba rhododendron	X	X		X	X	X	X	X		
Rhododendron maximum	rosebay rhododendron	X	X		X	X		X	X		
Rhododendron periclymenoides	pinxter flower, wild azalea	X	X	X	X	X			X		
Rhododendron viscosum	swamp azalea	X		X		X	X		X	X	
Rhus copallina	winged sumac	X	X	X		X	X	X	X		
Rosa carolina	pasture rose, Carolina rose	X	X	X		X	X	X	X		
Rosa palustris	swamp rose	X	X	X		X	X				X
Rubus allegheniensis	Alleghany blackberry	X	X				X	X			
Rubus cuneifolius	blackberry		X	X		X	X	X	X		
Rubus odoratus	purple flowering raspberry	X				X			X		
Salix humilis	prairie willow	X	X				X	X			
Salix sericea	silky willow	X	X	X		X	X				X
Sambucus canadensis	common elderberry	X	X	X			X		X	X	
Spiraea alba	narrow-leaved meadowsweet	X					X		X		
Spiraea latifolia	broad-leaved meadowsweet	X					X		X		
Spiraea tomentosa	meadowsweet	X	X	X		X	X			X	
Stewartia malacodendron	silky camellia			X	X	X			X		
Stewartia ovata	mountain camellia	X	X		X	X			X		
Styrax grandifolia	bigleaf snowbell		X	X	X	X			X		
Vaccinium arboreum	sparkleberry		X	X	X	X		X	X		
Vaccinium corymbosum	highbush blueberry	X	X	X	X	X	X	X	X	X	
Vaccinium crassifolium	creeping blueberry			X		X			X		
Vaccinium elliottii	mayberry			X	X				X		
Vaccinium stamineum	deerberry, gooseberry	X	X	X	X	X		X			
Vaccinium pallidum	lowbush blueberry	X	X		X	X		X			
Viburnum acerifolium	maple-leaf viburnum	X	X		X	X		X	X		
Viburnum dentatum	Southern arrowwood viburnum	X	X	X	X	X	X		X		
Viburnum nudum	possumhaw viburnum	X	X	X	X	X				X	
Viburnum prunifolium	blackhaw viburnum	X	X	X	X	X			X		
Viburnum rafinesquianum	downy arrowwood		X		X	X			X		
Viburnum rufidulum	rusty blackhaw		X	X	X	X		X			
Xanthorhiza simplicissima	yellowroot	X	X	X	X			X	X		

8.03

ESTIMATING RUNOFF

Estimating peak rate of runoff, volume of runoff, and soil loss are basic to the design of erosion and sedimentation control facilities.

There are a number of acceptable methods of determining runoff. Two acceptable methods, the rational method and the Natural Resources Conservation Service (NRCS), formally the SCS, peak discharge method, are described in this section.

The rational method is very simple in concept but relies on considerable judgement and experience to evaluate all factors properly. It is used primarily for small drainage areas (less than 50 acres). The NRCS method is more sophisticated hydrologically and offers a more accurate approximation of runoff, particularly for areas larger than 20 acres. Choice of method for small areas depends primarily on the experience of the designer.

Rational Method

The rational formula is:

$$Q = CIA$$

where:

Q = peak rate of runoff in cubic feet per second (cfs)
C = runoff coefficient, an empirical coefficient representing the relationship between rainfall rate and runoff rate
I = average intensity of rainfall in inches/hour, for a storm duration equal to the time of concentration, T_C
A = drainage area in acres

The general procedure for determining peak discharge using the rational formula is presented below and illustrated in Sample Problem 8.03a.

Step 1. Determine the drainage area in acres.

Step 2. Determine the runoff coefficient, C, for the type of soil/cover in the drainage area (Table 8.03b).

If the land use and soil cover is homogenous over the drainage area, a C value can be determined directly from Table 8.03b. If there are multiple soil cover conditions, a weighted average must be calculated, or the area may be subdivided.

Step 3. Determine the time of concentration, T_C, for the drainage area.

Shortcut to Time of Concentration, T_C, calculation:

As long as a watershed's area is less than 4.6S, $A_{(acres)} < 4.6\ S_{\%}$, where S is the slope in percent, the total time of concentration can be taken to be 5 minutes for bare soil. This is helpful to know because it will save the time of calculating time of concentration by other methods, including the Kinematic Wave Theory (below) which requires an iterative solution.

The Kinematic Wave Theory defines time of concentration as the "travel time of a wave to move from the hydraulically most distant point in the catchment to the outlet (Bedient and Huber, 1992)". The formula for the time of concentration for overland flow is:

$$T_C = \frac{\left[\dfrac{L}{\left(\dfrac{1.49 * S^{1/2}}{n}\right)\left(\dfrac{I_i * C}{43{,}200}\right)^{2/3}}\right]^{3/5}}{60}$$

where:

L = length of overland flow plane (feet)

S = slope (ft/ft)

n = Manning's roughness

Ii = rainfall intensity

C = rational runoff coefficient

Because both time of concentration and rainfall intensity are unknown variables in one equation, the solution must be found through iterations. The use of a spreadsheet is recommended. An example is shown in Table 8.03a.

Table 8.03a Time of Concentration

Solving for Time of Concentration (overland flow)
Kinematic Wave Theory

Length of overland flow:	100 feet
Manning's "n" surface:	0.020
Average watershed slope:	0.030 foot per foot
Rational Coefficient:	0.33

Surface Manning's "n"	
Smooth Surface:	0.011
Bare Earth:	0.020
Fallow:	0.050
Cultivated, < 20% residue:	0.060
Cultivated, > 20% residue:	0.170
Grass, short:	0.150
Grass, dense:	0.240
Grass, Bermuda:	0.410
Woods, light:	0.400
Woods, dense:	0.800

Trial Time of Duration T_r (minutes)	**Rainfall Intensity** i (inches/hour)	**Calculated Time of Concentration** T_C (minutes)
5	7.08	2.90
10	5.66	3.17
15	4.78	3.39
30	3.46	3.86
60 (1 hour)	2.25	4.58

Enter the Rainfall Intensity Values for the Corresponding Times of Duration from the Table 8.03c, Intensity Duration Frequency, or the NOAA Precipitation Frequency Data Server, http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html. Select the Trial Time of Duration that is equal to or less than the calculated Time of Concentration, or the Calculated Time of Concentration if less than 5 minutes. This is the overland flow component of the Time of Concentration.

In this example, there is no Trial Time of Duration that is less than corresponding Calculated Time of Concentration. In this case, select a Rainfall Intensity of 7.08 inches/hour and a Time of Concentration for Overland Flow of 2.90 minutes.

The above method estimates the time of concentration for **overland flow**. After short distances of 400 feet at most, sheet flow tends to concentrate in rills and then gullies of increasing proportions. Such flow is usually referred to as **shallow concentrated flow** (HEC-22, Urban Drainage Manual, FWHA). The NRCS TR-55 Manual (1986) assumed a maximum sheet flow of 300 feet, and the more recent WinTR-55 User Manual (2003) allowed no more than 100 feet of overland flow. Shallow concentrated flow is an important component in determining Time of Concentration.

Both the FWHA and NRCS procedures use similar formulas for the velocity of **shallow concentrated flow,** where...

$$V = 16.1345 * S^{1/2} \quad \text{(Unpaved)}$$

$$V = 20.3282 * S^{1/2} \quad \text{(Paved)}$$

where:

V = average velocity (ft/s), and
S = slope (ft/ft)

Flow in gullies empty into **open channels or pipes**. Cross-section geometry and roughness should be obtained for all channel reaches in the watershed. Manning's equation can be used to estimate average flow velocities in pipes and open channels as follows:

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

where:

n = roughness coefficient
V = velocity (ft/s)
R = hydraulic radius (ft)
S = slope (ft)

For a circular pipe flowing full, the hydraulic radius is one-fourth of the diameter. For a wide rectangular channel (width > 10 * depth), the hydraulic radius is approximately equal to the depth.

The travel time for **shallow concentrated flow** and **open channels and pipes** is then calculated from the velocities of those travel segments by the following equation:

$$T_i = \frac{L}{(60 * V)}$$

where:

T_i = travel time for segment i, minutes
L = flow length for segment i, (ft)

For short flow lengths, the time of travel in open channels or pipes may not significantly add to the time of concentration. For longer flow lengths, it may be more accurate to calculate the kinematic wave speed in the open channel or pipe rather than the velocity.

The wave travel time in an open channel can be estimated by calculating the kinematic wave speed in feet per second, converting to feet per minute, and dividing the length (ft) by the average velocity. The kinematic wave speed, C, in an open channel is determined by the following equation:

$$C = V + \left[\frac{32.2\,(A)}{W_T}\right]^{1/2}$$

where:

C = wave speed (ft/s)
V = velocity (ft/s)
A = the cross-sectional area of flow (ft^2)
W_T = the top width of the channel flow (ft)

$$T_C = \frac{L}{60\,(C)}$$

where:

T_C = Time of Concentration for open channel (minutes)
L = length of channel segment (ft)
C = wave speed (ft/s)

The total time of concentration is the sum of the overland, shallow concentrated and channel flow times.

Step 4. Determine the rainfall intensity, duration and frequency. The tables provided were excerpted from the "Precipitation-Frequency Atlas of the United Sates" NOAA Atlas 14, Volume 2, Version 2, G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M. Yekta, and D. Riley, NOAA, National Weather Service, Silver Spring, Maryland, 2004. An interactive web-site that includes many more observation records across North Carolina may be used to obtain data for a more specific locale at http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html .

Step 5. Determine peak discharge, Q (cubic feet per second), by multiplying the previously determined factors using the rational formula (Sample Problem 8.03a);

$$Q = CIA$$

Table 8.03b
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, ave., 2-7%	0.10-0.15
Residential:		Sandy soil, steep, 7%	0.15-0.20
Single-family areas	0.30-0.50	Heavy soil, flat, 2%	0.13-0.17
Multi units, detached	0.40-0.60	Heavy soil, ave., 2-7%	0.18-0.22
Multi units, Attached	0.60-0.75	Heavy soil, steep, 7%	0.25-0.35
Suburban	0.25-0.40		
Industrial:		Agricultural land:	
Light areas	0.50-0.80	Bare packed soil	
Heavy areas	0.60-0.90	Smooth	0.30-0.60
Parks, cemeteries	0.10-0.25	Rough	0.20-0.50
Playgrounds	0.20-0.35	Cultivated rows	
Railroad yard areas	0.20-0.40	Heavy soil no crop	0.30-0.60
Unimproved areas	0.10-0.30	Heavy soil with crop	0.20-0.50
Streets:		Sandy soil no crop	0.20-0.40
Asphalt	0.70-0.95	Sandy soil with crop	0.10-0.25
Concrete	0.80-0.95	Pasture	
Brick	0.70-0.85	Heavy soil	0.15-0.45
Drives and walks	0.75-0.85	Sandy soil	0.05-0.25
Roofs	0.75-0.85	Woodlands	0.05-0.25

NOTE: The designer must use judgement to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

Sample Problem 8.03a Determination of Peak Runoff Rate Using the Rational Method

Q = CIA

Given:

Drainage area:	20 acres
Graded areas:	12 acres
Woodland:	8 acres
Maximum slope length:	100 ft overland flow, 300 ft shallow concentrated flow
Average slope:	3%, area bare
Location:	Raleigh, NC

Find:

Peak runoff rate from 10-year frequency storm

Solution:

(1) Drainage area: 20 acres (given)

(2) Determine runoff coefficient, C.
Calculate Weighted Average

	Area		C from Table 8.03b		
Graded[1]	12	x	0.45	=	5.4
Woodland	8	x	0.15	=	1.2
	20				6.6

C = 6.6/20 = 0.33

(3) Find the overland time of concentration using iterations of the kinematic wave equation (Table 8.03a) using a slope length of 100 ft for overland flow and 300 feet for shallow concentrated flow (unpaved). The average watershed slope is 3%. Assume overland flow on bare earth. Work an example with the spreadsheet (pasted in below)

NOTE: Any time of flow in shallow concentrated flow or channel flow should be added to the overland flow to determine T_C.

To find the time of flow in shallow concentrated flow, use the procedures from FWHA and NRCS described on page 8.03.4.

First, calculate the velocity of the shallow concentrated flow:

$$V = 16.1345 * S^{1/2} \quad \text{(Unpaved)}$$
$$V = 16.1345 * (0.03)^{1/2} = 2.79 \text{ ft/s}$$

The travel time for shallow concentrated flow may then be calculated for the segment by:

$$T = \frac{L}{60 * V}$$

where T = travel time, minutes

L = flow length of segmer

$$T = \frac{300}{60 * 2.79} = 1.79 \text{ minutes}$$

The total time of concentration, T_C, may be found by summing the T_C for overland flow and the travel time in shallow concentrated flow:

$T_C = T_C$ (overland) + T_C (shallow concentrated) + T_C (channel)
T_C = 2.90 minutes + 1.79 minutes
T_C = 4.7 minutes, Use 5 minutes as the minimum T_C

I = 7.08 inches/hour (from Table 8.03C) using a 10-year storm, 5 minute duration.

(4) Q = CIA
Q = 0.33*7.08*20 = 46.7cfs, Use 47 cfs.

Watershed Basin Number	
Total Drainage Area	20
Rational Method for Flow	
Subarea A (acres)	12
Subarea A Runoff Coefficient	0.45
Subarea B (acres)	8
Subarea B Runoff Coefficient	0.15
Subarea C (acres)	
Subarea C Runoff Coefficient	
Subarea D (acres)	
Subarea D Runoff Coefficient	
Weighted Runoff Coefficient	**0.33**
2-year Rainfall Intensity (IDF)	0
10-year Rainfall Intensity (IDF)	7.08
Q2 Flow	**0**
Q10 Flow	**46.7**

Revised 11/25/2008 TGH

RUNOFF COEFFICIENT

LAND USE	**C**
BUSINESS:	
DOWNTOWN AREAS	0.7-0.95
NEIGHBORHOOD AREAS	0.5-0.7
RESIDENTIAL:	
SINGLE FAMILY AREAS	0.3-0.5
MULTI UNITS, DETACHED	0.4-0.6
MULTI UNITS, ATTACHED	0.6-0.75
SUBURBAN	0.25-0.4
INDUSTRIAL:	
LIGHT AREAS	0.5-0.8
HEAVY AREAS	0.6-0.9
PARKS, CEMETARIES	0.1-0.25
PLAYGROUNDS	0.2-0.35
RAILROAD YARD AREAS	0.2-0.4
UNIMPROVED AREAS	0.1-0.3
STREETS:	
ASPHALT	0.7-0.95
CONCRETE	0.8-0.95
BRICK	0.7-0.85
DRIVES AND WALKS	0.75-0.85
ROOFS	0.75-0.85
LAWNS:	
SANDY SOIL, FLAT, 2%	0.05-0.1
SANDY SOIL, AVE., 2-7%	0.1-0.15
SANDY SOIL, STEEP, 7%	0.15-0.2
HEAVY SOIL, FLAT, 2%	0.13-0.17
HEAVY SOIL, AVE., 2-7%	0.18-0.22
HEAVY SOIL, STEEP, 7%	0.25-0.35
AGRICULTURAL LAND:	
BARE PACKED SOIL	
SMOOTH	0.3-0.6
ROUGH	0.2-0.5
CULTIVATED ROWS	
HEAVY SOIL NO CROP	0.3-0.6
HEAVY SOIL WITH CROP	0.2-0.5
SANDY SOIL NO CROP	0.2-0.4
SANDY SOIL WITH CROP	0.1-0.25
PASTURE	
HEAVY SOIL	0.15-0.45
SANDY SOIL	0.05-0.25
WOODLANDS	0.05-0.25

Solving for Time of Concentration
Kinematic Wave Theory

User Data / Calculated Value

Length of overland flow	100.000	feet
Mannings "n" for surface	0.020	
Average watershed slope	0.030	ft./ft.
Constant alpha	12.904	
Constant m	1.667	
Weighted Runoff Coefficient	0.33	

Surface Mannings n	
Smooth Surface	0.011
Bare Earth	0.020
Fallow	0.050
Cultivated, <= 20% Residue	0.060
Cultivated, > 20% Residue	0.170
Grass, Short	0.150
Grass, Dense	0.240
Grass, Bermuda	0.410
Woods, Light	0.400
Woods, Dense	0.800

http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html

Trail Time of Duration tr (minutes)		Rainfall Intensity(IDF) i (Inches/hour)	Calculation of Time of Concentration tc (minutes)
5		7.08	2.90
10		5.66	3.18
15		4.78	3.40
30		3.46	3.87
60	(1 hour)	2.25	4.60
120	(2 hours)	1.33	5.67
180	(3 hours)	0.95	6.49
360	(6 hours)	0.98	6.41
720	(12 hours)	0.34	9.79
1440	(24 hours)	0.21	11.87

Enter the Rainfall Intensity Values for the Corresponding Times of Duration from the NWS hyperlink provided.
Select the smallest Trial Time of Duration that is equal to or less than the calculated Time of Concentration, or the Calculated Time of Concentration if it is less than 5 minutes. This is the overland flow component of the Time of Concentration.

Overland Flow	tc (minutes)	**2.9**

Calculate the shallow concentrated flow component of the Time of Concentration.
Calculate the channel flow component of the Time of Concentration.
Sum these three components. This is the total Time of Concentration.

Shallow Concentrated Flow	
Paved	
Flow Length	0
Slope	0.03
tc (minutes)	**0.0**
Unpaved	
Flow Length	300
Slope	0.03
tc (minutes)	**1.8**

Channel Flow	
Flow Length	0
Slope	0.03
Hydraulic Radius	1
Mannings n	0.035
tc (minutes)	**0.0**

Total Time of Concentration	**4.7**

Al Jarrett Shortcut, for Bare Soil		
Average Watershed Slope	5	%
Total Drainage Area A	10	acres
4.6*S	23	
If A<4.6*S, Assume Tc=5 minutes		

Table 8.03c Intensity Duration Frequency

For use with Rational Method**

Murphy, North Carolina 35.0961N, 84.0239W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	4.93	3.94	3.30	2.28	1.43	0.89	0.62	0.38	0.24	0.15
10	6.78	5.42	4.57	3.31	2.16	1.29	0.92	0.55	0.34	0.21
25	7.90	6.29	5.31	3.94	2.62	1.57	1.13	0.68	0.41	0.25
100	9.62	7.64	6.44	4.93	3.40	2.06	1.50	0.90	0.53	0.33

Asheville, North Carolina 35.4358N, 82.5392W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.21	4.16	3.46	2.41	1.51	0.89	0.63	0.38	0.24	0.14
10	7.06	5.65	4.76	3.45	2.25	1.30	0.91	0.55	0.34	0.20
25	8.09	6.44	5.45	4.03	2.69	1.56	1.10	0.66	0.40	0.24
100	9.68	7.69	6.48	4.96	3.42	2.00	1.43	0.86	0.50	0.30

Boone, North Carolina 36.2167N, 81.6667W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.71	4.57	3.83	2.64	1.66	1.00	0.72	0.48	0.31	0.18
10	7.50	6.00	5.06	3.67	2.39	1.46	1.06	0.69	0.44	0.28
25	8.59	6.85	5.78	4.28	2.85	1.77	1.29	0.83	0.52	0.34
100	10.38	8.25	6.95	5.32	3.67	2.35	1.72	1.08	0.65	0.44

Charlotte, North Carolina, 35.2333N, 80.85W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.68	4.54	3.80	2.63	1.65	0.96	0.68	0.41	0.24	0.14
10	7.26	5.80	4.89	3.55	2.31	1.36	0.98	0.59	0.35	0.20
25	8.02	6.38	5.40	4.00	2.66	1.59	1.15	0.70	0.42	0.24
100	9.00	7.15	6.03	4.62	3.18	1.93	1.43	0.87	0.53	0.30

Greensboro, North Carolina 36.975N, 79.9436W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.46	4.36	3.66	2.52	1.58	0.93	0.66	0.40	0.23	0.14
10	6.85	5.48	4.62	3.35	2.18	1.30	0.92	0.56	0.33	0.20
25	7.39	5.89	4.98	3.69	2.46	1.49	1.06	0.65	0.39	0.23
100	7.93	6.30	5.31	4.07	2.80	1.75	1.24	0.78	0.48	0.29

* ARI is the Average Return Interval.

** Intensity Duration Frequency table is measured in inches per hour.

Raleigh, North Carolina 35.8706N, 78.7864W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	5.58	4.46	3.74	2.58	1.62	0.94	0.66	0.40	0.24	0.14
10	7.08	5.66	4.78	3.46	2.25	1.33	0.95	0.58	0.34	0.021
25	7.78	6.19	5.24	3.88	2.58	1.54	1.11	0.68	0.41	0.24
100	8.64	6.86	5.78	4.43	3.05	1.85	1.36	0.84	0.51	0.30

Fayetteville, North Carolina 35.0583N, 78.8583W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.11	4.88	4.09	2.83	1.77	1.04	0.74	0.44	0.26	0.15
10	7.96	6.36	5.36	3.88	2.53	1.54	1.10	0.66	0.39	0.23
25	8.94	7.13	6.02	4.46	2.97	1.83	1.32	0.80	0.47	0.28
100	10.44	8.29	6.99	5.35	3.69	2.29	1.69	1.03	0.62	0.36

Wilmington, North Carolina 34.2683N, 77.9061W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	7.39	5.92	4.96	3.42	2.15	1.28	0.91	0.56	0.33	0.19
10	9.70	7.75	6.54	4.74	3.08	1.94	1.39	0.87	0.51	0.30
25	10.98	8.75	7.40	5.48	3.65	2.38	1.73	1.08	0.64	0.38
100	12.92	10.27	8.65	6.63	4.56	3.18	2.37	1.49	0.89	0.53

Washington, North Carolina 35.5333N, 77.0167W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.41	5.12	4.29	2.96	1.86	1.10	0.78	0.47	0.27	0.16
10	8.38	6.70	5.65	4.09	2.66	1.64	1.19	0.72	0.42	0.25
25	9.48	7.55	6.38	4.73	3.15	1.99	1.46	0.88	0.52	0.31
100	11.16	8.87	7.47	5.72	3.94	2.58	1.93	1.18	0.70	0.42

Manteo Airport, North Carolina 35.9167N, 75.7000W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.46	5.16	4.32	2.99	1.87	1.08	0.79	0.48	0.29	0.17
10	8.47	6.77	5.71	4.14	2.69	1.62	1.20	0.74	0.44	0.27
25	9.56	7.62	6.44	4.77	3.17	1.96	1.47	0.91	0.54	0.33
100	11.26	8.95	7.54	5.77	3.98	2.54	1.95	1.21	0.73	0.44

Cape Hatteras, North Carolina, 35.2322N, 75.6225W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	7.20	5.75	4.82	3.33	2.09	1.29	0.94	0.58	0.34	0.20
10	9.41	7.52	6.35	4.60	2.99	1.93	1.43	0.89	0.53	0.31
25	10.66	8.49	7.18	5.31	3.54	2.33	1.75	1.09	0.65	0.38
100	12.53	9.95	8.39	6.42	4.42	3.03	2.32	1.45	0.88	0.51

SCS (NRCS) Peak Discharge Method

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met. The following excerpt presents the portion of TR-55 for determining peak discharge. New rainfall data from NOAA is presented in tabular form.

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is:

Equation 8.03a

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. Ia is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, Ia was found to be approximated by the following empirical equation:

Equation 8.03b

$$I_a = 0.2S$$

By removing Ia as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 8.03b into equation 8.03a gives:

Equation 8.03c

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

Equation 8.03d

$$S = \frac{1000}{CN} - 10$$

Figure 8.03a and Table 8.03d solve equations 8.03c and 8.03d for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 8.03b is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in Tables 8.03e-8.03g represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 8.03c assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced.

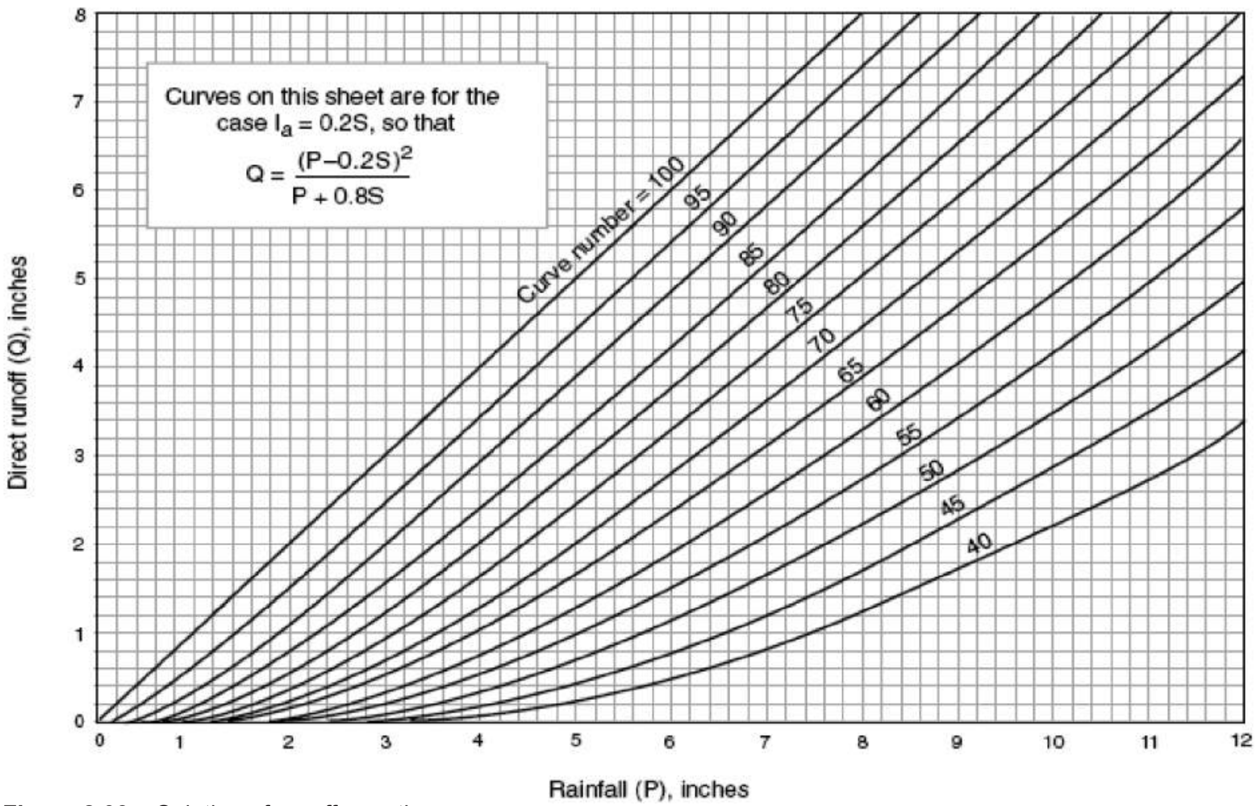


Figure 8.03a Solution of runoff equation

Cover type

Table 8.03e addresses most cover types, such as vegetation, bare soil, and impervious surfaces. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photographs, and land use maps.

Treatment

Treatment is a cover type modifier (used only in Table 8.03f) to describe the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage.

Hydrologic condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. Good hydrologic condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are (a) canopy or density of lawns, crops, or other vegetative areas; (b) amount of year-round cover; (c) amount of grass or close-seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

Table 8.03d Runoff depth for selected CN's and rainfall amounts [1]

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	----inches----												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0.00	0.00	0.00	0.00	0.00	0.00	.03	.07	.15	.27	.46	.74	.99
1.4	0.00	0.00	0.00	0.00	0.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	0.00	0.00	0.00	0.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	0.00	0.00	0.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	0.00	0.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	0.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

1 / Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Figure 8.03b Flow chart for selecting the appropriate figure or table for determining runoff curve numbers

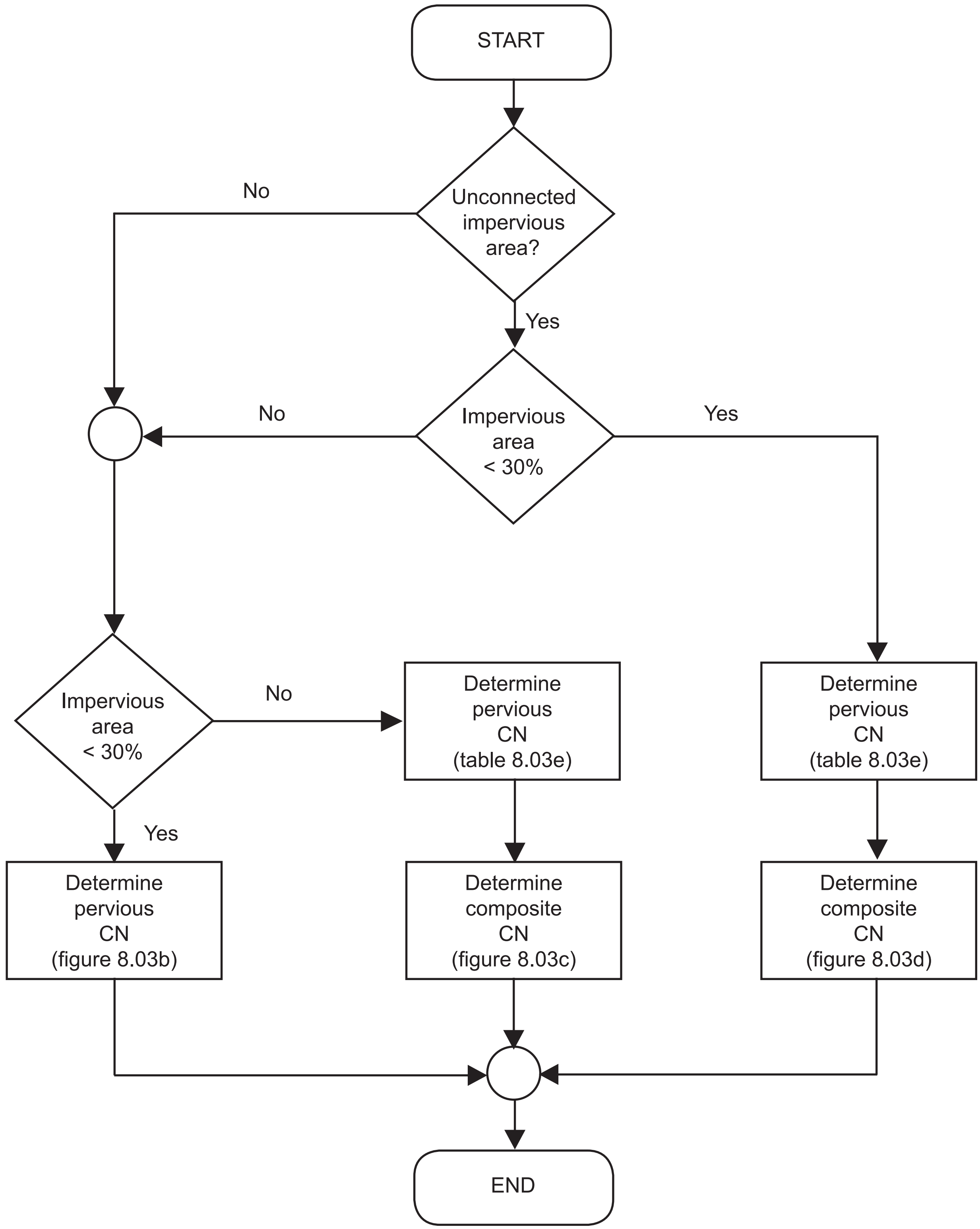


Table 8.03e Runoff curve numbers of urban areas[1]

Cover Description: Cover type and hydrologic condition	Average percent impervious area[2]	Curve number for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[4]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1. Average runoff condition, and Ia = 0.2S.
2. The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using Figure 8.03c or 8.03d.
3. CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4. Composite CN's to use for the design of temporary measures during grading and construction should be computed using Figure 8.03c or 8.03d based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 8.03f Runoff curve numbers for cultivated agriculture lands[1]

----------Cover description----------			Curve numbers for ------hydrologic soil groups------			
Cover type	Treatments[2]	Hydrologic conditions[3]	A	B	C	D
Fallow	Bare soil	————	77	86	91	94
Row crops	Straight row	Good	67	78	85	89
	Contoured & terraced	Good	62	71	78	81

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 8.03g Runoff curve numbers for other agriculture lands[1]

Cover description		Curve numbers for hydrologic soil groups			
Cover type	Hydrologic conditions[3]	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Urban impervious area modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for urban areas (Rawls et al., 1981). For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

Connected impervious areas — An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area and then into the drainage system.

Urban CN's (Table 8.03e) were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN vales were developed on the assumptions that (a) pervious urban areas are equivalent to pasture in good hydrologic condition and (b) impervious areas have a CN of 98 and are directly connected to the drainage system. Some assumed percentages of impervious area are shown in Table 8.03e.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table 8.03e are not applicable, use Figure 8.03c to compute a composite CN. For example, Table 8.03e gives a CN of 70 for a 1/2-acre lot in HSG B, with assumed impervious area of 25 percent. However, if the lot has 20 percent impervious area and a pervious area CN of 61, the composite CN obtained from Figure 8.03c is 68. The CN difference between 70 and 68 reflects the difference in percent impervious area.

Unconnected impervious areas — Runoff from these areas is spread over a pervious area as sheet flow. To determine CN when all or part of the impervious area is not directly connected to the drainage system, (1) use Figure 8.03d if total impervious area is less than 30 percent or (2) use Figure 8.03c if the total impervious area is equal to or greater than 30 percent, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

When impervious area is less than 30 percent, obtain the composite CN by entering the right half of Figure 8.03d with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN. For example, for a 1/2-acre lot with 20 percent total impervious area (75 percent of which is unconnected) and pervious CN of 61, the composite CN from Figure 8.03d is 66. If all of the impervious area is connected, the resulting CN (from Figure 8.03c) would be 68.

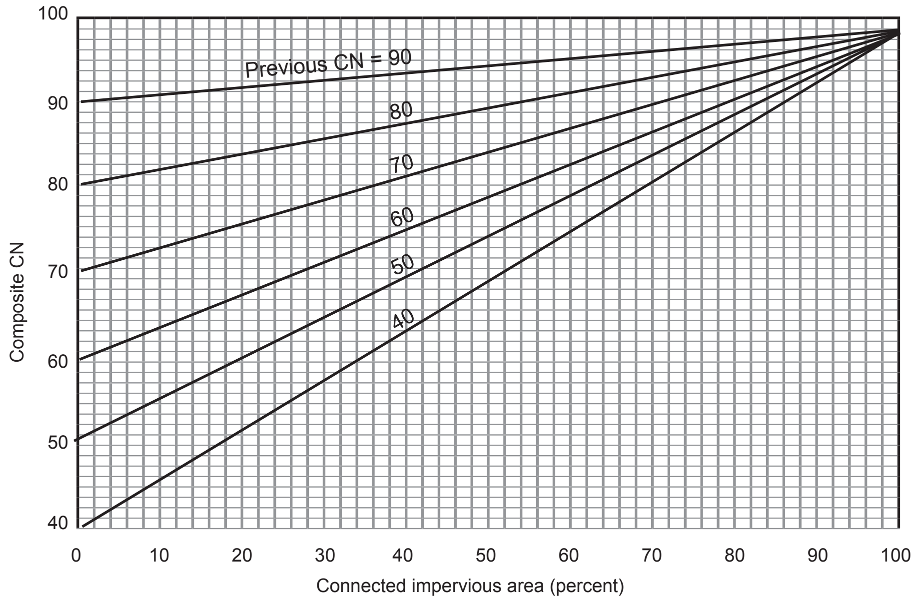


Figure 8.03c Composite CN with connected impervious area

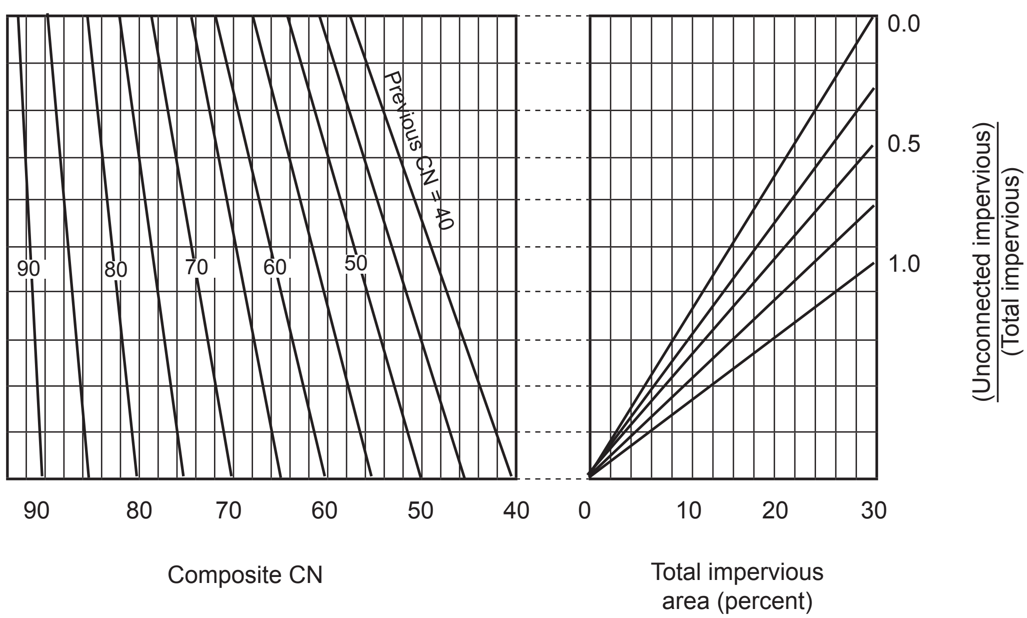


Figure 8.03d Composite CN with unconnected impervious areas and total impervious are less than 30%

Runoff

When CN and the amount of rainfall have been determined for the watershed, determine runoff depth by using Figure 8.03a, Table 8.03d, or equations 8.03c and 8.03d. The runoff is usually rounded to the nearest hundredth of an inch.

Limitations

- Curve numbers describe average conditions that are useful for design purposes. If the rainfall event used is a historical storm, the modeling accuracy decreases.
- Use the runoff curve number equation with caution when re-creating specific features of an actual storm. The equation does not contain an expression for time and, therefore, does not account for rainfall duration or intensity.
- The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place. The opposite effect, a greater initial loss, can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must redevelop equation 8.03c, Figure 8.03a, Table 8.03d, and Table 8.03e by using the original rainfall-runoff data to establish new S or CN relationships for each cover and hydrologic soil group.
- Runoff from snowmelt or rain on frozen ground cannot be estimated using these procedures.
- The CN procedure is less accurate when runoff is less than 0.5 inch. As a check, use another procedure to determine runoff.
- The SCS runoff procedures apply only to direct surface runoff: do not overlook large sources of subsurface flow or high ground water levels that contribute to runoff. These conditions are often related to HSG A soils and forest areas that have been assigned relatively low CN's in Table 8.03e. Good judgment and experience based on stream gage records are needed to adjust CN's as conditions warrant.
- When the weighted CN is less than 40, use another procedure to determine runoff.

Example 8.03a

The example below illustrates the procedure for computing runoff curve number (CN) and runoff (Q) in inches. Worksheet 2 is provided to assist TR-55 users.

The watershed covers 250 acres in Dyer County, northwestern Tennessee. Seventy percent (175 acres) is a Loring soil, which is in hydrologic soil group C. Thirty percent (75 acres) is a Memphis soil, which is in group B. The event is a 25-year frequency, 24-hour storm with total rainfall of 6 inches.

Seventy percent (175 acres) of the watershed, consisting of all the Memphis soil and 100 acres of the Loring soil, is 1/2-acre residential lots with lawns in good hydrologic condition. The rest of the watershed is scattered open space in good hydrologic condition. (See Figure 8.03e).

Figure 8.03e Worksheet 1 for example 8.03a

Worksheet 1: Runoff curve number and runoff

Project: Heavenly Acres	By: WJR	Date: 10/1/2006
Location: Dare County, North Carolina	Checked: NM	Date: 10/3/2006

Check one: ☐ Present ☒ Developed 175 Acres residential

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN[1] (Table 8.03e / Figure 8.03c / Figure 8.03d)	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
Memphis, B	25% impervious 1/2 acre lots, good condition	70	75	5250
Loring, C	25% impervious 1/2 acre lots, good condition	80	100	8000
Loring, C	Open space, good condition	74	75	5550
1: Use only one CN source per line		**Totals ➡**	25	18,800

$$\text{CN (weighted)} = \frac{\text{total product}}{\text{total area}} = \frac{18,800}{2500} = 75.2$$

Use CN ➡ 75

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	25		
Rainfall, P (24-hr) .... in	6.0		
Runoff, Q .... in	3.28		

(Use P and CN with table 8.03d, figure 8.03a, or equations 8.03c and 8.03d)

Worksheet 1: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] Table 8.03e	CN [1] Figure 8.03c	CN [1] Figure 8.03d	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
1: Use only one CN source per line		**Totals ➡**				

$$\text{CN (weighted)} = \frac{\text{total product}}{\text{total area}} = \underline{\qquad\qquad} =$$

Use CN ➡ ☐

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr			
Rainfall, P (24-hr) .... in			
Runoff, Q .... in			

(Use P and CN with table 8.03d, figure 8.03a, or equations 8.03c and 8.03d)

Time of Concentration and Travel Time

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors affecting time of concentration and travel time

Surface roughness

One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel shape and flow patterns

In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope

Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of travel time and time of concentration

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

Equation 8.03e

$$T_t = \frac{L}{3600V}$$

where:

T_t = Travel time (hr)
L = flow length (ft)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments:

Equation 8.03f

$$T_c = T_{t_1} + T_{t_2} + \ldots T_{t_m}$$

where:

T_c = time of concentration (hr)
m = number of flow segments

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 8.03h gives Manning's n values for sheet flow for various surface conditions.

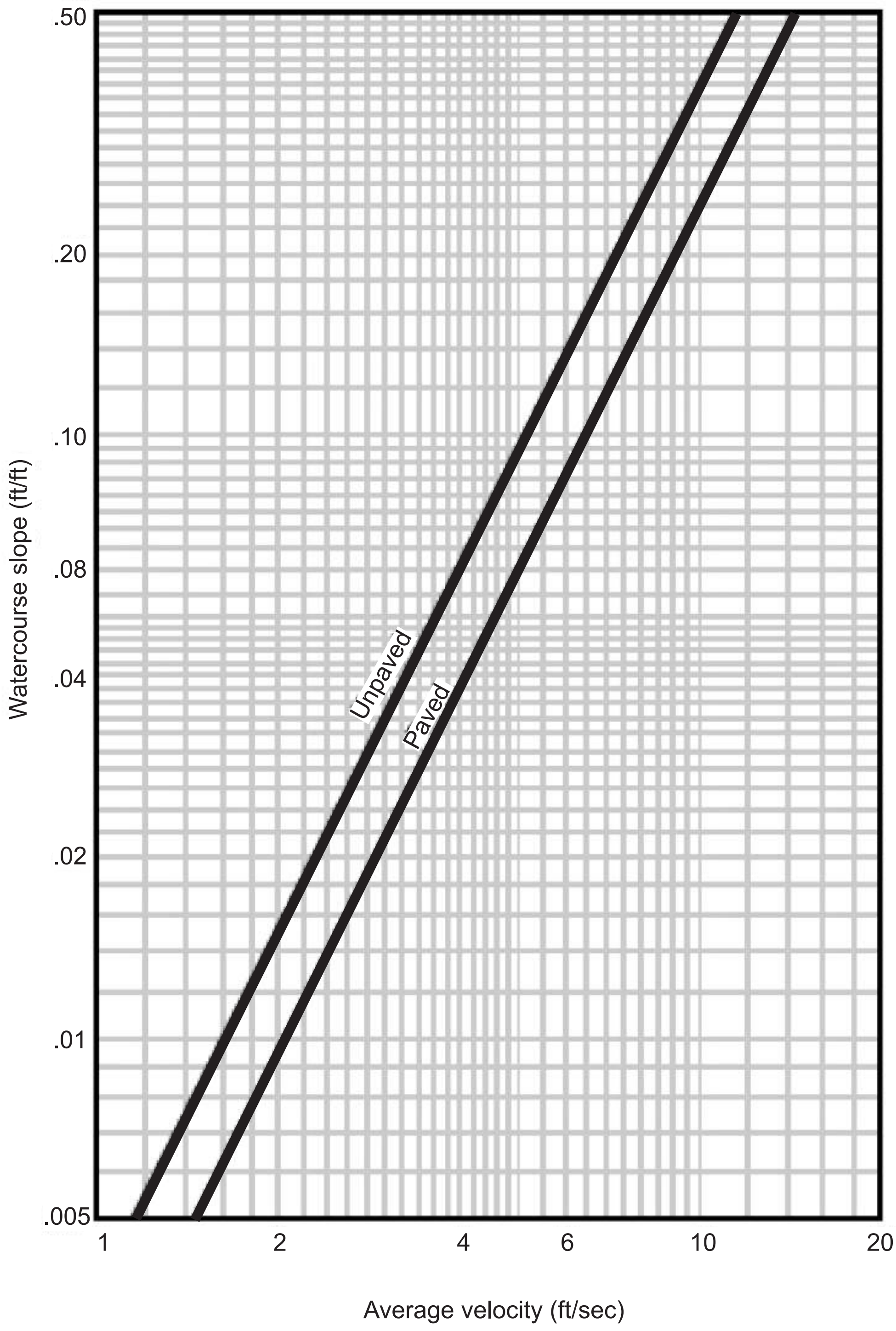


Figure 8.03f Average velocities for estimating travel time for shallow concentrated flow

Table 8.03h Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surface (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairies	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (nutral)	0.13
Woods: [3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

Equation 8.03g

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}s^{0.4}}$$

where:

T_t = Travel time (hr)
n = Manning's roughness coefficient (Table 8.03h)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure 8.03f, in which average velocity is a function of watercourse slope and type of channel. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in Figure 8.03f, use equation 8.03e to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation.

Manning's equation is:

Equation 8.03h

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$$

where:

V = average velocity (ft/s)
r = hydralic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of hydraulic grade line (land slope, ft/ft)
n = Manning's roughness coefficient for open channel flow

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 8.03h, T_t for the channel segment can be estimated using equation 8.03e.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 8.03g was developed for use with the four standard rainfall intensity-duration relationships.

- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.

- The minimum T_c used in TR-55 is 0.1 hour.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

Example 8.03b

The sketch below shows a watershed in Dyer County, northwestern Tennessee. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft; and length (L) = 100 ft. Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1,400 ft. Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (p_w) = 28.2 ft; s = 0.005 ft/ft; and L = 7,300 ft.

See Figure 8.03h for the computations made on worksheet 2.

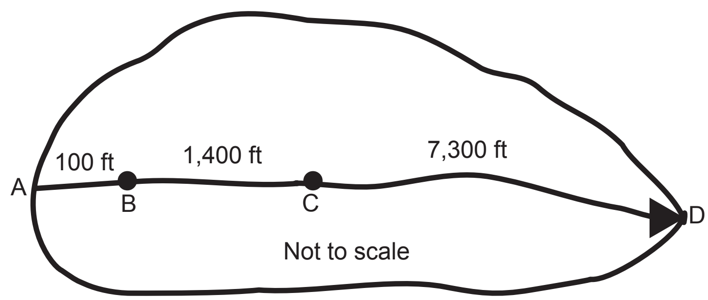


Figure 8.03g

Figure 8.03h Worksheet 2 for example 8.03b

Worksheet 2: Time of Concentration (T_c) or travel time (T_t)

Project Heavenly Acres	By DW	Date 10/6/2006
Location Dare County, North Carolina	Checked NM	Date 10/8/2006

Check one: [ ] Present [X] Developed

Check one: [X] T_c [ ] T_t through subarea

Note: Space for as many as two segments per flow can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Segment ID:	AB			
1.	Surface description (table 8.03h)	Dense Grass			
2.	Manning's roughness coefficient, n (table 8.03h)...	0.24			
3.	Flow length, L (total L + 300ft) ....ft	100			
4.	Two-year 24-hour rainfall, P_2 ....in	3.6			
5.	Land slope, s ....ft/ft	0.01			
6.	$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t ....hr	0.30	+		= 0.30

Shallow concentrated flow

	Segment ID:	BC			
7.	Surface description (paved or unpaved).............	Unpaved			
8.	Flow length, L ....ft	1400			
9.	Watercourse slope, s ....ft/ft	0.01			
10.	Average velocity, V (figure 3-1) ....ft/s	1.6			
11.	$T_t = \frac{L}{3600\,V}$ Compute T_t ....hr	0.24	+		= 0.24

Channel flow

	Segment ID:	CD			
12.	Cross sectional flow area, a ....ft^2	27			
13.	Wetted perimeter, P_w ....ft	28.2			
14.	Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ....ft	0.957			
15.	Channel slope, s ....ft/ft	0.005			
16.	Manning's roughness coeficient, n	0.05			
17.	$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V ....ft/s	2.05			
18.	Flow length, L ....ft	7300			
19.	$T_t = \frac{L}{3600V}$ Compute T_t ....hr	0.99	+		= 0.99
20.	Watershed or subarea or (add in step 6,11, and 19) ....Hr				1.53

Worksheet 2: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

Note: Space for as many as two segments per flow can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID:				
1. Surface description (table 8.03h)........................				
2. Manning's roughness coefficient, n (table 8.03h)				
3. Flow length, L (total L + 300ft) ....ft				
4. Two-year 24-hour rainfall, P_2 ....in				
5. Land slope, s ....ft/ft				
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t ....hr		+		=

Shallow concentrated flow

Segment ID:				
7. Surface description (paved or unpaved).............				
8. Flow length, L ....ft				
9. Watercourse slope, s ....ft/ft				
10. Average velocity, V (figure 3-1) ....ft/s				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t ....hr		+		=

Channel flow

Segment ID:				
12. Cross sectional flow area, a ....ft^2				
13. Wetted perimeter, P_w ....ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ....ft				
15. Channel slope, s ....ft/ft				
16. Manning's roughness coeficient, n				
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V ....ft/s				
18. Flow length, L ....ft				
19. $T_t = \frac{L}{3600V}$ Compute T_t ....hr		+		=
20. Watershed or subarea or (add in step 6,11, and 19) ....Hr				

Graphical Peak Discharge Method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is:

Equation 8.03i

$$q_p = q_u A_m Q F_p$$

where:

q_p = peak discharge (cfs)
q_u = unit peak discharge (csm/in)
A_m = discharge area (mi^2)
Q = runoff
F_p = pond and swamp adjustment factor

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi^2), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from Tables 8.03i. The CN is used to determine the initial abstraction (I_a) from Table 8.03h. I_a / P is then computed.

If the computed I_a / P ratio is outside the range in Figure 8.03k and 8.03l for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 8.03i illustrates the sensitivity of I_a / P to CN and P.

Peak discharge per square mile per inch of runoff (qu) is obtained from Figure 8.03k and 8.03l by using T_c, rainfall distribution type, and I_a / P ratio. The pond and swamp adjustment factor is obtained from Table 8.03j (rounded to the nearest table value). Use Worksheet 3 to aid in computing the peak discharge using the Graphical method.

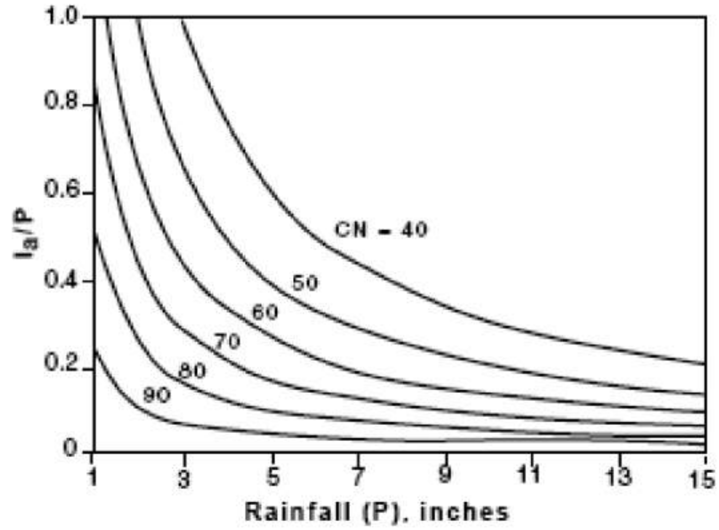


Figure 8.03i Variation of I_a / P for P and CN

Table 8.03i I_a values for runoff curve number

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Table 8.03j Precipitation Frequency Estimates

For use with NRCS Method**

Murphy, North Carolina 35.0961N, 84.0239W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.41	0.66	0.83	1.14	1.43	1.71	1.85	2.29	2.90	3.48
10	0.56	0.90	1.14	1.66	2.16	2.57	2.76	3.32	4.14	6.08
25	0.66	1.05	1.33	1.97	2.62	3.14	3.38	4.05	4.95	6.08
100	0.80	1.27	1.61	2.47	3.40	4.13	4.50	5.38	6.33	7.93

Asheville, North Carolina 35.4358N, 82.5392W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.43	0.69	0.87	1.21	1.51	1.77	1.88	2.30	2.91	3.47
10	0.59	0.94	1.19	1.72	2.25	2.60	2.74	3.29	4.10	4.91
25	0.67	1.07	1.36	2.02	2.69	3.13	3.31	3.96	4.83	5.79
100	0.81	1.28	1.62	2.48	3.42	4.00	4.29	5.12	6.04	7.24

Boone, North Carolina 36.2167N, 81.6667W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.48	0.76	0.96	1.32	1.66	2.00	2.18	2.85	3.77	4.39
10	0.62	1.00	1.26	1.83	2.39	2.92	3.18	4.10	5.28	6.61
25	0.72	1.14	1.45	2.14	2.85	3.55	3.87	4.94	6.21	8.07
100	0.86	1.38	1.74	2.66	3.67	4.69	5.15	6.47	7.82	10.65

Charlotte, North Carolina, 35.2333N, 80.85W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.47	0.76	0.95	1.31	1.65	1.92	2.04	2.46	2.91	3.37
10	0.60	0.97	1.22	1.77	2.31	2.72	2.93	3.55	4.23	4.90
25	0.67	1.06	1.35	2.00	2.66	3.17	3.46	4.19	5.04	5.82
100	0.75	1.19	1.51	2.31	3.18	3.85	4.29	5.22	6.36	7.30

Greensboro, North Carolina 36.975N, 79.9436W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.46	0.73	0.91	1.26	1.58	1.85	1.98	2.36	2.81	3.31
10	0.57	0.91	1.16	1.68	2.18	2.60	2.77	3.37	4.02	4.76
25	0.62	0.98	1.25	1.84	2.46	2.98	3.17	3.90	4.71	5.26
100	0.66	1.05	1.33	2.03	2.80	3.46	3.72	4.68	5.81	7.00

* ARI is the Average Return Interval.
**Precipitation Frequency Estimates are measured in inches.

Raleigh, North Carolina 35.8706N, 78.7864W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.47	0.74	0.94	1.29	1.62	1.88	1.99	2.42	2.87	3.42
10	0.59	0.94	1.19	1.73	2.25	2.66	2.85	3.46	4.14	4.93
25	0.65	1.03	1.31	1.94	2.58	3.08	3.34	4.06	4.90	5.83
100	0.72	1.14	1.45	2.21	3.05	3.69	4.10	5.01	6.13	7.25

Fayetteville, North Carolina 35.0583N, 78.8583W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.51	0.81	1.02	1.41	1.77	2.08	2.21	2.64	3.11	3.66
10	0.66	1.06	1.34	1.94	2.53	3.08	3.30	3.96	4.71	5.55
25	0.74	1.19	1.51	2.23	2.97	3.66	3.98	4.77	5.72	6.74
100	0.87	1.38	1.75	2.67	3.69	4.59	5.09	6.14	7.45	8.73

Wilmington, North Carolina 34.2683N, 77.9061W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.62	0.99	1.24	1.71	2.15	2.56	2.73	3.38	3.96	4.66
10	0.81	1.29	1.63	2.37	3.08	3.87	4.18	5.20	6.15	7.24
25	0.92	1.46	1.85	2.74	3.65	4.75	5.20	6.49	7.73	9.10
100	1.08	1.71	2.16	3.31	4.56	6.37	7.13	8.93	10.78	12.64

Washington, North Carolina 35.5333N, 77.0167W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.53	0.85	1.07	1.48	1.86	2.20	2.36	2.82	3.30	3.89
10	0.70	1.12	1.41	2.05	2.66	3.29	3.57	4.29	5.07	5.99
25	0.79	1.26	1.60	2.36	3.15	3.98	4.37	5.27	6.28	7.41
100	0.93	1.48	1.87	2.86	3.94	5.17	5.80	7.04	8.49	9.96

Manteo Airport, North Carolina 35.9167N, 75.7000W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.54	0.86	1.08	1.49	1.87	2.17	2.38	2.90	3.45	4.15
10	0.71	1.13	1.43	2.07	2.69	3.25	3.61	4.42	5.29	6.38
25	0.80	1.27	1.61	2.38	3.17	3.92	4.42	5.43	6.55	7.89
100	0.94	1.49	1.89	2.89	3.98	5.08	5.85	7.23	8.85	10.62

Cape Hatteras, North Carolina, 35.2322N, 75.6225W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.60	0.96	1.21	1.67	2.09	2.58	2.83	3.49	4.14	4.77
10	0.78	1.25	1.59	2.30	2.99	3.86	4.29	5.30	6.35	7.34
25	0.89	1.42	1.79	2.66	3.54	4.67	5.26	6.52	7.86	9.08
100	1.04	1.66	2.10	3.21	4.42	6.06	6.97	8.69	10.62	12.21

Table 8.03k Adjustment factor (F_p) for pond and swamp areas that are spread throughout the watershed

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Limitations

The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method. Use TR-20 if the watershed is very complex or a higher degree of accuracy is required.

- The watershed must be hydrologically homogeneous, that is, describable by one CN. Land use, soils, and cover are distributed uniformly throughout the watershed.
- The watershed may have only one main stream or, if more than one, the branches must have nearly equal T_c' s.
- The method cannot perform valley or reservoir routing.
- The F_p factor can be applied only for ponds or swamps that are not in the T_c flow path.
- Accuracy of peak discharge estimated by this method will be reduced if I_a / P values are used that are outside the range given in Figure 8.03k. The limiting I_a / P values are recommended for use.
- This method should be used only if the weighted CN is greater than 40.
- When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure for estimating T_c.
- T_c values with this method may range from 0.1 to 10 hours.

Example 8.03c

Compute the 25-year peak discharge for the 250-acre watershed described in examples 8.03a and 8.03b. Example 8.03c shows how Worksheet 3 is used to compute q_p as 345 cfs.

