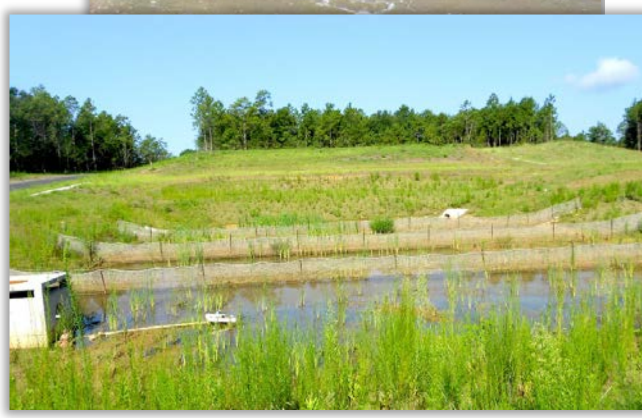
Alabama Handbook for

Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas



Volume 1

Developing Plans and Designing Best Management Practices

Alabama Soil and Water Conservation Committee
Montgomery, Alabama

Foreword

A concerted effort has been made to make the September 2014 Handbook an accurate and comprehensive handbook useful to those involved in the technical aspects associated with land disturbances.

The Handbook is available primarily as an electronic version from the following web site:

http://swcc.alabama.gov/pages/erosion_control.aspx?sm=b_b

It may be review and copied without a charge.

Hardcopies of the Handbook will not be distributed to a mailing list as was done when the Handbook was updated in 2009. Instead, a hard copy of the Handbook or a CD may be purchased from the Alabama Chapter of the Soil and Water Conservation Society through the Jefferson County Soil and Water Conservation Foundation. Order forms are available on the website listed for viewing the Handbook.

Constructive comments on the contents of the 2014 Handbook should be provided in writing to the Alabama Soil and Water Conservation Committee at the following address:

Alabama Soil and Water Conservation Committee
P. O. Box 304880
Montgomery, AL 36130-4800

The preparation of this handbook was financed in part through a grant from the U.S. Environmental Protection Agency to the Alabama Soil and Water Conservation Committee under provisions of Section 319(h) of the Federal Water Pollution Control Act, as amended.

Acknowledgements

This 2014 Handbook update is a product of a partnership project between Alabama Soil and Water Conservation Committee, Alabama Chapter of the Soil and Water Conservation Society, Alabama Association of Conservation Districts, Alabama Department of Environmental Management, Alabama Department of Transportation, Associated General Contractors of Alabama, Home Builders Association of Alabama, the USDA - Natural Resources Conservation Service, Auburn University and Alabama Cooperative Extension System.

Steering Committee – September 2014

Stephen M. Cauthen, Director
Alabama Soil and Water Conservation Committee, Montgomery, Alabama

Jack Wadsworth, Chairman, Urban Conservation Committee
Alabama Association of Conservation Districts, Autauga County, Alabama

Kory Boling, Member Services Director
Home Builders Association of Alabama, Montgomery, Alabama

Eve Brantley, Associate Professor, Auburn University Department of Crop, Soil and Environmental Sciences and Water Quality Coordinator, Alabama Cooperative Extension System, *Auburn, Alabama*

Barry Fagan, Environmental Program Engineer
Alabama Department of Transportation, Montgomery, Alabama

Jeff Kitchens, Chief Stormwater Management Branch of the Water Division
Alabama Department of Environmental Management, Montgomery, Alabama

Jeff Rodgers, Vice-President, AGC Birmingham Chapter Headquarters
Alabama Associated General Contractors, Birmingham, Alabama

Patti Hurley, Senior Environmental Scientist, Office of Education and Outreach
Alabama Department of Environmental Management, Montgomery, Alabama

Monday Mbila, President
Alabama Chapter of the Soil and Water Conservation Society, Huntsville, Alabama

Diane Guthrie, State Conservation Engineer
USDA-Natural Resources Conservation Service, Auburn, Alabama

Handbook Authors – 2002 through September 2014

Jim Baier, Assistant Professor-Biosystems Engineering
Auburn University, Auburn, Alabama (no longer with Auburn University)

Eve Brantley, Associate Professor, Department of Crop, Soil and Environmental Sciences, Auburn University and Water Quality Coordinator, Alabama Cooperative Extension System, Auburn, Alabama

H. Jeff Holloway, Resources Engineer
USDA-Natural Resources Conservation Service, Oxford, Alabama (now works in Georgia)

Richard Hulcher, Chief, Office of Field Services
Alabama Department of Environmental Management, Montgomery, Alabama

Charlene M. LeBlue, Associate Professor
School of Architecture, Auburn University, Auburn, Alabama

Tim Logiotatos, Environmental Engineer
City of Auburn, Auburn, Alabama (no longer works with City of Auburn)

Eddie R. Jolley, Conservation Agronomist
USDA-Natural Resources Conservation Service, Auburn, Alabama

Jerry L. Johnson, State Staff Forester
USDA-Natural Resources Conservation Service, Auburn, Alabama (deceased)

Lawrence McGhee, State Soil Scientist
USDA-Natural Resources Conservation Service, Auburn, Alabama

Earl L. Norton, Handbook Coordinator
Alabama Chapter, Soil and Water Conservation Society, Auburn, Alabama

Perry L. Oakes, State Conservation Engineer
USDA-Natural Resources Conservation Service, Auburn, Alabama (retired from NRCS)

Teresa Paglione, Cultural Resources Specialist,
USDA-Natural Resources Conservation Service, Auburn, Alabama

Kenneth M. Rogers, Conservation Agronomist
USDA-Natural Resources Conservation Service, Auburn, Alabama (retired from NRCS)

B. Dewayne Smith, Associate
Malcolm Pirnie, Inc., Auburn, Alabama (no longer with Malcolm Pirnie)

E. Don Surrency, Plant Materials Specialist
USDA-Natural Resources Conservation Service, Athens, Georgia (retired from NRCS)

Jeffery Thurmond, Wildlife Biologist
USDA-Natural Resources Conservation Service, Auburn, Alabama

Technical Advisors
Tim Albritton, State Staff Forester
USDA-Natural Resources Conservation Service, Auburn, Alabama

Audrey Marshall, Information Technology Specialist, Opelika, Alabama

L. Fay Garner, Public Affairs Assistant
Natural Resources Specialist, Auburn, Alabama

Charles H. Gilliam, Professor,
Department of Horticulture, Auburn University, Auburn, Alabama

AUTOCAD drawings provided by:
Jeff Dowdy, Civil Engineering Technician
Natural Resources Conservation Service, Auburn, Alabama

This Page Intentionally Left Blank

Table of Contents

Appendix (filed in either Volume I or Volume II) Note: The Appendix should be inserted by the user in the Handbook Volume that will make it most useful to the user.

Introduction

The *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* provides guidance for preventing or minimizing the related problems of erosion, sediment and stormwater on construction sites and eroding urban areas. It provides a basis for developing sound plans and implementing appropriate measures, commonly referred to as Best Management Practices. It can help users meet environmental and regulatory objectives.

The Handbook recognizes that erosion and runoff are influenced by the combination of climate, topography, soils, vegetative cover and the extent of land-disturbing activities. Because topography, soils, environmental conditions, and to a lesser extent local climate vary widely over the state, the application of the procedures and criteria in the Handbook should be tailored to local site-specific conditions and user objectives.

Erosion at construction sites and the resulting sediment-laden and turbid stormwater runoff impact individuals, our society and the environment. Damages occur on-site and off-site if land, water and related resources are degraded. Similar impacts may occur as a result of erosion in urban areas on non-construction sites.

The Alabama Soil and Water Conservation Committee, acting under authorities set forth in section 9-8-22 of the Code of Alabama 1975, printed the first edition of the Handbook in 1993. Its purpose was to aid land users, including developers, contractors, consultants, city, county and state planners and planning boards, other governmental officials, and homeowners in adequately addressing the soil erosion, sediment, and stormwater problems associated with land disturbing activities associated with non-agricultural development. The First Revision of the Handbook was completed in 2002. It added Chapter 9 and provided thirteen additional practices that were not in the original Handbook.

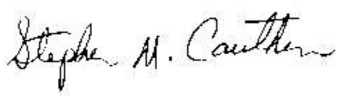
The Handbook June 2003 update involved all parts of the previous handbook and divided it into two volumes to make the contents more user-friendly. Additional practices were added to make the Handbook more comprehensive. Revision No. 1 dated January 2006 was made to add the Bioretention and Stream Diversion practices, to revise the procedure for determining the size of rip-rap for the Channel Stabilization practice and to correct several grammatical errors.

Revision No. 2 of March 2009 made significant changes including adding the concept of Low Impact Development and revising practices in the Sediment Control section.

Revision No. 3 of September 2014, made improvements by incorporating industry suggestions and further integrating the concepts of Low Impact Development to mesh with the new LID Handbook in Alabama. Some of the more significant changes include replacing exotic invasive species with native species in the Shrub, Vine and Groundcover Planting practice, modifying the specifications of the Class A Silt Fence in the Sediment Barrier practice, adding the practice Flocculant as a Sediment Control measure, and providing CAD drawings for several of the practices that were supported earlier with only figures.

It is a goal of the Alabama Soil and Water Conservation Committee that we keep the Handbook current with changing technology. Although we cannot use the Handbook to identify and recommend specific products, we recognize that product development will continue and that over time we gain a better understanding of the effectiveness of practices and systems. We desire that the Handbook framework accommodate, usually in a generic context, those products that are needed in Alabama and our understanding of how they should be used to efficiently protect our land and water resources.

As we look to the future, we urge those that make decisions affecting our land and water resources to voluntarily embrace sound technology, practice strong stewardship of our land and water resources, and encourage their colleagues to promote voluntary conservation efforts. Yes, regulations are necessary for several reasons, but a conservation ethic that recognizes that our natural resources should be protected during and after development puts the tasks of erosion control, sediment control and stormwater management in an important and positive context. Using this approach maximizes benefits the citizens of Alabama and protects the State's precious environment.



Stephen M. Cauthen, Executive Director
Alabama Soil and Water Conservation Committee

Chapter 1

Erosion, Sedimentation and Stormwater Processes

This chapter is intended to only be an introduction to the processes referred to as erosion, sedimentation and stormwater management. If in-depth information is needed on these subjects, other references should be used.

Erosion and Sedimentation Processes

Erosion

Erosion is the process by which the land surface is worn away by the action of water, wind, ice or gravity. Water-related erosion is the primary problem in the developing areas of Alabama and is the primary type of erosion that this handbook addresses.

The Appalachian Plateau, Limestone Valleys and Uplands, and Piedmont Plateau of Northern Alabama are all products of geologic uplift and extended erosion caused by natural forces. The Coastal Plain and the Blackland Prairie of Alabama represent the sedimentation and deposition product from millions of years of geologic erosion from the upland sources. With the exception of shorelines and stream channels where erosion may be rapid and catastrophic, geologic erosion occurs at very slow rates. This natural erosion process, which has taken place over millions of years, has probably occurred at rates comparable to erosion on our current forests.

In contrast to geologic erosion, the erosion accelerated by the disturbances of humans, through agriculture and non-agricultural uses of the land, has caused several inches of erosion over the last 100 to 150 years, a comparatively short period. Thus, “accelerated erosion" can be very significant and potentially create related adverse impacts. Accelerated erosion occurs in non-agricultural areas where developing sites are either poorly planned or the plans that appear adequate are not installed and maintained properly.

To understand erosion caused by water, it is helpful to think of the erosive action of water as the effects of the energy developed by rain as it falls or as the energy derived from water's motion as it runs across the land surface. Both falling rain and flowing water, typically referred to as stormwater, perform work in detaching and moving soil particles, but their actions are different. The force of falling rain is applied vertically. The force of flowing water is applied mostly horizontally.
The energy of raindrops falling on bare soils detaches soil particles. Water flowing over exposed soil picks up detached soil particles. As the velocity of flowing water increases, additional soil particles are detached and transported. Flowing water concentrates because of surface irregularities. If not prevented, these flows will create small channels, or rills, and eventually larger channels, or gullies of varying widths and depths. If the volume and velocity of storm runoff leaving a disturbed site increases because of the activities on the site, it is likely to cause additional erosion of streambanks and possibly floodplains beyond the rate of geologic erosion.

Although not as prominent in the Southeast as erosion caused by water, wind erosion can cause on-site health and safety problems and is a source of fugitive dust.

Sedimentation and Turbidity

Sedimentation is the process that describes soil particles settling out of suspension as the velocity of water decreases. The larger and heavier particles (gravel and sand) settle out more rapidly than silt and clay particles. The silt and clay particles are easily transported and settle out very slowly. It is difficult, and perhaps impossible in some instances to totally eliminate the transport of the clay and silt particles even with the most effective erosion control programs.

Turbidity occurs in conjunction with sedimentation. Turbidity, a cloudy, muddy condition in the water, occurs when eroded soil is suspended in the water (i.e. before it settles out). Turbid water can stress or kill fish by clogging their gills and making it hard for them to see food sources.

Factors Influencing Erosion

The erosion process is influenced primarily by climate, topography, soils, and vegetative cover. The following description of the factors is an overview adequate for this handbook, however it is recognized that this is a very complex subject and that there are many details not included.

Climate

Climate includes rainfall, temperature and wind. The frequency, intensity and duration of rainfall are the principal aspects of rainfall influencing the volume of runoff, erosion and sediment (potential) from a given area. As the volume and intensity of rainfall increase, the ability of water to detach and transport soil particles increases. When storms are frequent, intense, and of long duration, the potential for erosion of bare soils is high. Temperature has a major influence on soil erosion. Frozen soils are relatively erosion resistant. However, bare soils with high moisture content are subject to uplift or "spew" by freezing action and are usually very easily eroded upon thawing. Wind contributes to the drying of soil and increases the need for irrigation for new plantings and for applying wind erosion control practices during periods of bare soils.

Topography

Topography includes the shape and slope characteristics of an area or watershed and influences the amount and duration of runoff. The longer the slope length and the steeper the slope gradient, the greater the potential for runoff, erosion and sediment delivery.

Soils

Soils aspects include soil texture, soil structure, organic matter content and permeability. In addition, in many situations soil compaction is significant. These aspects greatly determine the erodibility of soil.

Soils containing high percentages of sand and silt are the most susceptible to detachment because they lack inherent cohesiveness characteristics. However, the high infiltration rates of sands either prevent or delay runoff except where overland flow is concentrated. Clearly, well-graded and well-drained sands are usually the least erodible soils in the context of sheet and rill erosion.

Clay and organic matter act as a binder to soil particles thus reducing erodibility. As the clay and organic matter content of soils increase, the erodibility decreases. But, while clays have a tendency to resist erosion, they are easily transported by water once detached.

Soils high in organic matter resist raindrop impact and the organic matter also increases the binding characteristics of the soil.

Sandy and silty soils on slopes are highly susceptible to gully erosion where flows concentrate because they lack inherent cohesiveness.

Small clay particles, referred to as colloids, resist the action of gravity and remain in suspension for long periods of time. Colloids are a potential major contributor to turbidity where they are delivered to receiving waters.

Vegetative Cover

Vegetative cover is an extremely important factor in reducing erosion at a site. Vegetative cover will:

a. Absorb energy of raindrops.

b. Bind soil particles and prevent or reduce soil detachment by raindrops or overland flow.

c. Slow velocity of runoff water.

d. Increase the ability of a soil to absorb water.
e. Remove subsurface water between rainfall events through the process of evapotranspiration.
f. Reduce off-site fugitive dust.

By limiting the amount of vegetation disturbed and the exposure of soils to erosive elements, soil erosion can be greatly reduced.

Stormwater

Water flowing over the land during and immediately following a rainstorm is called stormwater runoff. The runoff passing a particular point is equal to the total amount of rainfall upstream of that point less the amounts of infiltration, transpiration, evaporation, surface storage and other losses. The amount of these losses is a function of climate, soils, geology, topography, vegetative cover and, impervious surfaces.

In an undeveloped area, stormwater runoff is managed by nature through the hydrologic cycle. The cycle begins with rainfall. Rain either stands where it falls and evaporates or it is absorbed into the ground near the surface, to feed trees and vegetation, ultimately to be returned to the atmosphere by transpiration; or it percolates deeply into the ground replenishing the groundwater supply. The remainder of the rainfall collects into rivulets. This collected runoff increases in quantity as it moves down the watershed, through drainageways, streams, reservoirs and to its ultimate destination, the river and then the sea. Evaporation from the sea surface begins the cycle again.

This simple explanation of the hydrologic cycle belies its complexity. Nature's inability to accommodate severe rainfalls without significant damage, even in undeveloped areas, is very apparent. Nature's stormwater management systems are not static but are constantly changing. Streams meander, banks erode, vegetation changes with the seasons, and lakes fill with sediment and eventually disappear. The stripping of ground and tree cover by fire can change an entire system forcing new natural accommodations throughout the system.

The volume of stormwater runoff is governed primarily by infiltration characteristics and is related to the land use and its impervious surfaces, soil type, topography and vegetative cover. Thus, runoff is directly related to the percentage of the area covered by roofs, streets and other impervious surfaces. Water intercepted by vegetation and evaporated or transpired is lost from runoff. A small portion of the water that infiltrates into the soil and groundwater is delivered to the stream as delayed flow and does not contribute directly to peak stormwater runoff. Impervious surfaces normally contribute almost all of the total rain immediately to stormwater runoff.

There are 4 distinct yet interrelated effects of land use changes on the hydrology of an area:

1) changes in peak flow characteristics; 2) changes in total runoff; 3) changes in water quality; and 4) changes in the hydrologic amenities (Leopold, 1968). The hydrologic amenities are what might be called the appearance or the impression which the river, its channel and its valleys, leaves with the observer.

Of all land use changes affecting the hydrology of an area, urbanization is the most forceful. As an area becomes urbanized, the peak rate of runoff and volume of runoff increase. These effects are caused by: 1) a reduction in the opportunity for infiltration, evaporation, transpiration and depression storage; 2) an increase in the amount of imperviousness; 3) modification of the surface drainage pattern, including the associated development of stormwater management facilities.

Summary of Hazards Associated with Land Development

Land development clearly increases potential erosion and sediment hazards <u>on-site</u> by removing vegetative cover, developing cuts and fills that are more susceptible to erosion than the previously undisturbed soils and changing water conveyance routes. More subtle changes related to erosion and sediment include soil compaction (both planned and unplanned), longer slopes and more and faster stormwater runoff.

Land development, in most instances, has the following potential effects <u>off-site</u> both during and following the development phase and clearly reflect the impacts of changed use of the land on stormwater:

- Increased volumes of storm runoff.
- Higher peak flows of storm runoff if not modified by planned measures.
- Increased loads of sediment and other pollutants associated with the site unless prevented or minimized by planned measures.

Other potential off-site effects include increased flooding, accelerated erosion of stream systems, increased sediment deposition in both streams and floodplains, and adversely impacting the biological communities associated with the streams and floodplains.

Each progression toward more intensive land use tends to disrupt the ongoing natural processes which protect and preserve water quantity and water quality. Therefore, to ensure future protection of water resources, it is imperative that land uses be managed in a responsible way.

As we reflect on the processes and the potential impact, we should recognize the importance of sound site planning, timely and proper installation of the measures planned and the need for long-term maintenance of measures that sustain site stabilization. If the best available technology is used for planning, design, installation and maintenance of erosion and sediment control and stormwater management the impacts of land development will be minimized. Other chapters of this handbook present relevant planning considerations, design criteria and installation and maintenance information.

Chapter 2

General Planning Concepts for Erosion Control, Sediment Control and Stormwater Management

This chapter provides important concepts and other selected information that is important for qualified design professionals to know about various aspects of erosion control, sediment control and stormwater management. It is believed that the contents will, as a minimum, cause qualified design professionals to recognize when other professionals may need to be involved. A qualified design professional should recognize that planning involves several disciplines and that each discipline has a body of in-depth knowledge that is important and needed on complex sites. Although often discussed separately, erosion control, sediment control and stormwater management are interrelated and when planning occurs the thought process must conceive a system of practices and measures that consider all three together.

The basic details of planning, including step-by-step procedures, are located in Chapter 3.

Potential Erosion and Sediment Problems Associated with Land Development

The principal effect land development activities have on the erosion process consists of exposing disturbed soils to raindrops and to storm runoff. Shaping of land for construction or development purposes alters the soil cover in many ways, often detrimentally affecting physical properties of the soil, onsite drainage and storm runoff patterns and, eventually, off-site stream and stream flow characteristics. Adverse effects of erosion and sedimentation include impacts on soil, water quantity, water quality and the aquatic ecosystem. Potential hazards associated with development include the following items.

1. An increase in developed areas exposed to storm runoff and soil erosion.

2. Increased volumes of storm runoff, accelerated soil erosion and sediment yield and higher peak flows caused by:

    a. Removal of existing protective vegetative cover.

    b. Exposure of underlying soil or geologic formations potentially more erodible than original soil surface.

    c. Reduced capacity of exposed soils to absorb rainfall due to compaction caused by heavy equipment.

d. Enlarged drainage areas caused by grading operations, diversions and street construction.

e. Prolonged exposure of unprotected disturbed areas due to scheduling problems and/or delayed construction.

f. Shortened times of concentration of surface runoff caused by altering slope steepness, slope length, and surface roughness and through installation of "improved" storm drainage facilities.

g. Increased impervious surfaces associated with the construction of streets, buildings, sidewalks and paved driveways and parking lot.

3. Creation of aspects facing south and west that may hinder plant growth due to adverse temperature and moisture conditions.

4. Exposure of subsurface materials which are rocky, acid, droughty or otherwise unfavorable to the establishment of vegetation.

Erosion and Sediment Control

A wide array of practices and measures are used for erosion and sediment control. Most of the practices and measures have application over the State and only a few, such as those practices used for dune stabilization, have use in a small geographical area.

There are numerous simple concepts that can provide an effective framework for minimizing erosion on a construction site and reducing delivery of sediment off of the site.

- Minimize the area disturbed by leaving existing vegetation that does not have to be removed.
- Minimize the period of bare ground by shortening construction periods and staging a project when possible.
- Sequence installation in a manner that supports shortened construction periods and permits the use of temporary and permanent seeding when the practices can be most effective.
- Use sediment control and turbidity measures that minimize sediment and turbid water from leaving the disturbed site.
- Plan appropriate erosion control for all kinds of erosion that may occur depending upon specific site conditions.

- Give special attention to cut and fill slopes.
- Give special attention to sites that are transected by streams or are in close proximity to streams or reservoirs.
- Make erosion control plantings at every opportunity.
- Prevent sediment from leaving a construction site at entrance/exits during muddy periods.
- Maintain practices to ensure their effectiveness. This includes regular and timely inspections.

Potential Stormwater Problems Associated with Land Development

All forms of land use affect water quality. In an undeveloped area, many ongoing physical, chemical and biological processes interact to recycle most of the materials found in the runoff. As the human land use intensifies, these processes are disrupted. Man's activities add materials to the land surface (pesticides, fertilizers, animal wastes, oil, grease, heavy metals, etc.). These materials are then washed off by the rainfall and runoff, thereby increasing the pollutant load carried to receiving waters by stormwater runoff.

Of primary importance to water quality is the "first flush". This term describes the washing action that stormwater has on accumulated pollutants in the watershed. In the early stages of runoff, the land surfaces, especially impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This flushing creates a shock loading of pollutants. Extensive studies in Florida have determined that the first flush equates to the first 1" of runoff which carries 90% of the pollution load from a storm (USGS, 1984). More recently, research has identified that the first ½", of runoff provides the first flush in some instances while other research has determined that runoff in excess of 1", including cut/fill areas associated with construction, may be more realistic. It is proper to say at this time that the amount of runoff that creates the "first flush" depends on several factors, including the activity, site conditions and pollutants. Treatment of the first flush, whatever the runoff amount, will help ensure that the water quality effects of stormwater are minimized.

Finally, the value of the hydrologic environment as an amenity is primarily affected by three factors: stability of the stream channel, accumulation of trash, and disruption of the stream community. A channel which is gradually enlarged because of increased floods caused by urbanization tends to have unstable and unvegetated banks, scoured or muddy channel beds, and unusual accumulations of sediment and debris. Together with the accumulation of trash in the channel and floodplain (beer cans, lumber scraps, lawn clippings, concrete, wire, etc.) these all tend to severely decrease the visual attractiveness of a stream. Ultimately these factors disrupt the natural balance in the streams' biota resulting from the addition of nutrients, organics, and sediment. These disruptions increase algal growth and turbidity, lower the oxygen content of the water, and thereby change the biological character of the stream.

In summary, each progression toward more intensive land use tends to disrupt the ongoing natural processes which protect and preserve water quality. Therefore, to ensure future protection of water resources, it is imperative that land uses be managed in a responsible way.

What is Stormwater Management?

Historically, urbanization has resulted in the development of stormwater management systems to reduce flooding. These systems were required because man was unwilling to suffer inconvenience where it could be avoided and because he would not tolerate the loss of life or property. Typically such concerns have meant that stormwater management systems were designed for safety and convenience without recognition of other important considerations. Therefore, no matter how large the rainfall or its duration, the stormwater system was expected to remove the runoff as quickly as possible, to restore maximum convenience in the shortest possible time. In other words, until recently, stormwater management was concerned with only the quantitative effects of runoff.

Today, however, stormwater management is far more comprehensive. An effective program involves the implementation of actions to control water in its hydrologic cycle with the objectives of providing: (1) flood control; (2) nonpoint source pollution control; and (3) off-site erosion control. Stormwater management applies to rural and urban areas alike; however, the techniques presented in this manual are most relevant to urban or urbanizing situations.

To accomplish the three objectives of stormwater management, it is necessary to ensure that the volume, rate, timing and pollutant load of runoff after development are similar to that which occurred prior to development. The approach suggested in this manual is to minimize the adverse impacts of stormwater through a coordinated system of source controls. Source controls emphasize the prevention and reduction of nonpoint pollution and excess stormwater flow before it ever reaches a collection system or receiving waters. Typical control strategies and management criteria to accomplish the objectives of stormwater management are discussed below.

Flood Control

This has been the most common goal of local stormwater management programs. The property damage, safety hazards, and inconvenience which can result from increased stream flooding in urbanizing watersheds usually get wide public attention and urgent demands for government action. Two levels of drainage systems must be considered in developing a management strategy for flood control: the primary drainage system and the major drainage system.

The primary drainage system consists of the street gutters and ditches, storm sewers, culverts, and open channels which are designed to prevent inconvenience and minor property damages from relatively frequent storm events. Of course, the most effective strategy for flood control at this level is to plan and design the primary drainage system adequately in advance, keeping in mind the future development potential of the drainage area. Unfortunately, many existing drainage systems were designed on a piecemeal, “as needed” basis with little regard for future upstream development. The capacity of such systems often becomes severely inadequate as upstream development progresses, resulting in frequent minor flooding and property damages.

One strategy for dealing with this problem is to replace or modify elements of the primary drainage system to provide the required capacity. This option is often expensive and does not control the source of the problem. However, this may be the only feasible method of correcting existing problems. To prevent future problems, an alternative strategy may be employed. Persons wishing to undertake new development may be required to control runoff from their sites in a manner which will not adversely affect the downstream drainage system. This control is usually accomplished through stormwater detention criteria.

Typical detention criteria will specify that stormwater runoff from a new development must be controlled so that the post-development peak runoff rate does not exceed the pre-development peak rate for some specific frequency design storm or range of design storm events. In many localities, a 10-year design storm is specified to preserve the effectiveness of downstream drainage structures which were originally designed to pass a 10-year pre-development storm. Other localities require that larger storms (i.e., 50-100 year events) must be detained and released at a controlled rate to reduce the downstream effects of major storms.

It should be kept in mind that the larger the storm event which is required to be controlled and the slower the allowable release rate, the greater the storage volume which will be required in the detention facility.

The major drainage system comes into play when the capacity of the primary drainage system is exceeded.

This major system consists of the flood plains and surface flow routes which water will follow during major storms. The most effective strategy for dealing with flooding at this level is to ensure that stormwater has a route to follow which will not cause major property damage or loss of life. To implement this strategy, flood plain ordinances, zoning regulations or other land use controls should be used to restrict flood plain development. In areas where development has already encroached on the flood plain, land owners should be encouraged to purchase flood insurance, if available.

Nonpoint Source Pollution Control

Pollutants which are washed from the land surface and carried into the streams, rivers, and lakes with stormwater runoff have only recently been recognized as major contributors to water quality degradation in urban and urbanizing watersheds. The goal of controlling this problem is therefore relatively new. Nonpoint source pollution control is likely to receive highest priority in watersheds which feed public water supplies or recreation reservoirs; however, this goal should be addressed in all local stormwater management programs.

In urban areas most of the stormwater detention practices which are used to control runoff quantity may also be adapted for use as best management practices for nonpoint source pollution control. The design criteria of these practices for this purpose, however, are often different. The primary design strategy for pollution removal is to maximize the detention time of captured runoff. Although there have not been many monitoring studies to produce definitive design criteria, it is believed that basin drawdown times between 30-40 hours will result in significant pollutant removal. The required storage volume of detention facilities can be tied to a first flush capture (i.e., the initial 0.1” to 1” of runoff).

Off-Site Erosion Control

This goal must be addressed in all local stormwater management programs. The strategies for dealing with this problem are similar to those for flood control. The major difference is in the frequency of the storm which must be controlled.

Studies have shown that most natural stream channels are formed with a bank-full capacity to pass runoff from a storm with a 1.5 to 2-year recurrence interval. As upstream development occurs, the volume and velocity of flow from these relatively frequent storms increase. Even smaller storms with less than 1-year recurrence intervals begin to cause streams to flow full or flood.

Stream channels are often subject to a 3 to 5-fold increase in the frequency of bank-full flows in a typical urbanizing watershed. This increase in the flooding frequency places a stress on the channel to adjust its shape and alignment to accommodate the increased flow. Unfortunately, this adjustment takes place in a very short time period (in geologic terms) and the transition is usually not a smooth one. Meandering stream channels which were once parabolic in shape and covered with vegetation typically become straight, wide rectangular channels with barren vertical banks. This process of channel erosion often causes significant property damage, and the resulting sediment which is generated is transported downstream, further contributing to channel degradation.

An old strategy for dealing with this problem is to increase the carrying capacity and stability of affected streams through channel modifications (i.e. straightening, widening, lining with non-erodible material, etc.). Modifications to natural, continuous flowing streams, however, can be the subject of intense local controversy and requires special permits such as a 404 permit issued by the Corp of Engineers. Recent innovations based on natural stream hydrology concepts are rapidly gaining favor and should be considered because of their beneficial effects on the aquatic environment.

Wherever modifications to natural flowing streams are being considered, extreme care must be taken to weigh the benefits of such modifications against the cost and the concerns of the local citizens. Where channel modifications are necessary, an attempt must be made to incorporate measures which will minimize adverse impacts to fish, wildlife, and the aesthetic quality of the stream.

On-site stormwater detention criteria for new development projects can also be an effective strategy for preventing future increases in channel erosion. However, such criteria should be tied to more frequent storm events than typical flood control criteria. Maintaining the pre-development peak runoff rate from a 10-year storm, for example, will probably not effectively reduce downstream erosion since the majority of storm events will pass right through the detention system unimpeded.

For example, the minimum state or local stormwater management criteria could be tied to a 2-year storm event. Receiving channels would then be capable of passing a 2-year storm without flooding or erosion after development of the site or stormwater would be detained on the site so that the pre-development peak flow rate from a 2-year storm is not exceeded after development. While flows from larger, less frequent storm events may cause erosion problems downstream, it is felt that because such events will occur less often, streams will have more time to recover and restabilize themselves.

Local stormwater detention criteria can be made more restrictive by requiring that storms larger than a 2-year event be detained. However, the allowable release rate should be tied to the actual carrying capacity of the receiving stream or the 2-year pre-development peak runoff rate.

Multiple-Purpose Criteria

Stormwater management criteria for flood control, erosion control, and pollution control are not necessarily mutually exclusive. In many cases, stormwater can be managed to accomplish all three goals simultaneously. For example, a stormwater detention basin can be designed as a multipurpose structure by incorporating different release rates at different stages (storage elevations).

The first stage is designed to capture an initial volume of runoff (i.e., the first flush) and release it very slowly through a subsurface drainage system. The second stage begins with an orifice cut in the riser pipe which has the capacity to pass stormwater runoff at a 2-year pre-development rate when water elevation reaches the top of the riser. The purpose of this stage would be to control downstream channel erosion from frequent storms. The top of the riser pipe could serve as the outlet for the third stage and may be designed to pass a l0-year storm at a pre-development rate for moderate flood protection downstream. The emergency spillway should be designed to pass at least the l00-year storm. While such a multi-purpose design may not be feasible for all detention systems, there are often innovative approaches which can be taken to satisfy two or more local stormwater management goals.

Flexibility

Flexibility is extremely important in stormwater management programs. Each development project has a unique set of conditions and circumstances and a different potential for affecting the downstream drainage system.

Criteria which may be perfectly applicable to one project may be totally unsuitable for another. For example, requiring stormwater detention for flood control may be highly applicable to projects constructed in the upper reaches of a watershed, but may be unnecessary or even undesirable for new projects constructed near the outlet of the watershed.

A qualified design professional should be given an opportunity to design a drainage system which contributes to the achievement of established local stormwater management goals in the most cost-effective manner. To accomplish this, each project must be considered on an individual basis.

Principles of Stormwater Management

It is much more efficient and cost-effective to prevent problems than to attempt to correct problems after the fact. Sound land use planning decisions based on the site planning principles are essential as the first, and perhaps the most important, step in managing stormwater related problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers, etc.) and redevelopment plans should include a comprehensive stormwater management system.

Every piece of land is part of a larger watershed. A stormwater management system for each development project should be based on, and should support a plan for the entire drainage basin.

Optimum design of the stormwater management system should mimic (and use) the features and functions of the natural drainage system which is largely capital, energy and maintenance cost free. Every site contains natural features which contribute to the management of stormwater under the existing conditions. Depending upon the site, existing features such as natural drainageways, depressions, wetlands, floodplains, highly permeable soils, and vegetation provide natural infiltration, help control the velocity of runoff, extend the time of concentration, filter sediments and other pollutants, and recycle nutrients. Each development plan should carefully map and identify the existing natural system. “Natural” engineering techniques should be used to preserve and enhance the natural features and processes of a site and to maximize the economic and environmental benefits. Engineering design can and should be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

The volume, rate, timing and pollutant load of stormwater after development should closely approximate the conditions which occurred before development. To accomplish these objectives two overall concepts must be considered: (1) the perviousness of the site should be maintained to the greatest extent possible; and (2) the rate of runoff should be slowed. Preference should be given to stormwater management systems which use measures that maintain vegetative and porous land cover and include on-site storage mechanisms. These systems will promote infiltration, filtering and slowing of the runoff.

Maximize on-site storage of stormwater. Provision for storage can reduce peak runoff rates; aid in groundwater recharge; provide settling of pollutants; lower the probability of downstream flooding, stream erosion and sedimentation; and provide water for other beneficial uses. Stormwater runoff should never be discharged directly into surface or ground waters. Runoff should be routed over a longer distance, through grassed waterways, wetlands, vegetated buffers and other works designed to increase overland flow. These systems provide time for increased infiltration and evaporation, allow suspended solids to settle, and remove pollutants before they are introduced to waters of the State.

Stormwater management systems, especially those emphasizing vegetative practices, should be planned, constructed and stabilized in advance of the facilities that will discharge into them. This principle is frequently ignored thereby causing unnecessary off-site impacts, extra maintenance, re-working of grades, re-vegetation of slopes and grassed waterways, and extra expense to the developer. The stormwater management system, including erosion and sedimentation controls, should be constructed and stabilized at the start of site disturbance and construction activities.

The stormwater management system must be designed beginning with the outlet or point of outflow from the project. The downstream conveyance system should be evaluated to ensure that it contains sufficient capacity to accept the design discharge without adverse downstream impacts such as flooding, streambank erosion and sedimentation. It may be necessary to stabilize the downstream conveyance system, especially near the stormwater system outlet. A common problem is a restricted outlet which causes stormwater to back up and exceed the storage capacity of the collection and treatment system resulting in temporary upstream flooding. This may lead to hydraulic failure of the stormwater management system causing re-suspension of the pollutants and/or expensive repairs to damaged structures or property. In such circumstances it is advisable to use more than one outlet or to increase the on-site storage volume.

Stormwater is a component of the total water resources which should not be casually discarded but used to replenish those resources. Stormwater represents a potential resource out of place, with its location determining whether it is a liability or an asset. Given the water quantity and quality problems and challenges facing Alabama, it is imperative that stormwater is considered to be an asset. Treated stormwater has a great potential for providing many beneficial uses such as irrigation (farm, lawn, parks, golf courses, etc.), recreational lakes, groundwater recharge, industrial cooling and process water, and other non-potable domestic uses.

Whenever practical, multiple use temporary storage basins should be an integral component of the stormwater management system. All too often, storage facilities planned as part of the system are conventional, unimaginative ponds which are aesthetically unpleasing. Recreational areas (e.g., ball fields, tennis courts, volleyball courts, etc.), greenbelt areas, neighborhood parks and even parking facilities provide excellent settings for the temporary storage of stormwater. Such areas are not usually in use during periods of precipitation and the ponding of stormwater for short durations does not seriously impede their primary functions. Storage areas should be designed with sinuous shorelines. Shorelines which are sinuous rather than straight increase the length of the shoreline. The increased shoreline also provides more space for the growth of shoreline vegetation thus providing for greater pollutant filtering and for increased and diversified aquatic habitat.

Vegetated buffer strips should be retained in their natural state or created along the banks of all water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff, provide public access, enhance the site amenities, and function as a floodplain during periods of high water. They also provide a pervious strip along a shoreline which can accept sheet flow from developed areas and help minimize the adverse impacts of untreated stormwater.

The stormwater management system must receive regular maintenance. Failure to provide proper maintenance reduces the pollutant removal efficiency of the system and reduces the system's hydraulic capacity. Lack of maintenance, especially to vegetative systems which may require revegetating, can increase the pollutant load of stormwater discharges. The key to effective maintenance is the clear assignment of responsibilities to an established agency (local government) or organization (homeowners association) and a regular schedule of inspections to determine maintenance needs. In addition, stormwater system designers should find ways to make their systems as simple, natural and maintenance free as possible.

Low Impact Development

Low Impact Development or LID is "an innovative stormwater management system approach with a basic principal that is modeled after nature" (Low Impact Development Center). It is the practice of taking steps during design development to minimize changes to the hydrologic cycle (runoff and infiltration after a storm). LID strategies integrate green space, native landscaping, natural hydrologic functions, and various other techniques to generate less runoff from developed land (NRDC, Stormwater Strategies Report, 2001). These types of practices encourage infiltration and reduce the volume of stormwater discharged from the site. Many innovative site designs and stormwater management practices are grouped together under the heading of LID, but true LID strategies have certain key distinctions. These key distinctions of LID include:

- Stormwater management at a local scale to minimize impact of development on the local watershed.
- Ecosystem-based. Design what you are building as a functional part of the ecosystem (not apart from it).
- Relies on advanced technologies more than conservation and growth management (Smart Growth plans).

LID promotes hydrologic function at the lot level. It addresses stormwater through small, cost-effective landscape features referred to as integrated management practices (IMP) and stormwater control measures (SCM). Green infrastructure and LID are commonly used interchangeably. Green infrastructure is a network of practices that use vegetation, soils, and natural processes to manage water and create healthier urban environments (US EPA).

The Alabama Handbook for Low Impact Development is available online (www.aces.edu/lid). Chapters on community planning and codes and ordinances are available through this resource.

Integrated Management Practices

The term IMP is used to denote controls that are integrated throughout the project and provide landscape amenity. Stormwater control measure or SCM is generally preferred instead of BMP due to its specificity to the field of stormwater and improved definition / description. The terms BMP and IMP are frequently used interchangeably. When Integrated Management Practices are linked together they form *BMP trains* that address water quantity and water quality in succession. Such a train could be created by linking a rain barrel (overflow) to a rain garden, and the overflow drain of the rain garden to a constructed wetland.

History of LID

Many communities are turning to LID to assist with stormwater management. Conventional solutions to handling stormwater runoff are not always compatible with community interests, or local, state, and federal water quality regulations. Prince George's County, Maryland is known as the originator of the LID movement, and has pioneered many stormwater management practices and protective policies since the early 1980's. The state of Wisconsin has also promoted LID since the late 1980's, but dates to the early 1900's in the origin of sustainable products such as Milorganite, a fertilizer used in the golf course industry made from the byproduct of the Milwaukee sanitary sewer system.

What are the Key elements of LID?

The key elements of LID include:

- Conservation
- Small scale controls
- Customized site design
- Pollution prevention and education
- Directing runoff to natural areas

The preservation of native trees, understory vegetation and natural drainage processes are important in LID development. They are enhanced by the small scale controls on the lot level that mimic natural hydrology and processes. The customized design of these controls protects these processes and reduces pollutant loads, and sends stormwater to areas of infiltration to facilitate ground water recharge.

Planners/designers should consider using LID because it enhances the local environment, protects public health, improves community livability and saves developers and local governments' money. There is at least a 25% - 30% reduction in costs associated with site development, stormwater fees, and maintenance for residential developments that use LID techniques (Low Impact Development Center). These savings are recognized through reductions in clearing, grading, pipes, ponds, inlets curbs, and paving.

Low Impact Development practices are applied to open space, roof tops, streetscapes, parking lots, sidewalks, and medians. The preservation of existing open space or the creation of new open space allows for large conservation areas where stormwater can soak into the ground and promote groundwater recharge. Roof top gardens or green roofs provide excellent insulation in warm climates and reduce heat island effects in urban environments. LID promotes narrow streets and driveways, which reduce impervious surfaces as well as flooding and pollution from stormwater. There is typically no curb and gutter in LID developments, and houses are usually closer to the street. Shared driveways are quite common.

Typical LID design components

Typical LID design components to be considered include vegetation, pervious surfaces and bioretention systems. Vegetation removes water through evapotranspiration and assists in pollutant removal through nutrient cycling. Pervious surfaces allow stormwater to infiltrate into underlying soils promoting groundwater recharge and pollutant processing while reducing the volume of rainwater runoff. Bioretention systems detain water long enough for infiltration and pollution removal to occur. Bioretention systems may be designed as buffer strips, rain gardens, stormwater wetlands and grass swales.

Bioretention areas

Bioretention areas, also known as bioretention filters or cells, capture and temporarily store water. Water is conveyed to the treatment area as sheet flow. They can be designed to capture the first inch of rain and allow it to soak into the soil, watering the plants in the rain garden. Bioretention is designed to detain water just long enough for infiltration and pollution removal to occur, but not cause mosquito problems.

Rain gardens are residential practices that typically use native plants. Native plants are used because they are more drought-tolerant, and require less maintenance. Pollutant removal is facilitated by microbes that live in the soil and interact with the plant roots. Stormwater drains from the rain garden within 24 – 48 hours eliminating concerns about mosquito habitat. Pathogens are left high and dry as water is absorbed.

Landscaping is critical to performance and function of a bioretention cell or rain garden. A diversity of plant types should be planted to replicate a natural ecosystem. Trees should be spaced at least 10 feet apart, hardwood mulch should be used (not pine bark; it floats), and plants should be both water tolerant and drought tolerant.

Bioretention cells and rain gardens come in many shapes and sizes and can be used in commercial and residential landscapes, parking lots and medians, highway drainage, and on golf courses. The design can be tweaked to fit many uses. Basically, they take advantage of an existing low spot, are excavated and filled with amended soil to aid in the drainage process. There is an overflow drain that may be a perforated pipe or an existing stormwater outlet that has been raised to aid the ponding of water.

Rain Barrels & Cisterns

Rain Barrels are small roof recapture systems that store residential rooftop runoff for localized use. Water collected in a rain barrel would normally flow through a gutter system or flows off a roof on to the ground possibly causing erosion. A rain barrel can save approximately 1,300 gallons of water during peak summer months of normal rainfall (Center for Watershed Protection, 2007). For every inch of rain that falls on a catchment area of 1,000 square feet, you can expect to collect approximately 600 gallons of rainwater All systems should use covered barrels or cisterns that keep the water from accumulating leaves and other contaminants. Perhaps the simplest use of rainwater is to put a barrel under one of the gutter downspouts and use the water on sensitive indoor plants. Storing rainwater for garden and outdoor work use helps recharge groundwater naturally by slowing down and reducing stormwater runoff.

Cisterns work on the same principal as rain barrels but typically have a large storage capacity. Modern cisterns are manufactured of plastic and may or may not be completely enclosed. Rather they typically have a lid made of the same material as the cistern, which is removable by the user. In the USA, cisterns are predominately used for irrigation; however, some areas promote reuse of gray water (water from hand washing, dish washing, etc.) for toilet flushing.

Filter strips, grass swales and stormwater wetlands

Filter strips can be designed as landscape features within parking lots or other areas to collect flow from large impervious surfaces. Grass swales use grass or other vegetation to reduce runoff velocity and allow filtration, while high volume flows are channeled away safely. They function as alternatives to curb and gutter systems. Stormwater wetlands treat stormwater runoff by slowing stormwater and trapping pollutants.

Pervious Paving

Porous pavements allow air and water to pass through the surface providing groundwater recharge. “If used properly, porous pavements can facilitate biodegradation of the oils from cars and trucks, help rainwater infiltrate soil, decrease urban heating, replenish groundwater, allow tree roots to breathe, and reduce total runoff, including the magnitude and frequency of flash flooding.” In his book, *Porous Pavements* (2005), Ferguson identifies nine categories of porous pavement: decks, open-celled paving grids, open-graded aggregate, open-jointed paving blocks, plastic geocells, porous asphalt, pervious concrete, porous turf, and soft paving. It is the most popular form of structural post-construction BMP in Alabama.

Mixing Structural and Nonstructural Post-Construction BMPs

Mixing structural and nonstructural post-construction BMPs allow for the flexibility to create the proper BMP efficiency and cost for pollutant removal. The resulting configuration resembles a BMP Train, that is, a string of mix and match BMPs that are custom selected to a site’s pollutant situation. There are now several BMP calculators (typically Excel format) that will calculate the train's efficiency and cost.

The benefits of LID provide high level of water quality treatment. LID tends to control volume of the first flush (first ½ inch to 1 inch) runoff. It is cost effective for developers and local governments, and is aesthetically pleasing. LID increases quality of water in local streams, rivers, lakes or bays. It also controls impacts to our natural ecosystems through selective BMP implementation. Instead of large investments in complex and costly centralized conveyance and treatment infrastructure, LID allows for the integration of treatment and management measures into urban site features. This involves strategic placement of distributed lot-level controls that can be customized to more closely mimic a watershed's hydrology and water quality regime. The result is a hydrologically functional landscape that generates less surface runoff, less pollution, less erosion, and less overall damage to lakes, streams, and coastal waters.

References

The Alabama Handbook for Low Impact Development. Alabama Cooperative Extension System. Retrieved June 2014 www.aces.edu/lid

Ferguson, Bruce K. 2005. *Porous Pavements*. Boca Raton; CRC Press.

Low Impact Development. November 2007. http://www.aces.edu/waterquality/nemo/lid.htm

Stormwater Strategies--Community Responses to Runoff Pollution. Natural Resource Defense Council 2001 Report. Chapter 12—Low Impact Development. November 2007. http://www.nrdc.org/water/pollution/storm/chap12.asp

What is Green Infrastructure, US EPA. Retrieved June 2014 http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

Vegetation for Erosion and Sediment Control

Introduction

A dense, vigorous growing vegetative cover protects the soil surface from raindrop impact, a major force in causing erosion and sedimentation. Also, vegetation will shield 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.

Suitable vegetative cover offers excellent erosion protection and sediment control. Vegetative cover is essential to the design and stabilization of many structural erosion control practices. Vegetative cover is relatively inexpensive to achieve and maintain. Also, it is often the only practical, long-term solution to stabilization and erosion control on many disturbed sites.

Timely vegetative establishment or retention reduces the cost of vegetation, minimizes maintenance and repairs, and makes structural erosion control measures more effective and less costly to maintain. Landscaping is also less costly where soils have not been eroded. Natural areas (those left undisturbed) can provide low-maintenance landscaping, shade, and screening. Large trees increase property values 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, and complements architecture. Property values can be increased dramatically by small investments in erosion control.

Plant selection should be considered early in the process of preparing the erosion and sediment control plan. A diversity of species can be grown in Alabama due to the variation in both soils and climate. However, for practical, economical stabilization and long-term protection of disturbed sites, plant selection should be made with care. Many plants that will grow in Alabama are inappropriate for soil stabilization because they do not protect the soil effectively, or they cannot be established quickly. Some plants may be very effective for soil stabilization, but are not aesthetically acceptable on some sites.

Stabilization of most disturbed sites requires grasses and/or legumes that grow close together to provide a thick close-growing cover. This is true even where part or the entire site is planted to trees or shrubs. In landscape plantings, disturbed areas between trees and shrubs must also be protected either by mulching or by permanent grass, legumes, or mixtures.

Trees are excellent for long-term soil and water protection, but they will not stabilize concentrated flow areas.

Site Planning For Tree Protection

Select trees to be saved before beginning construction. No tree should be destroyed or altered until the construction plans are final. Flood plains and wetlands should be left in their natural condition. Locate roadways to cause the least damage to valuable trees. Follow contours where feasible to minimize cuts and fills. Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the drip line of trees.

Storage areas for construction materials and worker parking areas should be noted on the site plan, and located where they will not cause soil compacting over roots.

When retaining existing trees in parking areas, leave enough ground ungraded around the tree to allow for its survival. Tree wells may be needed.