Figure 8.03j Worksheet 3 for example 8.03c

Worksheet 3: Graphical Peak Discharge Method

Project Heavenly Acres	By RHM	Date 10/15/06
Location Dare County, NC	Checked NM	Date 10/17/06

Check one: ☐ Present ☒ Developed

1. Data

Drainage area .... A_m = 0.39 mi^2 (acres/640)

Runoff curve number .... CN = 75 (From worksheet 1)

Time of concentration .... T_c = 1.53 hr (from worksheet 2)

Rainfall disturbance .... = II (I, IA, II, III)

Pond and swamp areas sprea throughout watershed .... = — — percent of Am (— — acres or mi^2 covered)

	Storm #1	Storm #2	Storm #3
2. Frequency ....yr	25		
3. Rainfall, P (24-hour) ....in	6.0		
4. Initial abstraction, I_a ....in (Use CN with table 8.03h)	0.667		
5. Compute I_a/P	0.11		
6. Unit peak discharge, q_u ....csm/in (Use T_c and I_a/P with figure 8.03k)	270		
7. Runoff, Q ....in (From worksheet 1) Figure 8.03e	3.28		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 8.03j. Factor is 1.0 for zero percent pond and swamp area.)	1.0		
9. Peak discharge, q_p ....ft^3/s (Where $q_p = q_u A_m Q F_p$)	345		

Worksheet 3: Graphical Peak Discharge Method

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Data

Drainage area .... A_m = ______________ mi^2 (acres/640)

Runoff curve number .... CN = ________________ (From worksheet 1)

Time of concentration .... T_c = _________________ hr (from worksheet 2)

Rainfall disturbance .... = ___________________ (I, IA, II, III)

Pond and swamp areas sprea throughout watershed .... = _____________ percent of Am (______acres or mi^2 covered)

	Storm #1	Storm #2	Storm #3
2. Frequency ....yr			
3. Rainfall, P (24-hour) ....in			
4. Initial abstraction, I_a ....in (Use CN with table 8.03h)			
5. Compute I_a/P			
6. Unit peak discharge, q_u ....csm/in (Use T_c and I_a/P with figure 8.03k)			
7. Runoff, Q ....in (From worksheet 1) Figure 8.03e			
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 8.03j. Factor is 1.0 for zero percent pond and swamp area.)			
9. Peak discharge, q_p ....ft^3/s (Where $q_p = q_u A_m Q F_p$)			

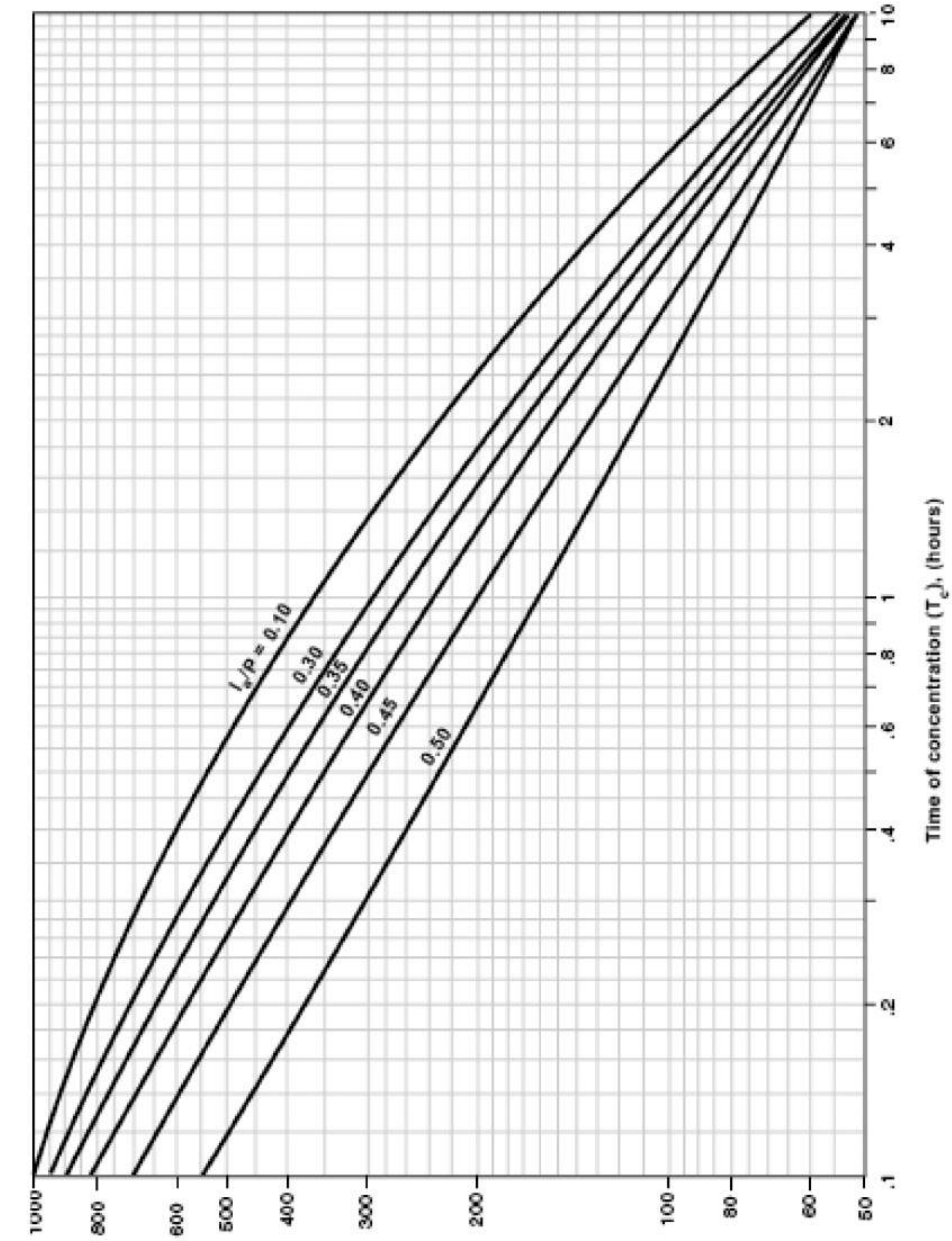


Figure 8.03k Unit peak discharge (q_u) for NRCS (SCS) type II rainfall distribution for NC except lower coastal plain.

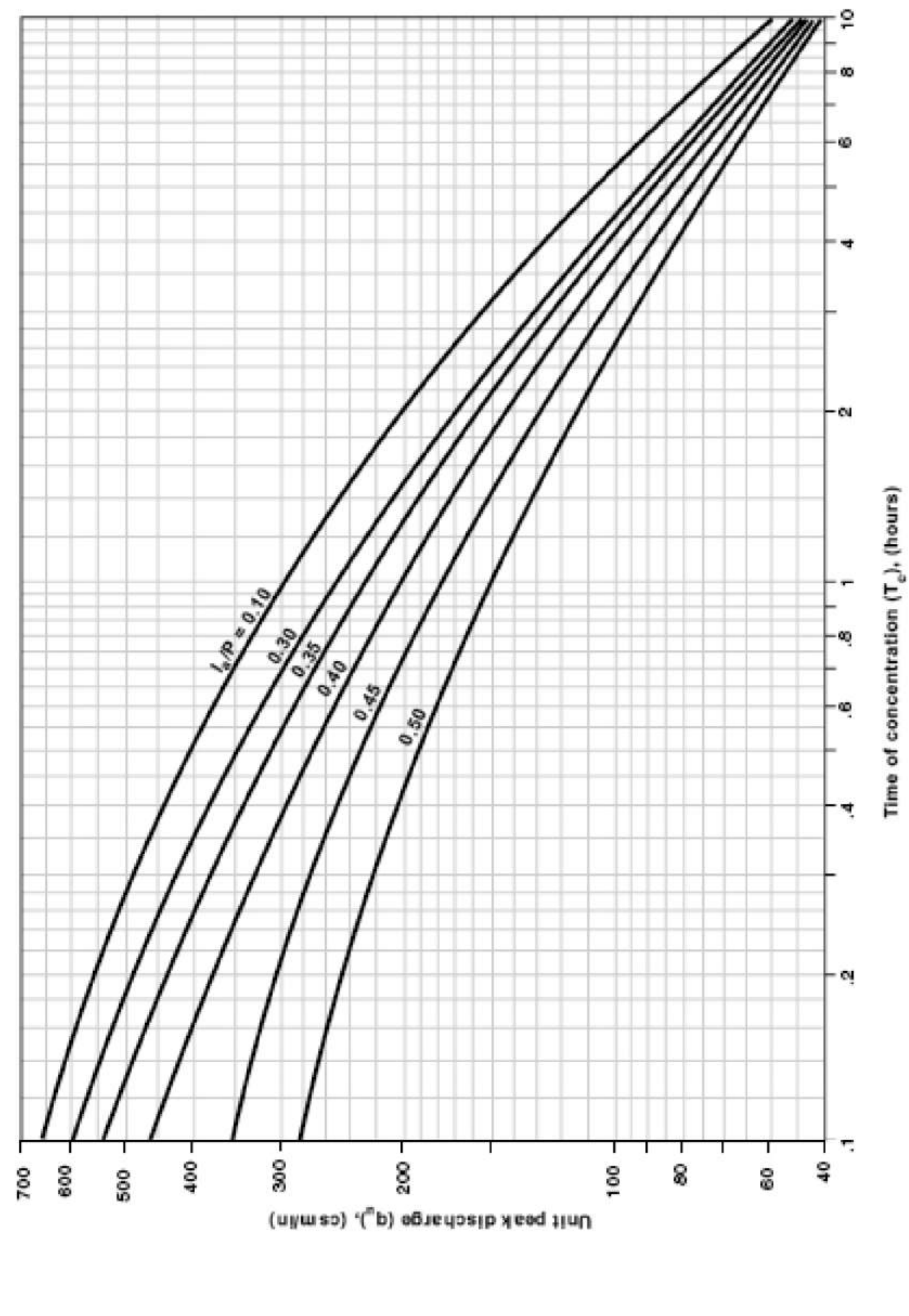


Figure 8.03l Unit peak discharge (q_u) for NRCS (SCS) type **III** rainfall distribution for lower coastal plain of North Carolina

8.04 ESTIMATING ROUGHNESS COEFFICIENTS

This section describes a method for estimating the roughness coefficient *n* for use in hydraulic computations associated with natural streams, floodways, and excavated channels. The procedure applies to the estimation of *n* in Manning's formula (*Appendix 8.05*).

The coefficient of roughness *n* quantifies retardation of flow due to roughness of channel sides, bottom, and irregularities.

Estimation of *n* requires the application of subjective judgement to evaluate five primary factors:

- irregularity of the surfaces of the channel sides and bottom;
- variations in the shape and size of the channel cross sections;
- obstructions in the channel;
- vegetation in the channel; and
- meandering of the channel.

Procedure For Estimating *n*

The procedure for estimating *n* involves selecting a basic value for a straight, uniform, smooth channel in the existing soil materials, then modifying that value with each of the five primary factors listed above.

In selecting modifying values, it is important that each factor be examined and considered independently.

Step 1. Selection of basic value of *n*. Select a basic *n* value for a straight, uniform, smooth channel in the natural materials involved. The conditions of straight alignment, uniform cross section, and smooth side and bottom surfaces without vegetation should be kept in mind. Thus, basic *n* varies only with the material than forms the sides and bottom of the channel. Select the basic *n* for natural or excavated channels from Table 8.04a. If the bottom and sides of a channel consist of different materials, select an intermediate value.

Table 8.04a
Basic Value of Roughness Coefficient for Channel Materials

Soil Material	Basic *n*
Channels in earth	0.02
Channels in fine gravel	0.024
Channels cut into rock	0.025
Channels in coarse gravel	0.028

Step 2. Selection of modifying value for surface irregularity. This factor is based on the degree of roughness or irregularity of the surfaces of channel sides and bottom. Consider the actual surface irregularity, first in relation to the degree of surface smoothness obtainable with the natural materials involved, and second in relation to the depths of flow expected. If the surface irregularity is comparable to the best surface possible for the channel materials, assign a modifying value of zero. Irregularity induces turbulence that calls for increased modifying values. Table 8.04b may be used as a guide to selection of these modifying values.

Table 8.04b Modifying Value for Roughness Coefficient Due to Surface Irregularity of Channels

Degree of Irregularity	Surface Comparable	Modifying Value
Smooth	The best obtainable for the materials	0.000
Minor	Well-dredged channels; slightly eroded or scoured side slope of canals or drainage channels	0.005
Moderate	Fair to poorly dredged channels; moderately sloughed or eroded side slopes of canals or drainage channels	0.010
Severe	Badly sloughed banks of natural channels; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged and irregular surfaces of channels excavated in rock	0.020

Source for Tables b - f: Estimating Hydraulic Roughness Coefficients

Step 3. Selection of modifying value for variations in the shape and size of cross sections. In considering this factor, judge the approximate magnitude of increase and decrease in successive cross sections as compared to the average. Gradual and uniform changes do not cause significant turbulence. Turbulence increases with the frequency and abruptness of alternation from large to small channel sections.

Shape changes causing the greatest turbulence are those for which flow shifts from side to side in the channel. Select modifying values based on Table 8.04c.

Step 4. Selection of modifying value for obstructions. This factor is based on the presence and characteristics of obstructions such as debris deposits, stumps, exposed roots, boulders, and fallen and lodged logs. Take care that conditions considered in other steps not be double-counted in this step.

In judging the relative effect of obstructions, consider the degree to which the obstructions reduce the average cross-sectional area at various depths and the characteristics of the obstructions. Sharp-edged or angular objects induce more turbulence than curved, smooth-surfaced objects. Also consider the

Table 8.04c Modifying Value for Roughness Coefficient Due to Variations of Channel Cross Section

Character of Variation	Modifying Value
Changes in size or shape occurring gradually	0.000
Large and small sections alternating occasionally, or shape changes causing occasional shift of main flow from side to side	0.005
Large and small sections alternating frequently, or shape changes causing frequent shift of main flow from side to side	0.010 - 0.015

transverse and longitudinal position and spacing of obstructions in the reach. Select modifying values based on Table 8.04d.

Step 5. Selection of modifying value for vegetation. The retarding effect of vegetation is due primarily to turbulence induced as the water flows around and between limbs, stems, and foliage and secondarily to reduction in cross section. As depth and velocity increase, the force of flowing water tends to bend the vegetation. Therefore, the ability of vegetation to cause turbulence is related to its resistance to bending. Note that the amount and characteristics of foliage vary seasonally. In judging the retarding effect of vegetation, consider the following: height of vegetation in relation to depth of flow, its resistance to bending, the degree to which the cross section is occupied or blocked, and the transverse and longitudinal distribution of densities and heights of vegetation in the reach. Use Table 8.04e as a guide.

Step 6. Computation of n_s for the reach. The first estimate of roughness for the reach, n_s, is obtained by neglecting meandering and adding the basic n value obtained in step 1 and modifying values from steps 2 through 5.

$$n_s = n + \Sigma \text{ modifying values}$$

Step 7. Meander. The modifying value for meandering is not independent of the other modifying values. It is estimated from the n_s obtained in step 6, and the ratio of the meandering length to the straight length. The modifying value for meandering may be selected from Table 8.04f.

Step 8. Computation of n for a channel reach with meandering. Add the modifying value obtained in step 7, to n_s, obtained in step 6.

The procedure for estimating roughness for an existing channel is illustrated in Sample Problem 8.04a.

Out-of-Bank Condition Channel And Flood Plain Flow

Work with natural floodways and streams often requires consideration of a wide range of discharges. At higher stages, both channel and overbank or flood plain flow may occur. Usually, the retardance of the flood plain differs significantly from that of the channel, and the hydraulic computations can be improved by subdividing the cross section and assigning different n values for flow in the channel and the flood plain. If conditions warrant, the flood plain may be subdivided further. **Do not average channel n with flood plain n.** The n value for in-bank and out-of-bank flow in the channel may be averaged.

Table 8.04d Modifying Value for Roughness Coefficient Due to Obstructions in the Channel

Relative Effect of Obstructions	Modifying Value
Negligible	0.000
Minor	0.010 to 0.015
Appreciable	0.020 to 0.0.30
Severe	0.040 to 0.060

Table 8.04e Modifying Value for Roughness Coefficient Due to Vegetation in the Channel

Vegetation and Flow Conditions Comparable to:	Range in Modifying Value
Low Effect	
Dense growths of flexible turf grass or weeds, such as Bermudagrass and Kentucky bluegrass. Average depth of flow is 2 to 3 times the height of the vegetation	0.005 to 0.010
Medium Effect	
Turf grasses where the average depth of flow is 1 to 2 times the height of vegetation	0.010 to 0.025
Stemmy grasses, weeds or tree seedlings with moderate cover where the average depth of flow is 2 to 3 times the height of vegetation	
Brushy growths, moderately dense, similar to willows 1 to 2 years old, dormant season, along side slopes of channel with no significant vegetation along the channel bottom, where the hydraulic radius is greater than 2 feet	
High Effect	
Grasses where the average depth of flow is about equal to the height of vegetation	0.025 to 0.050
Dormant season, willow or cottonwood trees 8 - 10 years old, intergrown with some weeds and brush; hydraulic radius 2 to 4 feet	
1-year old, intergrown with some weeds in full foliage along side slopes; no significant vegetation along channel bottom; hydraulic radius 2 to 4 feet	
Grasses where average depth of flow is less than one-half the height of vegetation	
Very High Effect	
Growing season, bushy willows about 1-year old, intergrown with weeds in full foliage along side slopes; dense growth of cattails or similar rooted vegetation along channel bottom; hydraulic radius greater than 4 feet	0.050 to 0.100
Growing season, trees intergrown with weeds and brush, all in full foliage; hydraulic radius greater than 4 feet	

Table 8.04f Modifying Value for Roughness Coefficient Due to Meander in the Channel

Meander Ratio[1]	Degree of Meandering	Modifying Value
0.0 to 1.2	Minor	0.000
1.2 to 1.5	Appreciable	0.15 n_s
1.5 and greater	Severe	0.30 n_s

[1]Meander ratio is the total length of reach divided by the straight line distance.

To compute a roughness coefficient for flood plain flow, consider all factors except meandering. Flood plain *n* values normally are greater than channel values, primarily due to shallower depths of flow. The two factors requiring most careful consideration in the flood plain are obstructions and vegetation. Many flood plains have fairly dense networks of obstructions to be evaluated. Vegetation should be judged on the basis of growing-season conditions.

Sample Problem 8.04a Estimation of roughness coefficient for an existing channel

Description of reach:

Soil—Natural channel with lower part of banks and bottom yellowish gray clay, upper part light gray silty clay.

Side slopes—Fairly regular; bottom uneven and irregular.

Cross section—Very little variation in the shape; moderate, gradual variation is size. Average cross section approximately trapezoidal with side slopes about 1.5:1 and bottom width about 10 feet. At bankfull stage, the average depth is about 8.5 feet and the average top width is about 35 feet.

Vegetation—Side slopes covered with heavy growth of poplar trees, 2 to 3 inches in diameter, large willows, and climbing vines; thick, bottom growth of waterweed; summer condition with the vegetation in full foliage.

Alignment—Significant meandering; total length of meandering channel, 1120 feet; straight line distance, 800 feet.

Solution:

Step Number	Description	*n* Values
1	Soil materials indicate minimum basic *n*	0.02
	Modification for:	
2	Moderately irregular surface	0.01
3	Changes in size and shape judged insignificant	0.00
4	No obstructions indicated	0.00
5	Dense vegetation	0.08
6	Straight channel subtotal, n_s =	0.11
7	Meandering appreciable, meandering ratio: 1120/800 = 1.4 Select 0.15 from Table 8.04f	
8	Modified value = (0.15)(0.11) = 0.0165 or	0.02
	Total roughness coefficient *n* =	0.13

8.05

DESIGN OF STABLE CHANNELS AND DIVERSIONS

This section addresses the design of stable conveyance channels and diversions using flexible linings. A stable channel is defined as a channel which is nonsilting and nonscouring. To minimize silting in the channel, flow velocities should remain constant or increase slightly throughout the channel length. This is especially important in designing diversion channels and can be accomplished by adjusting channel grade. Procedures presented in this section address the problems of erosion and scour. More advanced procedures for permanent, unlined channels may be found elsewhere. (References: Garde and Ranga Raju, 1980)

Diversions are channels usually with a supporting ridge on the lower side. They are generally located to divert flows across a slope and are designed following the same procedures as other channels. Design tables for vegetated diversions and waterways are included at the end of this section.

Flexible channel linings are generally preferred to rigid linings from an erosion control standpoint because they conform to changes in channel shape without failure and are less susceptible to damage from frost heaving, soil swelling and shrinking, and excessive soil pore water pressure from lack of drainage. Flexible linings also are generally less expensive to construct, and when vegetated, are more natural in appearance. On the other hand, flexible linings generally have higher roughness and require a larger cross section for the same discharge.

EROSION CONTROL CRITERIA

The minimum design criteria for conveyance channels require that two primary conditions be satisfied: the channel system must have capacity for the peak flow expected from the 10-year storm and the channel lining must be resistant to erosion for the design velocity. In some cases, out-of-bank flow may be considered a functional part of the channel system. In these cases, flow capacities and design velocities should be considered separately for out-of-bank flows and channel flows.

Both the capacity of the channel and the velocity of flow are functions of the channel lining, cross-sectional area and slope. The channel system must carry the design flow, fit site conditions, and be stable.

STABLE CHANNEL DESIGN METHODS

Two accepted procedures for designing stable channels with flexible linings are: (1) the permissible velocity approach; and (2) the tractive force approach. Under the permissible velocity approach, the channel is considered stable if the design, mean velocity is lower than the maximum permissible velocity. Under the tractive force approach, erosive stress evaluated at the boundary between flowing water and lining materials must be less than the minimum unit tractive force that will cause serious erosion of material from a level channel bed.

The permissible velocity procedure is recommended for the design of vegetative channels because of common usage and the availability of reliable design tables. The tractive force approach is recommended for design of channels with temporary synthetic liners or riprap liners. The tractive force procedure is described in full in the U.S. Department of Transportation, Federal Highway Administration Bulletin, *Design of Roadside Channels with Flexible Linings*.

Permissible Velocity Procedure

The permissible velocity procedure uses two equations to calculate flow:

Manning's equation,

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

where:

V = average velocity in the channel in ft/sec.

n = Manning's roughness coefficient, based upon the lining of the channel

R = hydraulic radius, wetted cross-sectional area/wetted perimeter in ft

S = slope of the channel in ft/ft

and the continuity equation,

$$Q = AV$$

where:

Q = flow in the channel in cfs

A = cross-sectional area of flow within the channel in ft^2

V = average velocity in the channel in ft/sec.

Manning's equation and the continuity equation are used together to determine channel capacity and flow velocity. A nomograph for solving Manning's equation is given in Figure 8.05a.

Selecting Permanent Channel Lining

Channel lining materials include such flexible materials as grass, riprap and gabions, as well as rigid materials such as paving blocks, flag stone, gunite, asphalt, and concrete. The design of concrete and similar rigid linings is generally not restricted by flow velocities. However, flexible channel linings do have maximum permissible flow velocities beyond which they are susceptible to erosion. The designer should select the type of liner that best fits site conditions.

Table 8.05a lists maximum permissible velocities for established grass linings and soil conditions. Before grass is established, permissible velocity is determined by the choice of temporary liner. Permissible velocities for riprap linings are higher than for grass and depend on the stone size selected.

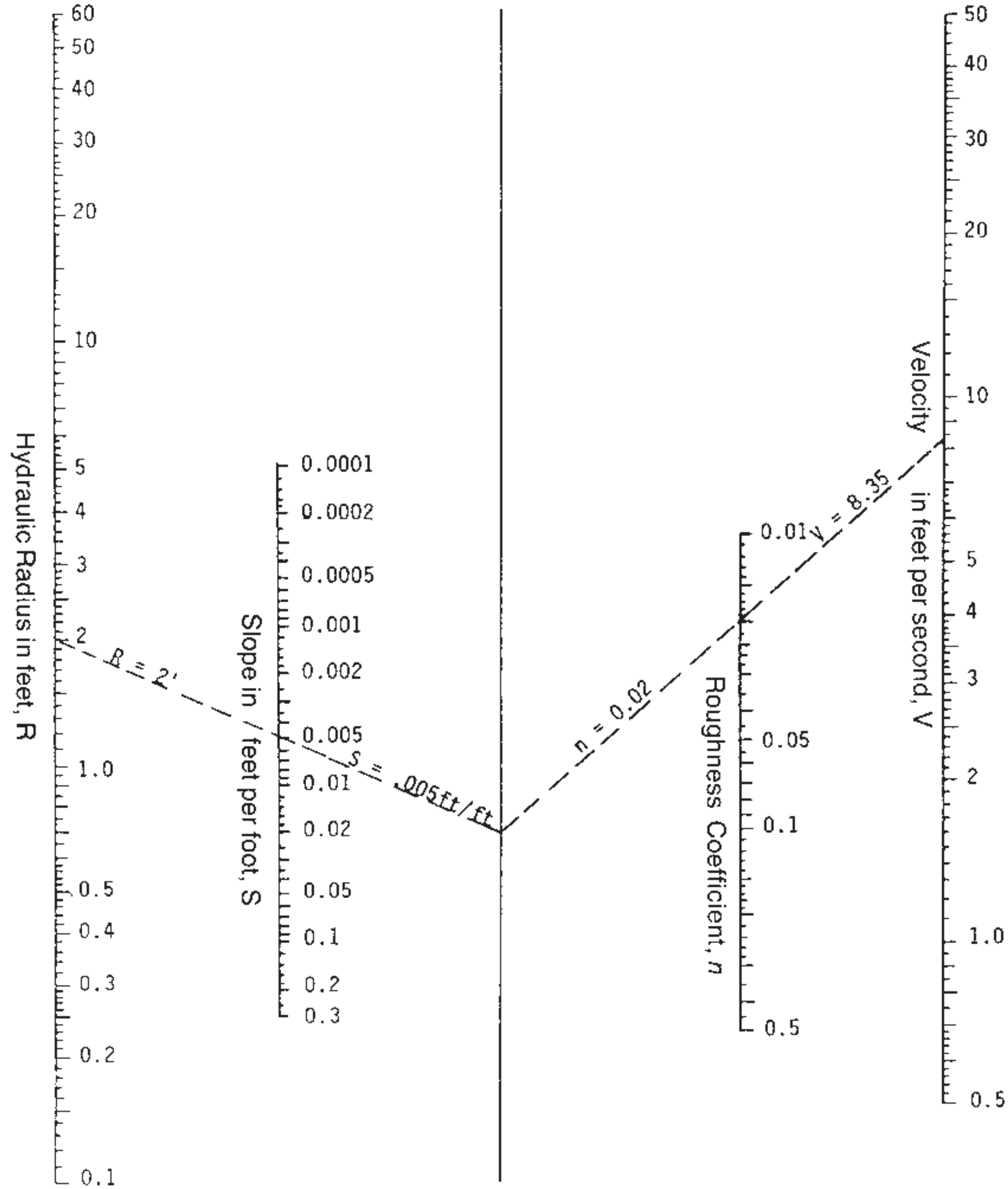


Figure 8.05a Nomograph for solution of Manning equation.

Table 8.05a
Maximum Allowable Design Velocities[1]
for Vegetated Channels

Typical Channel Slope Application	Soil Characteristics[2]	Grass Lining	Permissible Velocity[3] for Established Grass Lining (ft/sec)
0-5%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	5.0
		Tall fescue	4.5
		Bahiagrass	4.5
		Kentucky bluegrass	4.5
		Grass-legume mixture	3.5
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	6.0
		Tall fescue	5.5
		Bahiagrass	5.5
		Kentucky bluegrass	5.5
		Grass-legume mixture	4.5
5-10%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	4.5
		Tall fescue	4.0
		Bahiagrass	4.0
		Kentucky bluegrass	4.0
		Grass-legume mixture	3.0
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	5.5
		Tall fescue	5.0
		Bahiagrass	5.0
		Kentucky bluegrass	5.0
		Grass-legume mixture	3.5
>10%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	3.5
		Tall fescue	2.5
		Bahiagrass	2.5
		Kentucky bluegrass	2.5
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	4.5
		Tall fescue	3.5
		Bahiagrass	3.5
		Kentucky bluegrass	3.5

Source: USDA-SCS Modified

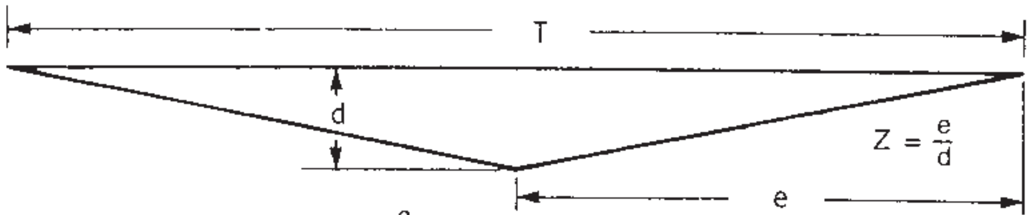
NOTE: [1]Permissible Velocity based on 10-year storm peak runoff
[2]Soil erodibility based on resistance to soil movement from concentrated flowing water.
[3]Before grass is established, permissible velocity is determined by the type of temporary liner used.

Selecting Channel Cross-Section Geometry

To calculate the required size of an open channel, assume the design flow is uniform and does not vary with time. Since actual flow conditions change throughout the length of a channel, subdivide the channel into design reaches, and design each reach to carry the appropriate capacity.

The three most commonly used channel cross-sections are "V"-shaped, parabolic, and trapezoidal. Figure 8.05b gives mathematical formulas for the area, hydraulic radius and top width of each of these shapes.

V-Shape



Cross-Sectional Area (A) = Zd^2

Top Width (T) = 2dZ

Hydraulic Radius (R) = $\dfrac{Zd}{2\sqrt{Z^2 + 1}}$

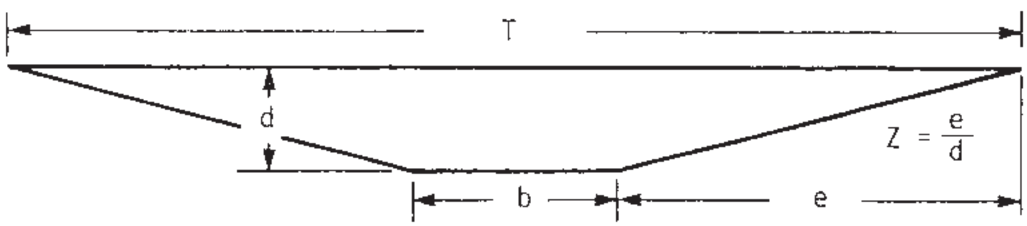
Parabolic Shape

Cross-Sectional Area (A) = $\frac{2}{3}$ Td

Top Width (T) = $\dfrac{1.5\,A}{d}$

Hydraulic Radius = $\dfrac{T^2 d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $bd + Zd^2$

Top Width (T) = b + 2dZ

Hydraulic Radius = $\dfrac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Figure 8.05b Channel geometries for v-shaped, parabolic and trapezoidal channels.

Design Procedure-Permissible Velocity

The following is a step-by-step procedure for designing a runoff conveyance channel using Manning's equation and the continuity equation:

Step 1. Determine the required flow capacity, Q, by estimating peak runoff rate for the design storm (*Appendix 8.03*).

Step 2. Determine the slope and select channel geometry and lining.

Step 3. Determine the permissible velocity for the lining selected, or the desired velocity, if paved. (see Table 8.05a, page 8.05.4)

Step 4. Make an initial estimate of channel size—divide the required Q by the permissible velocity to reach a "first try" estimate of channel flow area. Then select a geometry, depth, and top width to fit site conditions.

Step 5. Calculate the hydraulic radius, R, from channel geometry (Figure 8.05b, page 8.05.5).

Step 6. Determine roughness coefficient *n*.

Structural Linings—see Table 8.05b, page 8.05.6.

Grass Lining:

a. Determine retardance class for vegetation from Table 8.05c, page 8.05.8. To meet stability requirement, use retardance for newly mowed condition (generally C or D). To determine channel capacity, use at least one retardance class higher.

b. Determine *n* from Figure 8.05c, page 8.05.7.

Step 7. Calculate the actual channel velocity, V, using Manning's equation (Figure 8.05a, pg. 8.05.3), and calculate channel capacity, Q, using the continuity equation.

Step 8. Check results against permissible velocity and required design capacity to determine if design is acceptable.

Step 9. If design is not acceptable, alter channel dimensions as appropriate. For trapezoidal channels, this adjustment is usually made by changing the bottom width.

Table 8.05b
Manning's *n* for Structural Channel Linings

Channel Lining	Recommended *n* values
Asphaltic concrete, machine placed	0.014
Asphalt, exposed prefabricated	0.015
Concrete	0.015
Metal, corrugated	0.024
Plastic	0.013
Shotcrete	0.017
Gabion	0.030
Earth	0.020

Source: American Society of Civil Engineers (modified)

Step 10. For grass-lined channels once the appropriate channel dimensions have been selected for low retardance conditions, repeat steps 6 through 8 using a higher retardance class, corresponding to tall grass. Adjust capacity of the channel by varying depth where site conditions permit.

NOTE 1: If design velocity is greater than 2.0 ft/sec., a temporary lining may be required to stabilize the channel until vegetation is established. The temporary liner may be designed for peak flow from the 2-year storm. If a channel requires a temporary lining, the designer should analyze shear stresses in the channel to select the liner that provides protection and promotes establishment of vegetation. For the design of temporary liners, use tractive force procedure.

NOTE 2: Design Tables—Vegetated Channels and Diversions at the end of this section may be used to design grass-lined channels with parabolic cross-sections.

Step 11. Check outlet for carrying capacity and stability. If discharge velocities exceed allowable velocities for the receiving stream, an outlet protection structure will be required (Table 8.05d, page 8.05.9).

Sample Problem 8.05a illustrates the design of a grass-lined channel.

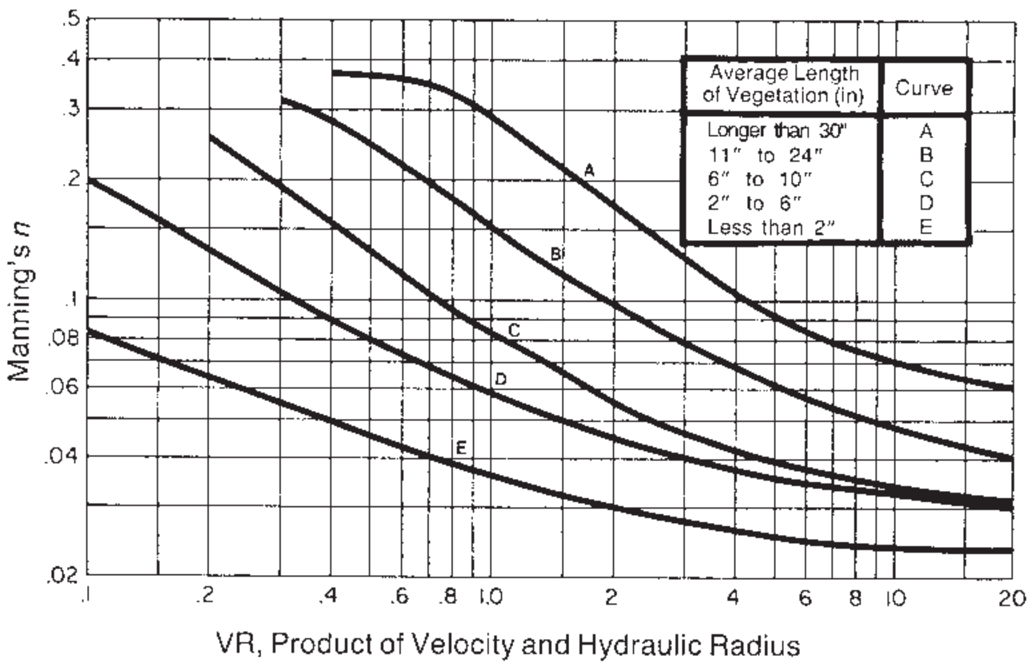


Figure 8.05c Manning's *n* related to velocity, hydraulic radius, and vegetal retardance.
Note: From Sample Problem 8.05a multiply Vp x Hydralulic Radius (4.5x0.54=2.43), then enter the product of VR and extend a straight line up to Retardance class "D", next project a straight line to the left to determine a trial manning's *n*.

Table 8.05c
Retardance Classification for Vegetal Covers

Retardance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36")
	Weeping lovegrass	Excellent stand, tall (average 30")
B	Tall fescue	Good stand, uncut, (average 18")
	Bermudagrass	Good stand, tall (average 12")
	Grass-legume mixture (tall fescue,red fescue, sericea lespedeza)	Good stand, uncut
	Grass mixture (timothy, smooth bromegrass or orchardgrass)	Good stand, uncut (average 20")
	Sericea lespedeza	Good stand, not woody, tall (average 19")
	Reed canarygrass	Good stand, cut, (average 12-15")
	Alfalfa	Good stand, uncut (average 11")
C	Tall fescue	Good stand (8-12")
	Bermudagrass	Good stand, cut (average 6")
	Bahiagrass	Good stand, uncut (6-8")
	Grass-legume mixture-- summer (orchardgrass, redtop and annual lespedeza)	Good stand, uncut (6-8")
	Centipedegrass	Very dense cover (average 6")
	Kentucky bluegrass	Good stand, headed (6-12")
	Redtop	Good stand, uncut (15-20")
D	Tall fescue	Good stand, cut (3-4")
	Bermudagrass	Good stand, cut (2.5")
	Bahiagrass	Good stand, cut (3-4")
	Grass-legume mixture-- fall-spring (orchardgrass, redtop, and annual lespedeza)	Good stand, uncut (4-5")
	Red fescue	Good stand, uncut (12-18")
	Centipedegrass	Good stand, cut (3-4")
	Kentucky bluegrass	Good stand, cut (3-4")
E	Bermudagrass	Good stand, cut (1.5")
	Bermudagrass	Burned stubble

Modified from: USDA-SCS, 1969. Engineering Field Manual.

Table 8.05d Maximum Permissible Velocities for Unprotected Soils in Existing Channels.

Materials	Maximum Permissible Velocities (fps)
Fine Sand (noncolloidal)	2.5
Sand Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5

Sample Problem 8.05a Design of a Grass-lined Channel.

Given:

Design Q_{10} = 16.6 cfs

Proposed channel grade = 2%
Proposed vegetation: Tall fescue
Soil: Creedmoor (easily erodible)
Permissible velocity, V_p = 4.5 ft/s (Table 8.05a)
Retardance class: “B” uncut, “D” cut (Table 8.05c).
Trapezoidal channel dimensions:
designing for low retardance condition (retardance class D)
design to meet V_p.

Find:

Channel dimensions

Solution:

Make an initial estimate of channel size

A = Q/V, 16.6 cfs/4.5 ft/sec = 3.69 ft^2
Try bottom width = 3.0 ft w/side slopes of 3:1

$Z = 3$
$A = bd + Zd^2$
$P = b + 2d\sqrt{Z^2 + 1}$
$R = AP$

An iterative solution using Figure 8.05a to relate flow depth to Manning’s *n* proceeds as follows: Manning’s equation is used to check velocities.
*From Fig. 8.05c, pg. 8.05.7, Retardance Class d (VR=4.5x0.54=2.43)

d (ft)	A (ft^2)	R (ft)	*n	Vt (fps)	Q (cfs)	Comments
0.8	4.32	0.54	0.043	3.25	14.0	$V<V_p$ OK, $Q<Q_{10}$ (too small, try deeper channel)
0.9	5.13	0.59	0.042	3.53	18.10	$V<V_p$, OK, $Q>Q_{10}$, OK

Now design for high retardance (class B):

For the ease of construction and maintenance assume and try d = 1.5 ft and trial velocity V_t = 3.0 ft/sec

d (ft)	A (ft^2)	R (ft)	V_t (fps)	n	V (fps)	Q (cfs)	Comments
1.5	11.25	0.90	3.0	0.08	2.5	28	reduce V_t
			2.0	0.11	1.8	20	reduce V_t
			1.6	0.12	1.6	18	
			**1.5	0.13	1.5	17	$Q>Q_{10}$ OK

** These assumptions = actual V (fps.) (chart continued on next page)

(continued)
Sample Problem 8.05a
Design of a
Grass-lined Channel.

Channel summary:

Trapezoidal shape, Z = 3, b = 3 ft, d = 1.5 ft, grade = 2%

Note: In Sample Problem 8.05a the "n-value" is first chosen based on a permissible velocity and not a design velocity criteria. Therefore, the use of Table 8.05c may not be as accurate as individual retardance class charts when a design velocity is the determining factor.

Tractive Force Procedure

The design of riprap-lined channels and temporary channel linings is based on analysis of tractive force.

NOTE: This procedure is for uniform flow in channels and is *not* to be used for design of deenergizing devices and may not be valid for larger channels.

To calculate the required size of an open channel, assume the design flow is uniform and does not vary with time. Since actual flow conditions change through the length of a channel, subdivide the channel into design reaches as appropriate.

PERMISSIBLE SHEAR STRESS

The permissible shear stress, T_d, is the force required to initiate movement of the lining material. Permissible shear stress for the liner is not related to the erodibility of the underlying soil. However, if the lining is eroded or broken, the bed material will be exposed to the erosive force of the flow.

COMPUTING NORMAL DEPTH

The first step in selecting an appropriate lining is to compute the design flow depth (the normal depth) and determine the shear stress.

Normal depths can be calculated by Manning's equation as shown for trapezoidal channels in Figure 8.05d. Values of the Manning's roughness coefficient for different ranges of depth are provided in Table 8.05e for temporary linings and Table 8.05f for riprap. The coefficient of roughness generally decreases with increasing flow depth.

Table 8.05e
Manning's Roughness Coefficients for Temporary Lining Materials

n* value for Depth Ranges

Lining Type	0-0.5 ft	0.5-2.0 ft	>2.0 ft
Woven Paper Net	0.016	0.015	0.015
Jute Net	0.028	0.022	0.019
Fiberglass Roving	0.028	0.021	0.019
Straw with Net	0.065	0.033	0.025
Curled Wood Mat	0.066	0.035	0.028
Synthetic Mat	0.036	0.025	0.021

* Adapted from: FHWA-HEC 15, Pg. 37 - April 1988

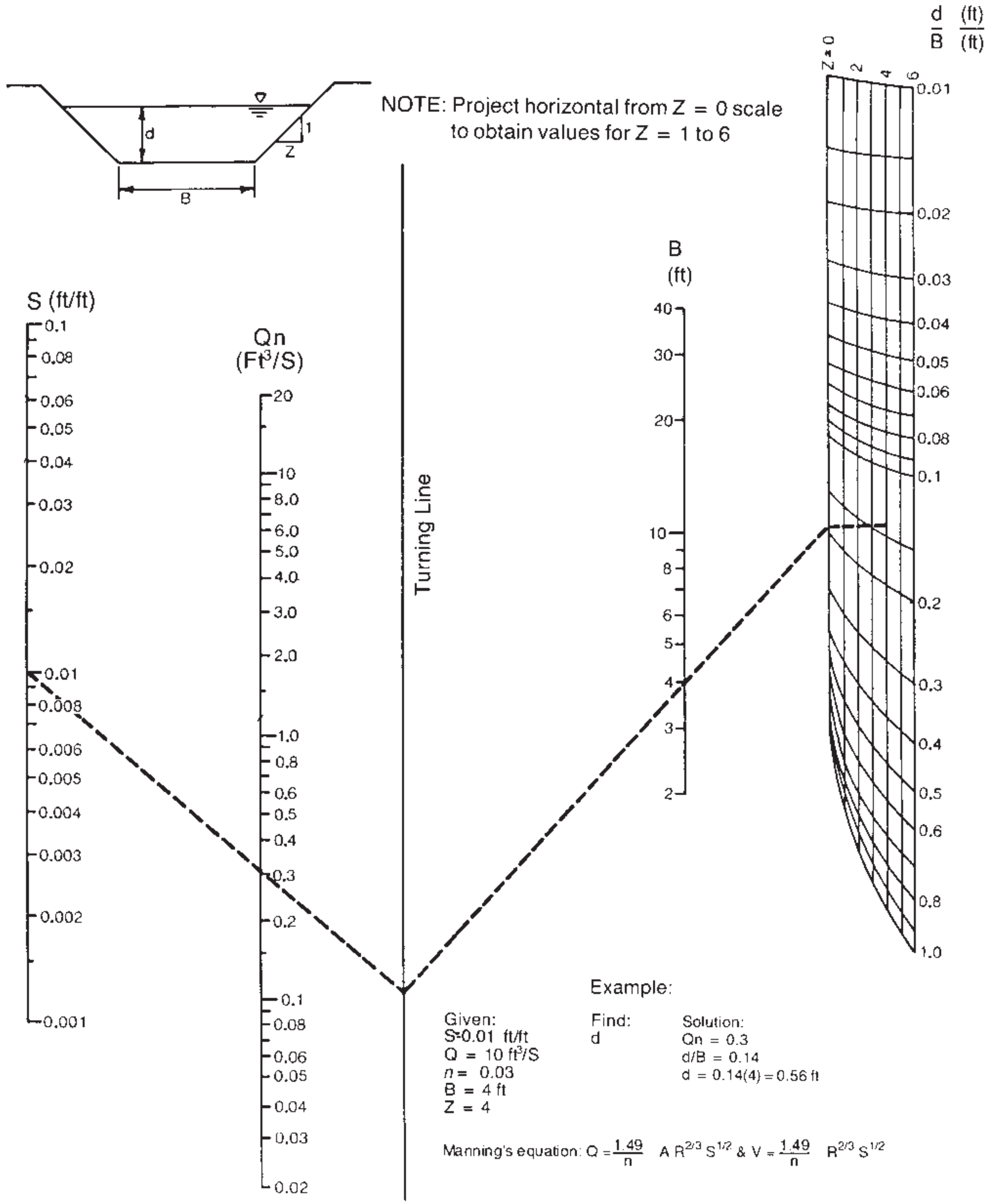


Figure 8.05d Solution of Manning's equation for trapezoidal channels of various side slopes.
Adapted from: FHWA-HEC. 15, Pg 40 - April 1988

Table 8.05f Manning's Roughness Coefficient

Lining Category	Lining Type	*n* - value: *n* value for Depth Ranges 0-0.5 ft (0-15 cm)	0.5-2.0 ft (15-60 cm)	2.0 ft (>60 cm)
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Gravel Riprap	1-inch (2.5-cm) D_{50}	0.044	0.033	0.030
	2-inch (5-cm) D_{50}	0.066	0.041	0.034
Rock Riprap	6-inch (15-cm) D_{50}	0.104	0.069	0.035
	12-inch (30-cm) D_{50}	--	0.078	0.040

Note: Values listed are representative values for the respective depth ranges. Manning's roughness coefficients, *n*, vary with the flow depth.

DETERMINING SHEAR STRESS

Shear stress, T, at normal depth is computed for the lining by the following equation:

$$T = yds$$
$$T_d = \text{Permissible shear stress}$$

where:

T = shear stress in lb/ft^2
y = unit weight of water, 62.4 lb/ft^3
d = flow depth in ft
s = channel gradient in ft/ft

If the permissible shear stress, T_d, given in Table 8.05g is greater than the computed shear stress, the riprap or temporary lining is considered acceptable. If a lining is unacceptable, select a lining with a higher permissible shear stress and repeat the calculations for normal depth and shear stress. In some cases it may be necessary to alter channel dimensions to reduce the shear stress.

Computing tractive force around a channel bend requires special considerations because the change in flow direction imposes higher shear stress on the channel bottom and banks. The maximum shear stress in a bend, T_b, is given by the following equation:

$$T_b = K_b T$$

where:

T_b = bend shear stress in lb/ft^2
k_b = bend factor
T = computed stress for straight channel in lb/ft^2

The value of k_b is related to the radius of curvature of the channel at its center line, R_c, and the bottom width of the channel, B, Figure 8.05e. The length of channel requiring protection downstream from a bend, L_p, is a function of the roughness of the lining material and the hydraulic radius as shown in Figure 8.05f.

Table 8.05g Permissible Shear Stresses for Riprap and Temporary Liners

Lining Category	**Lining Type**	**Permissible Unit Shear Stress, T_d (lb/ft^2)**
Temporary	Woven Paper Net	0.15
	Jute Net	0.45
	Fiberglass Roving:	
	Single	0.60
	Double	0.85
	Straw with Net	1.45
	Curled Wood mat	1.55
	Synthetic Mat	2.00
	d_{50} **Stone Size** (inches)	
Gravel Riprap	1	0.33
	2	0.67
Rock Riprap	6	2.00
	9	3.00
	12	4.00
	15	5.00
	18	6.00
	21	7.80
	24	8.00

Adapted From: FHWA, HEC-15, April 1983, pgs. 17 & 37.

Design Procedure-Temporary Liners

The following is a step-by-step procedure for designing a temporary liner for a channel. Because temporary liners have a short period of service, the design Q may be reduced. For liners that are needed for six months or less, the 2-year frequency storm is recommended.

Step 1. Select a liner material suitable for site conditions and application. Determine roughness coefficient from manufacturer's specifications or Table 8.05e, page 8.05.10.

Step 2. Calculate the normal flow depth using Manning's equation (Figure 8.05d). Check to see that depth is consistent with that assumed for selection of Manning's *n* in Figure 8.05d, page 8.05.11. For smaller runoffs Figure 8.05d is not as clearly defined. Recommended solutions can be determined by using the Manning equation.

Step 3. Calculate shear stress at normal depth.

Step 4. Compare computed shear stress with the permissible shear stress for the liner.

Step 5. If computed shear is greater than permissible shear, adjust channel dimensions to reduce shear, or select a more resistant lining and repeat steps 1 through 4.

Design of a channel with temporary lining is illustrated in Sample Problem 8.05b, page 8.05.14.

Sample Problem 8.05b Design of a Temporary Liner for a Vegetated Channel

Given:

Q_2 = 16.6 cfs
Bottom width = 3.0 ft
Z = 3
n = 0.02 (Use basic *n* value for channels cut in earth (Table 8.05b)
V_p = 2.0 ft/sec maximum allowable velocity for bare soil (pg. 6.30.1)
Channel gradient = 2%

Find:

Suitable temporary liner material

Solution:

Using Manning's equation:

b(ft)	d(ft)	A(ft²)	R(ft)	V(fps)	Q(cfs)	Comments
3.0	0.59	2.82	0.42	5.88	16.60	$V>V_p$, (needs protection) $Q \geq Q_2$, OK

Velocity >2.0 fps channel requires temporary liner:*

Calculate channel design with straw with net as temporary liner.
n = 0.033 (Table 8.05e). T_d = 1.45 (Table 8.05g, pg. 8.05.13)

b(ft)	d(ft)	A(ft²)	R(ft)	V(fps)	Q(cfs)	Comments
3.0	0.76	4.05	1.94	4.10	16.60	$V<T_d$, OK

Calculate shear stress for Q_2 conditions:

T = yds where: y = unit weight of water (62.4 lb/ft³)
d = flow depth in ft
s = channel gradient in ft/ft

T = (62.4)(0.76)(0.02) = 0.95 $T<T_d$, OK

Temporary liner: straw with net.

*In some cases the solution is not as clearly defined; the use of a more conservative material is recommended.

DESIGN OF RIPRAP LINING-MILD GRADIENT

The mild gradient channel procedure is applicable for channel grades less than 10%. The method assumes that the channel cross section has been designed properly, including undercut and that the remaining problem is to provide a stable riprap lining.

Side slope stability. As the angle of the side slope approaches the angle of repose of the channel lining, the lining material becomes less stable. The stability of a side slope is given by the tractive force ratio, K_2, a function of the side slope and the angle of repose of the rock lining material.

The rock size to be used for the channel lining can be determined by comparing the tractive force ratio, an indicator of side slope stability, to the shear stress on the sides and shear stress on the bottom of the channel. The angle of repose for different rock shapes and sized is shown in Figure 8.05g. The required rock size (mean diameter of the gradation, d_{50}) for the side slopes is determined from the following equation:

$$d_{50\,(sides)} = \frac{K_1}{K_2}\, d_{50\,(bottom)}$$

where:

K_1 = ratio of shear stress on the sides, T_s, and bottom, T, of a trapezoidal channel (Figure 8.05h),

K_2 = tractive force ratio (Figure 8.05i).

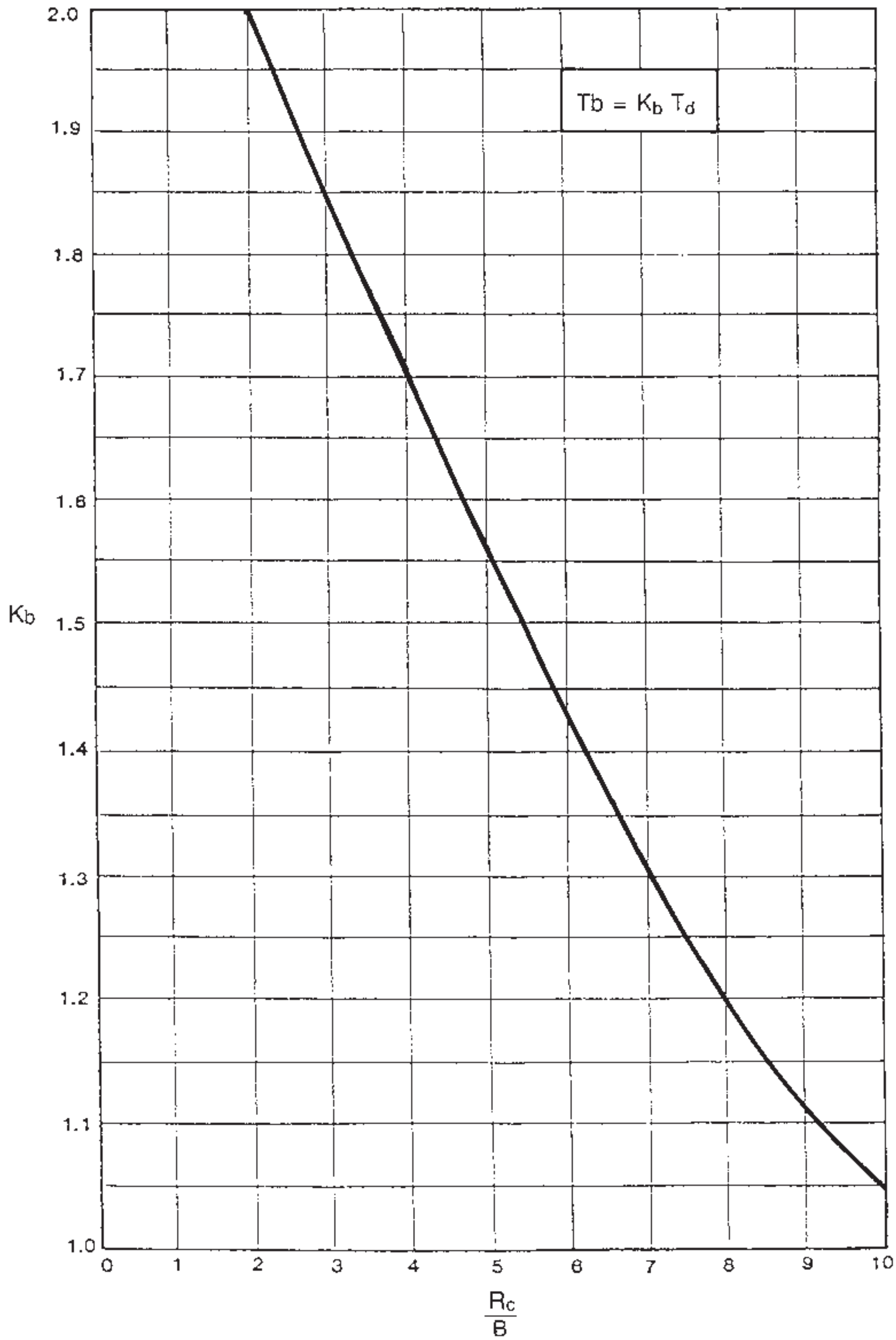


Figure 8.05e K_b factor for maximum shear stress on channel bends.
Adapted from: FHWA-HEC 15, Pg. 47 - April 1988

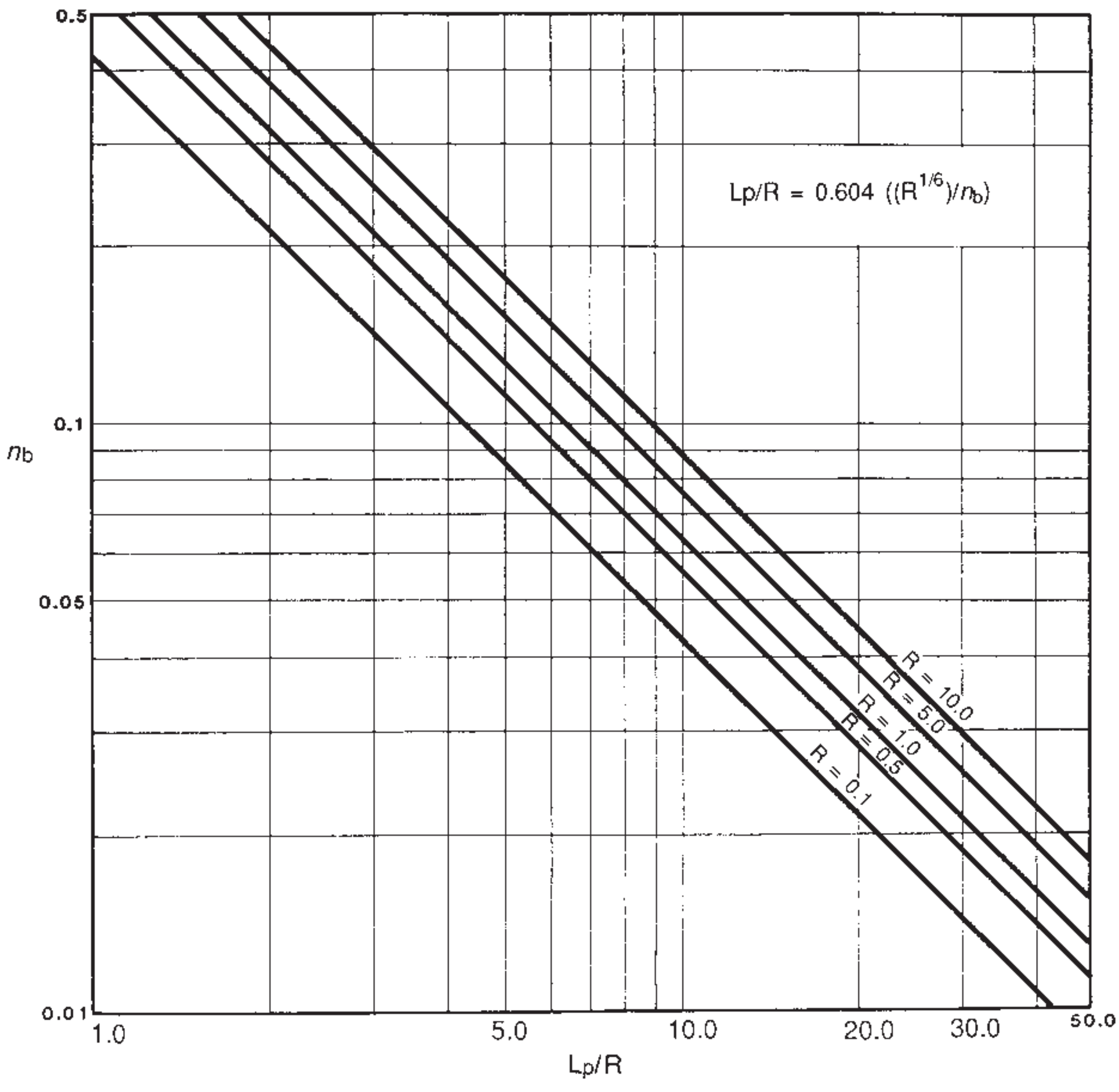


Figure 8.05f Protection length, L_p, downstream from a channel bend.
n_b = Manning Roughness of the lining material in the bend and the depth of flow (see tables 8.05e and f).
R = Hydraulic Radius = Area/wetted perimeter
Adapted from: FHWA-HEC 15, pg 48 - April 1988

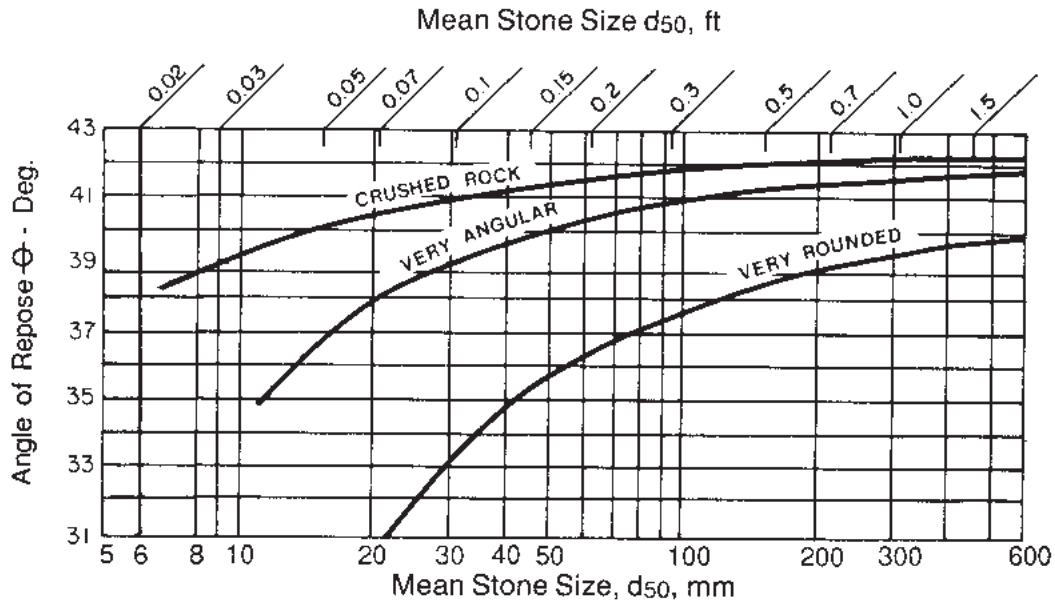


Figure 8.05g Angle of repose for different rock shapes and sizes.
Adapted from: FHWA, HEC-15, pg. 49 - April 1988

Selection of riprap gradation and thickness. Riprap gradation should have a smooth size distribution curve. The largest stone size in the gradation should not exceed 1.5 times the d_{50} size. The most important criterion is that interstices formed by larger stones be filled with smaller sizes in an interlocking fashion, preventing the formation of open pockets. These gradation requirements apply regardless of the type of filter design used.