Locate erosion and sediment control measures within the limits of clearing and not in wooded areas to prevent deposition of sediment within the drip line of trees being preserved. Sediment basins should be constructed in the natural depressions if possible rather than in locations where extensive grading and tree removal will be required.

Selecting Trees to Be Retained or Planted

Trees may be exposed to insufficient sunlight and water; high winds; heat radiation from highways and parking lots; pollutants from cars and industries; root amputation because of sewer, water, gas and electric lines; and pruning or "topping" because of power lines; and covering of roots by pavement and compaction. These items make the selection and management of trees extremely important.

The proper development of a forested urban site requires a plan for tree retention or tree planting before construction begins. An overall requirement for selecting trees is that those trees selected should be appropriate for the proposed use of the development. The selection of tree species depends on the desired function of the tree, whether it be just erosion control or other functions such as shade, privacy screening, noise screening, appearance, enhancement of wildlife habitat or a combination of these. The following characteristics of a tree should be considered when choosing a tree to retain or plant.

Hardiness

Select trees that are recommended for the area. See practice Tree Planting on Disturbed Areas.

Mature Height and Spread

The eventual height of a tree must be considered in relation to location on the site to avoid future problems with buildings and utility lines. See practice Tree Planting on Disturbed Areas.

Growth Rate

Some trees attain mature height at an early age, others take many years. Fast growing trees may be brittle and possibly short-lived while slow growing trees are usually less brittle and live longer.

Root System

Avoid trees which have fibrous roots which may cause damage to water lines, septic tanks or sidewalks and driveways.

Cleanliness

Maintenance problems can be avoided by not selecting trees that drop seedpods, cones, flowers, or twigs in large amounts.

Moisture and Fertility Requirements

If suitable soils with adequate fertility are not available, trees tolerant of poor growing conditions should be planted.

Ornamental Effects

If a tree is unusually attractive in appearance, some other shortcomings may be overlooked.

Evergreen vs. Deciduous

Evergreens retain their leaves throughout the year, and are useful for privacy screens and noise barriers. Most deciduous trees drop their leaves in the fall and are preferable as shade trees. Some deciduous trees do not drop their leaves until spring.

Pest Resistance

Insects and disease problems exist among many trees. Each pest is related to the trees species itself, its vigor and the site on which it is planted. Where control techniques are available, the tree owner's commitment and ability to apply them to a pest problem will determine whether the tree should be planted.

Life Expectancy and Present Age

Tree species with expected long life spans should be favored. Long-lived species that are old may succumb to the stresses of construction, so younger trees of desirable species are preferred since they are more resilient and will last longer.

Health and Disease Susceptibility

Unhealthy trees and those with damaged areas should be considered for removal.

Structure

Check for structural defects that indicate weakness or reduce the aesthetic value of a tree: trees growing from old stumps, large trees with overhanging limbs that endanger property, trees with brittle wood, misshapen trunks or crowns, and small crowns at the top of tall trunks. Trees with strong tap or fibrous root systems are preferred to trees with weak rooting habits.

Aesthetics

Trees that are attractive and pleasing to the eye are desirable. Trees that have beauty during several seasons of the year are desirable and add value to the site.

Comfort

Trees provide cooling during the summer and buffer the cold winds of winter. Summer temperatures may be 10 degrees cooler under hardwoods than under conifers. Most deciduous trees drop their leaves in winter, allowing the sun to warm buildings and soil. Evergreens are more effective wind buffers.

Wildlife

Preference may be given to trees that provide food and cover for wildlife.

Relationship to Other Trees

Trees growing alone generally are more valuable than trees growing in groups but trees in groups are more effective in preventing erosion and reducing stormwater runoff.

Suitability for the Site

Consider the height and spread of trees and how they may interfere with proposed structures and overhead utilities. Roots may interfere with walls, walks, driveways, patios, parking lots, waterlines, and septic systems.

Desirable trees should be identified and located on a map as part of the planning process.

Exotic Invasive Species

Exotic invasive species should not be planted! We have learned over the years that although a specimen tree, such as a Bradford pear, may be beautiful at a particular site there will likely be adverse impacts in later years. In the case of Bradford pear, its seed are spread by animals and it is becoming an unwanted plant pest throughout the state. See the section on Exotic Invasive Species at the end of this chapter for more details on this topic.

Damage to Trees from Construction

Construction activities expose existing trees to a variety of stresses resulting in injury ranging from superficial wounds to death. Understanding the types of damages that may occur to trees is important in planning for protection.

Surface Impacts

Tree trunks are often damaged during construction activities. Trees scarred by construction equipment are more susceptible to damage by insects and disease. Excessive pruning of trees to prevent contact with utility lines or buildings may destroy the visual appeal of the tree, may provide a source of entry for disease causing fungi, or it may kill the tree.

Wind damage is a greater potential problem especially when some of the trees have been removed from a group of trees because the survivors are exposed to greater wind velocities. Also, trees develop root anchorage where it is needed the most. Isolated trees develop anchorage rather equally all around with stronger root development on the side of the prevailing wind. The more a tree has been protected from the wind the less anchorage it usually has. The result of thinning of trees may be that some of the remaining trees are blown over by strong winds (windthrow). A factor related to thinning is that thinning in favor of a single tall tree increases the hazard of lightning strike.

Root Zone Impacts

Disturbing the relationship between soil and tree roots can damage or kill a tree. The roots of an existing tree are established in an area where a specific environment of soil, water, oxygen, and nutrients are present. The mass of the root system must be the correct size to balance the intake of water from the soil with the transpiration of water from the leaves.

Raising the grade as little as 6” can retard the normal exchange of air and gases. Roots may suffocate due to lack of oxygen or be damaged by toxic gases and chemicals released by soil bacteria. Raising the grade may also elevate the water table and change the potential of the soil to function as a growing medium suitable for the trees that were growing there before the filling occurred.

Lowering the grade is usually not as damaging as elevating the grade. Shallow cuts of 6” to 8” will remove most of the topsoil and some feeder roots and expose some to drying and freezing. Deep cuts may sever a large portion of the root system, depriving the tree of water and increasing the chance of windthrow. Lowering the grade may also lower the water table.

Trenching or excavating through a tree’s root system eliminates part of the root system and can be very detrimental. Trees which lose as much as 40 percent of their root system usually die within 2 to 5 years. Tunneling may be a better alternative with species that do not have tap roots.

Soil compaction caused by heavy equipment, materials storage, and paving within the drip line of trees restricts air and water from roots by reducing pore space of the soil and by reducing infiltration.

Site Considerations for Non-woody Vegetation

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

Soils

Many soils characteristics, including acidity, moisture retention, drainage, texture, organic matter, fertility, and slope influence the selection of plants and their establishment requirements. For example, bahiagrass and centipede are suited to droughty soils since they are more drought tolerant than most other grasses. Appendix A1 Soils in Alabama contains tables that provide a number of interpretations related to the soils that occur in Alabama. One characteristic that will not be found in tables is the occurrence of compaction created incidentally as a result of equipment traffic, especially when the soil is wet or moist. Compaction can have an extremely adverse impact on plant establishment and maintenance and should be addressed before establishment of vegetative cover.

Slope

The steeper the slope, the more essential is a vigorous vegetative cover. Good establishment practices, including seedbed preparation, liming fertilizing, proper planting, mulching, and anchoring of mulch are critical. The degree of slope may limit the equipment that can be used in seedbed preparation, planting, and maintenance.

Woody plants, shrubs, vines, and trees generally provide better long-term erosion control on steep slopes. They may be more costly and slower to establish, but can provide substantial savings in maintenance. Also, they can be more desirable in the overall landscape plan.

Aspect

Aspect affects soil temperature and available moisture. South and west facing slopes tend to be warmer and drier, and often require special treatment. Warm season species tend to do better on south and west facing slopes in Alabama because they are usually more drought and heat tolerant.

Climate

The regional climate must be considered in selecting well adapted plant species. Species adaptation and seeding dates in Alabama are based on three broad geographical areas: North, Central, and South. Climatic differences determine the appropriate plant selections based on such factors as cold-hardiness, heat tolerance, and tolerance to a cool growing season.

Management Requirements

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

Select plant species that are wear resistant and have rapid wear recovery for sites that receive heavy use, such as a sports field. A wear resistant plant that also recovers rapidly from foot traffic is bermudagrass. Bermudagrass also has a fast establishment rate and is adapted to all geographical areas in Alabama.

Where a neat appearance is desired, use plants that respond to frequent mowing and other types of intensives maintenance. Likely choices for quality turf in north Alabama are bermudagrass or tall fescue, while in central or south Alabama bermudagrass, centipede, or zoysia are good choices.

At sites where low maintenance is desired, low fertility requirements and vegetation persistence are particularly important. Sericea lespedeza and tall fescue are good choices in north Alabama while bahiagrass and centipede do well in central and south Alabama.

Seasonal Considerations for Non-Woody Vegetation

Newly constructed slopes and other barren areas should be seeded or sodded as soon as possible after grading. Grading operations should be planned around optimal seeding dates for the particular region, where feasible. The most effective times for planting perennial grasses and legumes generally extend from March through May and from late 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 should be planted or the area may be stabilized with crimped or tackified mulch. Temporary seedings of annual species (small grains, ryegrass, millets etc.) often succeed at times of the year that are unsuitable for seeding permanent (perennial) species. Planting dates may differ for temporary species depending on the geographical area of Alabama.

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

Selecting Grasses and/or Legumes

Mixtures vs. Single Species Plantings

A mixture may be more desirable than a single species. Mixtures can be selected to provide cover more quickly and can be more enduring than a single species. Mixtures need not be elaborate. The addition of a quick-growing annual or short-lived perennial provides early protection and facilitates establishment of a slower growing long-lived perennial. It is important to evaluate the merits and weakness of each species in selecting the mixtures for the specific site to be treated. If a quick establishing species such as common bermudagrass is planned for the final cover then a mixture is probably not appropriate.

Companion or "Nurse" Crop

The addition of a companion or "nurse" crop (quick-growing annual or weak perennial added to permanent mixtures) is a good practice on difficult sites, late seeding, or in situations where the development of permanent cover is likely to be slow. The companion crop germinates and grows rapidly, holding the soil until the perennial species becomes established. The seeding rate of the companion crop must be limited to avoid crowding and competing with the desired perennial species, especially under optimum growing conditions. It is important to not plant a nurse crop that will compete to the detriment of the desired species.

Plant Species Selection

Information on plant species adapted for soil stabilization use in Alabama is contained later in this chapter and in the tables associated with the practices that are used for plantings. Using this information makes plant selection straight-forward for most situations. Specific seeding rates and planting dates are given in the tables of the practices.

Annuals

Annual plants grow rapidly, then mature and die in one growing season. They are useful for quick, temporary cover or as a companion crop for slower growing perennials.

Small Grain

Rye (cereal) is usually superior to other small grains (wheat, oats, or barley) for temporary cover. It has more cold hardiness than other annuals and will germinate and grow at lower temperatures. It will provide more fall and early winter growth and matures earlier than other small grains. Rye germinates quickly and is tolerant of poor soils. Including rye in fall seeded perennial mixtures is particularly helpful on difficult soils and erodible slopes or when seeding is late. However, seeding rates of rye should be limited to the suggested rates because a thick stand will suppress the growth of perennial seedlings. No more than 60 lbs/acre should be planted when rye is used as a companion crop. Rye grows fairly tall in the spring which may be undesirable. If this is a problem some of the shorter growing varieties of wheat may be used.

Annual Ryegrass

Annual ryegrass is outstanding for temporary cover because it provides dense cover rapidly. **It is not recommended for use as a companion crop in perennial mixtures in Alabama because it is highly competitive and crowds out most other species leaving no lasting cover.** Also, if allowed to mature the seed volunteers and can seriously interfere with subsequent efforts to establish permanent cover.

Millets

Millets (Browntop, Foxtail) are warm season annuals, useful for temporary seeding or as a nurse crop. Browntop millet has early rapid growth and grows to 2 to 3 feet in height. Foxtail is a fine stemmed plant growing to a height of 4 to 5 feet. The leaves are broad and flat. Foxtail millets do best under fairly abundant moisture conditions.

Sudangrass and Sorghum-sudangrass Hybrids

Sudangrass and sorghum-sudangrass hybrids, like the millets, are warm season annuals which are useful for temporary vegetation. The small stemmed, shorter growing varieties are more satisfactory for temporary vegetation than the tall coarse-stemmed varieties.

Annual Lespedeza

Annual lespedeza is a warm-season reseeding annual legume that grows to a height of 6-12”. It is tolerant of low fertility and is adapted to the climate and most soils throughout Alabama. It is not adapted to alkaline soils of the Black Belt or deep sands. It is a good companion crop for spring planted sericea lespedeza, filling in weak or spotty stands the first season without suppressing the sericea. Annual lespedeza can heal thin areas in the perennial cover for several years after initial establishment. Two species of annual lespedeza are grown in Alabama. “Common” annual lespedeza volunteers in many parts of Alabama and is sold under the variety name Kobe. Korean lespedeza is a slightly larger, coarser and earlier-maturing plant sold under several variety names. Kobe is superior on sandy soils and preferable in south Alabama. Korean is better in north Alabama because the seeds mature earlier.

The preferred seeding dates for annual lespedeza are in the late winter to early spring. It can be included with a fall seeding, in which case some seeds remain dormant over the winter and germinate the following spring.

Cool-Season Perennials

Perennial plants, once established, will live for more than one year. They may die back during a dormant period, but will grow back from their underground tubers or rhizomes in succeeding years. Stands of perennials will persist for a number of years 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. Tall fescue is the only cool-season perennial grass recommended for vegetating disturbed soils in Alabama. A description of tall fescue follows.

Tall Fescue

Tall fescue, a cool-season grass, is the most widely used species in north Alabama for erosion control. It is well adapted to all of north Alabama and all but the droughty soils of central Alabama. Also, it can be grown on the Black Belt soils of Alabama. It thrives in full sun to partial shade and is fairly easy to establish.

Liberal fertilization and proper liming are essential for prompt establishment, but once established it can tolerate minimal maintenance almost indefinitely. It will provide stabilization the year of establishment if planted early during the planting period. Because tall fescue has a bunch growth habit, it is slow to fill in areas with poor stands. Therefore, some replanting may be required on eroded areas or areas of spotty stands to complete stand establishment. Fescue does not tolerate frequent and close mowing during the summer, especially on sites that are droughty.

White Clover

White clover is sometimes planted with tall fescue. It is usually short-lived.

Crownvetch

Crownvetch is a deep-rooted, perennial legume adapted only to north exposures in the northern tier of counties in Alabama. It is useful on steep slopes and rocky areas that are likely to be left unmowed. Crownvetch requires a specific inoculant. Because site requirements are so unique, crownvetch is not included in this handbook as a species to plant (in Alabama).

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. Most species of warm-season perennials do better in the southern one-half of Alabama, but there are species or varieties that will grow in north Alabama. The following grasses have proven the most useful for soil stabilization.

Bahiagrass

Bahiagrass is a warm-season perennial grass particularly well adapted for growing on sandy soils in the southern half of Alabama. It will tolerate acid and low fertility soils, grow in full sun to light shade, and persist almost indefinitely with little or no maintenance after it is established. However, bahiagrass seedlings are small and lack the vigor some species of warm-season grasses possess; it usually takes 2 years to establish a good sod. Bahiagrass is established with seed.

Bahiagrass produces a fairly dense sod suitable for low maintenance areas. It has a high resistance to wear and recovers fairly fast from wear. It produces rhizomes and will fill in small bare spots, but not fast like bermudagrass. Bahiagrass produces seed heads about one to 2 feet in height throughout the growing season and, where this is not a problem, it is probably the best choice for stabilizing soil in the southern one half of the State. It grows slowly in the northern part of the state and is not recommended for erosion control plantings. Pensacola is the recommended variety of bahiagrass for soil stabilization in Alabama. It is more tolerant to upland sites and more cold tolerant than Argentine bahiagrass. Argentine bahiagrass is not recommended for erosion control in Alabama.

Common Bermudagrass

Common Bermudagrass is a long-lived perennial that spreads by stolons and rhizomes. It will grow in all areas of the State on suitable sites. It is best adapted to well-drained fertile soils and will survive extreme heat and drought. It does poorly on extremely droughty sandy soils and will not grow on poorly drained soils. It is not shade tolerant. It responds well to fertilizer and will establish a dense sod quickly from seed. Bermudagrass requires more maintenance than bahiagrass and, if a regular maintenance fertility program is not used, it will tend to slowly decline. It has a high resistance to wear and fast recovery from wear which makes it a good choice for heavy use areas that have high fertility.

There are two types of bermudagrass which are important in soil stabilization: common bermudagrass, which can be established with seed or sprigs, and turf-type bermudagrasses which must be established from vegetative material. Common has longer internodes and larger leaves than the turf-type hybrid bermudagrass. When using common bermudagrass for permanent vegetation, only seed that is 98% pure common bermudagrass should be planted. Common bermudagrass seed are often contaminated with giant-type bermudagrass seed. Giant-type bermudagrass is very competitive and fast growing, but it is not cold hardy in Alabama. So when common bermudagrass seed contains even a small percent of giant type bermudagrass seed, they will be "choked out" by the giant-type bermudagrass. Since the giant-type bermudagrass will be killed by a cold winter, a good bermudagrass sod the year of establishment can become a poor stand the following year.

The turf type hybrid bermudagrass varieties have fine leaves and short internodes which make them desirable for lawn, golf courses and other areas where a quality turf is desired. However, turf type hybrid bermudagrass is more costly to establish because it must be planted from sprigs, plugs, or solid sodded.

The agronomic varieties of hybrid bermudagrass, such as Coastal, do not lend themselves to soil stabilization of construction areas. The height may be undesirable in certain areas and they too must be established with vegetative material which usually makes them too costly to establish. Also the stand declines without costly maintenance.

Sericea Lespedeza

Sericea lespedeza, or sericea as it is commonly known, is a deep-rooted, drought resistant perennial legume, adapted to all but the poorly drained and deep sandy soils of Alabama. It is long-lived, tolerant of low fertility soils, pest free, and will fix nitrogen. It can be a valuable component in most low maintenance mixtures. Sericea is slow to establish and will not contribute much to prevention of erosion the first year; however, once established it persists indefinitely on suitable sites. Where esthetic is important, sericea may be considered unsightly because the old top growth breaks down slowly and the previous years' growth is conspicuous in following years. It may invade adjoining sites that have full sunlight and is recognized by the forest industry as an invasive species.

Plantings that include sericea should usually include a companion crop such as annual lespedeza or common bermudagrass. Sericea should be planted as early as possible within the planting date to avoid as much weed competition as possible. Also, sericea may be planted in the late fall and winter months because many of the seed will lie dormant until the following spring.

Sericea does not tolerate frequent mowing and late mowing before frost because these mowing regimes deplete food reserves and adversely affect the stand the next year. Sericea has lost favor as a roadside plant since it is not tolerant to chemical spray treatments often used on roadsides to control weeds and to retard growth of favored grasses.

Selecting Shrubs, Vines and Groundcovers to be Retained or Planted

As with trees, several plant characteristics and environmental requirements should be considered when selecting shrubs, vines and groundcovers. Closer adherences to plant requirements yield a greater chance of achieving a successful landscape.

Hardiness

Plants have varying capacities to tolerate cold or heat. Cold tolerance is of most concern. The state of Alabama spans two major plant hardiness zones, Zone 7 (from the central part of the state northward) and Zone 8 (the southern half of the state). The zones are determined by the range of average annual minimum temperatures. The average range of minimum temperatures for Zone 7 is 0 to 10 degrees F; for Zone 8 it is 10 to 20 degrees F (See Plant Adaptation Zones in practice Shrub, Vine and Groundcover Planting).
Landscape plants which are not capable of tolerating temperatures below 10 degrees should not be expected to escape injury during an average winter in Zone 7. However, they should be adequately adapted to Zone 8.

Plant hardiness can be greatly influenced by nearby bodies of water since water buffers change in temperature. Structures or other plants can moderate extreme temperatures and shelter landscape plants, enabling marginal species to better tolerate winter conditions.

Summer Heat Tolerance

A plant’s capacity to survive the stress of high temperature is also a concern. Heat interacts with other environmental factors, especially soil moisture conditions and sunlight to influence the range of adaptability of a plant. Usually associated with high temperatures is rapid depletion of soil moisture, especially in late summer. Direct sunlight increases the severity of heat effects on plants. Since Alabama has periods of high temperatures and short winters, spruce, hemlock, and yew are generally poor performers. Other conifers such as deodar cedars and cryptomeria are not hardy further north into Zone 6 but offer good substitutes for hemlocks and spruces in Alabama.

Moisture Requirements and Soil Drainage

Landscape plants vary widely in the amount of moisture they need to thrive. If a drought tolerant plant receives a lot of rain, it can be more susceptible to invasion by normally weak pathogens, especially where the soil drains slowly. On the other hand, plants which require large amounts of water for best performance are easily drought stressed when water is withheld or if planted in very well-drained soils. Such conditions may actually attract insect pests to stressed plants.

Plants that normally require a lot of water can be irrigated so that the ornamental attributes of the plant are maintained. However, this is a use of water resources that can be avoided if consideration is given to appropriate plant selection.

Soil pH

Soil pH can have a profound influence on the performance of landscape plants. However, most landscape plants perform adequately within a soil pH range of 5.5 to 6.2. Plants listed in Tables SVG 1-5 should grow satisfactorily within this pH range.

Plant Pest Susceptibility

It is unwise to use pest-susceptible plants in areas where those particular pests thrive. For example, most species of euonymus are attacked by euonymus scale. Other landscape options for plant materials might be selected which do not have the same susceptibilities. Most plants listed in Tables SVG 1-5 have few major pest problems.

Nutritional Requirements

Newly set plants often require little additional fertilizer because of the presence of residual fertilizer in the root ball. At this stage, supplying water is far more important than adding fertilizer. Also, most well-established shrubs require less fertilizer to maintain an attractive plant than is usually required by poorly established shrubs.

Light Requirement

Plants which require full sun (at least 8 hours of direct sunlight per day) are weakened in low light situations. Plants that need some shade are often vigorous and unattractive in full sun.

Rate of Growth and Mature Size

Obviously, for rapid cover, faster-growing plants are desired. However, mature size and other plant characteristics should be considered. For example, where a screen is needed, a slower-growing evergreen shrub may be desired over a fast-growing deciduous plant. Take all plant characteristics into account when selecting plants for a site. If money is available, both needs can be met by planting fast growing, short-lived plants to provide a quick screen and at the same time planting slower growing plants and allowing them to mature. When the fast-growing plants become over grown, they can be removed to allow the more desirable plants to take their place.

Treating Sites to Establish Grass, Legumes, Shrubs, Vines and Groundcover

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. These qualities are particularly beneficial to plant establishment. Consequently, where practical, topsoil should be stripped prior to construction and stockpiled for use in final vegetation of the site. Stockpiling topsoil may eliminate costly amendments and repair measures later. Topsoil may not be required for the establishment of less demanding, lower maintenance plants, but it is essential on sites having shallow soils or soils with other severe limitations. It is essential for establishing fine turf and ornamentals.

The need for topsoil 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.

Soil Amendments

Lime is almost always required on disturbed sites in Alabama to decrease soil acidity. Lime raises the pH, reduces exchangeable aluminum, and supplies calcium and magnesium for vigorous plant growth. Only the alkaline soils of the Black Belt and north Alabama do not require lime. A soil test should be used to determine the need for liming materials.

Plant nutrients, such as phosphorus and potassium, will usually be required even on the best soils. Plant nutrient application rates for a particular species of vegetative cover should be applied according to a soil test report.

Soil amendments should be applied uniformly and well mixed with the top 6” of soil during seedbed preparation.

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, chiseling, or some similar method of land preparation. Tillage should be done on the contour where feasible to reduce runoff and erosion. Lime and fertilizer should be incorporated during the tillage.

Planting Methods

Seeding is by far the fastest and most economical establishment method that can be used with most species. Seedbed preparation, liming, and fertilization are essentially the same regardless of the establishment method chosen.

Uniform seed distribution is essential. This is best obtained using a cyclone seeder, conventional grain drill, drill seeder, cultipacker seeder, or hydraulic seeder. The drills and cultipacker seeder are pulled by a tractor and require a fairly clean, smooth seedbed.

Seeding rates recommended in this handbook are for Pure Live Seed and take into account the “insurance” effect of extra seed. Rates exceeding those given are not recommended because over dense stands are more subject to drought, competitive interference and are unnecessarily costly.

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 distraction.

A drill seeder (or no-till planter) can plant seed into an existing cover or mulch or be used to restore or repair a weak stand. It can be used on moderately uneven, rough surfaces. It is designed to penetrate the sod, or other residue such as dead temporary cover, open narrow slits, and deposit seed with a minimum of surface disturbance.

Hydroseeding may be the most effective seeding method on steep slopes where equipment cannot work safely. A rough surface is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged or rough seedbed gives the best results when hydroseeding is used.

Sprigging refers to planting stem fragments consisting of runners (stolons) or lateral, below-ground stems (rhizomes), which are sold by the bushel. Sprigs can be broadcast or planted in furrows using a transplanter. This method works well with bermudagrass. Also sprigs may be broadcast and covered with soil by light disking, and cultipacking. Broadcasting is easier but requires more planting material. Common bermudagrass will cover over much more quickly than the lawn type bermudagrass.

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

In sodding, the soil surface is completely covered by laying cut sections of turf. Turf-type bermuda, centipede, and zoysia are usually the types of turf used for sodding. Plantings must be watered 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 grass swales 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 can be done almost anytime of the year in Alabama.

Inoculation of Legumes

Legumes have bacteria called 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 in that a given species will inoculate some legumes but not others. Therefore, successful establishment of legumes 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 inoculating various legume seed are usually available through seed dealers.

Among the legumes listed for use in this handbook, crimson clover is the only one generally requiring inoculation. Lespedeza nodule bacteria are widely distributed in the soils of Alabama unless the site has had all surface soil removed.

Irrigation

Irrigation, though not usually required except for Sodding, can extend seeding dates into the summer and ensure 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 during droughts. If supplementary water is used to get seedlings up, it must be continued until plants become completely established.

Mulching

Mulch is essential to the successful establishment of vegetation of most disturbed sites. Mulch protects sites from erosion until the vegetation is established. In addition, mulch aids seed germination and seedling growth by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature changes.

Mulch may be used also to 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.

Small grain straw (wheat, oats, barley or rye) is the most widely used and one of the best mulch materials. However, there are other materials, including manufactured mulches that work well. Mulching materials covered in this handbook have their respective advantages and appropriate applications, and a material should not be selected on the basis of cost alone. The effectiveness of straw mulch is increased by crimping or tacking and crimping or tacking usually should be a requirement.

Maintenance

Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if not repaired, can result is excessive soil loss from an otherwise stable site. A single heavy rain will enlarge rills and bare spots and the longer repairs are delayed the more costly they become. Prompt action will keep soil loss, sediment damage, and repair costs down. New plantings should be inspected frequently and maintenance performed as needed. If rills and eroded areas develop, they must be repaired, seeded, and mulched as soon as possible.

Maintenance requirements extend beyond the seeding phase. Damage to vegetation from disease, insects, traffic, etc., can occur at any time. Pest control (weed or insect) may be needed at any time. Weak or damaged spots must be fertilized, seeded and mulched as promptly as possible.

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

Measures for Stabilizing Coastal Dunes

Introduction

Dunes are reservoirs of sand that help keep a sea shore intact. They act as flexible barriers to high tides and waves, and dissipate energy that can cause shore recession (beach erosion). Coastal dune ridges block the movement of storm tides and waves into the low-lying areas behind a beach. If they do give way to storm winds and water, these shifting mounds of sand will soon reappear. Dunes are not effective, however, against persistent, continuous beach erosion caused by permanent changes in the shoreline.

Dunes are formed by waves and wind, and when unstable, they are extremely vulnerable to these same forces. They may be stabilized by grasses and woody plants that are well adapted to this environment.

Dunes stabilized with grasses provide for enrichment of dunes, a natural barrier, reducing the velocity of waves and absorbing their energy. These stabilizing plants are tolerant of salt, intense heat, soils lacking humus, and a limited water supply. As sand piles up around beach grass plants, new shoots emerge from the sand surface and trap more windblown sand. Structures such as crosswalks and sand fences also catch and hold sand, and help to build or repair dunes.

Dune stabilization projects usually require a combination of vegetative and structural measures. They include planting adapted dune grasses, providing adequate moisture during the first growing season (often with an irrigation system), and constructing walkover structures to prevent pedestrian traffic from destroying dune vegetation. The use of sand fences and dune vegetative plantings are more effective than using either vegetation or structural measures alone.

Selecting Vegetative Measures

There are only a few plant species that are tolerant of the stresses of the beach environment. These plants must be able to survive being buried by blowing sand, sand blasting, salt spray, saltwater flooding, drought, heat, and low nutrient supply. Perennial grasses are effective under these conditions. From 1984 to 1989, the USDA, Natural Resources Conservation Service (formerly Soil Conservation Service) Jimmy Carter Plant Materials Center (PMC) evaluated sea oats, marshhay cordgrass, and bitter panicum for dune stabilization on Tybee, Jekyll, and St. Simons Islands Georgia, and at Gulf Shores Alabama. As a result, the Jimmy Carter PMC recommends the following plant materials for coastal dune stabilization: sea oats (Uniola paniculata); 'FLAGEO' marshhay cordgrass (Spartina patens); 'NORTHPA' bitter panicum (Panicum amarum); 'SOUTHPA' bitter panicum (Panicum amarum); 'ATLANTIC' coastal panicgrass (Panicum amarum var. amarulum).

Sea Oats

Sea oats is a warm-season dune grass ranging throughout the Gulf and south Atlantic coastal region from southeastern Virginia to Mexico. It is vigorous, drought tolerant, heat tolerant and relatively free of pests. This perennial is the most important and widespread grass on southern coastal dunes.

The leaves are narrow and pale green, and in northern locations, they die back close to the ground each winter. The seed head matures in the fall and has compressed spikelets at the end of stiff stems 3 feet long or more.

Sea oats can be established by digging and dividing native plants, or from small potted plants grown from seed that are commercially available. Under natural conditions, seed germination is not high and seedling survival is low. When replanting seedlings, set the stock at least 1 foot deep into the sand and pack it tightly.

'FLAGEO' Marshhay Cordgrass

'FLAGEO' marshhay cordgrass was cooperatively released in 1990 by the NRCS Jimmy Carter PMC, the Brooksville PMC (Florida) and Fort Valley State College in Fort Valley, Georgia. This perennial occurs on dunes throughout the south Atlantic and Gulf regions and in Puerto Rico and is especially salt tolerant.

The stems of marshhay cordgrass are slender and grow 2 to 3 feet tall and the leaves are rolled inward, resembling rushes. The seed head is composed of two or more compressed spikes attached at nearly a right angle to the culm. The plant spreads by means of a network of slender rhizomes.

Plantings of vegetative material in early spring can be successful. For large plantings, bare root planting stock is recommended. Stems rooted at the base, preferably with a section of rhizome attached, can be planted at a depth of 4” to 5”.

'NORTHPA' and 'SOUTHPA' Bitter Panicum

'NORTHPA' and 'SOUTHPA' bitter panicum varieties were released by the Brooksville, PMC in 1992. Vegetative plant material is commercially available.

Bitter panicum is a perennial grass found throughout the south Atlantic and Gulf regions. It is most common in southern Florida and Texas.

The plant grows to an average height of 3 to 4 feet. The leaves are smooth and bluish green and the seed head is narrow, compressed, and generally sparsely seeded. The plant spreads from an aggressive, scattered system of rhizomes, but the stands are rather open.

Bitter panicum produces few viable seed, and it is better adapted for transplanting than sea oats. It can be propagated from a stem with part of the rhizome attached or from an 8” to 12” length of rhizome without any above ground parts. Plant the rhizome 4” deep in early spring, spaced no more than 6 feet apart.

Another method of propagation is to snap off robust stems at ground level and plant them at an angle of about 45 degrees so that several nodes are buried.

'ATLANTIC' Coastal Panicgrass

'ATLANTIC' coastal panicgrass was released by the Cape May Plant Materials Center (New Jersey). Its origin is Princess Ann County, Virginia. Seed is commercially available.

'ATLANTIC' coastal panicgrass is a somewhat dense, upright perennial bunchgrass found on coastal dunes throughout the south Atlantic and Gulf regions. It is a dominant plant at many locations, especially in west Florida, Alabama, and Texas.

The stems are coarse, straight, stiff, and grow up to 4 feet tall. Partially compressed seed heads produce moderate amounts of viable seed each fall. The crowns enlarge slowly from short, almost vertical tillers.

It can be propagated by either seeding or planting divided plant parts. Plant the seed 1 to 3” deep in dune sand, and mulch the area for best results. Seedling survival depends on adequate rainfall after germination. Clumps of coastal panicgrass can be dug, divided, and planted with good results during the summer rainy season.

Irrigation

Irrigation is required on all dune plantings to provide adequate moisture during the initial establishment period. The irrigation system will consist of mains and laterals, control zones, supports, control valves, fittings, and related hardware that is capable of applying ½” of water over the entire zone in an 8 hour period.

Structural Measures

The coastal dune stabilization plan should include structural measures such as dune walkovers and sand fences.

Dune Sand Fence

Dune sand fence is an artificial barrier of evenly spaced wooded slats or approved fabric erected perpendicular to the prevailing wind and supported by posts. It reduces wind velocity at the ground surface and traps blowing sand. Dune sand fences are used primarily to build frontal ocean dunes to control erosion and flooding from wave overwash.

Dune Walkover

Dune walkover structures control pedestrian traffic and keep traffic off of the sand, allowing the dune vegetation to establish and protect the dunes from erosion.

Dune Maintenance

Well stabilized dunes will not remain that way unless a reasonable maintenance program is followed. Major considerations include:

Control of Foot and Vehicular Traffic

The primary dune is intolerant of trampling. Traffic should be prevented to the extent possible. However, since dunes must be crossed to reach the beach, mechanical crossovers should be installed at selected sites. Elevated walkovers are satisfactory. These walkways should be curved to reduce wind erosion. The inland or secondary dune should also be protected from pedestrian and vehicular traffic.

Maintenance of Dune Line

A dune system is like a chain in that it is no stronger than its weakest point. Consequently, to receive maximum protection from dunes, a strong and uniform dune line must be maintained. Blow outs, wash pits, and other natural or human produced damage must be repaired quickly to prevent weakening of the entire protective dune system. Blow outs in a dune system can be repaired by placing sand fences between existing dunes, and tying the ends of the fence into these dunes.

Maintain sand fences and erect additional sand fences as needed, until the eroding area has been permanently stabilized or until the dune has reached the desired height and is properly vegetated. Any loose or damaged boards on cross-over structures should be repaired or replaced.

Maintenance of Vegetation

Maintain plantings by applying fertilizer as needed to keep a healthy stand with the desired density. A minimum annual application of 50 lbs/acre of an inorganic nitrogen fertilizer is usually needed for grass stands. Sparse areas should be replanted during the next planting season for the desired grass or legume.

Exotic Invasive Species

Introduction

Exotic invasive species are becoming an increasing problem over the countryside. From well-known species such as wisteria to lesser known plants such as cogangrass, it is important that exotic invasive species be understood and appropriate measures be taken to prevent their introduction and spread on construction sites.

Some Invasive Species

Cogangrass came into Southern U.S. ports in the early 1900’s as a packing material and slowly established along the Gulf coast (particularly in the Mobile area) for a number of years. More recently, it has spread along Interstates 10 and 65 quite rapidly and is now found in other areas where it was spread by wind or mowing equipment to new sites. It is listed first because it is so invasive, so competitive to other plants, so hot when it burns, and so difficult to control. Every precaution should be taken to prevent its spread!

Chinese privet, while not commonly used in new landscape plantings, is a species that was once prized as a “hedge”. Over the years, as a result of birds spreading the seed, privet has become established along the edge of many open sites and is invading open areas along streams and other sites that are undergoing plant succession. Privet is mentioned as an example of what can happen when an invasive species that is difficult to control is planted. A planner should recognize the importance of not using an invasive even though the plant may be pretty or have other desirable characteristics.

There are too many invasive species to list them all, but a few others that definitely have the potential to be damaging to most landscapes and should not be planted include the following: autumn olive, Bradford pear, bush honeysuckle, giant reed, Japanese climbing fern, and Japanese honeysuckle, The reference at the end of this section provides a comprehensive listing of species that may become a problem to forest sites and other sites that are not managed intensely.

There are a few invasive plants that will continue to be used in the erosion and sediment control industry that are potential problems in some situations but are used because there are no acceptable alternatives. These species include the following: bahiagrass, common bermudagrass , lovegrass, sericea lespedeza, and tall fescuegrass.

Addressing Invasives

There are two avenues for addressing invasive species. First, planners should be careful in specifying the species to plant. To this end, the tables for Shrub, Vine and Groundcover Planting were revised in the 2014 revision of this Handbook to remove exotic invasive species. Second, species that can be spread by seed and vegetative parts, such as cogangrass, should be recognized and precautions should be taken by those that move equipment from one site to another, to prevent their equipment from moving seeds and plant parts to uncontaminated sites.

Excellent references are available to help in identifying invasive species and in planning ways to minimize their spread. One such reference is A Management Guide for Invasive Plants in Southern Forests, USDA Forest Service, Southern Research Station, General Technical Report SRS-131. Another way to learn about invasives is to participate in the Alabama Invasive Plant Council, www.se-eppc.org/alabama.

Chapter 3

Plan Preparation

What is a Plan for Erosion and Sediment Control and Stormwater Management

A plan for erosion and sediment control and stormwater management is the document which provides the practices and measures to prevent or reduce erosion on construction sites and minimize the impacts of sediment, turbidity and hydrologic changes off-site. It is the part of a Stormwater Pollution Prevention Plan (defined in glossary) or Construction Best Management Practices Plan (CBMPP) that identifies appropriate measures for erosion and sediment control for a specific construction site. Plan components are described in detail later in this chapter.

Designs of practices are usually prepared after a plan is adopted and, therefore, designs are not considered a part of the plan. Design of practices may also require the plan to be modified based on design requirements. Practice design criteria in Chapter 4 and guidelines for Installation and Maintenance of Best Management Practices in Chapter 3 of Volume II provide a basis for developing sound specifications.

Who is Responsible for the Plan

The owner or lessee of the land planned for development or needing treatment from a previous disturbance has the responsibility for plan preparation and adequacy. Although the owner or lessee may designate a qualified design professional to prepare and implement the plan, the owner or lessee retains the ultimate responsibility.

If during construction it becomes obvious that additional practices or measures are needed or that the system that is planned is not appropriate, the shortcoming should be brought to the attention of the project manager for action by an appropriate design professional and concurrence by the owner or the owner’s designee. In this scenario, additional planning must continue to ensure that the plan is up-to-date and adequate.

What Is an "Adequate" Plan

An adequate plan contains sufficient information to describe the system intended to control erosion on the construction site, minimize related off-site sediment delivery and turbidity and address potential problems associated with hydrologic changes off-site. If regulations exist, more details may be required to satisfy the approving authority that the potential problems of erosion and sediment will be adequately addressed.

The length and complexity of the plan should be commensurate with the size and importance of the project, severity of site conditions, and the potential for off-site damage. Obviously, a plan for constructing a house on a single subdivision lot will not need to be as complex as a plan for a shopping center development. Plans for projects undertaken on relatively flat terrain will generally be less complicated than plans for projects constructed with steep slopes with higher erosion and sediment delivery potential. The greatest level of planning and detail should be evident on plans for projects which are adjacent to flowing streams, wetlands, dense population centers, high value properties, coastal resources and other critical habitats where damage may be particularly costly or detrimental to the environment.

The Step-by-Step Procedures for Plan Development outlined later in this chapter are recommended for the development of all plans. It is recognized that additional information may be needed to meet state and local requirements.

The checklist following the procedures can be used by qualified design professionals as a checklist for plan content and format.

General Considerations for Preparing Plans

Qualified design professionals should have a sound understanding of the state and local laws and regulations related to erosion and sediment control and stormwater management. In addition, they must be competent in the principles of erosion and sediment control and stormwater management.

Developers and qualified design professionals can minimize erosion, off-site sediment delivery, turbidity issues and other construction problems by selecting areas appropriate for the intended use because tracts of land vary in suitability for development. Knowing the soil type, topography, natural landscape values, drainage patterns, receiving stream characteristics and classification, flooding potential, areas of contaminated soil, and other pertinent data are useful in identifying both beneficial features and potential problems and challenges of a site.

A plan should contain enough information to ensure that the party responsible for development of a site can install the measures in the correct sequence at the appropriate season of the year. Sufficient information should be included to provide for maintaining the practices and measures during construction and after installation has been completed. A schedule of regular inspections and repair of erosion and sediment control BMP's should be set forth to ensure that maintenance receives appropriate attention and is accomplished.

Will the development of the site result in increased peak rates of runoff? Will this result in flooding or channel degradation downstream? If so, considerations should be given to stormwater control structures on the site. Local ordinances related to stormwater management must be considered and met.

The length and complexity of a plan should be commensurate with the size and importance of the project, severity of site conditions, and the potential for off-site impacts. A plan may contain a description of the potential erosion and sediment-related problems. If a site is in the coastal zone, in a watershed with a formally designated impaired stream, or has contaminated soil or hazardous waste on the site, additional attention will be required during plan development – see Areas of Special Concern below.

For regulated sites in Alabama, the plan must satisfy the Alabama Department of Environmental Management requirement that the potential problems related to erosion, sediment and stormwater will be adequately addressed.

New or innovative conservation measures or modifications to standard measures in this handbook may be used if the proposed measure is expected by the qualified design professional to be as effective as the practice for which it is being substituted.

Where applicable, the plan for a site should be included in the general construction contract. To facilitate reviews and its use on the site, the plan should be prepared and assembled so that it may be reviewed as a separate document.

Areas of Special Concern

Contaminated Sites

For sites that are contaminated with hazardous constituents (based on background levels), care should be taken to ensure that the contamination is appropriately managed. When soil potentially containing hazardous constituents (based on background levels) is excavated at a site, it should be stored in covered roll-offs or some other conveyance until an adequate waste determination, as required by both State and federal law has been conducted. Soil that is contaminated above Alabama Department of Environmental Management established toxic concentrations or contaminated with listed hazardous wastes must be manifested and disposed at an approved hazardous waste treatment, storage, disposal (TSD) facility. Also, equipment used in the excavation process must be adequately decontaminated and all waste materials produced as a result of the decontamination procedures disposed in accordance applicable State and federal requirements.

Solid waste that has been disposed illegally (unpermitted solid waste dumps or burial sites) may be encountered during construction activities and a variety of solid waste is generated during construction activity. Persons should contact the Alabama Department of Environmental Management Land Division if there are questions on how to proceed if illegal solid waste dumps or buried solid waste are encountered, or regarding proper management of solid waste generated during construction. Brownfield sites (see Glossary for definition) may have issues that call for unique approaches for remediation and or construction. The Alabama Department of Environmental Management Land Division provides oversight of assessment and remediation activities concerning these types of sites through its Brownfield Redevelopment and Voluntary Cleanup Program.

Cultural Resources

Cultural resources that may be altered, disturbed or destroyed by project implementation should be reported. Cultural resources consist of prehistoric and historic archaeological sites and historic structures (bridges, objects, buildings, etc., 50 years or older). If a cultural resource is known to exist or is discovered during project implementation, the Alabama Historic Commission should be contacted immediately for further guidance. The Alabama Historical Commission also maintains a listing of Historic Districts and Historic Structures and is responsible for maintaining the Archaeological Site Files, a database that contains the locations and significance of previously recorded archaeological sites. Under normal circumstances, after a cultural resource has been recorded, the project will be allowed to proceed as planned.

Sensitive Waters

Waters that have been designated by the Alabama Department of Environmental Management for special emphasis (i.e. Tier 1) or protection (i.e. Outstanding Alabama Water) may require additional erosion and sediment control measures to provide a higher level of water quality protection than would otherwise be required. Also, additional requirements may be imposed by state regulations for review of plans before permits are issued.

Sites in Coastal Zone

Construction plans prepared for sites in the designated coastal areas of Alabama must comply with the guidelines contained in the Coastal Nonpoint Pollution Control Program (CNPCP). While the practices that are needed are similar to those needed throughout the state, except for the dune related practices, there are additional requirements related to permitting within this Coastal Management Area that influence the requirements for plan content. It is recommended that construction practices (including Detention, Retention and Bioretention) within the Coastal Area be designed to yield greater than 35% reduction in nutrients and a minimum of 80% reduction in total suspended solids (TSS). Another example of such a requirement is the construction of a Dune Sand Fence (DSF) which meets the guidance from the CNPCP office and the US Fish and Wildlife Service to benefit endangered and threatened sea turtles.

Stream Alterations

Streams, both perennial and intermittent, are considered “waters” of the United States and are regulated as “wetlands” under the Clean Water Act, Section 404 by the Army Corps of Engineers. Relocating streams or other modifications must be approved by the Corps of Engineers. In-depth guidance for obtaining approval for alterations of streams is beyond the scope of this handbook. Detailed information should be obtained from the Army Corps of Engineers serving the area
Stream alterations also require a 401 Clean Water Certification from the Corps of Engineers. Alterations also require approval by the Alabama Department of Environmental Management under applicable rules of the department.
Associated with streams are the nearby adjacent areas and local regulations involving buffer zones may prohibit or otherwise restrict disturbances and construction in these areas.

Wetlands

Construction plans must respect the wetland regulations of the Clean Water Act, Section 404, and all applicable Alabama Department of Environmental Management rules. While the details of the regulations are beyond the scope of this handbook, it must be noted that wetlands cannot be altered by dredging and filling except in small increments approved by the Army Corps of Engineers and, in addition, construction plans shall be prepared to prevent negatively impacting wetlands off-site.

Threatened and Endangered Species

Threatened and endangered species habitat that may be altered, disturbed or destroyed should be reported. If a Threatened and Endangered Species is found within the proposed work area, the U. S. Fish and Wildlife Service should be contacted for consultation before additional work proceeds.

Components of a Plan

This subtopic describes the typical components that should be included in a plan. Local or state regulations may require additional items or more detailed information than listed.

There are typically two components of a plan: a Site Plan Map showing locations of the planned practices and a Written Narrative. Supporting materials are essential to develop the plan and they should be a part of the associated file material available with the plan. In addition, additional components such as a site location map are needed or required to satisfy regulatory requirements.

Site Plan Map (Sometimes Referred to as Treatment Map)

This map may include a site development drawing and a site erosion and sediment control drawing depicting types and, to the extent possible, locations of planned practices. Map scales and drawings should be appropriate for clear interpretation. Site planners are urged to use the standard coding system for practices contained at the end of this chapter. Use of the coding system will result in increased uniformity of plans and better readability for plan reviewers, job superintendents, and inspectors statewide.

Written Narrative

Where needed, addition information that is not included on the site plan map should be included in a plan narrative that is written in a clear, concise manner. Typical items to include are the planned measures. Other items that may be needed include (a) a construction schedule that provides information both on sequence and time of year for installing the various practices and measures. (b) information on maintaining the practices and measures during construction and after installation have been completed and (c) a schedule for regular inspections and repair of erosion and sediment control and stormwater measures during construction. In some instances, existing conditions at the site and adjacent areas and rationale for those decisions involved in choosing erosion and sediment control measures may be included to help clarify the plan.

Adequate information provided by the narrative is important for the plan reviewer, the construction superintendent and the inspector. These details help insure that erosion and sediment control and stormwater measures are understood and properly installed. In addition, other information may be required in the plan by the Alabama Department of Environmental Management and local governments. Much of the additional information is cover by the following section Supporting Materials and Supporting Data.

Supporting Materials (Referred to later in Chapter as Supporting Data)

These items include inventory information collected and used during the planning process (contour maps, soils maps, charts, or other materials as applicable used in evaluating the site and formulating the plan). Supporting materials are important to all those involved in plan formulation and plan reviews and should be available to those with a specific need for them.

Step-By-Step Procedures for Plan Development

The context of the procedures presented in this subtopic is that a professional skilled in erosion and sediment control and stormwater management will assist another professional that is developing the overall site plan.

Step 1- Data Collection

Data collection includes inventorying the existing site conditions to gather information which will help in developing the most effective erosion and sediment control plan. The information should be shown to the extent practical on a map and explained in well-organized notes. This information eventually becomes a part of Supporting Data and is used to analyze and evaluate the site and practice options.

Topography

A large-scale topographic map of the site should be prepared. The suggested contour interval is usually 1 to 2 feet depending upon the slope of the terrain. However, the interval may be increased on steep slopes.

Drainage Patterns

All existing drainage swales and patterns on the site should be located and clearly marked on the topographic map.

Soils

Major soil type(s) on the site should be noted and shown on the topographic map if the information is available. Soils information for previously undisturbed sites can be obtained from soil survey information for the county of the site location. Soil information can be found on the Web Soil Survey (http://websoilsurvey.nrcs.usda.gov) or obtained from the local Natural Resources Conservation Service (NRCS) office. On site soils evaluations and borings can be provided by soil consultants. For ease of interpretation, soils information should be plotted directly onto the map or an overlay of the same scale.

Groundcover

The existing vegetation on the site should be determined. Such features as trees and other woody vegetation, grassy areas, and unique vegetation should be shown on the map or described in the notes describing the site. In addition, existing bare or exposed soil areas should be indicated. This information may be important in determining clearing limits and establishing stages of construction.

Adjacent Areas

Areas adjacent to the site should be inventoried and important features that may be impacted by the proposed plan should be marked on the topographic map or identified in the notes. Applicable features include streams, springs, sinkholes, roads, wells, houses, other buildings, utilities and other land areas.

Floodplain Boundaries

Floodplains should be determined. Sources of information include soil surveys available from the Natural Resources Conservation Service, topographic maps, flood insurance maps, and flood plain maps that are available from many municipalities.

Receiving Waters

The use classification and special designation of streams and lakes that receive stormwater from the proposed site should be determined. This information is available from the Alabama Department of Environmental Management.

Wetlands

Wetlands and other areas that are possibly wetlands should be identified. Wetlands may be quite apparent or there may be areas that are questionable. Maps developed as part of the National Wetlands Inventory, USGS topographic maps and soil surveys should be collected to evaluate an area for wetlands. Boundaries of wetlands must be delineated if wetlands exist on areas to be disturbed by construction.

Contaminated Sites

Trash, abandoned appliances, potential contaminated soil and hazardous waste or any other material that should not be on the site should be identified. Brownfields fit into this category.

Cultural Resources

If federal funds (grants or other directed federal funds) or federal property is involved, a cultural resources review or survey is required before any ground–disturbing activities may begin (Section 106, National Historic Preservation Act). On public and private lands, the Alabama Historical Commission is the primary state agency responsible for archaeological resources protection and maintains the State Archaeological Site Files. According to the Code of Alabama (Alabama Code), the State reserves the right to explore, excavate and survey prehistoric and historic sites. In addition to cultural resource regulations, there are laws protecting cemeteries and human remains (marked and un-marked); permits are required to excavate graves.

Threatened and Endangered Species

Threatened and endangered species that may exist in the area and their associated habitat should be considered. Lists containing both the species and their habitat characteristics are available from the local office of the Natural Resources Conservation Service.

Step 2- Data Analysis

When all of the data in Step 1 are considered, a picture of a site's potentials and limitations should emerge. The qualified design professional should be able to determine those areas which have potentially critical erosion hazards and the potential for construction disturbances to cause adverse offsite impacts. The following are some important points to consider in site analysis:

Topography

Topographic considerations are slope steepness and slope length and the longer and steeper the slope, the greater the erosion potential from surface runoff. Slope modifications with large cuts and fills may exacerbate the potential for erosion.

Drainage Patterns

Swales, depressions, and natural watercourses, should be evaluated in order to plan where water will concentrate and the measures that will be needed to maintain a stable condition for concentrated flow. Where it is possible, natural drainageways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. Man-made ditches and waterways become part of the erosion and turbidity problem if they are not properly stabilized. Potential for flooding and possible sites for stormwater detention ponds, sediment basins and low impact features such as rain gardens should be determined.

Soils

Soil properties such as depth to bedrock, depth to seasonal high water table, permeability, shrink-swell potential and texture should exert a strong influence on development decisions. Also, the flood hazard related to the soils can be determined based on the relationship between soils and flooding. A list of common Alabama soils along with interpretations for developmental uses is included in Appendix A1.

Groundcover

Groundcover is the most important factor in terms of preventing erosion. Any existing vegetation which can be saved will help prevent erosion. Trees and other vegetation protect the soil as well as beautify the site after construction. Therefore, it is important to recognize vegetation that can be retained during, and possibly after construction, to assist in stabilizing the site.

Adjacent Areas

The analysis of adjacent properties should focus on areas downslope, upslope and downstream from the construction project. The potential for sediment deposition on adjacent properties because of construction-related erosion should be analyzed so that appropriate erosion and sediment control measures can be planned. Obviously, the potential for impacting streams with turbidity must be considered. In some instances, water that enters the site from upslope should be diverted to minimize the potential for erosion, sediment and turbidity.

Floodplains

Floodplains are generally restrictive in nature and the uses planned within them must be consistent with local regulations. The location of facilities within floodplains should usually be avoided to prevent restriction of flood flows and potential changes in peaks flood stages downstream.

Receiving Waters

Watercourses which will receive direct runoff from the site should be of major concern: these streams should be analyzed to determine their use classification and if they have a sensitive water designation. The potential impact from sediment and turbidity pollution on these watercourses should be considered as well as the potential for downstream channel erosion due to increased velocity of stormwater runoff from the site.

Wetlands

Wetlands or the absence of wetlands should be determined by a qualified professional. Wetland boundaries should be clearly marked by a wetland delineator to provide a distinct location and boundary to use during the planning, design and construction phases of a project.

Waste Materials

Sites with known or potential contamination by petroleum, chemical spills, etc. should have a thorough assessment conducted by a qualified professional and result in a comprehensive site assessment. Details of this activity are beyond the scope of this handbook. The Alabama Department of Environmental Management should be contacted for assessment procedures.

Cultural Resources

The presence of cultural resources within the area of potential effect (includes the immediate project area and any off-site areas, such as borrow pits, fill disposal or temporary storage areas, and equipment staging areas) should be considered. Care should be taken to avoid disturbing cultural resources; previously unknown or undocumented cultural resources should be reported to the Alabama Historical Commission.

Threatened and Endangered Species

Habitat for threatened and endangered species (TES) should be evaluated. If potential exists for occurrence of TES a determination of their occurrence should be made by a qualified professional.

Step 3-Facility Plan Development

This step applies to sites that are in the planning stage where planning of the facilities have not been firmly determined. After analyzing the data about the site and determining any site limitations, the erosion and sediment control professional can assist the professional developing the overall site plan formulate a site plan that is in harmony with the conditions unique to the site. An attempt should be made to locate the buildings, roads, and parking lots and develop landscaping plans to utilize the strengths and overcome the limitations of the site. *Ideally, there can be flexibility in the location of facilities and low-impact development concepts will be strongly considered*. The following are some points to consider in making these decisions:

- Fit development to terrain. The development of an area should be tailored, as much as possible, to existing site conditions. For example, confine construction activities to the least critical areas. This will avoid unnecessary land disturbance while minimizing the erosion hazards and development costs, including cost of erosion and sediment control.

- Cluster buildings together. This minimizes the amount of disturbed area, concentrates utility lines and connections while leaving more open natural space. The cluster concept not only lessens the erodible area, but it generally reduces runoff and development costs.

- Minimize impervious areas. Keep paved areas such as parking lots and roads to a minimum. This goes hand in hand with cluster developments in eliminating the need for duplicating parking areas, access roads, etc. The more land that is kept in vegetative cover, the more water will infiltrate thus minimizing runoff and erosion. Consider the use of special paving products which will allow water to infiltrate or cellular blocks which have soil and vegetation components.

- Utilize the natural drainage system. If the natural drainage system of a site can be preserved instead of being replaced with storm sewers or concrete channels, the potential for downstream damages due to increased runoff can be reduced.

- Determine if there are any “environmentally sensitive” areas (areas of special concern), to be protected during and after project implementation. In general, most erosion and control projects will have an overall beneficial effect to cultural resources since they would be protected from further environmental degradation.

Step 4-Planning for Erosion and Sediment Control and Stormwater Management

When the site facility plan layout has been developed, a plan is developed to minimize erosion on-site and delivery of sediment and turbid water off-site. Additional objectives may include those related to increased peaks and runoff associated with a development, flood control and off-site erosion control.

The following procedure is recommended for formulating the system of practices and measures for erosion and sediment control and stormwater management.

- Divide the site into drainage areas. Determine how runoff will travel over the site.

- Determine limits of clearing and grading. Decide exactly which areas must be disturbed in order to accommodate the proposed construction. Pay special attention to critical areas which can be avoided (areas with high potential for erosion and needing special treatment if disturbed). The important point in this activity is to minimize the areas to be disturbed.

- Select erosion and sediment control and stormwater management practices and measures using a systems concept. Practices and measures should be selected that are compatible and, as a system, can be expected to meet objectives for the development or activity.

Consider how erosion and sediment can be controlled in each small drainage area of the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downslope and downstream.

Plan to sequence construction so that no area remains exposed for unnecessarily long periods of time. On large projects, stage the construction, if possible, so that one area can be stabilized before another is disturbed. Sequencing and staging may influence the choice of practices.

The practices and measures in this Handbook are divided into 6 descriptive categories that relate to their functions: site preparation, surface stabilization, runoff control, runoff conveyance, storm drain inlet protection, sediment control, stormwater management and stream protection. Other categories that are sometimes used, such as vegetative, structural and management measures, are imbedded into the 6 categories.

Again, review each drainage area, determine the categories that apply and select practice(s) to comprise a technically sound and cost-effective system.

- **Site Preparation** (Construction Exit Pad, Land Grading, and Topsoiling)

  Construction Exit Pad should be planned for early installation at each access point that vehicles will leave the disturbed area of a construction site and enter a public road. The stockpiling of topsoil should be done as an initial part of earthmoving. Most sites have enough topsoil available for stockpiling to provide adequate amounts for topsoiling the areas to be established to permanent vegetation. Land grading techniques can be done to compliment erosion control systems by timing of grading specific areas and surface roughening areas which may involve what is referred to in the Southeastern United States as “tracking”.

- **Surface Stabilization** (Preservation of Vegetation, Dust control, Temporary Seeding, Permanent Seeding, Mulching, Sodding, Chemical Stabilization, Erosion Control Blanket, Tree Planting on Disturbed Areas, Retaining Wall, Shrub, Vine and Groundcover, Dune Sand Fence, Dune Vegetation Planting, Dune Walkover, and Groundskeeping)

  Most qualified design professionals agree that vegetative measures should be maximized to provide as much erosion and sediment control as possible. Structural measures are generally more costly than vegetative controls but they are necessary on areas where vegetation and reinforcement with erosion control blankets or chemical measures will not provide adequate erosion control. Temporary practices from this category are needed on most sites and final stabilization of all landscapes requires one or more practices from this category.

- **Runoff Conveyance** (Check Dam, Diversion, Drop Structure, Grass Swale, Lined Swale, Outlet Protection, Riprap-lined Channel, Subsurface Drain, and Temporary Slope Drain)

  Diversions are particularly important in (1) diverting clean water away from a disturbed site (2) in preventing flows from eroding cut and fill slopes and (3) in breaking (shortening) slope lengths. The other practices in this category are needed to safely move concentrated flows of stormwater in channels. Concentrated flows are the potential cause of gullies and the runoff conveyance practices are used to prevent gully erosion. Subsurface drains are used to facilitate another practice, such as Grass Swale, in becoming successfully established and maintained. One or more practices from this category are needed on sites with channel flow.

- **Sediment Control** (Block and Gravel Inlet Protection, Brush/Fabric Dam, Fabric Drop Inlet Protection, Filter Strip, Floating Turbidity Barrier, Floffulant, Rock Filter Dam, Sediment Barrier, Sediment Basin, and Sediment Trap)

  Sediment control practices function primarily on the basis that sediment laden water will deposit at least part of its load while the water is ponded on the construction site by the practice. Flocculant is recognized for its value in both capturing sediment and in turbidity control. All of the sediment control practices are considered temporary. The effectiveness of each practice is dependent upon the unique attribute of the practice, the texture of the sediment in suspension and suspension time.

- **Stormwater Management** (Bioretention Area, Stormwater Detention Basin, and Porous Pavement)

  Stormwater management practices detain or retain stormwater on the construction site. These practices are designed to minimize stormwater runoff. Stormwater Management in Chapter 2 describes the planning considerations for stormwater management. Local regulations address the requirements for projects that are under their jurisdiction. Even where stormwater detention is not required by regulations, the qualified design professional should determine if detention is needed based on potential impacts. Low impact development measures that slow runoff and increase infiltration, such as bioretention areas and additional green space can contribute significantly to reducing peaks and volume of runoff. Additional low impact practices are found in the Low Impact Development Handbook for the State of Alabama. If significant storage is needed on-site a stormwater detention pond may be used and, for an additional temporary benefit, retrofitted as a sediment basin to address sediment and turbidity issues.

- **Stream Protection** (Buffer Zone, Channel Stabilization, Streambank Protection, and Temporary Stream Crossing)

  These stream protection practices are primarily intended to be used to preserve or repair streams. Designing new channels is beyond the scope of this handbook. One or more of these practices should be considered essential where a construction project includes a perennial or intermittent stream.

Step 5-Plan Assembly

The final step of plan development consists of compiling and consolidating the pertinent information into a site-specific plan for erosion control, sediment control and stormwater management. The major plan components are a <u>narrative</u> and a <u>site plan map</u>. <u>Supporting data</u> is assembled to substantiate planning options considered and developed and to aid in review of a plan. For a plan to be effective the works that are planned must reflect what is needed for the site, the planned works must be understood and accepted by the developer, and the document must be presented so clearly that the contents be contracted and constructed to meet developer and environmental objectives.

The following checklist may be used in assembling the narrative and site plan map to be sure all major items are included.

Checklist for Plans

Narrative

Explain the solutions for existing and predicted problems in the narrative (tables and charts may be used to display information in a format that is easier to understand).

Project Description

Briefly describe the nature and purpose of the land disturbing activity and the amount of disturbance involved.

Practices and Measures

Identify the practices and methods which will be used to control erosion on the site, prevent or minimize sediment from leaving the site, and address turbidity and hydrologic changes associated with the proposed project. Sequence and staging of construction activities to minimize disturbance and erosion should be addressed.

Inspections

Prescribe a schedule for inspections and repair of practices.

Maintenance

Include statement(s) explaining how the project will be maintained during construction until final stabilization. In some instances, maintenance that will be needed after construction should be included.

Site Plan Map

The site plan map is one or a series of maps or drawings pictorially explaining information contained in the narrative.

Site Plan Label

The label should include the name of owner, name of site or facility, county name, location (township, range and section) name of qualified design professional, and date plan made, and if applicable, date of latest revision.

Existing Contours

The existing contours of the site should be shown on a map (the scale used for this map should be of sufficient scale for meaningful evaluations). The scale of the site plan may range from 1” = 100 feet to 1” = 20 feet.

Existing Vegetation

The existing tree lines, grassy areas, or unique vegetation should be shown on a map.

North Arrow

The direction of north in relation to the site should be shown. The top of all maps should be north, if practical.

Existing Drainage Patterns

The dividing lines and the direction of flow for the different drainage areas should be shown on a map.

Final Contours

Planned contours should be shown on a map.

Development Features

The outline of buildings, roads, drainage appurtenances, utilities, landscaping features, parking areas, improvements, impervious areas, topographic features, and similar man-made installations should be shown to scale and relative location.

Limits of Clearing and Grading

Areas which are to be cleared and graded should be outlined on a map.

Wetlands

The location of wetlands is important and should be shown accurately and preferably on the site map

Cultural Resources

The locations of cultural resources should be shown accurately on the plan map and construction plans. Their location is essential if these areas are to be avoided or protected during project construction.

Location of Practices and Legend

The locations of the erosion and sediment control and stormwater management practices planned for the site should be shown on a map. A combination of symbols and acronyms are used to identify the practices. A list of the acronyms is included at the end of this chapter under “Legend of Measures for Erosion and Sediment Control and Stormwater Management.”

Site Location or Vicinity Map (if required by regulatory agency)

Provide a small map locating the site in relation to the surrounding area. A portion of a 7.5 minute series U.S.G.S. topographic map that covers the project area usually meets this requirement.

Supporting Data (relevant materials collected and generated during all stages of planning).

Existing Site Conditions

This material describes the existing topography, vegetation, and drainage.

Adjacent Areas

This material describes the adjacent and neighboring areas such as streams, lakes, residential areas, roads, etc., which might be affected by the land disturbance.

Soils

Include a brief description of the soils on the site giving relevant information such as soil map units, erodibility, permeability, depth, texture, soil structure, and any other limitations. The boundaries of the different soil types should be shown on a map.

Critical Areas

Identify and describe areas on the site which have potential serious erosion problems.

Areas of Special Concern

Include relevant information affecting planning on Coastal Zone Program requirements, contaminated soils, new or innovative practices, stream alterations, wetlands, impaired waters, and cultural resources. If federal lands or federal funds are involved, a letter from the lead federal agency stating that there would be no adverse effect to cultural resources and allowing the project to proceed as planned or amended will be required; a similar letter from the Alabama Historical Commission may be necessary if cultural resources are present on State and private lands.

Calculations and Design Data Needed During Planning

Include estimates used to evaluate practices that are chosen based on peak flows, acres of runoff, erosion rates, erosion control options, etc.

Legend of Measures for Erosion and Sediment Control and Stormwater Management

Site Preparation

(CEP) Construction Exit Pad
(LG) Land Grading
(TSG) Topsoiling

Surface Stabilization

(CHS) Chemical Stabilization
(DSF) Dune Sand Fence
(DVP) Dune Vegetation Planting
(DW) Dune Walkover
(DC) Dust Control
(ECB) Erosion Control Blanket
(GK) Groundskeeping
(MU) Mulching
(PS) Permanent Seeding
(PV) Preservation of Vegetation
(RW) Retaining Wall
(SVG) Shrub, Vine and Groundcover Planting
(SOD) Sodding
(TS) Temporary Seeding
(TP) Tree Planting on Disturbed Areas

Runoff Conveyance

(CD) Check Dam
(DV) Diversion
(DS) Drop Structure
(GS) Grass Swale
(LS) Lined Swale
(OP) Outlet Protection
(RS) Riprap-lined Swale
(SD) Subsurface Drain
(TDS)Temporary Slope Drain

Sediment Control

(BIP) Block and Gravel Inlet Protection
(BFB) Brush/Fabric Barrier
(FIP) Fabric Drop Inlet Protection
(FS) Filter Strip
(FB) Floating Turbidity Barrier
(FL) Flocculant
(RD) Rock Filter Dam
(SB) Sediment Barrier
(SBN)Sediment Basin
(ST) Sediment Trap

Stormwater Management

(BA) Bioretention Area
(PP) Porous Pavement
(SDB) Stormwater Detention Basin

Stream Protection

(BZ) Buffer Zone
(CS) Channel Stabilization
(SP) Streambank Protection
(TSC) Temporary Stream Crossing

Chapter 4

Best Management Practices Design

Construction Exit Pad (CEP)

Practice Description

A construction pad is a stone base pad designed to provide a buffer area where mud and caked soil can be removed from the tires of construction vehicles to avoid transporting it onto public roads. This practice applies anywhere traffic will be leaving a construction site and moving directly onto a public road or street.

Planning Considerations

Roads and streets adjacent to construction sites should be kept clean for the general safety and welfare of the public. A construction exit pad (Figure CEP-1) should be provided where mud can be removed from construction vehicle tires before they enter a public road.

Where possible the construction exit pad should be located and constructed at a site where surface runoff from the pad will not transport sediment from the pad off the site. If the pad slope toward the road exceeds 2%, a diversion ridge 6” to 8” high with 3:1 side slopes should be constructed across the foundation approximately 15 feet from the entrance. This diversion ridge should divert surface runoff from the pad away from the road and into a sediment trap or basin.

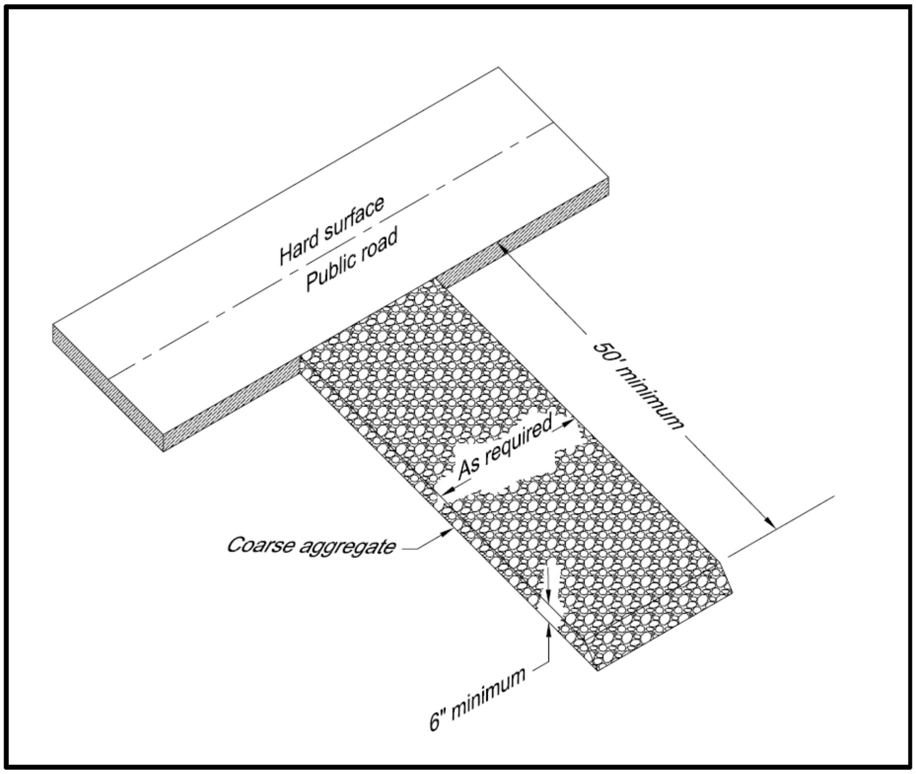


Figure CEP-1 Gravel Construction Exit

If the action of the vehicle traveling over the gravel pad does not sufficiently remove the mud or if the site is in a particularly sensitive area, a washing facility should be included with the pad (Figure CEP-2). When a washing facility is required all wash water shall be diverted to a sediment trap or basin.

If the construction exit pad is located in an area with soils that will not support traffic when wet, an underliner of geotextile will be required to provide stability to the pad.

Construction of stabilized roads throughout the development site should be considered to lessen the amount of mud transported by vehicular traffic. The construction exit pad should be located to provide for maximum use by construction vehicles.

Consideration should be given to limiting construction vehicles to only one ingress and egress point. Measures may be necessary to make existing traffic use the construction exit pad.

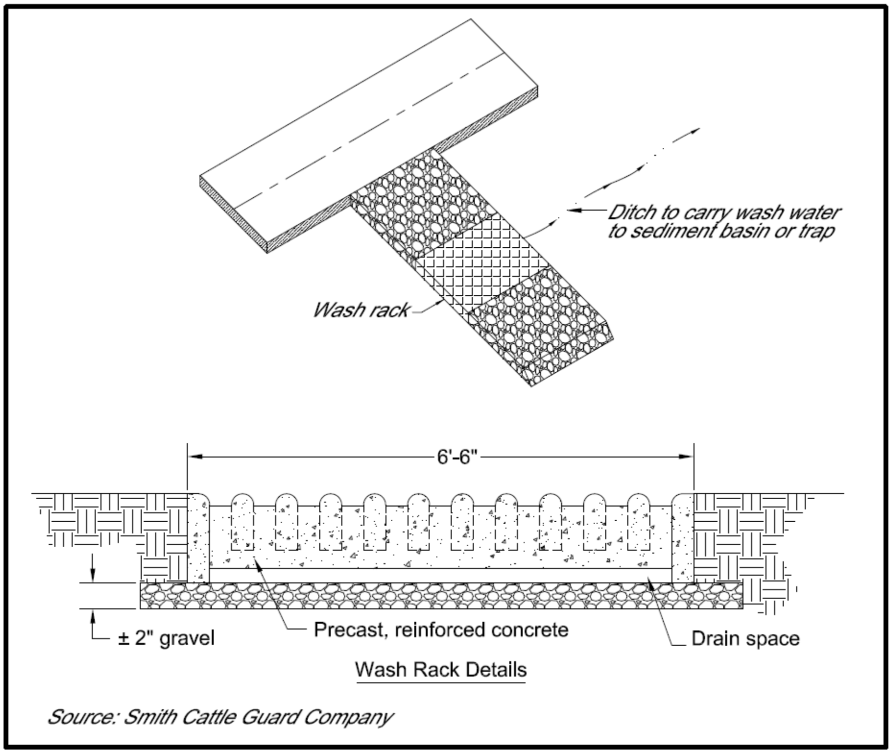


Figure CEP-2 Construction Exit with Wash Rack

Design Criteria

Aggregate size

Aggregate should be Alabama Highway Department coarse aggregate gradation No.1.

Pad Thickness

The exit pad shall have a minimum aggregate thickness of 6".

Geotextiles

A non-woven geotextile shall be placed underneath the aggregate. The geotextile shall be of the strength and durability required for the project to ensure the aggregate and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

Pad Length

The exit pad should provide for entering and parking the longest anticipated construction vehicles. A pad is typically 50 feet long but the required length may be longer or shorter.

Pad Width

The exit pad width is typically 20 feet but may be narrower or wider to equal the full width of the vehicular egress.

Washing

A washing facility shall be provided if necessary to prevent mud and caked soil from being transported to public streets and highways. It shall be constructed of concrete, stone, and/or other durable materials. Provisions shall be provided for the mud and other material to be carried away from the washing facility to a sediment trap or basin to allow for settlement of the sediment from the runoff before it is released from the site.

Land Grading (LG)

Practice Description

Land grading is reshaping of the ground surface to provide 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. This practice applies to sites where the existing topography must be modified to prepare for another land use, or where adapting proposed development to the existing landscape can reduce the erosion potential of the site and the cost of installing erosion and sediment control measures. In some instances other practices such as diversions or benches can be used to reduce the length of continuous slopes and reduce erosion potential.

Planning Considerations

A detailed plan should be developed by a qualified design professional for all land grading activities at the project site. The plan should show all areas to be disturbed, the areas of cut, areas of fill, and the finished elevation for all graded areas. Areas that will be mowed after the site is developed should have slopes planned that are not too steep for the type of mowing equipment that will be used for regular maintenance.

The grading plan should be designed to protect existing vegetation where possible, especially around natural drainageways. Grading activities should be scheduled to minimize the area disturbed at any one time during the construction process. The plan should include provisions for stabilizing disturbed areas immediately after final grading is completed. Provisions should also be made to protect existing underground utilities. Finally, topsoil should be removed and stockpiled for use in revegetating the site.

The grading plan should also include necessary practices for controlling sediment and erosion at the site. These practices could include stable outlets and slope breaks such as diversions or benches.

Design Criteria

Site Preparation

A detailed survey of the construction site should be performed by a qualified surveyor prior to grading plan development. This survey should include existing topographic information at the site including existing elevations, existing drainage patterns, locations of existing overhead and underground utilities, and construction limit boundaries.

The grading plan should require that the existing topsoil at sites to be graded be removed as the first step in the grading process. The plan should include a location on the construction site where topsoil will be stockpiled. Stockpiled topsoil should be protected by temporary vegetation (see Temporary Vegetation practice) or other appropriate temporary cover, such as plastic, until it is used to cover disturbed areas in advance of permanent vegetation of the site.

The grading plan should include a schedule of disturbance activities that minimizes the area disturbed at any point in time using sequencing and staging concepts. In areas where clearing of existing vegetation is planned, the area should be cleared and grubbed by removing trees, vegetation, roots and other debris such as trash. In areas to be filled all loose or weak soil and oversized rocks should be removed from the area. The foundation of the area to be filled should consist of soil or rock material of adequate strength to support the proposed fill material and the structures to be built at the site. The exact depth of material to be removed should be determined by a qualified geotechnical professional according to accepted engineering standards.

Grading

A plan for placement of fill should be developed by a qualified geotechnical professional. The plan should specify the source of fill materials, which should be obtained on site if possible. Materials used for fill, when placed according to the plans and specifications, should provide sufficient strength to support structures planned for construction at the location.

Loose fill material should be placed in layers not exceeding 9” in thickness. The materials should be compacted to a moisture content and to a dry density that will produce the design bearing strength required for structures planned at the site. A qualified geotechnical engineer should provide fill placement specifications using standard accepted engineering practices.
Long and/or steep slope lengths can result in rill and gully erosion on slopes. Erosion on these type slopes can be minimized by breaking the slope with

diversions or benches (see Diversion practice). Diversion widths should be compatible with the expected maintenance equipment. Care is needed in locating outlets that will be stable and not cause gully erosion. The following table gives general guidance on the horizontal spacing of slope breaks:

Table LG-1 Guidelines for Spacing Slope Breaks [1]

Slope (H:V)	Horizontal Spacing (Ft)
1:1	20
2:1	40
3:1	60
4:1 and 5:1	80
6:1 to 9:1	120
10:1 or flatter	200

[1] Adjustments in spacing may be made to account for soil and site conditions and professional experience of the site designer.

In areas where seepage and ground water are present subsurface drains should be installed to improve slope stability or soil bearing capacity (see Subsurface Drain practice).

Steep slopes should be avoided if possible. Slopes that are to be vegetated should be 2 horizontal to 1 vertical or flatter. If the slope is to be maintained by tractor or other equipment the slope should be 3 horizontal to 1 vertical or flatter. Slopes should be designed to blend with surrounding topography as much as possible.

Erosion Control

The grading plan should include provisions for stabilization of graded areas immediately after final grading is completed. On areas that will have no additional disturbance, permanent vegetation should be applied immediately to the site (see Permanent Seeding practice) if grading is finished during the planting season. If grading is finished outside of the recommended planting dates a temporary cover should be installed using a Temporary Seeding or other appropriate cover and the Permanent Seeding planned for the next planting period. On areas where work is to be interrupted or delayed for 14 calendar days or longer, such as topsoil stockpiles, the area should be stabilized using mulch or temporary seeding (see Mulching or Temporary Seeding practice). Other stabilization measures such as hydraulic mulch or erosion control blankets should be used in extreme conditions, such as steep slopes and channels.

Where practical, runoff from undisturbed off-site areas should be diverted around the construction site to prevent erosion on the disturbed areas (see Diversion practice).

Sediment Control

Required sediment control practices should be installed before the land disturbance activities in the drainage area of the sediment control practices. Until disturbed areas can be stabilized, appropriate sediment control measures will be maintained to minimize sediment delivery off-site. Measures should include as a minimum:

- Sediment Barriers – Placed along toes of slopes (see Sediment Barrier practice).

- Sediment Basins – Divert sediment laden runoff to basins as needed to minimize off-site sedimentation (see Sediment Basin practice).

- Inlet Protection – Where sediment-laden runoff is diverted to on-site stormwater drain inlets, the inlets should be protected with an appropriate sediment control practice.

- Stabilized Outlets – All runoff from the site should be conveyed in stabilized channels (see Grassed Swale, Lined Swale, Rip-rap Lined Swale, or other appropriate channel stabilization).

Topsoiling (TSG)

Practice Description

Topsoiling is the removal of a desirable soil surface, referred to as topsoil, at a site prior to construction and using it on areas to be vegetated. Topsoiling a site usually improves the quality of the plant growth medium at the site and increases the likelihood of successful plant establishment and performance. This practice applies to sites that are to be disturbed by excavation, compaction or filling, and to other areas where the subsoil is unsuitable for plant growth.

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.

The depth of topsoil found on an undisturbed site may be quite variable over the proposed construction area because different soils have various depths of the surface layer. On severely eroded sites ~~it~~ the original topsoil may be non-existent with the previous subsoil now occupying the surface.

Advantages of topsoil include its high organic-matter content and friable consistency (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 subsoil because it has less clay and more organic matter and the coarse texture of topsoil increases infiltration capacity and reduces runoff.

Although topsoil provides an excellent growth medium, there are disadvantages to its use. Stripping, stockpiling, and reapplying topsoil, or importing topsoil, increases construction time and may increase construction costs. Topsoiling can delay seeding or sodding operations, increasing the exposure time of denuded areas. Most topsoil contains weed seeds and weeds may compete with desirable species.

When properly limed and fertilized, subsoils may provide a good growth medium especially if there is adequate rainfall or irrigation water to allow root development in otherwise high density material. However, in most instances topsoiling should be used to provide the best opportunity for successful establishment and sustainability of the planned vegetative cover.

Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown. Topsoiling is a recommended procedure when establishing vegetation on shallow soils, soils containing potentially toxic materials, and soils of critically low pH (high acid) levels.

If topsoiling is to be done, the following items should be considered:

- An adequate volume of topsoil should exist on the site or be available locally. Topsoil will be spread at a lightly compacted depth of 4" or greater.

- Locate the topsoil stockpile should be located so that it meets specifications and does not interfere with work on the site, block drainage or release appreciable amounts of sediment.

- Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.

- Take care not to apply topsoil to subsoil if the two soils have contrasting textures without disking or chiseling to create a favorable interface and bond. Sandy topsoil over clayey subsoil without disking or chiseling is a particularly poor combination, as water creeps along the junction between the soil layers and on steep slopes may cause the topsoil to slough.

Design Criteria

Materials

Field evaluation of the site should be made to determine if there is sufficient surface soil of good quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, and clay loam). It shall be relatively free of debris, trash, stumps, rocks, roots and noxious weeds, and shall give evidence of being able to support healthy vegetation. It shall contain no substance that is potentially toxic to plant growth.

Topsoil should meet the following criteria:

- pH range should be from 6.0-7.0. If pH is less than 6.0, lime should be added in accordance with soil test results or in accordance with the recommendations of the vegetative establishment practice being used.

- Soluble salts shall not exceed 500 ppm.

- If additional off-site topsoil is needed, it should meet the standards stated above.

- The depth of material meeting the above qualifications should be at least 4”. 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.

Stripping

Strip only those areas that will be affected by construction or development. A normal stripping depth is 4-6” but deeper depths may be satisfactory if the soil is suitable and undercutting is allowable in locations such as buildings, water impoundment structures, roadways, etc. Appropriate sediment control measures such as sediment barriers, sediment basins, inlet protection, etc., should be in place before the topsoil is stripped. Stripping should not be done on areas intended to support conventional on-site effluent disposal lines (field lines).

Stockpiling

The stockpile location should be out of drainageways and traffic routes. Stockpiles should not be placed on steep slopes where undue erosion will take place. Measures should be taken to prevent erosion of the stockpiles. These would include:

- Mulching the stockpile when it is left inactive for over 13 days.

- Planting temporary vegetation when the stockpile is to be inactive over 30 days.

- Covering the stockpile with plastic whenever the piles are small and any soil loss would provide sediment to damage existing buildings or facilities or enter waters.
- Planting permanent vegetation when the stockpile use will be inactive over 12 months.

- In cases where the stockpile is small and will be removed in less than 14 days, it may be more practical to use a sediment barrier than an erosion control practice.

Site Preparation

Areas to be covered with topsoil shall be excavated, graded, filled and shaped to the proper lines, grades and elevations before topsoil placement is started.

The subgrades should be checked for pH and limed if it is less than 6.0. Liming shall be done in accordance with soil tests and in relation to the seeding mixture to be planted. Incorporate lime to a depth of at least 2" by disking.

Applying Topsoil

The subsoil should be disked or chiseled to a depth of 2" or more to enhance bonding of the subsoil and topsoil, immediately before placement of topsoil. Topsoil should be uniformly spread to a minimum compacted depth of 4". Required volumes of topsoil may be determined using Table TSG-1.

Table TSG-1 Volume of Soil Needed for Topsoiling

Depth to Spread (inches)	Cubic Yards Per 1,000 Sq. Ft.	Cubic Yards Per Acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	537
5	15.5	672
6	18.6	806

When applying topsoil, maintain needed erosion control practices such as diversions, grassed swales, lined swales, etc. Topsoil should not be spread when it or the subgrade is frozen or muddy.

Precautions should be taken to prevent layering of the topsoil over the subsoil. Mixing and bonding of the two soils should be enhanced.

Settling of the topsoil is necessary to bond the soils together, but excessive compaction should be prevented. Light compaction is necessary to increase soil strength, reduce erosion and enhance vegetation establishment.

Excessive compaction should be prohibited as it increases runoff and inhibits seed germination and root development.

Surface irregularities that would impede drainage, increase erosion or otherwise damage the site should be removed in final grading.

This Page Intentionally Left Blank

Chemical Stabilization (CHS)

Photo courtesy of Sunshine Supplies, Inc.

Practice Description

Chemical Stabilization erosion control involves the use of products, including soil binders that help to hold the soil in place, thereby reducing soil particle detachment and short-term erosion caused by water and wind. Water-soluble polyacrylamide (PAM) is often used for this purpose. Other products may also provide this benefit. The products are typically applied with temporary seeding and or mulching on areas where the timely establishment of temporary erosion control is so critical that seeding and mulching need additional reinforcement.

Planning Considerations

Chemical Stabilization products for surface stabilization are available in different formulations should be used in combination with other Best Management Practices. The use of seed and mulch should be considered for providing erosion protection beyond the life of the chemical or soil binder. If the area where Chemical Stabilization products have been applied is disturbed, the application will need to be repeated.

Following are additional considerations to enhance the use of or avoid problems:

- Use recommended setbacks (Buffer Zone) when applying near natural water bodies.

- Application delays between product mixing and application as well as ultraviolent light exposure may decrease the performance of some products.

- Products are generally not effective in concentrated flow areas.

- Seeded areas will also need mulch.

- It is important to closely follow manufacturer's recommendations on application procedures.

- Do not use products in a way that will be toxic to aquatic organisms.
- Requests to use products not approved for Chemical Stabilization on permitted sites should be made to the state environmental agency.

Design Criteria

Application rates shall conform to manufacturer's guidelines for application.

The following specific criteria shall be followed:

- Chemical mixtures shall be environmentally benign, harmless to fish, wildlife, and plants, and shall be non-combustible.

- Users of chemical stabilization products shall follow all Material Safety Data Sheet requirements and manufacturer's recommendations. In the case of PAM, the use of a specific product should be based on the jar test with soil from the site and there should be appropriate measures at the site to ensure that PAM is not carried in stormwater emptying directly into natural waterbodies. This means that runoff should be flowing to settling sites such as sediment basins or sediment traps or be flowing over sites such as filter strips, straw or matting that serves as a collection site for the sediments.

- Additives such as fertilizers, solubility promoters or inhibitors, etc. to chemical stabilization products shall be non-toxic.

- The manufacturer or supplier shall provide written application methods. The application method shall ensure uniform coverage to the target and avoid drift to non-target areas including waters of the state. The manufacturer or supplier shall also provide written instructions to ensure proper safety, storage, and mixing of the product.

Dune Sand Fence (DSF)

Photo courtesy of Alabama Department of Environmental Management

Practice Description

A dune sand fence is a temporary barrier consisting of wooden slots installed across a dune landscape perpendicular to the prevailing wind. Dune sand fence reduces wind velocity at the ground surface and traps blowing sand. Sand fencing and appropriate planting materials can be used to build frontal ocean dunes to control beach erosion and flooding behind frontal dunes from wave overwash. Sand fence is applicable where sand can be trapped to enhance dune vegetation.

Planning Considerations

Coastal beaches are subject to regulations from a variety of Federal, State, and local agencies including the requirements of the state Coastal Nonpoint Pollution Control Program and Coastal Zone Management Programs. Permits or other approval procedures must be requested and granted by all appropriate jurisdictions before work is performed.

Coastal areas are affected by many dynamic systems. Detailed studies are often required to determine the possible effects that may result from dune modifications. Environmental assessments are generally required including public review and comment.

Plans should include details to install an additional set of fences over the existing fence until the barrier dune has reached a protective height. Dune sand fences must be constructed in such a manner that impacts to nesting endangered sea turtles are minimized.

Dune sand fences are components of dune erosion control systems and are most effective when used with other practices including Dune Walkover and Dune Vegetation Planting.

The specific location of a sand fence is based on professional knowledge and experience considering the factors that relate to natural dune establishment and sustainability.

Design Criteria

Scheduling

Attempt to install sand fencing during the recommended planting periods for the associated dune vegetation plantings that are planned.

Site Preparation

Plan to determine if underground utilities exist on the site, mark their location and locate fence lines and stakes to not damage the utilities.

Obstacles that will prevent installation of the sand fence will need to be removed before any work begins.

Installing the Dune Sand Fence

Erect the sand fences a minimum of 100 feet (horizontal distance) from the Mean High Tide (MHT) line with two parallel lines or rows of fence approximately 30 feet apart. The rows should be roughly parallel to the water line and be as close as possible to a right angle to the prevailing winds. See Figure DSF-1 for a plan view of a conceptual erosion and sediment control system.

As the fences fill with sand, an additional set of fences should be planned to be placed over those that are filled until the barrier dune has reached a protective height. To widen an old dune, fencing should be set seaward at a distance of 15 feet from its current base.

Materials

Use standard commercial 4-foot sand fences that consist of wooden slats wired together with spaces between the slats. The distance between slats is 1¼” or approximately equal to the slat width. The fence should be sound and free of decay, broken wire, and missing or broken slats.

The fence should be made from Grade A or better spruce with slats 1¼” wide and about 1¼” of space between laths or pickets. The 4-feet high fence should be woven between 5 two-wire cables of copper bearing, galvanized wire. The laths or pickets should be hot dipped in a red oxide weather resistant stain.

Wooden posts for fence support may be of pressure treated yellow pine or untreated black locust, red cedar, white cedar or other wood of equal life and strength. Use standard fence posts at least 7 feet long with a diameter of 3” to 4”. Posts should be set at least 3 feet deep no further than 10 feet apart and not concreted in place. Four wire ties should be used to fasten the fence to the wood posts. Weave the fence between posts so that every other post will have fencing on the ocean side of posts. Tie wires should be no smaller than 12 gauge galvanized wire.

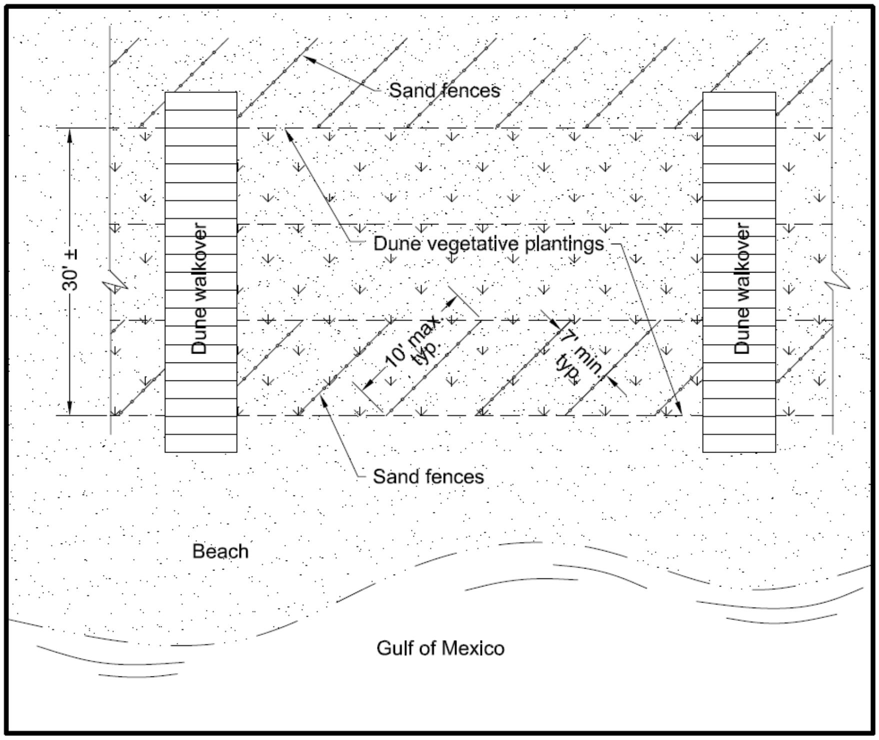


Figure DSF-1 Typical Dune Erosion Control System with Sand Fence

Construction Verification

Conduct inspections to determine that materials and installation meet plan specifications.

This Page Intentionally Left Blank

Dune Vegetation Planting (DVP)

Photo courtesy of Alabama Department of Environmental Management

Practice Description

Dune vegetation planting is the establishment of perennial vegetation on dunes from seed or vegetative material. Perennial dune vegetation provides economical long-term erosion control and helps prevent sediment from leaving the site. This practice is used where vegetation is desired and appropriate to permanently stabilize the dune. Additional measures, such as crosswalks and barriers, are often needed to develop successful establishment of the vegetation.

Planning Considerations

Coastal beaches are subject to regulations from a variety of Federal, State and local agencies. Permits must be requested and granted by all appropriate jurisdictions before work is performed.

Protection of dunes from human and vehicular traffic is essential if vegetation is to succeed.

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.

Mulch usually used with other seedings (straw, hay, netting, peg and twine, and asphalt) is not recommended due to the difficulty in applying and anchoring the mulch and its untidy appearance.

Supplemental water (irrigation) is usually required during the first growing season to obtain good plant survival.

Design Criteria

Plant Materials

Use commercially available plant materials/varieties that are adapted in Alabama for coastal dune stabilization. See the section Protecting the Coastal Dunes in Chapter 2, Table DVP-1 and the planting guides at the end of this practice for information to use in selecting plants.

Planting stock is available from commercial nurseries. Plants from 2-4" pots are generally adequate for most stabilization and building work. Smaller plants may be used on sites under ideal planting conditions or irrigation. Plants from pots larger than 4" are desirable only where aesthetics or traffic control is important, or erosion is extreme. Bare root stock dug from vigorous stands and planted when fresh gives survival and growth rates equal to potted materials. Unrooted stolons of bitter panicum may be cut after seed is mature and planted at 3 vertical cuttings per planting space or uncut stems in 3" to 4" deep furrows 12-18" apart. 'Atlantic' coastal panicgrass may be direct seeded at 15 pounds per acre, drilled or sowed in 2" deep furrows.

Table DVP-1 Commonly Used Plants for Dune Stabilization

Species	Plant Spacing	Preferred Planting Period*	Method
Sea Oats (Uniola paniculata)	12 – 36"	March 1-June 1	Potted plants
Atlantic Coastal Panicgrass (*Panicum amarum var-amarulum)*	12 – 36"	March 1- June 1	Seed or sprigs
Flageo Marshhay Cordgrass (*Spartina patens)*	12 – 24"	March 1- June 1	Sprigs
Sharpe Marshhay Cordgrass (*Spartina patens)*	12 – 24"	March 1- June 1	Sprigs
North PA Bitter Panicum (*Panicum amarum)*	24 – 36"	March 1- June 1	Potted plants or bare root plugs
South PA Bitter Panicum (*Panicum amarum)*	24 – 36"	March 1- June 1	Potted plants or bare root plugs

* See planting guide for each species for more details on planting dates.

Site Preparation

Tillage or liming is not required for planting on beach sand. Install the dune crossover structures, sand fences and the irrigation system prior to planting.

Planting Date

Plant vegetative material from fall until early spring. See plant guides for more detailed information on each species. Plantings should be made from late winter to early spring.

Planting Depth

Plants for the dunes should be planted at least 6-8” or deep enough to have adequate soil moisture at the time of planting.

Use freshly dug bare root tillers, rooted stem cuttings or nursery grown potted vegetative material.

Use a tree dibble, or spade to plant the vegetative material.

Spacing

Plantings must consist of at least 10 feet (strips) of dune building vegetation. Wider areas may be considered based on the severity of the site. Herbaceous plant spacing ranges from 1-3 feet, but is typically 18” for 1-4” potted stock or bare root plugs of the same diameter.

1st Year Fertilization

Initial fertilization is best done at planting with slow release complete fertilizer, such as 14-14-14, at a rate of 1 ounce per plant placed under the plant. Initial fertilization may also be provided with 200-300 pounds of mineral 13-13-13 per acre broadcast 6 weeks after planting.

2nd Year Fertilization

Maintenance fertilization should be provided with 400 pounds of 13-13-13 per acre per year split in two applications during the growing season before September 1. Fertilization is recommended until the plants spread to provide complete cover and after storms damage stands.

Irrigation

Supplemental water (irrigation) is usually needed on dune plantings to provide adequate moisture during the initial establishment period.

PLANTING GUIDE

‘Atlantic’ Coastal panicgrass (Panicum amarum var. amarulum)

Description: A tall, robust, warm-season, perennial grass. Growth habit is upright and the plant looks like a bunch grass, although it produces short rhizomes that may result in lateral spread of 4 to 8 inches annually. Plants are 3 to 7 feet in height with multi-stemmed bluish-green leaves ¾ to 1 inch wide by 12 to 20 inches long. Seed heads 4 to 8 feet in height are produced in late July through August or September and produce viable seed with strong seedling vigor.

- Native Habitat and Range: Coastal dunes throughout the North Atlantic and Gulf regions.

- Conservation Use: The principal use is in coastal dune erosion control. It is suitable for revegetating disturbed areas such as borrow and gravel pits and other areas with droughty and infertile conditions.

- Plant Materials: Seed and freshly dug root tillers (sprigs) are normally commercially available.

- Time of Planting: Plantings should be made from late winter until early spring and sprigs should be planted from November until March.

- Site Preparation and Seeding: Prepare a seedbed with tillage or drill seed and plant seed 2 inches deep. Surface seeding on sand dunes will likely not produce a successful stand. Use 10-15 pounds of seed per acre if planting and 20 pounds per acre if broadcasting.

- Planting Sprigs: Tillers (sprigs) should be planted in rows 6 to 8 feet apart and spaced about 18 inches apart in the rows. Tillers should be planted deep enough to be in moist soil (normally 4 to 10 inches) with the crown covered with ½ to 1 inch of soil packed firmly around each tiller. This type of planting requires about 5,000 tillers per acre. Closer spacing of rows will significantly increase the time of coverage.

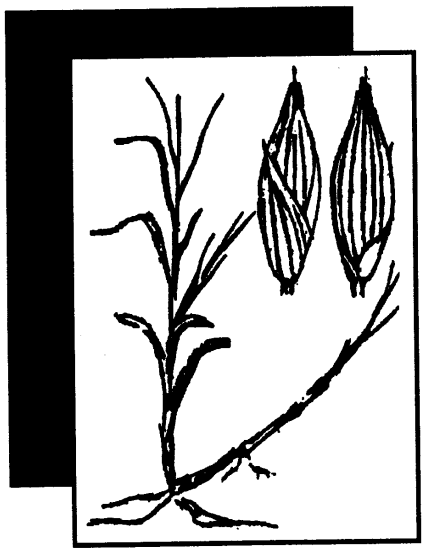
- Fertilizer: Fertilize at the time of planting with 200 to 300 pounds of 10-10-10 per acre or equivalent a few weeks after planting. Top dress with similar applications in late June and late summer until the stand is established.