In general, riprap constructed with angular stone performs best. Round stones are acceptable as riprap provided they are not placed on side slopes steeper than 3:1. Flat, slab-like stones should be avoided since they are easily dislodged by the flow. An approximate guide to stone shape is that neither the breadth nor the thickness of a single stone be less than one-third its length.

The thickness of a riprap lining should equal 1.5 times the diameter of the largest rock size in the gradation.

Filter design: When rock riprap is used, an appropriate underlying filter material must be selected. The filter material may be either a granular, gravel or sand filter blanket, or a geotextile fabric.

For a granular filter blanket, the following criteria must be met:

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

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

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

Where "filter" refers to the overlying riprap or gravel and "base" refers to the underlying soil, sand or gravel. The relationship must hold between the filter blanket and base material and between the riprap and filter blanket.

The minimum thickness for a filter blanket should not be less than 6 inches.

In selecting a filter fabric, the fabric should have a permeability at least equal to the soil and a pore structure that will hold back the base soil. The following properties are essential to assure performance under riprap:

- For filter fabric covering a base with granular particles containing 50 percent or less (by weight) of fine particles (less than U.S. Standard Sieve No. 200):
  a. d_{85} base (mm)/EOS* filter cloth (mm) > 1.
  b. Total open area of filter is less than 36%.

- Filter fabric covering other soils:
  a. EOS less than U.S. Standard Sieve No. 70.
  b. Total open area of filter less than 10%.

*EOS - Equivalent Opening Size to a U.S. Standard Sieve Size

Design Procedure- Riprap Lining, Mild Gradient

The following is a step-by-step procedure for designing a riprap channel lining with mild gradients. This procedure is designed for **smaller** channels that are generally used as erosion control measures, and is not intended for conveyance channels.

Additional design information for lined channels may be obtained from the National Technical Information Services (NTIS) by obtaining a copy of the National Cooperative Highway Research Program Report No. 108, titled "Tentative Design Procedure for Riprap - Lined Channels".

Step 1. Select a riprap size, and look up the Manning's *n* value (Table 8.05f) and permissible shear stress, T_d (Table 8.05g).

Step 2. Calculate the normal flow depth in the channel, using Manning's equation (Figure 8.05d). Check that the *n* value for the calculated normal depth is consistent with that determined in step 1.

Step 3. Calculate shear stress at normal depth.

Step 4. Compare the calculated shear stress with the permissible shear stress.

If the calculated shear stress is less than the permissible shear stress, then the selected riprap size is acceptable. Otherwise, the procedure must be repeated using a larger size riprap with a higher permissible shear stress.

Step 5. For riprap linings on side slopes steeper than 3:1, execute the supplemental procedure for steep side slope design presented below.

Supplemental Procedure for Riprap Channel With Steep Side Slopes. This procedure should be used when side slopes are steeper than 3:1.

Step 1. From Figure 8.05g, determine the angle of repose for the rock size and shape. NOTE: The side slopes selected for the channel must be stable for the soil conditions.

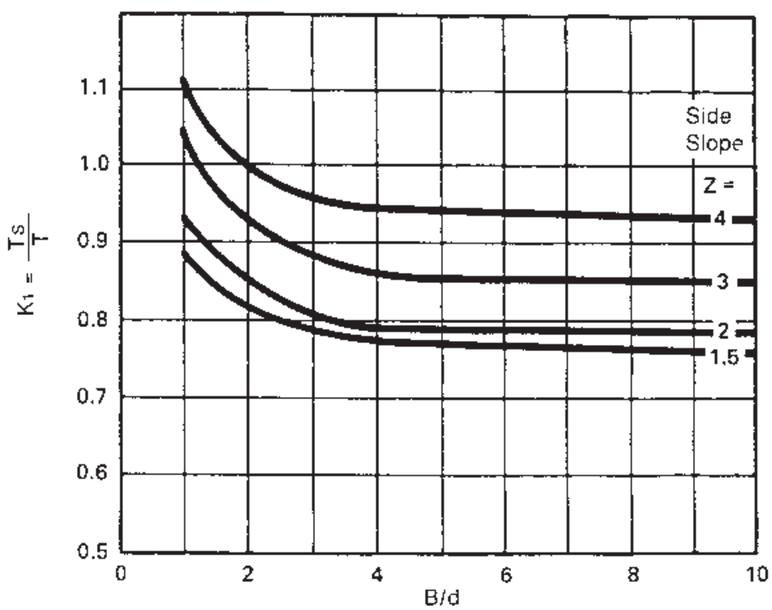


Figure 8.05h Ratio of side shear stress to bottom shear stress, K_1.

Step 2. From Figure 8.05h, determine K_1, the ratio of maximum side shear to maximum bottom shear for a trapezoidal channel, based on bottom width to depth ratio, b/d, and side slope, Z.

Step 3. From Figure 8.05i, determine K_2, the tractive force ratio, based on side slope and the stone angle of repose.

Step 4. The required d_{50} for side slopes is given by the following equation:

$$d_{50\,(sides)} = \frac{K_1}{K_2}\, d_{50\,(bottom)}$$

where:

K_1 = ratio of shear stress on the sides, T_s, and bottom, T, of a trapezoidal channel (Figure 8.05h),

K_2 = tractive force ratio (Figure 8.05i).

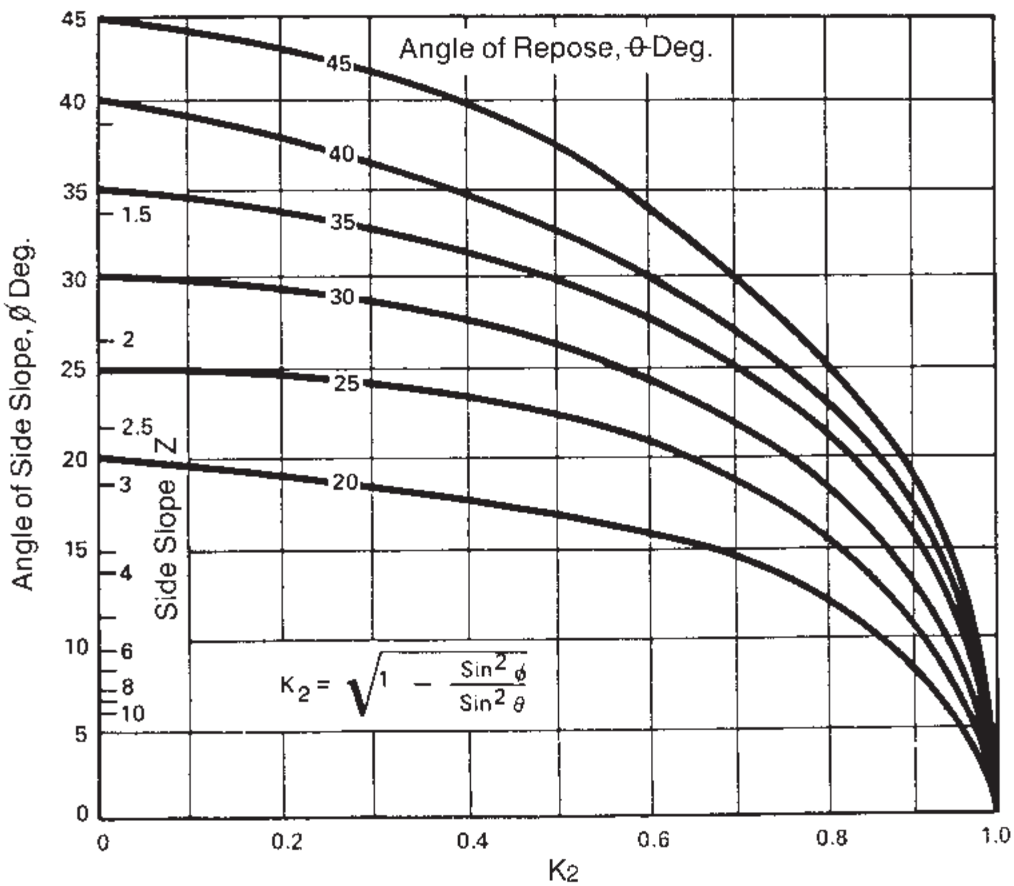


Figure 8.05i Tractive force ratio, K_2.
Adapted from: FHWA, HEC-15, pg. 51 - April 1988

Sample Problem 8.05c demonstrates the tractive force procedure for the design of mild gradient riprap channels.

DESIGN OF RIPRAP LINING-STEEP GRADIENTS

This section outlines the design of riprap channel lining for steep gradients. Achieving channel stability on steep gradients, 10% or more, usually requires some type of channel linings except where the channels can be constructed in durable bedrock.

Rigid channel linings may be more cost effective than riprap in steep slope conditions. Riprap stability on a steep slope depends on the average weight of the stones and the lift and drag forces induced by the flow. To resist these forces, steep channels require larger stones than mild slope channels, and the size of riprap linings increases quickly as discharge and channel gradient increases. The decision to select a rigid or flexible lining may be based on other site conditions, such as foundation material and maintenance requirements.

Transition sections protect transition regions of the channel both above and below the steep gradient section. The transition from a steep gradient to a culvert

Sample Problem 8.05c Design of a Mild Gradient Channel with Riprap Lining

Determine the mean riprap size and flow depth for a mild gradient channel:

Given:

Q = 22 cfs
s = 0.05 ft/ft
b = 4.0 ft
Z = 3

Find:

Flow depth and mean riprap size

Solution:

(1) Try d_{50} = 6 inches, depth 1.0 ft
From Table 8.05f; select n = 0.069
From Table 8.05g; permissible unit shear stress = 2.0 lb/ft^2

(2) From Figure 8.05d determine channel flow depth
Qn = (22)(0.069) = 1.52 d/b = 0.23 d = (0.23)(4.0) = 0.92 ft.
NOTE: Calculated depth is within selected depth range.

(3) Calculate shear stress
T = yds
T = (62.4 lb/ft^3)(0.92)(0.05) = 2.87 lb/ft^2
Exceeds allowable of 2.0 lb/ft^2

Try d_{50} = 1.0 ft, depth 1.0 ft

(1) n = 0.078; permissible unit shear stress = 4.0 lb/ft^2
(2) Qn = (22)(0.078) = 1.72; d/b = 0.245
d = (0.245)(4.0) = 0.98
(3) Shear stress (62.4)(0.98)(0.05) = 3.06 lb/ft^2 < 4.0 lb/ft^2 O.K.
Use d_{50} 1.0 ft

Determine maximum stone size and riprap thickness

(1) d_{max} = 1.5 x d_{50} = (1.5)(12 in) = 18 in, see pg. 8.05.17
(2) Thickness of riprap (installed *below* finished grade)
= 1.5 x d_{max} = (1.5) x (18 in) = 27 in

Continuing with the same problem
Given a channel bend of radius R_c = 30 ft (see pg. 8.05.12)

(1) R_c/B = 30/4.0 = 7.5
(2) K_b = 1.25 (Figure 8.05e, pg. 8.05.15)
(3) T_b = T x K_b = 3.06 lb/ft^2 x 1.25 = 3.83. This is less than the permissible shear stress for d_{50} = 1.0 ft O.K.
(4) For hydraulic radius, R = 0.67 and n_b = 0.078 the protection length downstream of the channel bend is found from Figure 8.05f, pg. 8.05.16. LP/R = 7.5, L_p = 5.0' The total length of protection is the sum of the length in the bend plus the length required for downstream protection.

Adapted from: FHWA, HEC-15, April 1988, pg. 26-29.

should allow room for some movement of riprap to prevent blockage of the culvert opening. Riprap should be placed flush with the invert of a culvert. The break between the steep slope and culvert entrance should equal three to five times the mean rock diameter. The transition from a steep gradient to a mild gradient channel may require an energy dissipation structure. The transition from a mild gradient to a steep gradient should be protected against local scour upstream from the transition for a distance approximately five times the uniform depth of flow in the downstream channel.

Channel alignment and freeboard. Bends should be avoided on steep gradient channels. A design requiring a bend in a steep channel should be redesigned if possible to eliminate the bend, or replaced by a conduit system.

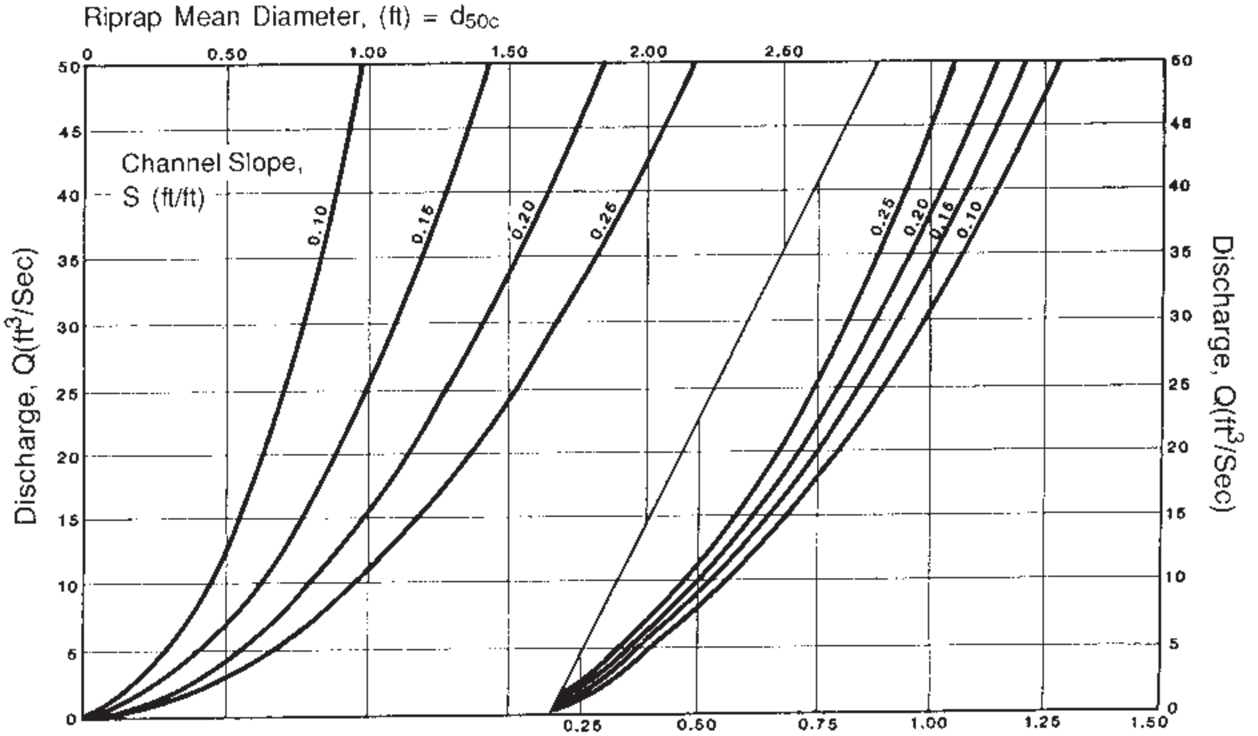


Figure 8.05j Steep slope riprap design, B = 2, Z = 3.
Adapted from: FHWA-HEC 15, pg. 61 -April 1988

Freeboard should be evaluated based on the consequences of overflow of the channel banks and may be affected by wave height, or super elevation of the flow in bends, of the channel

Riprap gradation, thickness and filter requirements. Riprap gradations, thickness and filter requirements are the same as those for mild slopes. It is important to note that riprap thickness is measured normal to the channel gradient.

Design Procedure-Riprap Lining, Steep Gradient

The design procedure for steep gradient channel linings is summarized below.

Step 1. Based on a known discharge and channel slope, use Figures 8.05j-8.05l to select a channel bottom width and channel size, and determine the mean riprap size and flow depth. For intermediate channel widths not given in these figures, interpolate between charts.

Step 2. To determine flow depth and riprap size for side slopes other than 3:1, proceed as follows:

a. Find the flow depth by the following equation:

$$d = \frac{A_3}{A_z} d_n$$

where values of the A_3/A_z ratio are found from Table 8.05h (the subscript refers to the side slope Z-value) and d_n is the flow depth from the design charts for side slopes of 3:1.

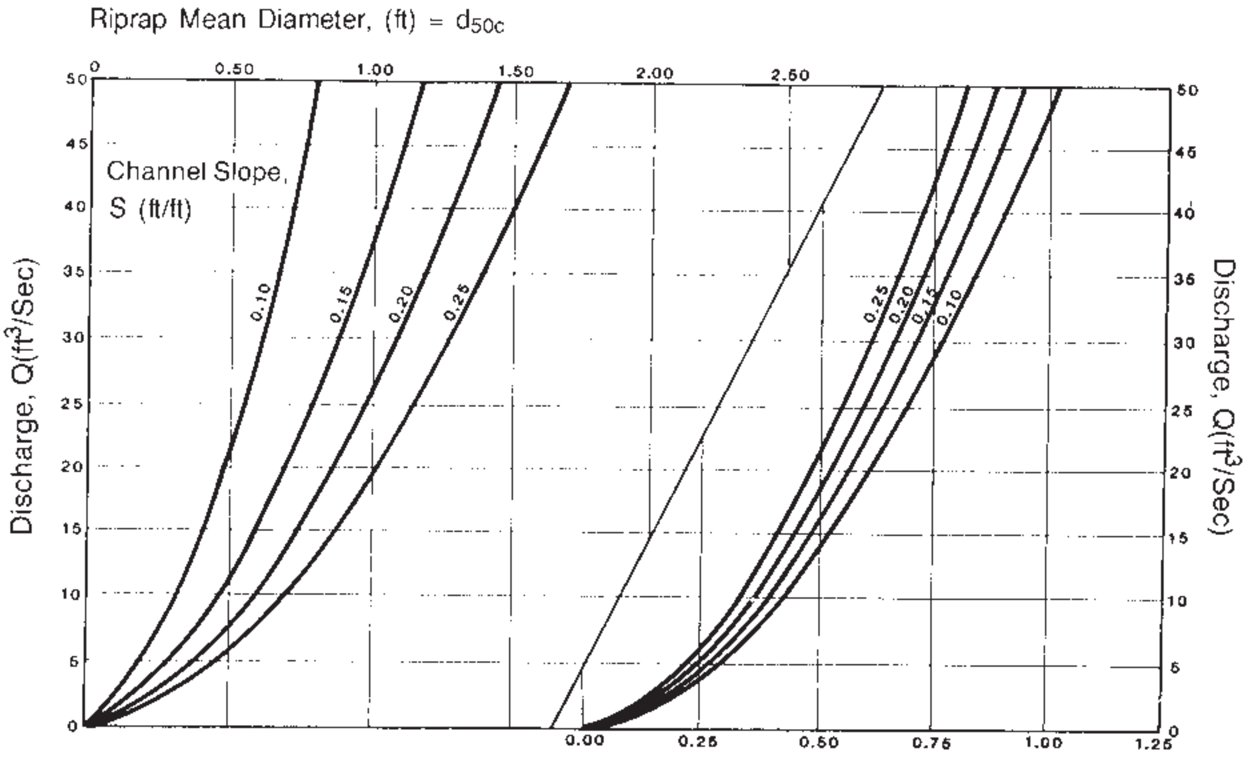


Figure 8.05k Steep slope riprap design, B = 4, Z = 3.

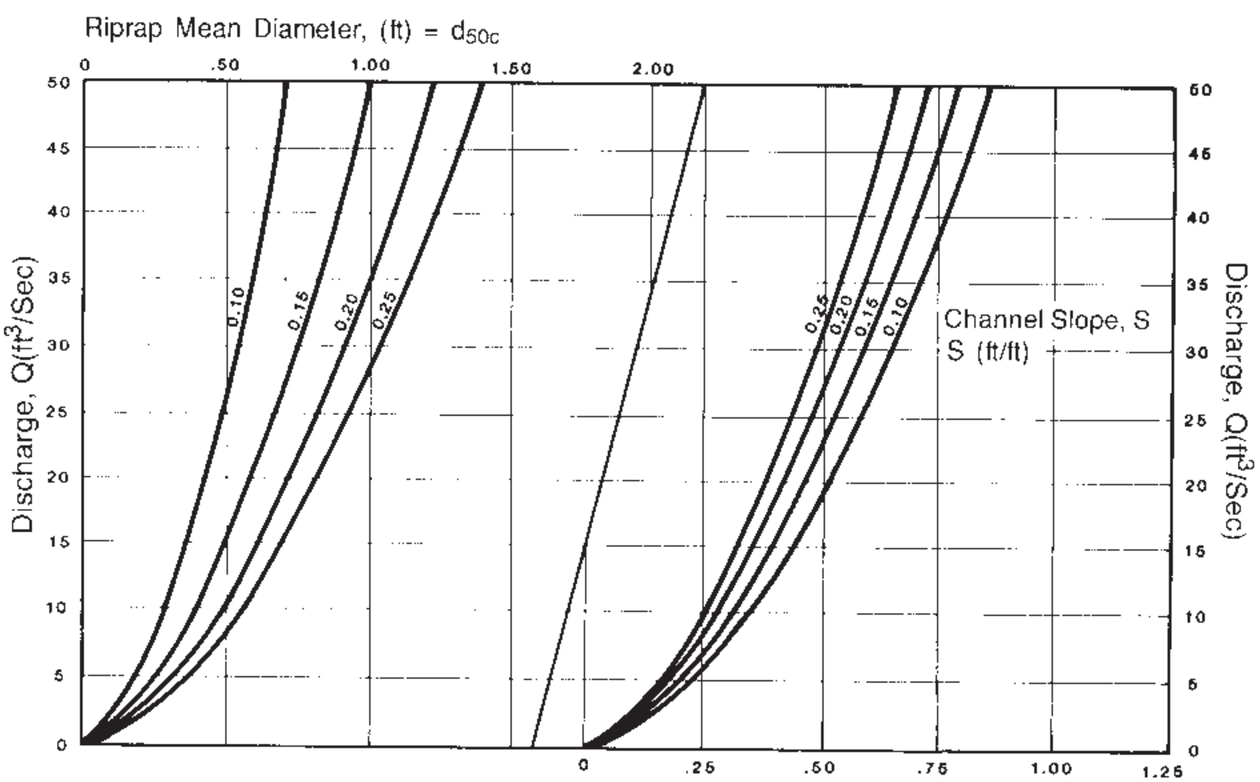


Figure 8.05l Steep slope riprap design, B = 6, Z = 3.

Table 8.05h
Values of A_3/A_z for Selected Side Slopes and Depth-to-Bottom Width Ratios[1]

	A_3/A_z				
d/b	2:1	3:1	4:1	5:1	6:1
0.10	1.083	1.000	0.928	0.866	0.812
0.20	1.142	1.000	0.888	0.800	0.727
0.30	1.187	1.000	0.853	0.760	0.678
0.40	1.222	1.000	0.846	0.733	0.647
0.50	1.250	1.000	0.833	0.714	0.625
0.60	1.272	1.000	0.823	0.700	0.608
0.70	1.291	1.000	0.815	0.688	0.596
0.80	1.307	1.000	0.809	0.680	0.586
0.90	1.321	1.000	0.804	0.672	0.578
1.00	1.333	1.000	0.800	0.666	0.571
1.10	1.343	1.000	0.796	0.661	0.565
1.20	1.352	1.000	0.793	0.657	0.561
1.30	1.361	1.000	0.790	0.653	0.556
1.40	1.368	1.000	0.787	0.650	0.553
1.50	1.378	1.000	0.785	0.647	0.550
1.60	1.381	1.000	0.783	0.644	0.547
1.70	1.386	1.000	0.782	0.642	0.544
1.80	1.391	1.000	0.780	0.640	0.542
1.90	1.395	1.000	0.779	0.638	0.540
2.00	1.400	1.000	0.777	0.636	0.538

[1]Based on the following equation:

$$A_3/A_z = \frac{1 + 3(d/b)}{1 + Z(d/b)}$$

Adapted from: FHWA-HEC 15, pg. 59 - April 1988

b. Find the riprap size using the following equation:

$$d_{50} = \frac{d}{d_n} d_{50c}$$

where d_n and d_{50c} are values from the design charts (Figures 8.05j, 8.05k, and 8.05l).

Sample problem 8.05d demonstrates the tractive force procedure for design of riprap channels on steep grade.

Stability Evaluation for Natural Channels

Determining flow capacity and velocity in a natural channel involves detailed analysis and evaluation. Variations in channel cross section, alignment, grade and roughness, and often changing conditions of in-bank and out-of-bank flow make accurate determination of channel capacity and velocity difficult.

The following procedure uses Manning's equation and the continuity equation to estimate stream channel capacity and velocity. Flow constrictions caused by culverts or bridges must be evaluated separately.

Sample Problem 8.05d Design of a Steep Gradient Channel with Riprap Lining.

Determine the mean riprap size and flow depth for a steep gradient channel:

Given:

Q = 30 cfs
s = 0.15 ft/ft
b = 3.0 ft
Z = 3

Find:

Flow depth (d_n) and mean riprap size d_{50c}

Solution:

(1) Enter Figure 8.05j,
for b = 2.0 given Q = 30 cfs and s = 0.15 ft/ft,

d_n = 0.92 ft
d_{50c} = 1.1 ft

Enter Figure 8.05k,
for b = 4.0 given Q = 30 ft^3/sec and S = 0.15 ft/ft,

d_n = 0.70 ft
d_{50c} = 0.9 ft

(2) Interpolating for a 3.0 ft bottom width gives,

d_n = 0.81 ft
d_{50c} = 1.0 ft

Survey of the Stream Channel

To apply Manning's equation to a natural stream, a field survey is necessary to determine the relevant channel characteristics. The field survey should identify the following:

- Control points along the channel to define channel reaches to be evaluated. These include confluences with tributaries, points of significant change in grade or cross section, bridges, or culverts that restrict the flow.
- The profile of the channel bottom along the centerline of the stream.
- Selected cross sections, at right angles to the channel centerline in each reach, to determine average channel cross section. The survey should also include elevation of the flood plain and valley abutments if out-of-bank flow is anticipated. An accurate topographic map may provide additional stream valley sections and profile points to supplement the field survey.
- Descriptions of relevant physical characteristics of the channel between control points, such as channel bed and bank materials, vegetation, obstructions, meander and other factors that determine the roughness coefficient *n*.

Determining an *n* Factor for a Natural Channel

An *n* value for each channel reach can be determined by following the procedure outlined in *Appendix 8.04*.

Permissible Velocity in Natural Channels

Natural channels seldom have uniform vegetative lining, especially those with continuous stream flow. Typical natural channels have beds of exposed soil, gravel deposits, rock outcroppings and sand bars, and banks ranging from exposed soil to dense native vegetation.

The permissible velocity in natural channels should be determined for the most erodible soil condition along the evaluation reach. Table 8.05d gives permissible velocities for existing channels in specified soil materials.

Evaluation Procedure

After the channel has been divided into reaches, the following procedure may be used to determine stability. The procedure should be applied to each evaluation reach, beginning at the lowest section and progressing upstream.

Step 1. Determine the peak runoff rate for a 10-year storm after site development, based on the **entire** contributing drainage area at the downstream end of each reach.

Step 2. Determine average cross-sectional area, hydraulic radius, slope and permissible velocity in the channel reach.

Step 3. Determine roughness coefficient, *n,* for the reach.

Step 4. Calculate bankfull velocity, V, and capacity, Q, using Manning's equation and the continuity equation.

Step 5. Compare actual bankfull channel capacity, Q, with the peak rate of runoff from step 1, and compare velocity, V, with the permissible velocity from step 2.

a. Calculated channel velocities for the 10-year peak must be equal to or less than the allowable velocity, or channel stabilization will be necessary (*Practice Standards and Specifications: 6.72, Vegetative Streambank Stabilization; 6.73, Structural Streambank Stabilization*).

b. If the capacity of the channel exceeds the peak runoff rate from the 10-year storm, compute the velocity, V, for the depth at which the 10-year storm discharge will flow for stability comparison.

c. If capacity of the channel is less than the peak runoff rate from the 10-year storm, a deeper flow depth must be determined (considering the quantity of out-of-bank flow) to provide the necessary capacity. The channel velocity at this stage must be calculated and compared to the allowable velocity to determine if the reach will require stabilization.

Design Tables for Grass-lined Channel

Tables 8.05i through 8.05o may be used to facilitate the design of grass-lined channels with parabolic cross-sections. These design tables are based on a retardance of “D” (vegetation newly cut) to determine V_1 for stability considerations. The top width, depth, and velocity, V_2, are based on a retardance of “C” (vegetation at normal cutting height for proper maintenance). Channel capacity is determined by these considerations.

Table 8.05c provides retardance classifications for selected vegetal covers. Table 8.05a gives maximum allowable velocities for grass-lined channels for various grasses, soil conditions, and slopes. The velocities in Table 8.05a guide the selection of V_1 in the Design Tables and should not be exceeded. It is good practice to use a value for V_1 that is significantly less than the maximum allowable when choosing a design cross section. The maximum allowable design velocity should only be used when soils will readily support vegetation, special care will be taken in establishing and maintaining grass linings, and a wider, shallower channel cannot be constructed due to site limitations. Riprap-lined and paved channels should be considered when design velocities approach maximum allowable for vegetation.

Sample Problem 8.05e illustrates the design of grass-lined channels with parabolic cross-sections.

Sample Problem 8.05e Design of grass-lined channel with a parabolic cross-section using Design Table 8.05i through 8.05o.

Determine the top width and depth for a vegetated channel.

Given:

Q: 40 cfs
Grade: 4%
Soil: easily erodible
Grass: bermudagrass

Site will allow a top width of 25 ft.

Find:

Channel top width and depth that will be stable and fit site conditions.

Solution:

From Table 8.05a use maximum permissible velocity = 5.0 ft/sec
From Design Table 8.05n use retardance “D” and “C”; grade 4.0%
Top width = 20.8 ft
Depth = 0.83 ft
V_2 = 3.42

NOTE: A design velocity V_1 of 4.0 ft/sec was used as it was less than maximum allowable and gave a top width that would fit site limitations. Wide, shallow vegetated channels are less subject to erosion, are less costly to maintain, and blend more readily into the natural landscape.

Design Tables for Grass-lined Diversions

Tables 8.05p through 8.05y may be used to facilitate the design of grass-lined diversions with parabolic cross-sections. These tables are based on a retardance of "D" (vegetation newly cut) to determine V_1 for stability considerations. To determine channel capacity, choose a retardance of "C" when proper maintenance is expected; otherwise, design channel capacity based on retardance "B". Table 8.05c provides retardance classifications for selected vegetal covers. Table 8.05a gives maximum allowable velocities for grass-lined channels. The permissible velocities guide the selection of V_1 and should not be exceeded. It is good practice to use a value for V_1 that is significantly less than the maximum allowable when choosing a design cross-section. When velocities approach the maximum allowable, flatter grades should be evaluated or a more erosion resistant liner such as riprap should be considered.

Sample Problem 8.05f
Design of grass-lined diversions with a parabolic cross-section using Design Tables 8.05p through 8.05y.

Determine the top width and depth for a vegetated diversion.

Given:

Q: 30 cfs
Grade: 1%
Soil: easily erodible
Grass: Tall fescue
Maintenance: low, will be cut only twice a year. Site will allow a top width of 18 ft.

Find:

Diversion top width and depth that will be stable and fit site conditions.

Solution:

From Table 8.05a use maximum permissible velocity = 4.5 ft/sec
From Table 8.05c use Design Tables for capacity based on retardance "B"
From Table 8.05r use retardance "D" and "B"; grade 1%
Top width = 15 ft
Depth = 2.4 ft
V_2 = 1.8 ft/sec
NOTE: V_1 < 4.5 ft/sec; Top width < 18 ft, design OK.
Since V_1 for 2.0 & 2.5 provides a wider top than acceptable,
try V_1 = 3.0 ft/sec.

NOTE: In this case any other cross-section shown opposite Q=30 would have been stable. It is good practice, however, to select a cross-section that will give a velocity, V_1, well below the maximum allowable whenever site conditions permit. Wide, shallow cross-sections are more stable and require less maintenance. It is also prudent to evaluate flatter design grades in order to best fit diversions to the site and keep velocities well below maximum allowable.

Table 8.05i
Parabolic Waterway Design (Retardance “D” and “C”, Grade 0.25%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	9.6	2.36	1.63																								
30	11.4	2.31	1.68																								
35	13.2	2.27	1.73																								
40	15.0	2.25	1.76	10.4	2.67	2.13																					
45	16.8	2.23	1.78	11.6	2.62	2.19																					
50	18.6	2.21	1.80	12.8	2.59	2.24																					
55	20.4	2.20	1.82	14.0	2.56	2.28																					
60	22.2	2.19	1.83	15.2	2.53	2.31																					
65	24.0	2.18	1.84	16.5	2.54	2.30																					
70	25.8	2.18	1.85	17.7	2.52	2.33	12.6	3.05	2.70																		
75	27.6	2.17	1.86	18.9	2.51	2.35	13.4	3.00	2.76																		
80	29.4	2.17	1.87	20.1	2.50	2.37	14.3	3.01	2.76																		
90	33.1	2.17	1.86	22.6	2.49	2.38	16.0	2.97	2.81																		
100	36.7	2.17	1.87	25.1	2.49	2.38	17.7	2.95	2.85																		
110	40.3	2.16	1.88	27.5	2.47	2.41	19.4	2.93	2.88																		
120	43.9	2.16	1.89	30.0	2.47	2.41	21.1	2.91	2.91	15.2	3.58	3.28															
130	47.6	2.16	1.88	32.5	2.48	2.41	22.8	2.89	2.93	16.4	3.55	3.32															
140	51.2	2.16	1.88	34.9	2.46	2.43	24.6	2.91	2.91	17.6	3.53	3.35															
150	54.8	2.16	1.89	37.4	2.47	2.42	26.3	2.90	2.93	18.8	3.51	3.39															
160	58.4	2.16	1.89	39.9	2.47	2.42	28.0	2.89	2.95	20.0	3.49	3.41															
170	62.0	2.16	1.89	42.3	2.46	2.43	29.7	2.88	2.96	21.2	3.47	3.44	16.7	4.03	3.75												
180	65.6	2.16	1.90	44.8	2.47	2.43	31.4	2.87	2.97	22.4	3.46	3.46	17.6	4.00	3.81												
190	69.2	2.16	1.90	47.2	2.46	2.44	33.1	2.87	2.98	23.6	3.45	3.48	18.5	3.97	3.85												
200	72.8	2.16	1.90	49.7	2.46	2.44	34.9	2.88	2.97	24.8	3.44	3.49	19.4	3.94	3.90												
220	80.0	2.16	1.90	54.6	2.46	2.44	38.3	2.87	2.99	27.2	3.42	3.53	21.3	3.92	3.92												
240	87.3	2.16	1.90	59.5	2.46	2.45	41.7	2.86	3.00	29.6	3.40	3.55	23.1	3.88	3.99												
260	94.5	2.16	1.90	64.5	2.46	2.44	45.2	2.86	3.00	32.1	3.41	3.54	25.0	3.87	4.01	19.5	4.57	4.34									
280	101.7	2.16	1.90	69.4	2.46	2.45	48.6	2.85	3.01	34.5	3.40	3.56	26.9	3.86	4.02	21.0	4.57	4.34									
300	108.9	2.16	1.90	74.3	2.46	2.45	52.1	2.86	3.00	36.9	3.39	3.58	28.7	3.83	4.07	22.4	4.53	4.40									

Table 8.05j
Parabolic Waterway Design (Retardance "D" and "C", Grade 0.5%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	8.6	1.63	1.58																								
20	11.3	1.58	1.66																								
25	14.1	1.57	1.67	9.0	1.91	2.14																					
30	16.9	1.56	1.68	10.7	1.87	2.21	8.2	2.18	2.48																		
35	19.6	1.55	1.71	12.4	1.85	2.26	9.4	2.10	2.62																		
40	22.4	1.55	1.71	14.1	1.83	2.30	10.7	2.08	2.66																		
45	25.1	1.54	1.73	15.8	1.82	2.33	11.9	2.03	2.76																		
50	27.9	1.54	1.73	17.5	1.80	2.35	13.2	2.02	2.78	9.6	2.42	3.19															
55	30.7	1.54	1.72	19.2	1.80	2.37	14.5	2.02	2.79	10.5	2.39	3.25															
60	33.4	1.54	1.74	20.9	1.79	2.38	15.8	2.01	2.80	11.4	2.37	3.30															
65	36.1	1.53	1.75	22.7	1.80	2.36	17.0	1.99	2.86	12.3	2.35	3.34															
70	38.9	1.54	1.74	24.4	1.80	2.37	18.3	1.99	2.86	13.2	2.33	3.38															
75	41.6	1.54	1.75	26.1	1.79	2.38	19.6	1.99	2.86	14.1	2.32	3.41	11.2	2.71	3.66												
80	44.3	1.53	1.75	27.8	1.79	2.39	20.9	1.99	2.86	15.0	2.31	3.43	11.8	2.65	3.80												
90	49.8	1.53	1.75	31.2	1.78	2.41	23.5	1.99	2.87	16.9	2.31	3.42	13.3	2.65	3.78												
100	55.3	1.53	1.75	34.6	1.78	2.42	26.0	1.97	2.90	18.7	2.29	3.47	14.7	2.63	3.85	11.9	3.02	4.13									
110	60.8	1.54	1.75	38.1	1.78	2.41	28.6	1.97	2.90	20.5	2.28	3.50	16.1	2.60	3.90	13.0	2.98	4.22									
120	66.3	1.54	1.75	41.5	1.78	2.42	31.2	1.98	2.90	22.4	2.29	3.49	17.5	2.58	3.94	14.1	2.94	4.30									
130	71.7	1.53	1.76	44.9	1.78	2.42	33.7	1.97	2.92	24.2	2.28	3.51	18.9	2.57	3.98	15.2	2.91	4.36									
140	77.2	1.54	1.76	48.3	1.78	2.43	36.3	1.97	2.92	26.0	2.27	3.54	20.4	2.58	3.95	16.4	2.93	4.34									
150	82.6	1.54	1.76	51.7	1.78	2.43	38.9	1.97	2.91	27.9	2.28	3.52	21.8	2.57	3.98	17.5	2.90	4.39	14.0	3.34	4.77						
160	88.0	1.53	1.76	55.1	1.78	2.44	41.4	1.97	2.93	29.7	2.27	3.54	23.2	2.56	4.01	18.6	2.88	4.44	14.9	3.33	4.80						
170	93.4	1.53	1.77	58.5	1.78	2.44	44.0	1.97	2.92	31.5	2.26	3.55	24.6	2.55	4.03	19.8	2.89	4.41	15.7	3.27	4.92						
180	98.8	1.53	1.77	61.9	1.78	2.44	46.5	1.96	2.94	33.3	2.26	3.57	26.1	2.56	4.01	20.9	2.88	4.45	16.6	3.26	4.94						
190	104.2	1.54	1.77	65.3	1.78	2.44	49.1	1.97	2.93	35.2	2.27	3.55	27.5	2.56	4.03	22.0	2.86	4.49	17.5	3.26	4.96						
200	109.6	1.54	1.77	68.7	1.78	2.44	51.6	1.96	2.94	37.0	2.26	3.56	28.9	2.55	4.04	23.1	2.85	4.52	18.4	3.25	4.98	15.3	3.72	5.23			
220	120.5	1.54	1.77	75.5	1.78	2.44	56.8	1.97	2.93	40.7	2.26	3.56	31.8	2.55	4.04	25.4	2.85	4.53	20.2	3.24	5.01	16.7	3.66	5.36			
240	131.3	1.54	1.77	82.3	1.78	2.45	61.9	1.97	2.94	44.3	2.26	3.58	34.6	2.54	4.07	27.7	2.85	4.53	22.0	3.23	5.04	18.2	3.65	5.38			
260	142.1	1.54	1.77	89.1	1.78	2.45	67.0	1.97	2.94	48.0	2.26	3.58	37.5	2.55	4.06	30.0	2.85	4.54	23.8	3.22	5.06	19.7	3.64	5.39			
280	152.9	1.54	1.78	95.9	1.78	2.45	72.1	1.97	2.95	51.6	2.25	3.59	40.3	2.54	4.08	32.2	2.83	4.58	25.6	3.21	5.08	21.1	3.61	5.48	17.5	4.14	5.75
300	163.7	1.54	1.78	102.6	1.78	2.46	77.2	1.97	2.95	55.3	2.26	3.59	43.2	2.54	4.08	34.5	2.83	4.58	27.3	3.18	5.15	22.6	3.60	5.49	18.7	4.12	5.80

Table 8.05k
Parabolic Waterway Design (Retardance “D” and “C”, Grade 1.0%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	13.4	1.13	1.47	8.4	1.30	2.03																					
20	17.8	1.12	1.49	11.1	1.27	2.10	7.6	1.52	2.55																		
25	22.2	1.11	1.50	13.9	1.27	2.09	9.4	1.49	2.64	7.6	1.62	2.99															
30	26.6	1.11	1.50	16.6	1.26	2.13	11.2	1.46	2.71	9.1	1.61	3.03															
35	30.9	1.11	1.52	19.3	1.25	2.15	13.0	1.45	2.75	10.5	1.57	3.14	8.0	1.80	3.59												
40	35.3	1.11	1.52	22.1	1.26	2.13	14.8	1.44	2.79	12.0	1.57	3.14	9.1	1.78	3.65												
45	39.7	1.11	1.52	24.8	1.25	2.15	16.7	1.45	2.76	13.4	1.55	3.21	10.2	1.76	3.70												
50	44.0	1.11	1.52	27.5	1.25	2.16	18.5	1.44	2.79	14.9	1.55	3.21	11.3	1.75	3.74	8.7	2.02	4.20									
55	48.3	1.11	1.53	30.2	1.25	2.16	20.3	1.43	2.80	16.3	1.54	3.26	12.4	1.75	3.76	9.5	1.99	4.30									
60	52.7	1.11	1.52	32.9	1.25	2.17	22.1	1.43	2.82	17.8	1.54	3.25	13.5	1.74	3.79	10.4	2.01	4.26									
65	57.0	1.11	1.53	35.6	1.25	2.17	23.9	1.43	2.83	19.2	1.53	3.29	14.6	1.73	3.81	11.2	1.98	4.33	9.3	2.22	4.66						
70	61.3	1.11	1.53	38.3	1.25	2.17	25.7	1.43	2.84	20.7	1.53	3.27	15.6	1.71	3.90	12.0	1.96	4.40	10.0	2.21	4.69						
75	65.6	1.11	1.53	41.0	1.25	2.18	27.5	1.42	2.85	22.1	1.53	3.31	16.7	1.71	3.90	12.8	1.95	4.46	10.7	2.21	4.71						
80	69.8	1.11	1.54	43.7	1.25	2.18	29.3	1.42	2.85	23.6	1.53	3.29	17.8	1.71	3.91	13.7	1.96	4.42	11.3	2.16	4.85						
90	78.5	1.11	1.54	49.1	1.25	2.18	32.9	1.42	2.87	26.5	1.53	3.31	20.0	1.70	3.93	15.3	1.93	4.52	12.7	2.16	4.87	10.6	2.42	5.20			
100	87.1	1.11	1.54	54.5	1.25	2.18	36.6	1.43	2.85	29.4	1.52	3.32	22.2	1.70	3.94	17.0	1.93	4.52	14.1	2.15	4.89	11.7	2.39	5.31			
110	95.6	1.11	1.54	59.9	1.25	2.18	40.2	1.42	2.86	32.3	1.52	3.33	24.4	1.70	3.94	18.7	1.93	4.52	15.4	2.12	5.00	12.9	2.40	5.28	11.1	2.59	5.67
120	104.2	1.11	1.54	65.2	1.25	2.19	43.8	1.42	2.87	35.2	1.52	3.33	26.6	1.70	3.95	20.3	1.92	4.59	16.8	2.12	5.00	14.0	2.37	5.36	12.1	2.59	5.69
130	112.7	1.11	1.55	70.6	1.25	2.19	47.4	1.42	2.87	38.1	1.52	3.34	28.8	1.70	3.95	22.0	1.92	4.58	18.2	2.13	5.00	15.1	2.35	5.44	13.0	2.55	5.83
140	121.2	1.11	1.55	76.0	1.25	2.19	51.0	1.42	2.87	41.0	1.52	3.34	30.9	1.69	3.99	23.7	1.92	4.57	19.6	2.13	5.00	16.2	2.34	5.50	14.0	2.55	5.83
150	129.7	1.11	1.55	81.3	1.25	2.19	54.6	1.42	2.87	43.9	1.52	3.34	33.1	1.69	3.99	25.3	1.91	4.62	20.9	2.11	5.07	17.4	2.35	5.46	15.0	2.55	5.84
160	138.1	1.11	1.55	86.6	1.25	2.20	58.2	1.42	2.88	46.8	1.52	3.34	35.3	1.69	3.99	27.0	1.91	4.61	22.3	2.11	5.06	18.5	2.33	5.51	15.9	2.52	5.95
170	146.6	1.11	1.55	91.9	1.25	2.20	61.7	1.42	2.89	49.7	1.52	3.34	37.5	1.69	3.99	28.7	1.92	4.60	23.7	2.11	5.05	19.6	2.32	5.56	16.9	2.52	5.94
180	155.0	1.11	1.55	97.2	1.25	2.20	65.3	1.42	2.89	52.5	1.52	3.36	39.6	1.69	4.01	30.3	1.91	4.63	25.0	2.10	5.10	20.7	2.31	5.60	17.9	2.52	5.93
190	163.4	1.11	1.55	102.5	1.25	2.20	68.9	1.42	2.89	55.4	1.52	3.36	41.8	1.69	4.01	32.0	1.91	4.62	26.4	2.10	5.09	21.9	2.32	5.56	18.8	2.50	6.02
200	171.7	1.11	1.56	107.8	1.25	2.20	72.4	1.42	2.90	58.3	1.52	3.35	44.0	1.69	4.00	33.6	1.91	4.65	27.8	2.11	5.08	23.0	2.32	5.59	19.8	2.50	6.01
220	188.7	1.11	1.56	118.4	1.25	2.21	79.6	1.42	2.89	64.0	1.52	3.37	48.4	1.70	4.00	37.0	1.91	4.63	30.5	2.10	5.12	25.3	2.32	5.59	21.7	2.48	6.08
240	205.5	1.11	1.56	129.0	1.25	2.21	86.7	1.42	2.90	69.8	1.52	3.37	52.7	1.69	4.01	40.3	1.91	4.65	33.3	2.10	5.11	27.5	2.30	5.65	23.6	2.47	6.13
260	222.4	1.11	1.56	139.6	1.25	2.21	93.9	1.42	2.90	75.5	1.52	3.38	57.1	1.69	4.01	43.6	1.91	4.66	36.0	2.10	5.14	29.8	2.30	5.64	25.6	2.48	6.11
280	239.1	1.11	1.56	150.2	1.25	2.22	101.0	1.42	2.91	81.3	1.52	3.37	61.4	1.69	4.02	46.9	1.90	4.68	38.8	2.10	5.12	32.1	2.31	5.63	27.5	2.47	6.15
300	255.9	1.11	1.56	160.8	1.25	2.22	108.1	1.42	2.91	87.0	1.52	3.38	65.7	1.69	4.03	50.3	1.91	4.66	41.5	2.10	5.14	34.3	2.30	5.68	29.5	2.48	6.12

Table 8.05I
Parabolic Waterway Design (Retardance “D” and “C”, Grade 2.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.8	0.81	1.32	12.8	0.91	1.90	9.3	1.00	2.37	6.7	1.15	2.85															
20	27.6	0.80	1.33	17.1	0.91	1.89	12.3	0.99	2.43	8.8	1.12	3.00	6.5	1.29	3.51	5.4	1.41	3.84									
25	34.5	0.81	1.33	21.3	0.91	1.91	15.4	0.99	2.43	11.0	1.11	3.01	8.0	1.25	3.69	6.7	1.38	3.96									
30	41.3	0.81	1.34	25.5	0.91	1.92	18.4	0.98	2.46	13.2	1.11	3.02	9.6	1.24	3.71	7.9	1.33	4.20	6.6	1.49	4.48						
35	48.0	0.80	1.35	29.7	0.91	1.93	21.5	0.99	2.44	15.3	1.10	3.08	11.1	1.22	3.82	9.2	1.33	4.23	7.6	1.45	4.68						
40	54.8	0.80	1.34	33.9	0.91	1.93	24.5	0.98	2.46	17.5	1.10	3.07	12.7	1.22	3.81	10.5	1.32	4.26	8.7	1.45	4.67	7.2	1.65	4.96			
45	61.5	0.80	1.35	38.1	0.91	1.93	27.5	0.98	2.47	19.6	1.10	3.11	14.3	1.23	3.80	11.8	1.32	4.27	9.7	1.43	4.80	8.0	1.61	5.16			
50	68.2	0.80	1.35	42.3	0.91	1.93	30.5	0.98	2.48	21.8	1.10	3.09	15.8	1.22	3.86	13.1	1.32	4.28	10.8	1.43	4.78	8.8	1.57	5.33	7.5	1.74	5.64
55	74.9	0.81	1.35	46.4	0.91	1.94	33.5	0.98	2.48	23.9	1.09	3.12	17.4	1.22	3.84	14.4	1.32	4.29	11.8	1.42	4.87	9.7	1.58	5.30	8.2	1.72	5.75
60	81.5	0.81	1.36	50.6	0.91	1.93	36.5	0.98	2.49	26.1	1.10	3.10	18.9	1.21	3.89	15.6	1.30	4.38	12.9	1.42	4.84	10.6	1.59	5.28	9.0	1.74	5.65
65	88.1	0.81	1.36	54.7	0.91	1.94	39.5	0.98	2.49	28.2	1.10	3.12	20.5	1.22	3.87	16.9	1.30	4.38	13.9	1.41	4.92	11.4	1.56	5.40	9.7	1.73	5.74
70	94.7	0.81	1.36	58.8	0.91	1.94	42.5	0.98	2.49	30.3	1.09	3.14	22.0	1.21	3.90	18.2	1.31	4.37	15.0	1.42	4.89	12.3	1.57	5.37	10.4	1.71	5.82
75	101.2	0.81	1.36	62.9	0.91	1.94	45.5	0.99	2.49	32.4	1.09	3.15	23.6	1.22	3.88	19.5	1.31	4.37	16.0	1.41	4.95	13.1	1.55	5.46	11.1	1.70	5.89
80	107.8	0.81	1.36	67.0	0.91	1.95	48.4	0.98	2.50	34.6	1.10	3.13	25.1	1.21	3.91	20.7	1.30	4.42	17.1	1.41	4.91	14.0	1.56	5.43	11.8	1.69	5.95
90	121.0	0.81	1.37	75.2	0.91	1.95	54.4	0.98	2.50	38.8	1.09	3.15	28.2	1.21	3.92	23.3	1.30	4.41	19.2	1.41	4.94	15.7	1.55	5.48	13.3	1.69	5.92
100	134.2	0.81	1.37	83.4	0.91	1.96	60.4	0.99	2.50	43.1	1.10	3.15	31.3	1.21	3.93	25.9	1.30	4.40	21.3	1.41	4.96	17.4	1.55	5.52	14.7	1.68	6.02
110	147.3	0.81	1.37	91.6	0.91	1.96	66.3	0.98	2.51	47.4	1.10	3.15	34.4	1.21	3.93	28.4	1.30	4.44	23.4	1.40	4.98	19.1	1.54	5.55	16.2	1.68	5.99
120	160.3	0.81	1.38	99.8	0.91	1.96	72.2	0.98	2.51	51.6	1.10	3.16	37.5	1.21	3.93	31.0	1.30	4.42	25.5	1.40	4.99	20.8	1.54	5.58	17.6	1.67	6.06
130	173.3	0.81	1.38	107.9	0.91	1.96	78.1	0.98	2.51	55.8	1.09	3.17	40.6	1.21	3.93	33.5	1.30	4.45	27.6	1.40	5.00	22.5	1.53	5.60	19.1	1.68	6.03
140	186.3	0.81	1.38	116.0	0.91	1.97	84.0	0.99	2.52	60.1	1.10	3.16	43.6	1.21	3.96	36.0	1.29	4.47	29.7	1.40	5.00	24.2	1.53	5.62	20.5	1.67	6.08
150	199.2	0.81	1.38	124.1	0.91	1.97	89.9	0.99	2.52	64.3	1.10	3.16	46.7	1.21	3.96	38.6	1.30	4.45	31.8	1.40	5.00	25.9	1.53	5.63	21.9	1.66	6.13
160	212.0	0.81	1.38	132.1	0.91	1.97	95.7	0.99	2.52	68.5	1.10	3.17	49.8	1.21	3.95	41.1	1.30	4.47	33.8	1.40	5.05	27.6	1.53	5.64	23.4	1.67	6.09
170	224.8	0.81	1.39	140.2	0.91	1.97	101.6	0.99	2.52	72.7	1.10	3.17	52.8	1.21	3.97	43.6	1.30	4.48	35.9	1.40	5.05	29.3	1.53	5.65	24.8	1.66	6.13
180	237.5	0.81	1.39	148.2	0.91	1.98	107.4	0.99	2.53	76.8	1.10	3.18	55.9	1.21	3.96	46.2	1.30	4.46	38.0	1.40	5.04	31.0	1.53	5.65	26.3	1.67	6.10
190	250.2	0.81	1.39	156.1	0.91	1.98	113.2	0.99	2.53	81.0	1.10	3.18	58.9	1.21	3.97	48.7	1.30	4.47	40.1	1.40	5.04	32.7	1.53	5.65	27.7	1.67	6.13
200	262.8	0.81	1.39	164.1	0.91	1.98	119.0	0.99	2.53	85.2	1.10	3.18	61.9	1.21	3.98	51.2	1.30	4.48	42.2	1.40	5.03	34.4	1.53	5.66	29.1	1.66	6.16
220	288.5	0.81	1.40	180.2	0.91	1.99	130.7	0.99	2.54	93.6	1.10	3.18	68.1	1.21	3.97	56.3	1.30	4.48	46.3	1.40	5.06	37.8	1.53	5.67	32.0	1.66	6.16
240	314.1	0.81	1.40	196.2	0.91	1.99	142.4	0.99	2.54	102.0	1.10	3.19	74.2	1.21	3.98	61.3	1.30	4.50	50.5	1.40	5.06	41.2	1.53	5.68	34.9	1.66	6.16
260	339.5	0.81	1.40	212.2	0.91	1.99	154.0	0.99	2.54	110.3	1.10	3.20	80.3	1.21	3.98	66.4	1.30	4.49	54.7	1.40	5.05	44.6	1.53	5.68	37.8	1.66	6.16
280	364.9	0.81	1.40	228.2	0.92	1.99	165.6	0.99	2.55	118.7	1.10	3.19	86.3	1.21	4.00	71.4	1.30	4.50	58.8	1.40	5.07	48.0	1.53	5.68	40.6	1.66	6.20
300	390.2	0.81	1.40	244.1	0.92	2.00	177.2	0.99	2.55	127.0	1.10	3.20	92.4	1.21	4.00	76.4	1.30	4.51	63.0	1.40	5.06	51.4	1.53	5.68	43.5	1.66	6.19