- Protect from damage by foot and vehicular traffic and remove debris.

PLANTING GUIDE

'NORTHPA' and 'SOUTHPA' Bitter panicum (*Panicum amarum*)

Description: Perennial, warm season grass growing to a height of 7 feet with a growth habit ranging from erect to prostrate. The leaves are 1/4- to 1/2-inch wide, 7 to 20 inches long, smooth without hair, and bluish in color. This robust grass spreads slowly from short, strong rhizomes, forming open clumps. Small quantities of poor quality seed are produced on compact panicles 6 to 12 inches long and 2 to 4 inches wide.



Bitter panicum

- **Native Habitat and Range:** Coastal dunes and sandy shores from New Jersey to Florida and Texas.

- **Conservation Use:** The principal use is in coastal dune erosion control and it may have a role in stabilizing other dry, sterile areas such as roadsides and minespoils.

- **Site Preparation:** Generally none required.

- **Plant Material:** Potted and bare root plants are available commercially. Freshly dug bare root tillers, rooted stem cuttings, and unrooted stem cuttings can also be obtained from vigorous stands.

- **Time of Planting:** Late fall with stem cuttings; late winter or early spring with potted plants; late spring with young tillers (when it coincides with the rainy season).

- **Spacing:** Plant potted and bare root material in a grid pattern 2 feet apart in 2 to 3 foot staggered rows. Plant stem cuttings three to a hole 2 feet apart in 2 to 3 foot staggered rows.

- **Depth:** Place plants 4 to 10 inches, or deeper, in moist soil. Plant stem cuttings at a 45-degree angle, deep enough to bury several nodes and leaving the top 6 to 10 inches of stem exposed.

- **Fertilizer:** Place one ounce of slow release fertilizer such as **Osmocote* in each hole as material is planted, or apply 200 to 300 pounds of 10-10-10 per acre 3 to 4 weeks after planting. Apply this same rate annually in June and repeat in August, until the stand fills in the spacing.

- **Maintenance:** Restrict traffic and livestock. Overgrazing and high palatibility were responsible for the decrease of this plant in the 19th century.

PLANTING GUIDE

'FLAGEO' Marshhay cordgrass *(Spartina patens)*

Description: Perennial, warm season grass with erect stems, mostly less than 40 inches tall. It spreads by long slender rhizomes. Leaves are less than 1/8-inch wide and are sometimes flat, but usually roll inward from the edges with the upper surface inside. There are 2 to 7 spikes on the seedhead. These 3/4- to 2-inch spikes are born against or away from the stem.

- Native Habitat and Range: Salt marshes and sandy meadows from Quebec, Canada to Florida and Texas, and saline marshes inland from New York to Michigan.

- Conservation Use: Saltmeadow cordgrass is used for coastal erosion control in backdune areas, along tidal river banks, and on salt marshes above the high tide line. Inland uses include stabilizing waterways, gullies, roadsides, and minespoil and saline oil seep areas. The 'salt hay' is used as a mulch and fed to cattle.

- Site Preparation: None required, but removal of trash on tidal areas will prevent burial of plants.

- Plant Material: Potted plants or bare root stock are available commercially and from vigorous stands. Use transplants that have 5 to 10 stems each.

- Time of Planting: Late winter and early spring, and at the beginning of the rainy season in Florida.

- Spacing: Place plants 12 to 24 inches apart, depending on severity of site.

- Depth: Plant 4 to 8 inches, or deeper, in moist soil.

- Fertilizer: On critical area plantings, place one ounce of slow release fertilizer such as **Osmocote* per plant at planting, or apply 200 to 300 pounds of 10-10-10 per acre several weeks after planting. Apply 200 to 300 pounds of 10-10-10 per acre annually in June until the stand fills in the spacing. Do not fertilize rangeland plantings.

- Maintenance: Minimize foot traffic and remove debris from planting.

Marshhay cordgrass

PLANTING GUIDE

Sea oats *(Uniola paniculata)*

Description: Perennial, erect, strong, rhizomatous, colonizing grasses native to the coastal sands and dunes of Florida and the southeastern United States. This grass forms in dense, rather stiff bunches 40 to 60 inches tall and 30 to 120 inches in diameter. Leaves are less than 1/2-inch in width, 16 to 28 inches long, and are usually flat. Leaves are rolled or involute on drying. Panicles of the seedhead are 8 to 12 inches long with numerous spikelets less than 1-inch long, each having 8 to 15 florets. Very little to no seed is produced by most seedheads and is readily eaten by birds. Only rarely is reproduction by natural germination of seed observed. Lateral spread and colony increase is accomplished by moderate to strong rhizome development.

Sea oats

- **Native Habitat and Range:** Sand dunes from southern Virginia to Florida and Texas.

- **Conservation Use:** Critical area stabilization of saline coastal sands and sand dunes.

- **Site Preparation:** Generally none required.

- **Plant Material:** Potted plants and bare root stock are available commercially and from vigorous stands. Use transplants with a minimum 30-inch stem height.

- **Time of Planting:** Late winter to early spring, and at the beginning of the rainy season in Florida.

- **Spacing:** Place plants 12 to 36 inches apart, depending on the pot size and severity of the site. Use 18-inch spacing for an average site using 2- to 4-inch pots.

- **Depth:** Place plants 8 to 12 inches, or deeper, in moist soil.

- **Fertilizer:** Place one ounce of slow release fertilizer such as **Osmocote* in each hole as material is planted, or apply 200 to 300 pounds of 10-10-10 per acre 3 to 4 weeks after planting. To maintain and/or develop the stand, apply 200 to 300 pounds of 10-10-10 (or equivalent) per acre annually June 1 to June 15 and repeated August 1 to August 15.

- **Maintenance:** Minimize foot traffic and remove debris from planting.

This Page Intentionally Left Blank

Dune Walkover (DW)

Photo courtesy of Alabama Department of Environmental Management

Practice Description

A dune walkover is a measure consisting of elevated walks that are constructed across the dune system. It provides pedestrian access to the beach area and protects the dunes from erosion. It is applicable on sparsely vegetated dunes where pedestrian access adversely impacts the vegetation and on dunes with adequate vegetation where pedestrian access is planned and vegetation is needed to protect the dunes from erosion.

Planning Considerations

Coastal beaches are subject to regulations from a variety of Federal, State, and local agencies. Permits must be requested and granted by all appropriate jurisdictions before work is performed.

Coastal areas are affected by many dynamic systems. Detailed studies are often required to determine the possible effects that may result from dune modifications. Environmental assessments are generally required including public review and comment.

Dune walkovers are components of dune erosion control systems and are most effective when used with other practices including Dune Vegetation Planting and Dune Sand Fence.

Design Criteria

Scheduling

Attempt to construct dune walkovers during the recommended planting periods for the associated dune vegetation plantings that are planned.

Site Preparation

Ensure that all necessary materials are on the site before any work begins.

Construction

Develop construction plans based on sound building concepts that meet the requirements of the Coastal Nonpoint Pollution Control Program. Plans for Dune walkovers should consider the following guidance.

- Locate cross-over structures at sites that consider both people and site protection concerns.

- All load-bearing connections to the post should be made by bolts or lag screws.

- Utilize appropriate standard drawings developed specifically for the coastal zone if they are available.

Materials

All lumber materials should be pressure treated no.2 yellow pine in accordance with American Wood Preservers Association standard C-2. Treatment should be to 0.40 lbs. CCA per cubic foot, or greater or other copper-based preservatives with treatment rates recommended for ground contact applications.

All nuts, bolts, washers, nails, and other hardware should be hot dipped galvanized metal or other corrosion resistant fasteners.

Erosion Control

Plan to minimize the size of all disturbed areas and vegetate as soon as each phase of construction is complete.

Develop a planting plan that utilizes adapted species. See Figure DCW-1 and Dune Vegetation Planting practice for details to incorporate into the planting plan.

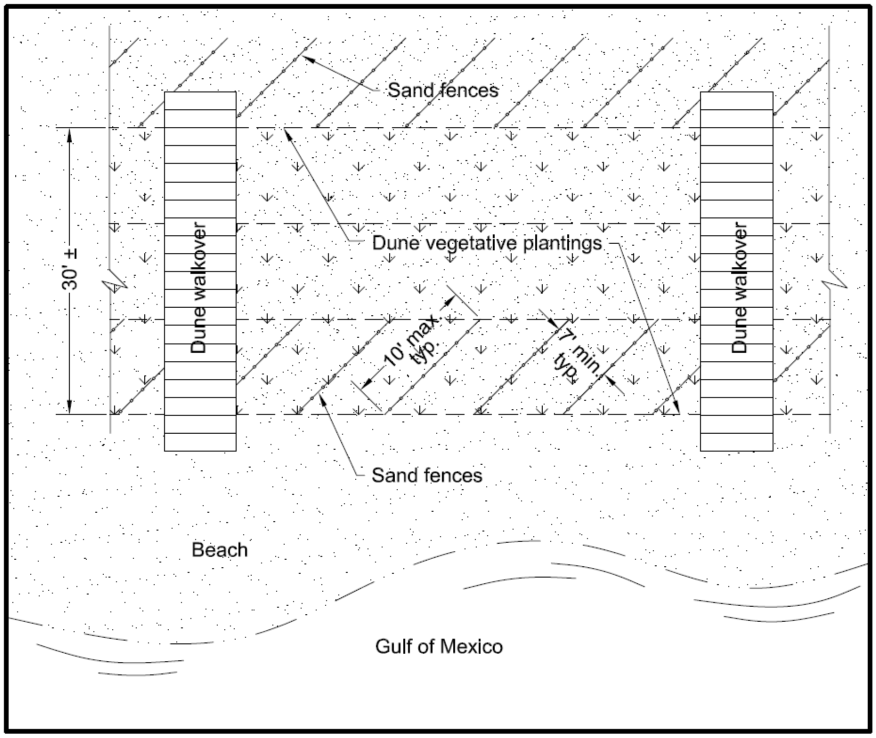


Figure DCW-1 Typical Dune Walkover System

Safety

Specify that equipment used in construction should be free of leaks of fuel and hydraulic fluids.

Plan for fencing and warning signs if trespassing is likely during construction.

Construction Verification

Plan for construction inspections to determine that materials and construction meet plan specifications.

This Page Intentionally Left Blank

Dust Control (DC)

Practice Description

Dust control includes a wide range of techniques that prevent or reduce movement of wind-borne soil particles (dust) during land disturbing activities. This practice applies to construction routes and other disturbed areas where on-site and off-site damage or hazards 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.

The scheduling of construction operations so that the least amount of area is disturbed at one time is important in planning for dust control.

The greatest dust problems occur during dry periods. Therefore, to the extent practicable do not expose large areas of bare soil during drought conditions.

Where wind erosion is a potential cause of dust problems, preserving vegetation should be considered as a passive measure. Leave undisturbed buffer areas between graded areas wherever possible.

Installing temporary or permanent surface stabilization measures immediately after completing land grading will minimize dust problems.

Design Criteria

Permanent Methods

Vegetative Cover

For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control. Establish vegetative cover according to the Permanent Seeding or Temporary Seeding practice.

Topsoiling

This entails covering the surface with less erosive soil material. See Topsoiling practice for guidance.

Stone

Stone used to stabilize construction roads can also be effective for dust control. Stone should be spread a minimum of 6" thick over construction roads in the disturbed area. For heavily traveled roads or roads subjected to heavy loads the stone thickness should be 8" to 10". A non-woven geotextile meeting the minimum requirements of ASSHTO M288 should be used under the stone.

Temporary Methods

Mulches

Mulch offers a fast, effective means of controlling dust when properly applied. See Mulching practice for guidelines for planning and installing the practice.

Temporary Vegetative Cover

For disturbed areas where no activity is anticipated for 14 days or longer, temporary seeding can effectively control dust. Establish vegetative cover according to Temporary Seeding practice guidelines.

Calcium Chloride

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. Sites may need to be retreated because the product degrades over time.

Spray-on Adhesives

Spray-on adhesives may be used on mineral soils for dust control. Traffic must be kept off treated areas to prevent the product from becoming ineffective. Examples of spray-on adhesives for use in dust control are listed in Table DC-1.

Table DC-1 Spray-on Adhesives for Dust Control on Mineral Soil

Material	Water Dilution	Type of Nozzle	Apply Gal/Ac
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

Chemical Stabilization (CHS)

Chemical products are available for use on mineral soils for dust control. Traffic must be often kept off treated areas to prevent the product from becoming ineffective. The manufacturer or supplier shall provide written application methods. The application method shall ensure uniform coverage to the target and avoid drift to non-target areas including waters of the State. The manufacturer or supplier shall also provide written instructions to ensure proper safety, storage, and mixing of the product. Refer to the Planning Considerations for the Chemical Stabilization practice for planning consideration before deciding to use these type products.

Sprinkling or Irrigation

Sprinkling is especially effective for dust control on haul roads and other traffic routes. Sprinkle the site until the surface is wet. Repeat as needed. Also bare areas may be kept wet with irrigation to control dust as an emergency treatment.

Tillage

Tillage is used to roughen the site and bring clods and moist soil to the surface. This is a temporary emergency measure that can be used on large open disturbed areas as soon as soil blowing starts. Begin tilling on the windward edge of the site. The depth of tillage is determined by the depth to moist soil and the amount of moist soil desired at the surface. In sandy soils, the depth to moist soil may make tillage impractical.

Barriers

A board fence, wind fence, sediment fence, hay bales, or similar barriers can control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals about 15 times the barrier height.

This Page Intentionally Left Blank

Erosion Control Blanket (ECB)

Photo courtesy of Environmental Plans and Review Section, Development Department, DeKalb County, GA.

Practice Description

To aid in controlling erosion on critical areas by providing a protective cover made of straw, jute, wood or other plant fibers; plastic, nylon, paper or cotton. This practice is best utilized on slopes and channels where the erosion hazard is high, and plant growth is likely to be too slow to provide adequate protective cover. Erosion control blankets are typically used as an alternative to mulching but can also be used to provide structural erosion protection. Some important factors in the choice of a blanket are: soil conditions, steepness of slope, length of slope, type and duration of protection required to establish desired vegetation, and probable sheer stress.

Planning Considerations

Care must be taken to choose the type of blanket that is most appropriate for the specific project needs. Fourteen classes of erosion control blankets are included in this practice and are from the list developed by the Erosion Control Technology Council (ECTC). Manufacturer's instructions and recommendations, as well as a site visit by the qualified design professional and site plan reviewer are highly recommended to determine a product's appropriateness.

Note: The Alabama Department of Transportation (ALDOT) identifies Rolled and Hydraulic Erosion Control Products based on performance. Description of ALDOT types can be found in Section 659 of their Standard Specifications for Highway

Construction. ALDOT recognizes some Hydraulic Erosion Control Products equal in performance to Rolled Products.

Temporary Erosion Control Blankets

Benefits of using temporary erosion control blankets include the following:

- Protection of the seed and soil from raindrop impact and subsequent displacement.
- Thermal consistency and moisture retention for the seedbed area.
- Stronger and faster germination of grasses and legumes.
- Spreading stormwater runoff to prevent rill erosion of slopes.
- Prevention of sloughing of topsoil added to steeper slopes.

Because temporary blankets will deteriorate in a short period of time, they provide no enduring reduction in erosion potential.

Permanent Erosion Control Blankets

Permanent erosion control blankets are also known as permanent soil reinforcing mats or turf reinforcement mats. Roots penetrate and become entangled in the matrix, forming a continuous anchorage for surface growth and promoting enhanced energy dissipation.

Benefits of using permanent erosion control blankets, in addition to the benefits gained from using a temporary blanket include the following:

- Sediment from stormwater flows is deposited in the matrix providing a fine soil growth medium for the development of roots.
- In stormwater channels, blankets and the vegetative root system form an erosion resistant cover which resists hydraulic uplift and shear forces of channel flows.

Tables ECB-1 and ECB-2 give typical applications of the different classes of erosion control blankets.

Design Criteria

General

All blankets shall be nontoxic to vegetation and to the germination of seed and shall not be injurious to the unprotected skin of humans. Erosion control products shall be of sufficient strength to hold the prepared ground and, if applicable, cover material (mulch, sod, etc.) in place until an acceptable growth of natural or planted material is established.

Erosion control products shall be identified by a classification designation (Class 1.A, 1.B, 1.C, etc.) where the classification is based on the physical properties of the product.

Table ECB-1 Temporary Erosion Control Blanket Classes and Applications

Class	Application
1.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
1.B	Designed for use on geotechnically stable slopes with gradients up to 4:1 and channels with shear stresses up to .5 pounds per square foot.
1.C	Designed for use on geotechnically stable slopes with gradients up to 3:1 and channels with shear stresses up to 1.5 pounds per square foot.
1.D	Designed for use on geotechnically stable slopes with gradients up to 2:1 and channels with shear stresses up to 1.75 pounds per square foot.
2.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
2.B	Designed for use on geotechnically stable slopes with gradients up to 4:1 and channels with shear stresses up to .5 pounds per square foot.
2.C	Designed for use on geotechnically stable slopes with gradients up to 3:1 and char stresses up to 1.5 pounds per square foot.
2.D	Designed for use on geotechnically stable slopes with gradients up to 2:1 and channels with shear stresses up to 1.75 pounds per square foot.
3.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
3.B	Designed for use on geotechnically stable slopes with gradients up to 1.5:1 and channels with shear stresses up to 2 pounds per square foot.
4	Designed for use on geotechnically stable slopes with gradients up to 1:1 and channels with shear stresses up to 2.25 pounds per square foot.

Table ECB-2 Permanent Erosion Control Blanket Classes and Applications

Class	Application
5.A	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 6 pounds per square foot.
5.B	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 8 pounds per square foot.
5.C	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 10 pounds per square foot.

Class Designations and Durability

Erosion control products shall have the configurations and durability as shown in Tables ECB-3 and ECB-4.

Table ECB-3 Typical Configuration and Durability of Temporary Erosion Control Blankets

Class Designation	Usual Configuration	Typical Durability
1.A Ultra-short term mulch control netting	Mulch control netting consisting of rapidly degrading photodegradable synthetic mesh or woven biodegradable natural fiber netting.	3 months
1.B Ultra-short term netless erosion control blanket	An erosion control blanket composed of processed rapidly degrading natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a continuous matrix.	3 months
1.C Ultra-short term single net erosion control blanket or open weave textile	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting to form a continuous matrix. Or an open weave textile composed of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3 months
1.D Ultra-short term double net erosion control blankets	An erosion control blanket composed of processed natural or polymer fibers mechanically bound between 2 rapidly degrading, synthetic or natural fiber nettings to form a continuous matrix.	3 months
2.A Short-term mulch control netting	Mulch control netting consisting of photodegradable synthetic mesh or woven biodegradable natural fiber netting.	12 months
2.B Short-term netless erosion control blanket	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a continuous matrix.	12 months
2.C Short-term single net erosion control blanket or open weave textile	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically bound together by a single degradable, synthetic or natural fiber netting to form a continuous matrix. Or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	12 months
2.D Short-term double net erosion control blanket	An erosion control blanket composed of processed natural or polymer fibers mechanically bound between 2 synthetic or natural fiber nettings to form a continuous matrix.	12 months
3.A Extended-term mulch control netting	Mulch control netting consisting of a slow degrading synthetic mesh or woven natural fiber netting.	24 months
3.B Extended-term erosion control blanket or open weave textile	An erosion control blanket composed of processed slow degrading natural and/or polymer fibers mechanically bound together between 2 slow degrading synthetic or natural fiber nettings to form a continuous matrix. Or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	24 months
4 Long-term erosion control blanket or open weave textile	An erosion control blanket composed of processed slow degrading natural and/or polymer fibers mechanically bound together between 2 slow degrading synthetic or natural fiber nettings to form a continuous matrix. Or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	36 months

Table ECB-4 Typical Configuration and Durability of Permanent Erosion Control Blankets

Class Designation	Usual Configuration	Typical Durability
5.A Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent
5.B Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent
5.C Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent

Materials Physical Requirements

A properly designed erosion control blanket installation requires selection of a product manufactured with physical properties to withstand the stresses the product will be subjected to for the design life of the product. Table ECB-5 gives the minimum physical requirements for each class of blanket.

Product Placement

The erosion control product should be placed immediately after completion of the preparation of the area where the product will be placed.

Follow the manufacturer’s recommendations for installation or use the following instructions. If there is a conflict, follow the manufacturer’s recommendations. Strips shall be rolled out parallel to the direction of flow, in flumes and ditches. On steep slopes, strips shall be rolled out in the direction of flow to reduce rill erosion. When 2 or more strips are required to cover an area, they shall overlap at least 3” (75 mm); however, some type blankets will not require lapping but are to be butted together and stapled with half of each staple located in each of the adjoining blankets. Ends of strips shall overlap at least 6” (150 mm) with the upgrade section on top. The upslope end (anchor slot) of each strip shall be buried in 6” (150 mm) vertical slots, and soil tamped firmly against it. When, in the opinion of the qualified design professional, that conditions warrant, any other edge exposed to excessive flow shall be buried as noted above. The erosion control product shall be spread evenly and smoothly, and most importantly, shall be in contact with the soil at all points. The product should not be stretched tight in such a manner that the material “tents” over the soil surface. If the manufacturer's recommendations for installation of the erosion control product are different that those given here, the Contractor will be required to follow the more stringent of the two.

Table ECB-5 Minimum Physical Requirements For Erosion Control Blankets

Class	Property				
	Minimum Tensile Strength (pounds/ft.) (ASTM D 4595) [1]	Minimum Permissible Shear Stress (pounds/sq. ft.) (ASTM D 6460)[2], [5]	Maximum "C" Factor for Temporary Products (ASTM D 6459)[3], [5]	UV Stability (Minimum % tensile retention) for Permanent Products (ASTM D 4355) (500 hour exp.)	Minimum Thickness (inches) For Permanent Products (ASTM D 6525)[4]
1.A [6]	5	0.25	0.10 @ 5:1	N/A	N/A
1.B	5	0.50	0.10 @ 4:1	N/A	N/A
1.C	50	1.50	0.15 @ 3:1	N/A	N/A
1.D	75	1.75	0.20 @ 2:1	N/A	N/A
2.A [6]	5	0.25	0.10 @ 5:1	N/A	N/A
2.B	5	0.50	0.10 @ 4:1	N/A	N/A
2.C	50	1.50	0.15 @ 3:1	N/A	N/A
2.D	75	1.75	0.20 @ 2:1	N/A	N/A
3.A [6]	25	0.25	0.10 @ 5:1	N/A	N/A
3.B	100	2.00	0.25 @ 1.5:1	N/A	N/A
4	125	2.25	0.25 @ 1:1	N/A	N/A
5.A [7]	125	6.00	N/A	80	0.25
5.B [7]	150	8.00	N/A	80	0.25
5.C [7]	175	10.00	N/A	80	0.25

1 Minimum average roll values, machine direction. For turf reinforcement mats used in field conditions with high loading and/or high survivability requirements tensile strengths of 3000 pounds/ft or greater.

2 Minimum shear stress the rolled erosion control products or turf reinforcement mats can sustain without physical damage or excess erosion (>.5" of soil loss) during a 30 minute flow event in large scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council Test Method no.3. For temporary products the permissible shear stress levels were established for each class based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.03 to 0.05.

3 "C" factor calculated as ratio of soil loss from rolled erosion control product protected slope (tested at the specified gradient) to soil loss from unprotected (control) plot in large scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council Test Method no.2.

4 Minimum average roll values.

5 Other large scale test methods may be determined acceptable.

6 Obtain maximum "C" factor and allowable shear stress for mulch control nettings with the netting used in conjunction with pre-applied mulch material.

7 For turf reinforcement mats containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

Check slots shall be placed so that one check slot, junction slot, or anchor slot of the erosion control product occurs every 50 feet (15 m) of slope. Check slots shall be made by burying a tight fold of the product vertically in the soil a minimum of 6" (150 mm) deep, and tamping and stapling the fold in place. If the manufacturer's recommendations for the installation of check slots are different than those given here, the Contractor will be required to follow the more stringent of the two.

Each strip shall be stapled in 3 rows, at each edge and the center, with staples spaced not more than 3 feet (900 mm) longitudinally. Check slots and ends of strips shall be stapled at 9” (225 mm) intervals across their width.

For temporary blankets, staples should be U-shaped wire with an 11 gauge thickness or greater. Staples should be of sufficient thickness for soil penetration without undue distortion. The legs of the staples shall be at least 6” long with a crown of 1”. Appropriate biodegradable staples can be used in lieu of wire staples.

Permanent blankets shall be anchored in one of two ways. Blankets can be anchored using sound wood stakes, 1” by 3” stock sawn in a triangular shape. The length of the stakes shall be from 12” to 18” depending upon the soil compaction at the site. Stakes shall be installed on 4 feet centers along each edge of the blanket. Blankets can also be anchored using U shaped staples of 11 gauge steel or greater with a minimum leg length of 8” and a 2” crown.

This Page Intentionally Left Blank

Groundskeeping (GK)

Practice Description

Groundskeeping, or “good housekeeping”, describes the various activities and measures, in addition to the specific practices used for erosion and sediment control that are essential during construction for the protection of environmental quality. Groundskeeping is applicable at all construction sites.

Planning Considerations

In addition to the sediment and erosion control practices included in the Handbook that deal directly with sediment and erosion control, some general groundskeeping practices are essential to the pollution prevention aspect of a Stormwater Pollution Prevention Plan. Groundskeeping addresses these practices. Included in the practice are the following different areas:

- Inspection and Maintenance Procedures
- Materials Inventory
- Spill Prevention and Material Management Practices
- Spill Controls
- Hazardous Products
- Air Emissions (excessive odor)
- Other Good Groundskeeping Practices (i.e. fugitive spray, excessive noise and aesthetics)

Design Criteria

Inspection and Maintenance Procedures

The following inspection and maintenance procedures need to be followed to maintain adequate sediment and erosion controls:

- All control measures need to be inspected at least once per week and following any accumulation of rainfall of ¾" or more within a 24-hour period. A more frequent inspection interval may be required by either a permitting agency or a permittee.
- All measures need to be maintained in good working order. If a repair is necessary, it should be initiated within 24 hours of report.
- Silt fence and straw bales need to be inspected weekly for proper anchorage and leakage underneath. Silt fencing should also be inspected for tears.
- Built-up sediment needs to be removed from silt barriers when it has reached ½ of the height of the barrier. Sediment needs to be placed in a stabilized site to prevent re-entry into the same site or another entrapment area.
- Sediment basins need to be inspected for depth of sediment on a monthly basis and built up sediment needs to be removed when ½ of the basin volume is filled.
- Temporary and permanent seeding and plantings need to be inspected for bare spots, washouts and unhealthy growth. A person should be designated to be responsible for maintaining planted areas until there is a uniform stand with 85% ground cover and growth has reached 1" in height.

Materials Inventory

A materials list should be compiled for items that will be stored outside on the site during construction. For example:

________ Pipe, fittings and joint compounds for underground utility piping
________ Gravel and stone bedding material
________ Concrete forming materials
________ Other (specify) ________________________________
____
____
____

Note: Fuels, oils and other petroleum products; forming oils and compounds; fertilizers; pesticides; strippers; detergents; cleaners; or any other hazardous or toxic compounds should not be stored outside on the site unless specifically agreed upon by all responsible parties, including those persons responsible for enforcing local ordinances and policies. On-site storage should meet all local, state and federal rules regarding secondary containment. Additionally, local ordinances may require fencing and security measures for storage of these products.

Spill Prevention and Material Management Practices

Petroleum Products

All vehicles kept on the site need to be monitored for leaks and receive regular preventive maintenance to reduce the chance of leakage. A Spill Prevention Control and Countermeasures (SPCC) plan should be developed for the facility to address the safe storage, handling and clean-up of petroleum products and other chemicals. Petroleum products should be stored in tightly sealed containers, which are clearly labeled. If petroleum products are stored on site, a secondary containment facility will be required if the cumulative storage capacity of all tanks, greater than 55 gallons, at the site exceeds 1,320 gallons. Any asphalt substances used on-site should be applied according to the manufacturer's recommendations.

Fueling & Servicing

No fueling, servicing, maintenance, or repair of equipment or machinery should be done within 50 feet of a stream, or within 100 feet of a stream classified for public water supply (PWS) or Outstanding Alabama Water (OAW), or designated as an Outstanding National Resource Water (ONRW), or a sinkhole.

Mud Tracking

A stabilized construction entrance needs to be designated on the plan. The practice Construction Exit Pad provides design details for planning such an entrance.

Only designated entrances should be used for construction access to the site. The General Contractor should be responsible for keeping mud cleaned from adjoining streets on a daily basis if needed.

Concrete Trucks

Concrete trucks should be allowed to wash only in locations where discharge is appropriately treated to meet applicable regulatory requirements. It is not permissible to discharge concrete wash directly to streams or storm drains. Concrete wash can contain sediment, as well as, alkalinity and chemical additives that could be harmful to fish, stream bottom macroinvertebrates and wildlife.

Disposal of Oil

No fuels, oils, lubricants, solvents, or other hazardous materials can be disposed of on the site. All hazardous material must be properly disposed of in accordance with State law.

Trash/Solid Waste

The General Contractor is responsible for disposing of all solid waste from the site in accordance with State law. Dumpsters or other collection facilities must be provided as needed. Solid waste may not be buried on the site.

Sanitary Waste

The General Contractor is responsible for providing sanitary facilities on the site. Sanitary waste may be disposed only in locations having a State permit. Portable toilets should be located so that accidental spills will not discharge into a storm sewer or concentrated flow area.

Other Discharges

Water for pressure testing sanitary sewers, flushing water lines, sand blasting, concrete cleansing, etc., may be discharged only in approved areas. Discharge of hydrostatic test water may require additional permitting, particularly if chlorinated public water is used.

Spill Controls

In addition to the good housekeeping practices and material management practices listed previously, the following procedures need to be followed for spill prevention and clean-up:

- Manufacturer's recommended methods for spill cleanup needs to be clearly posted and site personnel need to be made aware of the procedures and the location of the information and cleanup supplies. Refer to material safety data sheets (Material Safety Data Sheet).
- Material and equipment necessary for spill cleanup needs to be kept in the material storage area on-site. Equipment and materials include, but are not be limited to; brooms, dust pans, mops, rags, gloves, goggles, absorbent clay (kitty litter), sand, sawdust, absorbent mats, and plastic and metal trash containers specifically for this purpose.

- All spills need to be cleaned up immediately after discovery and properly containerized for proper disposal. Burial is not acceptable.
- The spill area must be kept well ventilated and personnel need to wear appropriate protective clothing to prevent injury from contact with a hazardous substance.

- Spills of toxic or hazardous material must be reported immediately to the appropriate state or local government agency, regardless of the size.

- The spill prevention plan needs to be adjusted to include measures to prevent this type of spill from being repeated, and the plan needs to show how to clean up the spill if another one does occur.

Contaminated Soils

Removal of contaminated soils and underground storage tanks should be based on information provided by the Alabama Department of Environmental Management following a proper site assessment.

Hazardous Products

- Products must be kept in original containers unless they are not resealable. If product is transferred to a new container, it must be properly marked and labeled.

- Original labels and material safety data sheets should be retained.

- If surplus product must be disposed, disposal must be done in accordance with Alabama Department of Environmental Management regulations.

Air Emissions

Burning

Burning on the site may require a permit from the Alabama Forestry Commission. County or city ordinances may also apply. Starting disposal fires with diesel fuel or old tires is not a recommended practice. The use of burn pits with fans to generate hot disposal fires decreases the fire disposal time and minimizes smoke.

Dust Control

Apply measures that minimize dust. Stabilizing areas with mulch as soon as possible can minimize dust. Watering should be provided in unstabilized areas.

Other Good Groundskeeping Practices

The following good housekeeping practices also need to be followed during the construction of the project:

- An effort should be made to store only enough products to do the job.

- All materials stored on-site should be stored in a neat, orderly manner in their appropriate containers and, if possible, under a roof or other enclosure.

- Products should be kept in their original containers with the original manufacturer's label.

- Whenever possible, all of a product should be used up before disposing of the container.

- Manufacturer's recommendations for proper use and disposal must be followed (see Material Safety Data Sheet).

- The site superintendent should inspect daily to ensure proper usage, storage and disposal of materials.

- Fertilizers need to be applied only in the minimum amounts recommended by the manufacturer.

- All paint containers need to be tightly sealed and stored when not required for use. Excess paint shall not be dumped into the storm sewer system but should be properly disposed of according to manufacturer's instructions (see Material Safety Data Sheet) and State regulations.

- The site should be kept clean and well groomed (trash picked up regularly, weeds mowed and signs maintained).

- Offsite fugitive spray from dust control, sand blasting and pressure washing must be minimized to the extent possible.

- Locate activities that generate odors and noise as far from surrounding properties as possible (this item includes portable toilets burn sites, fueling areas, equipment repair areas and dumpsters).

Mulching (MU)

Practice Description

Mulching is the application of plant residues such as straw or other suitable fibrous materials to the soil surface. Mulch protects the soil surface from the erosive force of raindrop impact and reduces the velocity of overland flow. It helps seedlings germinate and grow by conserving moisture, protecting against temperature extremes and controlling weeds. Mulch also maintains the infiltration capacity of the soil. Mulch can be applied to seeded areas to help establish plant cover. It can also be used in unseeded areas to protect against erosion over the winter or until final grading and shaping can be accomplished except in areas with concentrated flow.

Planning Considerations

Surface mulch is the most effective, practical means of controlling runoff and erosion on disturbed land prior to vegetation establishment. Mulch absorbs the energy associated with raindrops and thereby minimizes soil particle detachment, which is the initiation step of erosion.

Mulch also reduces soil moisture loss by evaporation, prevents crusting and sealing of the soil surface, moderates soil temperatures, and provides a suitable microclimate for seed germination.

Organic mulches such as straw, wood chips and shredded bark have been found to be very effective mulch materials. Materials containing weed and grass seeds which may compete with establishing vegetation should not be used. Also, 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.

Hydraulic Erosion Control Products (HECPs) as defined by the Erosion Control Technology Council (ECTC) can also be used as effective mulch applications. HECPs are designated as 5 different types based on product characteristics and performance. Information from the ECTC table dated August 2010 is provided as Table MU-1. To ensure that you use the most valid information refer to the latest HECP specifications provided by the ECTC or the manufacturer's recommendation. The Alabama Department of Transportation (ALDOT) characterizes mulches based on performance levels identified in Sections 656 and 659 of their Standard Specifications for Highway Construction.

The choice of materials for mulching should be based on soil conditions, season, type of vegetation to establish, and size of the area. Properly applied and tacked mulch is always beneficial. Mulching is especially important when conditions of germination are not optimum, such as midsummer and early winter, and on difficult sites such as cut slopes, fill slopes and droughty soils.

Straw has traditionally been the most commonly used mulching material in conjunction with seeding. Wheat straw is the mostly commonly used straw, and can be spread by hand or with a mulch blower. If the site is susceptible to blowing wind, the straw should be tacked down with a tackifier, or a crimper to prevent loss.

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

Compost, peanut hulls, and pine straw are organic materials that potentially make excellent mulches but may only be available locally or seasonally. Creative use of these materials may reduce costs.

Jute mesh or the various types of netting is very effective in holding mulch in place on waterways and slopes before grasses become established.

Erosion control blankets promote seedling growth in the same way as organic mulches and are suited for use in areas with concentrated flows (see Erosion Control Blanket practice).

Table MU-1 Hydraulic Erosion Control Products (HECP) Specification Chart [1]

Hydraulic Erosion Control							
Type HECP[2]	Term	Functional Longevity[3]	Typical Application Rates Lbs/acre (kg/ha)	Typical Maximum Slope Gradient (H:V)	Maximum Uninterrupted Slope Length (ft)	Maximum C Factor[4, 5] (3:1 test)	Minimum Vegetation Establishment[6]
1	Ultra Short	1 month	1500—2500 (1700—2800)	≤ 4:1	20	0.75	150 %
2	Short Term	2 month	2000—3000 (2250—3400)	≤ 3:1	25	0.5	150 %
3	Moderate	3 month	2000—3500 (2250—3900)	≤ 2:1	50	0.15	200 %
4	Extended Term	6 month	2500—4000 (2800—4500)	≤ 1:1	75	0.1	300 %
5	Long Term	12 month	3000—4500 (3400—5100)	≤ 0.5:1	100	0.02	400 %

[1] This table is for general guidelines only. Refer to manufacturer for application rates, instructions, gradients, maximum continuous slope lengths and other site specific recommendations.

[2] These categories are independent of rolled erosion control products (RECPs) categories, despite the identical names.

[3] A manufacturer's estimated time period, based upon field observations, that a materials can be anticipated to provide erosion control as influenced by it composition and site-specific conditions.

[4] "C" Factor calculated as ratio of soil loss from HECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot based on large-scale testing.

[5] Acceptable large-scale test methods may include ASTM D 6459, or other independent testing deemed acceptable by the engineer.

[6] Minimum vegetation establishment is calculated as outlined in ASTM D 7322 being a percentage by dividing the plant mass per area of the protected plot by the plant mass per area of the control plot.

EROSION CONTROL TECHNOLOGY COUNCIL —WWW.ECTC.ORG

ECTC makes no representations or warranties of any kind express or implied, about the completeness, accuracy, reliability, suitability or availability with respect to the website or the information, products, services, or related graphics contained on the website for any purpose. Any reliance you place on such information is therefore strictly at your own risk.

(Source: Erosion Control Technology Council, August 2010)

Design Criteria

Site Preparation

Before mulching, complete the required site preparation. Site preparation includes grading, if needed, and seedbed preparation and fertilizing, liming and seeding if a planting is being made by means other than hydroseeding.

Spreading the Mulch

Select a mulch material based on the site and practice requirements, availability of material, and availability of labor and equipment. Table MU-2 lists commonly used mulches.

Table MU-2 Mulching Materials and Application Rates

Material	Rate Per Acre and (Per 1000 $ft.^2$)	Notes
Straw with Seed	1 ½-2 tons (70 lbs-90 lbs)	Spread by hand or machine to attain 75% groundcover; anchor when subject to blowing.
Straw Alone (no seed)	2 ½-3 tons (115 lbs-160 lbs)	Spread by hand or machine; anchor when subject to blowing.
Wood Chips	5-6 tons (225 lbs-270 lbs)	Treat with 12 lbs. nitrogen/ton.
Bark	35 cubic yards (0.8 cubic yard)	Can apply with mulch blower.
Pine Straw	1-2 tons (45 lbs-90 lbs)	Spread by hand or machine; will not blow like straw.
Peanut Hulls	10-20 tons (450 lbs-900 lbs)	Will wash off slopes. Treat with 12 lbs. nitrogen/ton.
HECPs	0.75 – 2.25 tons (35 lbs – 103 lbs)	Refer to ECTC or Manufacturer's Specifications.

Uniformly spread organic mulches by hand or with a mulch blower at a rate which provides about 75% ground cover. Spread HECPs utilizing appropriate equipment and at rates as specified When spreading straw mulch by hand, divide the area to be mulched into sections of approximately 1000 sq. ft. and place 70-90 pounds of straw (1 ½ to 2 bales) in each section to facilitate uniform distribution. Caution, an over-application of wheat straw will reduce stand success – do not over-apply wheat straw when mulching a seeding!

When straw mulch is subject to be blown away by wind, it must be anchored immediately after spreading. It is best anchored with a mulch anchoring tool.

Application of a commercial tackifier through a hydroseeder is often practical for steep slopes and can be effective on most sites. Binders (tackifiers) 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 an array of commercially available synthetic binders and organic tackifiers.

In high wind situations like roadways, crimping the mulch is the best alternative as the use of mulch binders may still result in the mulch being rolled up on the edge.

Straw mulch may also be anchored with lightweight plastic, cotton, jute, wire or paper netting which is stapled over the mulch. The manufacturer's recommendations on stapling netting should be followed.

Maintenance

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

This Page Intentionally Left Blank

Permanent Seeding (PS)

Practice Description

Permanent seeding is the establishment of perennial vegetation on disturbed areas from seed. Permanent vegetation provides economical long-term erosion control and helps prevent sediment from leaving the site. This practice is used when vegetation is desired and appropriate to permanently stabilize the soil.

Planning Considerations

The advantages of seeding over other means of establishing plants include the smaller initial cost, lower labor input, and greater flexibility of method.

Disadvantages of seeding include potential for erosion during the establishment stage, seasonal limitations on suitable seeding dates, and weather-related problems such as droughts.

The probability of successful plant establishment can be maximized through good planning. The selection of plants for permanent vegetation must be site specific. Factors that should be considered are type of soils, climate, establishment rate, and management requirements of the vegetation. Other factors that may be important are wear, mowing tolerance, and salt tolerance of vegetation.

Plant selection for permanent vegetation should be based on plant characteristics, site and soil conditions, time of year of planting, method of planting, and the intended use of the vegetated area. Climate factors can vary widely in Alabama.

Important plant attributes are discussed in Vegetation Establishment for Erosion and Sediment Control in Chapter 2.

Plant selection may include companion plants to provide quick cover on difficult sites, late seedings, or where the desired permanent cover may be slow to establish. Annuals are usually used for companion plants and should be selected carefully to prevent using a species that provide so much competition that it prevents the establishment of the desired species.

Seeding properly carried out within the optimum dates has a higher probability of success. It is also possible to have satisfactory establishment when seeding outside these dates. However, as plantings are deviated from the optimum dates, the probability of failure increases rapidly. Seeding dates should be taken into account in scheduling land-disturbing activities.

Site quality impacts both short-term and long-term plant success. Sites that have compacted soils, soils that are shallow to rock or have textures that are too clayey or too sandy should be modified whenever practical to improve the potential for plant growth and long-term cover success.

The operation of equipment is restricted on slopes steeper than 3:1, severely limiting the quality of the seedbed that can be prepared. Provisions for establishment of vegetation on steep slopes can be made during final grading. In construction of fill slopes, for example, the last 4-6” might not be compacted. A loose, rough seedbed with irregularities that hold seeds and lime and fertilizer is essential for hydroseeding. Cut slopes should be roughened (see Land Grading practice).

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

The use of irrigation (temporary or permanent) will greatly improve the success of vegetation establishment.

Design Criteria

Plant Selection

Select plants that can be expected to meet planting objectives. To simplify plant selection, use Figure PS-1 Geographical Areas for Species Adaptation and Seeding Dates and Table PS-1, Commonly Used Plants for Permanent Cover. Mixtures commonly specified by the Alabama Department of Transportation are an appropriate alternative for plantings on rights-of-ways. Additional information related to plants commonly used in Alabama is found in Chapter 2 under the section Vegetation for Erosion and Sediment Control.

The plants used for temporary vegetation may be used for companion plants provided the seeding rate of the annual species is reduced by one half. See the Temporary Seeding practice for additional information on establishing temporary vegetation. **Ryegrass or other highly competitive plants should not be used as a companion plant**.

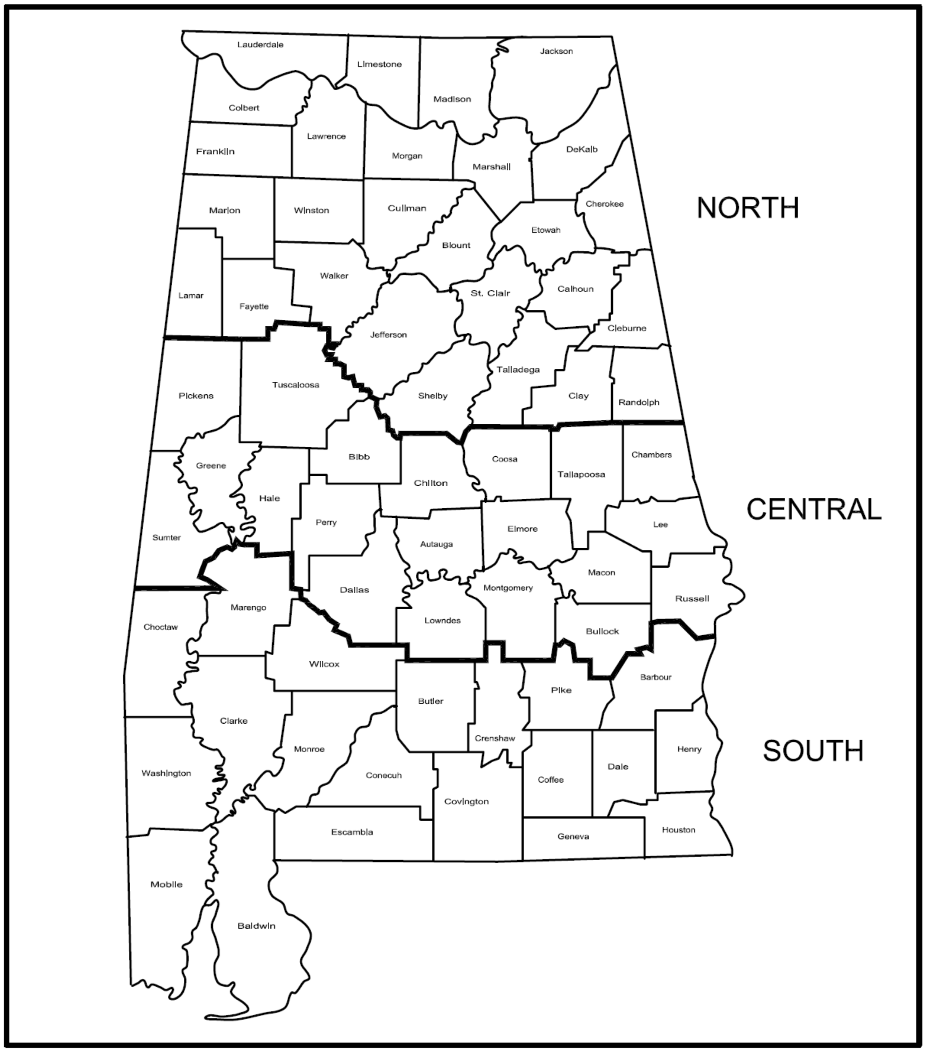


Figure PS-1 Geographical Areas for Species Adaptation and Seeding Dates

Note: Site conditions related to soils and aspect in counties adjacent to or close to county boundaries may justify adjustments in planting dates by qualified design professionals.

Table PS-1 Commonly Used Plants for Permanent Cover with Seeding Rates and Dates

Species	Seeding Rates/Ac PLS	North	Central	South
			Seeding Dates	
Bahiagrass, Pensacola	40 lbs	--	Mar 1-July 1	Feb 1-Nov 1
Bermudagrass, Common	10 lbs	Apr 1-July 1	Mar 15-July 15	Mar 1-July 15
Bahiagrass, Pensacola Bermudagrass, Common	30 lbs 5 lbs	--	Mar 1-July 1	Mar 1-July 15
Bermudagrass, Hybrid (Lawn Types)	Solid Sod	Anytime	Anytime	Anytime
Bermudagrass, Hybrid (Lawn Types)	Sprigs 1/sq ft	Mar 1-Aug 1	Mar 1-Aug 1	Feb 15-Sep 1
Fescue, Tall	40-50 lbs	Sep 1-Nov 1	Sep 1-Nov 1	--
Sericea	40-60 lbs	Mar 15-July 15	Mar 1-July 15	Feb 15-July 15
Sericea & Common Bermudagrass	40lbs 10 lbs	Mar 15-July 15	Mar 1-July 15	Feb 15-July 15
Switchgrass, Alamo	4 Lbs	Apr 1-Jun 15	Mar 15-Jun 15	Mar 15-Jun15

PLS means pure live seed and is used to adjust seeding rates. For example, to plant 10 lbs PLS of a species with germination of 80% and purity of 90%, PLS= 0.8X 0.9 = 72%. 10 lbs PLS = 10/0.72 = 13.9 lbs of the species to be planted.

Seedbed Requirements

Establishment of vegetation should not be attempted on sites that are unsuitable due to compaction or inappropriate soil texture, poor drainage, concentrated overland flow, or steepness of slope until measures have been completed to correct these problems. To maintain a good stand of vegetation, the soil must meet certain minimum requirements as a growth medium. A good growth medium should have these attributes:

- Sufficient pore space to permit root penetration.
- Enough fine-grained soil material (silt and clay) to maintain adequate moisture and nutrient supply.
- Sufficient depth of soil to provide an adequate root zone. The depth to rock or impermeable layers such as hardpans should be 12” or more, except on slopes steeper than 2:1 where topsoiling is not feasible.
- A favorable pH range for plant growth, usually 6.0-6.5.

- Sufficient nutrients (nitrogen, phosphorus and potassium) for initial plant establishment.

- Freedom from large roots, branches, stones, or large clods. Clods and stones may be left on slopes steeper than 3:1 if they are to be hydroseeded.

If any of the above attributes are not met: i.e., if the existing soil is too dense, coarse, shallow or acidic to foster vegetation – chiseling, topsoil, or special amendments should be used to improve soil conditions. The soil conditioners described below may be beneficial or topsoil may be applied (for guidance on topsoiling see Topsoiling practice). These amendments should only be necessary where soils have limitations that make them poor for plant growth or for turf establishment.

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

- Sand-should be clean and free of toxic materials.

- Vermiculite-use horticultural grade.

- Rotted manure-use stable or cattle manure not containing undue amounts of straw or other bedding materials.

- Thoroughly rotted sawdust-should be free of stones and debris. Add 6 lbs of nitrogen to each cubic yard.

Soil Amendments

Liming Materials

Lime (Agricultural limestone) should have a neutralizing value of not less than 90 percent calcium carbonate equivalent and 90 percent will pass through a 10 mesh sieve and 50 percent will pass through a 60 mesh sieve.

Selma chalk should have a neutralizing value of not less than 80 percent calcium carbonate equivalent and 90 percent will pass through a 10 mesh sieve.

Other liming materials that may be selected should be provided in amounts that provide equal value to the criteria listed for agricultural lime or be used in combination with agricultural limestone or Selma chalk to provide equivalent values to agricultural limestone.

Plant Nutrients

Commercial grade fertilizers that comply with current Alabama Fertilizer Laws should be used to supply nutrients required to establish vegetation.

Lime and fertilizer needs should be determined by soil tests. Soil testing is performed by the Auburn University Soil Testing Laboratory and provides recommendations based on field tests on Alabama soils. The local county Cooperative Extension Service can provide information on obtaining soil tests. Commercial laboratories that make recommendations based on soil analysis may be used.

When soil tests are not available, use the following rates for application of soil amendments.

Sandy soils: Use 1 ton/acre (exception on sandy soils – if the cover will be tall fescue and clover) use 2 tons/acre.
Clayey soils: 2 tons/acre.
(Do not apply lime to alkaline soils).

Grasses alone: Use 400 lbs/acre of 8-24-24 or the equivalent. Apply 30 lbs of additional nitrogen when grass has emerged and begun growth (approximately 0.8lbs/1000 ft^2).
Grass-legume mixtures: Use 800 to 1200 lbs/acre of 5-10-10 or the equivalent.
Legumes Alone: Use 400 to 600 lbs/acre of 0-20-20 or the equivalent.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

Application of Soil Amendments

Apply lime and fertilizer evenly and incorporate into the top 6" of soil by disking, chiseling or other suitable means during seedbed preparation. Operate machinery on the contour. On sites too steep for seedbed preparation, fertilizer and lime can be applied with a hydroseeder.

Seedbed Preparation

If needed, grade and shape to provide a surface on which equipment can safely and efficiently be used for seedbed preparation and seeding.

Install necessary sediment control practices before seedbed preparation and complete grading according to the approved plan.

Prepare a friable seedbed with tillage to a depth of at least 6". Break up large clods, alleviate compaction, and smooth and firm the soil into a uniform surface. Fill in or level depressions that can collect water.

Planting Methods

Seeding
Use certified seed for permanent seeding whenever possible. Certified seed is inspected by the Alabama Crop Improvement Association to meet high quality standards and will be tagged with a "Certified Seed" tag. (Note: all seed sold in Alabama is required by law to be tagged to identify seed purity, germination, and

presence of weed seeds. Seed must meet state standards for content of noxious weeds.)

Seeding dates are determined using Figure PS-1 and Table PS-1.

Inoculate legume seed with the Rhizobium bacteria appropriate to the species of legume. Details of legume inoculation are located in Chapter 2 in the part on Vegetation for Erosion and Sediment Control under Inoculation of Legumes.

Plant seed uniformly with a cyclone seeder, a drill seeder, a cultipacker seeder, or by hand on a fresh, firm, friable seedbed. If the seedbed has been sealed by rainfall, it should be disked so the seed will be sown into a freshly prepared seedbed.

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

Cover broadcast seed by raking or chain dragging; then firm the surface with a roller or cultipacker to provide good seed contact. Small grains should be planted no more than 1” deep and grasses and legume seed no more than ½” deep.

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

Mix seed, inoculant if required, and a seed carrier with water and apply as a slurry uniformly over the area to be treated. The seed carrier should be a cellulose fiber, natural wood fiber or other approved fiber mulch material which is dyed an appropriate color to facilitate uniform application of seed. Use the correct legume inoculant at 4 times the recommended rate when adding inoculant to a hydroseeder slurry. The mixture should be applied within one hour after mixing to reduce damage to seed.

Fertilizer should not be mixed with the seed-inoculant mixture because fertilizer salts may damage seed and reduce germination and seedling vigor.

Fertilizer may be applied with a hydroseeder as a separate operation after seedlings are established.

Lime is not normally applied with a hydraulic seeder because it is abrasive but if necessary it can be added to the seed slurry and applied at seeding or it may be applied with the fertilizer mixture. Also lime can be blown onto steeper slopes in dry form.

Sprigging
Hybrid bermudagrass cannot be grown from seed and must be planted vegetatively. Vegetative methods of establishing common and hybrid bermudagrass, centipedegrass and zoysia include sodding, plugging and sprigging (see Sodding practice).

When sprigs are planted with a sprigging machine, furrows should be 4-6” deep and 2 feet apart. Place sprigs no farther than 2 feet apart in the row and so that at least one rooting node is in the furrow.

When broadcasting is used for sprig planting, broadcast sprigs at the specified rate (Table PS-1). Press into the top ½” to 2” of soil with a cultipacker or with a disk set nearly straight so that the sprigs are not brought back to the surface. A mulch tacking machine may be used to press sprigs into the soil.

Mulching

The use of mulch provides instant cover and helps ensure establishment of vegetation under normal conditions and is essential to seeding success under harsh site conditions (see Mulching practice). Harsh site conditions include: slopes steeper than 3:1 and adverse soils (shallow, rocky, or high in clay or sand). Areas with concentrated flow should be treated differently and require sod, a hydromulch formulated for channels or an appropriate erosion control blanket.

Irrigation

Moisture is essential for seed germination and vegetation establishment. Supplemental irrigation can be very helpful in assuring adequate stands in dry seasons or to speed development of full cover. It is a requirement for establishment of vegetation from sod and sprigs and should be used elsewhere when feasible. However, irrigation is rarely critical for low-maintenance vegetation planted at the appropriate time of the year.

Water application rates must be carefully controlled to prevent runoff. Inadequate or excessive amounts of water can be more harmful than no supplemental water.

Maintenance

Generally, a stand of vegetation cannot be determined to be fully established until soil cover has been maintained for 1 full year from planting. Inspect vegetated areas for failure and make necessary repairs and vegetate as soon as possible.

If a stand has inadequate cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand after seedbed preparation or over-seed the stand. Consider a temporary seeding if the time of year is not appropriate for establishment of permanent vegetation (see Temporary Seeding practice).

If vegetation fails to grow, a soil test should be made to determine if soil acidity or nutrient imbalance is responsible.

To attain complete establishment, fertilization is usually required in the second growing season. Turf grasses require annual maintenance fertilization. Use soil tests if possible or follow the guidelines given for the specific seeding mixtures.

Protect vegetation during its establishing period from traffic that will be harmful. If appropriate, use either temporary fences or barriers to protect areas that may be damaged by excessive traffic.

This Page Intentionally Left Blank

Preservation of Vegetation (PV)

Practice Description

Preservation of vegetation is the avoidance of an area during land disturbing and construction activity to prevent mechanical and other injury to desirable plants in the planned landscape. The practice provides erosion and sediment control and is applicable where vegetative cover is desired and the existing plant community is compatible with the planned landscape.

Planning Considerations

Preservation of vegetation requires good site management to minimize the impact of construction activities on existing vegetation.

Plants to save should be identified prior to any construction activity.

Proper maintenance, especially during construction, is important to ensure healthy vegetation that can control erosion.

Different species, soil types, and climatic conditions will require different maintenance activities.

Design Criteria

Mark Plant Area for Retention

Groups of plants and individual trees to be retained should be located on a plan map. Limits of clearing should be planned outside the drip line of groups or individual trees to be saved. The clearing should never be closer than 5 feet to the trunk of a tree.

Flagging or other appropriate means of marking the site of the groups of plants and individual trees to be retained should be required before construction begins Individual trees to be retained should be marked with a highly visible paint or surveyor's ribbon in a band circling the tree at a height visible to equipment operators.

Plant Protection

Restrict construction equipment, vehicular traffic, stockpiles of construction materials, topsoil etc., from the areas where plants are retained and restrict these activities from occurring within the drip line of any tree to be retained. Trees being removed shall not be pushed into trees to be retained. Equipment operators shall not clean any of their equipment by slamming it against trees to be retained.

Restrict burning of debris within 100 feet of the plants being preserved. Fires shall be limited in size to prevent damage to any nearby trees.

Toxic material shall not be stored any closer than 100 feet to the drip line of any trees to be retained. Toxic materials shall be managed and disposed of according to state laws.

Fencing and Armoring

Groups of plants and trees should be protected by fencing or armoring where necessary (See Figure PV-l). The following types of fencing or armoring may be used:

- Board Fence-Board fence may be constructed with 4" square posts set securely in the ground and protruding at least 4 feet above the ground. A minimum of 2 horizontal boards should be placed between the posts. The fence should be placed at the limits of the clearing around the drip line of the tree. If it is not practical to erect a fence at the drip line, construct a triangular fence near the trunk. The limits of clearing will still be the drip line as the root zone within the drip line will still require protection.

- Cord Fence-Posts at least 2" square or 2" in diameter set securely in the ground and protruding at least 4 feet above the ground shall be placed at the limits of clearing with 2 rows of cord ¼" or thicker at least 2 feet apart running between posts with strips of surveyor's tape tied securely to the string at intervals of 3 feet or less.

- Earth Berms-Temporary earth berms may be constructed. The base of the berm on the tree side should be located along the limits of clearing. Earth berms may not be used for this purpose if their presence will create drainage patterns that cause erosion.

- Additional Trees-Additional trees may be left standing as protection between the trees to be retained and the limits of clearing. However, in order for this alternative to be used, trees in the buffer must be no more than 6 feet apart to prevent passage of equipment and material through the buffer.

- Plan for these additional trees to be evaluated prior to the completion of construction and either given sufficient treatment to ensure survival or be removed.

- Trunk Armoring-As a last resort, a tree may be armored with burlap wrapping and 2" studs wired vertically no more than 2" apart to a height of 5 feet. The armoring should encircle the tree trunk. Nothing should ever be nailed to a tree. The root zone within the drip line will still require protection.

- Fencing and armoring devices should be in place before any construction work is done and should be kept in good condition for the duration of construction activities. Fencing and armoring should not be removed until the completion of the construction project.

Raising the Grade

When the ground level must be raised around an existing tree or group of trees several methods may be used to insure survival.

A well may be created around a group of trees or an individual tree slightly beyond the drip line to retain the natural soil in the area of the feeder roots (see Figure PV-2).
When the well alternative is not practical or desirable, remove vegetation and organic matter from beneath the tree or trees for a distance of 3 feet beyond the drip line and loosen the surface soil to a depth of approximately 3" without damaging the roots.

Apply fertilizer in the root area of the tree to be retained. A soil test is the best way to determine what type of fertilizer to use. In the absence of a soil test, fertilizer should be applied at the rate of 1 to 2 pounds of 10-8-6 or 10-6-4 per inch of diameter at breast height (dbh) for trees under 6" dbh and at the rate of 2 to 4 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees over 6" dbh.

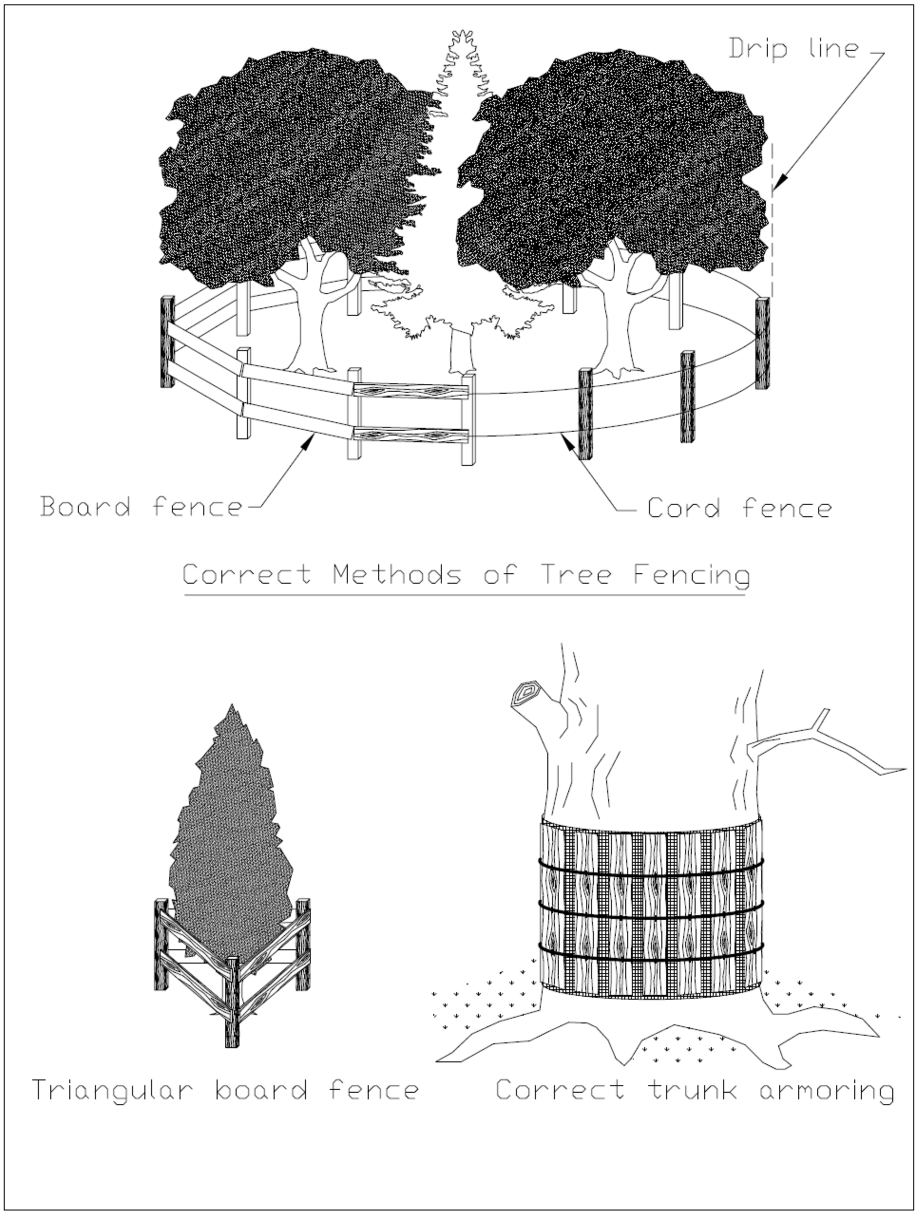


Figure PV-1 Fencing and Armoring

A dry well shall be constructed so as to allow for tree trunk diameter growth (see Figure PV-3). A space of at least 1 foot between the tree trunk and the well wall is adequate for old, slow growing trees. Clearance for younger trees shall be at least 2 feet. The well shall be high enough to bring the top just above the level of the proposed fill. The well wall shall taper slightly away from the tree trunk at a rate of 1” per foot of wall height.

The well wall shall be constructed of large stones, brick, building tile, concrete blocks, or cinder blocks. Openings should be left through the wall of the well to allow for free movement of air and water. Mortar shall only be used near the top of the well and only above the porous fill.

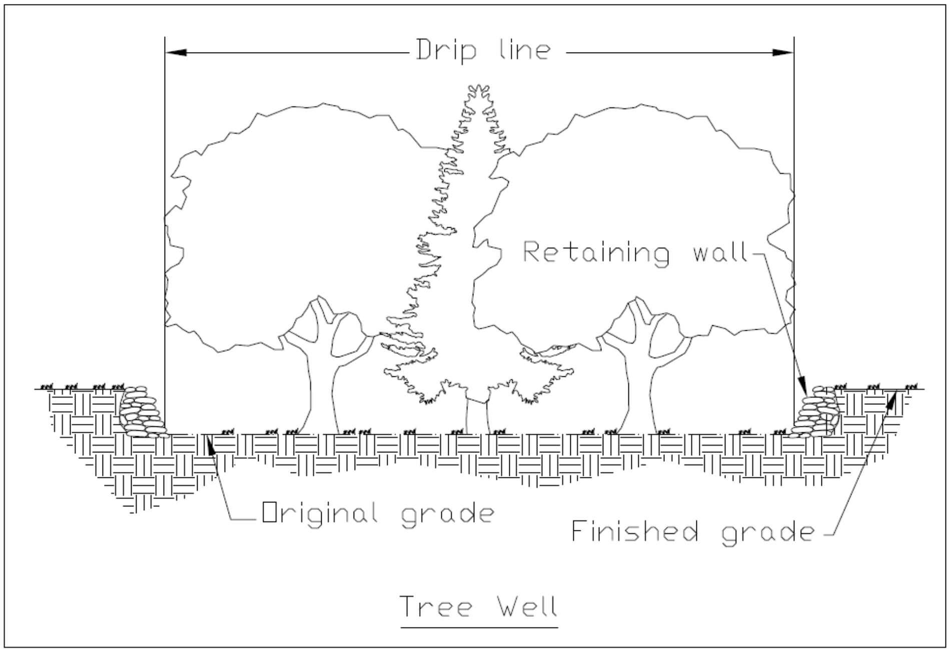


Figure PV-2 Tree Well

Drain lines composed of 4” high quality drain tiles shall begin at the lowest point inside the well and extend outward from the tree trunk in a wheel and spoke pattern with the trunk as the hub. Radial drain lines shall slope away from the well at a rate of ⅛” per foot. The circumference line of tiles should be located beneath the drip line of the trees. Vertical tiles or pipes shall be placed over the intersections of the two tile systems if a fill of more than 2 feet is contemplated. Vertical tiles shall be held in place with stone fill. Tile joints shall be tight. A few radial tiles shall extend beyond each intersection and shall slope sharply downward to insure good drainage. Tar paper or its approved equivalent shall be placed over the tile and/or pipe joints to prevent clogging and large stone shall be placed around and over drain tiles and/or pipes for protection.

A layer of 2” to 6” of stone shall be placed over the entire area under the tree from the well outward at least as far as the drip line. For fills up to 2 feet deep, a layer of stone 8” to 12” thick should be adequate.

A thick layer of this stone not to exceed 30” will be needed for deeper fills. A layer of ¾” to 1” stone covered by straw, fiberglass mat or a manufactured filter fabric shall be used to prevent soil from clogging the space between stones. Cinders shall not be used as fill material. Filling shall be completed with porous soil such as topsoil until the desired grade is reached. This soil shall be suitable to sustain specified vegetation.

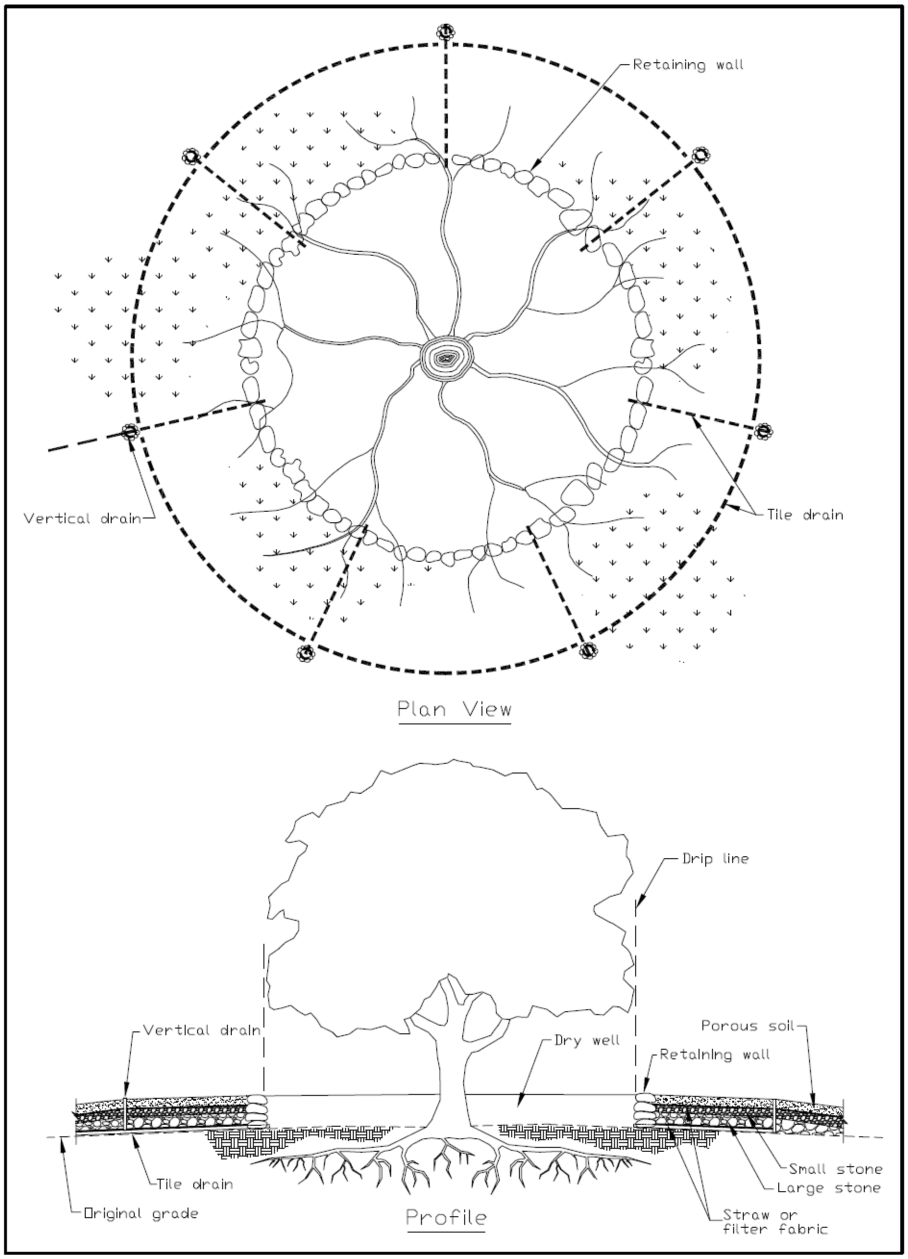


Figure PV-3 Tree Well Detail

Crushed stone shall be placed inside the dry well over the openings of the radial tiles to prevent clogging. The area between the trunk and the well wall shall either be covered by an iron grate or filled with a 50-50 mixture of crushed charcoal and sand to prevent anyone from falling into the dry well.

Where water drainage through the soil is not a problem, coarse gravel in the fill may be substituted for the tile. This material has sufficient porosity to ensure air drainage. Instead of the vertical tiles or pipes in the system, stones, crushed rock and gravel may be added so that the upper level of these porous materials slants toward the surface in the vicinity below the drip line.

Raising the grade on only one side of a tree or group of trees may be accomplished by constructing only half of one of these systems.

Lowering the Grade

Shrubs and trees shall be protected from the harmful grade cuts by the construction of a tree wall (see Figure PV-4). Following excavation, all tree roots that are exposed and/or damaged shall be trimmed cleanly and covered with moist peat moss, burlap or other suitable material to keep them from drying out.

The wall shall be constructed of large stones, brick, building tile, concrete block or cinder block. The wall should be backfilled with topsoil, peat moss, or other organic matter to retain moisture and aid in root development. Apply fertilizer and water thoroughly. The tree plants should be pruned to reduce the leaf surface in proportion to the amount of root loss. Drainage should be provided through the wall so water will not accumulate behind the wall. Lowering the grade on one side of the tree or group of trees can be accomplished by constructing only half of this system.

Trenching and Tunneling

Trenching should be done as far away from the trunks of trees as possible, preferably outside the branches or crown spreads of trees, to reduce the amount of root area damaged or killed by trenching activities. When possible trenches should avoid large roots or root concentrations. This can be accomplished by curving the trench or by tunneling under large roots and areas of heavy root concentration. Tunneling under a species that does not have a large tap root may be preferable to trenching beside it as it has less impact on root systems (see Figure PV-5).

Roots should not be left exposed to the air but should be covered with soil as soon as possible or protected and kept moist with burlap or peat moss until the trench or tunnel can be filled. The ends of damaged and cut roots shall be cut off smoothly and moist peat moss, burlap or topsoil should be placed over the exposed area.

Trenches and tunnels shall be filled as soon as possible. Care should be taken to ensure that air spaces are not left in the soil. Peat moss or other organic matter shall be added to the fill material as an aid to inducing and developing root growth. The tree should be fertilized and mulched to stimulate new root growth and enhance general tree vigor. If a large part of the root system has been damaged the crown leaf surface area should be reduced in proportion to the root damage. This may be accomplished by pruning 20-30 percent of the crown foliage. If the roots are damaged during the winter the crown should be pruned before the next growing season. If roots are cut during the growing season, pruning should be done immediately.

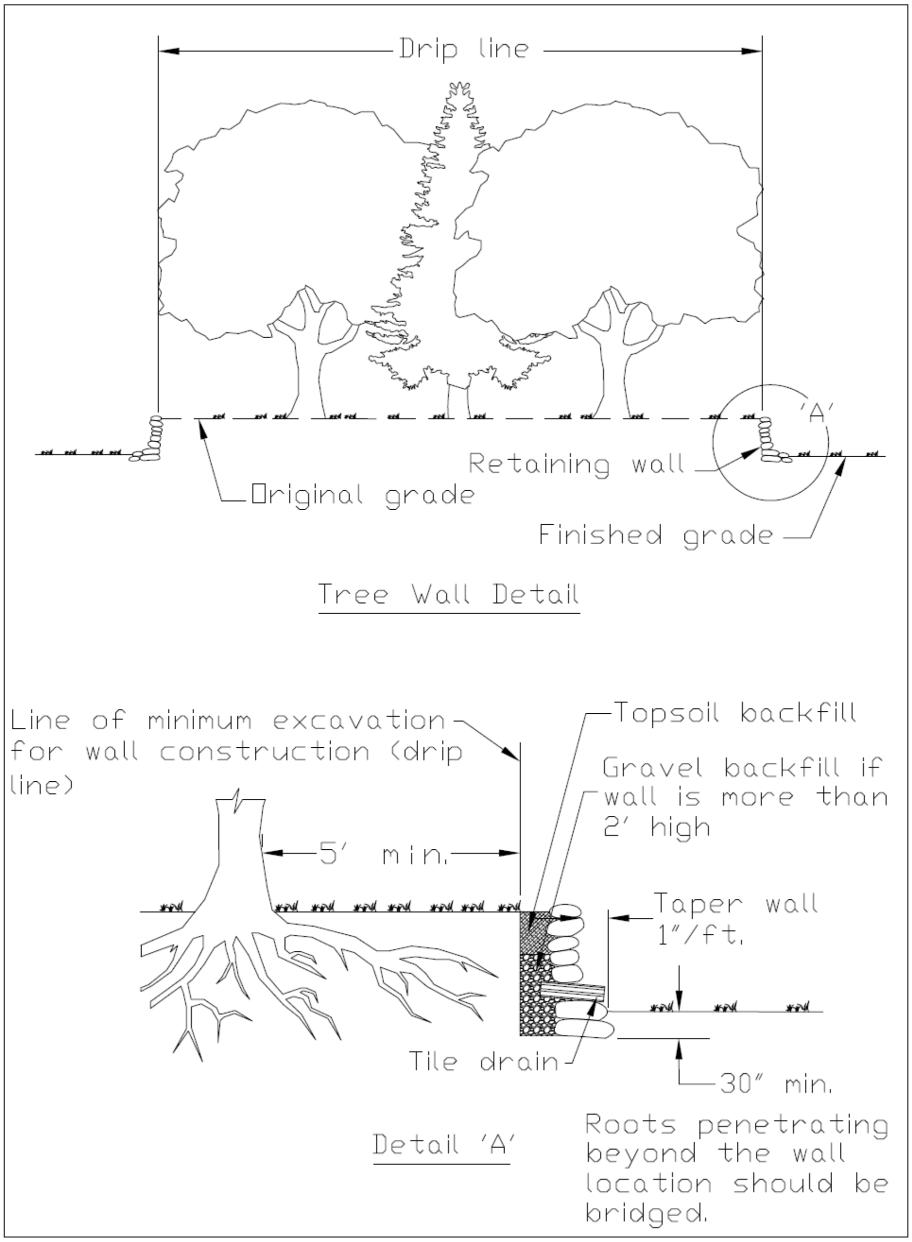


Figure PV-4 Tree Wall Detail

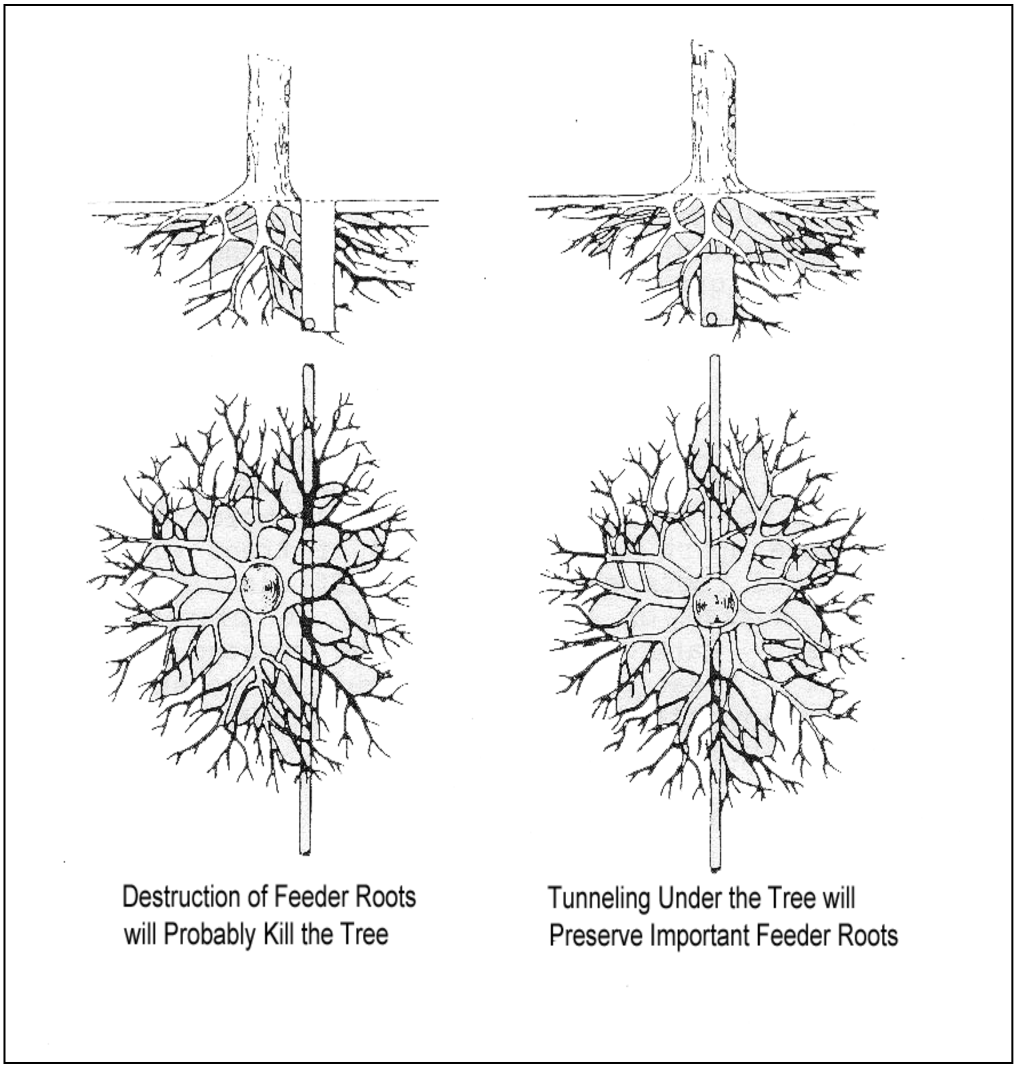


Figure PV-5 Trenching vs Tunneling

Treating Damaged Trees

When trees are damaged during construction activities certain maintenance practices can be applied to protect the health of the tree.

Soil aeration may be needed if the soil has been compacted. The soil around trees can be aerated by punching holes 1 foot deep and 18" apart under the crown of trees with an iron pipe.

Damaged roots should be cut off cleanly and moist peat moss, burlap or topsoil should be placed over the exposed area. Bark damage should be treated by removing loose bark.

Tree limbs damaged during construction or removed for any other reason shall be cut off above the collar at the branch junction.

Trees that have been stressed or damaged should be fertilized to aid their recovery.

Trees should be fertilized in the spring or fall. Fall applications are preferred.

Fertilizer should be applied to the soil over the feeder roots. In no case should it be applied closer than 3 feet to the trunk. Root systems of trees extend some distance beyond the drip line. The area to be fertilized should be increased by ¼ the area of the crown. A soil test is the best way to determine what type of fertilizer to use. In the absence of a soil test, fertilizer should be applied at the rate of 1 to 2 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees under 6” dbh and at the rate of 2 to 4 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees over 6” dbh.

A ground cover or organic mulch layer should be maintained around trees to prevent erosion, protect roots and to conserve water.

Retaining Wall (RW)

Practice Description

A retaining wall is a constructed wall used to eliminate steep slopes between areas that have abrupt changes in grade. This practice is used to replace cut or fill slopes in confined areas or where a wall is necessary to achieve stable slopes. A retaining wall can be constructed of reinforced concrete, treated timbers, gabions, reinforced earth (a system of face panels and buried reinforcement strips), and other manufactured products such as interlocking concrete blocks.

Planning Considerations

Retaining walls to stabilize the site should be used in conjunction with steep cut or fill slopes, which may be unstable due to steepness, space limitations, or poor soil conditions to stabilize the site. Retaining walls may be used to relieve the need to construct cuts into steep hillsides or on small lots where fill toe-outs or slope cut-outs would go off of the property being developed. Retaining walls may be required to get the best or intended use of the property.

Retaining walls can be constructed from the following materials:

- Reinforced concrete
- Concrete cribbing

- Geotextile wrapped face wall
- Geotextile reinforced steep slopes
- Modular blocks
- Treated timbers

Each case is different and the type retaining wall to be used should be selected by a qualified design professional based on the particular site conditions and what best meets the needs of the site. In most cases treated timber is the least desirable material because of its potential to decay.

Design Criteria

The design of a retaining wall is or can be a complicated engineering procedure. There are many factors to consider. Each case is different and requires a different set of considerations and a different design.

The qualified design professional should consider the stresses and forces outside and within the wall as well as allowable height and minimum thickness. Other considerations are foundation design with respect to loadings, bearing values of soils and footing dimensions.

Additional design factors include safety hazards, drainage aspects and appearance.

Each retaining wall requires a specific engineering design which requires the capabilities of a competent qualified design professional. Retaining walls are engineering structures which affect public property, life and welfare of citizens. Alabama law which regulates the practice of professional engineering in the State of Alabama must be followed on structures such as retaining walls. The State Board of Registration for Professional Engineers and Land Surveyors in Montgomery is responsible for administering the provisions of the law.

Shrub, Vine and Groundcover Planting (SVG)

Practice Description

Shrub, vine and groundcover planting is establishing shrubs, vines or groundcover to stabilize landscapes where establishing grass is difficult and mowing is not feasible. The practice is especially suited for steep slopes where aesthetics are important. Incidental benefits include providing food and shelter for wildlife, windbreaks or screens, and improved aesthetics.

Planning Considerations

Shrubs, vines and groundcovers 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 are capable of providing the rapid cover possible with grasses. Consequently, short-term stabilization efforts must involve using dependable mulch along with special cultural practices to ensure establishment.

Shrubs vary in form and differ from most trees in that multiple stems arise from a common base.

Shrubs can be used to attain additional benefits including the following:

- Increase the aesthetic value of plantings
- Provide visual screening and protective barriers

- Enhance windbreaks
- Provide food and cover for wildlife
- Accelerate the transition to a diverse landscape
- Provide post-construction landscaping

Groundcovers differ in growth rate and shade tolerance. Some are suitable only as part of a high-maintenance landscape; others can be used to stabilize large areas with little maintenance.

Competition from volunteer plants inhibits development and maintenance of the groundcover. Thick durable mulch such as shredded bark (not chips) or pine straw can prevent erosion and reduce weed competition.

Mulch is beneficial to plants at most stages of development but is particularly important for new plantings.

Design Criteria

Plant Selection

Specific characteristics and requirements of recommended species are given in Tables SVG-1 through SVG-5 Plants Suitable for Shrub, Vine and Groundcover Planting in Alabama. Other suitable plants may be identified by qualified design professionals based on plant suitability information including plant adaptation zones (see Figure SVG-1). Exotic invasive species should not be planted!

Site Preparation

Remove debris and other undesirable objects and smooth the area to accommodate the planting and mulching. Sites should be prepared in strips along the contour or at individual spots. Additional preparation will vary according to the type of plant and is discussed later under Planting.

Soil Amendments

Fertilizer and lime requirements are plant specific and the prescription for a planting should be based on a soil test or a plan prepared by a qualified design professional.

Soils low in organic matter may be improved by incorporating peat, compost, aged sawdust or well-rotted manure.

To eliminate competition from weeds, an appropriate preemergent herbicide may be useful if mechanical weeding is not practical or desired.

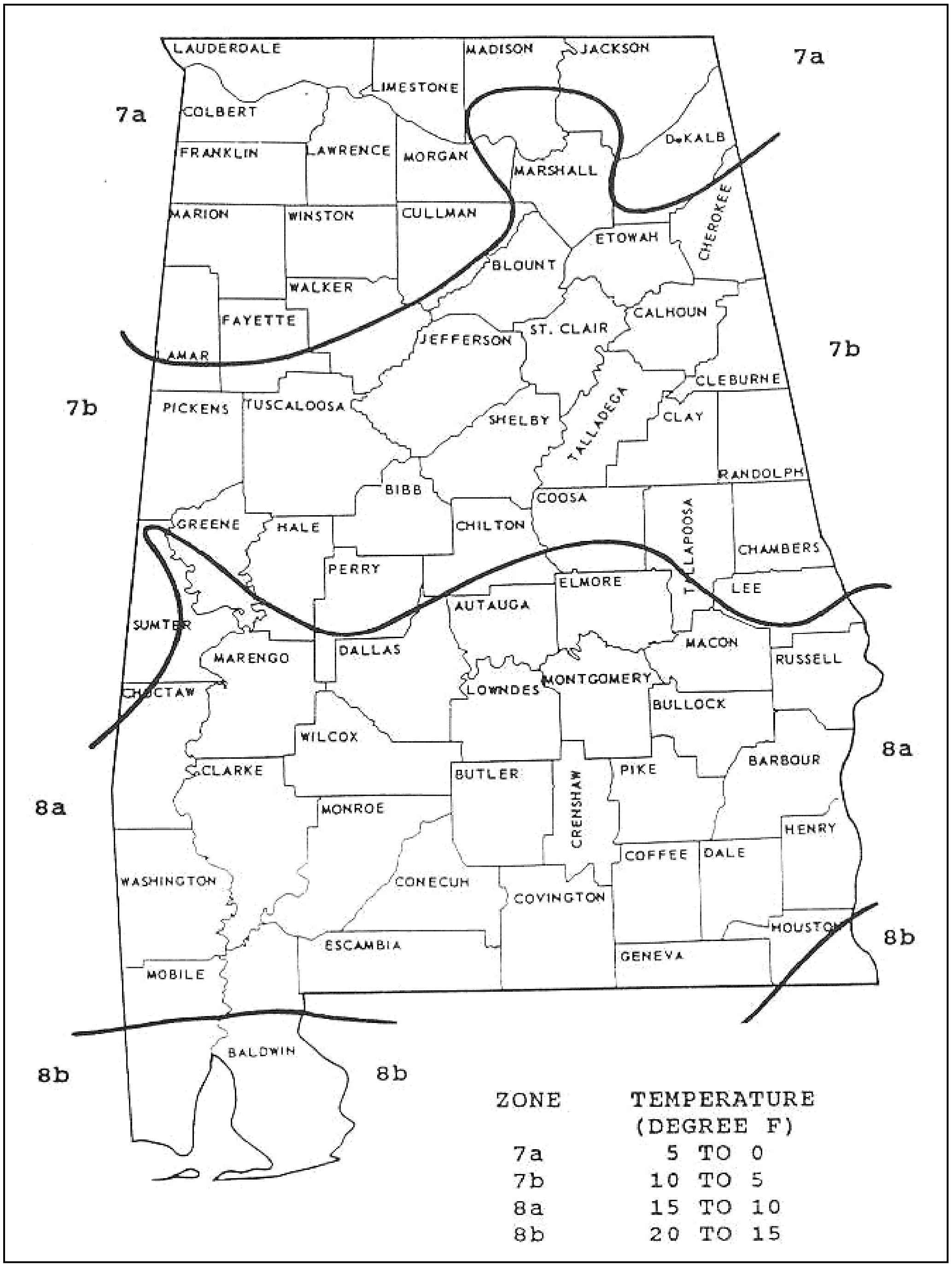


Figure SVG-1 Plant Adaptation Zones

Table SVG-1 Plants Suitable for Vine and Groundcover Planting in Alabama

Botanical Name and Common Name	Normal Height	Growth Rate[1]	Group [2]	Exposure [3]
Bignonia capreolata * Crossvine	50 ft.	M	E	S-PS
Boltonia asteroids Fasle Aster	5-6 ft.	S-M	D	S
Decumaria Barbara * Climbing Hydrangea	12-36 ft.	M	D	PS
Dryotperis ludoviciana Southern Woodfern	3-4 ft.	S-M	E	Sh
Gelsemium sempervirens * Yellow Jessamine	10-20 ft.	M-F	E	S-PS
Hemerocallis sp. Daylily	12-36 in.	M	D	S-PS
Heuchera spp. Heuchera Hybrids/ Alumroot	12-18 in.	M	D	PS
Hypericum calycinum St. Johnswort	12-18 in.	M	E	S-PS
Iris cristata Dwarf Crested Iris	6-12 in.	F	D	PS-Sh
Juniperus conferta Blue Pacific Shore Juniper	12-18 in.	F	E	S
Juniperus horizontalis Creeping Juniper	12-24 in.	M	E	S
Lonicera sempervirens * Coral Honeysuckel	15-20 ft.	M	E	S-PS
Phlox divaricata Creeping Phlox	6-12 in.	F	D	PS-Sh
Pholx subulata Moss Phlox or Thrift	4-6 in.	M	E	S
Osmunda cinnamomea Cinnamon Fern	2-3 ft.	M	D	PS-Sh

[1]Growth Rate: S=slow M=medium, F=fast
[2]Group: D=deciduous, E=evergreen
[3]Exposure: S=sun, PS=part shade, Sh=shade
* Denotes plants used as vines.

Table SVG-2 Plants Suitable for Small Shrub (2-5 ft.) Planting in Alabama

Botanical Name and Common Name	Normal Height	Growth Rate[1]	Group [2]	Exposure [3]
Abelia x grandiflora 'Prostrata' Prostrate Abelia	2-3 ft.	M	E	S
Baptisia spp. Blue Wild Indigo	2-4 ft.	M	D	S
Chaenomoles speciosa Flowering Quince	3-5 ft.	M-F	D	S-PS
Ilex cornuta 'Carissa' Carissa Holly	3-4 ft.	S	E	S-PS
Ilex cornuta 'Rotunda' Rotunda Holly	3-4 ft.	S	E	S-PS
Ilex crenata 'Compacta' Compacta Holly	4-5 ft.	S	E	S-PS
Ilex crenata 'Green Lustre' Green Lustre Holly	3-4 ft.	M	E	S-PS
Ilex vomitoria 'Nana' Dwarf Yaupon Holly	3-4 ft.	S	E	S-PS
Itea virginica Virginia Sweetspire	3-5 ft.	M-F	E	S-Sh
Jasminum floridum * Showy Jasmine	4-5 ft.	M	E	S-Sh
Jasminum nudiflorum Winter Jasmine	3-4 ft.	F	D	S-Sh
Juniperus horizontalis 'Plumosa' Andorra Juniper	2-3 ft.	S-M	E	S
Leucothoe axillaris Coastal Leucothoe	2-4 ft.	S-M	E	PS-Sh
Rhaphiolepis indica * Indian Hawthorn	3-4 ft.	S	E	S
Santolina chamaecyparissus Lavender Cotton	2-4 ft.	S	E	S
Spiraea x bumalda 'Anthony Waterer' Anthony Waterer Spirea	3-4 ft.	F	D	S-PS
Spiraea japonica 'Little Princess' Little Princess Spirea	2-3 ft.	M	D	S

[1] Growth Rate: S=slow M=medium, F=fast
[2] Group: D=deciduous, E=evergreen
[3] Exposure: S=sun, PS=part shade, Sh=shade
* For use in Southern half of state.

Table SVG-3 Plants Suitable for Medium Shrub (5-8 ft.) Planting in Alabama

Botanical Name and Common Name	Normal Height	Growth Rate[1]	Group [2]	Exposure [3]
Abelia x grandiflora Glossy Abelia	4-5 ft.	M-F	E	S-PS
Callicaparpa americana American Beautyberry	3-8 ft.	M-F	D	S-PS
Clethra alnifolia Summersweet Clethra	4-8 ft.	S-M	D	S-PS
Euonymus americanus Brook Euonymus / Hearts-a-busting	4-6 ft.	M	D	PS
Euonymus alatus 'Compactus' Dwarf Winged Euonymus	5-6 ft.	S	D	S-PS
Forsythia x intermedia Border Forsythia	8-10 ft.	F	D	S
Hydrangea quercifolia Oakleaf Hydrangea	6-8 ft.	S-M	D	S-PS
Ilex cornuta 'Burfordii Nana' Dwarf Burford Holly	6-7 ft.	S	E	S-PS
Ilex glabra Inkberry Holly	6-8 ft.	S	E	S-Sh
Illicium anisatum Japanses Anise Tree	6-10 ft.	M-F	E	PS
Illicium floridanum Florida Anise Tree	6-10 ft.	M-F	E	PS-Sh
Physocarpus opulofolius Ninebark	6-10 ft.	M	D	S-PS
Viburnum dentatum Arrowwood Viburnum	6-8 ft.	M-F	D	S-PS

[1] Growth Rate: S=slow M=medium, F=fast
[2] Group: D=deciduous, E=evergreen
[3] Exposure: S=sun, PS=part shade, Sh=shade

Table SVG-4 Plants Suitable for Large Shrub (8 ft. and up) Planting in Alabama

Botanical Name and Common Name	Normal Height	Growth Rate[1]	Group[2]	Exposure[3]
Aescula parviflora Bottlebrush Buckeye	8-12 ft.	S-M	D	S-PS
Agarista populifolia Pipestem Plant	8-12 ft.	M-F	E	Sh
Calycanthus floridus Sweetshrub	8-10 ft.	M	D	S-Sh
Ilex cornuta "Burfordii " Burford Holly	10-15 ft.	M	E	S-Sh
Morella cerifera * Southern Waxmyrtle	8-10 ft.	M	E	S-PS
Ternstroemia gymnanthera Cleyera	8-10 ft.	S	E	PS-Sh
Viburnum lantana Wayfaringtree Viburnum	10-15 ft.	M	D	S-PS
Viburnum plicatum var.tomentosum ** Doublefile Viburnum	8-10 ft.	M	D	PS
Viburnum x pragense Prague Viburnum	8-10 ft.	M	D	S-PS

[1] Growth Rate: S=slow M=medium, F=fast
[2] Group: D=deciduous, E=evergreen
[3] Exposure: S=sun, PS=part shade, Sh=shade
* For use in southern half of the state.
** For use in the northern half of the state.

Table SVG-5 Plants Suitable for Ornamental Grass Planting in Alabama

Botanical Name and Common Name	Height and Spread	Exposure [1]
Andropogon gerardii Big Blue Stem	4-6 ft	S
Carex pensylvanica Pennsylvania Sedge	2-3 ft.	PS
Carex stricta Upright Sedge	1-3 ft.	S
Chasmanthium latifolium River Oats	2-4 ft.	PS-Sh
Deschampsia flexuosa * Crinkle Hair Grass	6-12 in.	PS
Muhlenbergia capillaries Muhly Grass	2-3 ft.	S-Sh
Panicum virgatum Switchgrass	3-6 ft.	S-PS

[1] Exposure: S=sun, PS=part shade, Sh=shade
* For use only in the northern half of the state.

Planting

Individual Shrubs with Root Ball

Provide a relatively large area for initial root development. The hole should be dug to a depth that allows the root ball to extend 1” above the soil surface, and should be as big around as 3 to 5 times the diameter of the root ball. As soil is added the hole should be filled with water until the filling of the hole is complete.

Shrubs in Prepared Beds

Till or spade a bed to a depth of 8” to 12”. Contrary to the individual planting, soil amendments, such as peat or compost at a rate of 1 part amendment to 3 parts native soil, are beneficial to shrubs because they provide a uniform root environment across the bed area. Organic soil amendments enable plants to respond positively to water and fertilizers when they are applied. The hole for the shrub planted in a bed area should be a few inches wider in diameter than the root ball.

Plants in Containers

Remove container plants from their containers, cutting the container if necessary. If the plant is root-bound (roots circling the outside of the root ball), score the roots from top to bottom about 4 times, cutting about ¼ “ deep with a knife, or gently massage the root ball until roots point outward. Place the shrub into the hole. Using only the native backfill, add soil back to the hole until it is ½ to ⅔ full.

Water in the backfill soil around the root ball. Add soil to ground level and thoroughly water again. A small dike may be formed around the edge of the planting hole to hold water around the root ball if in sandy soils or on slopes. *Caution: in a dense clay soil, trapping additional water in the root zone can be detrimental because water drains poorly and creates an extended period of wetness*.

Bare Root Plants

Soak bare root plants in water. When planting, spread the roots in the hole and gradually add soil. Firm the soil, being careful to avoid breaking roots. Fill the hole with water, and allow it to drain. Then fill the hole with soil, and water again thoroughly.

Burlapped Plants

Cut any wire or string that is around plants stems. Do not remove the burlap. Fold the burlap back so it will be buried by soil. Burlap which is allowed to remain exposed after planting can act as a wick, causing the root ball to dry out. Follow the same procedure for filling the hole as that described for container plants.

Vine and Groundcovers

Most groundcovers are planted from container-grown nursery stock. Planting density determines how quickly full cover is achieved; a 1 foot spacing is often used for rapid cover. Large plants such as junipers can be spaced on 3 foot 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. Water slowly and over longer periods to allow for infiltration and reduce runoff.