Table 8.05m
Parabolic Waterway Design (Retardance "D" and "C", Grade 3.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	23.6	0.69	1.35	16.3	0.76	1.80	11.4	0.83	2.33	8.8	0.90	2.77	6.5	1.01	3.37	5.0	1.16	3.78									
20	31.4	0.69	1.36	21.7	0.76	1.81	15.2	0.83	2.34	11.7	0.90	2.81	8.6	0.99	3.48	6.6	1.13	3.94	5.9	1.19	4.17						
25	39.2	0.69	1.36	27.0	0.75	1.83	19.0	0.83	2.33	14.6	0.90	2.83	10.8	0.99	3.44	8.1	1.09	4.18	7.3	1.16	4.33	6.0	1.27	4.80			
30	46.9	0.69	1.37	32.4	0.75	1.82	22.7	0.83	2.36	17.4	0.88	2.89	12.9	0.98	3.49	9.7	1.08	4.22	8.7	1.15	4.44	7.1	1.24	5.03	5.8	1.41	5.37
35	54.6	0.69	1.37	37.7	0.75	1.83	26.4	0.83	2.38	20.3	0.89	2.88	15.0	0.98	3.53	11.3	1.08	4.25	10.1	1.13	4.51	8.3	1.24	5.02	6.7	1.38	5.55
40	62.2	0.69	1.37	43.0	0.75	1.83	30.2	0.83	2.37	23.2	0.89	2.88	17.1	0.98	3.55	12.9	1.08	4.26	11.5	1.13	4.57	9.4	1.22	5.17	7.6	1.36	5.70
45	69.9	0.70	1.37	48.3	0.75	1.83	33.9	0.83	2.37	26.0	0.88	2.90	19.2	0.97	3.57	14.5	1.08	4.27	12.9	1.12	4.61	10.6	1.22	5.14	8.5	1.34	5.81
50	77.4	0.69	1.38	53.5	0.75	1.84	37.6	0.83	2.38	28.9	0.89	2.89	21.3	0.97	3.58	16.0	1.06	4.36	14.3	1.12	4.63	11.7	1.21	5.24	9.4	1.33	5.90
55	85.0	0.70	1.38	58.7	0.75	1.85	41.2	0.83	2.40	31.7	0.89	2.91	23.4	0.97	3.58	17.6	1.06	4.35	15.7	1.11	4.66	12.9	1.21	5.20	10.4	1.35	5.80
60	92.5	0.70	1.38	64.0	0.75	1.84	44.9	0.83	2.40	34.5	0.88	2.92	25.5	0.97	3.59	19.2	1.07	4.35	17.1	1.11	4.67	14.0	1.20	5.28	11.3	1.34	5.87
65	99.9	0.69	1.39	69.1	0.75	1.85	48.6	0.83	2.39	37.3	0.88	2.93	27.6	0.97	3.59	20.8	1.07	4.34	18.5	1.11	4.69	15.2	1.21	5.24	12.2	1.33	5.93
70	107.3	0.69	1.39	74.3	0.75	1.86	52.2	0.83	2.40	40.1	0.88	2.93	29.7	0.98	3.59	22.3	1.06	4.39	19.9	1.11	4.69	16.3	1.20	5.30	13.1	1.32	5.98
75	114.7	0.70	1.39	79.4	0.75	1.86	55.8	0.83	2.41	42.9	0.88	2.94	31.8	0.98	3.59	23.9	1.06	4.38	21.3	1.11	4.70	17.5	1.21	5.26	14.0	1.32	6.02
80	122.1	0.70	1.40	84.5	0.75	1.87	59.4	0.83	2.42	45.7	0.88	2.94	33.9	0.98	3.58	25.5	1.07	4.36	22.7	1.11	4.70	18.6	1.20	5.31	15.0	1.33	5.94
90	137.0	0.70	1.40	94.9	0.75	1.87	66.7	0.83	2.42	51.4	0.89	2.93	38.0	0.97	3.61	28.6	1.06	4.40	25.5	1.11	4.72	20.9	1.20	5.33	16.8	1.32	6.01
100	151.8	0.70	1.40	105.2	0.75	1.87	74.0	0.83	2.42	57.0	0.89	2.94	42.2	0.98	3.61	31.7	1.06	4.42	28.3	1.11	4.73	23.2	1.20	5.34	18.6	1.31	6.08
110	166.6	0.70	1.41	115.5	0.75	1.87	81.3	0.83	2.42	62.6	0.89	2.95	46.4	0.98	3.61	34.9	1.06	4.40	31.0	1.10	4.78	25.5	1.20	5.34	20.5	1.32	6.04
120	181.3	0.70	1.41	125.7	0.75	1.88	88.5	0.83	2.43	68.2	0.89	2.95	50.5	0.98	3.62	38.0	1.06	4.42	33.8	1.11	4.78	27.7	1.19	5.40	22.3	1.32	6.08
130	195.9	0.70	1.41	135.9	0.76	1.88	95.7	0.83	2.43	73.7	0.89	2.96	54.6	0.98	3.63	41.1	1.06	4.43	36.6	1.11	4.77	30.0	1.19	5.40	24.2	1.32	6.04
140	210.5	0.70	1.41	146.1	0.76	1.88	102.8	0.83	2.44	79.3	0.89	2.96	58.8	0.98	3.62	44.2	1.06	4.44	39.4	1.11	4.77	32.3	1.20	5.39	26.0	1.32	6.08
150	225.0	0.70	1.42	156.2	0.76	1.89	110.0	0.83	2.44	84.8	0.89	2.96	62.9	0.98	3.63	47.3	1.06	4.44	42.1	1.11	4.80	34.6	1.20	5.38	27.8	1.31	6.11
160	239.4	0.70	1.42	166.2	0.76	1.89	117.1	0.83	2.45	90.3	0.89	2.97	67.0	0.98	3.63	50.4	1.06	4.45	44.9	1.11	4.79	36.8	1.19	5.42	29.6	1.31	6.13
170	253.7	0.70	1.42	176.2	0.76	1.90	124.2	0.83	2.45	95.8	0.89	2.97	71.1	0.98	3.64	53.5	1.06	4.45	47.7	1.11	4.78	39.1	1.20	5.41	31.5	1.32	6.09
180	268.0	0.70	1.43	186.2	0.76	1.90	131.2	0.83	2.46	101.3	0.89	2.97	75.2	0.98	3.64	56.6	1.06	4.45	50.4	1.11	4.80	41.3	1.19	5.44	33.3	1.32	6.11
190	282.2	0.70	1.43	196.1	0.76	1.90	138.3	0.83	2.46	106.7	0.89	2.98	79.2	0.98	3.65	59.7	1.07	4.45	53.1	1.11	4.81	43.6	1.20	5.42	35.1	1.32	6.12
200	296.3	0.70	1.43	206.0	0.76	1.90	145.3	0.83	2.46	112.2	0.89	2.98	83.3	0.98	3.65	62.7	1.06	4.47	55.9	1.11	4.80	45.8	1.19	5.45	36.9	1.32	6.14
220	325.1	0.70	1.44	226.1	0.76	1.91	159.5	0.83	2.47	123.2	0.89	2.98	91.5	0.98	3.65	68.9	1.06	4.47	61.4	1.11	4.81	50.4	1.20	5.43	40.6	1.32	6.12
240	353.8	0.70	1.44	246.2	0.76	1.91	173.7	0.83	2.47	134.2	0.89	2.99	99.7	0.98	3.65	75.1	1.07	4.47	66.9	1.11	4.81	54.9	1.20	5.44	44.2	1.32	6.15
260	382.4	0.70	1.44	266.1	0.76	1.92	187.8	0.83	2.48	145.1	0.89	2.99	107.8	0.98	3.67	81.3	1.07	4.47	72.4	1.11	4.82	59.4	1.20	5.45	47.8	1.31	6.17
280	410.8	0.70	1.45	286.0	0.76	1.92	201.9	0.83	2.48	156.0	0.89	3.00	116.0	0.98	3.66	87.4	1.07	4.48	77.9	1.11	4.82	63.9	1.20	5.46	51.5	1.32	6.15
300	439.0	0.70	1.45	305.8	0.76	1.92	215.9	0.83	2.49	166.9	0.89	3.00	124.1	0.98	3.67	93.6	1.07	4.47	83.3	1.11	4.83	68.4	1.20	5.46	55.1	1.32	6.17

Table 8.05n
Parabolic Waterway Design (Retardance “D” and “C”, Grade 4.0%)

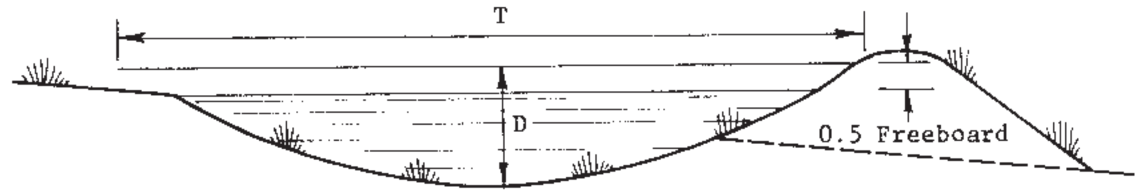
Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	27.9	0.62	1.29	19.9	0.66	1.68	13.9	0.73	2.20	10.3	0.79	2.73	7.9	0.85	3.28	6.3	0.92	3.78	4.9	1.06	4.21						
20	37.1	0.62	1.29	26.5	0.66	1.69	18.5	0.72	2.21	13.7	0.78	2.76	10.5	0.84	3.33	8.4	0.92	3.81	6.4	1.01	4.52	5.5	1.09	4.88			
25	46.2	0.62	1.30	33.0	0.66	1.70	23.0	0.72	2.24	17.1	0.78	2.77	13.1	0.84	3.35	10.5	0.92	3.82	8.0	1.01	4.55	6.8	1.06	5.09	5.7	1.20	5.34
30	55.3	0.62	1.30	39.5	0.66	1.70	27.6	0.72	2.23	20.4	0.77	2.82	15.7	0.84	3.36	12.5	0.91	3.92	9.5	0.99	4.71	8.2	1.07	5.03	6.7	1.15	5.71
35	64.3	0.62	1.31	46.0	0.66	1.71	32.1	0.72	2.25	23.8	0.78	2.81	18.3	0.84	3.37	14.6	0.91	3.90	11.1	0.99	4.70	9.5	1.06	5.15	7.8	1.15	5.77
40	73.3	0.62	1.31	52.4	0.66	1.71	36.6	0.72	2.25	27.1	0.77	2.83	20.8	0.83	3.42	16.6	0.90	3.96	12.7	1.00	4.68	10.8	1.04	5.24	8.9	1.14	5.81
45	82.2	0.62	1.32	58.8	0.66	1.72	41.1	0.72	2.26	30.4	0.77	2.85	23.4	0.84	3.41	18.7	0.91	3.94	14.2	0.98	4.77	12.2	1.05	5.17	10.0	1.14	5.83
50	91.1	0.62	1.32	65.2	0.66	1.72	45.6	0.72	2.26	33.7	0.77	2.86	26.0	0.84	3.40	20.7	0.90	3.97	15.8	0.99	4.74	13.5	1.05	5.24	11.1	1.14	5.85
55	99.9	0.62	1.32	71.5	0.66	1.73	50.1	0.72	2.26	37.0	0.77	2.86	28.5	0.84	3.43	22.8	0.91	3.95	17.3	0.98	4.80	14.8	1.04	5.28	12.2	1.14	5.87
60	108.7	0.62	1.32	77.8	0.66	1.73	54.5	0.72	2.26	40.3	0.77	2.87	31.0	0.83	3.45	24.8	0.90	3.97	18.9	0.99	4.77	16.1	1.04	5.32	13.3	1.14	5.88
65	117.4	0.62	1.33	84.1	0.66	1.73	58.9	0.72	2.27	43.6	0.77	2.87	33.6	0.84	3.43	26.8	0.90	3.99	20.4	0.98	4.81	17.5	1.05	5.26	14.3	1.12	6.00
70	126.1	0.62	1.33	90.3	0.66	1.74	63.3	0.72	2.27	46.9	0.77	2.86	36.1	0.84	3.44	28.8	0.90	4.01	21.9	0.98	4.85	18.8	1.04	5.29	15.4	1.12	6.00
75	134.7	0.62	1.33	96.5	0.66	1.74	67.7	0.72	2.28	50.1	0.77	2.88	38.6	0.84	3.45	30.9	0.91	3.98	23.5	0.98	4.82	20.1	1.04	5.31	16.5	1.13	5.99
80	143.3	0.62	1.34	102.7	0.66	1.74	72.1	0.72	2.28	53.3	0.77	2.89	41.1	0.84	3.46	32.9	0.91	3.99	25.0	0.98	4.84	21.4	1.04	5.33	17.6	1.13	5.98
90	160.8	0.62	1.34	115.2	0.66	1.75	80.9	0.72	2.28	59.9	0.77	2.89	46.2	0.84	3.46	36.9	0.90	4.01	28.1	0.98	4.85	24.0	1.04	5.38	19.7	1.12	6.07
100	178.2	0.62	1.34	127.7	0.66	1.75	89.7	0.72	2.29	66.4	0.77	2.90	51.2	0.84	3.47	41.0	0.91	4.00	31.2	0.98	4.85	26.7	1.04	5.35	21.9	1.12	6.05
110	195.4	0.62	1.35	140.1	0.66	1.76	98.5	0.72	2.29	72.9	0.77	2.90	56.2	0.84	3.48	45.0	0.90	4.02	34.3	0.98	4.85	29.3	1.04	5.37	24.1	1.12	6.03
120	212.6	0.62	1.35	152.5	0.66	1.76	107.2	0.72	2.30	79.4	0.77	2.90	61.2	0.84	3.49	49.0	0.90	4.03	37.3	0.98	4.88	31.9	1.04	5.40	26.2	1.12	6.09
130	229.6	0.62	1.35	164.8	0.66	1.76	115.9	0.72	2.30	85.9	0.77	2.91	66.2	0.84	3.49	53.0	0.90	4.03	40.4	0.98	4.87	34.6	1.04	5.36	28.4	1.12	6.07
140	246.6	0.62	1.36	177.0	0.66	1.77	124.5	0.72	2.30	92.3	0.77	2.91	71.2	0.84	3.49	57.0	0.90	4.04	43.4	0.98	4.90	37.2	1.04	5.38	30.5	1.12	6.10
150	263.5	0.62	1.36	189.1	0.66	1.77	133.2	0.73	2.30	98.7	0.77	2.92	76.2	0.84	3.49	61.0	0.91	4.04	46.5	0.98	4.88	39.8	1.04	5.39	32.7	1.12	6.08
160	280.3	0.62	1.36	201.2	0.66	1.78	141.7	0.73	2.31	105.1	0.77	2.92	81.1	0.84	3.50	65.0	0.91	4.04	49.5	0.98	4.90	42.4	1.04	5.40	34.8	1.12	6.11
170	296.9	0.62	1.37	213.3	0.67	1.78	150.3	0.73	2.31	111.5	0.78	2.92	86.0	0.84	3.51	68.9	0.91	4.05	52.5	0.98	4.91	45.0	1.04	5.40	36.9	1.12	6.13
180	313.5	0.62	1.37	225.3	0.67	1.78	158.8	0.73	2.32	117.8	0.78	2.93	90.9	0.84	3.52	72.9	0.91	4.05	55.6	0.98	4.90	47.6	1.04	5.40	39.1	1.12	6.11
190	330.0	0.62	1.37	237.2	0.67	1.79	167.3	0.73	2.32	124.2	0.78	2.93	95.8	0.84	3.52	76.8	0.91	4.06	58.6	0.98	4.90	50.2	1.04	5.40	41.2	1.12	6.12
200	346.4	0.62	1.37	249.1	0.67	1.79	175.7	0.73	2.32	130.5	0.78	2.93	100.7	0.84	3.52	80.7	0.91	4.07	61.6	0.98	4.91	52.7	1.04	5.43	43.3	1.12	6.14
220	380.0	0.62	1.38	273.3	0.67	1.79	192.9	0.73	2.33	143.3	0.78	2.93	110.6	0.84	3.53	88.7	0.91	4.07	67.6	0.98	4.93	57.9	1.04	5.44	47.6	1.12	6.14
240	413.3	0.62	1.38	297.4	0.67	1.80	209.9	0.73	2.33	156.0	0.78	2.94	120.4	0.84	3.53	96.6	0.91	4.07	73.7	0.98	4.93	63.1	1.04	5.44	51.9	1.12	6.14
260	446.5	0.62	1.39	321.4	0.67	1.80	227.0	0.73	2.33	168.7	0.78	2.94	130.2	0.84	3.54	104.5	0.91	4.08	79.7	0.98	4.94	68.3	1.04	5.44	56.2	1.12	6.13
280	479.5	0.62	1.39	345.3	0.67	1.80	243.9	0.73	2.34	181.3	0.78	2.95	140.0	0.84	3.54	112.3	0.91	4.09	85.8	0.99	4.93	73.5	1.04	5.44	60.4	1.12	6.15
300	512.3	0.62	1.39	369.0	0.67	1.81	260.8	0.73	2.34	193.9	0.78	2.95	149.8	0.84	3.55	120.2	0.91	4.09	91.8	0.99	4.94	78.6	1.04	5.46	64.7	1.12	6.14

Table 8.05o
Parabolic Waterway Design (Retardance "D" and "C", Grade 5.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	29.3	0.57	1.33	21.1	0.60	1.74	15.0	0.66	2.23	12.2	0.70	2.58	9.0	0.75	3.25	7.2	0.83	3.70	5.8	0.93	4.09	4.6	0.99	4.81			
20	39.0	0.57	1.33	28.1	0.61	1.74	19.9	0.66	2.26	16.2	0.70	2.62	12.0	0.75	3.26	9.5	0.81	3.84	7.6	0.89	4.35	6.1	0.97	4.95	5.3	1.06	5.21
25	48.6	0.57	1.34	35.1	0.61	1.73	24.8	0.66	2.28	20.3	0.70	2.59	15.0	0.75	3.27	11.9	0.81	3.82	9.5	0.89	4.37	7.6	0.96	5.03	6.5	1.02	5.56
30	58.1	0.57	1.34	42.0	0.61	1.74	29.7	0.66	2.28	24.3	0.70	2.61	18.0	0.76	3.26	14.2	0.80	3.89	11.3	0.87	4.49	9.1	0.96	5.08	7.8	1.01	5.59
35	67.6	0.57	1.35	48.8	0.61	1.75	34.6	0.66	2.28	28.2	0.70	2.64	20.9	0.75	3.30	16.6	0.81	3.86	13.2	0.88	4.47	10.5	0.94	5.26	9.1	1.01	5.60
40	77.0	0.57	1.35	55.7	0.61	1.75	39.5	0.66	2.28	32.2	0.70	2.64	23.9	0.75	3.29	18.9	0.80	3.90	15.1	0.88	4.46	12.0	0.94	5.26	10.3	0.99	5.77
45	86.4	0.57	1.35	62.5	0.61	1.75	44.3	0.66	2.29	36.1	0.70	2.65	26.8	0.75	3.31	21.3	0.81	3.87	16.9	0.87	4.52	13.5	0.94	5.25	11.6	1.00	5.75
50	95.7	0.57	1.36	69.2	0.61	1.76	49.1	0.66	2.30	40.1	0.70	2.64	29.7	0.75	3.32	23.6	0.81	3.89	18.8	0.88	4.50	15.0	0.94	5.25	12.9	1.00	5.73
55	105.0	0.57	1.36	75.9	0.61	1.77	53.9	0.66	2.30	44.0	0.70	2.65	32.6	0.75	3.33	25.9	0.81	3.90	20.6	0.87	4.54	16.5	0.94	5.24	14.1	0.99	5.84
60	114.2	0.57	1.36	82.6	0.61	1.77	58.7	0.66	2.30	47.9	0.70	2.66	35.5	0.75	3.34	28.2	0.81	3.92	22.4	0.87	4.57	17.9	0.93	5.32	15.4	0.99	5.81
65	123.4	0.57	1.36	89.3	0.61	1.77	63.4	0.66	2.31	51.8	0.70	2.66	38.4	0.75	3.34	30.5	0.81	3.92	24.3	0.87	4.54	19.4	0.94	5.30	16.7	1.00	5.78
70	132.4	0.57	1.37	95.9	0.61	1.77	68.2	0.66	2.31	55.6	0.70	2.67	41.3	0.75	3.34	32.8	0.81	3.93	26.1	0.87	4.56	20.8	0.93	5.36	17.9	0.99	5.85
75	141.5	0.57	1.37	102.4	0.61	1.78	72.9	0.66	2.31	59.4	0.70	2.68	44.1	0.75	3.36	35.1	0.81	3.93	27.9	0.87	4.58	22.3	0.93	5.34	19.2	1.00	5.82
80	150.5	0.57	1.37	109.0	0.61	1.78	77.5	0.66	2.32	63.3	0.70	2.68	47.0	0.75	3.36	37.4	0.81	3.92	29.7	0.87	4.60	23.8	0.94	5.32	20.4	0.99	5.88
90	168.8	0.57	1.38	122.3	0.61	1.79	87.0	0.66	2.33	71.0	0.70	2.69	52.8	0.75	3.36	42.0	0.81	3.93	33.4	0.87	4.59	26.7	0.94	5.35	22.9	0.99	5.91
100	187.0	0.57	1.38	135.5	0.61	1.79	96.5	0.66	2.33	78.7	0.70	2.70	58.5	0.75	3.37	46.5	0.81	3.96	37.0	0.87	4.62	29.6	0.93	5.38	25.5	0.99	5.86
110	205.1	0.57	1.38	148.7	0.61	1.79	105.9	0.66	2.33	86.4	0.70	2.70	64.3	0.75	3.37	51.1	0.81	3.96	40.7	0.87	4.61	32.5	0.93	5.39	28.0	0.99	5.88
120	223.1	0.57	1.39	161.8	0.61	1.80	115.3	0.66	2.33	94.1	0.70	2.70	70.0	0.75	3.38	55.7	0.81	3.96	44.3	0.87	4.62	35.4	0.93	5.41	30.5	0.99	5.89
130	240.9	0.57	1.39	174.8	0.61	1.80	124.6	0.66	2.34	101.7	0.70	2.71	75.7	0.76	3.38	60.2	0.81	3.97	47.9	0.87	4.64	38.3	0.93	5.41	33.0	0.99	5.90
140	258.7	0.57	1.40	187.7	0.61	1.81	133.9	0.66	2.34	109.3	0.70	2.71	81.3	0.75	3.39	64.7	0.81	3.98	51.5	0.87	4.64	41.2	0.93	5.42	35.5	0.99	5.91
150	276.4	0.58	1.40	200.6	0.61	1.81	143.1	0.66	2.35	116.8	0.70	2.72	87.0	0.76	3.39	69.3	0.81	3.97	55.1	0.87	4.65	44.1	0.93	5.42	37.9	0.99	5.96
160	293.9	0.58	1.40	213.4	0.61	1.81	152.3	0.66	2.35	124.3	0.70	2.72	92.6	0.76	3.40	73.7	0.81	3.99	58.7	0.87	4.65	47.0	0.94	5.42	40.4	0.99	5.95
170	311.4	0.58	1.40	226.1	0.61	1.82	161.5	0.66	2.35	131.8	0.70	2.73	98.2	0.76	3.41	78.2	0.81	3.99	62.3	0.87	4.65	49.9	0.94	5.41	42.9	0.99	5.95
180	328.7	0.58	1.41	238.8	0.61	1.82	170.6	0.66	2.36	139.2	0.70	2.73	103.8	0.76	3.41	82.7	0.81	3.99	65.9	0.87	4.65	52.7	0.93	5.44	45.4	0.99	5.94
190	346.0	0.58	1.41	251.4	0.61	1.83	179.7	0.67	2.36	146.6	0.70	2.74	109.4	0.76	3.41	87.1	0.81	4.00	69.4	0.87	4.67	55.6	0.94	5.43	47.8	0.99	5.97
200	363.1	0.58	1.42	263.9	0.61	1.83	188.7	0.67	2.37	154.0	0.70	2.74	114.9	0.76	3.42	91.6	0.81	4.00	73.0	0.87	4.66	58.4	0.94	5.45	50.3	0.99	5.96
220	398.3	0.58	1.42	289.6	0.62	1.83	207.1	0.67	2.37	169.0	0.70	2.75	126.1	0.76	3.43	100.6	0.81	4.00	80.1	0.87	4.68	64.2	0.94	5.45	55.2	0.99	5.99
240	433.2	0.58	1.42	315.0	0.62	1.84	225.4	0.67	2.37	184.0	0.70	2.75	137.4	0.76	3.43	109.5	081	4.01	87.3	0.87	4.68	69.9	0.94	5.46	60.2	0.99	5.98
260	467.9	0.58	1.43	340.4	0.62	1.84	243.7	0.67	2.38	198.9	0.70	2.76	148.5	0.76	3.44	118.5	0.81	4.01	94.4	0.87	4.69	75.6	0.94	5.47	65.1	0.99	5.99
280	502.5	0.58	1.43	365.6	0.62	1.84	261.8	0.67	2.38	213.7	0.70	2.76	159.7	0.76	3.44	127.4	0.81	4.02	101.5	0.87	4.70	81.4	0.94	5.46	70.0	0.99	6.01
300	536.7	0.58	1.43	390.7	0.62	1.85	279.9	0.67	2.38	228.5	0.71	2.77	170.7	0.76	3.45	136.2	0.81	4.03	108.6	0.87	4.70	87.0	0.94	5.48	74.9	0.99	6.01

Table 8.05p
Parabolic Diversion Design (Retardance “D” and “B”, Grade 0.25%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	12	3.8	1.0																								
30	14	3.6	1.1																								
35	17	3.5	1.1																								
40	19	3.5	1.2	13	4.1	1.4																					
45	21	3.4	1.2	14	4.0	1.4																					
50	23	3.4	1.2	16	3.9	1.5																					
55	26	3.4	1.2	17	3.9	1.5																					
60	28	3.4	1.2	19	3.9	1.5																					
65	30	3.4	1.2	20	3.8	1.6																					
70	32	3.4	1.2	22	3.8	1.6	15	4.5	1.8																		
75	34	3.4	1.2	23	3.8	1.6	16	4.4	1.9																		
80	37	3.4	1.2	25	3.8	1.6	17	4.4	1.9																		
90	41	3.4	1.2	28	3.8	1.6	19	4.3	1.9																		
100	46	3.4	1.2	31	3.7	1.6	21	4.3	2.0																		
110	50	3.4	1.2	34	3.7	1.6	23	4.2	2.0																		
120	55	3.4	1.3	37	3.7	1.6	26	4.2	2.0	18	5.0	2.3															
130	59	3.4	1.3	40	3.7	1.6	28	4.2	2.0	19	4.9	2.4															
140	64	3.3	1.3	43	3.7	1.7	30	4.2	2.0	21	4.9	2.4															
150	68	3.3	1.3	46	3.7	1.7	32	4.2	2.0	22	4.8	2.5															
160	73	3.3	1.3	49	3.7	1.7	34	4.2	2.0	24	4.8	2.5															
170	77	3.3	1.3	52	3.7	1.7	36	4.2	2.1	25	4.8	2.5	20	5.5	2.8												
180	82	3.3	1.3	55	3.7	1.7	38	4.2	2.1	26	4.7	2.6	21	5.4	2.8												
190	86	3.3	1.3	58	3.7	1.7	40	4.2	2.1	28	4.7	2.6	22	5.4	2.8												
200	91	3.3	1.3	61	3.7	1.7	42	4.2	2.1	29	4.7	2.6	23	5.3	2.9												
220				67	3.7	1.7	46	4.2	2.1	32	4.7	2.6	25	5.3	2.9												
240				73	3.7	1.7	50	4.1	2.1	35	4.7	2.6	27	5.2	3.0												
260				79	3.7	1.7	54	4.1	2.1	38	4.7	2.6	29	5.2	3.0	22	6.0	3.3									
280				85	3.7	1.7	59	4.1	2.1	40	4.6	2.6	31	5.1	3.1	24	5.9	3.4									
300				91	3.7	1.7	63	4.1	2.1	43	4.6	2.7	33	5.1	3.1	26	5.9	3.4									



T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05q
Parabolic Diversion Design (Retardance "D" and "B", Grade 0.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	12	2.8	1.0																								
20	15	2.7	1.0																								
25	18	2.7	1.1	12	3.1	1.4																					
30	22	2.6	1.1	14	3.0	1.4	10	3.4	1.6																		
35	25	2.6	1.1	16	3.0	1.5	12	3.3	1.7																		
40	29	2.6	1.1	18	2.9	1.5	13	3.2	1.8																		
45	33	2.6	1.1	20	2.9	1.5	15	3.2	1.8																		
50	36	2.6	1.1	22	2.9	1.5	17	3.1	1.9	12	3.7	2.1															
55	40	2.6	1.1	24	2.9	1.6	18	3.1	1.9	13	3.6	2.2															
60	43	2.6	1.1	27	2.9	1.6	20	3.1	1.9	14	3.6	2.2															
65	47	2.6	1.1	29	2.9	1.6	21	3.1	1.9	15	3.5	2.3															
70	50	2.6	1.1	31	2.9	1.6	23	3.1	1.9	16	3.5	2.3															
75	54	2.6	1.1	33	2.9	1.6	25	3.1	1.9	17	3.5	2.3	14	4.0	2.5												
80	58	2.6	1.1	35	2.9	1.6	26	3.1	1.9	18	3.5	2.4	15	3.9	2.6												
90	65	2.6	1.1	40	2.9	1.6	29	3.1	2.0	21	3.5	2.4	16	3.9	2.6												
100	72	2.6	1.1	44	2.8	1.6	32	3.1	2.0	23	3.4	2.4	18	3.8	2.7	14	4.3	3.0									
110	79	2.6	1.1	48	2.8	1.6	36	3.1	2.0	25	3.4	2.4	20	3.8	2.8	16	4.2	3.1									
120	86	2.6	1.1	52	2.8	1.6	39	3.1	2.0	27	3.4	2.5	21	3.7	2.8	17	4.1	3.1									
130	93	2.6	1.1	57	2.8	1.6	42	3.1	2.0	30	3.4	2.5	23	3.7	2.8	18	4.1	3.2									
140				61	2.8	1.6	45	3.1	2.0	32	3.4	2.5	25	3.7	2.8	19	4.1	3.2									
150				65	2.8	1.6	48	3.1	2.0	34	3.4	2.5	26	3.7	2.9	21	4.1	3.2	17	4.6	3.5						
160				70	2.8	1.6	52	3.0	2.0	36	3.4	2.5	28	3.7	2.9	22	4.0	3.3	18	4.5	3.6						
170				74	2.8	1.6	55	3.0	2.0	39	3.4	2.5	30	3.7	2.9	24	4.0	3.3	19	4.5	3.6						
180				78	2.8	1.6	58	3.0	2.0	41	3.4	2.5	31	3.7	2.9	25	4.0	3.3	20	4.5	3.7						
190				83	2.8	1.6	61	3.0	2.0	43	3.4	2.5	33	3.7	2.9	26	4.0	3.3	21	4.5	3.7						
200				87	2.8	1.6	64	3.0	2.0	45	3.4	2.5	35	3.7	2.9	27	4.0	3.3	22	4.4	3.8	18	5.0	4.0			
220				95	2.8	1.6	71	3.0	2.0	50	3.4	2.5	38	3.7	2.9	30	4.0	3.4	24	4.4	3.8	19	4.9	4.1			
240							77	3.0	2.0	54	3.4	2.5	42	3.7	2.9	33	4.0	3.4	26	4.4	3.8	21	4.9	4.1			
260							83	3.0	2.0	59	3.4	2.5	45	3.7	3.0	36	4.0	3.4	28	4.3	3.9	23	4.8	4.2			
280							90	3.0	2.0	63	3.4	2.5	48	3.7	3.0	38	4.0	3.4	30	4.3	3.9	24	4.8	4.2	20	5.4	4.5
300							96	3.0	2.0	68	3.4	2.5	52	3.6	3.0	41	4.0	3.4	32	4.3	3.9	26	4.8	4.3	21	5.3	4.6

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05r
Parabolic Diversion Design (Retardance "D" and "B", Grade 1.0%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	18	2.1	0.9	11	2.3	1.2																					
20	24	2.0	0.9	15	2.2	1.3	10	2.5	1.7																		
25	30	2.0	0.9	19	2.2	1.3	12	2.5	1.7	10	2.7	1.9															
30	36	2.0	0.9	22	2.2	1.4	15	2.4	1.8	12	2.6	2.0															
35	42	2.0	0.9	26	2.2	1.4	17	2.4	1.8	14	2.6	2.1	10	2.9	2.4												
40	48	2.0	1.0	29	2.2	1.4	19	2.4	1.8	15	2.5	2.1	12	2.8	2.5												
45	54	2.0	1.0	33	2.2	1.4	22	2.4	1.8	17	2.5	2.1	13	2.8	2.5												
50	59	2.0	1.0	37	2.2	1.4	24	2.4	1.9	19	2.5	2.2	14	2.8	2.5	11	3.1	2.9									
55	65	2.0	1.0	40	2.2	1.4	26	2.4	1.9	21	2.5	2.2	16	2.8	2.6	12	3.1	2.9									
60	71	2.0	1.0	44	2.2	1.4	29	2.4	1.9	23	2.5	2.2	17	2.7	2.6	13	3.0	3.0									
65	77	2.0	1.0	47	2.2	1.4	31	2.4	1.9	25	2.5	2.2	18	2.7	2.6	14	3.0	3.0	11	3.4	3.2						
70	83	2.0	1.0	51	2.2	1.4	33	2.4	1.9	26	2.5	2.2	20	2.7	2.6	15	3.0	3.0	12	3.3	3.3						
75	88	2.0	1.0	54	2.2	1.4	36	2.4	1.9	28	2.5	2.2	21	2.7	2.7	16	3.0	3.1	13	3.3	3.4						
80	94	2.0	1.0	58	2.2	1.4	38	2.4	1.9	30	2.5	2.2	23	2.7	2.7	17	3.0	3.1	14	3.2	3.4						
90				65	2.2	1.4	43	2.4	1.9	34	2.5	2.2	25	2.7	2.7	19	3.0	3.1	16	3.2	3.5	13	3.5	3.8			
100				72	2.2	1.4	47	2.4	1.9	38	2.5	2.2	28	2.7	2.7	21	3.0	3.1	17	3.2	3.6	14	3.4	3.9			
110				79	2.2	1.4	52	2.4	1.9	41	2.5	2.3	31	2.7	2.7	23	2.9	3.2	19	3.2	3.6	16	3.4	3.9	13	3.7	4.1
120				86	2.2	1.4	57	2.4	1.9	45	2.5	2.3	34	2.7	2.7	25	2.9	3.2	21	3.2	3.6	17	3.4	4.0	15	3.7	4.2
130				94	2.2	1.4	61	2.4	1.9	49	2.5	2.3	36	2.7	2.7	27	2.9	3.2	22	3.1	3.6	18	3.4	4.0	16	3.6	4.3
140							66	2.4	1.9	52	2.5	2.3	39	2.7	2.7	29	2.9	3.2	23	3.1	3.6	20	3.4	4.1	17	3.6	4.3
150							71	2.4	1.9	56	2.5	2.3	42	2.7	2.7	31	2.9	3.2	26	3.1	3.7	21	3.4	4.1	18	3.6	4.4
160							75	2.4	1.9	60	2.5	2.3	45	2.7	2.7	33	2.9	3.2	27	3.1	3.7	22	3.4	4.1	19	3.6	4.4
170							80	2.4	1.9	63	2.5	2.3	47	2.7	2.7	35	2.9	3.3	29	3.1	3.7	24	3.4	4.1	20	3.6	4.5
180							84	2.4	1.9	67	2.5	2.3	50	2.7	2.7	38	2.9	3.3	31	3.1	3.7	25	3.3	4.1	21	3.5	4.5
190							89	2.4	1.9	71	2.5	2.3	53	2.7	2.7	40	2.9	3.3	32	3.1	3.7	26	3.3	4.2	22	3.5	4.5
200							94	2.4	1.9	74	2.5	2.3	55	2.7	2.7	42	2.9	3.3	34	3.1	3.7	28	3.3	4.2	24	3.5	4.6
220										82	2.5	2.3	61	2.7	2.7	46	2.9	3.3	37	3.1	3.7	30	3.3	4.2	26	3.5	4.6
240										89	2.5	2.3	66	2.7	2.8	50	2.9	3.3	41	3.1	3.7	33	3.3	4.2	28	3.5	4.6
260										96	2.5	2.3	72	2.7	2.8	54	2.9	3.3	44	3.1	3.8	36	3.3	4.2	30	3.5	4.7
280													77	2.7	2.8	58	2.9	3.3	47	3.1	3.8	38	3.3	4.2	33	3.5	4.7
300													83	2.7	2.8	62	2.9	3.3	50	3.1	3.8	41	3.3	4.2	35	3.5	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05s
Parabolic Diversion Design (Retardance "D" and "B", Grade 1.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24	1.8	0.9	15	1.9	1.2	10	2.2	1.5																		
20	32	1.8	0.9	20	1.9	1.2	14	2.1	1.6																		
25	39	1.8	0.9	25	1.9	1.2	17	2.1	1.6	11	2.3	2.1															
30	47	1.8	0.9	31	1.9	1.2	20	2.1	1.6	13	2.3	2.2	11	2.4	2.4												
35	55	1.8	0.9	36	1.9	1.2	23	2.1	1.7	16	2.2	2.2	13	2.4	2.5	10	2.6	2.7									
40	63	1.8	0.9	41	1.9	1.2	27	2.1	1.7	18	2.2	2.2	14	2.3	2.6	12	2.5	2.8									
45	70	1.8	0.9	46	1.9	1.2	30	2.1	1.7	20	2.2	2.2	16	2.3	2.6	13	2.5	2.8	10	2.8	3.2						
50	78	1.8	0.9	51	1.9	1.2	33	2.1	1.7	22	2.2	2.2	18	2.3	2.6	15	2.5	2.9	11	2.8	3.3						
55	86	1.8	0.9	55	1.9	1.2	36	2.1	1.7	24	2.2	2.3	20	2.3	2.6	16	2.5	2.9	12	2.7	3.4	10	3.0	3.5			
60	93	1.8	0.9	60	1.9	1.2	40	2.0	1.7	26	2.2	2.3	21	2.3	2.6	17	2.5	2.9	13	2.7	3.4	11	3.0	3.6			
65				65	1.9	1.2	43	2.0	1.7	29	2.2	2.3	23	2.3	2.6	19	2.5	3.0	14	2.7	3.4	12	2.9	3.7			
70				70	1.9	1.2	46	2.0	1.7	31	2.2	2.3	25	2.3	2.6	20	2.5	3.0	15	2.7	3.4	13	2.9	3.8	11	3.1	4.0
75				75	1.9	1.2	49	2.0	1.7	33	2.2	2.3	26	2.3	2.7	22	2.5	3.0	16	2.7	3.5	14	2.9	3.8	12	3.1	4.0
80				80	1.9	1.2	52	2.0	1.7	35	2.2	2.3	28	2.3	2.7	23	2.5	3.0	18	2.7	3.5	15	2.9	3.8	13	3.1	4.2
90				90	1.9	1.2	59	2.0	1.7	39	2.2	2.3	32	2.3	2.7	26	2.5	3.0	20	2.7	3.5	16	2.8	3.9	14	3.0	4.2
100							65	2.0	1.7	44	2.2	2.3	35	2.3	2.7	29	2.4	3.0	22	2.7	3.5	18	2.8	4.0	15	3.0	4.3
110							72	2.0	1.7	48	2.2	2.3	39	2.3	2.7	31	2.4	3.0	24	2.7	3.5	20	2.8	4.0	17	3.0	4.4
120							78	2.0	1.7	52	2.2	2.3	42	2.3	2.7	34	2.4	3.0	26	2.6	3.6	22	2.8	4.0	18	3.0	4.4
130							85	2.0	1.7	57	2.2	2.3	45	2.3	2.7	37	2.4	3.0	28	2.6	3.6	23	2.8	4.0	19	3.0	4.4
140							91	2.0	1.7	61	2.2	2.3	49	2.3	2.7	40	2.4	3.1	30	2.6	3.6	25	2.8	4.0	21	3.0	4.5
150							97	2.0	1.7	65	2.2	2.3	52	2.3	2.7	43	2.4	3.1	32	2.6	3.6	27	2.8	4.0	22	2.9	4.5
160										69	2.2	2.3	56	2.3	2.7	45	2.4	3.1	34	2.6	3.6	29	2.8	4.1	24	2.9	4.5
170										74	2.2	2.3	59	2.3	2.7	48	2.4	3.1	37	2.6	3.6	30	2.8	4.1	25	2.9	4.5
180										78	2.2	2.3	63	2.3	2.7	51	2.4	3.1	39	2.6	3.6	32	2.8	4.1	27	2.9	4.6
190										82	2.2	2.3	66	2.3	2.7	54	2.4	3.1	41	2.6	3.7	34	2.8	4.1	28	2.9	4.6
200										86	2.2	2.3	69	2.3	2.7	56	2.4	3.1	43	2.6	3.7	36	2.8	4.1	30	2.9	4.6
220										95	2.2	2.3	76	2.3	2.7	62	2.4	3.1	47	2.6	3.7	39	2.8	4.1	33	2.9	4.6
240													83	2.3	2.7	68	2.4	3.1	51	2.6	3.7	43	2.8	4.1	35	2.9	4.6
260													90	2.3	2.7	73	2.4	3.1	55	2.6	3.7	46	2.8	4.1	38	2.9	4.6
280													97	2.3	2.7	79	2.4	3.1	60	2.6	3.7	50	2.8	4.1	41	2.9	4.6
300																84	2.4	3.1	64	2.6	3.7	53	2.8	4.1	44	2.9	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05t
Parabolic Diversion Design (Retardance “D” and “B”, Grade 2.0%)

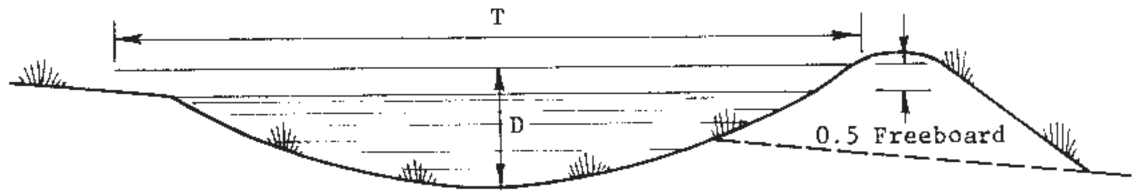
Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	30	1.6	0.8	18	1.8	1.2	13	1.9	1.4	9	2.1	1.8															
20	39	1.6	0.8	24	1.8	1.2	17	1.9	1.5	12	2.0	1.9															
25	49	1.6	0.8	30	1.7	1.2	21	1.9	1.5	15	2.0	2.0	11	2.2	2.4												
30	59	1.6	0.8	35	1.7	1.2	25	1.9	1.5	18	2.0	2.0	13	2.1	2.5	10	2.3	2.8									
35	68	1.6	0.8	41	1.7	1.2	29	1.9	1.5	21	2.0	2.0	15	2.1	2.5	12	2.2	2.9	10	2.4	3.0						
40	78	1.6	0.8	47	1.7	1.2	34	1.9	1.5	23	2.0	2.0	17	2.1	2.5	14	2.2	2.9	11	2.4	3.2						
45	88	1.6	0.8	53	1.7	1.2	38	1.9	1.5	26	2.0	2.0	19	2.1	2.5	15	2.2	2.9	13	2.4	3.2	10	2.6	3.5			
50	97	1.6	0.8	59	1.7	1.2	42	1.9	1.6	29	2.0	2.0	21	2.1	2.6	17	2.2	2.9	14	2.4	3.2	11	2.5	3.6			
55				64	1.7	1.2	46	1.8	1.6	32	2.0	2.0	23	2.1	2.6	19	2.2	2.9	15	2.4	3.3	12	2.5	3.7	10	2.7	4.0
60				70	1.7	1.2	50	1.8	1.6	35	2.0	2.0	25	2.1	2.6	20	2.2	3.0	17	2.4	3.3	13	2.5	3.7	11	2.7	4.0
65				76	1.7	1.2	54	1.8	1.6	38	2.0	2.0	27	2.1	2.6	22	2.2	3.0	18	2.3	3.4	15	2.5	3.7	12	2.7	4.1
70				81	1.7	1.2	58	1.8	1.6	41	2.0	2.1	29	2.1	2.6	24	2.2	3.0	19	2.3	3.4	16	2.5	3.8	13	2.7	4.1
75				87	1.7	1.2	62	1.8	1.6	43	2.0	2.1	31	2.1	2.6	25	2.2	3.0	21	2.3	3.4	17	2.5	3.8	14	2.7	4.1
80				93	1.7	1.2	68	1.8	1.6	46	2.0	2.1	33	2.1	2.6	27	2.2	3.0	22	2.3	3.4	18	2.5	3.8	15	2.6	4.2
90							74	1.8	1.6	52	2.0	2.1	37	2.1	2.6	30	2.2	3.0	25	2.3	3.4	20	2.5	3.8	17	2.6	4.2
100							83	1.8	1.6	58	2.0	2.1	41	2.1	2.6	34	2.2	3.0	27	2.3	3.4	22	2.5	3.9	18	2.6	4.3
110							91	1.8	1.6	63	2.0	2.1	45	2.1	2.6	37	2.2	3.0	30	2.3	3.4	24	2.5	3.9	20	2.6	4.3
120							99	1.8	1.6	69	2.0	2.1	49	2.1	2.6	40	2.2	3.0	33	2.3	3.4	26	2.4	3.9	22	2.6	4.3
130										75	2.0	2.1	53	2.1	2.6	44	2.2	3.0	35	2.3	3.4	29	2.4	3.9	24	2.6	4.3
140										80	2.0	2.1	57	2.1	2.6	47	2.2	3.0	38	2.3	3.5	31	2.4	3.9	26	2.6	4.4
150										86	2.0	2.1	61	2.1	2.7	50	2.2	3.0	41	2.3	3.5	33	2.4	3.9	27	2.6	4.4
160										91	2.0	2.1	65	2.1	2.7	53	2.2	3.0	43	2.3	3.5	35	2.4	3.9	29	2.6	4.4
170										97	2.0	2.1	69	2.1	2.7	57	2.2	3.1	46	2.3	3.5	37	2.4	4.0	31	2.6	4.4
180													73	2.1	2.7	60	2.2	3.1	49	2.3	3.5	39	2.4	4.0	33	2.6	4.4
190													77	2.1	2.7	63	2.2	3.1	51	2.3	3.5	41	2.4	4.0	34	2.6	4.5
200													81	2.1	2.7	66	2.2	3.1	54	2.3	3.5	44	2.4	4.0	36	2.6	4.5
220													89	2.1	2.7	73	2.2	3.1	59	2.3	3.5	48	2.4	4.0	40	2.6	4.5
240													97	2.1	2.7	79	2.2	3.1	65	2.3	3.5	52	2.4	4.0	43	2.6	4.5
260																86	2.2	3.1	70	2.3	3.5	56	2.4	4.0	47	2.6	4.5
280																92	2.2	3.1	75	2.3	3.5	61	2.4	4.0	50	2.6	4.5
300																99	2.2	3.1	81	2.3	3.5	65	2.4	4.0	54	2.6	4.5

T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05u
Parabolic Diversion Design (Retardance "D" and "B", Grade 0.25%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	11	2.9	1.6																								
30	13	2.8	1.7																								
35	15	2.8	1.7																								
40	17	2.8	1.8	11	3.2	2.1																					
45	19	2.7	1.8	13	3.1	2.2																					
50	21	2.7	1.8	14	3.1	2.2																					
55	23	2.7	1.8	15	3.1	2.3																					
60	25	2.7	1.8	17	3.0	2.3																					
65	27	2.7	1.8	18	3.0	2.3																					
70	29	2.7	1.9	19	3.0	2.3	14	3.6	2.7																		
75	31	2.7	1.9	21	3.0	2.3	15	3.5	2.8																		
80	33	2.7	1.9	22	3.0	2.4	16	3.5	2.8																		
90	37	2.7	1.9	25	3.0	2.4	17	3.5	2.8																		
100	41	2.7	1.9	28	3.0	2.4	19	3.5	2.9																		
110	45	2.7	1.9	30	3.0	2.4	21	3.4	2.9																		
120	49	2.7	1.9	33	3.0	2.4	23	3.4	2.9	16	4.1	3.3															
130	53	2.7	1.9	36	3.0	2.4	25	3.4	2.9	18	4.1	3.3															
140	57	2.7	1.9	38	3.0	2.4	27	3.4	2.9	19	4.0	3.4															
150	61	2.7	1.9	41	3.0	2.4	29	3.4	2.9	20	4.0	3.4															
160	65	2.7	1.9	44	3.0	2.4	30	3.4	3.0	21	4.0	3.4															
170	69	2.7	1.9	46	3.0	2.4	32	3.4	3.0	23	4.0	3.4	18	4.5	3.8												
180	73	2.7	1.9	49	3.0	2.4	34	3.4	3.0	24	4.0	3.5	19	4.5	3.8												
190	77	2.7	1.9	52	3.0	2.4	36	3.4	3.0	25	4.0	3.5	20	4.5	3.9												
200	81	2.7	1.9	55	3.0	2.4	38	3.4	3.0	27	3.9	3.5	21	4.4	3.9												
220	89	2.7	1.9	60	3.0	2.4	42	3.4	3.0	29	3.9	3.5	23	4.4	3.9												
240	97	2.7	1.9	65	3.0	2.5	45	3.4	3.0	32	3.9	3.6	25	4.4	4.0												
260				71	3.0	2.5	49	3.4	3.0	34	3.9	3.6	27	4.4	4.0	21	5.1	4.3									
280				76	3.0	2.5	53	3.4	3.0	37	3.9	3.6	29	4.4	4.0	22	5.1	4.3									
300				82	3.0	2.5	57	3.4	3.0	40	3.9	3.6	31	4.3	4.1	24	5.0	4.4									



T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05v
Parabolic Diversion Design (Retardance "D" and "C", Grade 0.5%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10	2.1	1.6																								
20	13	2.1	1.7																								
25	16	2.1	1.7	10	2.4	2.1																					
30	20	2.1	1.7	12	2.4	2.2	9	2.7	2.5																		
35	23	2.1	1.7	14	2.4	2.3	11	2.6	2.6																		
40	26	2.1	1.7	16	2.3	2.3	12	2.6	2.7																		
45	29	2.0	1.7	18	2.3	2.3	13	2.5	2.8																		
50	32	2.0	1.7	20	2.3	2.4	15	2.5	2.8	11	2.9	3.2															
55	35	2.0	1.7	22	2.3	2.4	16	2.5	2.8	12	2.9	3.3															
60	39	2.0	1.7	24	2.3	2.4	18	2.5	2.8	13	2.9	3.3															
65	42	2.0	1.8	26	2.3	2.4	19	2.5	2.9	14	2.9	3.3															
70	45	2.0	1.8	28	2.3	2.4	21	2.5	2.9	15	2.8	3.4															
75	48	2.0	1.8	30	2.3	2.4	22	2.5	2.9	16	2.8	3.4	12	3.2	3.7												
80	51	2.0	1.8	32	2.3	2.4	23	2.5	2.9	17	2.8	3.4	13	3.2	3.8												
90	57	2.0	1.8	35	2.3	2.4	26	2.5	2.9	19	2.8	3.4	15	3.2	3.8												
100	64	2.0	1.8	39	2.3	2.4	29	2.5	2.9	21	2.8	3.5	16	3.1	3.9	13	3.5	4.1									
110	70	2.0	1.8	43	2.3	2.4	32	2.5	2.9	23	2.8	3.5	18	3.1	3.9	14	3.5	4.2									
120	76	2.0	1.8	47	2.3	2.4	35	2.5	2.9	25	2.8	3.5	19	3.1	3.9	15	3.4	4.3									
130	83	2.0	1.8	51	2.3	2.4	38	2.5	2.9	27	2.8	3.5	21	3.1	4.0	17	3.4	4.4									
140	89	2.0	1.8	55	2.3	2.4	41	2.5	2.9	29	2.8	3.5	22	3.1	4.0	18	3.4	4.3									
150	95	2.0	1.8	59	2.3	2.4	44	2.5	2.9	31	2.8	3.5	24	3.1	4.0	19	3.4	4.4	15	3.8	4.8						
160				62	2.3	2.4	46	2.5	2.9	33	2.8	3.5	25	3.1	4.0	20	3.4	4.4	16	3.8	4.8						
170				66	2.3	2.4	49	2.5	2.9	35	2.8	3.6	27	3.1	4.0	22	3.4	4.4	17	3.8	4.9						
180				70	2.3	2.4	52	2.5	2.9	37	2.8	3.6	29	3.1	4.0	23	3.4	4.5	18	3.8	4.9						
190				74	2.3	2.4	55	2.5	2.9	39	2.8	3.6	30	3.1	4.0	24	3.4	4.5	19	3.8	5.0						
200				78	2.3	2.4	58	2.5	2.9	41	2.8	3.6	32	3.1	4.0	25	3.4	4.5	20	3.8	5.0	16	4.2	5.2			
220				86	2.3	2.4	64	2.5	2.9	45	2.8	3.6	35	3.1	4.0	28	3.4	4.5	22	3.7	5.0	18	4.2	5.3			
240				93	2.3	2.4	69	2.5	2.9	49	2.8	3.6	38	3.0	4.1	30	3.4	4.5	24	3.7	5.0	20	4.2	5.4			
260							75	2.5	2.9	53	2.8	3.6	41	3.0	4.1	33	3.4	4.5	26	3.7	5.0	21	4.1	5.4			
280							81	2.5	3.0	57	2.8	3.6	44	3.0	4.1	35	3.3	4.6	28	3.7	5.0	23	4.1	5.5	19	4.6	5.8
300							87	2.5	3.0	61	2.8	3.6	47	3.0	4.1	38	3.3	4.6	30	3.6	5.0	24	4.1	5.5	20	4.6	5.8