When to plant

Late winter (before leaves emerge) is the best time for planting deciduous shrubs and early fall is the best for evergreen shrubs. Shrubs grown in containers can be planted anytime during the year except when the ground is frozen.

Shrubs, vines and groundcovers are best planted in early fall or early spring. Plantings made at other times are likely to encounter periods of drought or cold weather that may affect survivability

Mulching

Once plants are installed, add mulch. On steep slopes or highly erodible soils, install erosion control netting or matting prior to planting, and tuck plants into the soil through slits in the net. Plant in a staggered pattern (see Mulching practice for more details on mulching).

Watering

Shrubs, vines and groundcovers need about an inch of water a week for the first 2 years after planting. When rain does not supply this need, plants should be watered. Shrubs should be watered deeply and not more than once a week. Vines and groundcover should be watered more frequently during the first few months in the area over and beyond the root ball if rainfall does not supply 1” of water per week.

Sodding (SOD)

Practice Description

Sodding is the use of a transplanted vegetative cover to provide immediate erosion control in disturbed areas. Sodding is well suited for stabilizing erodible areas such as grass-lined channels, slopes around storm drain inlets and outlets, diversions, swales, and slopes and filter strips that cannot be established by seed or that need immediate cover.

Planning Considerations

Advantages of sod include immediate erosion control, nearly year-round establishment capability, less chance of failure than with seeding, and rapid stabilization of surfaces for traffic areas, channel linings, or critical areas.

Initially it is more costly to install sod than to plant seed; however, the higher cost may be justified for specific situations where sod performs better than a seeded cover. Sodding may be more cost-efficient in the long term.

Sod can be laid during the times of the year when seeded grasses may fail, provided there is adequate water available for irrigation in the early establishment period. Irrigation is essential, at all times of the year, to ensure establishment of sod.

Sod placed around drop inlets can prevent erosion around the inlet and help maintain the necessary grade around the inlet.

The site to be sodded should be prepared for the sod before it is delivered so that the sod can be installed immediately. Leaving sod stacked or rolled can cause severe damage and loss of plant material.

Failure to remove compaction and to address pH and soil fertility deficiencies will likely cause a sodded stand to perform poorly or fail.

Design Criteria

Sod Selection

The species of sod selected should be adapted to both the site and the intended purpose. Species used in Alabama include bermuda, zoysia, centipede, St. Augustine, tall fescue, and bahiagrass. Tall fescue and bahiagrass are not readily available but can be obtained from some growers. Species selection is primarily determined by region, availability, and intended use. Use Table SOD-l and Figure SOD-1 for guidance in selecting sod.

Table SOD-1 Grasses Adapted for Sodding in Alabama

Warm Season Grasses		
Species	**Variety** [1]	**Area Adapted**
Bermudagrass	Tifway, TifSport, Celebration, TifGrand, Common	North, Central, South
Bahiagrass	Pensacola	Central, South
Centipede	Common, TifBlair	Central, South
St. Augustine	Common, and a few commercial varieties	South
Zoysia	Any selection available in Alabama, Zenith is seeded	Central, South
Cool Season Grasses		
Tall Fescue	Kentucky 31, Rebel (turf type)	North

[1] Listing of a variety is not an endorsement of a Company product. New and better varieties may become available over time.

Surface Preparation

Prior to laying sod, clear the soil surface of trash, debris, roots, branches, stones, and clods larger than 2” in diameter. Fill or level low spots in order to avoid standing water. Rake or harrow the site to achieve a smooth and mowable final grade. Apply appropriate soil amendments prior to final disking. Complete soil preparation by disking, chiseling or other appropriate means and then rolling or cultipacking to firm the soil. Limit the use of heavy equipment on the area to be sodded, particularly when the soil is wet, as this may cause excessive compaction and make it difficult for the sod to penetrate the soil and develop the root system that it should attain.

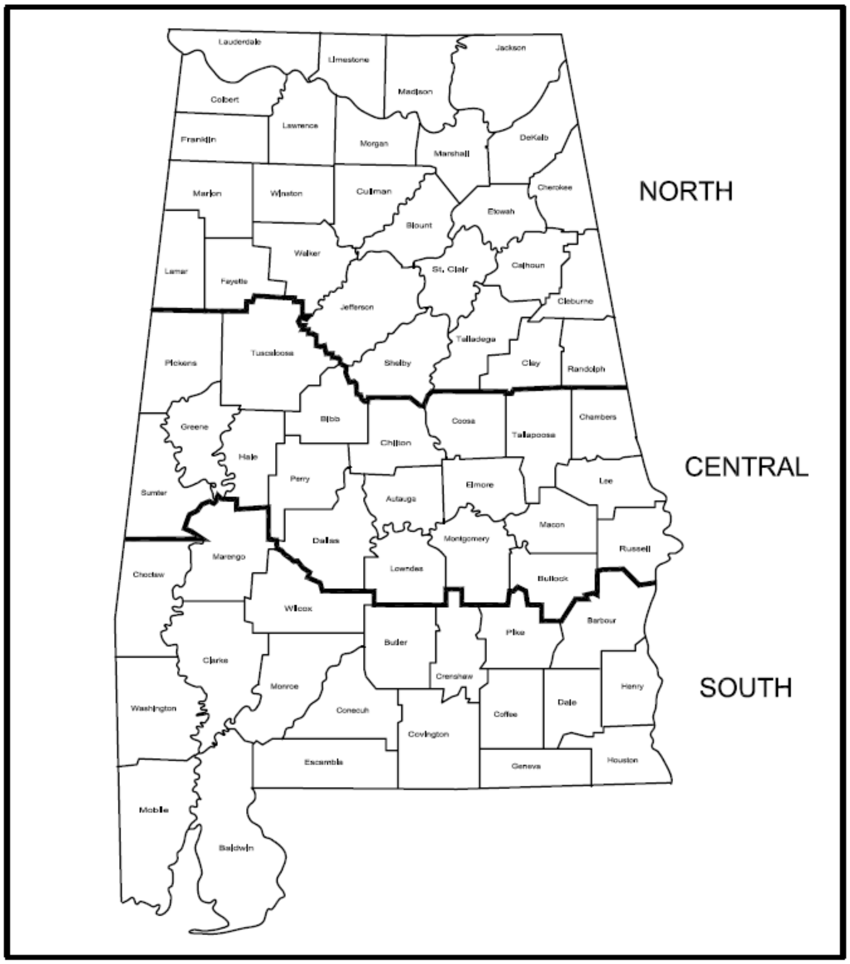


Figure SOD-1 Geographical Areas for Species Adaptation

Soil Amendments

Test soil to determine the requirements for lime and fertilizer. Soil tests may be conducted by Auburn University Soil Testing Laboratory or other laboratories that make recommendations based on soil analysis. When soil test recommendations are unavailable, the following soil amendments may be sufficient:

- Agricultural limestone at a rate of 2 tons per acre (90 lbs per 1000 sq. ft.). Other liming materials that may be selected should be provided in amounts that provide equal value to agricultural lime.

- Fertilizer at a rate of 1000 lbs per acre (25 lbs per 1000 sq. ft.) of 10-10-10.

- Equivalent nutrients may be applied with other fertilizer formulations. The soil amendments should be spread evenly over the treatment area and incorporated into the top 6” of soil by disking, chiseling or other effective, means. If topsoil is applied, follow specifications given in the Topsoiling practice. Minor surface smoothing may be necessary after incorporation of soil amendments.

Installing the Sod

A step-by-step procedure for installing sod is illustrated in Figure SOD-2 and described below.

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

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 and reduce root burning and dieback.

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

Lay the first row of sod in a straight line with subsequent rows placed parallel to and butting tightly against each other. Stagger strips in a brick-like pattern (see Figure SOD – 2). Be sure that the sod is not stretched or overlapped and that all joints are butted tightly to prevent voids. Use a knife or sharp spade to trim and fit irregularly shaped areas.

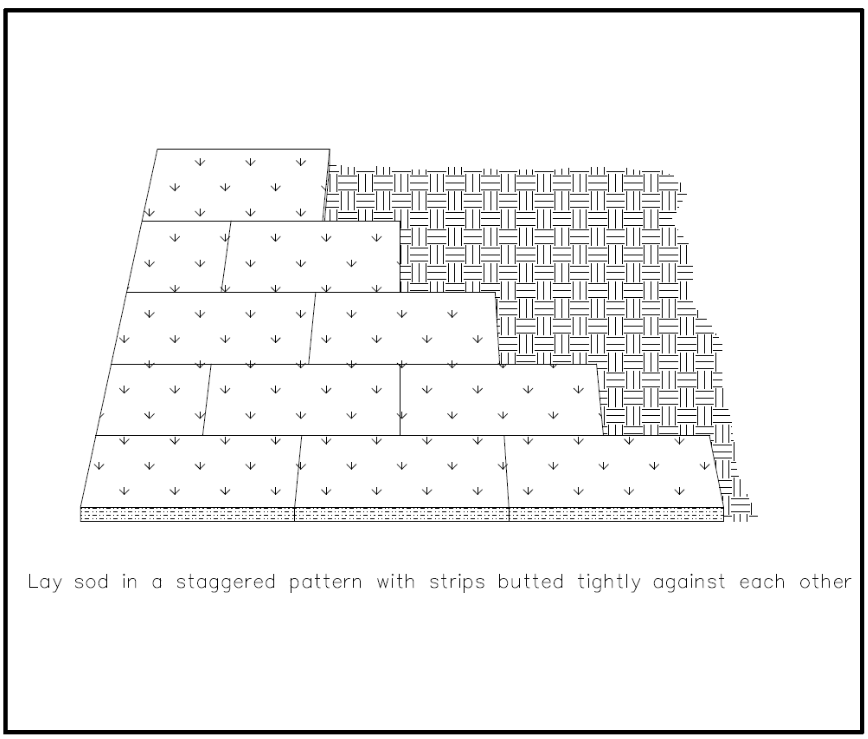


Figure SOD-2 Typical Installation of Grass Sod

Install strips of sod with their longest dimension perpendicular to the slope. On slopes 3:1 or greater, in grass swales or wherever erosion may be a problem, secure sod with pegs or staples. Jute or other netting material may be pegged over the sod for extra protection on critical areas (see Figure SOD – 3).

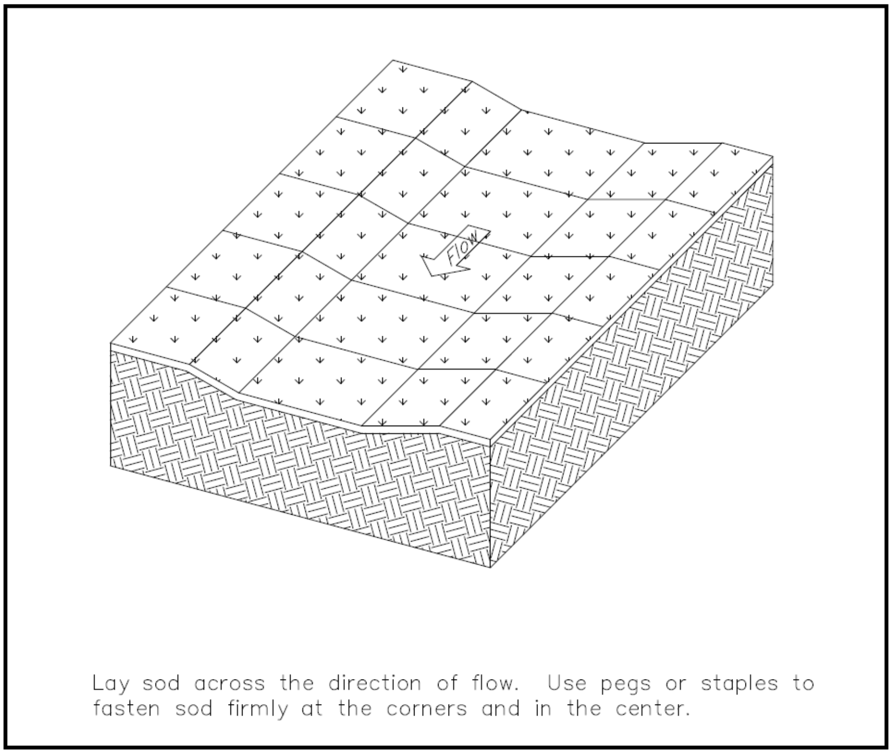


Figure SOD-3 Installation of Sod in Areas with Channel Flows

As sodding of clearly defined areas is completed, use a weighted roller on the sod to provide firm contact between roots and soil.

After rolling, irrigate until the soil is wet at least 6” below the sod.

Keep sodden areas moist to a depth of 4” until the grass takes root. This can be determined by gently tugging on the sod. Resistance indicates that rooting has occurred.

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

This Page Intentionally Left Blank

Temporary Seeding (TS)

Practice Description

Temporary seeding is the establishment of fast-growing annual vegetation from seed on disturbed areas. Temporary vegetation provides economical erosion control for up to a year and reduces the amount of sediment moving off the site.

This practice applies where short-lived vegetation can be established before final grading or in a season not suitable for planting the desired permanent species. It helps prevent costly maintenance operations on other practices such as sediment basins and sediment barriers. In addition, it reduces problems of mud and dust production from bare soil surfaces during construction. Temporary or permanent seeding is necessary to protect earthen structures such as dikes, diversions, grass-lined channels and the banks and dams of sediment basins.

Planning Considerations

Temporary vegetative cover can provide significant short-term erosion and sediment reduction before establishing perennial vegetation.

Temporary vegetation will reduce the amount of maintenance associated with sediment basins.

Temporary vegetation is used to provide cover for no more than 1 year. Permanent vegetation should be established at the proper planting time for permanent vegetative cover.

Certain plants species used for temporary vegetation will produce large quantities of residue which can provide mulch for establishment of the permanent vegetation.

Proper seedbed preparation and selection of appropriate species are important with this practice. Failure to follow establishment guidelines and recommendations carefully may result in an inadequate or short-lived stand of vegetation that will not control erosion.

The selection of plants for temporary vegetation must be site specific. Factors that should be considered are type of soils, climate, establishment rate, and management requirements of the vegetation. Other factors that may be important are wear, mowing tolerance, and salt tolerance of vegetation.

Seeding properly carried out within the optimum dates has a higher probability of success. It is also possible to have satisfactory establishment when seeding outside these dates. However, as plantings are deviated from the optimum dates, the probability of failure increases rapidly. Seeding dates should be taken into account in scheduling land-disturbing activities.

Site quality impacts both short-term and long-term plant success. Sites that have compacted soils should be modified whenever practical to improve the potential for plant growth.

The operation of equipment is restricted on slopes steeper than 3:1, severely limiting the quality of the seedbed that can be prepared. Provisions for establishment of vegetation on steep slopes can be made during final grading. In construction of fill slopes, for example, the last 4-6" might not be compacted. A loose, rough seedbed with irregularities that hold seeds and fertilizer is essential for hydroseeding. Cut slopes should be roughened (see practice Land Grading).

Good mulching practices are critical to protect against erosion on steep slopes. When using straw, anchor with netting or asphalt. On slopes steeper than 2:1, either hydraulic mulch or erosion control blanket is more appropriate than straw to protect the slope.

The use of irrigation (temporary or permanent) will greatly improve the success of vegetation establishment.

Design Criteria

Plant Selection

Select plants that can be expected to meet planting objectives. To simplify plant selection, use Table TS-1, Commonly Used Plants for Temporary Cover and Figure TS-1, Geographical Areas for Species Adaptation and Seeding Dates. Seeding mixtures commonly specified by the Alabama Department of Transportation are an appropriate alternative for plantings on rights-of-ways. Additional information related to plantings in Alabama is found in Chapter 2 in the section Non-woody Vegetation for Erosion and Sediment Control.

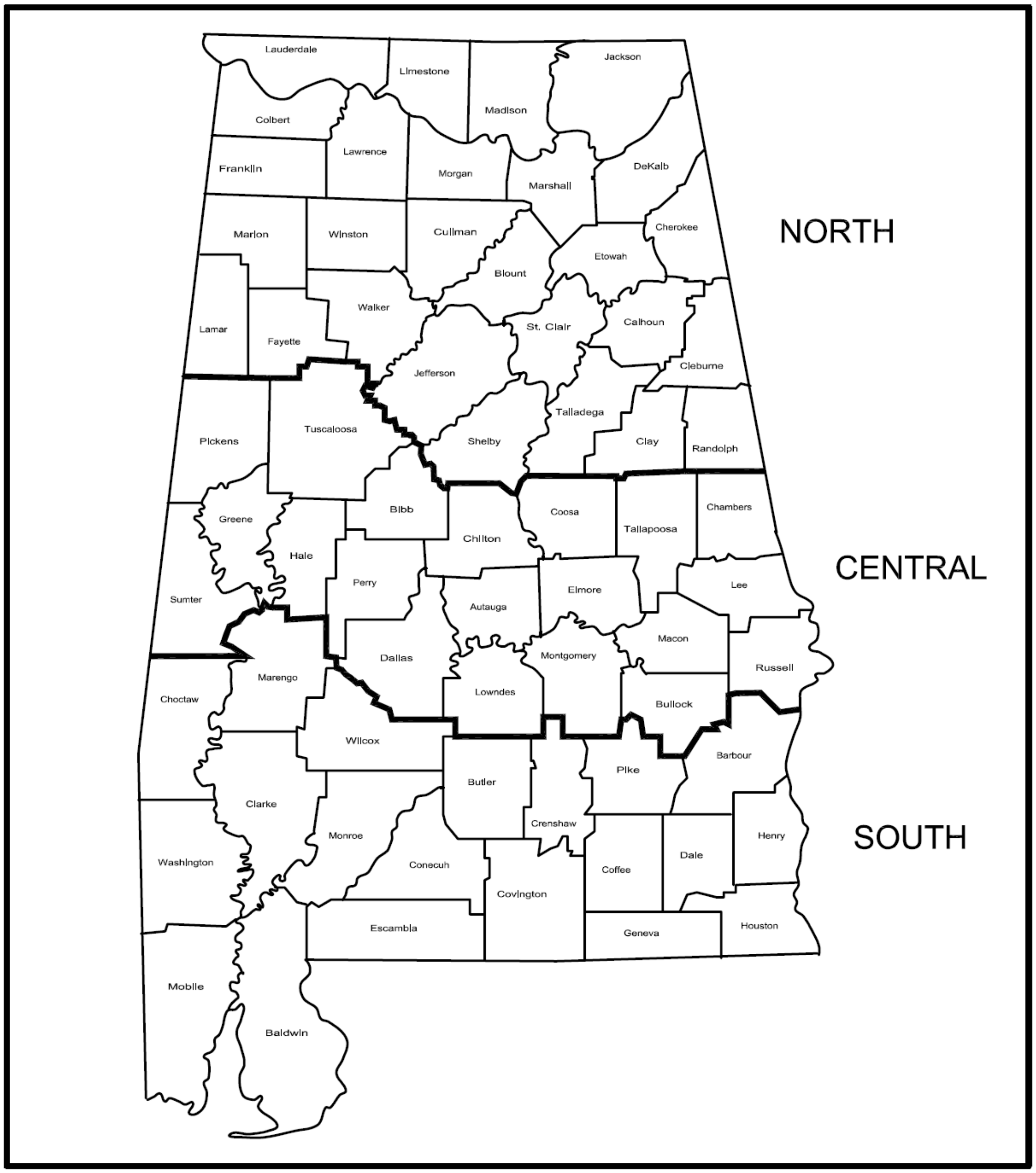


Figure TS-1 Geographical Areas for Species Adaptation and Seeding Dates

Note: Site conditions related to soils and aspect in counties adjacent to or close to county boundaries may justify adjustments in planting dates by qualified design professionals.

Table TS-I Commonly Used Plants for Temporary Cover

Species	Seeding Rate/AC PLS	North	Central	South
			Seeding Dates	
Millet, Browntop or German	40 lbs	Apr1-Aug 1	Apr1- Aug 15	Apr 1-Aug 15
Rye	3 bu	Sep I-Nov 15	Sep 15-Nov 15	Sep 15-Nov 15
Ryegrass	30 lbs	Aug I-Sep 15	Sep I-Oct 15	Sep 1-Oct 15
Sorghum-Sudan Hybrids	40 lbs	May I-Aug 1	Apr 15-Aug 1	Apr I-Aug 15
Sudangrass	40 lbs	May I-Aug I	Apr 15-Aug	Apr I-Aug 15
Wheat	3 bu	Sep I-Nov 1	Sep 15-Nov 15	Sep 15-Nov 15
Common Bermudagrass	10 lbs	Apr 1-July 1	Mar 15-July 15	Mar 1-July 15
Crimson Clover	10lbs	Sept 1-Nov 1	Sept 1-Nov 1	Sept 1-Nov 1

PLS means pure live seed and is used to adjust seeding rates. For example, to plant 10 lbs PLS of a species with germination of 80% and purity of 90%, PLS= 0.8X 0.9 = 72%. 10 lbs PLS = 10/0.72 = 13.9 lbs of the species to be planted.

Site Preparation and Soil Amendments

Complete grading and shaping before applying soil amendments if needed to provide a surface on which equipment can safely and efficiently be used to apply soil amendments and accomplish seedbed preparation and seeding.

Lime

Apply lime according to soil test recommendations. If a soil test is not available, use 1 ton of agricultural limestone or equivalent per acre on coarse textured soils and 2 tons per acre on fine textured soils. Do not apply lime to alkaline soils or to areas which have been limed during the preceding 2 years. Other liming materials that may be selected should be provided in amounts that provide equal value to the criteria listed for agricultural lime or be used in combination with agricultural limestone or Selma chalk to provide equivalent values to agricultural limestone.

Fertilizer

Apply fertilizer according to soil test results. If a soil test is not available, apply 8-24-24 fertilizer.

When vegetation has emerged to a stand and is growing, 30 to 40 lbs/acre (approximately 0.8 lbs/1000 ft^2) of additional nitrogen fertilizer should be applied.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

Application of Soil Amendments

Incorporate lime and fertilizer into the top 6” of soil during seedbed preparation.

Seedbed Preparation

Good seedbed preparation is essential to successful plant establishment. A good seedbed is well pulverized, loose, and smooth. If soils become compacted during grading, loosen them to a depth of 6” to 8” using a ripper or chisel plow.

If rainfall has caused the surface to become sealed or crusted, loosen it just prior to seeding by disking, raking, harrowing, or other suitable methods. When hydroseeding methods are used, the surface should be left with a more irregular surface of clods.

Planting Methods

Seeding
Evenly apply seed using a cyclone seeder (broadcast), drill seeder, cultipacker seeder, or hydroseeder. Broadcast seeding and hydroseeding are appropriate for steep slopes where equipment cannot operate safely. Small grains should be planted no more than 1” deep, and grasses and legumes no more than ½” deep. Seed that are broadcast must be covered by raking or chain dragging, and then lightly firmed with a roller or cultipacker.

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

Mix seed, inoculant if required, and a seed carrier with water and apply as slurry uniformly over the area to be treated. The seed carrier should be a cellulose fiber, natural wood fiber or other approved fiber mulch material which is dyed an appropriate color to facilitate uniform application of seed. Use the correct legume inoculant at 4 times the recommended rate when adding inoculant to hydroseeder slurry. The mixture should be applied within one hour after mixing to reduce damage to seed.

Fertilizer should not be mixed with the seed-inoculant mixture because fertilizer salts may damage seed and reduce germination and seedling vigor. Fertilizer may be applied with a hydro seeder as a separate operation after seedlings are established.

Mulching

The use of appropriate mulch provides instant cover and helps ensure establishment of vegetative cover under normal conditions and is essential to seeding success under harsh site conditions (see the Mulching practice for guidance). Harsh site conditions include the following: slopes steeper than 3:1 and adverse soils (soils that are shallow to rock, rocky, or high in clay or sand). Areas with concentrated flow should be treated differently and require a hydromulch formulated for channels or an appropriate erosion control blanket.

Tree Planting On Disturbed Areas (TP)

Practice Description

Tree planting on disturbed areas is planting trees on construction sites or other disturbed areas to stabilize the soil. The practice reduces erosion and minimizes the maintenance requirements after a site is stabilized. The practice is applicable to those areas where tree cover is desired and is compatible with the planned use of the area, particularly on steep slopes and adjacent to streams. Tree planting is usually used with other cover practices such as permanent seeding or sodding.

Planning Considerations

Control grasses and legumes when planted in combination with trees to reduce competition for moisture, nutrients and sunlight.

Select trees that are adapted to soil and climate.

Avoid planting species which are invasive or may become a nuisance.

Avoid trees that have undesirable characteristics.

Select trees that will improve aesthetics and provide food and cover for wildlife.

Consider using tree tubes as they will help protect the trees from wildlife damage, mowers, weed-eaters, etc. and increase growth of the seedling during the first year.

Tree mats around young seedlings can be helpful in reducing competition from weeds and grasses during the critical first year of growth.

Design Criteria

Planting Bare-rooted Tree Seedlings

Site Preparation

Compacted soil should be ripped or chiseled on the contour to permit adequate root development and proper tree growth. Debris should be removed from the site to facilitate tree planting.

Planting Methods

Tree seedlings may be planted by hand or machine. Any tool or piece of equipment that gives satisfactory results may be used. Dibble bars, mattocks, augers, post-hole diggers and shovels may be used to plant trees by hand. Wildland tree planting machines should be used on rough areas or areas with clayey or compacted soils. Old field tree planters should be limited to areas with sandy soils that are not compacted. Plantings on sloping land should be done on the contour.

When

Bare-root seedlings should be planted from December 1 to March 15. Planting should be done when the soil is neither too dry nor too wet. Planting should be avoided during freezing weather and when the ground is frozen.

Planting Rate

To control erosion pines should be planted at a rate of 600 to 700 trees per acre and hardwoods should be planted at a rate of 300 to 500 trees per acre. Severely eroding areas should be planted at the rate of 600 to 900 trees per acre for both pine and hardwood species.

Depth of Planting

Trees should be planted deeper than they grew in the nursery. Plant small stock 1” deeper and medium to large stock ½” deeper. On most soils, longleaf pine seedlings should be planted ¼” deeper than they grew in the nursery (note: this is not true for planting depth of container grown longleaf seedlings – see Site Preparation in next section for container grown seedlings).

Condition of Roots

Roots should be planted straight down and not twisted, balled, nor U-shaped. Soil should be packed firmly around the planted seedlings. No air pockets should be left in either machine furrows or holes made by planting tools.

Care of Seedlings

The roots of seedlings must be kept moist and cool at all times. After lifting, seedlings should not be exposed to sun, wind, heating, drying or freezing before they are planted. Baled seedlings may be kept up to 3 weeks if they are properly stacked, watered, and kept in a cool place. When planting is delayed longer than 3 weeks, the roots of seedlings should be covered with moist soil (heeled-in) or the seedlings should be put in cold storage.

During planting, the roots of seedlings must be kept moist and only one seedling should be planted at a time. At the end of each day, loose seedlings should be either repacked in wet moss or heeled-in.

Mulching

Mulching may be necessary on sloping land to reduce erosion. Mulch with wood chips, bark, pine needles, peanut hulls etc. should be done to a depth of no more than 3”. Mulch should not be placed against the trunk of the tree.

Planting Balled and Burlapped and Container-Grown Trees

Site Preparation

The planting hole should be dug deep and wide enough to allow proper placement of the root ball. The final level of the root ball’s top should be level with the ground surface (See Figure TP-1). For container grown longleaf seedlings, the planting depth should be slightly higher than the depth grown in the nursery.

As the hole is dug the topsoil should be kept separate from the subsoil. If possible the subsoil should be replaced with topsoil. If topsoil is unavailable the subsoil can be improved by mixing in ⅓ volume of peat moss or well-rotted manure.

Heavy or poorly drained soils are not good growth media for trees. When it is necessary to transplant trees into such soils, extra care should be taken.

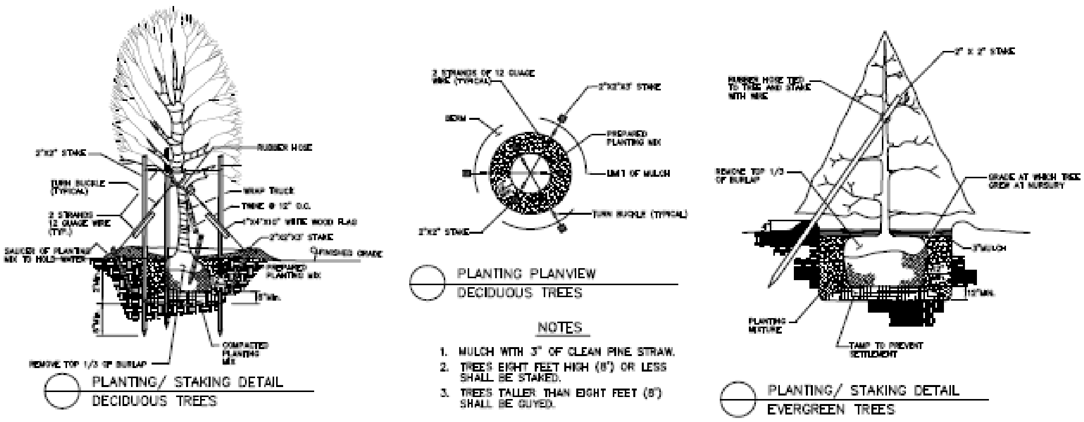


Figure TP-1 Tree Planting Diagram

Tree Preparation

The proper digging of a tree includes the conservation of as much of the root system as possible, particularly the fine roots. Soil adhering to the roots should be damp when the tree is dug, and kept moist until planting. The soil ball should be 12” in diameter for each inch of diameter of the trunk. The tree should be carefully excavated and the soil ball wrapped in burlap and tied with rope. Use of a mechanical tree spade is also acceptable.

Any trees that are to be transported for a long distance should have the branches bound with a soft rope to prevent damage.

Planting the Tree

Depth of planting must be close to the original depth. The tree may be set just a few inches higher than in its former location, especially if soil is poorly drained. Do not set the tree lower than before. Soil to be placed around the root ball should be moist but not wet.

Set the tree in the hole and if the tree is balled and burlapped remove the rope which holds the burlap. Loosen the burlap and remove completely if practical. Do not break the soil of the root ball. Fill the hole with soil halfway and add water to settle the soil and eliminate air pockets. When the water has drained off, fill the hole the remainder of the way. Use extra soil to form a shallow basin around the tree. This will help retain water.

Newly planted trees may need artificial support to prevent excessive swaying. Stakes and guy wires may be used (see Figure TP-l). Guying should be loose enough to allow some movement of the tree.

Mulching

Mulching may be necessary on sloping land to reduce erosion and should be used around balled and burlapped trees and container grown trees to help conserve soil moisture and reduce competition from weeds and grass. Apply mulch using wood chips, bark, pine needles, peanut hulls etc. to a depth of no more than 3”. Mulch should not be placed against the trunk of the tree.

This Page Intentionally Left Blank

Check Dam (CD)

Practice Description

A check dam (also referred to as a "ditch check") is a small barrier or dam constructed across a swale, drainage ditch or other area of concentrated flow for the purpose of reducing channel erosion. Channel erosion is reduced because check dams flatten the gradient of the flow channel and slow the velocity of channel flow. Check dams can be constructed of rock, wattles (sometimes referred to as tubes or rolls), sand bags, or other materials that may be acceptable to the design professional. Contrary to popular opinion, most check dams trap an insignificant volume of sediment, as check dams usually just trap the coarser grained material leaving the turbid water to flow downstream.

This practice applies in small open channels and drainageways, including temporary and permanent swales. Check dams are not to be used in a live stream. Situations of use include areas in need of protection during establishment of grass and areas that cannot receive a temporary or permanent non-erodible lining for an extended period of time.

Planning Considerations

Check dams are utilized in concentrated flow areas to provide temporary channel stabilization during the intense runoff periods associated with construction disturbances. Check dams may be constructed of rock, wattles, sand bags, or other suitable material, including manufactured products. Most check dams are constructed of rock. Rock may not be acceptable in some installations because of aesthetics and alternative types of check dams need to be considered. Rock check dams (Figures CD-1 and CD-2) are usually installed with backhoes or other suitable equipment but hand labor is likely needed to complete most installations to the quality needed. The rock is usually purchased and some locations in the state may not have rock readily available. The use of rock should be considered carefully in areas to be mowed. Some rock may be washed downstream and should be removed before each mowing operation. The use of small graded aggregate and geotextile can be used on the upstream face of the rock check dam to increase the sediment trapping efficiency of the rock check dam. Measures must be taken to prevent undermining of the check dam.

Water flowing over a check dam is very often super-critical and creates erosive forces on the down slope of the dam and immediately downstream of the dam. Some measures to prevent this erosion include placing larger rock on the downstream face of a rock dam, concrete grouting the downstream face of a rock dam, and providing erosion protection material just downstream of the dam.

Wattles have been found to be best installed without trenching and on top of stapled geotextile that extends up and downstream from the wattle. Wattles must be properly stapled and staked on top of the geotextile (see picture below).

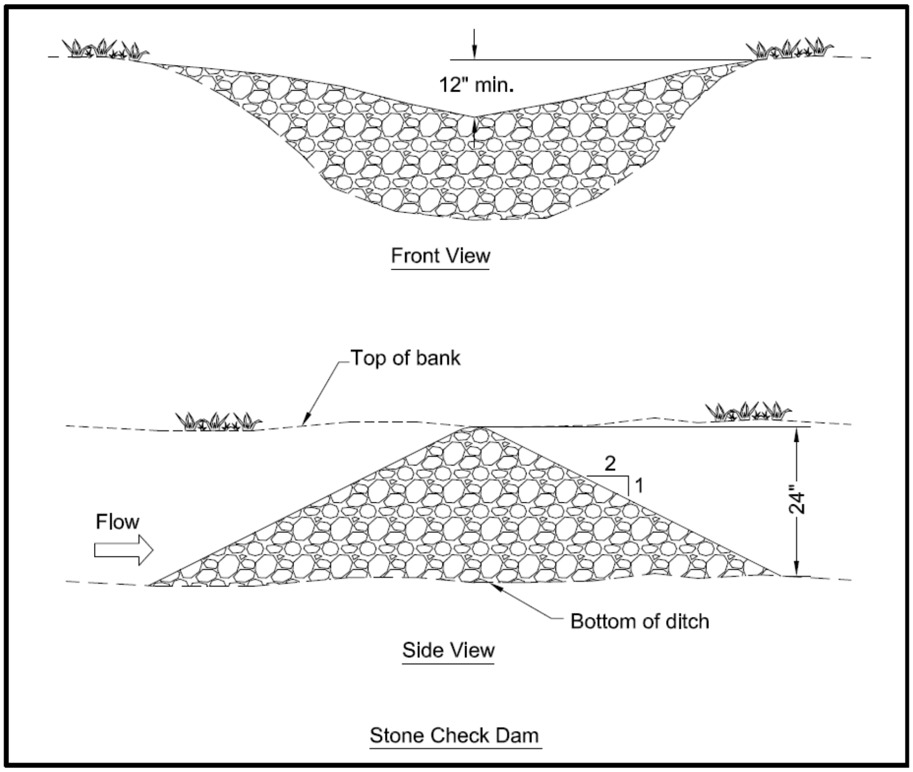


Figure CD-1 Profile and Cross-Section of Typical Rock Check Dams

Check dams should be planned to be compatible with the other features such as streets, walks, trails, sediment basins and rights-of-way or property lines. Check dams are installed with the center overflow area lower in elevation than the ends to ensure flow goes over the check dam and not around. Check dams are normally constructed in series and the dams should be located at a normal interval from other grade controls such as culverts or sediment basins.

The use of check dams are a temporary BMP and should be removed following construction to allow for final long term stabilization.

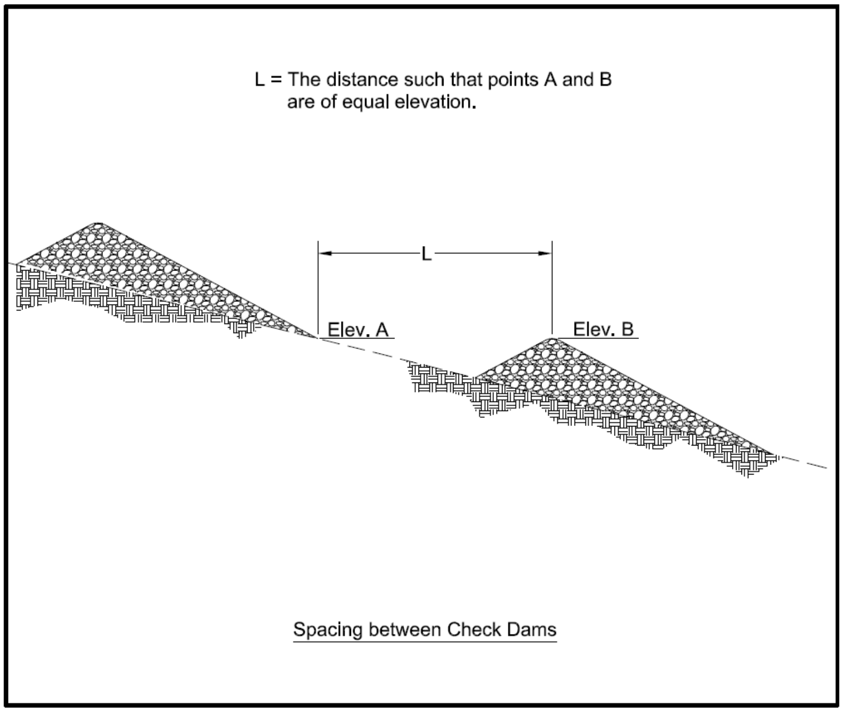


Figure CD-2 Profile of Typical Rock Check Dams

Design Criteria

Formal design is not required. The following limiting factors should be adhered to when designing check dams.

Drainage Area

Ten acres or less.

Maximum Height

Two feet when drainage area is less than 5 acres.

Three feet when drainage area is 5 to 10 acres.

Depth of Flow

Six inches when drainage area is less than 5 acres.

Twelve inches when drainage area is 5 to 10 acres.

The top of dam, perpendicular to flow, should be parabolic. The center of the dam should be constructed lower than the ends. The elevation of the center of the dam should be lower than the ends by the depth of flow listed above.

Side Slopes

2:1 or flatter.

Spacing

The elevation of the toe of the upstream dam should be at or below the elevation of crest of the downstream dam (Figure CD-2).

For example, if the channel is 3% grade, and the drainage area is 3 acres:

The check dam height would be 2 feet.

The check dam spacing should be 67 feet:

Spacing (ft) = dam height (ft) / channel grade

Spacing = 2 ft / 0.03 = 67 feet

Keyway

Measures should be taken to ensure the flow does not cause erosion underneath the check dam. This is often accomplished using geotextile underneath the check dam or in highly erosive soils a keyway lined with geotextile and filled with rock. Keyways if used should be keyed into the channel bottom and abutments to a depth of 12 to 24”. The keyway width should be at least 12”.

Rock Check Dams

Rock check dams should be constructed of appropriately sized durable rock riprap. Riprap gradation should conform to the requirements of Alabama Highway Department, Standard Specification for Highway Construction.

In soils where failure by piping of soils into the rock is likely, a non-woven geotextile will be used as a filter to separate the soils from the rock. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

This Page Intentionally Left Blank

Diversion (DV)

Practice Description

A diversion is a watercourse constructed across a slope consisting of an excavated channel, a compacted ridge or a combination of both. Most diversions are constructed by excavating a channel and using the excavated material to construct a ridge on the downslope side of the channel. Right-of-way diversions and temporary diversions are sometimes constructed by making a ridge, often called a berm, from fill material.

This practice applies to sites where stormwater runoff can be redirected to permanently protect structures or areas downslope from erosion, sediment, and excessive wetness or localized flooding. Diversions may be used to temporarily divert stormwater runoff to protect disturbed areas and slopes or to retain sediment on-site during construction.

Perimeter protection is sometimes used to describe both permanent and temporary diversions used at either the upslope or downslope side of a construction area.

Right-of-way diversions, sometimes referred to as water bars, are used to shorten the flow length on a sloping right-of-way and reduce the erosion potential of the stormwater runoff.

Planning Considerations

Diversions are designed to intercept and carry excess water to a stable outlet.

Diversions can be useful tools for managing surface water flows and preventing soil erosion. On moderately sloping areas, they may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion.

Diversions may be placed at the top of cut or fill slopes to keep runoff from upgradient drainage areas off the slope. The following picture illustrates the placement of a diversion near the top of the slope. Diversions are sometimes built at the base of steeper slopes to protect flatter developed areas which cannot withstand runoff water from outside areas. Also, they can be used to protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversion near the top of a slope

Diversions are preferable to other types of man-made stormwater conveyance systems because they more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum. When properly coordinated into the landscape design of a site, diversions can he visually pleasing as well as functional.

As with any earthen structure, it is very important to establish adequate vegetation as soon as possible after installation. It is usually important to stabilize the drainage area above the diversion so that sediment will not enter and accumulate in the diversion channel.

Design Criteria

Location

Diversion location should be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage (where seepage is a problem) and the development layout. Outlets must be stable after the diversion empties stormwater flow into it; therefore, care should be exercised in selecting the location of the diversion and its outlet.

Capacity

The diversion channel must have a minimum capacity to carry the runoff expected from a storm frequency meeting the requirements of Table DV-l with a freeboard of at least 0.3 foot (Figure DV-1).

The storm frequency should be used to determine the required channel capacity, Q (peak rate of runoff). The peak rate of runoff should be determined using the Natural Resources Conservation Service runoff curve no. (RCN) method or other equivalent methods.

Table DV-1 Design Frequency

Diversion Type	Typical Area of Protection	24-Hour Design Storm Frequency
Temporary	Construction Areas	2-year
	Building Sites	5-year
Permanent	Agricultural Land	10-year
	Mined Reclamation Area	10-year
	Recreation Areas	10-year
	Isolated Buildings	25-year
	Urban areas, Residential, School, Industrial Areas, etc.	50-year

Diversions designed to protect homes, schools, industrial buildings, roads, parking lots, and comparable high-risk areas, and those designed to function in connection with other structures, should have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.

Velocities

Diversions should be designed so that the design velocities will be safe for the planned type of protective vegetation and the expected maintenance,-Maximum permissible velocities are dependent upon the erosion resistance of the soil (Table DV-2) and the quality of the vegetation maintained.

Table DV-2 Permissible Velocities

Soil Texture	Velocity in Feet/Second		
	Conditions of Vegetation		
	Poor	Fair	Good
Sand, Silt, Sandy Loam, Silt Loam	1.5	2.0	3.0
Silty Clay Loam, Sandy Clay Loam	2.5	3.0	4.0
Clay	3.0	4.0	5.0

Channel Design

The diversion channel may be parabolic, trapezoidal or v-shaped as shown in Figure DV-1 and should be designed in accordance with the procedure provided in the Diversion Design section. Land slope must be considered when choosing channel dimensions. On steeper slopes, narrow and deep channels may be required. On more gentle slopes, broad, shallow channels can be used to facilitate maintenance.

Ridge Design

The supporting ridge cross section should meet the configuration and requirements of Figure DV-1.

The side slopes should be no steeper than 2:1. Side slopes should be flatter, 5:1 to 10:1, when the diversion is to be permanent with mowing and other maintenance activities performed on or around it.

The width of the ridge at the design water elevation should be a minimum of 4 feet.

The minimum freeboard should be 0.3 foot.

The design should include a 10% settlement factor.

Outlet

Diversions should have adequate outlets which will convey concentrated runoff without erosion. Acceptable outlets include practices such as Grassed Swale, Lined Swale, Drop Structure, Sediment Basin, and Stormwater Detention Basins.

Stabilization

Unless otherwise stabilized, the ridge and channel should be seeded within 13 days of installation in accordance with the applicable seeding practice, Permanent Seeding or Temporary Seeding.

Disturbed areas draining into the diversion should be seeded and mulched prior to or at the time the diversion is constructed in accordance with the Permanent Seeding or Temporary Seeding (whichever is applicable) practices.

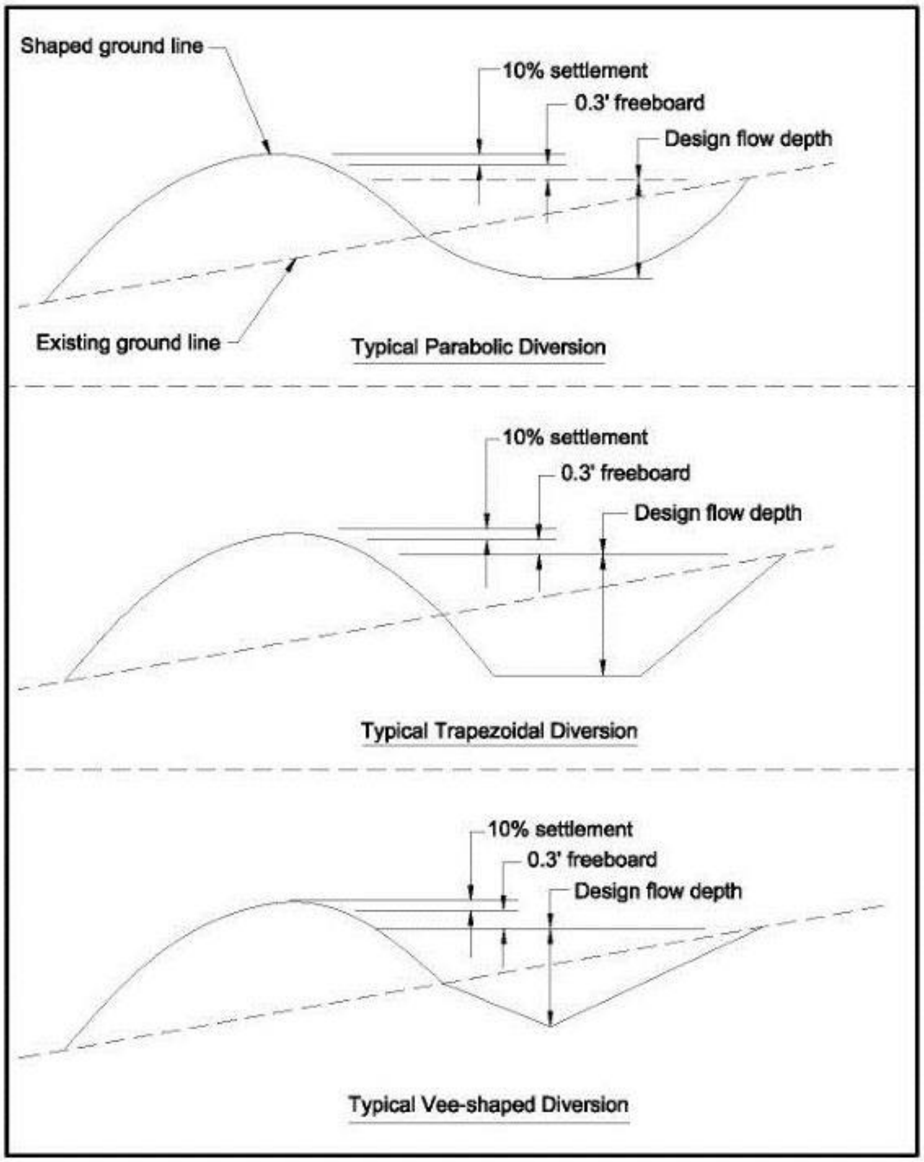


Figure DV-1 Typical Diversions Detail

Diversion Design

Note: This design example uses the Permissible Velocity approach. Diversion design using the Tractive Stress approach can also be used but is not discussed in this document.

Table DV-l through DV-16 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 V1 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”. Refer to Table DV-2 for maximum permissible velocities. The permissible velocities guide the selection of V1 and should not be exceeded. It is good practice to use a value for V1 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 erosion control blanket or riprap should be considered. After the diversion dimensions are selected in the design tables, the top width should be increased by 4 feet. and the depth by 0.3 foot. for freeboard.

Example Problem

Given

Q: 30 cfs
Grade: 1%
Soil: Sandy clay loam
Condition of vegetation expected: fair
Maintenance: low; will be cut only twice a year.
Site will allow a top width of 26 feet.

Find

Diversion top width and depth that will be stable and fit site conditions.

Solution

From Table DV-2 use maximum permissible velocity of 3.0 ft./sec.

Since maintenance will be low use “B” retardance for capacity.

From Table DV-4 use retardance “D” and “B”;
Grade 1.00 Percent Top width = 21.0 feet + 4 feet = 25.0 feet.

Depth = 1.6 feet + 0.3 foot = 1.9 feet.

V_2 = 1.3 ft./sec.

Note: V_1 < 3.0 ft./sec.; Top width < 26 feet, design O.K.

Note: It is good practice 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 always prudent to evaluate flatter design grades in order to best fit diversions to the site and keep velocities well below maximum allowable.

Table DV-3 Parabolic Diversion Design Chart (Retardance "D" and "B", Grade 0.50%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	10.0	2.2	1.0																								
20	13.7	2.1	1.0	8.4	2.7	1.3																					
25	17.4	2.1	1.0	11.3	2.4	1.4																					
30	21.0	2.0	1.0	13.9	2.3	1.4																					
35	24.6	2.0	1.1	16.4	2.3	1.4	10.7	2.8	1.8																		
40	28.5	2.0	1.0	18.9	2.3	1.4	12.6	2.7	1.8																		
45	31.9	2.0	1.1	21.4	2.3	1.4	14.4	2.6	1.8																		
50	35.5	2.0	1.1	23.9	2.2	1.4	16.2	2.5	1.8	9.9	3.4	2.2															
55	39.0	2.0	1.1	26.3	2.2	1.4	17.9	2.5	1.8	11.9	3.1	2.3															
60	42.5	2.0	1.1	28.8	2.2	1.4	19.7	2.5	1.8	13.2	3.0	2.3															
65	46.1	2.0	1.1	31.6	2.2	1.4	21.4	2.5	1.8	14.5	2.9	2.3															
70	49.6	2.0	1.1	34.0	2.2	1.4	23.1	2.5	1.8	15.8	2.9	2.3	11.0	3.6	2.6												
75	53.1	2.0	1.1	36.4	2.2	1.4	24.9	2.5	1.8	17.1	2.8	2.3	12.7	3.4	2.7												
80	56.6	2.0	1.1	38.8	2.2	1.4	26.6	2.5	1.8	18.4	2.8	2.3	13.7	3.3	2.7												
85	60.2	2.0	1.1	41.2	2.2	1.4	28.3	2.5	1.8	19.7	2.8	2.3	14.8	3.2	2.7												
90	63.7	2.0	1.1	43.6	2.2	1.4	30.0	2.4	1.8	20.9	2.8	2.3	15.9	3.2	2.7												
95	67.2	2.0	1.1	46.1	2.2	1.4	31.7	2.4	1.8	22.1	2.8	2.3	16.9	3.1	2.7												
100	70.8	2.0	1.1	48.5	2.2	1.4	33.7	2.4	1.8	23.4	2.8	2.3	17.9	3.1	2.7	12.3	3.9	3.1									
105	74.3	2.0	1.1	50.9	2.2	1.4	35.4	2.4	1.8	24.5	2.7	2.4	18.9	3.1	2.7	13.7	3.7	3.1									
110	77.8	2.0	1.1	53.3	2.2	1.4	37.1	2.4	1.8	25.8	2.7	2.4	19.9	3.1	2.7	14.6	3.6	3.1									
115	81.4	2.0	1.1	55.7	2.2	1.4	38.7	2.4	1.8	27.0	2.7	2.4	20.8	3.0	2.7	15.4	3.6	3.1									
120	84.9	2.0	1.1	58.1	2.2	1.4	40.4	2.4	1.9	28.2	2.7	2.4	21.8	3.0	2.7	16.3	3.5	3.1									
125	88.4	2.0	1.1	60.6	2.2	1.4	42.1	2.4	1.9	29.4	2.7	2.4	22.8	3.0	2.7	17.1	3.5	3.1									
130	92.0	2.0	1.1	63.0	2.2	1.4	43.8	2.4	1.9	30.6	2.7	2.4	23.8	3.0	2.7	17.9	3.5	3.1									
135	95.5	2.0	1.1	65.4	2.2	1.4	45.4	2.4	1.9	31.8	2.7	2.4	24.8	3.0	2.7	18.7	3.4	3.2									
140	99.0	2.0	1.1	67.8	2.2	1.4	47.1	2.4	1.9	33.1	2.7	2.4	25.7	3.0	2.8	19.4	3.4	3.2									
145	102.6	2.0	1.1	70.2	2.2	1.4	48.8	2.4	1.9	34.3	2.7	2.4	26.7	3.0	2.8	20.2	3.4	3.2	13.5	4.4	3.6						
150	106.1	2.0	1.1	72.6	2.2	1.4	50.5	2.4	1.9	35.5	2.7	2.4	27.7	3.0	2.8	21.0	3.4	3.2	14.4	4.3	3.6						

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-4 Parabolic Diversion Design Chart (Retardance “D” and “B”, Grade 1.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	9.7	1.6	1.0	6.2	2.0	1.2																					
15	14.8	1.5	1.0	10.2	1.7	1.3	6.5	2.2	1.5																		
20	20.2	1.5	1.0	13.8	1.7	1.3	9.6	1.9	1.6																		
25	25.1	1.5	1.0	17.4	1.7	1.3	12.2	1.9	1.6	8.5	2.2	2.0															
30	30.1	1.5	1.0	21.0	1.6	1.3	14.9	1.8	1.7	10.6	2.1	2.1															
35	35.1	1.5	1.0	24.7	1.6	1.3	17.5	1.8	1.7	12.6	2.0	2.1	8.9	2.4	2.5												
40	40.1	1.5	1.0	28.2	1.6	1.3	20.0	1.8	1.7	14.5	2.0	2.1	10.5	2.3	2.5												
45	45.1	1.5	1.0	31.7	1.6	1.3	22.5	1.8	1.7	16.4	2.0	2.1	12.1	2.2	2.5	8.2	2.8	2.9									
50	50.2	1.5	1.0	35.2	1.6	1.3	25.4	1.8	1.7	18.3	2.0	2.1	13.6	2.2	2.5	10.0	2.6	2.9									
55	55.2	1.5	1.0	38.8	1.6	1.3	27.9	1.8	1.7	20.3	1.9	2.1	15.1	2.2	2.5	11.2	2.5	3.0									
60	60.2	1.5	1.0	42.3	1.6	1.3	30.4	1.8	1.7	22.2	1.9	2.1	16.6	2.1	2.5	12.4	2.4	3.0									
65	65.2	1.5	1.0	45.8	1.6	1.3	32.9	1.8	1.7	24.0	1.9	2.1	18.0	2.1	2.5	13.6	2.4	3.0	8.9	3.1	3.5						
70	70.2	1.5	1.0	49.3	1.6	1.3	35.5	1.8	1.7	25.9	1.9	2.1	19.5	2.1	2.6	14.8	2.4	3.0	10.6	2.8	3.5						
75	75.2	1.5	1.0	52.8	1.6	1.3	38.0	1.8	1.7	28.2	1.9	2.1	20.9	2.1	2.6	16.0	2.3	3.0	11.5	2.8	3.5						
80	80.2	1.5	1.0	56.3	1.6	1.3	40.5	1.8	1.7	30.0	1.9	2.1	22.3	2.1	2.6	17.1	2.3	3.0	12.5	2.7	3.5						
85	85.2	1.5	1.0	59.8	1.6	1.3	43.0	1.8	1.7	31.9	1.9	2.1	23.7	2.1	2.6	18.3	2.3	3.0	13.5	2.7	3.6	9.8	3.3	3.9			
90	90.2	1.5	1.0	63.3	1.6	1.3	45.6	1.8	1.7	33.6	1.9	2.1	25.2	2.1	2.6	19.4	2.3	3.1	14.4	2.6	3.6	10.9	3.1	3.9			
95	95.2	1.5	1.0	66.9	1.6	1.3	48.1	1.8	1.7	35.5	1.9	2.1	26.6	2.1	2.6	20.5	2.3	3.1	15.3	2.6	3.6	12.0	3.0	3.9			
100	100.2	1.5	1.0	70.4	1.6	1.3	50.6	1.8	1.7	37.4	1.9	2.1	28.0	2.1	2.6	21.6	2.3	3.1	16.2	2.6	3.6	12.9	2.9	4.0			
105	105.3	1.5	1.0	73.9	1.6	1.3	53.1	1.8	1.7	39.2	1.9	2.1	29.8	2.1	2.6	22.8	2.3	3.1	17.1	2.6	3.6	13.7	2.9	4.0	10.8	3.4	4.3
110	110.3	1.5	1.0	77.4	1.6	1.3	55.7	1.8	1.7	41.1	1.9	2.1	31.3	2.1	2.6	23.9	2.3	3.1	18.0	2.6	3.6	14.4	2.9	4.0	12.0	3.2	4.3
115	115.3	1.5	1.0	80.9	1.6	1.3	58.2	1.8	1.7	42.9	1.9	2.1	32.7	2.1	2.6	25.0	2.3	3.1	18.9	2.5	3.6	15.2	2.8	4.0	12.7	3.2	4.3
120	120.3	1.5	1.0	84.4	1.6	1.3	60.7	1.8	1.7	44.8	1.9	2.1	34.1	2.1	2.6	26.1	2.2	3.1	19.7	2.5	3.6	16.0	2.8	4.0	13.4	3.1	4.3
125	125.3	1.5	1.0	88.0	1.6	1.3	63.2	1.8	1.7	46.7	1.9	2.1	35.5	2.1	2.6	27.2	2.2	3.1	20.6	2.5	3.6	16.8	2.8	4.0	14.1	3.1	4.3
130	130.3	1.5	1.0	91.5	1.6	1.3	65.8	1.8	1.7	48.5	1.9	2.1	36.9	2.1	2.6	28.4	2.2	3.1	21.5	2.5	3.6	17.4	2.8	4.0	14.8	3.1	4.3
135	135.3	1.5	1.0	95.0	1.6	1.3	68.3	1.8	1.7	50.4	1.9	2.1	38.3	2.1	2.6	29.5	2.2	3.1	22.4	2.5	3.6	18.2	2.8	4.0	15.5	3.0	4.3
140	140.3	1.5	1.0	98.5	1.6	1.3	70.8	1.8	1.7	52.2	1.9	2.1	39.7	2.0	2.6	30.6	2.2	3.1	23.2	2.5	3.6	18.9	2.7	4.0	16.1	3.0	4.4
145	145.3	1.5	1.0	102.0	1.6	1.3	73.3	1.8	1.7	54.1	1.9	2.1	41.1	2.0	2.6	32.1	2.2	3.0	24.1	2.5	3.6	19.7	2.7	4.0	16.8	3.0	4.4
150	150.3	1.5	1.0	105.5	1.6	1.3	75.9	1.8	1.7	56.0	1.9	2.1	42.5	2.0	2.6	33.2	2.2	3.0	25.0	2.5	3.6	20.4	2.7	4.1	17.5	2.9	4.4

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-5 Parabolic Diversion Design Chart (Retardance “D” and “B”, Grade 2.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	7.1	1.2	0.9																								
10	14.7	1.2	0.9	9.5	1.3	1.2	7.0	1.4	1.5																		
15	22.0	1.2	0.9	14.5	1.3	1.2	10.8	1.4	1.5	8.0	1.5	1.9	5.5	1.9	2.1												
20	29.3	1.2	0.9	19.6	1.2	1.2	14.6	1.3	1.5	10.9	1.5	1.9	8.1	1.6	2.3	5.5	2.1	2.6									
25	36.6	1.2	0.9	24.4	1.2	1.2	18.5	1.3	1.5	13.8	1.4	1.9	10.4	1.6	2.3	7.9	1.8	2.7									
30	43.9	1.2	0.9	29.3	1.2	1.2	22.2	1.3	1.6	16.6	1.4	1.9	12.7	1.5	2.3	9.7	1.7	2.7	7.3	2.0	3.1						
35	51.2	1.2	0.9	34.2	1.2	1.2	25.8	1.3	1.6	19.6	1.4	1.9	14.9	1.5	2.3	11.5	1.7	2.7	8.9	1.9	3.2						
40	58.5	1.2	0.9	39.0	1.2	1.2	29.5	1.3	1.6	22.4	1.4	1.9	17.1	1.5	2.3	13.3	1.6	2.8	10.4	1.8	3.2	8.0	2.1	3.6			
45	65.8	1.2	0.9	43.9	1.2	1.2	33.2	1.3	1.6	25.2	1.4	1.9	19.3	1.5	2.3	15.0	1.6	2.8	11.8	1.8	3.2	9.2	2.0	3.7			
50	73.1	1.2	0.9	48.8	1.2	1.2	36.8	1.3	1.6	28.0	1.4	1.9	21.7	1.5	2.3	16.7	1.6	2.8	13.2	1.8	3.2	10.5	1.9	3.7	7.9	2.3	4.1
55	80.4	1.2	0.9	53.6	1.2	1.2	40.5	1.3	1.6	30.7	1.4	1.9	23.9	1.5	2.3	18.5	1.6	2.8	14.6	1.7	3.2	11.7	1.9	3.7	9.2	2.2	4.1
60	87.7	1.2	0.9	58.5	1.2	1.2	44.2	1.3	1.6	33.5	1.4	1.9	26.0	1.5	2.3	20.2	1.6	2.8	16.0	1.7	3.2	12.8	1.9	3.7	10.2	2.1	4.1
65	95.0	1.2	0.9	63.4	1.2	1.2	47.9	1.3	1.6	36.3	1.4	1.9	28.2	1.5	2.3	22.1	1.6	2.8	17.4	1.7	3.3	14.0	1.9	3.7	11.3	2.1	4.2
70	102.3	1.2	0.9	68.2	1.2	1.2	51.6	1.3	1.6	39.1	1.4	1.9	30.3	1.5	2.3	23.8	1.6	2.8	18.8	1.7	3.3	15.2	1.9	3.7	12.3	2.1	4.2
75	109.6	1.2	0.9	73.1	1.2	1.2	55.2	1.3	1.6	41.9	1.4	1.9	32.5	1.5	2.3	25.5	1.6	2.8	20.1	1.7	3.3	16.2	1.8	3.7	13.2	2.0	4.2
80	116.9	1.2	0.9	78.0	1.2	1.2	58.9	1.3	1.6	44.7	1.4	1.9	34.6	1.5	2.3	27.2	1.6	2.8	21.5	1.7	3.3	17.4	1.8	3.8	14.2	2.0	4.2
85	124.2	1.2	0.9	82.9	1.2	1.2	62.6	1.3	1.6	47.4	1.4	1.9	36.8	1.5	2.3	28.9	1.6	2.8	22.9	1.7	3.3	18.6	1.8	3.8	15.1	2.0	4.2
90	131.5	1.2	0.9	87.7	1.2	1.2	66.3	1.3	1.6	50.2	1.4	1.9	39.0	1.5	2.3	30.6	1.6	2.8	24.6	1.7	3.2	19.8	1.8	3.8	16.1	2.0	4.2
95	138.8	1.2	0.9	92.6	1.2	1.2	69.9	1.3	1.6	53.0	1.4	1.9	41.1	1.5	2.3	32.3	1.6	2.8	25.9	1.7	3.3	20.8	1.8	3.8	17.0	2.0	4.2
100	146.1	1.2	0.9	97.5	1.2	1.2	73.6	1.3	1.6	55.8	1.4	1.9	43.3	1.5	2.3	34.0	1.6	2.8	27.3	1.7	3.3	21.9	1.8	3.8	18.0	2.0	4.2
105	153.4	1.2	0.9	102.3	1.2	1.2	77.3	1.3	1.6	58.6	1.4	1.9	45.4	1.5	2.3	35.7	1.6	2.8	28.6	1.7	3.3	23.0	1.8	3.8	18.9	2.0	4.2
110	160.7	1.2	0.9	107.2	1.2	1.2	81.0	1.3	1.6	61.4	1.4	1.9	47.6	1.5	2.3	37.3	1.6	2.8	30.0	1.7	3.3	24.1	1.8	3.8	19.8	2.0	4.2
115	168.0	1.2	0.9	112.1	1.2	1.2	84.7	1.3	1.6	64.2	1.4	1.9	49.8	1.5	2.3	39.0	1.6	2.8	31.3	1.7	3.3	25.3	1.8	3.8	20.8	2.0	4.2
120	175.3	1.2	0.9	117.0	1.2	1.2	88.3	1.3	1.6	67.0	1.4	1.9	51.9	1.5	2.3	40.7	1.6	2.8	32.7	1.7	3.3	26.7	1.8	3.7	21.7	2.0	4.2
125	182.6	1.2	0.9	121.8	1.2	1.2	92.0	1.3	1.6	69.7	1.4	1.9	54.1	1.5	2.3	42.4	1.6	2.8	34.1	1.7	3.3	27.8	1.8	3.7	22.6	1.9	4.3
130	189.9	1.2	0.9	126.7	1.2	1.2	95.7	1.3	1.6	72.5	1.4	1.9	56.2	1.5	2.3	44.1	1.6	2.8	35.4	1.7	3.3	28.9	1.8	3.7	23.6	1.9	4.3
135	197.3	1.2	0.9	131.6	1.2	1.2	99.4	1.3	1.6	75.3	1.4	1.9	58.4	1.5	2.3	45.8	1.6	2.8	36.8	1.7	3.3	30.0	1.8	3.7	24.5	1.9	4.3
140	204.6	1.2	0.9	136.5	1.2	1.2	103.1	1.3	1.6	78.1	1.4	1.9	60.6	1.5	2.3	47.5	1.6	2.8	38.1	1.7	3.3	31.1	1.8	3.7	25.4	1.9	4.3
145	211.9	1.2	0.9	141.3	1.2	1.2	106.7	1.3	1.6	80.9	1.4	1.9	62.7	1.5	2.3	49.2	1.6	2.8	39.5	1.7	3.3	32.3	1.8	3.7	26.4	1.9	4.3
150	219.2	1.2	0.9	146.2	1.2	1.2	110.4	1.3	1.6	83.7	1.4	1.9	64.9	1.5	2.3	50.9	1.6	2.8	40.8	1.7	3.3	33.4	1.8	3.7	27.3	1.9	4.3

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-6 Parabolic Diversion Design Chart (Retardance “D” and “B”, Grade 4.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.1	0.9	0.8	7.0	1.0	1.1	4.9	1.1	1.4																		
10	20.5	0.9	0.8	14.4	0.9	1.1	10.3	1.0	1.4	7.9	1.1	1.8	6.1	1.2	2.1	4.5	1.4	2.4									
15	30.7	0.9	0.8	21.5	0.9	1.1	15.7	1.0	1.4	12.0	1.1	1.8	9.4	1.1	2.1	7.4	1.2	2.5	5.8	1.4	2.8						
20	40.9	0.9	0.8	28.6	0.9	1.1	20.9	1.0	1.4	16.3	1.0	1.8	12.6	1.1	2.1	10.1	1.2	2.5	8.0	1.3	2.9	6.3	1.4	3.3			
25	51.1	0.9	0.8	35.8	0.9	1.1	26.1	1.0	1.4	20.3	1.0	1.8	16.0	1.1	2.1	12.7	1.2	2.5	10.2	1.3	2.9	8.2	1.4	3.4	6.5	1.5	3.8
30	61.3	0.9	0.8	42.9	0.9	1.1	31.4	1.0	1.4	24.4	1.0	1.8	19.2	1.1	2.1	15.2	1.2	2.5	12.3	1.3	2.9	10.0	1.3	3.4	8.1	1.5	3.8
35	71.5	0.9	0.8	50.1	0.9	1.1	36.6	1.0	1.4	28.3	1.0	1.8	22.4	1.1	2.1	18.0	1.2	2.5	14.4	1.2	2.9	11.7	1.3	3.4	9.6	1.4	3.8
40	81.8	0.9	0.8	57.2	0.9	1.1	41.8	1.0	1.5	32.4	1.0	1.8	25.6	1.1	2.1	20.6	1.2	2.5	16.5	1.2	2.9	13.5	1.3	3.4	11.1	1.4	3.8
45	92.0	0.9	0.8	64.4	0.9	1.1	47.0	1.0	1.5	36.4	1.0	1.8	28.8	1.1	2.1	23.1	1.2	2.5	18.8	1.2	2.9	15.2	1.3	3.4	12.6	1.4	3.9
50	102.2	0.9	0.8	71.5	0.9	1.1	52.2	1.0	1.5	40.5	1.0	1.8	32.0	1.1	2.1	25.7	1.2	2.5	20.9	1.2	2.9	17.0	1.3	3.4	14.0	1.4	3.9
55	112.4	0.9	0.8	78.7	0.9	1.1	57.5	1.0	1.5	44.5	1.0	1.8	35.2	1.1	2.1	28.2	1.2	2.5	23.0	1.2	2.9	18.9	1.3	3.4	15.4	1.4	3.9
60	122.6	0.9	0.8	85.8	0.9	1.1	62.7	1.0	1.5	48.5	1.0	1.8	38.4	1.1	2.2	30.8	1.2	2.5	25.1	1.2	2.9	20.6	1.3	3.4	16.9	1.4	3.9
65	132.8	0.9	0.8	93.0	0.9	1.1	67.9	1.0	1.5	52.8	1.0	1.8	41.5	1.1	2.2	33.4	1.2	2.5	27.2	1.2	2.9	22.3	1.3	3.4	18.3	1.4	3.9
70	143.1	0.9	0.8	100.1	0.9	1.1	73.1	1.0	1.5	56.6	1.0	1.8	44.7	1.1	2.2	35.9	1.2	2.5	29.2	1.2	2.9	24.0	1.3	3.4	20.0	1.4	3.9
75	153.3	0.9	0.8	107.3	0.9	1.1	78.3	1.0	1.5	60.7	1.0	1.8	47.9	1.1	2.2	38.5	1.2	2.5	31.3	1.2	2.9	25.7	1.3	3.4	21.4	1.4	3.9
80	163.5	0.9	0.8	114.4	0.9	1.1	83.6	1.0	1.5	64.7	1.0	1.8	51.1	1.1	2.2	41.0	1.2	2.5	33.4	1.2	2.9	27.4	1.3	3.4	22.8	1.4	3.9
85	173.7	0.9	0.8	121.6	0.9	1.1	88.8	1.0	1.5	68.8	1.0	1.8	64.3	1.1	2.2	43.6	1.2	2.5	35.5	1.2	2.9	29.1	1.3	3.4	24.2	1.4	3.9
90	183.9	0.9	0.8	128.7	0.9	1.1	94.0	1.0	1.5	72.8	1.0	1.8	57.5	1.1	2.2	46.2	1.2	2.5	37.6	1.2	2.9	30.8	1.3	3.4	25.7	1.4	3.9
95	194.1	0.9	0.8	135.9	0.9	1.1	99.2	1.0	1.5	76.8	1.0	1.8	60.7	1.1	2.2	48.7	1.2	2.5	39.7	1.2	2.9	32.5	1.3	3.4	27.1	1.4	3.9
100	204.4	0.9	0.8	143.0	0.9	1.1	104.4	1.0	1.5	80.9	1.0	1.8	63.9	1.1	2.2	51.3	1.2	2.5	41.7	1.2	2.9	34.2	1.3	3.4	28.5	1.3	3.9
105	214.6	0.9	0.8	150.2	0.9	1.1	109.7	1.0	1.5	84.9	1.0	1.8	67.1	1.1	2.2	53.9	1.2	2.5	43.8	1.2	2.9	35.9	1.3	3.4	29.9	1.3	3.9
110	224.8	0.9	0.8	157.4	0.9	1.1	114.9	1.0	1.5	89.0	1.0	1.8	70.3	1.1	2.2	56.4	1.2	2.5	45.9	1.2	2.9	37.6	1.3	3.4	31.3	1.3	3.9
115	235.0	0.9	0.8	164.5	0.9	1.1	120.1	1.0	1.5	93.0	1.0	1.8	73.5	1.1	2.2	59.0	1.2	2.5	48.0	1.2	2.9	39.3	1.3	3.4	32.7	1.3	3.9
120	245.2	0.9	0.8	171.7	0.9	1.1	125.3	1.0	1.5	97.1	1.0	1.8	76.7	1.1	2.2	61.5	1.2	2.5	49.9	1.2	3.0	41.0	1.3	3.4	34.2	1.3	3.9
125	255.5	0.9	0.8	178.8	0.9	1.1	130.5	1.0	1.5	101.1	1.0	1.8	79.9	1.1	2.2	64.1	1.2	2.5	52.0	1.2	3.0	42.7	1.3	3.4	35.6	1.3	3.9
130	265.7	0.9	0.8	186.0	0.9	1.1	135.8	1.0	1.5	105.1	1.0	1.8	83.0	1.1	2.2	66.7	1.2	2.5	54.1	1.2	3.0	44.4	1.3	3.4	37.0	1.3	3.9
135	275.9	0.9	0.8	193.1	0.9	1.1	141.0	1.0	1.5	109.2	1.0	1.8	86.2	1.1	2.2	69.2	1.2	2.5	56.1	1.2	3.0	46.1	1.3	3.4	38.4	1.3	3.9
140	286.1	0.9	0.8	200.3	0.9	1.1	146.2	1.0	1.5	113.2	1.0	1.8	89.4	1.1	2.2	71.8	1.2	2.5	58.2	1.2	3.0	47.8	1.3	3.4	39.9	1.3	3.9
145	296.3	0.9	0.8	207.4	0.9	1.1	151.4	1.0	1.5	117.3	1.0	1.8	92.6	1.1	2.2	74.4	1.2	2.5	60.3	1.2	3.0	49.6	1.3	3.4	41.3	1.3	3.9
150	306.5	0.9	0.8	214.6	0.9	1.1	156.7	1.0	1.5	121.3	1.0	1.8	95.8	1.1	2.2	76.9	1.2	2.5	62.4	1.2	3.0	51.3	1.3	3.4	42.7	1.3	3.9

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-7 Parabolic Diversion Design Chart (Retardance “D” and “B”, Grade 6.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.4	0.7	0.8	8.7	0.8	1.0	6.2	0.9	1.4	4.7	1.0	1.8	3.5	1.2	1.9												
10	24.7	0.7	0.8	17.6	0.8	1.0	12.8	0.9	1.4	9.8	0.9	1.7	7.8	1.0	2.0	6.2	1.0	2.3	4.9	1.1	2.7						
15	37.1	0.7	0.8	26.4	0.8	1.1	19.2	0.8	1.4	15.0	0.9	1.7	11.8	0.9	2.0	9.5	1.0	2.4	7.7	1.1	2.7	6.2	1.2	3.1	5.0	1.3	3.5
20	49.4	0.7	0.8	35.1	0.8	1.1	25.6	0.8	1.4	19.9	0.9	1.7	16.0	0.9	2.0	12.9	1.0	2.4	10.4	1.0	2.8	8.5	1.1	3.2	7.0	1.2	3.6
25	61.8	0.7	0.8	43.9	0.8	1.1	32.0	0.8	1.4	24.9	0.9	1.7	19.9	0.9	2.0	16.1	1.0	2.4	13.1	1.0	2.8	10.8	1.1	3.2	8.9	1.2	3.6
30	74.1	0.7	0.8	52.7	0.8	1.1	38.4	0.8	1.4	29.9	0.9	1.7	23.8	0.9	2.1	19.3	1.0	2.4	15.9	1.0	2.8	13.0	1.1	3.2	10.8	1.1	3.6
35	86.5	0.7	0.8	61.5	0.8	1.1	44.8	0.8	1.4	34.8	0.9	1.7	27.8	0.9	2.1	22.5	1.0	2.4	18.5	1.0	2.8	15.4	1.1	3.2	12.7	1.1	3.6
40	98.9	0.7	0.8	70.2	0.8	1.1	51.2	0.8	1.4	39.8	0.9	1.7	31.8	0.9	2.1	25.7	1.0	2.4	21.2	1.0	2.8	17.8	1.1	3.2	14.5	1.1	3.6
45	111.2	0.7	0.8	79.0	0.8	1.1	57.6	0.8	1.4	44.8	0.9	1.7	35.7	0.9	2.1	29.0	1.0	2.4	23.8	1.0	2.8	19.8	1.1	3.2	16.6	1.1	3.6
50	123.6	0.7	0.8	87.8	0.8	1.1	64.0	0.8	1.4	49.7	0.9	1.7	39.7	0.9	2.1	32.2	1.0	2.4	26.4	1.0	2.8	22.0	1.1	3.2	18.4	1.1	3.6
55	135.9	0.7	0.8	96.6	0.8	1.1	70.4	0.8	1.4	54.7	0.9	1.7	43.6	0.9	2.1	36.4	1.0	2.4	29.1	1.0	2.8	24.2	1.1	3.2	20.2	1.1	3.7
60	148.3	0.7	0.8	105.3	0.8	1.1	76.8	0.8	1.4	58.7	0.9	1.7	47.8	0.9	2.1	38.6	1.0	2.4	31.7	1.0	2.8	26.3	1.1	3.2	22.0	1.1	3.7
65	160.6	0.7	0.8	114.1	0.8	1.1	83.2	0.8	1.4	64.7	0.9	1.7	51.8	0.9	2.1	41.8	1.0	2.4	34.3	1.0	2.8	28.5	1.1	3.2	23.8	1.1	3.7
70	173.0	0.7	0.8	122.9	0.8	1.1	89.6	0.8	1.4	69.6	0.9	1.7	55.5	0.9	2.1	45.0	1.0	2.4	37.0	1.0	2.8	30.7	1.1	3.2	25.6	1.1	3.7
75	185.4	0.7	0.8	131.7	0.8	1.1	96.0	0.8	1.4	74.6	0.9	1.7	59.5	0.9	2.1	48.2	1.0	2.4	39.8	1.0	2.8	32.9	1.1	3.2	27.4	1.1	3.7
80	197.7	0.7	0.8	140.4	0.8	1.1	102.3	0.8	1.4	79.6	0.9	1.7	63.5	0.9	2.1	51.4	1.0	2.4	42.2	1.0	2.8	35.1	1.1	3.2	29.3	1.1	3.7
85	210.1	0.7	0.8	149.2	0.8	1.1	108.7	0.8	1.4	84.5	0.9	1.7	67.4	0.9	2.1	54.7	1.0	2.4	44.9	1.0	2.8	37.3	1.1	3.2	31.1	1.1	3.7
90	222.4	0.7	0.8	158.0	0.8	1.1	115.1	0.8	1.4	89.5	0.9	1.7	71.4	0.9	2.1	57.9	1.0	2.4	47.5	1.0	2.8	39.5	1.1	3.2	32.9	1.1	3.7
95	234.8	0.7	0.8	166.8	0.8	1.1	121.5	0.8	1.4	94.5	0.9	1.7	75.4	0.9	2.1	61.1	1.0	2.4	50.2	1.0	2.8	41.7	1.1	3.2	34.7	1.1	3.7
100	247.1	0.7	0.8	175.5	0.8	1.1	127.9	0.8	1.4	99.5	0.9	1.7	79.3	0.9	2.1	64.3	1.0	2.4	52.8	1.0	2.8	43.9	1.1	3.2	36.6	1.1	3.7
105	259.5	0.7	0.8	184.3	0.8	1.1	134.3	0.8	1.4	104.4	0.9	1.7	83.3	0.9	2.1	67.5	1.0	2.4	55.4	1.0	2.8	46.1	1.1	3.2	38.4	1.1	3.7
110	271.8	0.7	0.8	193.1	0.8	1.1	140.7	0.8	1.4	109.4	0.9	1.7	87.3	0.9	2.1	70.7	1.0	2.4	58.1	1.0	2.8	48.2	1.1	3.2	40.2	1.1	3.7
115	284.2	0.7	0.8	201.9	0.8	1.1	147.1	0.8	1.4	114.4	0.9	1.7	91.2	0.9	2.1	73.9	1.0	2.4	60.7	1.0	2.8	50.4	1.1	3.2	42.0	1.1	3.7
120	296.6	0.7	0.8	210.7	0.8	1.1	153.5	0.8	1.4	119.3	0.9	1.7	95.2	0.9	2.1	77.2	1.0	2.4	63.3	1.0	2.8	52.6	1.1	3.2	43.9	1.1	3.7
125	308.9	0.7	0.8	219.4	0.8	1.1	159.9	0.8	1.4	124.3	0.9	1.7	99.2	0.9	2.1	80.4	1.0	2.4	66.0	1.0	2.8	54.8	1.1	3.2	45.7	1.1	3.7
130	321.3	0.7	0.8	228.2	0.8	1.1	166.3	0.8	1.4	129.3	0.9	1.7	103.1	0.9	2.1	83.6	1.0	2.4	68.6	1.0	2.8	57.0	1.1	3.2	47.5	1.1	3.7
135	333.6	0.7	0.8	237.0	0.8	1.1	172.7	0.8	1.4	134.3	0.9	1.7	107.1	0.9	2.1	86.8	1.0	2.4	71.3	1.0	2.8	59.2	1.1	3.2	49.3	1.1	3.7
140	346.0	0.7	0.8	245.8	0.8	1.1	179.1	0.8	1.4	139.2	0.9	1.7	111.0	0.9	2.1	90.0	1.0	2.4	73.9	1.0	2.8	61.4	1.1	3.2	51.2	1.1	3.7
145	358.3	0.7	0.8	254.5	0.8	1.1	185.5	0.8	1.4	144.2	0.9	1.7	115.0	0.9	2.1	93.2	1.0	2.4	76.5	1.0	2.8	63.6	1.1	3.2	53.0	1.1	3.7
150	370.7	0.7	0.8	263.3	0.8	1.1	191.9	0.8	1.4	149.2	0.9	1.7	119.0	0.9	2.1	96.4	1.0	2.4	79.2	1.0	2.8	65.8	1.1	3.2	54.8	1.1	3.7

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-8 Parabolic Diversion Design Chart (Retardance “D” and “B”, Grade 8.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	14.0	0.7	0.8	10.1	0.7	1.0	7.4	0.8	1.3	5.5	0.8	1.6	4.4	0.9	1.9	3.4	1.0	2.1									
10	28.0	0.7	0.8	20.1	0.7	1.0	15.0	0.8	1.3	11.3	0.8	1.7	9.1	0.8	2.0	7.4	0.9	2.3	6.0	0.9	2.6	4.9	1.0	3.0	3.8	1.2	3.3
15	41.9	0.7	0.8	30.1	0.7	1.0	22.4	0.8	1.3	17.0	0.8	1.7	13.9	0.8	2.0	11.4	0.9	2.3	9.2	0.9	2.7	7.6	1.0	3.0	6.3	1.0	3.4
20	55.9	0.7	0.8	40.1	0.7	1.0	29.9	0.8	1.3	22.6	0.8	1.7	18.5	0.8	2.0	15.1	0.9	2.3	12.5	0.9	2.7	10.2	1.0	3.1	8.5	1.0	3.5
25	69.9	0.7	0.8	50.1	0.7	1.0	37.3	0.8	1.3	28.2	0.8	1.7	23.1	0.8	2.0	18.8	0.9	2.3	15.6	0.9	2.7	13.0	0.9	3.1	10.8	1.0	3.5
30	83.9	0.7	0.8	60.1	0.7	1.0	44.8	0.8	1.3	33.9	0.8	1.7	27.7	0.8	2.0	22.6	0.9	2.3	18.6	0.9	2.7	15.6	0.9	3.1	13.0	1.0	3.5
35	97.9	0.7	0.8	70.1	0.7	1.0	52.3	0.8	1.3	39.5	0.8	1.7	32.3	0.8	2.0	26.3	0.9	2.3	21.7	0.9	2.7	18.2	0.9	3.1	15.3	1.0	3.5
40	111.8	0.7	0.8	80.2	0.7	1.0	59.7	0.8	1.3	45.1	0.8	1.7	36.9	0.8	2.0	30.1	0.9	2.3	24.8	0.9	2.7	20.8	0.9	3.1	17.5	1.0	3.5
45	125.8	0.7	0.8	90.2	0.7	1.0	67.2	0.8	1.3	50.8	0.8	1.7	41.5	0.8	2.0	33.8	0.9	2.3	27.9	0.9	2.7	23.3	0.9	3.1	19.7	1.0	3.5
50	139.8	0.7	0.8	100.2	0.7	1.0	74.7	0.8	1.3	56.4	0.8	1.7	46.1	0.8	2.0	37.6	0.9	2.3	31.0	0.9	2.7	25.9	0.9	3.1	21.9	1.0	3.5
55	153.8	0.7	0.8	110.2	0.7	1.0	82.1	0.8	1.3	62.1	0.8	1.7	50.7	0.8	2.0	41.3	0.9	2.3	34.1	0.9	2.7	28.5	0.9	3.1	24.0	1.0	3.5
60	167.8	0.7	0.8	120.2	0.7	1.0	89.6	0.8	1.3	67.7	0.8	1.7	55.3	0.8	2.0	45.1	0.9	2.3	37.2	0.9	2.7	31.1	0.9	3.1	26.2	1.0	3.5
65	181.7	0.7	0.8	130.3	0.7	1.0	97.0	0.8	1.3	73.3	0.8	1.7	60.0	0.8	2.0	48.8	0.9	2.3	40.3	0.9	2.7	33.7	0.9	3.1	28.4	1.0	3.5
70	195.7	0.7	0.8	140.3	0.7	1.0	104.5	0.8	1.3	79.0	0.8	1.7	64.6	0.8	2.0	52.6	0.9	2.3	43.4	0.9	2.7	36.3	0.9	3.1	30.6	1.0	3.5
75	209.7	0.7	0.8	150.3	0.7	1.0	112.0	0.8	1.3	84.6	0.8	1.7	69.2	0.8	2.0	56.3	0.9	2.3	46.6	0.9	2.7	38.9	0.9	3.1	32.8	1.0	3.5
80	223.7	0.7	0.8	160.3	0.7	1.0	119.4	0.8	1.3	90.3	0.8	1.7	73.8	0.8	2.0	60.1	0.9	2.3	49.6	0.9	2.7	41.4	0.9	3.1	35.0	1.0	3.5
85	237.7	0.7	0.8	170.3	0.7	1.0	126.9	0.8	1.3	95.9	0.8	1.7	78.4	0.8	2.0	63.8	0.9	2.3	52.7	0.9	2.7	44.0	0.9	3.1	37.1	1.0	3.5
90	251.6	0.7	0.8	180.3	0.7	1.0	134.4	0.8	1.3	101.6	0.8	1.7	83.0	0.8	2.0	67.6	0.9	2.3	55.8	0.9	2.7	46.6	0.9	3.1	39.3	1.0	3.5
95	265.6	0.7	0.8	190.4	0.7	1.0	141.8	0.8	1.3	107.2	0.8	1.7	87.6	0.8	2.0	71.3	0.9	2.3	58.9	0.9	2.7	49.2	0.9	3.1	41.5	1.0	3.5
100	279.6	0.7	0.8	200.4	0.7	1.0	149.3	0.8	1.3	112.8	0.8	1.7	92.2	0.8	2.0	75.1	0.9	2.3	62.0	0.9	2.7	51.8	0.9	3.1	43.7	1.0	3.5
105	293.6	0.7	0.8	210.4	0.7	1.0	156.8	0.8	1.3	118.5	0.8	1.7	96.8	0.8	2.0	78.9	0.9	2.3	65.1	0.9	2.7	54.4	0.9	3.1	45.9	1.0	3.5
110	307.6	0.7	0.8	220.4	0.7	1.0	164.2	0.8	1.3	124.1	0.8	1.7	101.4	0.8	2.0	82.6	0.9	2.3	68.2	0.9	2.7	57.0	0.9	3.1	48.0	1.0	3.5
115	321.5	0.7	0.8	230.4	0.7	1.0	171.7	0.8	1.3	129.8	0.8	1.7	106.1	0.8	2.0	86.4	0.9	2.3	71.3	0.9	2.7	59.6	0.9	3.1	50.2	1.0	3.5
120	335.5	0.7	0.8	240.5	0.7	1.0	179.1	0.8	1.3	135.4	0.8	1.7	110.7	0.8	2.0	90.1	0.9	2.3	74.4	0.9	2.7	62.2	0.9	3.1	52.4	1.0	3.5
125	349.5	0.7	0.8	250.5	0.7	1.0	186.6	0.8	1.3	141.0	0.8	1.7	115.3	0.8	2.0	93.9	0.9	2.3	77.5	0.9	2.7	64.7	0.9	3.1	54.6	1.0	3.5
130	363.5	0.7	0.8	260.5	0.7	1.0	194.1	0.8	1.3	146.7	0.8	1.7	119.9	0.8	2.0	97.6	0.9	2.3	80.6	0.9	2.7	67.3	0.9	3.1	56.8	1.0	3.5
135	377.5	0.7	0.8	270.5	0.7	1.0	201.5	0.8	1.3	152.3	0.8	1.7	124.5	0.8	2.0	101.4	0.9	2.3	83.7	0.9	2.7	69.9	0.9	3.1	59.0	1.0	3.5
140	391.5	0.7	0.8	280.5	0.7	1.0	209.0	0.8	1.3	158.0	0.8	1.7	129.1	0.8	2.0	105.1	0.9	2.3	86.8	0.9	2.7	72.5	0.9	3.1	61.1	1.0	3.5
145	405.4	0.7	0.8	290.6	0.7	1.0	216.5	0.8	1.3	163.6	0.8	1.7	133.7	0.8	2.0	108.9	0.9	2.3	89.9	0.9	2.7	75.1	0.9	3.1	63.3	1.0	3.5
150	419.4	0.7	0.8	300.6	0.7	1.0	223.9	0.8	1.3	169.3	0.8	1.7	138.3	0.8	2.0	112.6	0.9	2.3	93.0	0.9	2.7	77.7	0.9	3.1	65.5	1.0	3.5

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-9 Parabolic Diversion Design Chart (Retardance "D" and "B", Grade 10.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	15.3	0.6	0.8	11.1	0.7	1.0	8.1	0.7	1.3	6.3	0.7	1.6
10	30.6	0.6	0.8	22.1	0.7	1.0	16.5	0.7	1.3	12.8	0.7	1.6
15	45.9	0.6	0.8	33.2	0.7	1.0	24.7	0.7	1.3	19.2	0.7	1.6
20	61.2	0.6	0.8	44.2	0.7	1.0	32.9	0.7	1.3	25.6	0.7	1.6
25	76.5	0.6	0.8	55.3	0.7	1.0	41.1	0.7	1.3	32.0	0.7	1.6
30	91.8	0.6	0.8	66.3	0.7	1.0	49.3	0.7	1.3	38.3	0.7	1.6
35	107.1	0.6	0.8	77.4	0.7	1.0	57.5	0.7	1.3	44.7	0.7	1.6
40	122.4	0.6	0.8	88.4	0.7	1.0	65.7	0.7	1.3	51.1	0.7	1.6
45	137.8	0.6	0.8	99.5	0.7	1.0	73.9	0.7	1.3	57.5	0.7	1.6
50	153.1	0.6	0.8	110.6	0.7	1.0	82.1	0.7	1.3	63.9	0.7	1.6
55	168.4	0.6	0.8	121.6	0.7	1.0	90.3	0.7	1.3	70.3	0.7	1.6
60	183.7	0.6	0.8	132.7	0.7	1.0	98.5	0.7	1.3	76.7	0.7	1.6
65	199.0	0.6	0.8	143.7	0.7	1.0	106.7	0.7	1.3	83.1	0.7	1.6
70	214.3	0.6	0.8	154.8	0.7	1.0	115.0	0.7	1.3	89.4	0.7	1.6
75	229.6	0.6	0.8	165.8	0.7	1.0	123.2	0.7	1.3	95.8	0.7	1.6
80	244.9	0.6	0.8	176.9	0.7	1.0	131.4	0.7	1.3	102.2	0.7	1.6
85	260.2	0.6	0.8	187.9	0.7	1.0	139.6	0.7	1.3	108.6	0.7	1.6
90	275.5	0.6	0.8	199.0	0.7	1.0	147.8	0.7	1.3	115.0	0.7	1.6
95	290.8	0.6	0.8	210.0	0.7	1.0	156.0	0.7	1.3	121.4	0.7	1.6
100	306.1	0.6	0.8	221.1	0.7	1.0	164.2	0.7	1.3	127.8	0.7	1.6
105	321.4	0.6	0.8	232.2	0.7	1.0	172.4	0.7	1.3	134.2	0.7	1.6
110	336.7	0.6	0.8	243.2	0.7	1.0	180.6	0.7	1.3	140.5	0.7	1.6
115	352.0	0.6	0.8	254.3	0.7	1.0	188.8	0.7	1.3	146.9	0.7	1.6
120	367.3	0.6	0.8	265.3	0.7	1.0	197.1	0.7	1.3	153.3	0.7	1.6
125	382.6	0.6	0.8	276.4	0.7	1.0	205.3	0.7	1.3	159.7	0.7	1.6
130	397.9	0.6	0.8	287.4	0.7	1.0	213.5	0.7	1.3	166.1	0.7	1.6
135	413.2	0.6	0.8	298.5	0.7	1.0	221.7	0.7	1.3	172.5	0.7	1.6
140	428.6	0.6	0.8	309.5	0.7	1.0	229.9	0.7	1.3	178.9	0.7	1.6
145	443.9	0.6	0.8	320.6	0.7	1.0	238.1	0.7	1.3	185.3	0.7	1.6
150	459.2	0.6	0.8	331.7	0.7	1.0	246.3	0.7	1.3	191.6	0.7	1.6

Q CFS	V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	4.8	0.8	1.9	4.0	0.9	2.2	3.1	1.0	2.4						
10	10.0	0.8	2.0	8.4	0.8	2.2	6.9	0.8	2.6	5.7	0.9	2.9	4.7	1.0	3.3
15	15.0	0.8	2.0	12.7	0.8	2.2	10.5	0.8	2.6	8.7	0.9	3.0	7.3	0.9	3.3
20	20.0	0.8	2.0	17.0	0.8	2.2	14.1	0.8	2.6	11.8	0.9	3.0	9.8	0.9	3.4
25	25.0	0.8	2.0	21.2	0.8	2.3	17.6	0.8	2.6	14.7	0.9	3.0	12.5	0.9	3.4
30	29.9	0.8	2.0	25.4	0.8	2.3	21.1	0.8	2.6	17.7	0.8	3.0	15.0	0.9	3.3
35	34.9	0.8	2.0	29.7	0.8	2.3	24.6	0.8	2.6	20.6	0.8	3.0	17.5	0.9	3.4
40	39.9	0.8	2.0	33.9	0.8	2.3	28.1	0.8	2.6	23.5	0.8	3.0	20.0	0.9	3.4
45	44.9	0.8	2.0	38.0	0.8	2.3	31.6	0.8	2.6	26.5	0.8	3.0	22.5	0.9	3.4
50	49.9	0.8	2.0	42.2	0.8	2.3	35.1	0.8	2.6	29.4	0.8	3.0	25.0	0.9	3.4
55	54.9	0.8	2.0	46.4	0.8	2.3	38.6	0.8	2.6	32.3	0.8	3.0	27.5	0.9	3.4
60	59.9	0.8	2.0	50.7	0.8	2.3	42.1	0.8	2.6	35.3	0.8	3.0	30.0	0.9	3.4
65	64.8	0.8	2.0	54.9	0.8	2.3	45.6	0.8	2.6	38.2	0.8	3.0	32.5	0.9	3.4
70	69.8	0.8	2.0	59.1	0.8	2.3	49.1	0.8	2.6	41.2	0.8	3.0	35.0	0.9	3.4
75	74.8	0.8	2.0	63.3	0.8	2.3	52.6	0.8	2.6	44.1	0.8	3.0	37.4	0.9	3.4
80	79.8	0.8	2.0	67.6	0.8	2.3	56.1	0.8	2.6	47.0	0.8	3.0	39.8	0.9	3.4
85	84.8	0.8	2.0	71.8	0.8	2.3	59.6	0.8	2.6	50.0	0.8	3.0	42.3	0.9	3.4
90	89.8	0.8	2.0	76.0	0.8	2.3	63.1	0.8	2.6	52.9	0.8	3.0	44.8	0.9	3.4
95	94.8	0.8	2.0	80.2	0.8	2.3	66.6	0.8	2.6	55.8	0.8	3.0	47.3	0.9	3.4
100	99.8	0.8	2.0	84.4	0.8	2.3	70.1	0.8	2.6	58.8	0.8	3.0	49.7	0.9	3.4
105	104.7	0.8	2.0	88.7	0.8	2.3	73.6	0.8	2.6	61.7	0.8	3.0	52.2	0.9	3.4
110	109.7	0.8	2.0	92.9	0.8	2.3	77.1	0.8	2.6	64.7	0.8	3.0	54.7	0.9	3.4
115	114.7	0.8	2.0	97.1	0.8	2.3	80.6	0.8	2.6	67.6	0.8	3.0	57.2	0.9	3.4
120	119.7	0.8	2.0	101.3	0.8	2.3	84.1	0.8	2.6	70.5	0.8	3.0	59.7	0.9	3.4
125	124.7	0.8	2.0	105.5	0.8	2.3	87.6	0.8	2.6	73.5	0.8	3.0	62.2	0.9	3.4
130	129.7	0.8	2.0	109.8	0.8	2.3	91.1	0.8	2.6	76.4	0.8	3.0	64.7	0.9	3.4
135	134.7	0.8	2.0	114.0	0.8	2.3	94.6	0.8	2.6	79.3	0.8	3.0	67.2	0.9	3.4
140	139.7	0.8	2.0	118.2	0.8	2.3	98.1	0.8	2.6	82.3	0.8	3.0	69.6	0.9	3.4
145	144.6	0.8	2.0	122.4	0.8	2.3	101.7	0.8	2.6	85.2	0.8	3.0	72.1	0.9	3.4
150	149.6	0.8	2.0	126.7	0.8	2.3	105.2	0.8	2.6	88.2	0.9	3.0	74.6	0.9	3.4