T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05w
Parabolic Diversion Design (Retardance “D” and “C”, Grade 1.0%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	16	1.6	1.5	10	1.8	2.0																					
20	22	1.6	1.5	13	1.8	2.1																					
25	27	1.6	1.5	17	1.8	2.1	11	2.0	2.6																		
30	32	1.6	1.5	20	1.8	2.1	13	2.0	2.7	11	2.1	3.0															
35	37	1.6	1.5	23	1.8	2.2	15	2.0	2.8	12	2.1	3.1															
40	43	1.6	1.5	26	1.8	2.2	17	1.9	2.8	14	2.1	3.1	10	2.3	3.7												
45	48	1.6	1.5	29	1.8	2.2	19	1.9	2.8	16	2.1	3.2	12	2.3	3.7												
50	53	1.6	1.5	33	1.8	2.2	22	1.9	2.8	17	2.1	3.2	13	2.3	3.7	10	2.5	4.2									
55	58	1.6	1.5	36	1.8	2.2	24	1.9	2.8	19	2.0	3.3	14	2.3	3.8	11	2.5	4.3									
60	64	1.6	1.5	39	1.8	2.2	26	1.9	2.8	21	2.0	3.3	15	2.2	3.8	12	2.5	4.3									
65	69	1.6	1.5	42	1.8	2.2	28	1.9	2.8	22	2.0	3.3	17	2.2	3.8	13	2.5	4.3	10	2.7	4.7						
70	74	1.6	1.5	45	1.8	2.2	30	1.9	2.8	24	2.0	3.3	18	2.2	3.9	14	2.5	4.4	11	2.7	4.7						
75	79	1.6	1.5	49	1.8	2.2	32	1.9	2.9	26	2.0	3.3	19	2.2	3.9	15	2.5	4.5	12	2.7	4.7						
80	84	1.6	1.5	52	1.8	2.2	34	1.9	2.9	27	2.0	3.3	20	2.2	3.9	16	2.5	4.5	13	2.7	4.9						
90	95	1.6	1.5	58	1.8	2.2	38	1.9	2.9	31	2.0	3.3	23	2.2	3.9	17	2.4	4.5	14	2.7	4.9	12	2.9	5.2			
100				65	1.8	2.2	43	1.9	2.9	34	2.0	3.3	25	2.2	3.9	19	2.4	4.5	16	2.7	4.9	13	2.9	5.3			
110				71	1.8	2.2	47	1.9	2.9	37	2.0	3.3	28	2.2	3.9	21	2.4	4.5	17	2.6	5.0	14	2.9	5.3	12	3.1	5.7
120				77	1.8	2.2	51	1.9	2.9	41	2.0	3.3	30	2.2	4.0	23	2.4	4.5	19	2.6	5.0	16	2.9	5.4	13	3.1	5.7
130				84	1.8	2.2	55	1.9	2.9	44	2.0	3.3	33	2.2	4.0	25	2.4	4.5	20	2.6	5.0	17	2.9	5.4	14	3.1	5.8
140				90	1.8	2.2	59	1.9	2.9	47	2.0	3.3	35	2.2	4.0	27	2.4	4.5	22	2.6	5.0	18	2.8	5.5	15	3.1	5.8
150				96	1.8	2.2	64	1.9	2.9	51	2.0	3.3	38	2.2	4.0	29	2.4	4.5	23	2.6	5.0	19	2.8	5.5	17	3.1	5.8
160							68	1.9	2.9	54	2.0	3.3	40	2.2	4.0	30	2.4	4.5	25	2.6	5.0	20	2.8	5.5	18	3.0	6.0
170							72	1.9	2.9	57	2.0	3.3	43	2.2	4.0	32	2.4	4.5	26	2.5	5.0	22	2.8	5.5	19	3.0	6.0
180							76	1.9	2.9	61	2.0	3.4	45	2.2	4.0	34	2.4	4.5	28	2.6	5.0	23	2.8	5.5	20	3.0	6.0
190							80	1.9	2.9	64	2.0	3.4	48	2.2	4.0	36	2.4	4.5	29	2.6	5.0	24	2.8	5.5	21	3.0	6.0
200							84	1.9	2.9	67	2.0	3.4	50	2.2	4.0	38	2.4	4.5	31	2.6	5.0	25	2.8	5.5	22	3.0	6.0
220							93	1.9	2.9	74	2.0	3.4	55	2.2	4.0	42	2.4	4.5	34	2.6	5.0	28	2.8	5.5	24	3.0	6.0
240										81	2.0	3.4	60	2.2	4.0	45	2.4	4.5	37	2.6	5.0	30	2.8	5.5	26	3.0	6.0
260										87	2.0	3.4	65	2.2	4.0	49	2.4	4.5	40	2.6	5.0	33	2.8	5.5	28	3.0	6.0
280										94	2.0	3.4	70	2.2	4.0	53	2.4	4.5	43	2.6	5.0	36	2.8	5.5	30	3.0	6.0
300													75	2.2	4.0	57	2.4	4.5	46	2.5	5.0	38	2.8	5.5	32	3.0	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05x
Parabolic Diversion Design (Retardance “D” and “C”, Grade 1.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	21	1.4	1.4	14	1.6	1.9																					
20	28	1.4	1.4	18	1.5	1.9	12	1.7	2.5																		
25	35	1.4	1.4	23	1.5	1.9	15	1.7	2.6	10	1.9	3.2															
30	42	1.4	1.4	27	1.5	1.9	18	1.7	2.6	12	1.8	3.2	10	2.0	3.6												
35	49	1.4	1.4	32	1.5	2.0	21	1.6	2.6	14	1.8	3.3	11	1.9	3.7	10	2.1	4.1									
40	56	1.4	1.4	36	1.5	2.0	24	1.6	2.6	16	1.8	3.3	13	1.9	3.7	11	2.1	4.2									
45	63	1.4	1.4	41	1.5	2.0	27	1.6	2.6	18	1.8	3.4	15	1.9	3.8	12	2.0	4.3									
50	70	1.4	1.4	45	1.5	2.0	30	1.6	2.7	20	1.8	3.4	16	1.9	3.9	13	2.0	4.3	10	2.3	4.8						
55	76	1.4	1.5	50	1.5	2.0	33	1.6	2.7	22	1.8	3.4	18	1.9	3.9	14	2.0	4.3	11	2.3	4.9						
60	83	1.4	1.5	54	1.5	2.0	35	1.6	2.7	24	1.8	3.4	19	1.9	3.9	16	2.0	4.4	12	2.3	4.9	10	2.4	5.2			
65	90	1.4	1.5	58	1.5	2.0	38	1.6	2.7	26	1.8	3.4	21	1.9	3.9	17	2.0	4.4	13	2.2	5.0	11	2.4	5.3			
70	97	1.4	1.5	63	1.5	2.0	41	1.6	2.7	28	1.8	3.4	22	1.9	3.9	18	2.0	4.4	14	2.2	5.0	12	2.4	5.4	10	2.6	5.6
75				67	1.5	2.0	44	1.6	2.7	30	1.8	3.4	24	1.9	3.9	19	2.0	4.4	15	2.2	5.0	12	2.4	5.4	11	2.6	5.6
80				72	1.5	2.0	47	1.6	2.7	32	1.8	3.4	26	1.9	3.9	21	2.0	4.4	16	2.2	5.0	13	2.4	5.4	12	2.5	5.8
90				80	1.5	2.0	53	1.6	2.7	36	1.8	3.5	29	1.9	3.9	23	2.0	4.4	18	2.2	5.0	15	2.4	5.4	13	2.5	5.9
100				89	1.5	2.0	59	1.6	2.7	39	1.8	3.5	32	1.9	3.9	26	2.0	4.5	20	2.2	5.0	17	2.4	5.4	14	2.5	6.0
110				98	1.5	2.0	64	1.6	2.7	43	1.8	3.5	35	1.9	3.9	28	2.0	4.5	22	2.2	5.0	18	2.3	5.5	15	2.5	6.0
120							70	1.6	2.7	47	1.8	3.5	38	1.9	4.0	31	2.0	4.5	24	2.2	5.0	20	2.3	5.5	17	2.5	6.0
130							76	1.6	2.7	51	1.8	3.5	41	1.9	4.0	33	2.0	4.5	26	2.2	5.0	21	2.3	5.5	18	2.5	6.0
140							82	1.6	2.7	55	1.8	3.5	44	1.9	4.0	36	2.0	4.5	27	2.2	5.0	23	2.3	5.5	19	2.5	6.0
150							87	1.6	2.7	59	1.8	3.5	47	1.9	4.0	39	2.0	4.5	29	2.2	5.0	25	2.3	5.5	21	2.5	6.0
160							93	1.6	2.7	63	1.8	3.5	51	1.9	4.0	41	2.0	4.5	31	2.2	5.0	26	2.3	5.5	22	2.5	6.0
170							99	1.6	2.7	67	1.8	3.5	54	1.9	4.0	44	2.0	4.5	33	2.2	5.0	28	2.3	5.5	23	2.5	6.0
180										70	1.8	3.5	57	1.9	4.0	46	2.0	4.5	35	2.2	5.0	29	2.3	5.5	25	2.5	6.0
190										74	1.8	3.5	60	1.9	4.0	49	2.0	4.5	37	2.2	5.0	31	2.3	5.5	26	2.5	6.0
200										78	1.8	3.5	63	1.9	4.0	51	2.0	4.5	39	2.2	5.0	33	2.3	5.5	27	2.5	6.0
220										86	1.8	3.5	69	1.9	4.0	56	2.0	4.5	43	2.2	5.0	36	2.3	5.5	30	2.5	6.0
240										93	1.8	3.5	75	1.9	4.0	61	2.0	4.5	47	2.2	5.0	39	2.3	5.5	33	2.5	6.0
260													82	1.9	4.0	66	2.0	4.5	51	2.2	5.0	42	2.3	5.5	35	2.5	6.0
280													88	1.9	4.0	71	2.0	4.5	54	2.2	5.0	46	2.3	5.5	38	2.5	6.0
300													94	1.9	4.0	76	2.0	4.5	58	2.2	5.0	49	2.3	5.5	41	2.5	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05y
Parabolic Diversion Design (Retardance “D” and “C”, Grade 2.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	27	1.3	1.3	16	1.4	1.9	11	1.5	2.4																		
20	35	1.3	1.3	21	1.4	1.9	15	1.5	2.4	11	1.6	3.0															
25	44	1.3	1.3	27	1.4	1.9	19	1.5	2.4	13	1.6	3.0	10	1.8	3.7												
30	53	1.3	1.3	32	1.4	1.9	23	1.5	2.5	16	1.6	3.0	11	1.7	3.7	10	1.8	4.2									
35	61	1.3	1.3	37	1.4	1.9	26	1.5	2.5	19	1.6	3.1	13	1.7	3.8	11	1.8	4.2									
40	70	1.3	1.3	42	1.4	1.9	30	1.5	2.5	21	1.6	3.1	15	1.7	3.8	12	1.8	4.3	10	2.0	4.7						
45	78	1.3	1.4	48	1.4	1.9	34	1.5	2.5	24	1.6	3.1	17	1.7	3.8	14	1.8	4.3	11	1.9	4.8						
50	87	1.3	1.4	53	1.4	1.9	38	1.5	2.5	26	1.6	3.1	19	1.7	3.8	15	1.8	4.3	13	1.9	4.8	10	2.1	5.3			
55	95	1.3	1.4	58	1.4	1.9	41	1.5	2.5	29	1.6	3.1	21	1.7	3.8	17	1.8	4.3	14	1.9	4.9	11	2.1	5.3			
60				63	1.4	1.9	45	1.5	2.5	32	1.6	3.1	23	1.7	3.9	18	1.8	4.4	15	1.9	4.9	12	2.1	5.3	10	2.2	5.7
65				68	1.4	1.9	49	1.5	2.5	34	1.6	3.1	24	1.7	3.9	20	1.8	4.4	16	1.9	4.9	13	2.1	5.4	11	2.2	5.7
70				73	1.4	1.9	52	1.5	2.5	37	1.6	3.1	26	1.7	3.9	22	1.8	4.4	18	1.9	4.9	14	2.1	5.4	12	2.2	5.8
75				78	1.4	1.9	56	1.5	2.5	39	1.6	3.1	28	1.7	3.9	23	1.8	4.4	19	1.9	4.9	15	2.1	5.4	13	2.2	5.9
80				83	1.4	2.0	60	1.5	2.5	42	1.6	3.1	30	1.7	3.9	24	1.8	4.4	20	1.9	4.9	16	2.1	5.4	14	2.2	5.9
90				94	1.4	2.0	67	1.5	2.5	47	1.6	3.2	34	1.7	3.9	28	1.8	4.4	22	1.9	4.9	18	2.1	5.5	15	2.2	5.9
100							74	1.5	2.5	52	1.6	3.2	37	1.7	3.9	31	1.8	4.4	25	1.9	5.0	20	2.1	5.5	17	2.2	6.0
110							81	1.5	2.5	57	1.6	3.2	41	1.7	3.9	34	1.8	4.4	27	1.9	5.0	22	2.0	5.5	19	2.2	6.0
120							89	1.5	2.5	62	1.6	3.2	45	1.7	3.9	37	1.8	4.4	30	1.9	5.0	24	2.0	5.5	20	2.2	6.0
130							96	1.5	2.5	67	1.6	3.2	48	1.7	3.9	40	1.8	4.5	32	1.9	5.0	26	2.0	5.5	22	2.2	6.0
140										73	1.6	3.2	52	1.7	4.0	42	1.8	4.5	35	1.9	5.0	28	2.0	5.5	23	2.2	6.0
150										78	1.6	3.2	56	1.7	4.0	46	1.8	4.5	37	1.9	5.0	30	2.0	5.5	25	2.2	6.0
160										83	1.6	3.2	59	1.7	4.0	48	1.8	4.5	39	1.9	5.0	32	2.0	5.5	27	2.2	6.0
170										88	1.6	3.2	63	1.7	4.0	51	1.8	4.5	42	1.9	5.0	34	2.0	5.5	28	2.2	6.0
180										93	1.6	3.2	67	1.7	4.0	54	1.8	4.5	44	1.9	5.0	36	2.0	5.5	30	2.2	6.0
190										98	1.6	3.2	70	1.7	4.0	57	1.8	4.5	47	1.9	5.0	38	2.0	5.5	32	2.2	6.0
200													74	1.7	4.0	60	1.8	4.5	49	1.9	5.0	40	2.0	5.5	33	2.2	6.0
220													81	1.7	4.0	66	1.8	4.5	54	1.9	5.0	44	2.0	5.5	37	2.2	6.0
240													88	1.7	4.0	72	1.8	4.5	59	1.9	5.0	48	2.0	5.5	40	2.2	6.0
260													96	1.7	4.0	78	1.8	4.5	64	1.9	5.0	51	2.0	5.5	43	2.2	6.0
280																84	1.8	4.5	69	1.9	5.0	55	2.0	5.5	46	2.2	6.0
300																90	1.8	4.5	73	1.9	5.0	59	2.0	5.5	50	2.2	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

8.06 DESIGN OF RIPRAP OUTLET PROTECTION

Riprap (large stones of various sizes) is often used to prevent erosion at the ends of culverts and other pipe conduits. It converts high-velocity, concentrated pipe flow into low-velocity, open channel flow. Stone should be sized and the apron shaped to protect receiving channels from erosion caused by maximum pipe exit velocities. Riprap outlet structures should meet all requirements in *Practice Standards and Specifications: 6.41, Outlet Stabilization Structure*.

Several methods are available for designing riprap outlet structures. The method presented in this section is adapted from procedures used by the USDA Soil Conservation Service. Outlet protection is provided by a level apron of sufficient length and flare to reduce flow velocities to nonerosive levels.

Design Procedure for Riprap Outlet Protection

The following procedure uses two sets of design curves: Figure 8.06a is used for minimum tailwater conditions, and Figure 8.06b for maximum tailwater conditions.

Step 1. Determine the tailwater depth from channel characteristics below the pipe outlet for the design capacity of the pipe. If the tailwater depth is less than half the outlet pipe diameter, it is classified minimum tailwater condition. If it is greater than half the pipe diameter, it is classified maximum condition. Pipes that outlet onto wide flat areas with no defined channel are assumed to have a minimum tailwater condition unless reliable flood stage elevations show otherwise.

Step 2. Based on the tailwater conditions determined in step 1, enter Figure 8.06a or Figure 8.06b, and determine d_{50} riprap size and minimum apron length (L_a). The d_{50} size is the median stone size in a well-graded riprap apron.

Step 3. Determine apron width at the pipe outlet, the apron shape, and the apron width at the outlet end from the same figure used in Step 2.

Step 4. Determine the maximum stone diameter:

$$d_{max} = 1.5 \times d_{50}$$

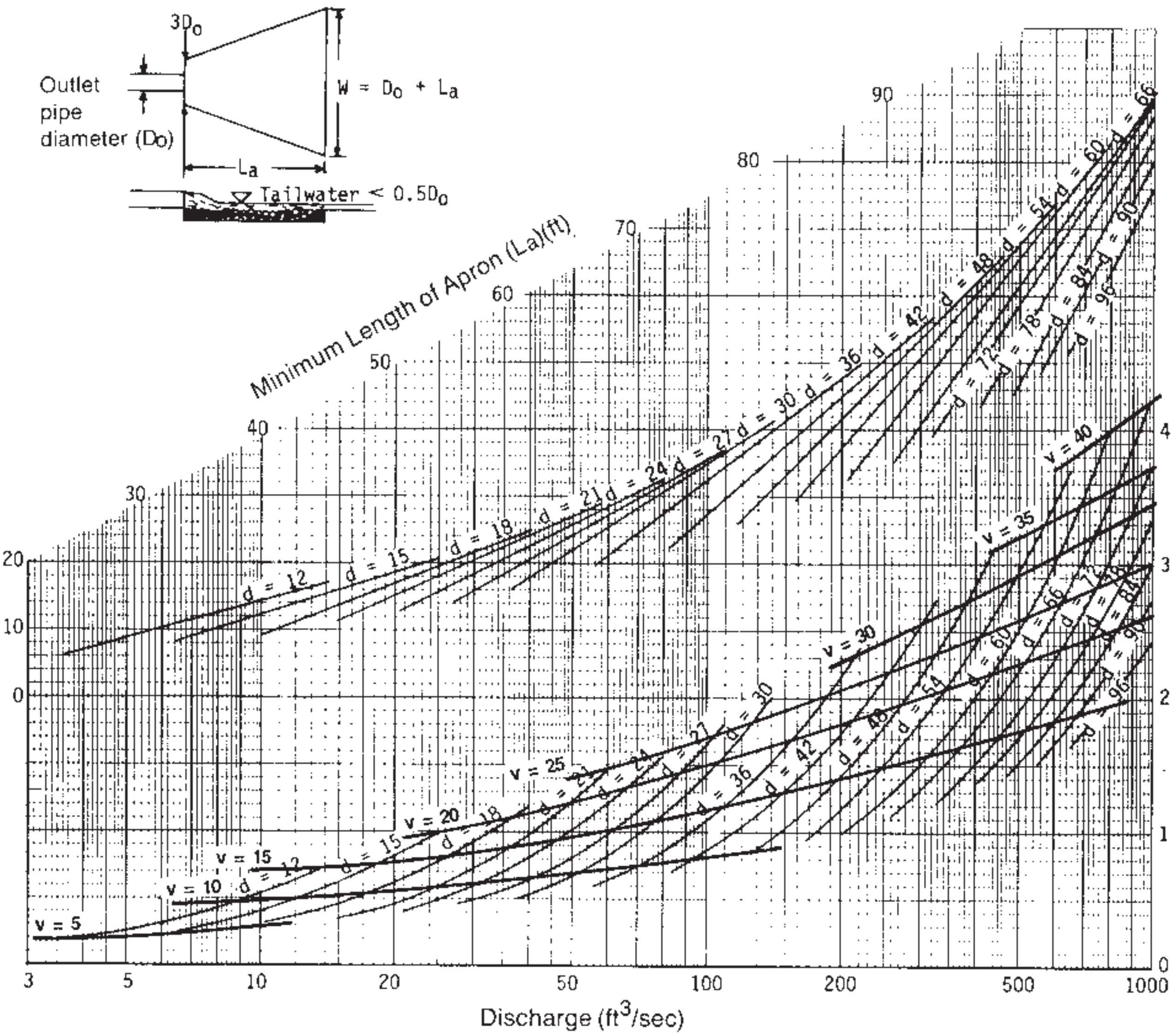
Step 5. Determine the apron thickness:

$$\text{Apron thickness} = 1.5 \times d_{max}$$

Step 6. Fit the riprap apron to the site by making it level for the minimum length, L_a, from Figure 8.06a or Figure 8.06b. Extend the apron farther downstream and along channel banks until stability is assured. Keep the apron as straight as possible and align it with the flow of the receiving stream. Make any necessary alignment bends near the pipe outlet so that the entrance into the receiving stream is straight.

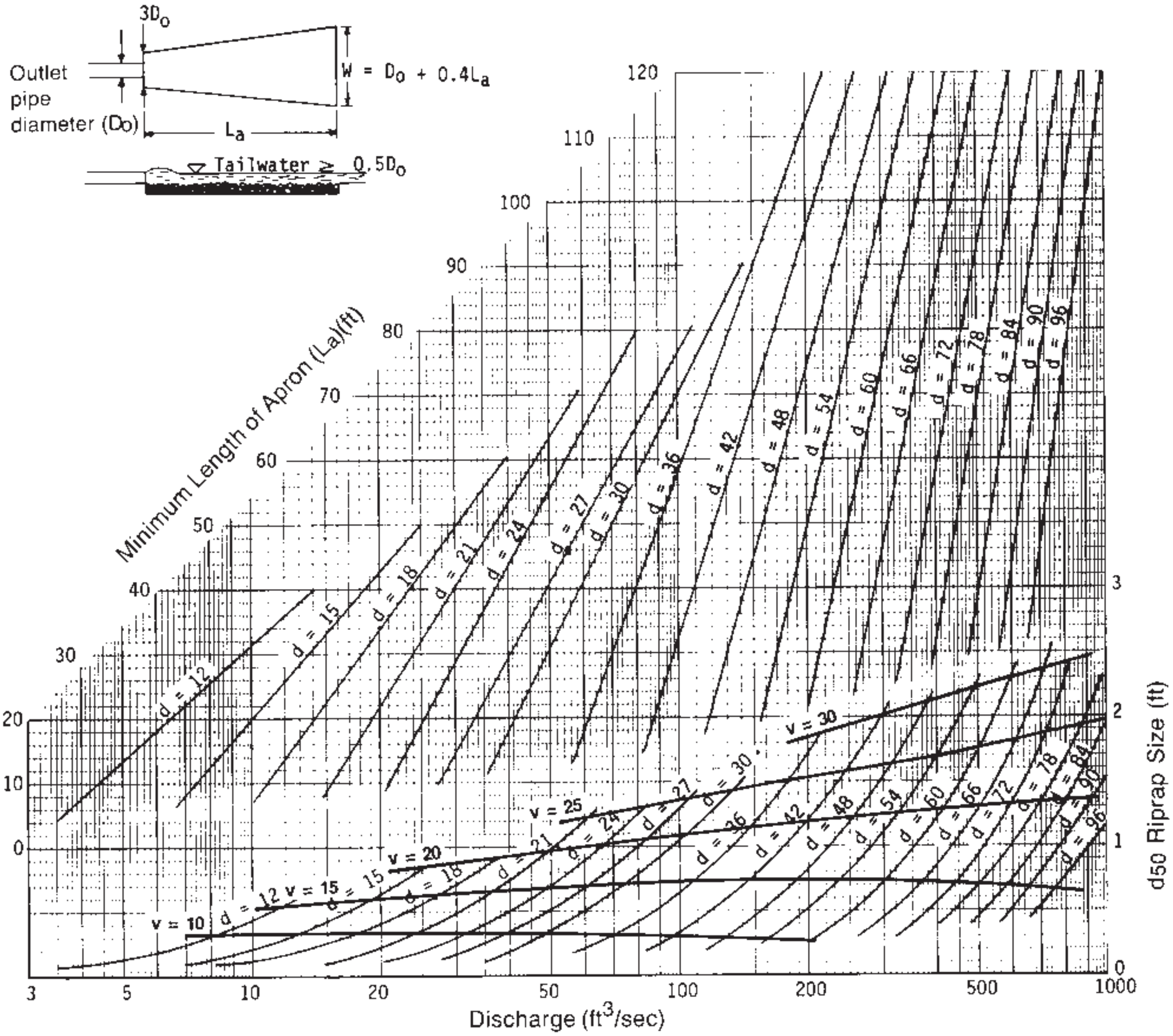
Some locations may require lining of the entire channel cross section to assure stability.

It may be necessary to increase the size of riprap where protection of the channel side slopes is necessary (*Appendix 8.05*). Where overfalls exist at pipe outlets or flows are excessive, a plunge pool should be considered, see page 8.06.8.



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).



Curves may not be extrapolated.

Figure 8.06b Design of outlet protection from a round pipe flowing full, maximum tailwater condition ($T_w \geq 0.5$ diameter).

NEW YORK DOT DISSIPATOR METHOD FOR USE IN DEFINED CHANNELS

(Source: "Bank and channel lining procedures", New York Department of Transportation, Division of Design and Construction, 1971.)

NOTE: To use the following chart you must know:

(1) Q full capacity
(2) Q_{10}
(3) V full
(4) V_{10}

where Q = discharge in cfs and V = Velocity in FPS.

ESTIMATION OF STONE SIZE AND DIMENSIONS FOR CULVERT APRONS

Step 1) Compute flow velocity V_o at culvert or paved channel outlet.

Step 2) For pipe culverts D_o is diameter.
For pipe arch, arch and box culverts, and paved channel outlets, $D_o = A_o$ where A. = cross-sectional area of flow at outlet.

For multiple culverts, use D_o = 1.25 x D_o of single culvert.

Step 3) For apron grades of 10% or steeper, use recommendations For next higher zone. (Zones 1 through 6).

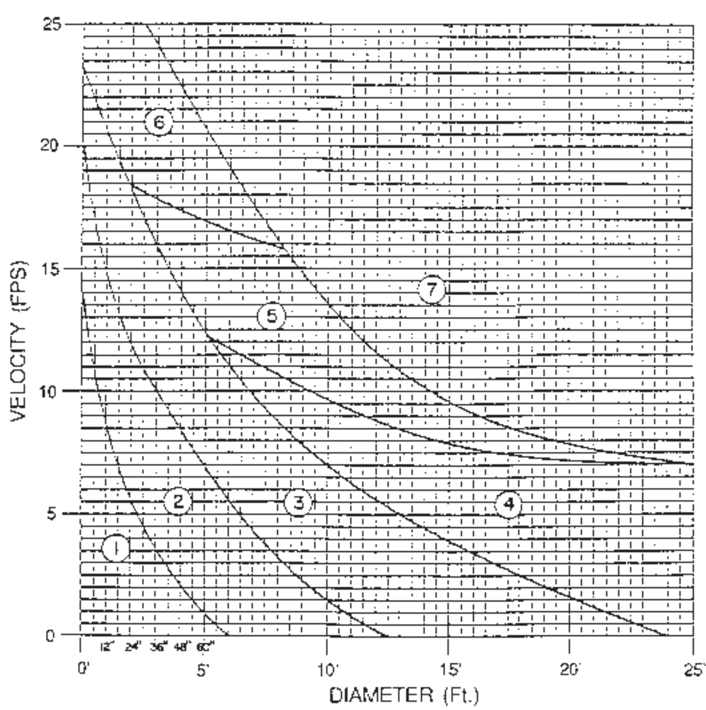


Figure 8.06c

ZONE	APRON MATERIAL		LENGTH OF APRON	
			TO PROTECT CULVERT L1	TO PREVENT SCOUR HOLE USE L2 ALWAYS L2
1	STONE FILLING (FINE)	CL. A	$3 \times D_0$	$4 \times D_o$
2	STONE FILLING (LIGHT)	CL. B	$3 \times D_0$	$6 \times D_o$
3	STONE FILLING (MEDIUM)	CL. 1	$4 \times D_0$	$8 \times D_o$
4	STONE FILLING (HEAVY)	CL. 1	$4 \times D_0$	$8 \times D_o$
5	STONE FILLING (HEAVY)	CL. 2	$5 \times D_0$	$10 \times D_o$
6	STONE FILLING (HEAVY)	CL. 2	$6 \times D_0$	$10 \times D_o$
7	SPECIAL STUDY REQUIRED (ENERGY DISSIPATORS, STILLING BASIN OR LARGER SIZE STONE).			

Figure 8.06d

Width = 3 times pipe dia. (min.)

DETERMINATION OF STONE SIZES FOR DUMPED STONE CHANNEL LININGS AND REVETMENTS

Step 1. Use figure 8.06.b.3 to determine maximum stone size (e.g. for 12 Fps = 20” or 550 lbs.

Step 2. Use figure 8.06.b.4 to determine acceptable size range for stone (for 12 FPS it is 125-500 lbs. for 75% of stone, and the maximum and minimum range in weight should be 25-500 lbs.).

NOTE: In determining channel velocities for stone linings and revetment, use the following coefficients of roughness:

	Diameter (inches)	Manning’s “n”	Min. thickness of lining	(inches)
Fine	3	0.031	9	12
Light	6	0.035	12	18
Medium	13	0.040	18	24
Heavy	23	0.044	30	36
			(Channels)	(Dissapators)

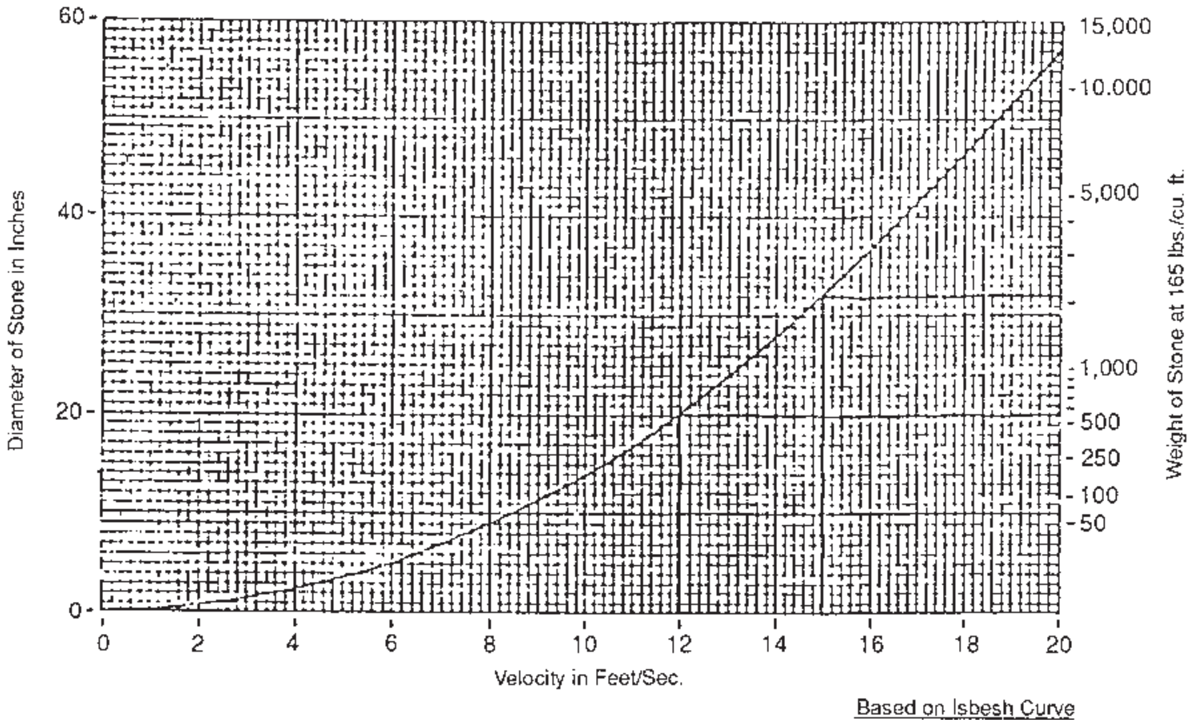


Figure 8.06e Maximum Stone Size for Riprap

Maximum weight of stone required	Minimum and maximum range in weight of stones	Weight range of 75% of stones
(lbs.)	(lbs.)	(lbs.)
150	25 - 150	50 - 150
200	25 - 200	50 - 200
250	25 - 250	50 - 250
400	25 - 400	100 - 400
600	25 - 600	150 - 600
800	25 - 800	200 - 800
1,000	50 - 1000	250 - 1000
1,300	50 - 1,300	325 - 1,300
1,600	50 - 1,600	400 - 1,600
2,000	75 - 2,000	600 - 2,000
2,700	100 - 2,700	800 - 2,700

Figure 8.06f Gradation of Riprap

Source: "Bank and channel lining procedures, " New York Department of Transportation, Division of Design and Construction, 1971.

PLUNGE POOL OUTLET DESIGN

Existing methods for sizing a plunge pool below a pipe outlet have been developed by the Federal Highway Administration (FHWA) and the United States Department of Agriculture (USDA). The FHWA published HEC 14, Hydraulic Design of Dissipaters for culverts and channels in 1983. It can be downloaded from the FHWA Hydraulic Engineering web site. Many of the design procedures in HEC 14 may also be performed using HY8 Energy, a design software that may also be downloaded for free from the FHWA. HY8 Energy will also calculate the anticipated dimensions of a scour hole below an unprotected pipe.

The USDA has developed design criteria for plunge pool outlet protection based on the relative position of the pipe outlet to the downstream tailwater elevation. USDA Design Note 6 is for cantilevered pipe, when the outlet is above the tailwater surface. This situation is most common at the barrel pipe outlet of ponds or sediment basins. Culverts in streams should not be cantilevered, as this poses a barrier to the movement of aquatic life. In fact, culverts in streams are now frequently embedded below grade. Plunge pools in this situation must be designed for the submerged outlet condition. A design methodology developed by the USDA is also presented below.

USDA Design Note 6

Note: An Excel spreadsheet is available for Design Note 6.

The energy in flow exiting from a spillway usually requires dissipation before being released to the outlet channel. For flow exiting from a conduit, when an open plunge pool is acceptable, an excavated riprap lined hole at the downstream end of the conduit can be an economical energy dissipater. However, the size of plunge pool, location relative to the conduit outlet, and size of riprap must be properly designed for the plunge pool to operate successfully.

The plunge pool dimensions were developed using a discharge parameter. The parameter is based on the design discharge, Q, pipe diameter, D, and combined with the acceleration of gravity, g, resulting in a dimensionless parameter of

$$\frac{Q}{\sqrt{gD^5}}$$

The depth of erosion created by the discharging jet can be controlled by the bed material size. The bed material is represented by its mean grain size, d_{50}, the size of which 50 percent by weight is finer in diameter. The d_{50} bed material size must be checked to assure that it is adequate to control shallow beach type erosion at the top of the plunge pool. The d_{50} size is adequate and beach erosion will not occur if:

$$\frac{Q}{\sqrt{gD^5}} < [\, 1.0 + 25 \frac{d_{50}}{D} \,]$$

If the bed material is not large enough, protection will need to be added. In case of riprap, a larger particle gradation will be required.

Nomenclature

a_1 = Thickness of riprap, ft

a_2 = Thickness of riprap and filter material, ft

A_1 = Plan rectangular area of the plunge pool at the invert elevation of the outlet channel, ft^2

A_2 = Plan rectangular area at the bottom of the plunge pool at a distance Z below the invert elevation of the outlet channel, ft^2.

d_{50} = Size of rock in riprap of which 50 percent by weight is finer, ft

D = Cantilever outlet pipe diameter, ft

e = Base of natural logarithms

F_d = Densimetric Froude number

g = Acceleration of gravity, ft/sec^2

L_e = Minimum horizontal distance from the center of the pool to the water surface contour at the upstream or downstream end of an elliptical-shape plunge pool, ft

L_r = Adjusted horizontal distance from the center of the pool to the water surface contour at the upstream or downstream end of the rectangular-shape plunge pool, ft

L_{r2} = One-half the length of the bottom of a rectangular-shape plunge pool, ft

Q = Design discharge, cfs

S = Sine of the angle whose tangent is the slope of the pipe

V_{ao} = Volume of the plunge pool between the invert elevation of the outlet channel and the exposed riprap surface, cu. yds.

V_{a1} = Volume of the plunge pool between the invert elevation of the outlet channel and a surface at a thickness, a_1, below the exposed riprap surface, cu. yds.

V_{a2} = Volume of the plunge pool between the invert elevation of the outlet channel and a surface at a thickness, a_2, below the exposed riprap surface, cu. yds.

V_h = Horizontal component of the jet impingement velocity, V_P, ft/sec

V_o = Velocity in the pipe corresponding to the design discharge, Q, ft/sec

V_p = Velocity where the jet plunges into the water surface, ft/sec

V_v = Vertical component of the jet impingement velocity, V_P, ft/sec

W_e = One-half the minimum width at the center of the elliptical-shape plunge pool at the water surface elevation, ft

W_r = One-half the adjusted width at the center of the rectangular-shape plunge pool at the water surface elevation, ft

W_{r2} = One-half the width of the bottom of a rectangular plunge pool, ft

X_m = Horizontal distance from the pipe exit to the center of the plunge pool, ft

X_p = Horizontal distance from the pipe exit to the center of the jet plunging into the water surface, ft

z_ℓ = Side slope ratio of the upstream or downstream slope of the rectangular-shape plunge pool

z_w = Side slope ratio of the side slopes of the rectangular-shape plunge pool

z_d = Water depth above the invert elevation of the outlet channel, ft

z_m = Maximum computed depth of the plunge pool, ft

z_p = Vertical distance from the tailwater surface to the cantilever pipe invert, ft

ρ = Water density

ρ_s = Bed material or riprap particle density

α = Jet impingement angle where the jet plunges Into the water surface

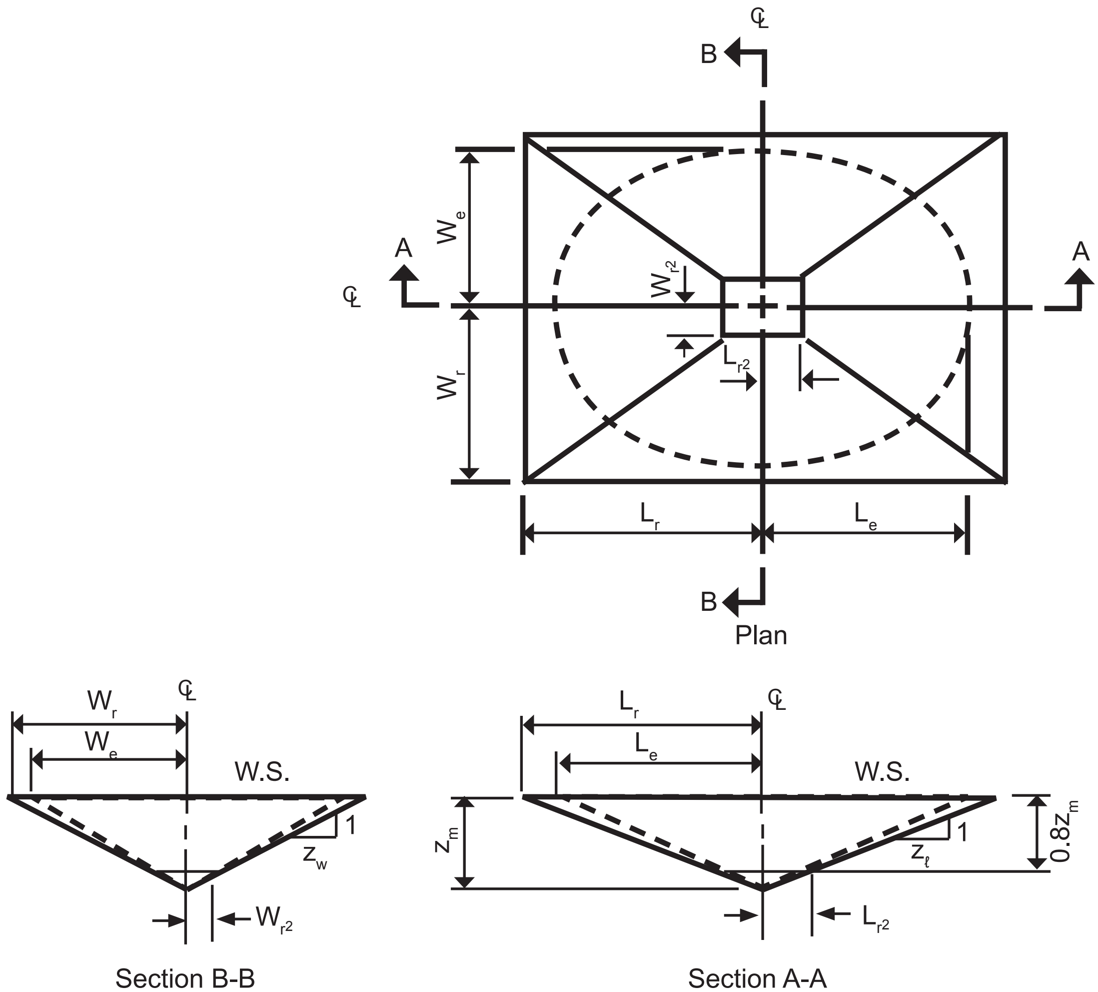


Figure 8.06g Plunge pool

Procedure

The step procedure given below is in a form that can easily be programmed on either programmable calculators or computers.

1. Compute: $\dfrac{Q}{\sqrt{gD^5}}$

2. Compute: $V_o = \dfrac{4Q}{\pi D^2}$

3. Compute: $V_h = V_o \cos(\sin^{-1} s)$

$$V_v = \sqrt{(V_o s)^2 + 2g\left[z_p + \frac{D}{2}\cos(\sin^{-1} s)\right]}$$

$$\tan\alpha = \frac{V_v}{V_h}$$

$$V_p = \sqrt{V_h^2 + V_v^2}$$

$$X_p = \frac{V_h}{g} (V_v - V_o s)$$

4. Compute: $F_d = \dfrac{V_p}{\sqrt{g\, d_{50} (\rho_s - \rho) / \rho}}$

5. Compute: $\dfrac{z_p}{D}$ if < 1, go to step 6a; if > 1, go to step 6b

6a. Compute: $z_m = 7.5\, D\, [1 - e^{-0.6 (F_d - 2)}]$; go to step 7

6b. Compute: $z_m = 10.5\, D\, [1 - e^{-0.35 (F_d - 2)}]$

7. Compute: $1.0 + 25 \dfrac{d_{50}}{D}$

8. Compute: If $\dfrac{Q}{\sqrt{gD^5}} < 1.0 + 25 \dfrac{d_{50}}{D}$, then go to step 9; otherwise, make design adjustments to increase d_{50} and return to step 4

9. Compute: $X_m = [\, X_p + \dfrac{z_m}{\tan \alpha}\,]\, 1.15 e^{-0.15 [Q/(gD^5)^{1/2}]}$

10. Compute: $L_e = z_m \left[\dfrac{3}{2} + \dfrac{1}{3} \dfrac{Q}{\sqrt{gD^5}} \right]$

$$W_e = z_m \left[1.5 + 0.15 \frac{Q}{\sqrt{gD^5}} \right]$$

11. Compute: Determine A_2, plan rectangular area of the plunge pool bottom at $0.8z_m$ below the water surface

$L_{r2} = 0.2\, L_e$

$W_{r2} = 0.2\, W_e$

$A_2 = 4\, L_{r2} W_{r2}$

12. Compute: Check the side slopes of the plunge pool and adjust, if necessary to acceptable grades, z_ℓ and z_w. The final length and width of the plunge pool at the water surface are $2L_r$ and $2W_r$, respectively.

$L_r = 0.8\, z_m z_\ell + L_{r2}$

$W_r = 0.8\, z_m z_w + W_{r2}$

13. Compute: If $L_r < X_m$, increase side slope, z_ℓ, so that $L_r > X_m$

14. Compute: Determine A_1, plan rectangular area of the plunge pool at the invert elevation of the outlet channel

$A_1 = 4\, (L_r - z_\ell z_d)\, (W_r - z_w z_d)$

15. Compute: Plunge Pool Volume:
The volume between a horizontal plane at the invert elevation of the outlet channel and the exposed riprap surface is V_{ao}

$$V_{ao} = \frac{1}{81}\left[A_1 + A_2 + \sqrt{A_1 A_2}\right]\left[0.8z_m - z_d\right], \text{ cu. yds.}$$

The volume between a horizontal plane at the inverted elevation of the outlet channel and a surface at a thickness, a_1, below the exposed riprap surface is V_{a1}

$$V_{a1} = \frac{1}{81}\left[A_{1(a_1)} + A_{2(a_1)} + \sqrt{A_{1(a_1)} A_{2(a_1)}}\right]\left[0.8z_m - z_d + a_1\right], \text{ cu. yds.}$$

where: $A_{1(a_1)} = 4\left[L_r - z_\ell z_d + a_1\sqrt{1 + z_\ell^2}\right]\left[W_r - z_w z_d + a_1\sqrt{1 + z_w^2}\right]$

and, $A_{2(a_1)} = 4\left[L_{r^2} + a_1(\sqrt{1 + z_\ell^2} - z_\ell)\right]\left[W_{r^2} + a_1(\sqrt{1 + z_w^2} - z_w)\right]$

The volume riprap at thickness, a_1, below a horizontal plane at the invert elevation of the outlet channel, exclusive of the volume of the riprap filter cap is $V_{a1} - V_{ao}$, cu. yds.

The volume between a horizontal plane at the inverted elevation of the outlet channel and a surface at a thickness, a_2, below the exposed riprap surface is V_{a2} .

$$V_{a2} = \frac{1}{81}\left[A_{1(a_2)} + A_{2(a_2)} + \sqrt{A_{1(a_2)} A_{2(a_2)}}\right]\left[0.8z_m - z_d + a_2\right], \text{ cu. yds.}$$

where: $A_{1(a_2)} = 4\left[L_r - z_\ell z_d + a_2\sqrt{1 + z_\ell^2}\right]\left[W_r - z_w z_d + a_2\sqrt{1 + z_w^2}\right]$

and, $A_{2(a_2)} = 4\left[L_{r^2} + a_2(\sqrt{1 + z_\ell^2} - z_\ell)\right]\left[W_{r^2} + a_2(\sqrt{1 + z_w^2} - z_w)\right]$

The volume of filter material of thickness, $a_2 - a_1$, below a horizontal plane at the invert of the riprap filter cap, is equal to $V_{a2} - V_{a1}$, cu. yds.

Plunge Pool Design at Submerged Pipe Spillway Outlets

Note: An Excel spreadsheet is available for this method

Procedure

1. Determine Design Flow, Q, Pipe Diameter, D_o, and downstream Tailwater Elevation, TW. This procedure is valid for a ratio of $0.7 \leq TW / D_o \leq 2$. The dimensions determined by this procedure are shown on Figure 8.06h, and as defined as follows:

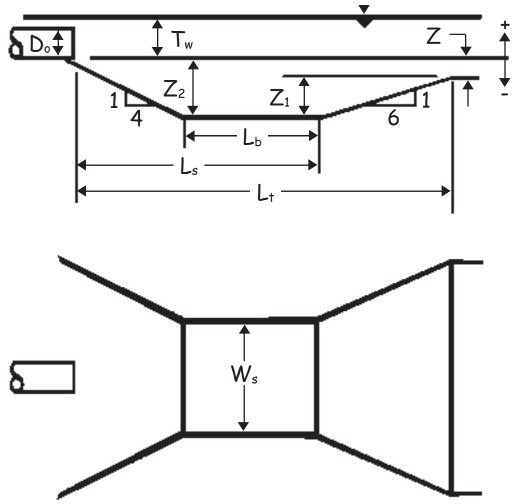


Figure 8.06h

A_o = Cross-sectional area of pipe

D_o = Pipe diameter

D_{50} = Diameter of average size of riprap

g = Acceleration due to gravity [9.81 m/s^2 (32.17 ft/s^2)]

L_b = bottom length of plunge pool

L_s = Length from outlet to downstream end of bottom of plunge pool

L_t = [$L_s - 6(Z_1)$], length from outlet to downstream end of plunge pool

Q = discharge

S = slope of pipe outlet

TW = tailwater elevation relative to outlet invert, measured adjacent to outlet, positive up

V_o = Q/A_o = mean pipe velocity

W_s = bottom width of plunge pool

W_t = top width of plunge pool for Z_1 depth plunge pool

W_{TW} = top width of plunge pool at tailwater elevation

x = distance downstream of pipe exit

y = distance normal to pipe centerline

Z = distance from outlet invert to natural bed elevation, negative down

Z_1 = ($Z_2 - Z_1$), depth of plunge pool; distance from natural channel bed elevation to bottom of plunge pool, negative down

Z_2 = distance from outlet invert to bottom of plunge pool, negative down

Z_p = height of pipe invert above (+) or below (–) the tailwater surface

2. Select a median stone size, D_{50}.

3. Determine the plunge pool depth to pipe diameter ratio.

$$\frac{Z_2}{D_o} = -3.75 \left\{ \log \frac{Q^2}{gD_o^5} - \log \left[4.35 \frac{D_{50}}{D_o} \right]^{1.18} \right\}$$

4. Determine the plunge pool width, W_s to pipe diameter ratio.

$$\frac{W_s}{D_o} = 3.0 - \frac{Z_2}{D_o}$$

Side slope of the plunge pool should be 2H:1V or flatter.

5. Determine the plunge pool length to pipe diameter ratio.

$$\frac{L_s}{D_o} = 10 - 1.5 \frac{Z_2}{D_o}$$

6. Calculate values for Z_2, W_s and L_s by multiplying the ratios by D_o

$$\left\{ \left(\frac{Z_2}{D_o} \right) \left(\frac{W_s}{D_o} \right) \left(\frac{L_s}{D_o} \right) \right\} D_o = Z_2, W_s, L_s$$

7. Determine Z_1.

$Z_1 = Z_2 - Z$

8. Determine L_t and L_b .

$L_t = L_s - 6Z_1$ (Z_1 is negative down)

$L_b = L_s + 4Z_2$ (Z_2 is negative down)

9. Determine the plunge pool top width, W_t, and the water surface top width of tailwater, W_{TW}.

$W_t = W_s - 4Z_2$ (Z_2 is negative down)

$W_{TW} = W_s + 4(TW - Z_2)$ (Z_2 is negative down)

This method is valid for:

$$\frac{Q^2}{gD_o^5} > 0.5$$

$$\frac{Z_1}{D_o} \leq -0.25$$

References

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

USDA. SCS. 1986 Design Note No.6. Riprap Lined Plunge Pool for Cantilevered Outlet.

USDOT, FHWA. 1983 Hydraulic Engineering Circular No.14. Hydraulic Design of Energy Dissipaters for Culverts and Channels.

8.07

SEDIMENT BASIN DESIGN

The design of temporary sediment basins for construction sites should meet all minimum requirements contained in *Practice Standards and Specifications: 6.61, Sediment Basin*.

The following outline provides guidance in designing sediment basins to meet those requirements.

Size, Location, and Efficiency

Structures intended for more than 3 years of use should be designed as permanent structures. **Procedures outlined in this section do not apply to permanent structures.** 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.

Basic requirements for design of a sediment basin are the following:

- drainage area less than 100 acres;
- design structure life less than 3 years;
- minimum design storm, 10-yr peak runoff with minimum 1 ft freeboard;
- In High Quality Water (HQW) Zones, minimum design storm, 25-yr peak runoff with minimum 1 foot freeboard. The sediment basin shall settle the 40-micron particle with a minimum efficiency of at least 70% during the 2-yr peak runoff event. See appendices beginning on pg. 8.07.13.
- hazard classification: sudden failure should not cause loss of life or serious property damage.

Basin location—Locate the basin so that a maximum amount of runoff from disturbed areas can be brought into the structure. It should be accessible for periodic cleanout and should not interfere with construction activities. When possible delay clearing the sediment impoundment area until the dam is in place. Keep the remaining temporary pool area undisturbed.

Basin volume—Minimum volume of the basin should be 1,800 ft^3/acre for the disturbed area draining into the basin. Volume is measured below the principal spillway crest. Where possible the entire drainage basin is used for this computation, rather than the disturbed area alone, to help ensure adequate trapping efficiency.

Trapping efficiency—For additional information see Appendices pg. 8.07.13-8.07.42) Maximize the trapping efficiency of the basin by:

- diverting runoff from undisturbed areas away from the basin;
- limiting drainage area to increase the ratio of basin surface area to peak inflow rate. This ratio should be 435 ft^2/cfs or greater to achieve more than 75% efficiency on most soils. Subdivide area with additional traps and barriers to limit inflow rate and improve efficiency;
- maximizing the length-to-width ratio of the basin. Length to width should be 2:1 to 6:1;
- locating sediment inflow points as far as possible from the principal spillway inlet;
- controlling flow at inlet points to maintain nonerosive velocities.

Basin cleanout—Plan to remove sediment when approximately one half of the basin volume has been filled. **The minimum volume requirement (1,800 ft^3/acre) must always be met.**

Spillway System Design

The spillway system, consisting of a principal spillway and an emergency spillway, should carry the peak runoff from a 10-year storm with a minimum 1 foot freeboard above the design water surface in the emergency spillway. Base runoff computations on the most severe soil cover conditions expected during the effective life of the structure (*Appendix 8.03*).

PRINCIPAL SPILLWAY

The principal spillway consists of a vertical pipe riser fastened to a horizontal pipe barrel with watertight connectors. The horizontal conduit must extend beyond the toe of the dam and must be stabilized, usually by riprap.

Minimum capacity—2-year peak runoff, computed for water surface at the emergency spillway elevation.

Crest elevation of the riser may be set no lower than the elevation of the sediment detention pool as a minimum.

Barrel conduit and riser—The minimum barrel conduit size allowable is 15 inches for corrugated pipe and 12 inches for smooth-walled pipe. Limit the maximum barrel diameter to 30 inches. The riser should have a cross-sectional area at least 1.5 times that of the barrel. Rod and lug type connector bands with gaskets are recommended for corrugated pipe to provide positive watertight connections.

Basin dewatering should be from the water surface, using a floating surface intake or by operating a flash board riser.

The minimum dewatering time is 48 hours, and not more than 1 foot of stage draw-down per day.

Trash guard—Install a trash guard on top of the riser. A fabricated cone of steel rods, spaced 2 inches apart, fastened to the top of the riser is recommended.

Protection against piping—Secure at least one watertight antiseep collar with a minimum projecting of 1.5 feet around 12-inch or larger conduits. Locate the collar just downstream from the centerline of the dam. A properly designed drainage diaphragm installed around the barrel may be substituted for an antiseep collar.

Protection against flotation—Anchor the riser with a mass with a buoyant weight greater than 1.1 times the weight of water displaced by the riser.

Stabilize the outlet below the barrel against erosion (*Appendix 8.06*).

EMERGENCY SPILLWAY
Construct the entire flow area of the emergency spillway in undisturbed soil. Cross section should be trapezoidal, with side slopes 3:1 or flatter. Select vegetated lining to meet flow requirements and site conditions (Figure 8.07a)

Capacity—Design the emergency spillway for runoff from the 10-year storm less any reduction due to flow in the principal spillway.

Inlet protection—Ensure that the approach section has a slope toward the impoundment area of not less than 2% and is flared at its entrance, gradually reducing to the design width of the control section.

The control section should be level and straight and at least 20 ft long. Determine the width and depth for the required capacity and site conditions. Wide, shallow spillways are preferred because they reduce outlet velocities.

The outlet section should be straight, aligned and sloped to assure supercritical flow with exit velocities not exceeding values acceptable for site conditions.

Outlet velocity—Ensure that the velocity of flow from the basin is nonerosive for existing site conditions. It may be necessary to stabilize the downstream areas or the receiving channels.

EMBANKMENT DESIGN
There should be a cutoff trench in stable soil material under the dam at the centerline, extending up the abutments to the elevation of the emergency spillway. The trench should be at least 2 feet deep with 1:1 side slopes, and sufficiently wide to allow compaction by machine.

Top width—Fill height 10 feet: minimum top width 8 feet
Fill height 10-15 feet: minimum top width 10 feet

Allowment for settlement—10% of fill height.

Side slope—2.5:1 or flatter

Freeboard—minimum 1 foot between the settled top of the dam and the design water level in the emergency spillway.

Embankment material should be a stable mineral soil, free of roots, woody vegetation, rocks or other objectionable materials, with adequate moisture for compaction. Place fill in 8-inch layers through the length of dam and compact by routing construction hauling equipment over it. Equipment must traverse the entire surface of each layer by at least one wheel width.

EROSION CONTROL
Construct the structure to minimize the area disturbed. Divert surface water away from disturbed areas. Complete the embankment before clearing the impoundment area. Stabilize the emergency spillway, embankment, and all other disturbed areas above the crest elevation of the principal spillway immediately after construction (*Practices 6.10-6.15, Surface Stabilization*).

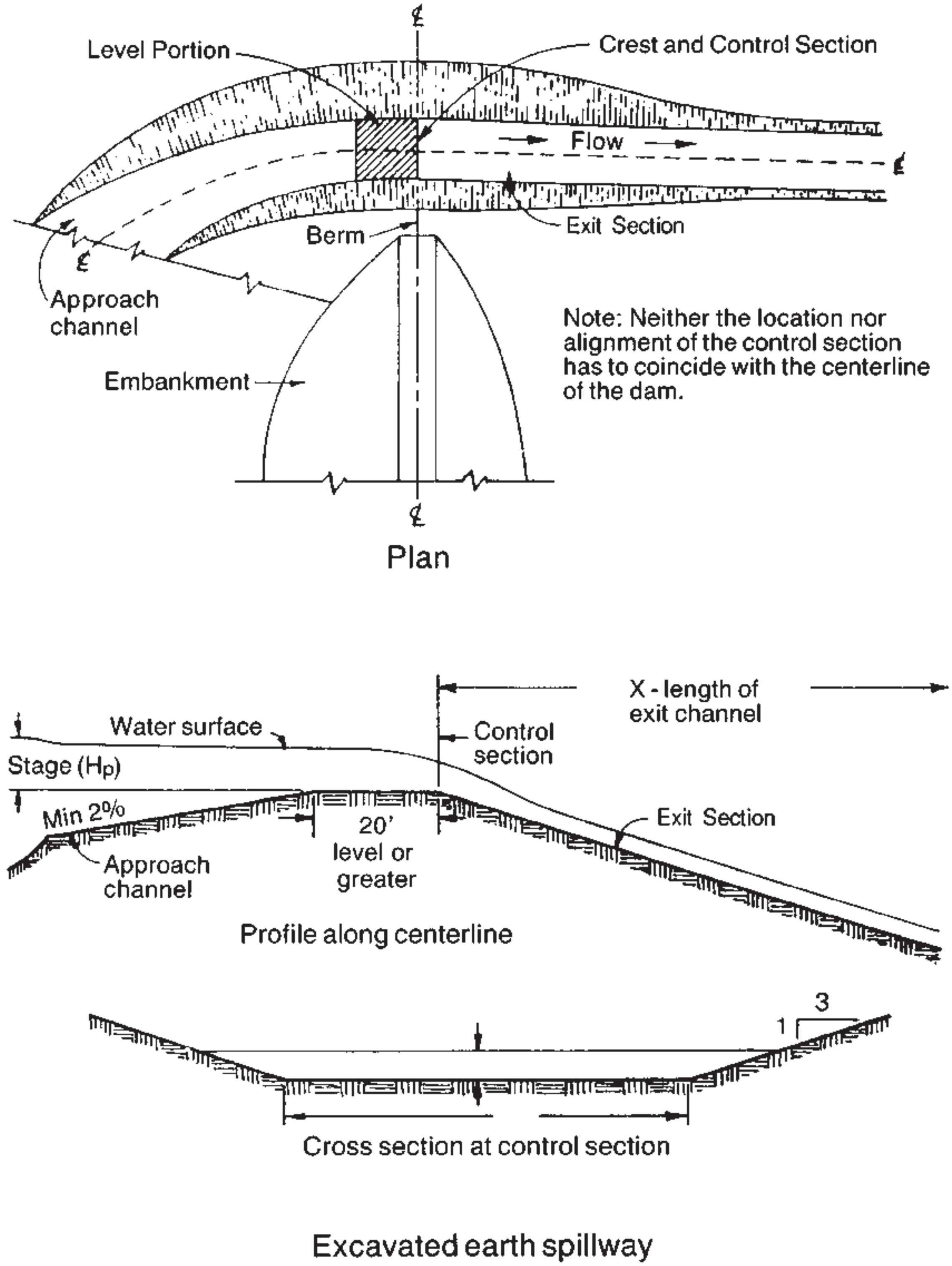


Figure 8.07a Design of excavated earthen spillway.

Safety—Avoid steep side slopes. Fence basins properly and mark them with warning signs if trespassing is likely. Follow all State and local safety requirements.

Design Procedure

Step 1. Determine peak flow, Q_{10}, for the basin drainage area (*Appendix 8.03*).

Step 2. Determine any site limitations for the sediment pool elevation, emergency spillway or top of the dam.

Step 3. Determine basin volumes:

- Compute minimum volume required (1800 ft^3/acre disturbed).
- Specify sediment cleanout level to be marked on riser (one-half the design volume referenced to the top of the riser) and sediment storage area to be cleared after the dam is built.

Step 4. Determine area and shape of basin:

- Check length/width ratio (should be 2:1 to 6:1).
- Compute the basin surface area at principal spillway elevation.
- Check the ratio of basin surface area to peak inflow rate (should be greater than or equal to 435 ft^2/cfs). Employ diversions with additional traps and basins to reduce area drained.

Determine barrel capacity required for site conditions (minimum capacity for Q_p is the 2-year peak runoff, Q_2.

Step 5. Determine the principal spillway discharge capacity.

- The combined capacities of the principal and emergency spillways must be at least the 10-year peak flow for the entire watershed of the basin.
- The principal spillway is analyzed for three possible limiting flow types: Weir flow, Orifice flow, and Pipe flow. The principal spillway discharge capacity is the smallest of these three flow rates. Discharges through a skimmer should be disregarded during this computation. Weir, orifice and pipe flow may be determined by the following equations:

1. Weir Flow: $Q = CLH^{1.5}$

where:
Q = discharge in cubic feet per second (cfs)
C = weir coefficient, use 3.1 for corrugated metal pipe risers.
L = circumference of the riser in feet
H = head above riser crest in feet

2. Orifice Flow: $Q = CA\,(2gH)^{0.5}$

where:
Q = discharge in cubic feet per second (cfs)
C = orifice coefficient, use C = 0.6 for corrugated metal pipe risers.
A = cross-sectional area of the riser pipe in square feet
g = acceleration due to gravity, 32.2 ft/sec^2
H = head above riser crest in feet

3. Pipe Flow: $Q = a \left[\frac{2gh}{1 + K_m + K_p L}\right]^{0.5}$

where:

Q = discharge in cubic feet per second (cfs)
a = cross-sectional area of the barrel in square feet
g = acceleration due to gravity, 32.2 ft/sec^2
h = head above the centerline of the outlet end of the barrel
K_m = coefficient of minor losses, can be assumed to be 1.0 for most principal spillway systems
L = barrel length in feet
K_p = pipe friction coefficient:

$$= \frac{5087n^2}{di^{4/3}}$$

(See Table 8.07c for K_p values for common size of pipe.)

n = Manning's coefficient of roughness, use n = 0.025 for corrugated metal pipe
n = 0.015 for reinforced concrete pipe
di = inside diameter of the barrel in inches

Select riser and barrel dimensions so that the riser has a cross-sectional area at least 1.5 times that of the barrel. Spillway hydraulics are improved by maximizing weir flow and minimizing orifice flow. See Table 8.07b for recommended riser/barrel proportions.

Table 8.07a K_p Values for Common Sizes of Pipe

Pipe Diameter (inches)	Flow Area (square feet)	Manning's Coefficient	
		0.015	0.025
6	0.196	0.1050	0.2916
8	0.349	0.0715	0.1987
10	0.545	0.0531	0.1476
12	.0785	0.0417	0.1157
14	1.069	0.0339	0.0942
15	1.23	0.0309	0.0859
16	1.40	0.0284	0.0789
18	1.77	0.0243	0.0674
21	2.41	0.0198	0.0549
24	3.14	0.0165	0.0459
27	3.98	0.0141	0.0393
30	4.91	0.0123	0.0341
36	7.07	0.0096	0.0267
42	9.62	0.0078	0.0218
48	12.57	0.0066	0.0182
54	15.90	0.0056	0.0156
60	19.64	0.0049	0.0135

RISER
Select trail riser and barrel dimensions. Use the weir, orifice and pipe flow equations to determine if the 2-year peak discharge is passed without activating the emergency spillway. Determine riser size from Table 8.07b. Check the head and stage requirements. If the design stage is too high, choose larger dimensions and recalculate. As a minimum, set the elevation of the riser at the same elevation as the top of the sediment pool. A riser height 2 to 5 times the barrel diameter is recommended. Select the type of trash guard.

Select a dewatering device. If a skimmer is used, refer to the manufacturers dewatering data, or Table 6.64.a.

Step 6. Design antiseep collar.
Ensure that antiseep collars are no closer than 2 ft from a pipe joint. Collar must project at least 1.5 ft from the pipe. Indicate watertight connections.

Step 7. Design antiflotation block.
Determine the weight of water displaced by the empty riser, and design a block with buoyant weight 1.1 times the weight of water displaced.

Step 8. Design outlet.
Determine discharge velocity from the barrel. Design outlet protection to assure stable conditions. Riprap placement is usually necessary (*Appendix 8.06*).

Step 9. Design emergency spillway.

- Determine the required capacity for the emergency spillway as

$$Q_e = Q_{10} - Q_p \; (Q_p \geq Q_2)$$

- From Table 8.07e or Table 8.07f, select the width and depth of the outlet, depending on soil conditions. In general, the wider bottom widths and lower slopes are preferred to minimize exit velocities at supercritical flow.

- An acceptable alternative is the use of the weir equation

$$Q = CLH^{1.5}$$

  Where this option is used, the maximum value of C should be 2.8. L is the bottom width of the spillway at the crest, and H is the depth of flow above the spillway crest in feet. Note: Manning's channel equation should not be used to size the spillway crest. However, it should be used to design the outlet channel below the spillway crest.

- The total of the emergency and principle spillway capacities must equal or exceed the required 10-year peak discharge.

- Set the elevation of the crest of the emergency spillway a minimum of 1 foot above the crest of the riser.

Step 10. Spillway approach section.
Adjust the spillway alignment so that the control section and outlet section are straight. The entrance width should be 1.5 times the width of the control section with a smooth transition to the width of the control section. Approach channel should slope toward the reservoir no less than 2%.

Table 8.07b Design chart for riser outlet

Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (d) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes-3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%

Find: Bottom width and Stage in Spillway

Procedure: Enter table from left at 90 c.f.s. Note that Spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. State in Spillway will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = 0.40. Maximum velocity 5.50 ft. per sec.

Table 8.07d
Design Table for Vegetated Spillways Excavated in Very Erodible Soils
(side slopes-3 horizontal:1 vertical)

Discharge Q CFS	Slope Range		Bottom Width Feet	Stage Feet
	Minimum Percent	Maximum Percent		
10	3.5	4.7	8	.68
15	3.4	4.4	12	.69
	3.4	5.9	16	.60
20	3.3	3.3	12	.80
	3.3	4.1	16	.70
	3.5	5.3	20	.62
25	3.3	3.3	16	.79
	3.3	4.0	20	.70
	3.5	4.9	24	.64
30	3.3	3.3	20	.78
	3.3	4.0	24	.71
	3.4	4.7	28	.65
	3.4	5.5	32	.61
35	3.2	3.2	24	.77
	3.3	3.9	28	.71
	3.5	4.6	32	.66
	3.5	5.2	36	.62
40	3.3	3.3	28	.76
	3.4	3.8	32	.71
	3.4	4.4	36	.67
	3.4	5.0	40	.64
45	3.3	3.3	32	.76
	3.4	3.8	36	.71
	3.4	4.3	40	.67
	3.4	4.8	44	.64
50	3.3	3.3	36	.75
	3.3	3.8	40	.71
	3.3	4.3	44	.68
60	3.2	3.2	44	.75
	3.2	3.7	48	.72
70	3.3	3.3	52	.75
80	3.1	3.1	56	.78

Example of Use

Given: Discharge, Q = 38 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Spillway.

Procedure: Enter table from left at 40 c.f.s. Note that Spillway slope (4.0%) falls within slope ranges corresponding to bottom widths of 36 and 40 ft. Use wider bottom width, 40 ft., to minimize velocity. Stage in Spillway will be 0.64 ft.

Note: Computations based on: Roughness coefficient, n = 0.40. Maximum velocity = 3.50 ft. per sec.

Step 11. Spillway control section

- Locate the control section in the spillway near where it intersects the extension of the centerline of the dam.
- Keep a level area to extend at least 20 ft upstream from the outlet end of the control section, to ensure a straight alignment.
- Side slopes should be 3:1.

Step 12. Design spillway exit section.

- Spillway exit should align with the control section and have the same bottom width and side slopes.
- Slope should be sufficient to maintain supercritical flow, but make sure it does not create erosive velocities for site conditions. (Stay within slope ranges in appropriate design tables.)
- Extend the exit channel to a point where the water may be released without damage.

Step 13. Size the embankment.

- Set the design elevation of the top of the dam a minimum of 1 ft above the water surface for the design flow in the emergency spillway.
- Constructed height should be 10% greater than the design to allow for settlement.
- Base top width on the design height.
- Set side slopes 2.5:1 or flatter.
- Determine depth of cutoff trench from site borings. It should extend to a stable, tight soil layer (a minimum of 2 ft deep).
- Select borrow site–the emergency spillway cut will provide a significant amount of fill.

Step 14. Erosion control

- Locate and design diversions to protect embankment and spillway (*Practice Standards and Specifications: 6.20, Temporary Diversions*).
- Select surface protection measures to control erosion (*Practice Standards and Specifications: 6.10, Temporary Seeding; 6.14, Mulching; and 6.15, Riprap*).
- Select groundcover for emergency spillway to provide protection for design flow velocity and site conditions. Riprap stone over geotextile fabric may be required in erodible soils or when the spillway is not in undisturbed soils.

Step 15. Safety.

- Construct a fence and install warning signs as needed.

EFFICIENCY-BASED SEDIMENT BASINS

DEFINITION

Efficiency-based sediment basins are sediment basins that are designed to settle particles of a given size at a specified minimum settling efficiency during the passage of a specified design storm.

PURPOSE

To capture fine sediment particles with a high degree of confidence at sites in sensitive areas.

CONDITION WHERE PRACTICE APPLIES

Efficiency-based basins are to be used for sediment basins on sites located in areas designated as High Quality Waters.

PLANNING CONSIDERATIONS

Basin site selection

Locate sediment basins in drainage swales near periphery of the site and at other points in the disturbed area where it is important to remove fine sediment particles from stormwater runoff. It is especially important to consider:

- Topography: The ideal shape of a sediment basin is broad and shallow, with length about three times width.

- Drainage area: The drainage area of the sediment basin is the <u>maximum</u> area that will contribute flow to the basin during any phase of land disturbance.

- Offsite water: The drainage area of any watercourse that contributes off-site flow to the sediment basin must be included in the drainage area of the sediment basin.

- Diversion channels: Construct diversion channels where needed to ensure that all stormwater intended for treatment in the sediment basin is conveyed to the basin in all phases of land disturbance.

Basin description

The sediment basin will consist of a dike or dam fitted with a riser-barrel principal spillway and an emergency spillway, a sediment storage volume, a stormwater treatment volume, and an inlet zone.

Preparation of source data

Analytical verification of expected basin performance will depend on three sets of information:

- The inflow hydrograph is based upon data collected on local rainfall statistics, soil conditions and watershed size and topography.
- The stage-storage function is based on the size and shape of the sediment and water storage area behind the dam.
- The stage-discharge function is based on the hydraulics of the principal spillway.

DESIGN CRITERIA

Design objective

The sediment basin shall be designed to settle the 40 micron particle with minimum settling efficiency of 70 percent during the two-year storm event.

Basin configuration

In the design and configuration, the following elements of the basin should be considered:

- Inlet and outlet zone: Arrange the basin inlet and outlet to interrupt the flow path by baffles or by directing the inlet flow so that flow will not tend to flow in a narrow band directly from inlet to outlet.
- Sediment-storage zone/cleanout schedule: Consider carefully the size of the sediment-storage volume in relation to the cleanout schedule. A small sediment-storage zone will lead to a smaller pond, but it will require more frequent cleanout.
- Riser/barrel: Design, fabrication, installation and maintenance of this feature are critical in determining settling behavior of the basin.
- Drain hole(s): These holes provide slow drawdown of the water level after a storm so that fine particles are captured before water release. They should be checked after a rainfall event to remove any blockage.
- **Emergency spillway: Provide an emergency spillway to pass safely that flow that exceeds the design storm for sediment control.**
- Dam: The dam or dike should be carefully designed and constructed for safe and effective performance.

HYDROLOGIC DATA

In the procedures that follow, locally specific hydrologic data are necessary. Refer to the table for the values that apply at the location of interest.

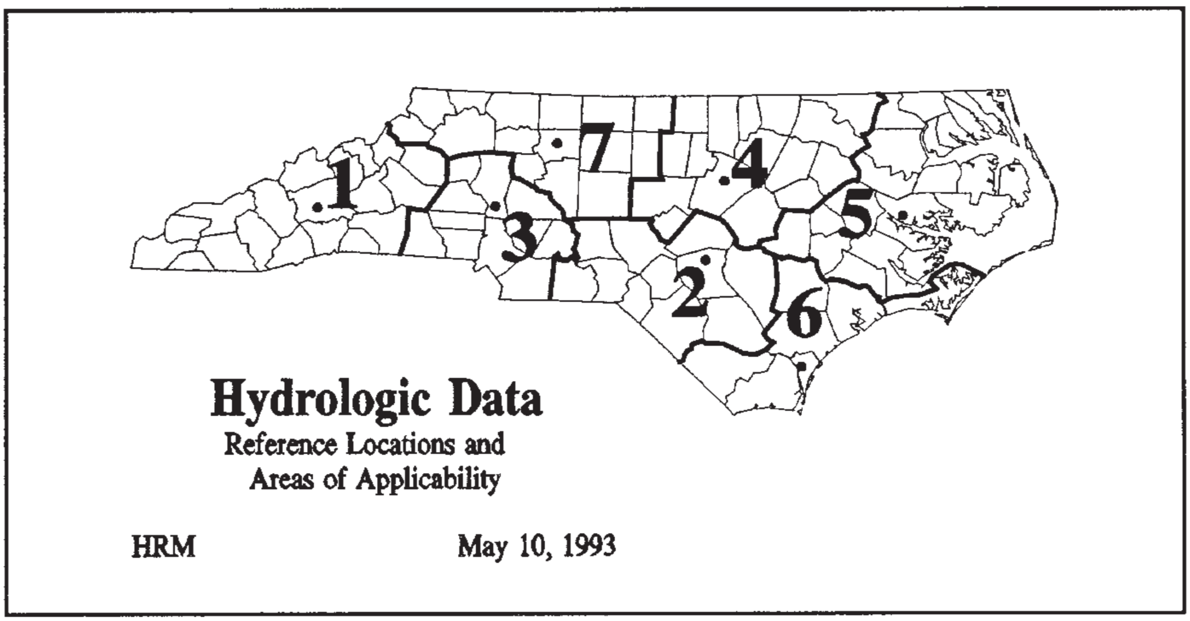
For use in the Rational Equation, the applicable value of rainfall intensity, *I*, can be found by the expression

$$I = \frac{g}{h + T_c}$$

in which I = Applicable rainfall intensity (in/hr)

T_c = Time of concentration at the point of interest (min)

g and h are locally specific constants obtained from the table below.



Hydrologic Reference Data

Region	Office	2-yr intensity values g	2-yr intensity values h	2-yr, 6-hr precip (in)	2-yr, 24 hr precip (in)
1	Asheville	145	23	2.8	3.80
2	Fayetteville	149	20	2.9	3.80
3	Mooresville	130	19	2.6	3.50
4	Raleigh	132	18	2.7	3.60
5	Washington	153	21	3.0	4.00
6	Wilmington	171	24	3.3	4.50
7	Winston-Salem	126	19	2.6	3.50

ALTERNATIVE PROCEDURES

Three alternative procedures are given for designing sediment basins. Method 1 applies to basins on relatively small and uncomplicated sites for which a conservative approximation is appropriate. Method 2 is for small and intermediate sites for which rectangular approximations of basin geometry are reasonable. Method 3 is the most precise in representing site conditions, basin geometry and settling behavior.

Method 1 can be applied to sediment traps fitted with stone spillways. Stone spillways are not suitable for basins designed by Methods 2 and 3.

These procedures provide for the configuration of the outlet devices and sediment settling and storage zones of the basins. **The designer must also insure that the basin is capable of passing the 25-year storm without overtopping the dam or dike.**

METHOD 1

Select basin location

Determine values of input data

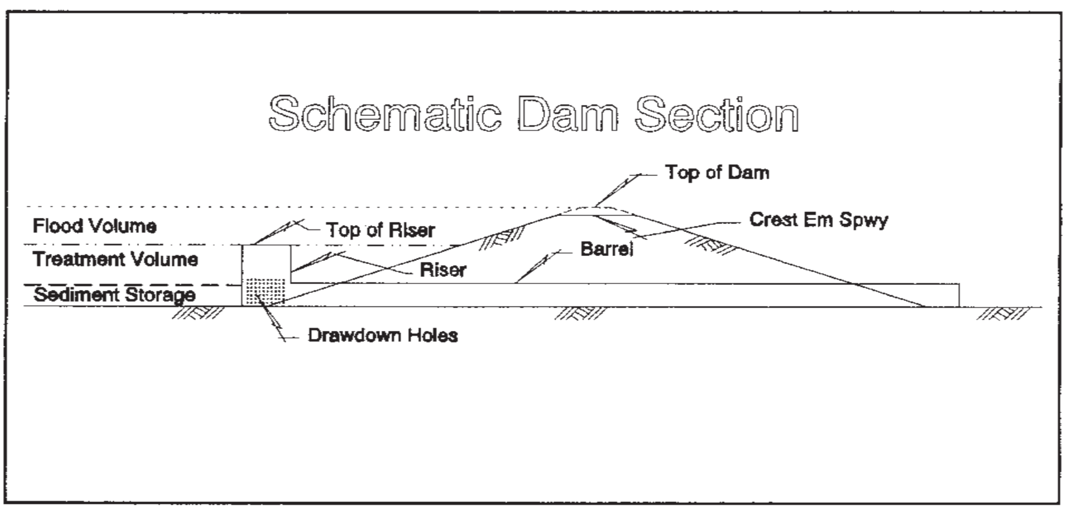
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  SCS Curve Number
  Area available for basin (sq ft)

- Storm data

  2-yr, 24-hr rainfall depth (in)

Review the schematic of the riser/barrel and dike



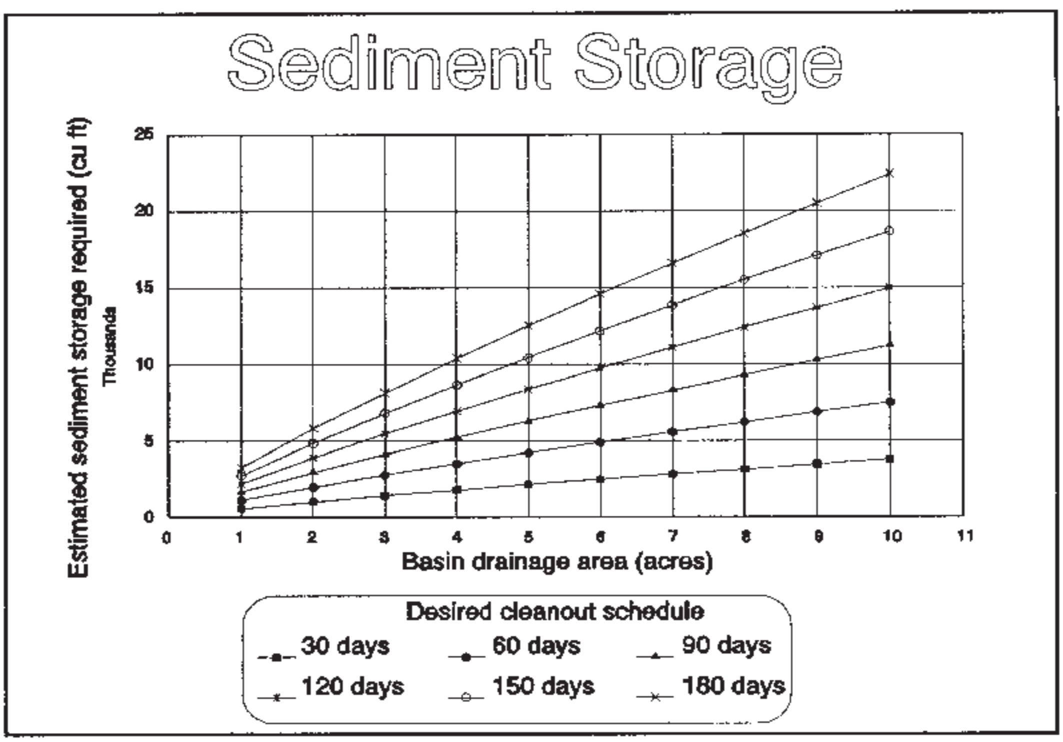
Compute estimated volume of sediment to be stored before cleanout

- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)
- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Estimate volume of stormwater to be treated by the procedure or the graph

- Determine runoff depth of 2-yr, 24-hr storm.

$$S = \frac{1000}{CN} - 10$$

in which S = Ultimate soil storage capacity (in)
CN = SCS CN for basin drainage area

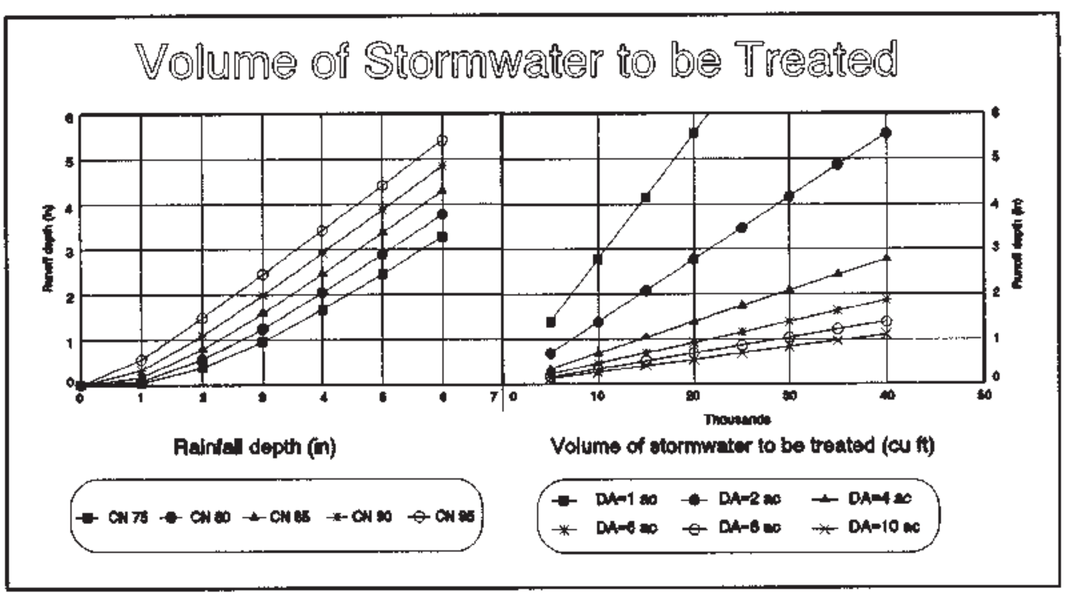
$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which Q^* = Estimated runoff depth (in)
P = 2-yr, 24-hr rainfall depth (in)
S = Ultimate soil storage capacity (in)

- Compute volume of stormwater to be treated.

$$V_s = 3630Q^*A$$

in which V_s = Volume of stormwater to be treated (cu ft)
Q^* = Estimated runoff depth (in)
A = Basin drainage area (ac)



- Decide on the dimensions of the basin.

- Set the width and length such that the length is three times the width.

- Determine the basin surface area (width times length).

- Determine the depth of sediment storage by dividing the sediment storage volume by the basin surface area. Check to insure that this is a safe and workable depth. It will be full of water during rainy periods.

- Determine the depth of treatment volume by dividing the treatment volume by the basin surface area.

- The total height of the riser is the sum of the depths of sediment storage and treatment volume.

Select the sizes of the riser/barrel and emergency spillways to safely convey the maximum peak rate of runoff from the 25-year storm.

- Refer to *Appendix 8.07*.

Set the number and diameter of drawdown holes to drain the pond after a storm.

Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07)*

METHOD 2

Note: This procedure assumes that the basin bottom is essentially flat and that the sides are nearly vertical. The basin surface area is the area of the bottom of the basin.

Select basin location

Determine values of input data

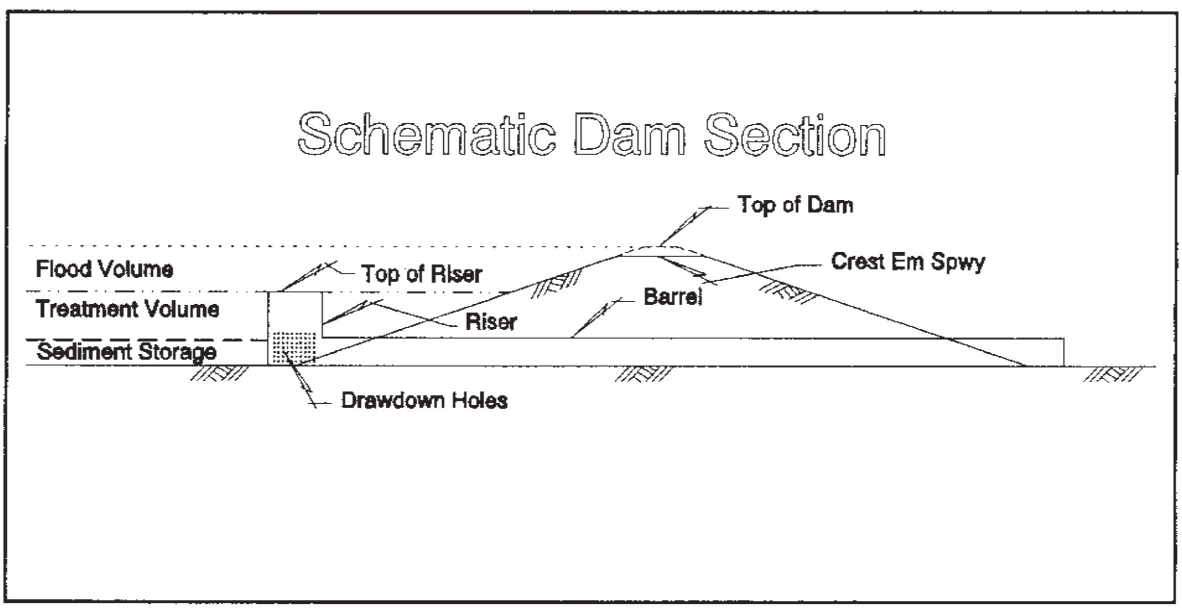
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  Time of concentration (min)
  Rational runoff coefficient
  SCS Curve Number
  Area available for basin (sq ft)

- Storm data

  2-yr, 6-hr rainfall depth (in)
  2-yr rainfall intensity for the time of concentration

Review the schematic of the riser/barrel and dike



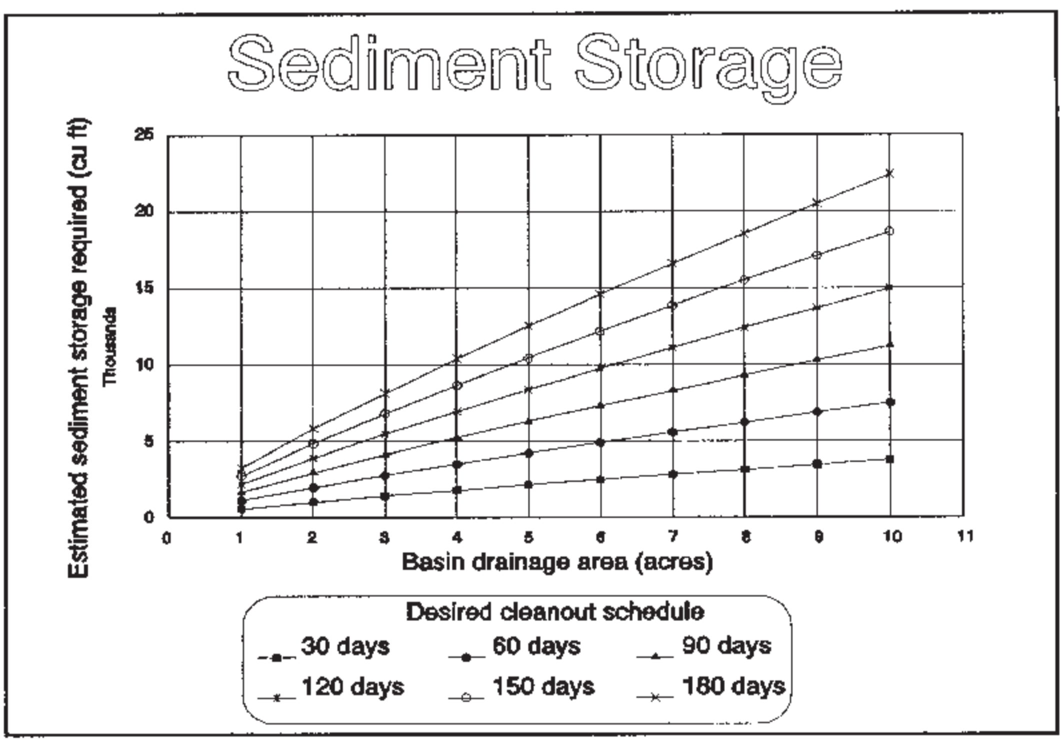
Compute estimated volume of sediment to be stored before cleanout

- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)
- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Formulate inflow hydrograph

Note: The inflow hydrograph should be formulated for the worst combination of cover conditions and contributory drainage area during the period of disturbance.

- Estimate the peak flow, Q_p, by Rational method (*Appendix 8.03*).
- Estimate the time to peak, T_p:

  Determine the depth of runoff in the 2-yr, 6-hr storm using the SCS method.

$$S = \frac{1000}{CN} - 10$$

in which S = Ultimate soil storage capacity (in)
CN = SCS CN for basin drainage area

$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which Q* = Estimated runoff depth (in)
P = 2-yr, 6-hr rainfall depth (in)
S = Ultimate soil storage capacity (in)

Determine the time to peak.

$$T_p = \frac{43.5Q^*A}{Q_p}$$

in which Q* = Estimated runoff depth (in)
A = Drainage area (ac)
Q_p = Estimated peak flow by Rational equation (cfs)
T_p = Time to peak (min)

- Discharges at various times of interest can be computed for the estimated inflow hydrograph by the step function given below. (*Note: It is not necessary to compute points on the hydrograph unless the designer wishes to verify the design by flood routing*).

  For times of interest between 0 and 1.25 T_p:

$$Q = \frac{Q_p}{2}\left[1 - \cos\left(\frac{\pi t}{T_p}\right)\right]$$

  For times of interest longer than 1.25 T_p:

$$Q = 4.34\ Q_p\ exp\left[-1.30\ \left(\frac{t}{T_p}\right)\right]$$

in which

Q_p	=	Peak flow (cfs)
T_p	=	Time to peak (min)
t	=	Time of interest for which the flow is sought (min)
Q	=	Flow at time of interest (cfs)

In these expressions, the argument of the cosine is in units of radians (the calculator should be in "radians mode"). The exponential function, *exp*, is frequently written as e^x, where x is the argument, as in *exp(x)*.

Set basin configuration

- Select basis surface area, length and width.
- Estimate allowable maximum outflow.

$$Q_o = \frac{A_s}{458}$$

in which

A_s	=	Surface area of the basin (sq ft)
Q_o	=	Allowable maximum outflow (cfs)

- Estimate required stormwater storage.

$$S = 60(Q_p - Q_o)T_p$$

in which

Q_p	=	Estimated peak inflow (cfs)
T_p	=	Estimated time to peak (min)
Q_o	=	Allowable maximum outflow (cfs)
S	=	Estimated stormwater storage required (cu ft)

- Determine maximum pond volume

  The maximum pond volume is the sum of the sediment storage, V_c, and the stormwater storage, S.

- Determine expected maximum stage.

$$Z_{max} = \frac{\textit{Maximum pond volume}}{A_s}$$

in which A_s = Surface area of the basin (sq ft)
Z_{max} = Expected maximum stage (ft)
(Maximum pond volume is expressed in cubic feet)

- Select barrel size.

  The barrel should be selected to deliver the expected maximum outflow, Q_o, when the water surface is at the maximum expected stage, Z_{max}. Selection may be made by using commonly available culvert capacity charts and tables, or it may be sized by application of the orifice equation. (Note that the orifice equation applies when the pipe is *inlet controlled.* If the outlet is submerged by high tailwater, the barrel must be analyzed under *outlet control*.) The orifice equation may be modified for direct application as:

$$Q = 0.0437 C_D D^2 \sqrt{Z_{max} - \frac{D}{24}}$$

in which C_D = Coefficient of discharge (typically 0.6)
D = Pipe diameter (in)
Z_{max} = Expected maximum stage (ft)
Q = Discharge delivered by pipe (cfs)

  Proceed by selecting a pipe diameter, computing the discharge, Q, and comparing it to the expected maximum outflow, Q_o. Select the pipe whose delivered discharge, Q, is at or just below the expected maximum outflow, Q_o.

- Select riser size.

  The cross section of the riser should be at least 1.5 times the cross-sectional area of the barrel.

- Compute stage of top of riser.

  The stage or elevation of the top of the riser should be sufficiently below the maximum expected water level to allow flow to enter the riser freely, but the top of riser should not be set grossly below the maximum expected water level. It is recommended that the location of the top of the riser be computed from the maximum expected water level, Z_{max}, and an application of the weir equation:

$$Z_{riser} = Z_{max} - \left[\frac{Q_o}{0.86D} \right]^{\frac{2}{3}}$$

in which Q_o = Expected maximum outflow (cfs)
D = Selected pipe diameter (in)
Z_{max} = Maximum expected water level (ft)
Z_{riser} = Recommended top of riser (ft above bottom of pond)

- Specify location, number and size of drawdown holes.
- Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07*)
- **Specify location, stage and length of emergency spillway to safely convey the maximum peak rate of runoff from the 25-year storm.** (*Appendix 8.07*)
- Configure dam or dike. (*Appendix 8.07*)
- Check and verify results.
- Prepare construction details and specifications.

METHOD 3

Note: This procedure allows more design control over the elements of the basin, and it considers more precisely such influences on settling behavior as the topography of the basin, and the shape of the hydrograph. When the trial basin is configured, the design storm must be routed through the facility to verify that settling performance is acceptable. It can be shown that settling performance is acceptable if, when the design hydrograph is routed through the sediment basin, the ratio of surface area to outflow exceeds 458 sq ft/cfs in all time steps.

Select basin location

Determine values of input data

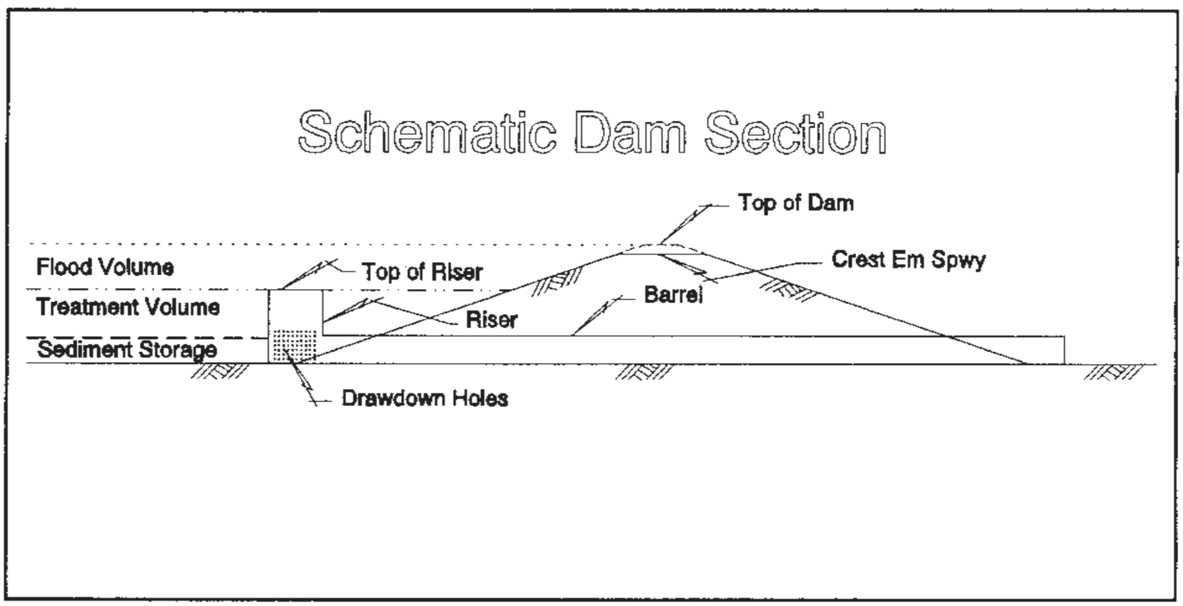
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  Time of concentration (min)
  Rational runoff coefficient
  SCS Curve Number
  Area available for basin (sq ft)
  Topography of the basin (contour map)

- Storm data

  2-yr, 6-hr rainfall depth (in)
  2-yr rainfall intensity for the time of concentration

Review the schematic of the riser/barrel and dike



Compute estimated volume of sediment to be stored before cleanout

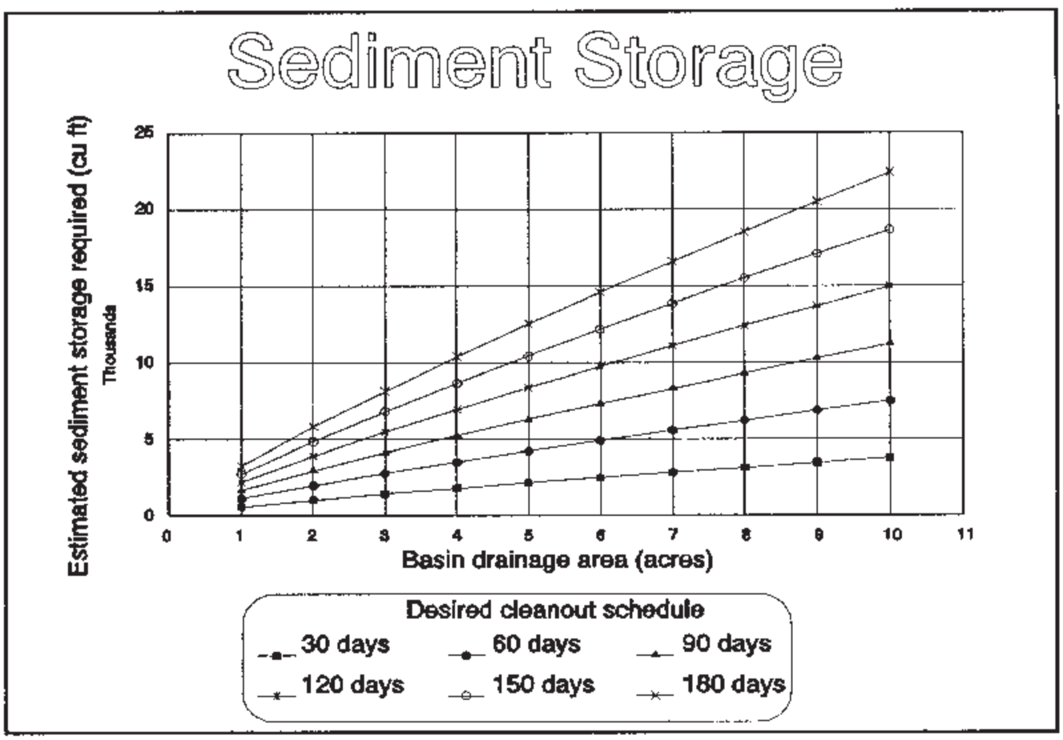
- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)

- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Formulate inflow hydrograph

Note: The inflow hydrograph should be formulated for the worst combination of cover conditions and contributory drainage area during the period of disturbance.

- Estimate the peak flow, Q_p, by Rational method (*Appendix 8.03*).
- Estimate the time to peak, T_p:

Determine the depth of runoff in the 2-yr, 6-hr storm using the SCS method.

$$S = \frac{1000}{CN} - 10$$

in which	S	=	Ultimate soil storage capacity (in)
	CN	=	SCS CN for basin drainage area

$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which	Q*	=	Estimated runoff depth (in)
	P	=	2-yr, 6-hr rainfall depth (in)
	S	=	Ultimate soil storage capacity (in)

Determine the time to peak.

$$T_p = \frac{43.5Q^*A}{Q_p}$$

in which	Q*	=	Estimated runoff depth (in)
	A	=	Drainage area (ac)
	Q_p	=	Estimated peak flow by Rational equation (cfs)
	T_p	=	Time to peak (min)

- For the routing, discharges at various times of interest can be computed for the estimated inflow hydrograph by the step function given below.

  For times of interest between 0 and 1.25 T_p:

$$Q = \frac{Q_p}{2}\left[1 - \cos\left(\frac{\prod t}{T_p}\right)\right]$$

  For times of interest longer than 1.25 T_p:

$$Q = 4.34\, Q_p\, exp\left[-1.30 \left(\frac{t}{T_p}\right)\right]$$

in which Q_p = Peak flow (cfs)
T_p = Time to peak (min)
t = Time of interest for which the flow is sought (min)
Q = Flow at time of interest (cfs)

  In these expressions, the argument of the cosine is in units of radians (the calculator should be in "radians mode"). The exponential function, *exp*, is frequently written as e^x, where x is the argument, as in *exp(x)*.

Determine the stage-storage relation representing basin topography

The stage-storage relation can be formulated as a graph or as a mathematical expression. The latter is more useful in this application because it includes in a straightforward manner both water volume information and surface area information as they relate to depth in a pond of complex shape. Stage is the depth of water relative to the bottom of the pond. Storage is the volume of storage at a given stage. Storage includes both water and sediment stored above the bottom of the pond.

A stage-storage function may be formulated for a given basin as follows:

- Compute a set of representative storage volumes at various stages by applying the average-end area method of volume computation vertically to the set of known contours that express the basin topography. Arrange them as a list of stages, Z, and associated storages, S. If one plots the logarithms of storage versus the logarithms of stage, the resulting graph is usually a remarkably straight line, even for the apparently complex topography of a natural draw or swale. This observation leads to the power-curve representation described below.
- The expression for the stage-storage function is

$$S=K_s Z^b$$

in which Z = Stage (ft above the pond bottom)
S = Storage (cu ft)
K_s and b are constants to be determined for the basin of interest.

- There are two reasonable ways to determine K_s and b from the stage-storage list. One is to use a linear regression routine applied to the logarithms of the data and back calculate the constants, K_s and b, from the regression results. The regression procedure is preferred because the shape information contained in a number of contours can be used to set the constants. Regression routines are included in many scientific calculators and spreadsheet programs. Consult the appropriate manual for details.

  The other method is to obtain an approximation of the constants algebraically by using stage and storage values from two of the contours. It is usually best to select one point near the maximum expected water-surface elevation and the other at about mid-depth. The precision of the result can be tested and improved by trial and error.

  Select two points on the stage-storage function as described above. Let the lower be point number one and the upper be point number two.

  Estimate the exponent:

$$b = \frac{\ln\left[\dfrac{S_2}{S_1}\right]}{\ln\left[\dfrac{Z_2}{Z_1}\right]}$$

  Estimate the coefficient:

$$K_s = \frac{S_2}{Z_2^{\,b}}$$

in which Z = Stage of the specified point (ft above pond bottom)
S = Storage of the specified point (cu ft)
K_s and b are constants determined for the basin of interest.

- Test the validity of the function by substitution of known values of storage to estimate the associated stages. If the estimated stages agree acceptably with the actual stages (say with 0.1 ft or so), the expression is valid. For that check, the expression can be reformulated as

$$Z = \left[\frac{S}{K_s}\right]^{\frac{1}{b}}$$

  in which the variables are the same as above.

- The stage-storage function can be reformulated to yield a stage-area function for use in determining pond surface area when the water surface is at any stage in the range used to determine the function. The relationship between pond surface area and discharge determines significantly the extent to which particles are settled.

  The stage-area function is

$$A_s = bK_sZ^{(b-1)}$$

in which Z = Stage of the specified point (ft above pond bottom)
S = Pond surface area (sq ft)
K_s and b are constants determined for the basin of interest.

Select the trial barrel

In order to reduce the number of riser/barrel selections, a trial barrel size can be obtained by using an approximate relationship that suggests an expected maximum water level in the pond during routing. This expression is based on the minimum surface-area-to-discharge-ratio, the estimated effect on the hydrograph of temporary storage of stormwater, and the effect of the topography of the pond on settling behavior.

- Determine three coefficients:

$$C_1 = K_s$$

$$C_2 = \frac{60bK_sT_p}{458}$$

$$C_3 = 60\,Q_pT_p + K_sZ_{sed}^b$$

in which
K_g = Stage-storage coefficient
b = Stage-storage exponent
Q_p = Peak inflow (cfs)
T_p = Time to peak (min)
Z_{sed} = Stage of top of sediment storage (ft)

- Using the coefficients, compute the expected maximum stage, Z, by trial and error:

$$C_1Z^b + C_2Z^{b-1} = C_3$$

- The expected peak outflow can be estimated from

$$Q_0 = Q_p - \frac{K_s(Z^b - Z^b_{sed})}{60T_p}$$

in which the variables are the same as above.

- Select the diameter of the barrel to deliver the expected maximum outflow, Q_o, when the water level is at the computed expected maximum, Z. Selection may be made by using commonly available culvert capacity charts and tables, or it may be sized by application of the orifice equation. (Note that the orifice equation applies when the pipe is *inlet controlled.* If the outlet is submerged by high tailwater, the barrel must be analyzed under *outlet control*.) The orifice equation may be modified for direct application as:

$$Q = 0.0437 C_D D^2 \sqrt{Z_{max} - \frac{D}{24}}$$

in which C_D = Coefficient of discharge (typically 0.6)
D = Pipe diameter (in)
Z_{max} = Expected maximum stage (ft)
Q = Discharge delivered by pipe (cfs)

Select the trial riser

The cross section of the riser should be at least 1.5 times the cross-sectional area of the barrel.

- Compute stage of top of riser.

The stage or elevation of the top of the riser should be sufficiently below the maximum expected water level to allow flow to enter the riser freely, but the top of the riser should not be set grossly below the maximum expected water level. It is recommended that the location of the top of the riser be computed from the maximum expected water level, Z_{max}, and an application of the weir equation:

$$Z_{riser} = Z_{max} - \left[\frac{Q_o}{0.86D}\right]^{\frac{2}{3}}$$

in which Q_o = Expected maximum outflow (cfs)
D = Selected pipe diameter (in)
Z_{max} = Maximum expected water level (ft)
Z_{riser} = Recommended top of riser (ft above bottom of pond)

Verify the design by flood routing and settling analysis

The system can be analyzed by one of several commonly available routing procedures. Analysis of settling behavior can be done by computing water-surface area at each time step in the routing and verifying in all time steps that surface area divided by basin outflow exceeds 458 sq ft/cfs. The following should be considered in the routing:

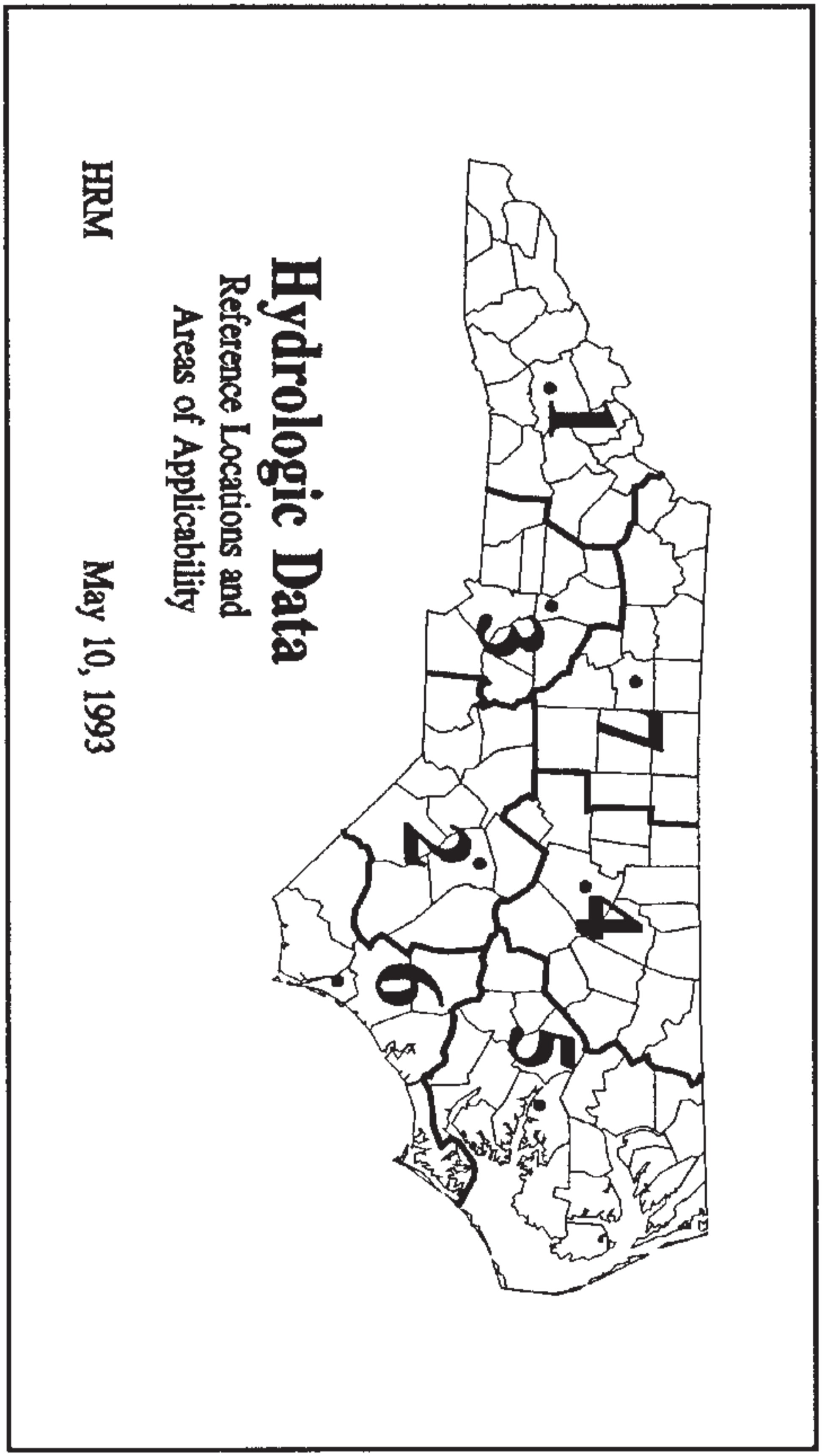
- Points on the inflow hydrograph can be computed using the inflow hydrograph equations described above.
- Base stage-storage data on the stage-storage function.
- Develop stage-discharge data for the riser/barrel selected.
- The initial conditions (at time = 0) should reflect that the sediment storage is full. Set initial water level at the top of the sediment storage, and set initial value of water storage equal to the volume of sediment stored.
- The value of water-surface area can be computed at any time step from the stage-area function using the current stage.
- Other hydrograph formulation procedures, such as SCS TR-55, can be incorporated into the above methodology as follows. If a hydrograph is based on the 2-yr, 24-hr storm, ignore the insignificant low flow early and late in the storm. Retain the portion of the hydrograph from the time of significant rise of the rising limb through the falling limb. Let T_p be as measured from the time of significant rise of the rising limb to the time of peak. Then use Q_p and T_p in the above computations.

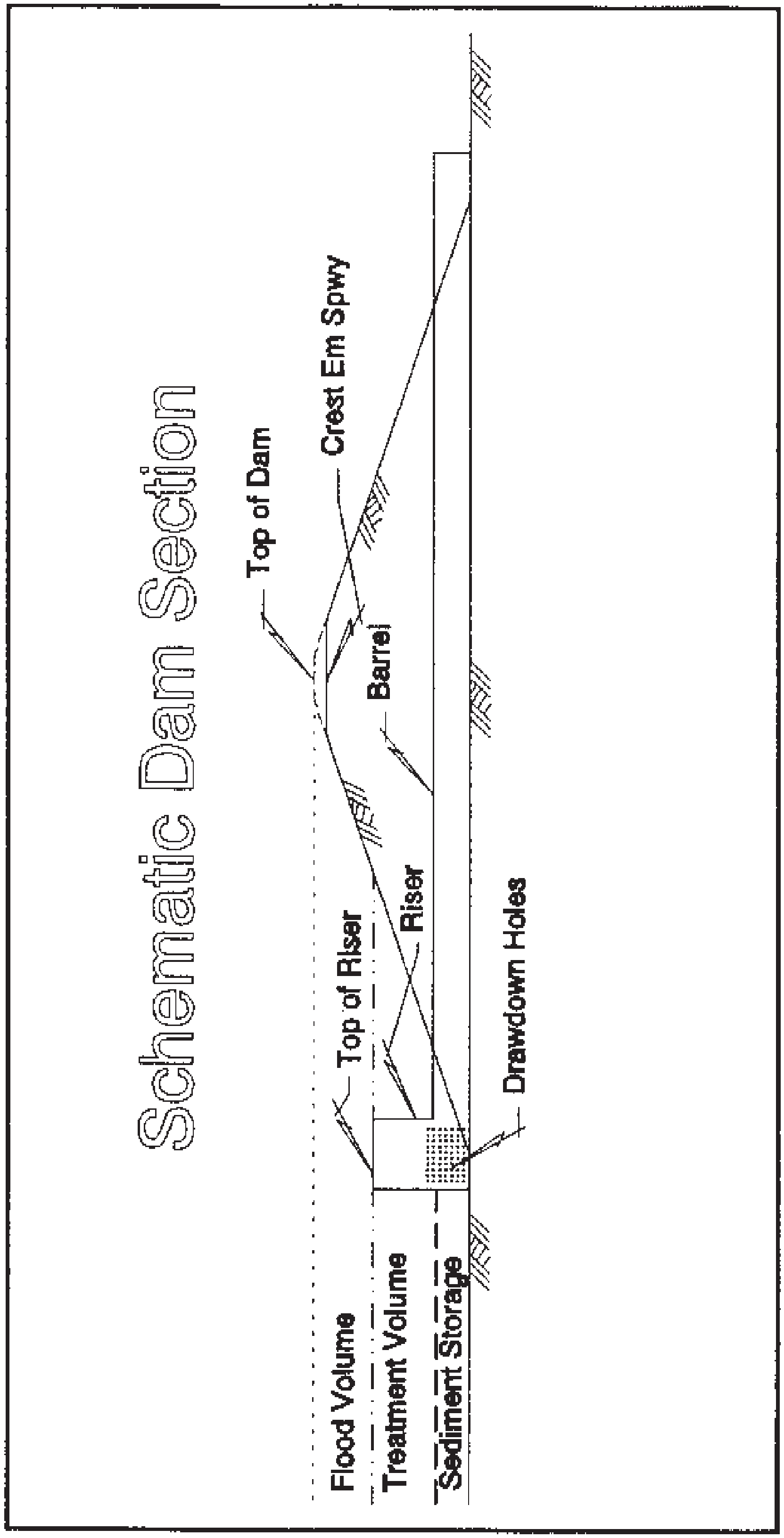
Specify location, number and size of drawdown holes

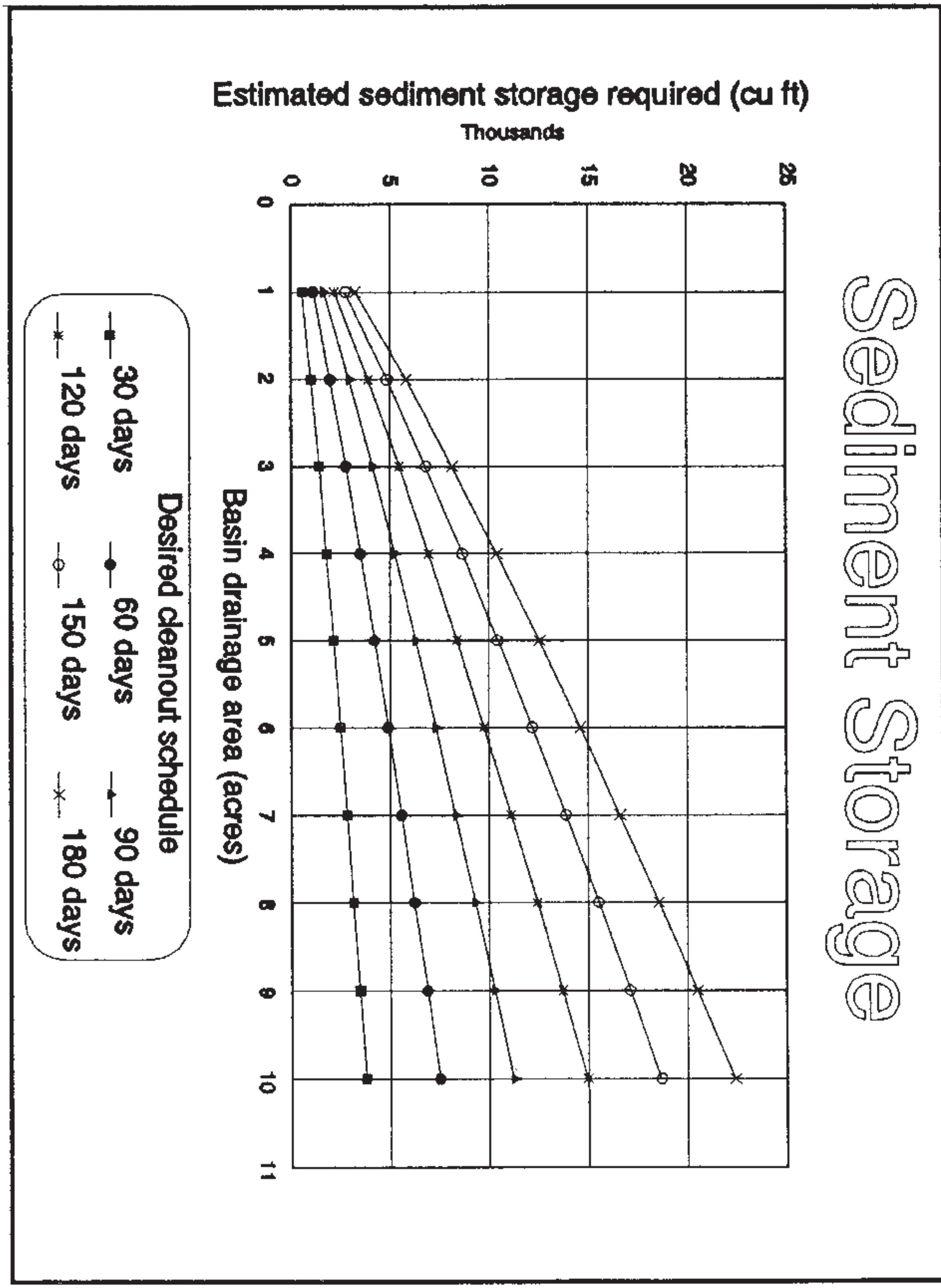
Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07*)

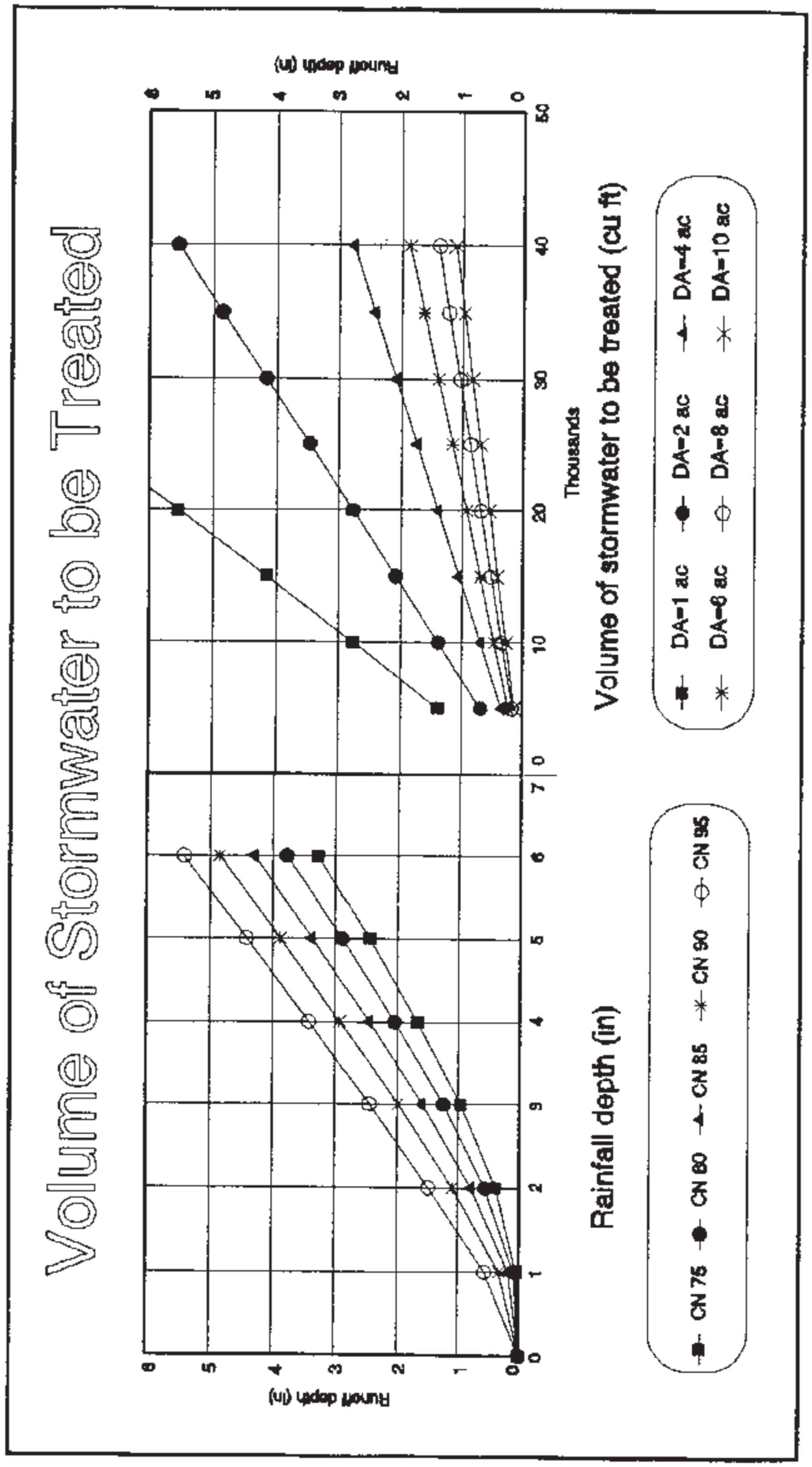
Complete detailed design

- **Specify location, stage and length of emergency spillway to safely convey the maximum peak rate of runoff from the 25-year storm.** (*Appendix 8.07*)
- Configure dam or dike. (*Appendix 8.07*)
- Check and verify results.
- Prepare construction details and specifications.


Hydrologic Data
Reference Locations and
Areas of Applicability
HRM
May 10, 1993
1
2
3
4
5
6
7


Schematic Dam Section
Top of Dam
Crest Em Spwy
Barrel
Riser
Top of Riser
Drawdown Holes
Flood Volume
Treatment Volume
Sediment Storage


Sediment Storage
Estimated sediment storage required (cu ft)
Thousands
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
9
10
11
Basin drainage area (acres)
Desired cleanout schedule
30 days
60 days
90 days
120 days
150 days
180 days


Volume of Stormwater to be Treated
Runoff depth (in)
Rainfall depth (in)
CN 75
CN 80
CN 85
CN 90
CN 95
Volume of stormwater to be treated (cu ft)
Thousands
DA=1 ac
DA=2 ac
DA=4 ac
DA=6 ac
DA=8 ac
DA=10 ac

8.08

THE SEDIMENTATION CONTROL LAW

The following pages contain the complete text of the North Carolina Sedimentation Pollution Control Act of 1973. The Act creates the North Carolina Sedimentation Control Commission and authorizes this commission to adopt and enforce rules and regulations for control of erosion and sedimentation from land-disturbing activities. The Act also establishes mandatory standards for land-disturbing activities, specifies the authority of the Secretary of the Department of Environment, Health, and Natural Resources, and encourages the development of educational activities and local erosion control programs. Finally, the Act establishes civil and criminal penalties with injunctive relief for violation of the State Program.

8

Sedimentation Pollution Control Act of 1973

(As Amended through 2005)

North Carolina General Statutes Chapter 113A Article 4

§ 113A-50. Short title.

This Article shall be known as and may be cited as the "Sedimentation Pollution Control Act of 1973." (1973, c. 392, s. 1.)

§ 113A-51. Preamble.

The sedimentation of streams, lakes and other waters of this State constitutes a major pollution problem. Sedimentation occurs from the erosion or depositing of soil and other materials into the waters, principally from construction sites and road maintenance. The continued development of this State will result in an intensification of pollution through sedimentation unless timely and appropriate action is taken. Control of erosion and sedimentation is deemed vital to the public interest and necessary to the public health and welfare, and expenditures of funds for erosion and sedimentation control programs shall be deemed for a public purpose. It is the purpose of this Article to provide for the creation, administration, and enforcement of a program and for the adoption of minimal mandatory standards which will permit development of this State to continue with the least detrimental effects from pollution by sedimentation. In recognition of the desirability of early coordination of sedimentation control planning, it is the intention of the General Assembly that preconstruction conferences be held among the affected parties, subject to the availability of staff.(1973, c. 392, s. 2; 1975, c. 647, s. 3.)

§ 113A-52. Definitions.

As used in this Article, unless the context otherwise requires:

(1) Repealed by Session Laws 1973, c. 1417, s. 1.

(1a) "Affiliate" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "affiliate" as a person that directly, or indirectly through one or more intermediaries, controls, is controlled by, or is under common control of another person.

(2) "Commission" means the North Carolina Sedimentation Control Commission.

(3) "Department" means the North Carolina Department of Environment and Natural Resources.

(4) "District" means any Soil and Water Conservation District created pursuant to Chapter 139, North Carolina General Statutes.

(5) "Erosion" means the wearing away of land surface by the action of wind, water, gravity, or any combination thereof.

(6) "Land-disturbing activity" means any use of the land by any person in residential, industrial,

educational, institutional or commercial development, highway and road construction and maintenance that results in a change in the natural cover or topography and that may cause or contribute to sedimentation.

(7) "Local government" means any county, incorporated village, town, or city, or any combination of counties, incorporated villages, towns, and cities, acting through a joint program pursuant to the provisions of this Article.

(7a) "Parent" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "parent" as an affiliate that directly, or indirectly through one or more intermediaries, controls another person.

(8) "Person" means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, interstate body, or other legal entity.

(9) "Secretary" means the Secretary of Environment and Natural Resources.

(10) "Sediment" means solid particulate matter, both mineral and organic, that has been or is being transported by water, air, gravity, or ice from its site of origin.

(10a) Subsidiary" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "subsidiary" as an affiliate that is directly, or indirectly through one or more intermediaries, controlled by another person.

(10b) "Tract" means all contiguous land and bodies of water being disturbed or to be disturbed as a unit, regardless of ownership.

(11) "Working days" means days exclusive of Saturday and Sunday during which weather conditions or soil conditions permit land-disturbing activity to be undertaken.(1973, c. 392, s. 3; c. 1417, s. 1; 1975, c. 647, s. 1; 1977, c. 771, s. 4; 1989, c. 179, s. 1; c. 727, s. 218(60); 1989 (Reg. Sess., 1990), c. 1004, s. 19(b); 1991, c. 275, s. 1; 1993 (Reg. Sess., 1994), c. 776, s. 1; 1997-443, s. 11A.119(a).)

§ 113A-52.01. Applicability of this Article.

This Article shall not apply to the following land-disturbing activities:

(1) Activities, including the breeding and grazing of livestock, undertaken on agricultural land for the production of plants and animals useful to man, including, but not limited to:

a. Forages and sod crops, grains and feed crops, tobacco, cotton, and peanuts.

b. Dairy animals and dairy products.

c. Poultry and poultry products.

d. Livestock, including beef cattle, llamas, sheep, swine, horses, ponies, mules, and goats.

e. Bees and apiary products.

f. Fur producing animals.

(2) Activities undertaken on forestland for the production and harvesting of timber and timber products and conducted in accordance with best management practices set out in Forest Practice Guidelines Related to Water Quality, as adopted by the Department.

(3) Activities for which a permit is required under the Mining Act of 1971, Article 7 of Chapter 74 of the General Statutes.

(4) For the duration of an emergency, activities essential to protect human life.(1993 (Reg. Sess., 1994), c. 776, s. 2; 1997-84, s. 1.)

§ 113A-52.1. Forest Practice Guidelines.

(a) The Department shall adopt Forest Practice Guidelines Related to Water Quality (best management practices). The adoption of Forest Practices Guidelines Related to Water Quality under this section is subject to the provisions of Chapter 150B of the General Statutes.

(b) If land-disturbing activity undertaken on forestland for the production and harvesting of timber and timber products is not conducted in accordance with Forest Practice Guidelines Related to Water Quality, the provisions of this Article shall apply to such activity and any related land-disturbing activity on the tract.

(c) The Secretary shall establish a Technical Advisory Committee to assist in the development and periodic review of Forest Practice Guidelines Related to Water Quality. The Technical Advisory Committee shall consist of one member from the forest products industry, one member who is a consulting forester, one member who is a private landowner knowledgeable in forestry, one member from the United States Forest Service, one member from the academic community who is knowledgeable in forestry, one member who is knowledgeable in erosion and sedimentation control, one member who is knowledgeable in wildlife management, one member who is knowledgeable in marine fisheries management, one member who is knowledgeable in water quality, and one member from the conservation community. (1989, c. 179, s. 2.)

§ 113A-53. Repealed by Session Laws 1973, c. 1262, s. 41.

§ 113A-54. Powers and duties of the Commission.

(a) The Commission shall, in cooperation with the Secretary of Transportation and other appropriate State and federal agencies, develop, promulgate, publicize, and administer a comprehensive State erosion and sedimentation control program.

(b) The Commission shall develop and adopt and shall revise as necessary from time to time, rules and regulations for the control of erosion and sedimentation resulting from land- disturbing activities. The Commission shall adopt or revise its rules and regulations in accordance with Chapter 150B of the General Statutes.

(c) The rules and regulations adopted pursuant to G.S. 113A-54(b) for carrying out the erosion and sedimentation control program shall:

(1) Be based upon relevant physical and developmental information concerning the watershed and drainage basins of the State, including, but not limited to, data relating to land use, soils, hydrology, geology, grading, ground cover, size of land area being disturbed, proximate water bodies and their characteristics, transportation, and public facilities and services;

(2) Include such survey of lands and waters as may be deemed appropriate by the Commission or required by any applicable laws to identify those areas, including multijurisdictional and watershed areas, with critical erosion and sedimentation problems; and

(3) Contain conservation standards for various types of soils and land uses, which standards shall include criteria and alternative techniques and methods for the control of erosion and sedimentation resulting from land-disturbing activities.

(d) In implementing the erosion and sedimentation control program, the Commission shall:

(1) Assist and encourage local governments in developing erosion and sedimentation control programs and, as a part of this assistance, the Commission shall develop a model local erosion and sedimentation control ordinance. The Commission shall approve, approve as modified, or disapprove local programs submitted to it pursuant to G.S. 113A-60.

(2) Assist and encourage other State agencies in developing erosion and sedimentation control programs to be administered in their jurisdictions. The Commission shall approve, approve as modified, or disapprove programs submitted pursuant to G.S. 113A-56 and from time to time shall review these programs for compliance with rules adopted by the Commission and for adequate enforcement.

(3) Develop recommended methods of control of sedimentation and prepare and make available for distribution publications and other materials dealing with sedimentation control techniques appropriate for use by persons engaged in land-disturbing activities, general educational materials on erosion and sedimentation control, and instructional materials for persons involved in the enforcement of this Article and erosion and sedimentation control rules, ordinances, regulations, and plans.

(4) Require submission of erosion and sedimentation control plans by those responsible for initiating land-disturbing activities for approval prior to commencement of the activities.

(e) To assist it in developing the erosion and sedimentation control program required by this Article, the Commission is authorized to appoint an advisory committee consisting of technical experts in the fields of water resources, soil science, engineering, and landscape architecture.

(f) Repealed by Session Laws 1987, c. 827, s. 10, effective August 13, 1987. (1973, c. 392, s. 5; c. 1331, s. 3; c. 1417, s. 6; 1975, 2nd Sess., c. 983, s. 74; 1977, c. 464, s. 35; 1979, c. 922, s. 2; 1983 (Reg. Sess., 1984), c. 1014, ss. 1, 2; 1987, c. 827, s. 10; 1987 (Reg. Sess., 1988), c. 1000, s. 3; 1989, c. 676, s. 1; 1993 (Reg. Sess., 1994), c. 776, s. 3; 2002-165, ss. 2.2, 2.3.)

§ 113A-54.1. Approval of erosion control plans.

(a) A draft erosion and sedimentation control plan must contain the applicant's address and, if the applicant is not a resident of North Carolina, designate a North Carolina agent for the purpose of receiving notice from the Commission or the Secretary of compliance or noncompliance with the plan, this Article, or any rules adopted pursuant to this Article. If the applicant is not the owner of the land to be disturbed, the draft erosion and sedimentation control plan must include the owner's written consent for the applicant to submit a draft erosion and sedimentation control plan and to conduct the anticipated land-disturbing activity. The Commission shall approve, approve with modifications, or disapprove a draft erosion and sedimentation control plan for those land-disturbing activities for which prior plan approval is required within 30 days of receipt. The Commission shall condition approval of a draft erosion and sedimentation control plan upon the applicant's compliance with federal and State water quality laws, regulations, and rules. Failure to approve, approve with modifications, or disapprove a completed draft erosion and sedimentation control plan within 30 days of receipt shall be deemed approval of the plan. If the Commission disapproves a draft erosion and sedimentation control plan or a revised erosion and sedimentation control plan, it must state in writing the specific reasons that the plan was disapproved. Failure to approve, approve with modifications, or disapprove a revised erosion and sedimentation control plan within 15 days of receipt shall be deemed approval of the plan. The Commission may establish an expiration date for erosion and sedimentation control plans approved under this Article.

(b) If, following commencement of a land-disturbing activity pursuant to an approved erosion and sedimentation control plan, the Commission determines that the plan is inadequate to meet the requirements of this Article, the Commission may require any revision of the plan that is necessary to comply with this

Article. Failure to approve, approve with modifications, or disapprove a revised erosion and sedimentation control plan within 15 days of receipt shall be deemed approval of the plan.

(c) The Commission shall disapprove an erosion and sedimentation control plan 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. The Director of the Division of Land Resources may disapprove an erosion and sedimentation control plan upon finding that an applicant or a parent, subsidiary, or other affiliate of the applicant:

(1) Is conducting or has conducted land-disturbing activity without an approved plan, or has received notice of violation of a plan previously approved by the Commission or a local government pursuant to this Article and has not complied with the notice within the time specified in the notice;

(2) Has failed to pay a civil penalty assessed pursuant to this Article or a local ordinance adopted pursuant to this Article by the time the payment is due;

(3) Has been convicted of a misdemeanor pursuant to G.S. 113A-64(b) or any criminal provision of a local ordinance adopted pursuant to this Article; or

(4) Has failed to substantially comply with State rules or local ordinances and regulations adopted pursuant to this Article.

(d) In the event that an erosion and sedimentation control plan is disapproved by the Director pursuant to subsection (c) of this section, the Director shall state in writing the specific reasons that the plan was disapproved. The applicant may appeal the Director's disapproval of the plan to the Commission. For purposes of this subsection and subsection (c) of this section, an applicant's record may be considered for only the two years prior to the application date. (1989, c. 676, s. 2; 1993 (Reg. Sess., 1994), c. 776, s. 4; 1998-221, s. 1.11(a); 1999-379, s. 1; 2005-386, s. 7.1.)

§ 113A-54.2. Approval Fees.

(a) The Commission may establish a fee schedule for the review and approval of erosion and sedimentation control plans under this Article. In establishing the fee schedule, the Commission shall consider the administrative and personnel costs incurred by the Department for reviewing the plans and for related compliance activities. An application fee may not exceed fifty dollars ($50.00) per acre of disturbed land shown on an erosion and sedimentation control plan or of land actually disturbed during the life of the project.

(b) The Sedimentation Account is established as a nonreverting account within the Department. Fees collected under this section shall be credited to the Account and shall be applied to the costs of administering this Article.

(c) Repealed by Session Laws 1991 (Reg. Sess., 1992), c. 1039, s. 3, effective July 24, 1992.

(d) This section may not limit the existing authority of local programs approved pursuant to this Article to assess fees for the approval of erosion and sedimentation control plans. (1989 (Reg. Sess., 1990), c. 906, s. 1; 1991 (Reg. Sess., 1992), c. 1039, s. 3; 1993 (Reg. Sess., 1994), c. 776, s. 5; 1999-379, s. 5; 2002-165, s. 2.4.)

§ 113A-55. Authority of the Secretary.

The sedimentation control program developed by the Commission shall be administered by the Secretary under the direction of the Commission. To this end the Secretary shall employ the necessary clerical, technical, and administrative personnel, and assign tasks to the various divisions of the Department for the purpose of implementing this Article. The Secretary may bring enforcement actions pursuant to G.S.

113A-64 and G.S. 113A-65. The Secretary shall make final agency decisions in contested cases that arise from civil penalty assessments pursuant to G.S. 113A-64. (1973, c. 392, s. 6; c. 1417, s. 3; 1993 (Reg. Sess., 1994), c. 776, s. 6.)

§ 113A-56. Jurisdiction of the Commission.

(a) The Commission shall have jurisdiction, to the exclusion of local governments, to adopt rules concerning land-disturbing activities that are:

(1) Conducted by the State;

(2) Conducted by the United States;

(3) Conducted by persons having the power of eminent domain;

(4) Conducted by local governments; or

(5) Funded in whole or in part by the State or the United States.

(b) The Commission may delegate the jurisdiction conferred by G.S. 113A- 56(a), in whole or in part, to any other State agency that has submitted an erosion and sedimentation control program to be administered by it, if the program has been approved by the Commission as being in conformity with the general State program.

(c) The Commission shall have concurrent jurisdiction with local governments over all other land-disturbing activities. (1973, c. 392, s. 7; c. 1417, s. 4; 1987, c. 827, s. 130; 1987 (Reg. Sess., 1988), c. 1000, s. 4; 2002-165, s. 2.5.)

§ 113A-57. Mandatory standards for land-disturbing activity.

No land-disturbing activity subject to this Article shall be undertaken except in accordance with the following mandatory requirements:

(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-isturbing activity in connection with the construction of facilities to be located on, over, or under a lake or natural watercourse.

(2) The angle for graded slopes and fills shall be no greater than the angle that can be retained by vegetative cover or other adequate erosion-control devices or structures. In any event, slopes left exposed will, within 21 calendar days of completion of any phase of grading, be planted or otherwise provided with temporary or permanent ground cover, devices, or structures sufficient to restrain erosion.

(3) Whenever land-disturbing activity that will disturb more than one acre is undertaken on a tract, the person conducting the land-disturbing activity shall install erosion and sedimentation control devices and practices that are sufficient to retain the sediment generated by the land-disturbing activity within the boundaries of the tract during construction upon and development of the tract, and shall plant or otherwise provide a permanent ground cover sufficient to restrain erosion after completion of construction or development within a time

period to be specified by rule of the Commission.

(4) No person shall initiate any land-disturbing activity that will disturb more than one acre on a tract unless, 30 or more days prior to initiating the activity, an erosion and sedimentation control plan for the activity is filed with the agency having jurisdiction and approved by the agency. An erosion and sedimentation control plan may be filed less than 30 days prior to initiation of a land-disturbing activity if the plan is submitted under an approved express permit program, and the land-disturbing activity may be initiated and conducted in accordance with the plan once the plan has been approved. The agency having jurisdiction shall forward to the Director of the Division of Water Quality a copy of each erosion and sedimentation control plan for a land-disturbing activity that involves the utilization of ditches for the purpose of de-watering or lowering the water table of the tract. (1973, c. 392, s. 8; c. 1417, s. 5; 1975, c. 647, s. 2; 1979, c. 564; 1983 (Reg. Sess., 1984), c. 1014, s. 3; 1987, c. 827, s. 131; 1989, c. 676, s. 3; 1991, c. 275, s. 2; 1998-99, s. 1; 1999-379, s. 2; 2002-165, s. 2.6; 2005-386, s. 7.2; 2005-443, s. 2.)

§ 113A-58. Enforcement authority of the Commission.

In implementing the provisions of this Article the Commission is authorized and directed to:

(1) Inspect or cause to be inspected the sites of land-disturbing activities to determine whether applicable laws, regulations or erosion and sedimentation control plans are being complied with;

(2) Make requests, or delegate to the Secretary authority to make requests, of the Attorney General or solicitors for prosecutions of violations of this Article. (1973, c. 392, s. 9; 2002-165, s. 2.7.)

§ 113A-59. Educational activities.

The Commission in conjunction with the soil and water conservation districts, the North Carolina Agricultural Extension Service, and other appropriate State and federal agencies shall conduct educational programs in erosion and sedimentation control, such programs to be directed towards State and local governmental officials, persons engaged in land-disturbing activities, and interested citizen groups. (1973, c. 392, s.10.)

§ 113A-60. Local erosion and sedimentation control programs.

(a) A local government may submit to the Commission for its approval an erosion and sedimentation control program for its jurisdiction, and to this end local governments are authorized to adopt ordinances and regulations necessary to establish and enforce erosion and sedimentation control programs. Local governments are authorized to create or designate agencies or subdivisions of local government to administer and enforce the programs. An ordinance adopted by a local government shall at least meet and may exceed the minimum requirements of this Article and the rules adopted pursuant to this Article. Two or more units of local government are authorized to establish a joint program and to enter into any agreements that are necessary for the proper administration and enforcement of the program. The resolutions establishing any joint program must be duly recorded in the minutes of the governing body of each unit of local government participating in the program, and a certified copy of each resolution must be filed with the Commission.

(b) The Commission shall review each program submitted and within 90 days of receipt thereof shall notify the local government submitting the program that it has been approved, approved with modifications, or disapproved. The Commission shall only approve a program upon determining that its standards equal or exceed those of this Article and rules adopted pursuant to this Article.

(c) If the Commission determines that any local government is failing to administer or enforce an approved erosion and sedimentation control program, it shall notify the local government in writing and shall specify the deficiencies of administration and enforcement. If the local government has not taken corrective action within 30 days of receipt of notification from the Commission, the Commission shall assume administration and enforcement of the program until such time as the local government indicates its willingness and ability to resume administration and enforcement of the program. (1973, c. 392, s. 11; 1993 (Reg. Sess., 1994), c. 776, s. 7; 2202-165, s. 2.8.)

§ 113A-61. Local approval of erosion and sedimentation control plans.

(a) For those land-disturbing activities for which prior approval of an erosion and sedimentation control plan is required, the Commission may require that a local government that administers an erosion and sedimentation control program approved under G.S. 113A-60 require the applicant to submit a copy of the erosionand sedimentation control plan to the appropriate soil and water conservation district or districts at the same time the applicant submits the erosion and sedimentation control plan to the local government for approval. The soil and water conservation district or districts shall review the plan and submit any comments and recommendations to the local government within 20 days after the soil and water conservation district received the erosion and sedimentation control plan or within any shorter period of time as may be agreed upon by the soil and water conservation district and the local government. Failure of a soil and water conservation district to submit comments and recommendations within 20 days or within agreed upon shorter period of time shall not delay final action on the proposed plan by the local government.

(b) Local governments shall review each erosion and sedimentation control plan submitted to them and within 30 days of receipt thereof shall notify the person submitting the plan that it has been approved, approved with modifications, or disapproved. A local government shall only approve a plan upon determining that it complies with all applicable State and local regulations for erosion and sedimentation control.

(b1) A local government shall condition approval of a draft erosion and sedimentation control plan upon the applicant's compliance with federal and State water quality laws, regulations, and rules. A local government shall disapprove an erosion and sedimentation control plan 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. A local government may disapprove an erosion and sedimentation control plan upon finding that an applicant or aparent, subsidiary, or other affiliate of the applicant:

(1) Is conducting or has conducted land-disturbing activity without an approved plan, or has received notice of violation of a plan previously approved by the Commission or a local government pursuant to this Article and has not complied with the notice within the time specified in the notice.

(2) Has failed to pay a civil penalty assessed pursuant to this Article or a local ordinance adopted pursuant to this Article by the time the payment is due.

(3) Has been convicted of a misdemeanor pursuant to G.S. 113A-64(b) or any criminal provision of a local ordinance adopted pursuant to this Article.

(4) Has failed to substantially comply with State rules or local ordinances and regulations adopted pursuant to this Article.

(b2) In the event that an erosion and sedimentation control plan is disapproved by a local government pursuant to subsection (b1) of this section, the local government shall so notify the Director of the Division of Land Resources within 10 days of such disapproval. The local government shall advise the applicant and the Director in writing as to the specific reasons that the plan was disapproved. Notwithstanding the provisions of subsection (c) of this section, the applicant may appeal the local government's disapproval of the plan directly to the Commission. For purposes of this subsection and subsection (b1) of this section, an applicant's record may be considered for only the two years prior to the application date.

(c) The disapproval or modification of any proposed erosion and sedimentation control plan by a local government shall entitle the person submitting the plan to a public hearing if such person submits written demand for a hearing within 15 days after receipt of written notice of the disapproval or modification. The hearings shall be conducted pursuant to procedures adopted by the local government. If the local government upholds the disapproval or modification of a proposed erosion and sedimentation control plan following the public hearing, the person submitting the erosion and sedimentation control plan shall be entitled to appeal the local government's action disapproving or modifying the plan to the Commission. The Commission, by regulation, shall direct the Secretary to appoint such employees of the Department as may be necessary to hear appeals from the disapproval or modification of erosion and sedimentation control plans by local governments. In addition to providing for the appeal of local government decisions disapproving or modifying erosion and sedimentation control plans to designated employees of the Department, the Commission shall designate an erosion and sedimentation control plan review committee consisting of three members of the Commission. The person submitting the erosion and sedimentation control plan may appeal the decisionof an employee of the Department who has heard an appeal of a local government action disapproving or modifying an erosion and sedimentation control plan to the erosion and sedimentation control plan review committee of the Commission. Judicial review of the final action of the erosion and sedimentation control plan review committee of the Commission may be had in the superior court of the county in which the local government is situated.

(d) Repealed by Session Laws 1989, c. 676, s. 4, effective October 1, 1989. (1973, c. 392, s. 12; 1979, c. 922, s. 1; 1989, c. 676, s. 4; 1993 (Reg. Sess., 1994), c. 776, ss. 8, 9; 1998-221, s. 1.11(b); 1999-379, s. 3; 2002-165, s. 2.9.)

§ 113A-61.1. Inspection of land-disturbing activity; notice of violation.

(a) The Commission, a local government that administers an erosion and sedimentation controlprogram approved under G.S. 113A-60, or other approving authority shall provide for inspection of land-disturbing activities to ensure compliance with this Article and to determine whether the measures required in an erosion and sedimentation control plan are effective in controlling erosion and sedimentation resulting from the land-disturbing activity. Notice of this right of inspection shall be included in the certificate of approval of each erosion and sedimentation control plan.

(b) No person shall willfully resist, delay, or obstruct an authorized representative of the Commission, an authorized representative of a local government, or an employee or an agent of the Department while the representative, employee, or agent is inspecting or attempting to inspect a land-disturbing activity under this section.

(c) If the Secretary, a local government that administers an erosion and sedimentation control program approved under G.S. 113A-60, or other approving authority determines that the person engaged in the land-disturbing activity has failed to comply with this Article, the Secretary, local government, or other approving authority shall immediately serve a notice of violation upon that person. The notice may be served by any means authorized under G.S. 1A- 1, Rule 4. A notice of violation shall specify a date by which the person must comply with this Article and inform the person of the actions that need to be taken to comply with this Article. Any person who fails to comply within the time specified is subject to additional civil and criminal penalties for a continuing violation as provided in G.S. 113A-64. (1989, c. 676, s. 5; 1993 (Reg. Sess., 1994), c. 776, s. 10; 1999-379, s. 6; 2002-165, s. 2.10.)

§ 113A-62. Cooperation with the United States.

The Commission is authorized to cooperate and enter into agreements with any agency of the United

States government in connection with plans for erosion and sedimentation control with respect to land-disturbing activities on lands that are under the jurisdiction of such agency. (1973, c. 392, s. 13; 2002-165, s. 2.11.)

§ 113A-63. Financial and other assistance.

The Commission and local governments are authorized to receive from federal, State, and other public and private sources financial, technical, and other assistance for use in accomplishing the purposes of this Article.(1973, c. 392, s. 14.)

§ 113A-64. Penalties.

(a) Civil Penalties. --

(1) Any person who violates any of the provisions of this Article or any ordinance, rule, or order adopted or issued pursuant to this Article by the Commission or by a local government, or who initiates or continues a land-disturbing activity for which an erosion and sedimentation control plan is required except in accordance with the terms, conditions, and provisions of an approved plan, is subject to a civil penalty. The maximum civil penalty for a violation is five thousand dollars ($5,000). A civil penalty may be assessed from the date of the violation. Each day of a continuing violation shall constitute a separate violation.

(2) The Secretary or a local government that administers an erosion and sedimentation control-program approved under G.S. 113A-60 shall determine the amount of the civil penalty and shall notify the person who is assessed the civil penalty of the amount of the penalty and the reason for assessing the penalty. The notice of assessment shall be served by any means authorized under G.S. 1A-1, Rule 4, and shall direct the violator to either pay the assessment or contest the assessment within 30 days by filing a petition for a contested case under Article 3 of Chapter 150B of the General Statutes. If a violator does not pay a civil penalty assessed by the Secretary within 30 days after it is due, the Department shall request the Attorney General to institute a civil action to recover the amount of the assessment. If a violator does not pay a civil penalty assessed by a local government within 30 days after it is due, the local government may institute a civil action to recover the amount of the assessment. The civil action may be brought in the superior court of any county where the violation occurred or the violator's residence or principal place of business is located. A civil action must be filed within three years of the date the assessment was due. An assessment that is not contested is due when the violator is served with a notice of assessment. An assessment that is contested is due at the conclusion of the administrative and judicial review of the assessment.

(3) In determining the amount of the penalty, the Secretary shall consider the degree and extent of harm caused by the violation, the cost of rectifying the damage, the amount of money the violator saved by noncompliance, whether the violation was committed willfully and the prior record of the violator in complying or failing to comply with this Article.

(4) Repealed by Session Laws 1993 (Reg. Sess., 1994), c. 776, s. 11, effective October 1, 1994.

(5) The clear proceeds of civil penalties collected by the Department or other State agency under this subsection shall be remitted to the Civil Penalty and Forfeiture Fund in accordance with G.S. 115C-457.2. Civil penalties collected by a local government under this subsection shall be credited to the general fund of the local government as nontax revenue.

(b) Criminal Penalties. -- Any person who knowingly or willfully violates any provision of this Article or any ordinance, rule, regulation, or order duly adopted or issued by the Commission or a local government, or who knowingly or willfully initiates or continues a land- disturbing activity for which an erosion and sedimentation control plan is required, except in accordance with the terms, conditions, and provisions of an approved plan, shall be guilty of a Class 2 misdemeanor that may include a fine not to exceed five thousand dollars ($5,000). (1973, c. 392, s. 15; 1977, c. 852; 1987, c. 246, s. 3; 1987 (Reg. Sess., 1988), c. 1000, s. 5; 1989, c. 676, s. 6; 1991, c. 412, s. 2; c. 725, s. 5; 1993, c. 539, s. 873; 1994, Ex. Sess., c. 24, s. 14(c); 1993 (Reg. Sess., 1994), c. 776, s. 11; 1998-215, s. 52; 1999-379, s. 4; 2002-165, s. 2.12.)

§ 113A-64.1. Restoration of areas affected by failure to comply.

The Secretary or a local government that administers a local erosion and sedimentation control program approved under G.S. 113A-60 may require a person who engaged in a land-disturbing activity and failed to retain sediment generated by the activity, as required by G.S. 113A-57(3), to restore the waters and land affected by the failure so as to minimize the detrimental effects of the resulting pollution by sedimentation. This authority is in addition to any other civil or criminal penalty or injunctive relief authorized under this Article. (1993 (Reg. Sess., 1994), c. 776, s. 12; 2002-165, s. 2.13.)

§ 113A-65. Injunctive relief.

(a) Violation of State Program. -- Whenever the Secretary has reasonable cause to believe that any person is violating or is threatening to violate the requirements of this Article he may, either before or after the institution of any other action or proceeding authorized by this Article, institute a civil action for injunctive relief to restrain the violation or threatened violation. The action shall be brought in the superior court of the county in which the violation or threatened violation is occurring or about to occur, and shall be in the name of the State upon the relation of the Secretary.

(b) Violation of Local Program. -- Whenever the governing body of a local government having jurisdiction has reasonable cause to believe that any person is violating or is threatening to violate any ordinance, rule, regulation, or order adopted or issued by the local government pursuant to this Article, or any term, condition or provision of an erosion and sedimentation control plan over which it has jurisdiction, may, either before or after the institution of any other action or proceeding authorized by this Article, institute a civil action in the name of the local government for injunctive relief to restrain the violation or threatened violation. The action shall be brought in the superior court of the county in which the violation is occurring or is threatened.

(c) Abatement, etc., of Violation. -- Upon determination by a court that an alleged violation is occurring or is threatened, the court shall enter any order or judgment that is necessary to abate the violation, to ensure that restoration is performed, or to prevent the threatened violation. The institution of an action for injunctive relief under subsections (a) or (b) of this section shall not relieve any party to the proceeding from any civil or criminal penalty prescribed for violations of this Article. (1973, c. 392, s. 16; 1993 (Reg. Sess., 1994), c. 776, s. 13; 2002-165, s. 2.14.)

§ 113A-65.1. Stop-work orders.

(a) The Secretary may issue a stop-work order if he finds that a land-disturbing activity is being conducted in violation of this Article or of any rule adopted or order issued pursuant to this Article, that the violation is knowing and willful, and that either:

(1) Off-site sedimentation has eliminated or severely degraded a use in a lake or natural watercourse or that such degradation is imminent.

(2) Off-site sedimentation has caused severe damage to adjacent land or that such damage is

imminent.

(3) The land-disturbing activity is being conducted without an approved plan.

(b) The stop-work order shall be in writing and shall state what work is to be stopped and what measures are required to abate the violation. The order shall include a statement of the findings made by the Secretary pursuant to subsection (a) of this section, and shall list the conditions under which work that has been stopped by the order may be resumed. The delivery of equipment and materials which does not contribute to the violation may continue while the stop- work order is in effect. A copy of this section shall be attached to the order.

(c) The stop-work order shall be served by the sheriff of the county in which the land- disturbing activity is being conducted or by some other person duly authorized by law to serve process as provided by G.S. 1A-1, Rule 4, and shall be served on the person at the site of the land-disturbing activity who is in operational control of the land-disturbing activity. The sheriff or other person duly authorized by law to serve process shall post a copy of the stop- work order in a conspicuous place at the site of the land-disturbing activity. The Department shall also deliver a copy of the stop-work order to any person that the Department has reason to believe may be responsible for the violation.

(d) The directives of a stop-work order become effective upon service of the order. Thereafter, any person notified of the stop-work order who violates any of the directives set out in the order may be assessed a civil penalty as provided in G.S. 113A-64(a). A stop-work order issued pursuant to this section may be issued for a period not to exceed five days.

(e) The Secretary shall designate an employee of the Department to monitor compliance with the stop-work order. The name of the employee so designated shall be included in the stop- work order. The employee so designated, or the Secretary, shall rescind the stop-work order if all the violations for which the stop-work order are issued are corrected, no other violations have occurred, and all measures necessary to abate the violations have been taken. The Secretary shall rescind a stop-work order that is issued in error.

(f) The issuance of a stop-work order shall be a final agency decision subject to judicial review in the same manner as an order in a contested case pursuant to Article 4 of Chapter 150B of the General Statutes. The petition for judicial review shall be filed in the superior court of the county in which the land-disturbing activity is being conducted.

(g) As used in this section, days are computed as provided in G.S. 1A-1, Rule 6. Except as otherwise provided, the Secretary may delegate any power or duty under this section to the Director of the Division of Land Resources of the Department or to any person who has supervisory authority over the Director. The Director may delegate any power or duty so delegated only to a person who is designated as acting Director.

(h) The Attorney General shall file a cause of action to abate the violations which resulted in the issuance of a stop-work order within two business days of the service of the stop-work order. The cause of action shall include a motion for an ex parte temporary restraining order to abate the violation and to effect necessary remedial measures. The resident superior court judge, or any judge assigned to hear the motion for the temporary restraining order, shall hear and determine the motion within two days of the filing of the complaint. The clerk of superior court shall accept complaints filed pursuant to this section without the payment of filing fees. Filing fees shall be paid to the clerk of superior court within 30 days of the filing of the complaint. (1991, c. 412, s. 1; 1998-99, s. 2; 2005-386, s. 7.3.)

§ 113A-66. Civil relief.

(a) Any person injured by a violation of this Article or any ordinance, rule, or order duly adopted by the Secretary or a local government, or by the initiation or continuation of a land- disturbing activity for which an erosion and sedimentation control plan is required other than in accordance with the terms, conditions, and provisions of an approved plan, may bring a civil action against the person alleged to be in violation (including the State and any local government). The action may seek any of the following:

(1) Injunctive relief.

(2) An order enforcing the law, rule, ordinance, order, or erosion and sedimentation control plan violated.

(3) Damages caused by the violation.

(4) Repealed by Session Laws 2202-165, s. 2.15, effective October 23, 2002. If the amount of actual damages as found by the court or jury in suits brought under this subsection is five thousand dollars ($5,000) or less, the plaintiff shall be awarded costs of litigation including reasonable attorneys fees and expert witness fees.

(b) Civil actions under this section shall be brought in the superior court of the county in which the alleged violations occurred.

(c) The court, in issuing any final order in any action brought pursuant to this section may award costs of litigation (including reasonable attorney and expert-witness fees) to any party, whenever it determines that such an award is appropriate. The court may, if a temporary restraining order or preliminary injunction is sought, require, the filing of a bond or equivalent security, the amount of such bond or security to be determined by the court.

(d) Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek injunctive or other relief. (1973, c. 392, s. 17; 1987 (Reg. Sess., 1988), c. 1000, s. 6; 2002-165, s. 2.15.)

SEDIMENTATION CONTROL COMMISSION

§ 143B-298. Sedimentation Control Commission - creation; powers and duties.

There is hereby created the Sedimentation Control Commission of the Department of Environment, Health, and Natural Resources with the power and duty to develop and administer a sedimentation control program as herein provided. The Sedimentation Control Commission has the following powers and duties:

(1) In cooperation with the Secretary of the Department of Transportation and Highway Safety and other appropriate State and federal agencies, develop, promulgate, publicize, and administer a comprehensive State erosion and sedimentation control program.

(2) Develop and adopt on or before July 1, 1974, rules and regulations for the control of erosion and sedimentation pursuant to G.S. 113A-54.

(3) Conduct public hearings pursuant to G.S. 113A-54.

(4) Assist local governments in developing erosion and sedimentation control programs pursuant to G.S. 113A-60.

(5) Assist and encourage other State agencies in developing erosion and sedimentation control programs pursuant to G.S. 113A-56.

(6) Develop recommended methods of control of sedimentation and prepare and make available for distribution publications and other materials dealing with sedimentation control techniquespursuant to G.S. 113A-54. (1973, c. 1262, s. 39; 1977, c. 771, s. 4; 1989, c. 727, s. 218(137).)

§ 143B-299. Sedimentation Control Commission - members;selection; compensation; meetings.

(a) Creation; Membership. -- There is hereby created in the Department of Environment, Health, and Natural Resources the North Carolina Sedimentation Control Commission, which is charged with the duty of developing and administering the sedimentation control program provided for in this Article. The Commission shall consist of the following members:

(1) A person to be nominated jointly by the boards of the North Carolina League of Municipalities and the North Carolina Association of County Commissioners;

(2) A person to be nominated by the Board of the North Carolina Home Builders Association;

(3) A person to be nominated by the Carolinas Branch, Associated General Contractors of America;

(4) The president, vice-president, or general counsel of a North Carolina public utility company;

(5) The Director of the North Carolina Water Resources Research Institute;

(6) A member of the State Mining Commission who shall be a representative of nongovernmental conservation interests, as required by G.S. 74-38(b);

(7) A member of the State Soil and Water Conservation Commission;

(8) A member of the Environmental Management Commission;

(9) A soil scientist from the faculty of North Carolina State University;

(10) Two persons who shall be representatives of nongovernmental conservation interests; and

(11) A professional engineer registered under the provisions of Chapter 89C of the General Statutes nominated by the Professional Engineers of North Carolina, Inc.

(b) Appointment. -- The Commission members shall be appointed by the Governor. All Commission members, except the person filling position number five, as specified above, shall serve staggered terms of office of three years and until their successors are appointed and duly qualified. The person filling position number five shall serve as a member of the Commission, subject to removal by the Governor as hereinafter specified in this section, so long as he continues as Director of the Water Resources Research Institute. The terms of office of members filling positions two, four, seven, and eight shall expire on 30 June of years evenly divisible by three. The terms of office of members filling positions one, three, and ten shall expire on 30 June of years that follow by one year those years that are evenly divisible by three. The terms of office of members filling positions six, nine, and eleven shall expire on 30 June of years that precede by one year those years that are evenly divisible by three. Except for the person filling position number five, no member of the Commission shall serve more than two complete consecutive three-year terms. Any member appointed by the Governor to fill a vacancy occurring in any of the appointments shall be appointed for the remainder of the term of the member causing the vacancy. The Governor may at any time remove any member of the Commission for inefficiency, neglect of duty, malfeasance, misfeasance, nonfeasance or, in the case of members filling positions five, six, seven, eight, nine, and eleven as specified above, because they no longer possess the required qualifications for membership. In each instance appointments to fill vacancies in the membership of the Commission shall be a person or persons with similar experience and qualifications in the same field required of the member being replaced. The office of the North Carolina Sedimentation Control Commission is declared to be an office that may be held concurrently with any other elective or appointive office, under the authority of Article VI, Sec. 9, of the North Carolina Constitution.

(b1) Chairman. -- The Governor shall designate a member of the Commission to serve as chairman.

(c) Compensation. -- The members of the Commission shall receive the usual and customary per diem allowed for the other members of boards and commissions of the State and as fixed in the Biennial Appropriation Act, and, in addition, the members of the Commission shall receive subsistence and travel expenses according to the prevailing State practice and as allowed and fixed by statute for such purposes, which said travel expenses shall also be allowed while going to or from any place of meeting or when on official business for the Commission. The per diem payments made to each member of the Commission shall include necessary time spent in traveling to and from their places of residence within the State to any place of meeting or while traveling on official business for the Commission.

(d) Meetings of Commission. -- The Commission shall meet at the call of the chairman and shallhold special meetings at the call of a majority of the members. (1973, c. 1262, s. 40; 1977, c. 771, s. 4; 1981, c. 248, ss. 1, 2; 1989, c. 727, s. 218(138); 1989 (Reg. Sess., 1990), c. 1004, s. 19(b); 1991, c. 551, s. 1.)

§ 113A-67. Annual Report.

The Department shall report to the Environmental Review Commission on the implementation of this Article on or before 1 October of each year. The Department shall include in the report an analysis of how the implementation of the Sedimentation Pollution Control Act of 1973 is affecting activities that contribute to the sedimentation of streams, rivers, lakes, and other waters of the State. The report shall also include a review of the effectiveness of local erosion and sedimentation control programs. (2004-195, s. 2.1.)

BUILDING PERMITS

In 1988, the General Assembly amended G.S. 153A-357 and 160A-417 regarding building permits. The amendments were as follows:

> G.S. 153-357(b): "No permit shall be issued pursuant to subsection (a) for any land-disturbing activity, as defined in G.S. 113A-52(6), for any activity covered by G.S. 113A-57, unless an erosion control plan has been approved by the Sedimentation Pollution Control Commission pursuant to G.S. 113A-54(d)(4) or by a local government pursuant to G.S. 113A-61 for the site of the activity or a tract of land including the site of the activity."
>
> G.S. 160A-417(b): "No permit shall be issued pursuant to subsection (a) for any land-disturbing activity, as defined in G.S. 113A-52(6), for any activity covered by G.S. 113A-57, unless an erosion control plan has been approved by the Sedimentation Pollution Control Commission pursuant to G.S. 113A-61 for the site of the activity or a tract of land including the site of the activity."

CHAPTER 4 - SEDIMENTATION CONTROL

This Chapter 4 of Title 15A of the North Carolina Administrative Code (T15A.04); SEDIMENTATION CONTROL; has been transferred and recodified from Chapter 16 of Title 15 of the North Carolina Administrative Code (T15.16), effective November 1, 1989. The recodification was pursuant to G.S. 143B-279.1.

SUBCHAPTER 4A - SEDIMENTATION CONTROL COMMISSION ORGANIZATION

15A NCAC 04A .0101 OFFICES OF THE SEDIMENTATION CONTROL COMMISSION

Persons may write or visit the North Carolina Sedimentation Control Commission offices at the Archdale Building, 512 N. Salisbury Street, P.O. Box 27687, Raleigh, North Carolina 27611. Persons may write or visit regional offices of the Commission's staff in the Land Quality Section of the Division of Land Resources at the following locations:

(1) Interchange Building
59 Woodfin Place
P.O. Box 370
Asheville, N.C. 28801

(2) 585 Waughtown Street
Winston-Salem, N.C. 27107

(3) 919 North Main Street
P.O. Box 950
Mooresville, N.C. 28115

(4) 3800 Barrett Drive
P.O. Box 27687
Raleigh, N.C. 27611

(5) Wachovia Building
Suite 714
Fayetteville, N.C. 28301

(6) 1424 Carolina Avenue
P.O. Box 2188
Washington, N.C. 27889

(7) 127 Cardinal Dr., Ext.
Wilmington, N.C. 28405-3845

History Note: Authority G.S. 143B-298;
Eff. February 1, 1976;
Amended Eff. October 1, 1995; February 1, 1992; May 1, 1990; December 1, 1988.

15A NCAC 04A .0102 PURPOSES
15A NCAC 04A .0103 STRUCTURE
15A NCAC 04A .0104 DELEGATION

History Note: Authority G.S. 113A-54(b)(d)(3); 113A-56(a)(b); 113A-58(1); 113A-61(d); 143B-298;
Eff. February 1, 1976;
Amended Eff. August 1, 1985; November 1, 1984; June 5, 1981; January 31, 1979;
Repealed Eff. August 1, 1988.

15A NCAC 04A .0105 DEFINITIONS

As used in this Chapter, the following terms shall have these meanings:

(1) "Accelerated Erosion" means any increase over the rate of natural erosion, as a result of land-disturbing activities.

(2) "Adequate Erosion Control Measure, Structure, or Device" means one which controls the soil material within the land area under responsible control of the person conducting the land-disturbing activity.

(3) "Borrow" means fill material which is required for on-site construction and is obtained from other locations.
(4) "Buffer Zone" means the strip of land adjacent to a lake or natural watercourse.
(5) "Ground Cover" means any natural vegetative growth or other material which renders the soil surface stable against accelerated erosion.
(6) "Lake or Natural Watercourse" means any stream, river, brook, swamp, sound, bay, creek, run, branch, canal, waterway, estuary, and any reservoir, lake or pond, natural or impounded in which sediment may be moved or carried in suspension, and which could be damaged by accumulation of sediment.
(7) "Natural Erosion" means erosion as defined in G.S. 113A-52(5) under natural environmental conditions undisturbed by man.
(8) "Person Who Violates", as used in G.S. 113A-64, means:
  (a) the developer or other person who has or holds himself out as having financial or operational control over the land-disturbing activity; or
  (b) the landowner or person in possession or control of the land when he has directly or indirectly allowed the land-disturbing activity or has benefitted from it or he has failed to comply with any provision of the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, the North Carolina Administrative Code, Title 15A, Chapter 4, or any order or local ordinance adopted pursuant to the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, as imposes a duty upon him.
(9) "Person Conducting Land Disturbing Activity" means any person who may be held responsible for a violation unless expressly provided otherwise by the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, the North Carolina Administrative Code, Title 15A Chapter 4, or any order or local ordinance adopted pursuant to the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66.
(10) "Phase of Grading" means one of two types of grading, rough or fine.
(11) "Plan" means an erosion control plan.
(12) "Sedimentation" means the process by which sediment resulting from accelerated erosion has been or is being transported off the site of the land-disturbing activity or into a lake or natural watercourse.
(13) "Storm Water Runoff" means the direct runoff of water resulting from precipitation in any form.
(14) "Being Conducted" means a land-disturbing activity has been initiated and permanent stabilization of the site has not been completed.
(15) "Uncovered" means the removal of ground cover from, on, or above the soil surface.
(16) "Undertaken" means the initiating of any activity, or phase of activity, which results or will result in a change in the ground cover or topography of a tract of land.
(17) "Waste" means surplus materials resulting from on-site construction and disposed of at other locations.
(18) "Energy Dissipator" means a structure or a shaped channel section with mechanical armoring placed at the outlet of pipes or conduits to receive and break down the energy from high velocity flow.
(19) "Storm Drainage Facilities" means the system of inlets, conduits, channels, ditches and appurtenances which serve to collect and convey stormwater through and from a given drainage area.
(20) "Ten Year Storm" means the surface runoff resulting from a rainfall of an intensity expected to be equaled or exceeded, on the average, once in 10 years, and of a duration which will produce the maximum peak rate of runoff, for the watershed of interest under average antecedent wetness conditions.
(21) "Velocity" means the average velocity of flow through the cross section of the main channel at the peak flow of the storm of interest. The cross section of the main channel shall be that area defined by the geometry of the channel plus the area of flow below the flood height defined by vertical lines at the main channel banks. Overload flows are not to be included for the purpose of computing velocity of flow.
(22) "Discharge Point" means that point at which runoff leaves a tract of land.

(23) "Completion of Construction or Development" means that no further land-disturbing activity is required on a phase of a project except that which is necessary for establishing a permanent ground cover.

(24) "High Quality Waters" means those classified as such in 15A NCAC 2B .0101(e)(5) - General Procedures, which is incorporated herein by reference to include further amendments.

(25) "High Quality Water (HQW) Zones" means areas in the Coastal Counties that are within 575 feet of High Quality Waters and for the remainder of the state areas that are within one mile of and drain to HQW's.

(26) "Director" means the Director of the Division of Land Resources of the Department of Environment, Health, and Natural Resources.

(27) "Coastal counties" means the following counties: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Gates, Hertford, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell and Washington.

(28) "Twenty-five Year Storm" means the surface runoff resulting from a rainfall of an intensity expected to be equaled or exceeded, on the average, once in 25 years, and of a duration which will produce the maximum peak rate of runoff, from the watershed of interest under average antecedent wetness conditions.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Filed as a Temporary Amendment Eff. November 1, 1990 for a period of 180 days to expire on April 29, 1991;
Statutory Authority G.S. 113A-52; 113A-54;
Eff. November 1, 1984;
Amended Eff. May 1, 1990;
ARRC Objection Lodged November 14, 1990;
ARRC Objection Removed December 20, 1990;
Amended Eff. October 1, 1995; April 1, 1992; January 1, 1991.

SUBCHAPTER 4B - EROSION AND SEDIMENT CONTROL

15A NCAC 04B .0101 AUTHORITY

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0102 PURPOSE
15A NCAC 04B .0103 SCOPE

History Note: *Authority G.S. 113A-54(a)(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0104 DEFINITIONS

History Note: *Authority G.S. 113A-52; 113A-54;*
Eff. February 1, 1976;
Amended Eff. March 14, 1980; January 31, 1979; July 1, 1978;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0105 PROTECTION OF PROPERTY
Persons conducting land-disturbing activity shall take all reasonable measures to protect all public and private property from damage caused by such activities.

History Note: *Authority G.S. 113A-54(b); 113A-54(d)(2);*
Eff. February 1, 1976;
Amended Eff. August 1, 1988; November 1, 1984.

15A NCAC 04B .0106 BASIC CONTROL OBJECTIVES
(a) An erosion and sedimentation control plan may be disapproved pursuant to 15A NCAC 4B .0118 if the plan fails to address the following control objectives:

(1) Identify Critical Areas: Identify site areas subject to severe erosion, and off-site areas especially vulnerable to damage from erosion and sedimentation.
(2) Limit Exposed Areas. Limit the size of the area exposed at any one time.
(3) Limit Time of Exposure. Limit exposure to the shortest feasible time.
(4) Control Surface Water. Control surface water run-off originating upgrade of exposed areas in order to reduce erosion and sediment loss during exposure.
(5) Control Sedimentation. All land-disturbing activity is to be planned and conducted so as to prevent off-site sedimentation damage.
(6) Manage Storm Water Runoff. When the increased velocity of storm water runoff resulting from a land-disturbing activity causes accelerated erosion of the receiving watercourse, plans shall include measures to control the velocity to the point of discharge.

(b) When deemed necessary by the approving authority a preconstruction conference may be required.

History Note: *Authority G.S. 113A-54(d)(4); 113A-54.1;*
Eff. February 1, 1976;
Amended Eff. July 1, 2000; February 1, 1992; May 1, 1990; November 1, 1984; March 14, 1980.

15A NCAC 04B .0107 MANDATORY STANDARDS FOR LAND-DISTURBING ACTIVITY

(a) No land-disturbing activity subject to these Rules shall be undertaken except in accordance with the G.S. 113A-57.
(b) Pursuant to G.S. 113A-57(3), provisions for a ground cover sufficient to restrain erosion must be accomplished within 15 working days or 90 calendar days following completion of construction or development, whichever period is shorter, except as provided in 15A NCAC 4B .0124(e).
(c) Pursuant to G.S. 113A-57(4) and 113A-54(d)(4), an erosion and sedimentation control plan must be both filed and approved by the agency having jurisdiction.

History Note: *Authority G.S. 113A-54(d)(4); 113A-57; 113A-57(3)(4);*
Eff. February 1, 1976;
Amended Eff. July 1, 2000; May 1, 1990; August 1, 1988; November 1, 1984; March 14, 1980.

15A NCAC 04B .0108 DESIGN AND PERFORMANCE STANDARD

Erosion and sedimentation control measures, structures, and devices shall be so planned, designed, and constructed to provide protection from the run off of that 10 year storm which produces the maximum peak rate of run off as calculated according to procedures in the United States Department of Agriculture Soil Conservation Service's "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; July 1, 1978.

15A NCAC 04B .0109 STORM WATER OUTLET PROTECTION

(a) Persons shall conduct land disturbing activity so that the post construction velocity of the ten year storm run off in the receiving watercourse to the discharge point does not exceed the greater of:

(1) the velocity established by the table in Paragraph (d) of this Rule; or
(2) the velocity of the ten year storm run off in the receiving watercourse prior to development.

If conditions (1) or (2) of this Paragraph cannot be met, then the receiving watercourse to and including the discharge point shall be designed and constructed to withstand the expected velocity anywhere the velocity exceeds the "prior to development" velocity by ten percent.
(b) Acceptable Management Measures. The commission recognizes that management of storm water run off to control downstream erosion constitutes a developing technology and consequently invites the use of innovative techniques shown to produce successful results. Alternatives include:

(1) Compensate for increased run off from areas rendered impervious by designing measures to promote infiltration.
(2) Avoid increases in storm water discharge velocities by using vegetated or roughened swales and waterways in place of closed drains and paved sections.
(3) Provide energy dissipators at storm drainage outlets to reduce flow velocities to the discharge points.
(4) Protect watercourses subject to accelerated erosion by improving cross sections and/or providing erosion-resistant lining.

(c) Exceptions. This Rule shall not apply when storm water discharge velocities will not create an erosion problem in the receiving watercourse.

(d) The following table sets maximum permissible velocity for storm water discharges:

Material	Maximum Permissible Velocities For F.P.S.	M.P.S.
Fine Sand (noncolloidal)	2.5	.8
Sandy Loam (noncolloidal)	2.5	.8
Silt Loam (noncolloidal)	3.0	.9
Ordinary Firm Loam	3.5	1.1
Fine Gravel	5.0	1.5
Stiff Clay (very colloidal)	5.0	1.5
Graded, Loam to Cobbles (noncolloidal)	5.0	1.5
Graded, Silt to Cobbles (colloidal)	5.5	1.7
Alluvial Silts (noncolloidal)	3.5	1.1
Alluvial Silts (colloidal)	5.0	1.5
Coarse Gravel (noncolloidal)	6.0	1.8
Cobbles and Shingles	5.5	1.7
Shales and Hard Pans	6.0	1.8

Source: Adapted from recommendations by Special Committee on Irrigation Research, American Society of Civil Engineers, 1926, for channels with straight alignment. For sinuous channels multiply allowable velocity by 0.95 for slightly sinuous, by 0.9 for moderately sinuous channels, and by 0.8 for highly sinuous channels.

History Note: *Authority G.S. 113A-54(b)(c);*
Eff. February 1, 1976;
Amended Eff. February 1, 1992; May 1, 1990; November 1, 1984; July 1, 1978.

15A NCAC 04B .0110 BORROW AND WASTE AREAS

If the same person conducts the land disturbing activity and any related borrow or waste activity, the related borrow or waste activity shall constitute part of the land disturbing activity unless the borrow or waste activity is regulated under the Mining Act of 1971, or is a landfill regulated by the Division of Solid Waste Management. If the land disturbing activity and any related borrow or waste activity are not conducted by the same person, they shall be considered separate land-disturbing activities.

History Note: *Authority G.S. 74-67; 113A-54(b); 130A-166.21;*
Eff. February 1, 1976;
Amended Eff. May 1, 1990; November 1, 1984.

15A NCAC 04B .0111 ACCESS AND HAUL ROADS

Temporary access and haul roads, other than public roads, constructed or used in connection with any land-disturbing activity shall be considered a part of such activity.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976.

15A NCAC 04B .0112 OPERATIONS IN LAKES OR NATURAL WATERCOURSES

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.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0113 RESPONSIBILITY FOR MAINTENANCE

During the development of a site, the person conducting the land-disturbing activity shall install and maintain all temporary and permanent erosion and sedimentation control measures as required by the approved plan or any provision of the Act, these Rules, or any order or local ordinance adopted pursuant to the Act. After site development, the land owner or person in possession or control of the land shall install and/or maintain all necessary permanent erosion and sediment control measures, except those measures installed within a road or street right of way or easement accepted for maintenance by a governmental agency.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; July 1, 1978.

15A NCAC 04B .0114 GUIDELINES FOR EROSION AND SEDIMENT CONTROL PRACTICES

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0115 ADDITIONAL MEASURES

Whenever the commission or a local government determines that significant erosion and sedimentation continues despite the installation of protective practices, the person conducting the land disturbing activity will be required to and shall take additional protective action.

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0116 EXISTING UNCOVERED AREAS

(a) All uncovered areas which:

(1) existed on the effective date of these Rules;
(2) resulted from land disturbing activity;
(3) exceed one acre;
(4) are experiencing continued accelerated erosion; and
(5) are causing off-site damage from sedimentation,

shall be provided with ground cover or other protective measures, structures, or devices sufficient to restrain accelerated erosion and control off-site sedimentation.

(b) The commission or local government shall serve a notice to comply with the provisions of G.S. 113A-50 et. seq. or any ordinance, rule or order adopted or issued pursuant to G.S. 113A-50 et. seq. by the Commission or by a local government upon the landowner or other person in possession or control of the land by any means authorized under G.S. 1A-1, Rule 4. The notice shall state the measures needed and the time allowed for compliance. The commission or local government issuing the notice shall consider the economic feasibility, technological expertise and quantity of work required, and shall establish reasonable time limits for compliance.

(c) State agency erosion and sedimentation control programs submitted to the commission for delegation of authority to administer such programs shall contain provisions for the treatment of existing exposed areas. Such provisions shall consider the economic feasibility, existing technology, and quantity of work required.

(d) This Rule shall not require ground cover on cleared land forming the future basin of a planned reservoir.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; February 1, 1992; May 1, 1990; November 1, 1984.

15A NCAC 04B .0117 STATEMENT OF FINANCIAL RESPONSIBILITY AND OWNERSHIP

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. May 1, 1990.

15A NCAC 04B .0118 APPROVAL OF PLANS

(a) Persons conducting land-disturbing activity on a tract which covers one or more acres shall file three copies of the erosion and sedimentation control plan with the local government having jurisdiction or with the Commission if no local government has jurisdiction, at least 30 days prior to beginning such activity and shall keep another copy of the plan on file at the job site. After approving a plan, if the Commission or local government determines, either upon review of such plan or on inspection of the job site, that a significant risk of accelerated erosion or off-site sedimentation exists, the Commission or local government shall require a revised plan. Pending the preparation of the revised plan, work shall cease or shall continue under conditions outlined by the appropriate authority.

(b) Commission Approval:

(1) The Commission shall review plans for all land-disturbing activity over which the Commission has exclusive jurisdiction by statute and all other land-disturbing activity if no local government has jurisdiction.

(2) The Commission shall complete its review of any completed plan within 30 days of receipt and shall notify the person submitting the plan in writing that it has been:

(A) approved,
(B) approved with modification,
(C) approved with performance reservations, or
(D) disapproved.

(3) The Commission's disapproval, modification, or performance reservations of any proposed plan, shall entitle the person submitting the plan to an administrative hearing in accordance with the provisions of G.S. 150B-23. (This Section does not modify any other rights to a contested case hearing which may arise under G.S. 150B-23).

(4) Subparagraph (b)(3) of this Rule shall not apply to the approval or modification of plans reviewed by the Commission pursuant to G.S. 113A-61(c).

(5) Any plan submitted for a land-disturbing activity for which an environmental document is required by the North Carolina Environmental Policy Act shall be deemed incomplete until a complete environmental document is available for review. The Commission shall promptly notify the person submitting the plan that the 30 day time limit for review of the plan pursuant to Subparagraph (b)(2) of this Rule shall not begin until a complete environmental document is available for review.

(c) Erosion and sedimentation control plans may also be disapproved unless they include an authorized statement of financial responsibility and ownership. This statement shall be signed by the person financially responsible for the land-disturbing activity or his attorney in fact. The statement shall include the mailing and street addresses of the principal place of business of the person financially responsible and of the owner of the land or their registered agents.

(d) Local Government Approval:

(1) Local Governments administering erosion and sedimentation control programs shall develop and publish procedures for approval of plans. Such procedures shall respect applicable laws, ordinances, and rules, and shall contain procedures for appeal consistent with the local government's organization and operations.

(2) The secretary shall appoint such employee(s) of the Department as he deems necessary to consider appeals from the local government's final disapproval or modification of a plan. Within 30 days following receipt of notification of the appeal, such departmental employee shall complete the review and shall notify the local government and the person appealing the local government's decision that the plan should be approved, approved with modifications, approved with performance reservations, or disapproved.

(3) If either the local government or the person submitting the plan disagrees with the decision reached by an employee of the Department then he may appeal the decision to the Commission by filing notice within 15 days with the Director of the Division of Land Resources. The director shall make the proposed erosion control plan and the records relating to the local government's and departmental employees' review, available to an appeals review committee consisting of three members of the Commission appointed by the chairman. Within 10 days following receipt of the notification of appeal, the appeals review committee shall notify the local government and the person submitting the plan of a place and time for consideration of the appeal, and shall afford both parties an opportunity to present written or oral arguments. The appeals review committee shall notify both parties of its decision concerning the approval, disapproval, or modification of the proposed plan within 30 days following such hearing.

(e) The applicant's right under G.S. 113A-54.1(d) to appeal the Director's disapproval of an erosion control plan under G.S. 113A-54.1(c) gives rise to a right to a contested case under G.S. 150B, Article 3. An applicant desiring to appeal the Director's disapproval of an erosion control plan shall file with the Office of Administrative Hearings a contested case petition under G.S. 150B, Article 3. The general time limitation for filing a petition, and the commencement of the time limitation, shall be as set out in G.S. 150B-23(f). Contested cases shall be conducted under the procedures of G.S. 150B, Article 3 and applicable rules of the Office of Administrative Hearings. The Commission shall make the final decision on any contested case under G.S. 150B-36.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Statutory Authority G.S. 113A-2; 113A-54; 113A-54.1; 113A-60(a); 113A-61(b); 113A-61(c); 150B, Article 3; 150B-23;
Eff. February 1, 1976;
Amended Eff. June 1, 1995; February 1, 1992; May 1, 1990; August 1, 1988.

15A NCAC 04B .0119 COMPLIANCE WITH PLAN REQUIREMENT

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0120 INSPECTIONS AND INVESTIGATIONS

(a) The Commission, Department of Environment, Health, and Natural Resources or local government may require written statements, or the filing of reports under oath, concerning land disturbing activity.

(b) Inspection of sites shall be carried out by the staff of Department of Environment, Health, and Natural Resources or other qualified persons authorized by the Commission or Department of Environment, Health, and Natural Resources as necessary to carry out its duties under the Act.

(c) No person shall refuse entry or access to any representative of the Commission or any representative of a local government who requests entry for purposes of inspection.

History Note: *Authority G.S. 113A-54(b); 113A-58; 113A-61.1;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; May 1, 1990; November 1, 1984.

15A NCAC 04B .0121 PENALTIES

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0122 SEVERABILITY CLAUSE

If any of these provisions are held invalid or unenforceable, all of the other provisions shall nevertheless continue in full force and effect.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0123 EFFECTIVE DATE

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; November 15, 1976;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0124 DESIGN STANDARDS IN SENSITIVE WATERSHEDS

(a) Uncovered areas in HQW zones shall be limited at any time to a maximum total area within the boundaries of the tract of 20 acres. Only the portion of the land-disturbing activity within a HQW zone shall be governed by this Rule. Larger areas may be uncovered within the boundaries of the tract with the written approval of the Director.
(b) Erosion and sedimentation control measures, structures, and devices within HQW zones shall be so planned, designed and constructed to provide protection from the runoff of the 25 year storm which produces the maximum peak rate of runoff as calculated according to procedures in the United States Department of Agricultural Soil Conservation Service's "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.
(c) Sediment basins within HQW zones shall be designed and constructed such that the basin will have a settling efficiency of at least 70 percent for the 40 micron (0.04mm) size soil particle transported into the basin by the runoff of that two-year storm which produces the maximum peak rate of runoff as calculated according to procedures in the United States Department of Agriculture Soil Conservation Services "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.
(d) Newly constructed open channels in HQW zones shall be designed and constructed with side slopes no steeper than two horizontal to one vertical if a vegetative cover is used for stabilization unless soil conditions permit a steeper slope or where the slopes are stabilized by using mechanical devices, structural devices or other acceptable ditch liners. In any event, the angle for side slopes shall be sufficient to restrain accelerated erosion.
(e) Pursuant to G.S. 113A-57(3) provisions for a ground cover sufficient to restrain erosion must be provided for any portion of a land-disturbing activity in a HQW zone within 15 working days or 60 calendar days following completion of construction or development, whichever period is shorter.

History Note: *Authority G.S. 113A-54(b); 113A-54(c)(1);*
Eff. May 1, 1990.

15A NCAC 04B .0125 BUFFER ZONE REQUIREMENTS

(a) Unless otherwise provided, the width of a buffer zone is measured from the edge of the water to the nearest edge of the disturbed area, with the 25 percent of the strip nearer the land-disturbing activity containing natural or artificial means of confining visible siltation.
(b) The 25 foot minimum width for an undisturbed buffer zone adjacent to designated trout waters shall be measured horizontally from the top of the bank.
(c) Where a temporary and minimal disturbance is permitted as an exception by G.S. 113A-57(1), land-disturbing activities in the buffer zone adjacent to designated trout waters shall be limited to a maximum of ten percent of the total length of the buffer zone within the tract to be distributed such that there is not more than 100 linear feet of disturbance in each 1000 linear feet of buffer zone. Larger areas may be disturbed with the written approval of the Director.
(d) No land-disturbing activity shall be undertaken within a buffer zone adjacent to designated trout waters that will cause adverse temperature fluctuations, as set forth in 15A NCAC 2B .0211 "Fresh Surface Water Classification and Standards", in these waters.

History Note: *Authority G.S. 113A-54(b); 113A-54(c)(1); 113A-57(1);*
Eff. May 1, 1990;
Amended Eff. February 1, 1992.

15A NCAC 04B .0126 PLAN REVIEW FEE

(a) A nonrefundable plan review processing fee, in the amount stated in Paragraph (e) of this Rule, shall be paid when an erosion and sedimentation control plan is filed in accordance with 15A NCAC 04B .0118.
(b) Each plan shall be deemed incomplete until the plan review processing fee is paid.
(c) The plan review processing fee shall be based on the number of acres, or any part of an acre, of disturbed land shown on the plan.
(d) No plan review processing fee shall be charged for review of a revised plan unless the revised plan contains an increase in the number of acres to be disturbed. If the revised plan contains an increase in the number of acres to be disturbed, the plan review processing fee to be charged shall be the amount stated in Paragraph (e) of the Rule for each additional acre (or any part thereof) disturbed.
(e) The nonrefundable plan review processing fee shall be fifty dollars ($50.00) for each acre or part of any acre of disturbed land.
(f) Payment of the plan review processing fee may be by check or money order made payable to the "N.C. Department of Environment and Natural Resources". The payment shall refer to the erosion and sedimentation control plan.

History Note: *Authority G.S. 113A-54; 113A-54.2;*
Filed as a Temporary Rule Eff. November 1, 1990, for a period of 180 days to expire on April 29, 1991; AARC Objection Lodged November 14, 1990;
AARC Objection Removed December 20, 1990;
Eff. January 1, 1991;
Amended Eff. August 1, 2002; July 1, 2000.

15A NCAC 04B .0127 PLAN APPROVAL CERTIFICATE

(a) Approval of a sedimentation and erosion control plan will be contained in a document called "Certificate of Plan Approval" to be issued by the Commission.
(b) The Certificate of Plan Approval must be posted at the primary entrance of the job site before construction begins.
(c) No person may initiate a land-disturbing activity until notifying the agency that issued the Plan Approval of the date that the land-disturbing activity will begin.

History Note: *Filed as a Temporary Rule Eff. November 1, 1990, for a period of 180 days to expire on April 29, 1991;*
Authority G.S. 113A-54(b);

ARRC Objection Lodged November 14, 1990;
ARRC Objection Removed December 20, 1990;
Eff. January 1, 1991;
Amended Eff. July 1, 2000.

15A NCAC 04B .0128 RAILROAD COMPANIES

(a) The Commission recognizes that under the Federal Railroad Safety Act of 1970 (FRSA), 45 U.S.C. 421 et seq., as interpreted by federal administrative rules and court decisions, existing railroad roadbeds comprise a zone of federal preeminence within which federal law takes precedence over the Act [the SPCA].
(b) While the specific definition of this zone of federal preeminence is a question of federal law and regulation, in general the zone of federal preeminence extends outward from the center of the railroad roadbed to and including drainage ditches and spoil banks on either side of the roadbed.
(c) In the event of a derailment, washout, or other emergency condition which requires immediate action to protect public safety, the zone of federal preeminence temporarily expands, for the duration of the emergency condition, to encompass areas adjacent to the roadbed within which emergency repairs are undertaken pursuant to the FRSA and Federal Railroad Administration rules.
(d) The Act and rules do not apply to activities conducted within the zone of federal preeminence. The Act and rules apply to all other activities conducted by railroad companies. Railroad companies shall take all reasonable measures that are consistent with the requirements of federal law to control sedimentation originating in the zone of federal preeminence.
(e) A railroad company's failure to comply with a requirement of the Act or rules in order to avoid creating a safety hazard or to avoid noncompliance with a federal safety requirement is not a knowing or willful violation of the Act or rules.
(f) The Commission will provide advice and technical assistance to railroad companies in the development and implementation of voluntary best management practices to reduce environmental impacts that may otherwise result from activities conducted within the zone of federal preeminence.

History Note: *Authority G.S. 113A-52(6); 113A-54(b); 113A-54(c); 113A-54(d)(4); 113A-57(1);*
Eff. August 1, 1995.

15A NCAC 04B .0129 EROSION CONTROL PLAN EXPIRATION DATE

An erosion control plan shall expire three years following the date of approval, if no land-disturbing activity has been undertaken.

History Note: *Authority G.S. 113A-54.1(a);*
Eff. October 1, 1995.

15A NCAC 04B .0130 EMERGENCIES

Any person who conducts an emergency repair essential to protect human life, that constitutes a land-disturbing activity within the meaning of G.S. 113A-52(6) and these Rules:

(1) shall notify the Commission of such repair as soon as reasonably possible, but in no event later than five working days after the emergency ends; and
(2) shall take all reasonable measures to protect all public and private property from damage caused by such repair as soon as reasonably possible, but in no event later than 15 working days after the emergency ends.

History Note: *Authority G.S. 113A-52.01(4); 113A-54(b);*
Eff. October 1, 1995.

SUBCHAPTER 4C - SEDIMENTATION CONTROL CIVIL PENALTIES

15A NCAC 04C .0101 PURPOSE AND SCOPE

History Note: *Authority G.S. 113A-54(b); 113A-64(a);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; October 5, 1980;
Repealed Eff. August 1, 1988.

15A NCAC 04C .0102 DEFINITIONS

History Note: *Authority G.S. 143B-10;*
Eff. February 1, 1976;
Amended Eff. January 31, 1979; September 3, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04C .0103 WHO MAY ASSESS
The director may assess civil penalties against any person responsible for a violation.

History Note: *Authority G.S. 113A-55; 113A-64; 143B-10;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04C .0104 WHEN ASSESSABLE

History Note: *Authority G.S. 113A-64;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04C .0105 AMOUNT OF ASSESSMENT

History Note: *Authority G.S. 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04C .0106 CRITERIA
In determining the amount of the civil penalty assessment, the director shall consider the following criteria:

(1) severity of the violation,
(2) degree and extent of the harm,
(3) type of violation,
(4) duration,
(5) cause,
(6) extent of any off-site damage which may have resulted,
(7) effectiveness of action taken by violator,
(8) adherence to plan submitted by violator,

(9) effectiveness of plan submitted by violator,
(10) cost of rectifying any damage,
(11) the violator's previous record in complying with rules of the commission,
(12) estimated cost of installing and/or maintaining corrective sediment control measures, and
(13) staff investigative costs.

History Note: *Authority G.S. 113A-54(b); 113A-55; 113A-64(a);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; April 1, 1978.

15A NCAC 04C .0107 PROCEDURES: NOTICES

(a) The notice of violation shall describe the violation with reasonable particularity, request that all illegal activity cease, and inform the violator that a civil penalty may be assessed pursuant to G.S. 113A-64. If particular actions need to be taken to comply with the Sedimentation Pollution Control Act, the notice shall specify the actions to be taken, shall specify a time period for compliance, and shall state that upon failure to comply within the allotted time the person shall become subject to the assessment of a civil penalty for each day of the continuing violation beginning with the date of the violation.
(b) The stop work order provided in G.S. 113A-65.1 shall serve as the notice of violation for purposes of the assessment of a civil penalty pursuant to G.S. 113A-64(a)(1). Copies of the stop work order shall be served upon persons the Department has reason to believe may be responsible for the violation by any means authorized under G.S. 1A-1, Rule 4.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Authority G.S. 113A-54; 113A-61.1; 113A-64; 113A-65.1; 143B-10;
Eff. February 1, 1976;
Amended Eff. August 1, 2000; October 1, 1995; April 1, 1992; May 1, 1990; November 1, 1984;
Temporary Amendment Eff. August 1, 2000;
Amended Eff. April 1, 2001.

15A NCAC 04C .0108 REQUESTS FOR ADMINISTRATIVE HEARING

After receipt of notification of any assessment, the assessed person must select one of the following options within 30 days:

(1) tender payment; or
(2) file a petition for an administrative hearing in accordance with G.S. 150B-23.

History Note: *Authority G.S. 113A-64; 143B-10; 150B-23;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; October 1, 1988; October 5, 1980; April 1, 1978.

15A NCAC 04C .0109 TENDER OF PAYMENT

The director shall accept and acknowledge all tenders of payment on behalf of the secretary.

History Note: *Authority G.S. 113A-55; 143B-10;*
Eff. February 1, 1976;
Amended Eff. October 5, 1980; April 1, 1978.

15A NCAC 04C .0110 ADMINISTRATIVE HEARING

Administrative hearings shall be conducted in accordance with the procedures outlined in G.S. 150B-22 et seq. and the contested case procedures in 15A NCAC 1B .0200.

History Note: *Authority G.S. 113A-55; 150B-22 et seq.;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; August 1, 1988; November 1, 1984; October 5, 1980.

15A NCAC 04C .0111 FURTHER REMEDIES

No provision of this Subchapter shall be construed to restrict or impair the right of the secretary, the director, or the Sedimentation Control Commission to pursue any other remedy provided by law for violations of the Sedimentation Pollution Control Act.

History Note: *Authority G.S. 113A-54; 113A-60; 113A-64 through 113A-66;*
Eff. February 1, 1976.

SUBCHAPTER 4D - LOCAL ORDINANCES

15A NCAC 04D .0101 SUBMISSION AND APPROVAL OF PROPOSED LOCAL ORDINANCES

History Note: *Authority G.S. 113A-54; 113A-60;*
Eff. February 1, 1976;
Repealed Eff. August 1, 1988.

15A NCAC 04D .0102 MODEL ORDINANCE

The commission has adopted a model ordinance. Local governmental units wishing to establish a local erosion and sedimentation control program may obtain a copy of the model ordinance upon writing to:
North Carolina Department of Environment, Health, and Natural Resources
Land Quality Section
P.O. Box 27687
Raleigh, North Carolina 27611

History Note: *Authority G.S. 113A-54(d); 113A-60;*
Eff. February 1, 1976;
Amended Eff. March 14, 1980; February 23, 1979;
Summary Rule Filed January 26, 1982;
Amended Eff. October 1, 1995; May 1, 1990; August 1, 1988; November 1, 1984.

15A NCAC 04D .0103 REVISIONS TO APPROVED LOCAL ORDINANCES

History Note: *Authority G.S. 113A-54(d); 113A-60;*
Eff. May 1, 1990;
Amended Eff. January 4, 1993;
Repealed Eff. October 1, 1995.

SUBCHAPTER 4E - RULEMAKING PROCEDURES

SECTION .0100 - GENERAL PROVISIONS

15A NCAC 04E .0101 GENERAL PURPOSE

Rules at 15A NCAC 1B .0100 are adopted by reference and with the rules of this Subchapter shall govern rule-making hearings conducted under the purview of the commission.

History Note: *Authority G.S. 113A-54; 113A-55; 150B;*
Eff. March 14, 1980;
Amended Eff. November 1, 1984.

15A NCAC 04E .0102 DEFINITIONS

As used in this Subchapter:

(1) "Commission" means the North Carolina Sedimentation Control Commission.
(2) "Director" means the Director of the Division of Land Resources of the Department of Environment, Health, and Natural Resources.

History Note: *Authority G.S. 113A-54; 113A-55;*
Eff. March 14, 1980;
Amended Eff. May 1, 1990.

15A NCAC 04E .0103 ADDRESS

History Note: *Authority G.S. 113A-54;*
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0104 COPIES OF RULES: INSPECTION

(a) Anyone desiring to obtain a copy of any or all of the rules of the commission may do so by requesting such from the director at the address of the commission as set forth at Rule .0001 of Subchapter A of this Chapter. The request must specify the rules requested, for example, 15A NCAC 4, Sedimentation Control, or 15A NCAC 4E, Rulemaking Procedures. The director may charge reasonable fees to recover mailing and duplication costs for requests of more than one copy of the same rule(s).
(b) The rules of the commission (15A NCAC 4) and other documents specified in G.S. 150B-11 are available for public inspection at the Office of the Director (P.O. Box 27687, 512 N. Salisbury Street, Raleigh, N.C. 27611) during regular office hours.

History Note: *Authority G.S. 113A-54; 113A-55; 150B-11;*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984.

15A NCAC 04E .0105 DELEGATIONS OF AUTHORITY TO THE DIRECTOR

History Note: *Authority G.S. 113A-54; 113A-55; 150B;*
Eff. March 14, 1980;
Amended Eff. November 1, 1984; June 5, 1981;
Repealed Eff. August 1, 1988.

SECTION .0200 - PETITIONS FOR RULEMAKING

15A NCAC 04E .0201 PETITION FOR RULEMAKING HEARINGS
Any person wishing to submit a petition requesting the adoption, amendment, or repeal of a rule by the commission shall forward the petition to the director at the address of the commission in Rule .0001 of Subchapter A of this Chapter. The first page of the petition should clearly bear the notation: RULEMAKING PETITION RE and then the subject area (for example, RE PLAN REQUIREMENTS, RE PENALTIES, RE INSPECTIONS) or an indication of any other area over which the commission may have rulemaking authority.

History Note: Authority G.S. 113A-54; 150B-16;
Eff. March 14, 1980;
Amended Eff. November 1, 1984.

15A NCAC 04E .0202 CONTENTS OF PETITION

History Note: Authority G.S. 113A-54; 150B-16;
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0203 DISPOSITION OF PETITIONS
(a) The director will determine whether the petition contains sufficient information for the commission to determine whether the public interest will be served by granting the request. The director may request additional information from the petitioner(s), he may contact interested persons or persons likely to be affected by the proposed rule and request comments, and he may use any other appropriate method for obtaining additional information.
(b) The commission will render a decision within 30 days after the petition is submitted. If the decision is to grant the petition, the director, within 30 days of submission, will initiate a rulemaking proceeding. If the decision is to deny the petition, the director will notify the petitioner(s) in writing, stating the reasons therefor.
(c) If the commission is not scheduled to meet within 30 days of submission of a petition the director may either:
(1) accept the petition and initiate a rulemaking proceeding; or
(2) Ask the chairman of the commission to call a special meeting of the commission so that a decision can be made by the commission within the 30 day time period required by 150B-16 and in accordance with the procedures set out in (b) of this Rule.

History Note: Authority G.S. 113A-54; 113A-55; 150B-16;
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984; June 5, 1981.

SECTION .0300 - NOTICE OF RULEMAKING HEARINGS

15A NCAC 04E .0301 TIMING OF NOTICE
History Note: Authority G.S. 113A-54; 150B-12;
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0302 NOTICE MAILING LIST

History Note: Authority G.S. 113A-54; 150B-12(b);
Eff. March 14, 1980;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04E .0303 ADDITIONAL INFORMATION

History Note: Authority G.S. 113A-54; 150B-12;
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

SECTION .0400 - RULEMAKING HEARINGS

15A NCAC 04E .0401 REQUEST TO PARTICIPATE
15A NCAC 04E .0402 CONTENTS OF REQUEST: GENERAL TIME LIMITATIONS

History Note: Authority G.S. 113A-54; 150B-12(d),(e);
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0403 WRITTEN SUBMISSIONS
(a) Any person may file a written submission containing data, comments, or arguments after distribution or publication of a rulemaking notice until the day of the hearing, unless a longer period has been prescribed in the notice or granted upon request. These written comments should be sent to the director at the address of the commission.
(b) The first page of any written submission shall clearly identify the rulemaking proceeding or proposed rule to which the comments are addressed and include a statement of the position of the person making the submission (for example, "In support of adopting proposed Rule .0000," "In opposition to adopting proposed Rule .0000").
(c) Upon receipt of written comments, acknowledgment will be made with an assurance that the comments therein will be considered fully by the commission.

History Note: Authority G.S. 113A-54; 150B-12(e);
Eff. March 14, 1980;
Amended Eff. June 5, 1981.

15A NCAC 04E .0404 PRESIDING OFFICER: POWERS AND DUTIES

History Note: Authority G.S. 113A-54; 150B-12;

Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0405 STATEMENT OF REASONS FOR DECISION
(a) Any interested person desiring a concise statement of the principal reasons for and against the adoption of a rule by the commission and the factors that led to overruling the considerations urged for or against its adoption may submit a request to the director of the address of the commission.
(b) The request must be made in writing and submitted prior to adoption of the rule or within 30 days thereafter.

History Note: Authority G.S. 113A-54; 150B-12(e);
Eff. March 14, 1980.

15A NCAC 04E .0406 RECORD OF PROCEEDINGS
A record of all rulemaking proceedings will be maintained by the director for as long as the rule is in effect, and for five years thereafter, following filing with the Office of Administrative Hearings. Record of rulemaking proceedings will be

available for public inspection during the hours of 8:30 AM to 5:30 PM on workdays.

History Note: *Authority G.S. 113A-54; 150B-11(2);*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984.

SECTION .0500 - DECLARATORY RULINGS

15A NCAC 04E .0501 SUBJECTS OF DECLARATORY RULINGS
Any person aggrieved by a statute administered or rule promulgated by the commission may request a declaratory ruling as to either the manner in which a statute or rule applies to a given factual situation, if at all, or whether a particular agency rule is valid. For purposes of this Section, an aggrieved person means a person substantially affected by a statute administered by the commission or a rule promulgated by the commission.

History Note: *Authority G.S. 113A-54; 150B-17;*
Eff. March 14, 1980.

15A NCAC 04E .0502 SUBMISSION OF REQUEST FOR RULING
All requests for declaratory rulings shall be written and mailed to the director at the address of the commission. The first page of the request should bear the notation: REQUEST FOR DECLARATORY RULING. The request must include the following information:

(1) name and address of petitioner;
(2) statute or rule to which petition relates;
(3) concise statement of the manner in which petitioner is aggrieved by the rule or statute or its potential application to him;
(4) a statement of whether an oral hearing is desired and, if so, the reason therefor.

History Note: *Authority G.S. 113A-54; 150B-17;*
Eff. March 14, 1980.

15A NCAC 04E .0503 DISPOSITION OF REQUESTS
(a) Upon receiving a request, the director is authorized to initiate a declaratory ruling proceeding to receive information concerning the request. A declaratory ruling proceeding may consist of written submissions, an oral hearing, or other procedures as may be appropriate in the circumstances of the particular request. If the proceeding takes the form of an oral hearing the director may direct that the proceeding take place before the commission.
(b) The director will compile the information collected in the proceeding, along with other relevant information, in a recommendation to the commission on whether to issue the ruling and what the ruling should be.
(c) A decision whether to issue the ruling will be made by the commission at the next regularly scheduled meeting of the commission within the 60 day period required by 150B-17 and after the director's recommendation is presented. If no meeting is scheduled within that time period, the director will ask the chairman of the commission to call a special meeting so that the commission can comply with the requirements of G.S. 150B-17.
(d) If the decision of the commission is to issue the ruling, the ruling will be issued by the commission with the 60 day period required by G.S. 150B-17. If necessary, the chairman of the commission will call a special meeting so that the commission can comply with this requirement.
(e) If the decision of the commission is to deny the request, the director will notify the petitioner(s) in writing stating the reasons therefor.
(f) For purposes of this Rule, the commission will ordinarily refuse to issue a declaratory ruling:

(1) unless the rule is unclear on its face;
(2) unless the petitioner shows that the circumstances are so changed since the adoption of the rule that such a ruling would be warranted;
(3) unless the petitioner shows that the agency did not give to the factors specified in the request for a

declaratory ruling a full consideration at the time the rule was issued;

(4) where there has been a similar controlling factual determination in a contested case or where the factual context being raised for a declaratory ruling was specifically considered upon the adoption of the rule or directive being questioned, as evidenced by the rulemaking record; or

(5) where the subject matter of the request is involved in pending litigation in any state or federal court in North Carolina.

History Note: *Authority G.S. 113A-54; 113A-55; 150B-17;*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; June 5, 1981.

15A NCAC 04E .0504 RECORD OF DECISION

A record of all declaratory rulemaking proceedings will be maintained in the director's office for as long as the ruling is in effect and for five years thereafter. This record will contain: the petition, the notice, all written submissions filed in the request, whether filed by the petitioner or any other person, and a record or summary of oral presentations, if any. Records of declaratory rulemaking proceedings will be available for public inspection during the regular office hours of the director.

History Note: *Authority G.S. 113A-54; 150B-11;*
Eff. March 14, 1980.

8.10 GLOSSARY

This glossary includes terms pertinent to sediment control. Some of these terms do not appear in the text, but all are in common usage by planners, engineers, soil scientists and conservationists.

AASHTO classification The official classification of soil materials and soil aggregate mixtures for highway construction used by the American Association of State Highway and Transportation Officials.

Abutment The sloping sides of a valley that support the ends of a dam.

Acid soil A soil with a preponderance of hydrogen ions (and probably of aluminum) in proportion to hydroxyl ions. Specifically, soil with a pH value less than 7.0. For most practical purposes, a soil with a pH value less than 6.6.

Acre-foot The volume of water that will cover 1 acre to a depth of 1 foot.

Alluvial soils Soils developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the original material by soil-forming processes.

Alluvium A general term for all detrital material deposited or in transit by streams, including gravel, sand, silt, clay, and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

Annual storm The highest peak storm discharge that is expected in any given year. This storm has a 2-year frequency of occurrence.

Antecedent moisture conditions (AMC) The degree of wetness of a watershed at the beginning of a storm.

Anti-seep collar A device constructed around a pipe or other conduit placed through a dam, levee, or dike for the purpose of preventing soil movement and piping failures.

Anti-vortex device A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Apron A pad of non-erosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices.

Aquifer An underground porous, water-bearing geological formation. The term is generally restricted to materials capable of yielding an appreciable supply of water.

Barrel A conduit placed through a dam, levee, or dike to control the release of water.

Base flow Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Bearing capacity The maximum load that a material can support before failing.

Bedrock The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium or hard and have a smooth or irregular surface.

Bentonite A highly plastic clay consisting of the minerals montmorillonite and beidellite that swells extensively when wet. Often used to seal soil to reduce seepage losses.

Berm A narrow shelf or flat area that breaks the continuity of a slope.

Borrow area A source of earth fill material used in the construction of embankments or other earth fill structures.

Bunchgrass Grass plant that forms a distinct clump and does not spread by long, horizontal stems.

Buoyant weight The downward force exerted by an object with a specific gravity greater than one, when it is submerged in water.

Capillary action The tendency of drier soil particles to attract moisture from wetter portions of soil.

Catch basin A chamber usually build at the curb line of a street, for the admission of surface water to a storm sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Channel A natural stream or excavated ditch that conveys water.

Channel stabilization Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops or other structures and/or by lining the channel with a suitable liner such as vegetation, riprap, concrete or other similar material.

Channelization Alteration of a stream channel by widening, deepening, straightening, or paving certain areas to improve flow characteristics.

Chute A high-velocity, open channel for conveying water down a steep slope without erosion, usually paved.

Clay (1) Soil fraction consisting of particles less than 0.002 mm in diameter. (2) A soil texture class which is dominated by clay or at least has a larger proportion of clay than either silt or sand.

Cohesion The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Cohesive soil A soil that, when unconfined, has considerable strength when air-dried and significant strength when saturated.

Compost Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Conservation district A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body but with limited authorities. Often called a soil conservation district or a soil and water conservation district.

Contour An imaginary line on the surface of the earth connecting points of the same elevation.

Cut Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below the original ground surface to the excavated surface.

Cut-and-fill Process of earth grading by excavating part of a higher area and using the excavated material for fill to raise the surface of an adjacent lower area.

Cutoff trench A long, narrow excavation (keyway) constructed along the center line of a dam, dike, levee or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Cutting A leaf, stem or branch cut from a plant to establish a new plant.

Dam A barrier to confine or impound water for storage or diversion, to prevent gully erosion, or for retention of soil, sediment, or other debris.

Debris dam A barrier built across a stream channel to retain logs, tree limbs, sand, gravel, silt or other material.

Design highwater The elevation of the water surface at peak flow conditions of the design flood.

Design life The period of time for which a facility is expected to perform its intended function.

Design storm A selected rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Desilting area An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water; located above a stock tank, pond, field, or other area needing protection from sediment accumulation.

Detention Managing stormwater runoff by temporary holding and controlled release.

Detention time The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Dewatering The removal of water temporarily impounded in a holding basin.

Dibble bar A heavy metal tool with a blade and a foot pedal used to open holes for planting seeds, sprigs, cuttings or seedlings.

Dike An embankment to confine or control water, often built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge Usually the rate of water flow; a volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day.

Dispersion, Soil The breaking down of fine soil aggregates into individual particles, resulting in single-grain structure. Ease of dispersion influences the erodibility of soils. Generally speaking, the more easily dispersed the soil, the more erodible it is.

Diversion A channel with a supporting ridge on the lower side constructed at the top, across, or at the bottom of a slope for the purpose of controlling surface runoff.

Diversion dike A barrier built to divert surface runoff.

Divide, Drainage The boundary between watersheds.

Drain A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drainage The removal of excess surface water or groundwater from land by means of ditches or subsurface drains.

Drainage, Soil As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation. Soil drainage conditions are defined as:

- Well drained—Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.
- Moderately well drained—Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.
- Somewhat poorly drained—Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.
- Poorly drained—Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.
- Very poorly drained—Water is removed so slowly that the water table remains at or near the surface for the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drainageway A natural or artificial depression that carries surface water to a larger watercourse or outlet such as a river, lake, or bay.

Drawdown Lowering of the water surface in an open channel or lake or groundwater.

Drop inlet Overall structure in which the water drops through a vertical riser connected to a discharge conduit or storm sewer.

Drop spillway Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop structure A structure for dropping water to a lower level and dissipating its surplus energy without erosion.

Dune A high ridge of sand usually formed by wind deposition and normally found along the coastline.

Dune formation The building of a dune by trapping blowing sand—either naturally by resident vegetation, or artificially by building sand fences and/or planting adapted vegetation such as American beachgrass or sea oats.

Dune, frontal or foredune The dune line nearest the ocean.

Earth dam Dam constructed of compacted suitable soil materials.

Embankment A man-made deposit of soil, rock, or other material often used to form an impoundment.

Emergency spillway Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy dissipator A device used to reduce the energy of flowing water to prevent erosion.

Environment The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erodibility Susceptibility to erosion.

Erosion The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are sued to describe different types of water erosion:

- Accelerated erosion—Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.
- Channel erosion—The erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.
- Gully erosion—The erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.
- Rill erosion—An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See Rill.
- Splash erosion—The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.
- Sheet erosion—The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Estuary Area where fresh water meets salt water, (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as spawning and feeding grounds for large numbers of marine organisms and provide shelter and food for birds and wildlife.

Evapotranspiration The combined loss of water from an area by evaporation from the soil surface and by transpiration of plants.

Excess rainfall The amount of rainfall that runs directly off an area.

Filter blanket A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

Filter fabric A woven or non-woven, water-permeable material generally made of synthetic products such as polypropylene and used in erosion and sediment control applications to trap sediment or prevent the movement of fine soil particles. Often used instead of a filter blanket.

Filter strip Usually long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties.

Flood peak The highest stage or greatest discharge attained by a flood event. Thus, peak stage or peak discharge.

Floodplain The lowland that borders a stream and is subject to flooding when the stream overflows its banks.

Flood stage The stage at which overflow of the natural banks of a stream begins.

Floodway A channel, either natural, excavated, or bounded by dikes and levees, used to carry flood flows.

Flume A constructed channel lined with erosion-resistant materials used to convey water on steep grades without erosion.

Fluvial sediment Those deposits produced by stream or river action.

Foundation drain A pipe or series of pipes which collects groundwater from the foundation or footing of structures to improve stability.

Freeboard A vertical distance between the elevation of the design high-water and the top of a dam, diversion ridge, or other water control device.

Frequency of storm (design storm frequency) The anticipated period in years that will elapse before another storm of equal intensity and/or total volume will recur: a 10-year storm can be expected to occur on the average once every 10 years.

Froude number (F) A calculated number for classifying water flow as critical ($F = 1$), supercritical ($F > 1$) or subcritical ($F < 1$).

Gabion A wire mesh cage, usually rectangular, filled with rock and used to protect channel banks and other sloping areas from erosion.

Gauge Device for measuring precipitation, water level, discharge, velocity, pressure, temperature, etc., e.g., a rain gauge. A measure of the thickness of metal, e.g., diameter of wire or wall thickness of steel pipe.

Gauging station A selected section of a stream channel equipped with a gauge, stage recorder, or other facilities for determining stream stage and discharge.

Gradation The distribution of the various sized particles that constitute a sediment, soil, or other material such as riprap.

Grade (1) The slope of a road, a channel, or natural ground. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grade stabilization structure A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel bottom.

Gradient Change of elevation, velocity, pressure, or other characteristics per unit length; slope.

Grading The cutting and/or filling of the land surface to a desired slope or elevation.

Grass A member of the botanical family *Gramineae*, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Grassed waterway A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to safely conduct surface water from an area.

Ground cover (Horticulture) Low-growing, spreading plants useful for low-maintenance landscape areas.

Habitat The environment in which the life needs of a plant or animal are supplied.

Head The height of water above any plain of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head or velocity head.

Head loss Energy loss due to friction, eddies, changes in velocity, elevation or direction of flow.

Headwater The source of a stream. The water upstream from a structure or point on a stream.

Hulled seed Seed from which some outer protective covering has been removed to speed germination. Scarified seed must also be hulled.

Hydrograph A graph showing for a given point on a stream the discharge, stage (depth), velocity, or other property of water with respect to time.

Hydrologic cycle The circuit of water movement from the atmosphere to the earth and back to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrology The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Impact basin A device used to dissipate the energy of flowing water to reduce erosion. Generally constructed of concrete partially submerged with baffles to dissipate velocities.

Impervious Not allowing infiltration.

Impoundment Generally, an artificial water storage area, as a reservoir, pit, dugout, sump, etc.

Inoculum A culture of microorganisms intentionally introduced into a medium such as seed, soil, or compost.

Invert The inside bottom of a culvert or other conduit.

Keyway A cutoff trench dug beneath the entire length of a dam to cut through soil layers that may cause seepage and possible dam failure.

Lag time The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Laminar flow Flow at relatively slow velocity in which fluid particles slide smoothly along straight lines everywhere parallel to the axis of a channel or pipe.

Land capability The suitability of land for use. Land capability classification involves consideration of: 1) the risks of land damage from erosion and other causes and 2) the difficulties in land use owing to physical land characteristics, including climate.

Land use controls Methods for regulating the uses to which a given land area may be put, including such things as zoning, subdivision regulation, and floodplain regulation.

Legume Any member of the pea or pulse family which includes peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, black locust, and kudzu. Practically all legumes are nitrogen-fixing plants.

Liquid limit The moisture content at which the soil passes from a plastic to a liquid state.

Loam A soil textural classification in which the proportions of sand, silt, and clay are well balanced. Loams have the best properties for cultivation of plants.

Mean depth Average depth; cross-sectional area of a stream or channel divided by its surface or top width.

Mean velocity The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Microclimate The climate specifically associated with a very small area such as a crevice in a rock outcropping.

Mulch A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Natural drainage The flow patterns of stormwater runoff over the land in its pre-development state.

Nitrogen fixation The conversion of atmospheric nitrogen into stable compounds usable by plants. Carried out by bacteria that colonize the roots of most legumes.

Node (Botany) The point on a plant stem where a leaf or leaves arise. Creeping stems (rhizomes and stolons), and in some plants the upright stem, produce roots at the nodes.

Nonpoint source pollution Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Normal depth Depth of flow in an open conduit during uniform flow for the given conditions.

Nutrient(s) A substance necessary for the growth and reproduction of organisms. In water, those substances that promote growth of algae and bacteria; chiefly nitrates and phosphates.

Open drain Natural watercourse or constructed open channel that conveys drainage water.

Outfall The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.

Outlet Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel A waterway constructed or altered primarily to carry water from man-made structures, such as smaller channels, tile lines, and diversions.

Overland flow irrigation A process of land application of wastewater that provides spray distribution onto gently sloping soil of relatively impervious nature, such as clays, for the purpose of attaining aerobic biotreatment of the exposed flow in contact with ground cover vegetation, followed by the collection of runoff waters in intercepting ditches or channels and the return of the wastewater back to the spray system, or its discharge into receiving waters; sometimes called spray runoff.

Peak discharge The maximum instantaneous flow from a given storm condition at a specific location.

Percolation The movement of water through soil.

Percolation rate The rate, usually expressed as inches/hour or inches/day, at which water moves through the soil profile.

Perennial stream A stream that maintains water in its channel throughout the year.

Permeability, Soil The quality of a soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Permeability rate The rate at which water will move through a saturated soil. Permeability rates area classified as follows:

- Very slow—Less than 0.06 inches per hour.
- Slow—0.06 to 0.20 inches per hour.
- Moderately slow—0.20 to 0.63 inches per hour.
- Moderate—0.63 to 2.0 inches per hour.
- Moderately rapid—2.0 to 6.3 inches per hour.
- Rapid—6.3 to 20.0 inches per hour.
- Very rapid—More than 20.0 inches per hour.

Pervious Allowing movement of water.

Pesticides Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodenticides, nematicides, fungicides, and growth regulators.

pH A numerical measure of hydrogen ion activity. The neutral point is pH 7.0. All pH values below 7.0 are acid and all above 7.0 are alkaline.

Phosphorus, Available Inorganic phosphorus that is readily available for plant growth.

Physiographic region (province) Large-scale unit of land defined by its climate, geology, and geomorphic history and therefore uniform in physiography.

Plasticity index The numerical difference between the liquid limit and the plastic limit of soil; the range of moisture content within which the soil remains plastic.

Plastic limit The moisture content at which a soil changes from a semi-solid to a plastic state.

Plunge pool A basin used to dissipate the energy or flowing water usually constructed to a design depth and shape. The pool may be protected from erosion by various lining materials.

Point source Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. (P.L. 92-500, Section 502(14).

Porosity The volume of pore space in soil or rock.

Principal spillway A dam spillway generally constructed of permanent material and designed to regulate the normal water level, provide flood protection and/or reduce the frequency of operation of the emergency spillway.

Rainfall intensity The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Rational method A means of computing storm drainage flow rates, Q, by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.

Reach The smallest subdivision of the drainage system consisting of a uniform length of open channel. Also, a discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

Receiving stream The body of water into which runoff or effluent is discharged.

Recharge Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recharge basin A basin provided to increase infiltration for the purpose of replenishing groundwater supply.

Retention The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Retention structure A natural or artificial basin that functions similar to a detention structure except that it maintains a permanent water supply.

Rhizome A modified plant step that grows horizontally underground. A rhizomatous plant spreads (reproduces) vegetatively and can be transplanted with rhizome fragments.

Rill A small intermittent watercourse with steep sides, usually only a few inches deep.

Riparian Of, on, or pertaining to the banks of a stream, river, or pond.

Riparian rights A principal of common law which requires that any user of waters adjoining or flowing through his lands must so use and protect them that he will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Riser The inlet portions of a drop inlet spillway that extend vertically from the pipe conduit barrel to the water surface.

Runoff That portion of precipitation that flows from a drainage area on the land surface, in open channels or in stormwater conveyance systems.

Sand (1) Soil particles between 0.05 and 2.0 mm in diameter. (2) A soil textural class inclusive of all soils which are at least 70% sand and 15% or less clay.

Saturation In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

Scarified seed Seed which has been subjected to abrasive treatment to encourage germination.

Scour The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the stream bed and outside bank of a curved channel.

Sediment Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site or origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment delivery ratio The fraction of the soil eroded from upland sources that actually reaches a stream channel or storage reservoir.

Sediment discharge The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Sediment pool The reservoir space allotted to the accumulation of sediment during the life of the structure.

Seedbed The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seedling A young plant grown from seed.

Settling basin An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Shoot The above-ground portion of a plant.

Silt (1) Soil fraction consisting of particles between 0.002 and 0.05 mm in diameter. (2) A soil textural class indicating more than 80% silt.

Slope Degree of deviation of a surface from the horizontal; measured as a numerical ration or percent. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), e.g., 2:1. Slope can also be expressed as the rise over the run. For instance, a 2:1 slope is a 50 percent slope.

Soil The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil horizon A horizontal layer of soil that, through processes of soil formation, has developed characteristics distinct from the layers above and below.

Soil profile A vertical section of the soil from the surface through all horizons.

Soil structure The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil texture The physical structure or character of soil determined by the relative proportions of the soil separates (sand, silt and clay) of which it is composed.

Spillway A passage such as a paved apron or channel for surplus water over or around or through a dam or similar structure. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Sprig Section of plant stem material (rhizome, shoot, or stolon) used in vegetative planting.

Stolon Modified plant stem that grows horizontally on the soil surface.

Storm frequency The time interval between major storms of predetermined intensity and volumes of runoff, e.g., a 5-year, 10-year or 20-year storm.

Storm sewer A sewer that carries stormwater, surface drainage, street wash and other wash waters, but excludes sewage and industrial wastes. Also called a storm drain.

Streambanks The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

Stream gauging The quantitative determination of stream flow using gauges, current meters, weirs, or other measuring instruments at selected locations. See Gauging station.

Subcritical flow Flow at relatively low velocity where the wave from a disturbance can move upstream. Froude No. less than 1.

Subsoil The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface drain A pervious backfilled trench usually containing stone and perforated pipe for intercepting groundwater or seepage.

Subwatershed A watershed subdivision of unspecified size that forms a convenient natural unit.

Supercritical flow Flow at relatively high velocity where the wave from a disturbance will always be swept downstream. Froude number is greater than 1.

Surface runoff Precipitation that falls onto the surfaces of roofs, streets, the ground, etc., and is not absorbed or retained by the surface, but collects and runs off.

Suspended solids Solids either floating or suspended in water or sewage and other liquid wastes.

Swale An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Tailwater depth The depth of flow immediately downstream from a discharge structure.

Tile drain Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Tile drainage Land drainage by means of a series of tile lines laid at a specified depth, grade and spacing.

Toe of dam The base or bottom of the sloping faces of a constructed dam at the point of intersection with the natural ground surface--normally a much flatter slope. A dam has an inside toe (the impoundment or upstream side) and an outside toe (the downstream side).

Toe of slope The base or bottom of a slope at the point where the ground surface abruptly changes to a significantly flatter grade.

Topography General term to include characteristics of the ground surface such as plains, hills, mountains, degree of relief, steepness of slopes, and other physiographic features.

Topsoil The dark-colored surface layer of A horizon of a soil. When present it ranges in depth from a fraction of an inch to 2 or 3 ft; equivalent to the plow layer of cultivated soils. Commonly used to refer to the surface soil layer(s), enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Toxicity The characteristic of being poisonous or harmful to plant or animal life; the relative degree or severity of this characteristic.

Trash rack A structural device used to prevent debris from entering a pipe spillway or other hydraulic structure.

Turbidity Cloudiness of a liquid, caused by suspended solids; a measure of the suspended solids in a liquid.

Turf Surface soil supporting a dense growth of grass and associated root mat.

Unified soil classification system A classification system based on the identification of soils according to their particle size, gradations, plasticity index, and liquid limit.

Uniform flow A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Vegetative stabilization Protection of erodible or sediment-producing areas with:

- permanent seeding, producing long-term vegetative cover,
- short-term seeding, producing areas covered with a temporary vegetative cover, or
- sodding, producing areas covered with a turf of perennial sod-forming grass.

Watercourse A definite channel with bed and banks within which concentrated water flows, either continuously or intermittently.

Water quality A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water resources The supply of groundwater and surface water in a given area.

Watershed The region drained by or contributing water to a stream, lake, or other body of water.

Watershed area All land and water within the confines of a drainage divide.

Water table The free surface of the groundwater. That surface subject to atmospheric pressure under the ground, generally rising and falling with the season, or from other conditions such as water withdrawal.

Weir Device for measuring or regulating the flow of water

Weir notch The opening in a weir for the passage of water.

Zoning ordinance An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and intense type of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial, or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

8.11 WHERE TO GO FOR HELP

The Land Quality Section of the North Carolina Department of Environment, Health, and Natural Resources employs some 50 properly qualified engineers, geologists, and technicians to implement laws pertaining to safety of non-federal dams, erosion and sediment control on construction sites, and responsible operation and reclamation of mines in North Carolina.

This section maintains seven regional field offices across the state and a central administrative office in Raleigh, which provides specialized technical and legal support.

The field office personnel are cross-trained to implement the inspection, public education, and enforcement responsibilities and dam safety, erosion control and mine reclamation. For further information or assistance please contact the nearest regional engineer or our Raleigh Headquarters.

1) Janet Boyer, P.E.
Asheville Regional Office
2090 U.S. Highway 70
Swannanoa, NC 28778
(828) 296-4500

2) Steve Cook, CPESC
Fayetteville Regional Office
Systel Building,
225 Green St., Suite 714
Fayetteville, NC 28301-5094
(910) 486-1541

3) Zahid Kahn
Mooresville Regional Office
610 East Center Ave.
Mooresville, NC 28115
(704) 663-1699

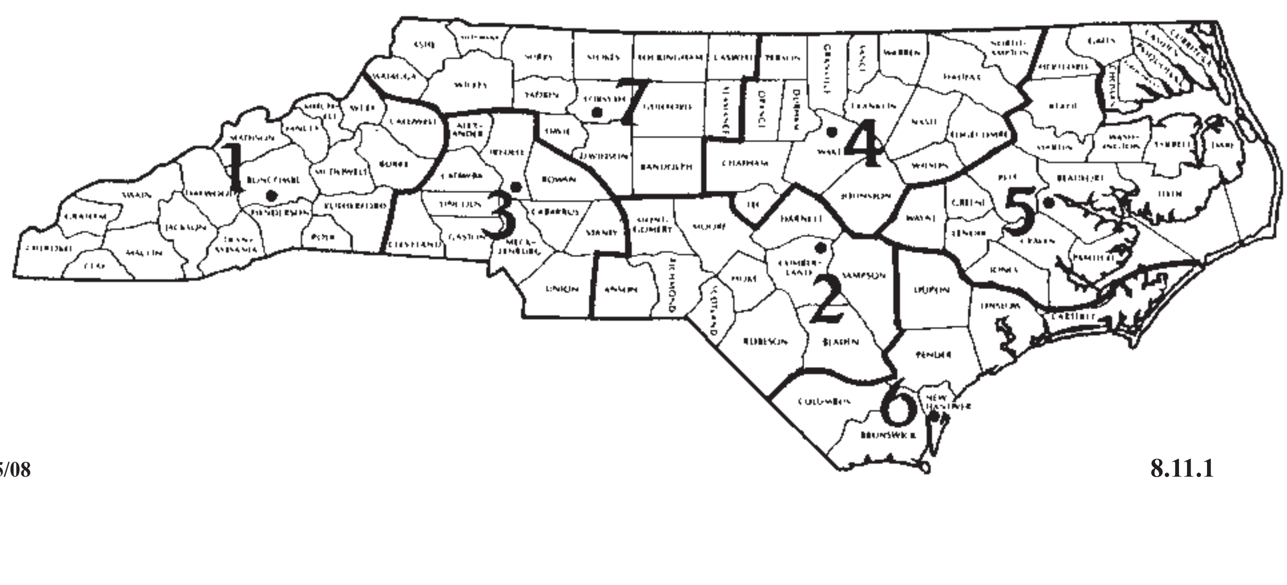
4) John Holley, P.E.
Raleigh Regional Office
3800 Barrett Dr.
Suite 101
Raleigh, NC 27609
(919) 591-4200

5) Pat McClain, P.E.
Washington Regional Office
943 Washington Square Mall
Washington, NC 27889
(252) 946-6481

6) Dan Sams, P.E.
Wlmington Regional Office
127 Cardinal Dr. Ext.
Wilmington, NC 28405-3845
(910) 796-7215

7) Matthew Gant, P.E.
Winston-Salem Regional Office
585 Waughtown St.
Winston-Salem, NC 27107
(336) 771-5000

* Raleigh Central Office
Francis M. Nevils, Jr., P. E.
Land Quality Section
1612 Mail Service Center
Raleigh, NC 27699-1612
(919) 733-4574



LOCAL ORDINANCES

The North Carolina Sediment Control Commission has approved a number of local erosion and sediment control programs for administration by county and municipal governments. For information concerning a specific local ordinance contact the appropriate office listed below.

TOWN OF APEX	Erosion Control Office PO Box 250 Apex, NC 27502	(919) 249-3397
CITY OF ASHEVILLE	City Engineer Office PO Box 7148 Asheville, NC 28802	(828) 259-5617
AVERY COUNTY	Ordinance Administrator PO Box 596 Newland, NC 28657	(828) 733-8204
TOWN OF BEECH MOUNTAIN	Code Enforcement Officer 403 Beech Mtn. Pkwy. Beech Mountain, NC 28604	(828) 387-4236
TOWN OF BOONE	Environmental Planner 1510 Blowing Rock Rd. Boone, NC 28607	(828) 262-4540
BUNCOMBE COUNTY	Erosion Control Officer 46 Valley St. Asheville, NC 28801	(828) 250-4848
CITY OF BURLINGTON	City Engineer 425 S. Lexington Ave. Burlington, NC 27215	(336) 222-5050
CALDWELL COUNTY	County Environmental Engineer 1051 Harper Avenue SW Lenoir, NC 28645	Phone: (828) 757-6860 Fax: (828) 757-6864 billd@caldwellcountync.org
CABARRUS COUNTY	Erosion Control Specialist 65 Church St. Concord, NC 28026-0707	(704) 920-2411
TOWN OF CARY	Erosion Control Supervisor 318 N. Academy St. Cary, NC 27513	(919) 469-4347
CATAWBA COUNTY	Water Resources Engineer PO Box 389 Newton, NC 28658	(828) 465-8161

TOWN OF CHAPEL HILL	Stormwater Management Engineer 209 N. Columbia St. Chapel Hill, NC 27516-3699	(919) 968-2833
CITY OF CHARLOTTE	WQ/Erosion Control Administrator 600 E. Fourth St., 14th Floor Charlotte, NC 28202	(704) 336-3632
CHATHAM COUNTY	Environmental Health Director PO Box 87 Pittsboro, NC 27312	(919) 542-8200
DURHAM CITY/ DURHAM CO.	County Engineer 120 E. Parrish St. Law Building, Suite 100 Durham, NC 27701	(919) 560-0739
GASTON COUNTY	Program Administrator 1303 Cherryville Highway Dallas, NC 28034	(704) 922-2154
GRANDFATHER VILLAGE	Zoning Administrator PO Box 368 Linville, NC 28646	(828) 898-4531
CITY OF GREENSBORO	Sediment and Erosion Control P.O. box 3136 Greensboro, NC 27402-3136	(336) 373-2158
CITY OF GREENVILLE	City Engineer 1500 Beatty St. Greenville, NC 27834	(252) 329-4467
GUILFORD COUNTY	Erosion Control Section Chief P.O. Box 3427 Greensboro, NC 27402	(336) 641-3803
HAYWOOD COUNTY	Erosion Control Specialist 1233 N. Main St., Annex II Waynesville, NC 28786	(828) 452-6706
CITY OF HENDERSON	Director of Engineering P.O. Box 1434 Henderson, NC 27536	(252) 431-6026
HENDERSON COUNTY	Erosion Control Division Chief 240 Second Avenue East Hendersonville, NC 28792	Phone: (828) 694-6523 Fax: (828) 698-6185 nberry@hendersoncountync.org
HIGHLANDS	Planning & Watershed Zoning Adm. P.O. Box 460 Highlands, NC 28741	(828) 526-2118

CITY OF HIGH POINT	Erosion Control Inspector P.O. Box 230 High Point, NC 27261	(336) 883-3199
TOWN OF HOLLY SPRINGS	Director of Engineering PO Box 8 Holly Springs, NC 27540	(919) 557-3926
IREDELL COUNTY	Erosion Control Administrator PO Box 788 Statesville, NC 28687	Phone: (704) 832-2352 Fax: (704) 878-3122 mselquist@co.iredell.nc.us
JACKSON COUNTY	Erosion Control Officer 401 Grindstaff Cove Rd., Suite 110 Sylva, NC 28779	(828) 631-2256
CITY OF JACKSONVILLE	Construction Specialist P.O. Box 128 Jacksonville, NC 28540	(910) 938-5262
TOWN OF KILL DEVIL HILLS	Building Inspector P.O. Box 1719 Kill Devil Hills, NC 27948	(252) 449-5318
TOWN OF KITTY HAWK	Environmental Planner P.O. Box 549 Kitty Hawk, NC 27949	(252) 261-3552
LINCOLN COUNTY	Natural Resources Conservationist 115 West Main Street Lincolnton, NC 28092	Phone: (704) 736-8501 Fax: (704) 736-8504 rmcswain@lincolncounty.org
MACON COUNTY	Erosion Control Officer 1834 Lakeside Dr. Franklin, NC 28734	(828) 349-2560
MECKLENBURG	North Office Manager 18335 Old Statesville Rd., Suite K Cornelius, NC 28031	(704) 336-7783
CITY OF MONROE	Engineer Director PO Box 69 Monroe, NC 28111-0069	(704) 282-4529
TOWN OF NAGS HEAD	Code Compliance Officer PO Box 99 Nags Head, NC 27959	(252) 441-5508
NEW HANOVER	Erosion Contol Engineer 230 Market Place Dr., Suite 160 Wilmington, NC 28403	(910) 798-7139
CITY OF NEWTON	Planning Director PO Box 550 Newton, NC 28658	(828) 465-7400

ORANGE COUNTY	Erosion Control Supervisor Orange Co. Planning Dept. P.O. Box 8181 Hillsborough, NC 27278	(919) 245-2586
PITT COUNTY	Planner II 1717 W. Fifth St. Greenville, NC 27834	(252) 902-3250
CITY OF RALEIGH	Senior Conservation Engineer 222 W. Hargett St. P.O. Box 590 Raleigh, NC 27602	(919) 890-3766
CITY OF ROCKY MOUNT	Assistant City Engineer P.O. Drawer 1180 Rocky Mount, NC 27802-1180	(252) 972-1122
ROWAN COUNTY	Environmental Specialist 402 N. Main St. Salisbury, NC 28144	(704) 638-3078
TOWN OF SOUTHERN PINES	Public Works Director 140 Memorial Park Ct. Southern Pines, NC 28387	(910) 692-1983
SWAIN COUNTY	Director of Inspections PO Box 2321 Bryson City, NC 28713	(828) 488-9134
WAKE COUNTY	Erosion & Sedimentation Control P.O. Box 550 Raleigh, NC 27602	(919) 856-6195
WATAUGA COUNTY	Property Development Coordinator I 842 West King St., #7 Boone, NC 28607	(828) 265-8043
WINSTON-SALEM/FORSYTH CO.	Erosion Control Engineer 100 E. First St., Suite 328 Winston-Salem, NC 27101	(336) 727-2388

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