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-10 Parabolic Diversion Design Chart (Retardance "D" and "C", Grade .50%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	8.4	1.6	1.7																								
20	11.7	1.5	1.7	7.1	2.0	2.2																					
25	14.9	1.5	1.7	9.7	1.8	2.2																					
30	18.0	1.5	1.7	12.0	1.7	2.2																					
35	21.0	1.5	1.7	14.2	1.7	2.2	9.3	2.1	2.7																		
40	24.4	1.5	1.7	16.3	1.7	2.2	10.9	2.0	2.7																		
45	27.4	1.5	1.7	18.5	1.7	2.2	12.5	2.0	2.7																		
50	30.5	1.5	1.7	20.6	1.7	2.2	14.1	1.9	2.7	8.7	2.6	3.3															
55	33.5	1.5	1.7	22.7	1.7	2.2	15.7	1.9	2.7	10.4	2.4	3.3															
60	36.6	1.5	1.7	24.8	1.7	2.2	17.2	1.9	2.7	11.7	2.3	3.3															
65	39.6	1.5	1.7	27.3	1.7	2.2	18.8	1.9	2.7	12.9	2.3	3.3															
70	42.6	1.5	1.7	29.4	1.7	2.2	20.3	1.9	2.7	14.0	2.2	3.3	9.8	2.8	3.8												
75	45.7	1.5	1.7	31.4	1.7	2.2	21.8	1.9	2.7	15.2	2.2	3.3	11.3	2.7	3.8												
80	48.7	1.5	1.7	33.5	1.7	2.2	23.3	1.9	2.7	16.3	2.2	3.3	12.2	2.6	3.8												
85	51.7	1.5	1.7	35.6	1.6	2.2	24.8	1.9	2.7	17.4	2.2	3.3	13.2	2.5	3.8												
90	54.8	1.5	1.7	37.7	1.6	2.2	26.3	1.9	2.7	18.5	2.2	3.3	14.2	2.5	3.8												
95	57.8	1.5	1.7	39.8	1.6	2.2	27.8	1.9	2.7	19.6	2.2	3.3	15.1	2.5	3.8												
100	60.9	1.5	1.7	41.9	1.6	2.2	29.7	1.9	2.7	20.7	2.2	3.3	16.0	2.5	3.8	11.0	3.2	4.3									
105	63.9	1.5	1.7	44.0	1.6	2.2	31.2	1.9	2.7	21.8	2.2	3.3	16.9	2.5	3.8	12.3	3.0	4.3									
110	66.9	1.5	1.7	46.1	1.6	2.2	32.6	1.9	2.7	22.9	2.2	3.3	17.8	2.4	3.8	13.1	2.9	4.3									
115	70.0	1.5	1.7	48.1	1.6	2.2	34.1	1.9	2.7	24.0	2.1	3.3	18.7	2.4	3.8	13.9	2.9	4.3									
120	73.0	1.5	1.7	50.2	1.6	2.2	35.6	1.9	2.7	25.1	2.1	3.3	19.6	2.4	3.8	14.6	2.9	4.3									
125	76.1	1.5	1.7	52.3	1.6	2.2	37.1	1.9	2.7	26.2	2.1	3.3	20.5	2.4	3.8	15.4	2.8	4.3									
130	79.1	1.5	1.7	54.4	1.6	2.2	38.5	1.9	2.7	27.3	2.1	3.3	21.3	2.4	3.8	16.1	2.8	4.3									
135	82.1	1.5	1.7	56.5	1.6	2.2	40.0	1.9	2.7	28.4	2.1	3.3	22.2	2.4	3.8	16.9	2.8	4.3									
140	85.2	1.5	1.7	58.6	1.6	2.2	41.5	1.9	2.7	29.4	2.1	3.3	23.1	2.4	3.8	17.6	2.8	4.3									
145	88.2	1.5	1.7	60.7	1.6	2.2	43.0	1.9	2.7	30.5	2.1	3.3	24.0	2.4	3.8	18.3	2.8	4.3	12.3	3.7	4.9						
150	91.3	1.6	1.7	62.8	1.6	2.2	44.5	1.9	2.7	31.6	2.1	3.3	24.8	2.4	3.8	19.0	2.7	4.3	13.1	3.5	4.9						

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-11 Parabolic Diversion Design Chart (Retardance "D" and "C", Grade 1.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	8.2	1.2	1.6	5.2	1.4	2.0																					
15	12.6	1.1	1.6	8.7	1.3	2.1	5.5	1.6	2.6																		
20	17.1	1.1	1.6	11.8	1.2	2.1	8.2	1.4	2.6																		
25	21.4	1.1	1.6	14.9	1.2	2.1	10.5	1.4	2.6	7.3	1.6	3.1															
30	25.7	1.1	1.6	18.0	1.2	2.1	12.8	1.4	2.6	9.1	1.6	3.2															
35	29.9	1.1	1.6	21.2	1.2	2.1	15.0	1.3	2.6	10.9	1.5	3.1	7.8	1.8	3.7												
40	34.2	1.1	1.6	24.3	1.2	2.1	17.3	1.3	2.6	12.6	1.5	3.1	9.2	1.7	3.7												
45	38.5	1.1	1.6	27.3	1.2	2.1	19.5	1.3	2.6	14.3	1.5	3.1	10.6	1.7	3.7	7.2	2.2	4.3									
50	42.7	1.1	1.6	30.3	1.2	2.1	21.9	1.3	2.6	16.0	1.5	3.2	11.9	1.7	3.7	8.8	2.0	4.3									
55	47.0	1.1	1.6	33.3	1.2	2.1	24.1	1.3	2.6	17.7	1.5	3.2	13.3	1.7	3.7	9.9	1.9	4.3									
60	51.3	1.1	1.6	36.3	1.2	2.1	26.3	1.3	2.6	19.3	1.5	3.2	14.6	1.7	3.7	11.0	1.9	4.3									
65	55.5	1.1	1.6	39.4	1.2	2.1	28.5	1.3	2.6	21.0	1.5	3.2	15.9	1.6	3.7	12.1	1.9	4.3	8.0	2.5	4.9						
70	59.8	1.1	1.6	42.4	1.2	2.1	30.7	1.3	2.6	22.7	1.5	3.2	17.1	1.6	3.7	13.2	1.9	4.3	9.5	2.3	4.8						
75	64.1	1.1	1.6	45.4	1.2	2.1	32.9	1.3	2.6	24.6	1.5	3.1	18.5	1.6	3.7	14.2	1.8	4.3	10.4	2.2	4.9						
80	68.3	1.1	1.6	48.4	1.2	2.1	35.0	1.3	2.6	26.2	1.5	3.1	19.8	1.6	3.7	15.2	1.8	4.3	11.3	2.2	4.9						
85	72.6	1.1	1.6	51.5	1.2	2.1	37.2	1.3	2.6	27.9	1.5	3.1	21.0	1.6	3.7	16.3	1.8	4.3	12.1	2.2	4.9	8.8	2.7	5.4			
90	76.9	1.1	1.6	54.5	1.2	2.1	39.4	1.3	2.6	29.5	1.5	3.1	22.3	1.6	3.7	17.3	1.8	4.3	13.0	2.1	4.9	9.8	2.6	5.4			
95	81.1	1.1	1.6	57.5	1.2	2.1	41.6	1.3	2.6	31.1	1.5	3.1	23.6	1.6	3.7	18.3	1.8	4.3	13.8	2.1	4.9	10.9	2.5	5.3			
100	85.4	1.1	1.6	60.5	1.2	2.1	43.8	1.3	2.6	32.7	1.5	3.1	24.9	1.6	3.7	19.3	1.8	4.3	14.6	2.1	4.9	11.6	2.4	5.4			
105	89.7	1.1	1.6	63.6	1.2	2.1	46.0	1.3	2.6	34.4	1.5	3.1	26.5	1.6	3.7	20.3	1.8	4.3	15.4	2.1	4.9	12.4	2.4	5.4	9.7	2.8	5.8
110	94.0	1.1	1.6	66.6	1.2	2.1	48.2	1.3	2.6	36.0	1.5	3.1	27.7	1.6	3.7	21.3	1.8	4.3	16.2	2.1	4.9	13.1	2.4	5.4	10.8	2.6	5.8
115	98.2	1.1	1.6	69.6	1.2	2.1	50.4	1.3	2.6	37.6	1.5	3.1	29.0	1.6	3.7	22.3	1.8	4.3	17.0	2.1	4.9	13.8	2.3	5.4	11.5	2.6	5.8
120	102.5	1.1	1.6	72.6	1.2	2.1	52.5	1.3	2.6	39.3	1.5	3.1	30.2	1.6	3.7	23.3	1.8	4.3	17.9	2.1	4.9	14.5	2.3	5.4	12.2	2.6	5.8
125	106.8	1.1	1.6	75.7	1.2	2.1	54.7	1.3	2.6	40.9	1.5	3.1	31.5	1.6	3.7	24.3	1.8	4.3	18.7	2.1	4.9	15.2	2.3	5.4	12.8	2.5	5.8
130	111.0	1.1	1.6	78.7	1.2	2.1	56.9	1.3	2.6	42.5	1.5	3.1	32.7	1.6	3.7	25.3	1.8	4.3	19.4	2.1	4.9	15.9	2.3	5.4	13.4	2.5	5.8
135	115.3	1.1	1.6	81.7	1.2	2.1	59.1	1.3	2.6	44.2	1.5	3.1	34.0	1.6	3.7	26.3	1.8	4.3	20.2	2.0	4.9	16.6	2.3	5.4	14.1	2.5	5.8
140	119.6	1.1	1.6	84.7	1.2	2.1	61.3	1.3	2.6	45.8	1.5	3.1	35.2	1.6	3.7	27.3	1.8	4.3	21.0	2.0	4.9	17.2	2.3	5.4	14.7	2.5	5.8
145	123.8	1.1	1.6	87.8	1.2	2.1	63.5	1.3	2.6	47.5	1.5	3.1	36.5	1.6	3.7	28.7	1.8	4.3	21.8	2.0	4.9	17.9	2.3	5.4	15.3	2.5	5.8
150	128.1	1.1	1.6	90.8	1.2	2.1	65.7	1.3	2.6	49.1	1.5	3.1	37.8	1.6	3.7	29.7	1.8	4.3	22.6	2.0	4.9	18.6	2.3	5.4	15.9	2.4	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-12 Parabolic Diversion Design Chart (Retardance "D" and "C", Grade 2.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.9	0.9	1.5																								
10	12.4	0.8	1.5	8.1	0.9	2.0	5.9	1.0	2.5																		
15	18.5	0.8	1.5	12.3	0.9	2.0	9.3	1.0	2.5	6.8	1.1	3.0	4.7	1.4	3.5												
20	24.7	0.8	1.5	16.7	0.9	2.0	12.5	1.0	2.5	9.4	1.1	3.0	7.0	1.2	3.6	4.7	1.5	4.1									
25	30.8	0.8	1.5	20.8	0.9	2.0	15.9	1.0	2.4	11.8	1.1	3.0	9.0	1.2	3.5	6.8	1.3	4.1									
30	37.0	0.8	1.5	25.0	0.9	2.0	19.0	1.0	2.5	14.3	1.1	3.0	11.0	1.2	3.5	8.5	1.3	4.1	6.4	1.5	4.7						
35	43.2	0.8	1.5	29.1	0.9	2.0	22.2	1.0	2.5	16.9	1.0	3.0	12.9	1.1	3.5	10.1	1.3	4.1	7.8	1.4	4.7						
40	49.3	0.8	1.5	33.3	0.9	2.0	25.3	1.0	2.5	19.3	1.0	3.0	14.8	1.1	3.5	11.6	1.3	4.1	9.1	1.4	4.7	7.1	1.6	5.2			
45	55.5	0.8	1.5	37.4	0.9	2.0	28.5	1.0	2.5	21.7	1.0	3.0	16.7	1.1	3.5	13.1	1.3	4.1	10.4	1.4	4.7	8.2	1.6	5.2			
50	61.7	0.8	1.5	41.6	0.9	2.0	31.7	1.0	2.5	24.1	1.0	3.0	18.8	1.1	3.5	14.7	1.2	4.1	11.7	1.4	4.7	9.3	1.5	5.3	7.1	1.8	5.8
55	67.8	0.8	1.5	45.7	0.9	2.0	34.8	1.0	2.5	26.5	1.0	3.0	20.7	1.1	3.5	16.2	1.2	4.1	12.9	1.4	4.7	10.4	1.5	5.3	8.2	1.7	5.8
60	74.0	0.8	1.5	49.9	0.9	2.0	38.0	1.0	2.5	28.9	1.0	3.0	22.6	1.1	3.5	17.7	1.2	4.1	14.1	1.4	4.7	11.4	1.5	5.3	9.2	1.7	5.8
65	80.2	0.8	1.5	54.0	0.9	2.0	41.1	1.0	2.5	31.4	1.0	3.0	24.5	1.1	3.5	19.5	1.2	4.1	15.4	1.3	4.7	12.4	1.5	5.3	10.1	1.7	5.8
70	86.3	0.8	1.5	58.2	0.9	2.0	44.3	1.0	2.5	33.8	1.0	3.0	26.3	1.1	3.5	21.0	1.2	4.1	16.6	1.3	4.7	13.5	1.5	5.3	11.0	1.6	5.8
75	92.5	0.8	1.5	62.3	0.9	2.0	47.5	1.0	2.5	36.2	1.0	3.0	28.2	1.1	3.5	22.4	1.2	4.1	17.8	1.3	4.7	14.5	1.5	5.3	11.8	1.6	5.8
80	98.7	0.8	1.5	66.5	0.9	2.0	50.6	1.0	2.5	38.6	1.0	3.0	30.1	1.1	3.5	23.9	1.2	4.1	19.0	1.3	4.7	15.5	1.5	5.3	12.7	1.6	5.8
85	104.8	0.8	1.5	70.6	0.9	2.0	53.8	1.0	2.5	41.0	1.0	3.0	32.0	1.1	3.5	25.4	1.2	4.1	20.3	1.3	4.7	16.5	1.5	5.3	13.6	1.6	5.8
90	111.0	0.8	1.5	74.8	0.9	2.0	57.0	1.0	2.5	43.4	1.0	3.0	33.8	1.1	3.5	26.9	1.2	4.1	21.8	1.3	4.6	17.5	1.5	5.3	14.4	1.6	5.8
95	117.2	0.8	1.5	78.9	0.9	2.0	60.1	1.0	2.5	45.8	1.0	3.0	35.7	1.1	3.5	28.4	1.2	4.1	23.0	1.3	4.6	18.6	1.5	5.3	15.3	1.6	5.8
100	123.3	0.8	1.5	83.1	0.9	2.0	63.3	1.0	2.5	48.2	1.0	3.0	37.6	1.1	3.5	29.9	1.2	4.1	24.2	1.3	4.6	19.6	1.5	5.3	16.2	1.6	5.8
105	129.5	0.8	1.5	87.3	0.9	2.0	66.4	1.0	2.5	50.6	1.0	3.0	39.5	1.1	3.5	31.4	1.2	4.1	25.4	1.3	4.6	20.6	1.5	5.3	17.0	1.6	5.8
110	135.7	0.8	1.5	91.4	0.9	2.0	69.6	1.0	2.5	53.0	1.0	3.0	41.3	1.1	3.5	32.9	1.2	4.1	26.6	1.3	4.7	21.6	1.4	5.3	17.9	1.6	5.8
115	141.8	0.8	1.5	95.6	0.9	2.0	72.8	1.0	2.5	55.4	1.0	3.0	43.2	1.1	3.5	34.4	1.2	4.1	27.9	1.3	4.7	22.6	1.4	5.3	18.7	1.6	5.8
120	148.0	0.8	1.5	99.7	0.9	2.0	75.9	1.0	2.5	57.9	1.0	3.0	45.1	1.1	3.5	35.9	1.2	4.1	29.1	1.3	4.7	23.9	1.4	5.2	19.5	1.6	5.8
125	154.1	0.8	1.5	103.9	0.9	2.0	79.1	1.0	2.5	60.3	1.0	3.0	47.0	1.1	3.5	37.4	1.2	4.1	30.3	1.3	4.7	24.8	1.4	5.2	20.4	1.6	5.8
130	160.3	0.8	1.5	108.0	0.9	2.0	82.3	1.0	2.5	62.7	1.0	3.0	48.8	1.1	3.5	38.9	1.2	4.1	31.5	1.3	4.7	25.8	1.4	5.3	21.2	1.6	5.8
135	166.5	0.8	1.5	112.2	0.9	2.0	85.4	1.0	2.5	65.1	1.0	3.0	50.7	1.1	3.5	40.3	1.2	4.1	32.7	1.3	4.7	26.8	1.4	5.3	22.1	1.6	5.8
140	172.6	0.8	1.5	116.3	0.9	2.0	88.6	1.0	2.5	67.5	1.0	3.0	52.6	1.1	3.5	41.8	1.2	4.1	33.9	1.3	4.7	27.8	1.4	5.3	22.9	1.6	5.8
145	178.8	0.8	1.5	120.5	0.9	2.0	91.8	1.0	2.5	69.9	1.0	3.0	54.5	1.1	3.5	43.3	1.2	4.1	35.1	1.3	4.7	28.8	1.4	5.3	23.7	1.6	5.8
150	185.0	0.8	1.5	124.6	0.9	2.0	94.9	1.0	2.5	72.3	1.0	3.0	56.4	1.1	3.5	44.8	1.2	4.1	36.3	1.3	4.7	29.8	1.4	5.3	24.6	1.6	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-13 Parabolic Diversion Design Chart (Retardance “D” and “C”, Grade 4.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	8.5	0.6	1.4	5.9	0.7	1.8	4.1	0.8	2.3																		
10	17.2	0.6	1.4	12.1	0.7	1.8	8.8	0.7	2.3	6.7	0.8	2.8	5.2	0.9	3.3	3.8	1.0	3.9									
15	25.8	0.6	1.4	18.1	0.7	1.8	13.4	0.7	2.3	10.3	0.8	2.8	8.1	0.8	3.4	6.4	0.9	3.9	4.9	1.0	4.5						
20	34.4	0.6	1.4	24.2	0.7	1.8	17.8	0.7	2.3	13.9	0.8	2.8	10.9	0.8	3.4	8.7	0.9	3.9	6.9	1.0	4.5	5.5	1.1	5.0			
25	43.0	0.6	1.4	30.2	0.7	1.9	22.3	0.7	2.3	17.4	0.8	2.8	13.8	0.8	3.3	10.9	0.9	3.9	8.8	1.0	4.5	7.1	1.0	5.1	5.7	1.2	5.6
30	51.6	0.6	1.4	36.3	0.7	1.9	26.7	0.7	2.3	20.8	0.8	2.8	16.5	0.8	3.3	13.2	0.9	3.9	10.7	0.9	4.5	8.7	1.0	5.1	7.1	1.1	5.6
35	60.2	0.6	1.4	42.3	0.7	1.9	31.1	0.7	2.3	24.3	0.8	2.8	19.3	0.8	3.4	15.6	0.9	3.9	12.5	0.9	4.5	10.3	1.0	5.0	8.4	1.1	5.6
40	68.8	0.6	1.4	48.3	0.7	1.9	35.6	0.7	2.3	27.8	0.8	2.8	22.0	0.8	3.4	17.8	0.9	3.9	14.4	0.9	4.5	11.8	1.0	5.0	9.8	1.1	5.7
45	77.4	0.6	1.4	54.4	0.7	1.9	40.0	0.7	2.4	31.2	0.8	2.8	24.8	0.8	3.4	20.0	0.9	3.9	16.4	0.9	4.4	13.3	1.0	5.0	11.1	1.1	5.7
50	86.0	0.6	1.4	60.4	0.7	1.9	44.5	0.7	2.4	34.7	0.8	2.8	27.5	0.8	3.4	22.2	0.9	3.9	18.2	0.9	4.4	14.9	1.0	5.0	12.3	1.1	5.7
55	94.6	0.6	1.4	66.5	0.7	1.9	48.9	0.7	2.4	38.2	0.8	2.8	30.3	0.8	3.4	24.4	0.9	3.9	20.0	0.9	4.4	16.6	1.0	5.0	13.6	1.1	5.7
60	103.2	0.6	1.4	72.5	0.7	1.9	53.4	0.7	2.4	41.7	0.8	2.8	33.0	0.8	3.4	26.6	0.9	3.9	21.8	0.9	4.5	18.1	1.0	5.0	14.9	1.1	5.7
65	111.8	0.6	1.4	78.5	0.7	1.9	57.8	0.7	2.4	45.1	0.8	2.8	35.8	0.8	3.4	28.9	0.9	3.9	23.6	0.9	4.5	19.6	1.0	5.0	16.2	1.1	5.7
70	120.4	0.6	1.4	84.6	0.7	1.9	62.3	0.7	2.4	48.6	0.8	2.8	38.6	0.8	3.4	31.1	0.9	3.9	25.4	0.9	4.5	21.1	1.0	5.0	17.7	1.1	5.6
75	129.0	0.6	1.4	90.6	0.7	1.9	66.7	0.7	2.4	52.1	0.8	2.8	41.3	0.8	3.4	33.3	0.9	3.9	27.2	0.9	4.5	22.6	1.0	5.0	19.0	1.1	5.6
80	137.6	0.6	1.4	96.7	0.7	1.9	71.2	0.7	2.4	55.5	0.8	2.8	44.1	0.8	3.4	35.5	0.9	3.9	29.1	0.9	4.5	24.1	1.0	5.0	20.2	1.1	5.6
85	146.2	0.6	1.4	102.7	0.7	1.9	75.6	0.7	2.4	59.0	0.8	2.8	46.8	0.8	3.4	37.7	0.9	3.9	30.9	0.9	4.5	25.6	1.0	5.0	21.5	1.1	5.6
90	154.8	0.6	1.4	108.7	0.7	1.9	80.0	0.7	2.4	62.5	0.8	2.8	49.6	0.8	3.4	39.9	0.9	3.9	32.7	0.9	4.5	27.1	1.0	5.0	22.8	1.1	5.6
95	163.4	0.6	1.4	114.8	0.7	1.9	84.5	0.7	2.4	65.9	0.8	2.8	52.3	0.8	3.4	42.2	0.9	3.9	34.5	0.9	4.5	28.6	1.0	5.0	24.0	1.1	5.6
100	172.0	0.6	1.4	120.8	0.7	1.9	88.9	0.7	2.4	69.4	0.8	2.8	55.1	0.8	3.4	44.4	0.9	3.9	36.3	0.9	4.5	30.1	1.0	5.0	25.3	1.1	5.6
105	180.6	0.6	1.4	126.9	0.7	1.9	93.4	0.7	2.4	72.9	0.8	2.8	57.8	0.8	3.4	46.6	0.9	3.9	38.1	0.9	4.5	31.6	1.0	5.0	26.5	1.1	5.6
110	189.2	0.6	1.4	132.9	0.7	1.9	97.8	0.7	2.4	76.3	0.8	2.8	60.6	0.8	3.4	48.8	0.9	3.9	39.9	0.9	4.5	33.1	1.0	5.0	27.8	1.1	5.6
115	197.8	0.6	1.4	138.9	0.7	1.9	102.3	0.7	2.4	79.8	0.8	2.8	63.3	0.8	3.4	51.0	0.9	3.9	41.7	0.9	4.5	34.6	1.0	5.0	29.0	1.1	5.6
120	206.4	0.6	1.4	145.0	0.7	1.9	106.7	0.7	2.4	83.3	0.8	2.8	66.1	0.8	3.4	53.3	0.9	3.9	43.6	0.9	4.5	36.1	1.0	5.0	30.2	1.1	5.7
125	215.0	0.6	1.4	151.0	0.7	1.9	111.2	0.7	2.4	86.8	0.8	2.8	68.8	0.8	3.4	55.5	0.9	3.9	45.4	0.9	4.5	37.6	1.0	5.0	31.5	1.1	5.7
130	223.7	0.6	1.4	157.1	0.7	1.9	115.6	0.7	2.4	90.2	0.8	2.8	71.6	0.8	3.4	57.7	0.9	3.9	47.2	0.9	4.5	39.1	1.0	5.0	32.7	1.1	5.7
135	232.3	0.6	1.4	163.1	0.7	1.9	120.1	0.7	2.4	93.7	0.8	2.8	74.3	0.8	3.4	59.9	0.9	3.9	49.0	0.9	4.5	40.6	1.0	5.0	34.0	1.1	5.7
140	240.9	0.6	1.4	169.1	0.7	1.9	124.5	0.7	2.4	97.2	0.8	2.8	77.1	0.8	3.4	62.1	0.9	3.9	50.8	0.9	4.5	42.1	1.0	5.0	35.2	1.1	5.7
145	249.5	0.6	1.4	175.2	0.7	1.9	129.0	0.7	2.4	100.6	0.8	2.8	79.8	0.8	3.4	64.3	0.9	3.9	52.6	0.9	4.5	43.6	1.0	5.0	36.5	1.1	5.7
150	258.1	0.6	1.4	181.2	0.7	1.9	133.4	0.7	2.4	104.1	0.8	2.8	82.6	0.8	3.4	66.6	0.9	3.9	54.4	0.9	4.5	45.1	1.0	5.0	37.8	1.1	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-14 Parabolic Diversion Design Chart (Retardance "D" and "C", Grade 6.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.6	0.5	1.3	7.3	0.6	1.8	5.3	0.6	2.3	4.0	0.7	2.8	2.9	0.8	3.2												
10	21.1	0.5	1.3	14.7	0.6	1.8	10.9	0.6	2.3	8.4	0.7	2.8	6.6	0.7	3.2	5.3	0.8	3.8	4.2	0.8	4.3						
15	31.6	0.5	1.3	22.1	0.6	1.8	16.3	0.6	2.3	12.7	0.6	2.7	10.1	0.7	3.3	8.2	0.7	3.8	6.6	0.8	4.3	5.4	0.9	4.9	4.3	1.0	5.5
20	42.1	0.5	1.3	29.5	0.6	1.8	21.7	0.6	2.3	17.0	0.6	2.7	13.6	0.7	3.2	11.1	0.7	3.7	9.0	0.8	4.3	7.4	0.8	4.9	6.1	0.9	5.5
25	52.7	0.5	1.3	36.8	0.6	1.8	27.1	0.6	2.3	21.2	0.6	2.8	17.0	0.7	3.2	13.9	0.7	3.8	11.3	0.8	4.3	9.3	0.8	4.9	7.8	0.9	5.5
30	63.2	0.5	1.3	44.2	0.6	1.8	32.5	0.6	2.3	25.4	0.6	2.8	20.4	0.7	3.2	16.6	0.7	3.8	13.7	0.8	4.3	11.3	0.8	4.9	9.4	0.9	5.5
35	73.7	0.5	1.3	51.6	0.6	1.8	38.0	0.6	2.3	29.7	0.6	2.8	23.8	0.7	3.2	19.4	0.7	3.8	16.0	0.8	4.3	13.4	0.8	4.9	11.1	0.9	5.5
40	84.2	0.5	1.3	58.9	0.6	1.8	43.4	0.6	2.3	33.9	0.6	2.8	27.2	0.7	3.3	22.2	0.7	3.8	18.3	0.8	4.3	15.3	0.8	4.9	12.7	0.9	5.5
45	94.8	0.5	1.3	66.3	0.6	1.8	48.8	0.6	2.3	38.2	0.6	2.8	30.7	0.7	3.3	24.9	0.7	3.8	20.6	0.8	4.3	17.2	0.8	4.9	14.5	0.9	5.4
50	105.3	0.5	1.3	73.6	0.6	1.8	54.2	0.6	2.3	42.4	0.6	2.8	34.1	0.7	3.3	27.7	0.7	3.8	22.8	0.8	4.3	19.1	0.8	4.9	16.1	0.9	5.4
55	115.8	0.5	1.3	81.0	0.6	1.8	59.7	0.6	2.3	46.6	0.6	2.8	37.5	0.7	3.3	30.5	0.7	3.8	25.1	0.8	4.3	21.0	0.8	4.9	17.7	0.9	5.4
60	126.4	0.5	1.3	88.4	0.6	1.8	65.1	0.6	2.3	50.9	0.6	2.8	40.9	0.7	3.3	33.3	0.7	3.8	27.4	0.8	4.3	22.9	0.8	4.9	19.3	0.9	5.4
65	136.9	0.5	1.3	95.7	0.6	1.8	70.5	0.6	2.3	55.1	0.6	2.8	44.3	0.7	3.3	36.0	0.7	3.8	29.7	0.8	4.3	24.8	0.8	4.9	20.9	0.9	5.4
70	147.4	0.5	1.3	103.1	0.6	1.8	75.9	0.6	2.3	59.3	0.6	2.8	47.7	0.7	3.3	38.8	0.7	3.8	32.0	0.8	4.3	26.7	0.8	4.9	22.5	0.9	5.4
75	158.0	0.5	1.3	110.5	0.6	1.8	81.3	0.6	2.3	63.6	0.6	2.8	51.1	0.7	3.3	41.6	0.7	3.8	34.3	0.8	4.3	28.6	0.8	4.9	24.1	0.9	5.4
80	168.5	0.5	1.3	117.8	0.6	1.8	86.8	0.6	2.3	67.8	0.6	2.8	54.5	0.7	3.3	44.3	0.7	3.8	36.5	0.8	4.3	30.5	0.8	4.9	25.7	0.9	5.5
85	179.0	0.5	1.3	125.2	0.6	1.8	92.2	0.6	2.3	72.0	0.6	2.8	57.9	0.7	3.3	47.1	0.7	3.8	38.8	0.8	4.3	32.4	0.8	4.9	27.3	0.9	5.5
90	189.6	0.5	1.3	132.6	0.6	1.8	97.6	0.6	2.3	76.3	0.6	2.8	61.3	0.7	3.3	49.9	0.7	3.8	41.1	0.8	4.3	34.3	0.8	4.9	28.9	0.9	5.5
95	200.1	0.5	1.3	139.9	0.6	1.8	103.0	0.6	2.3	80.5	0.6	2.8	64.7	0.7	3.3	52.6	0.7	3.8	43.4	0.8	4.3	36.2	0.8	4.9	30.5	0.9	5.5
100	210.6	0.5	1.3	147.3	0.6	1.8	108.5	0.6	2.3	84.8	0.6	2.8	68.1	0.7	3.3	55.4	0.7	3.8	45.7	0.8	4.3	38.1	0.8	4.9	32.1	0.9	5.5
105	221.1	0.5	1.3	154.6	0.6	1.8	113.9	0.6	2.3	89.0	0.6	2.8	71.5	0.7	3.3	58.2	0.7	3.8	47.9	0.8	4.3	40.0	0.8	4.9	33.7	0.9	5.5
110	231.7	0.5	1.3	162.0	0.6	1.8	119.3	0.6	2.3	93.2	0.6	2.8	74.9	0.7	3.3	60.9	0.7	3.8	50.2	0.8	4.3	41.9	0.8	4.9	35.3	0.9	5.5
115	242.2	0.5	1.3	169.4	0.6	1.8	124.7	0.6	2.3	97.5	0.6	2.8	78.3	0.7	3.3	63.7	0.7	3.8	52.5	0.8	4.3	43.8	0.8	4.9	36.9	0.9	5.5
120	252.7	0.5	1.3	176.7	0.6	1.8	130.2	0.6	2.3	101.7	0.6	2.8	81.7	0.7	3.3	66.5	0.7	3.8	54.8	0.8	4.3	45.7	0.8	4.9	38.5	0.9	5.5
125	263.3	0.5	1.3	184.1	0.6	1.8	135.6	0.6	2.3	106.0	0.6	2.8	85.1	0.7	3.3	69.3	0.7	3.8	57.1	0.8	4.3	47.6	0.8	4.9	40.1	0.9	5.5
130	273.8	0.5	1.3	191.5	0.6	1.8	141.0	0.6	2.3	110.2	0.6	2.8	88.5	0.7	3.3	72.0	0.7	3.8	59.4	0.8	4.3	49.5	0.8	4.9	41.7	0.9	5.5
135	284.3	0.5	1.3	198.8	0.6	1.8	146.4	0.6	2.3	114.4	0.6	2.8	91.9	0.7	3.3	74.8	0.7	3.8	61.6	0.8	4.3	51.4	0.8	4.9	43.3	0.9	5.5
140	294.9	0.5	1.3	206.2	0.6	1.8	151.8	0.6	2.3	118.7	0.6	2.8	95.3	0.7	3.3	77.6	0.7	3.8	63.9	0.8	4.3	53.3	0.8	4.9	44.9	0.9	5.5
145	305.4	0.5	1.3	213.6	0.6	1.8	157.3	0.6	2.3	122.9	0.6	2.8	98.7	0.7	3.3	80.3	0.7	3.8	66.2	0.8	4.3	55.2	0.8	4.9	46.5	0.9	5.5
150	315.9	0.5	1.3	220.9	0.6	1.8	162.7	0.6	2.3	127.1	0.6	2.8	102.1	0.7	3.3	83.1	0.7	3.8	68.5	0.8	4.3	57.1	0.8	4.9	48.1	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table DV-15 Parabolic Diversion Design Chart (Retardance “D” and “C”, Grade 8.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH' (D), AND V2 FOR RETARDANCE "C"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.0	0.5	1.3	8.5	0.5	1.7	6.2	0.5	2.2	4.6	0.6	2.7	3.7	0.6	3.2	2.9	0.7	3.6									
10	24.1	0.5	1.3	16.9	0.5	1.7	12.6	0.5	2.2	9.6	0.6	2.7	7.8	0.6	3.2	6.3	0.6	3.7	5.1	0.7	4.2	4.2	0.8	4.8	3.2	0.9	5.3
15	36.1	0.5	1.3	25.3	0.5	1.7	18.9	0.5	2.2	14.4	0.6	2.7	11.8	0.6	3.2	9.7	0.6	3.7	7.9	0.7	4.2	6.5	0.7	4.8	5.4	0.8	5.3
20	48.1	0.5	1.3	33.8	0.5	1.7	25.2	0.5	2.2	19.2	0.6	2.7	15.8	0.6	3.2	12.9	0.6	3.7	10.7	0.7	4.2	8.8	0.7	4.8	7.4	0.8	5.3
25	60.1	0.5	1.3	42.2	0.5	1.7	31.5	0.5	2.2	24.0	0.6	2.7	19.7	0.6	3.2	16.2	0.6	3.7	13.4	0.7	4.2	11.2	0.7	4.7	9.3	0.8	5.3
30	72.1	0.5	1.3	50.6	0.5	1.7	37.8	0.5	2.2	28.8	0.6	2.7	23.6	0.6	3.2	19.4	0.6	3.7	16.1	0.7	4.2	13.5	0.7	4.8	11.3	0.7	5.3
35	84.1	0.5	1.3	59.1	0.5	1.7	44.1	0.5	2.2	33.6	0.6	2.7	27.6	0.6	3.2	22.6	0.6	3.7	18.7	0.7	4.2	15.7	0.7	4.8	13.3	0.7	5.3
40	96.2	0.5	1.3	67.5	0.5	1.7	50.4	0.5	2.2	38.4	0.6	2.7	31.5	0.6	3.2	25.8	0.6	3.7	21.4	0.7	4.2	17.9	0.7	4.8	15.2	0.7	5.3
45	108.2	0.5	1.3	76.0	0.5	1.7	56.7	0.5	2.2	43.2	0.6	2.7	35.4	0.6	3.2	29.0	0.6	3.7	24.1	0.7	4.2	20.2	0.7	4.8	17.1	0.7	5.3
50	120.2	0.5	1.3	84.4	0.5	1.7	63.0	0.5	2.2	48.0	0.6	2.7	39.4	0.6	3.2	32.3	0.6	3.7	26.8	0.7	4.2	22.4	0.7	4.8	19.0	0.7	5.3
55	132.2	0.5	1.3	92.8	0.5	1.7	69.3	0.5	2.2	52.8	0.6	2.7	43.3	0.6	3.2	35.5	0.6	3.7	29.4	0.7	4.2	24.7	0.7	4.8	20.9	0.7	5.3
60	144.2	0.5	1.3	101.3	0.5	1.7	75.6	0.5	2.2	57.6	0.6	2.7	47.2	0.6	3.2	38.7	0.6	3.7	32.1	0.7	4.2	26.9	0.7	4.8	22.8	0.7	5.3
65	156.3	0.5	1.3	109.7	0.5	1.7	81.8	0.5	2.2	62.4	0.6	2.7	51.2	0.6	3.2	41.9	0.6	3.7	34.8	0.7	4.2	29.1	0.7	4.8	24.7	0.7	5.3
70	168.3	0.5	1.3	118.2	0.5	1.7	88.1	0.5	2.2	67.2	0.6	2.7	55.1	0.6	3.2	45.2	0.6	3.7	37.5	0.7	4.2	31.4	0.7	4.8	26.6	0.7	5.3
75	180.3	0.5	1.3	126.6	0.5	1.7	94.4	0.5	2.2	72.0	0.6	2.7	59.0	0.6	3.2	48.4	0.6	3.7	40.1	0.7	4.2	33.6	0.7	4.8	28.5	0.7	5.3
80	192.3	0.5	1.3	135.0	0.5	1.7	100.7	0.5	2.2	76.8	0.6	2.7	63.0	0.6	3.2	51.6	0.6	3.7	42.8	0.7	4.2	35.9	0.7	4.8	30.3	0.7	5.3
85	204.3	0.5	1.3	143.5	0.5	1.7	107.0	0.5	2.2	81.6	0.6	2.7	66.9	0.6	3.2	54.9	0.6	3.7	45.5	0.7	4.2	38.1	0.7	4.8	32.2	0.7	5.3
90	216.4	0.5	1.3	151.9	0.5	1.7	113.3	0.5	2.2	86.4	0.6	2.7	70.8	0.6	3.2	58.1	0.6	3.7	48.1	0.7	4.2	40.3	0.7	4.8	34.1	0.7	5.3
95	228.4	0.5	1.3	160.3	0.5	1.7	119.6	0.5	2.2	91.2	0.6	2.7	74.8	0.6	3.2	61.3	0.6	3.7	50.8	0.7	4.2	42.6	0.7	4.8	36.0	0.7	5.3
100	240.4	0.5	1.3	168.8	0.5	1.7	125.9	0.5	2.2	96.0	0.6	2.7	78.7	0.6	3.2	64.5	0.6	3.7	53.5	0.7	4.2	44.8	0.7	4.8	37.9	0.7	5.3
105	252.4	0.5	1.3	177.2	0.5	1.7	132.2	0.5	2.2	100.8	0.6	2.7	82.6	0.6	3.2	67.8	0.6	3.7	56.2	0.7	4.2	47.1	0.7	4.8	39.8	0.7	5.3
110	264.4	0.5	1.3	185.7	0.5	1.7	138.5	0.5	2.2	105.6	0.6	2.7	86.6	0.6	3.2	71.0	0.6	3.7	58.8	0.7	4.2	49.3	0.7	4.8	41.7	0.7	5.3
115	276.5	0.5	1.3	194.1	0.5	1.7	144.8	0.5	2.2	110.4	0.6	2.7	90.5	0.6	3.2	74.2	0.6	3.7	61.5	0.7	4.2	51.5	0.7	4.8	43.6	0.7	5.3
120	288.5	0.5	1.3	202.5	0.5	1.7	151.1	0.5	2.2	115.2	0.6	2.7	94.4	0.6	3.2	77.4	0.6	3.7	64.2	0.7	4.2	53.8	0.7	4.8	45.5	0.7	5.3
125	300.5	0.5	1.3	211.0	0.5	1.7	157.4	0.5	2.2	120.0	0.6	2.7	98.4	0.6	3.2	80.7	0.6	3.7	66.9	0.7	4.2	56.0	0.7	4.8	47.4	0.7	5.3
130	312.5	0.5	1.3	219.4	0.5	1.7	163.7	0.5	2.2	124.8	0.6	2.7	102.3	0.6	3.2	83.9	0.6	3.7	69.5	0.7	4.2	58.3	0.7	4.8	49.3	0.7	5.3
135	324.5	0.5	1.3	227.9	0.5	1.7	170.0	0.5	2.2	129.6	0.6	2.7	106.2	0.6	3.2	87.1	0.6	3.7	72.2	0.7	4.2	60.5	0.7	4.8	51.2	0.7	5.3
140	336.6	0.5	1.3	236.3	0.5	1.7	176.3	0.5	2.2	134.4	0.6	2.7	110.2	0.6	3.2	90.3	0.6	3.7	74.9	0.7	4.2	62.7	0.7	4.8	53.1	0.7	5.3
145	348.6	0.5	1.3	244.7	0.5	1.7	182.6	0.5	2.2	139.2	0.6	2.7	114.1	0.6	3.2	93.6	0.6	3.7	77.6	0.7	4.2	65.0	0.7	4.8	55.0	0.7	5.3
150	360.6	0.5	1.3	253.2	0.5	1.7	188.9	0.5	2.2	144.0	0.6	2.7	118.0	0.6	3.2	96.8	0.6	3.7	80.2	0.7	4.2	67.2	0.7	4.8	56.9	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second
Depth "D" does not include allowance for freeboard or settlement

Table DV-16 Parabolic Diversion Design Chart (Retardance “D” and “C”, Grade 10.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	13.3	0.4	1.3	9.4	0.5	1.7	6.8	0.5	2.2	5.3	0.5	2.6	4.1	0.6	3.2	3.4	0.6	3.6	2.6	0.7	4.1						
10	26.6	0.4	1.3	18.7	0.5	1.7	13.8	0.5	2.2	10.9	0.5	2.6	8.5	0.6	3.2	7.1	0.6	3.6	5.9	0.6	4.1	4.9	0.7	4.7	4.0	0.7	5.3
15	39.9	0.4	1.3	28.0	0.5	1.7	20.7	0.5	2.2	16.3	0.5	2.6	12.8	0.6	3.2	10.9	0.6	3.6	9.0	0.6	4.1	7.5	0.6	4.7	6.3	0.7	5.2
20	53.2	0.4	1.3	37.4	0.5	1.7	27.6	0.5	2.2	21.7	0.5	2.7	17.0	0.6	3.2	14.5	0.6	3.6	12.1	0.6	4.1	10.2	0.6	4.6	8.5	0.7	5.2
25	66.5	0.4	1.3	46.7	0.5	1.7	34.5	0.5	2.2	27.1	0.5	2.7	21.3	0.6	3.2	18.1	0.6	3.6	15.1	0.6	4.1	12.7	0.6	4.7	10.8	0.7	5.2
30	79.8	0.4	1.3	56.1	0.5	1.7	41.4	0.5	2.2	32.5	0.5	2.7	25.5	0.6	3.2	21.7	0.6	3.6	18.1	0.6	4.1	15.2	0.6	4.7	12.9	0.7	5.2
35	93.1	0.4	1.3	65.4	0.5	1.7	48.3	0.5	2.2	37.9	0.5	2.7	29.8	0.6	3.2	25.3	0.6	3.6	21.1	0.6	4.1	17.8	0.6	4.7	15.1	0.7	5.2
40	106.4	0.4	1.3	74.7	0.5	1.7	55.2	0.5	2.2	43.3	0.5	2.7	34.0	0.6	3.2	29.0	0.6	3.6	24.1	0.6	4.1	20.3	0.6	4.7	17.2	0.7	5.2
45	119.7	0.4	1.3	84.1	0.5	1.7	62.1	0.5	2.2	48.8	0.5	2.7	38.3	0.6	3.2	32.6	0.6	3.6	27.2	0.6	4.1	22.8	0.6	4.7	19.4	0.7	5.2
50	133.0	0.4	1.3	93.4	0.5	1.7	69.0	0.5	2.2	54.2	0.5	2.7	42.5	0.6	3.2	36.2	0.6	3.6	30.2	0.6	4.1	25.4	0.6	4.7	21.5	0.7	5.2
55	146.3	0.4	1.3	102.8	0.5	1.7	75.9	0.5	2.2	59.6	0.5	2.7	46.8	0.6	3.2	39.8	0.6	3.6	33.2	0.6	4.1	27.9	0.6	4.7	23.7	0.7	5.2
60	159.6	0.4	1.3	112.1	0.5	1.7	82.8	0.5	2.2	65.0	0.5	2.7	51.0	0.6	3.2	43.4	0.6	3.6	36.2	0.6	4.1	30.5	0.6	4.7	25.9	0.7	5.2
65	172.9	0.4	1.3	121.4	0.5	1.7	89.7	0.5	2.2	70.4	0.5	2.7	55.3	0.6	3.2	47.1	0.6	3.6	39.2	0.6	4.1	33.0	0.6	4.7	28.0	0.7	5.2
70	186.2	0.4	1.3	130.8	0.5	1.7	96.6	0.5	2.2	75.8	0.5	2.7	59.5	0.6	3.2	50.7	0.6	3.6	42.2	0.6	4.1	35.5	0.6	4.7	30.2	0.7	5.2
75	199.5	0.4	1.3	140.1	0.5	1.7	103.5	0.5	2.2	81.2	0.5	2.7	63.8	0.6	3.2	54.3	0.6	3.6	45.2	0.6	4.1	38.1	0.6	4.7	32.3	0.7	5.2
80	212.8	0.4	1.3	149.5	0.5	1.7	110.5	0.5	2.2	86.7	0.5	2.7	68.0	0.6	3.2	57.9	0.6	3.6	48.3	0.6	4.1	40.6	0.6	4.7	34.5	0.7	5.2
85	226.1	0.4	1.3	158.8	0.5	1.7	117.4	0.5	2.2	92.1	0.5	2.7	72.3	0.6	3.2	61.5	0.6	3.6	51.3	0.6	4.1	43.1	0.6	4.7	36.6	0.7	5.2
90	239.4	0.4	1.3	168.1	0.5	1.7	124.3	0.5	2.2	97.5	0.5	2.7	76.5	0.6	3.2	65.2	0.6	3.6	54.3	0.6	4.1	45.7	0.6	4.7	38.8	0.7	5.2
95	252.7	0.4	1.3	177.5	0.5	1.7	131.2	0.5	2.2	102.9	0.5	2.7	80.8	0.6	3.2	68.8	0.6	3.6	57.3	0.6	4.1	48.2	0.6	4.7	40.9	0.7	5.2
100	266.0	0.4	1.3	186.8	0.5	1.7	138.1	0.5	2.2	108.3	0.5	2.7	85.0	0.6	3.2	72.4	0.6	3.6	60.3	0.6	4.1	50.7	0.6	4.7	43.1	0.7	5.2
105	279.3	0.4	1.3	196.2	0.5	1.7	145.0	0.5	2.2	113.7	0.5	2.7	89.3	0.6	3.2	76.0	0.6	3.6	63.3	0.6	4.1	53.3	0.6	4.7	45.2	0.7	5.2
110	292.6	0.4	1.3	205.5	0.5	1.7	151.9	0.5	2.2	119.2	0.5	2.7	93.5	0.6	3.2	79.6	0.6	3.6	66.4	0.6	4.1	55.8	0.6	4.7	47.4	0.7	5.2
115	305.9	0.4	1.3	214.9	0.5	1.7	158.8	0.5	2.2	124.6	0.5	2.7	97.8	0.6	3.2	83.3	0.6	3.6	69.4	0.6	4.1	58.3	0.6	4.7	49.5	0.7	5.3
120	319.2	0.4	1.3	224.2	0.5	1.7	165.7	0.5	2.2	130.0	0.5	2.7	102.0	0.6	3.2	86.9	0.6	3.6	72.4	0.6	4.1	60.9	0.6	4.7	51.7	0.7	5.3
125	332.5	0.4	1.3	233.5	0.5	1.7	172.6	0.5	2.2	135.4	0.5	2.7	106.3	0.6	3.2	90.5	0.6	3.6	75.4	0.6	4.1	63.4	0.6	4.7	53.8	0.7	5.3
130	345.8	0.4	1.3	242.9	0.5	1.7	179.5	0.5	2.2	140.8	0.5	2.7	110.5	0.6	3.2	94.1	0.6	3.6	78.4	0.6	4.1	66.0	0.6	4.7	56.0	0.7	5.3
135	359.1	0.4	1.3	252.2	0.5	1.7	186.4	0.5	2.2	146.2	0.5	2.7	114.8	0.6	3.2	97.7	0.6	3.6	81.4	0.6	4.1	68.5	0.6	4.7	58.1	0.7	5.3
140	372.4	0.4	1.3	261.6	0.5	1.7	193.3	0.5	2.2	151.7	0.5	2.7	119.0	0.6	3.2	101.3	0.6	3.6	84.4	0.6	4.1	71.0	0.6	4.7	60.3	0.7	5.3
145	385.7	0.4	1.3	270.9	0.5	1.7	200.2	0.5	2.2	157.1	0.5	2.7	123.3	0.6	3.2	105.0	0.6	3.6	87.5	0.6	4.1	73.6	0.6	4.7	62.5	0.7	5.3
150	399.0	0.4	1.3	280.2	0.5	1.7	207.1	0.5	2.2	162.5	0.5	2.7	127.5	0.6	3.2	108.6	0.6	3.6	90.5	0.6	4.1	76.1	0.6	4.7	64.6	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

This Page Intentionally Left Blank

Drop Structure (DS)

Practice Description

A drop structure is an erosion control structure created by construction of a barrier across a drainageway or installing a permanent manufactured product down a slope. The purpose of a drop structure is to convey concentrated flow storm runoff from the top to the bottom of a slope or to lower water from a grassed swale into an open channel such as an intermittent or perennial stream. This practice applies where other erosion control measures are insufficient to prevent excessive erosion and off-site sedimentation.

Planning Considerations

This practice applies to sites where earth and vegetation cannot safely handle water at permissible velocities, where excessive grades or overfall conditions are encountered, or where water is to be structurally lowered from one elevation to another. These structures should be planned and installed as a part of an overall surface water disposal system. This practice does not apply to storm sewers, concrete overfall structures, in channel grade control structures, or road culverts.

Design Criteria

Design and specifications shall be prepared for each structure on an individual job basis depending on its purpose and site conditions.

Capacity

The minimum design capacity for pipe structures shall be as required to pass the peak runoff expected from a 2 year frequency, 24 hour duration storm. Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.
- Natural Resources Conservation Service formerly Soil Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds.
- Other comparable methods.

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the pipe structures during the planned life of the structure.

All pipe structures should be designed as island type structures with an emergency spillway to safely pass storms larger than the structure design storm. The minimum total capacity of the principal and emergency spillways shall be that required to handle the 25-year 24-hour duration storm, or the peak rate of flow from the contributing structure, whichever is greater. The emergency spillway should be located at the end of the embankment on natural ground. It should not be placed over the earthfill embankment.

General

The planning and design of antivortex devices, trash racks and anti-seep collars should be in accordance with the requirements for principal spillway pipe design in the Sediment Basin practice. In lieu of anti-seep collars, a sand drainage diaphragm with a filter compatible outlet can be used. Outlet protection for pipes should be designed according to the Outlet Protection practice.

Straight pipe structures should be built in accordance with Figure DS-l.

Pipe drop structures should be built in accordance with Figure DS-2.

The crest elevation for the emergency spillway shall be set at the minimum level necessary to ensure full pipe flow of the principal spillway. The top of the settled embankment shall be based on 1 foot of freeboard above the design flow depth in the emergency spillway.

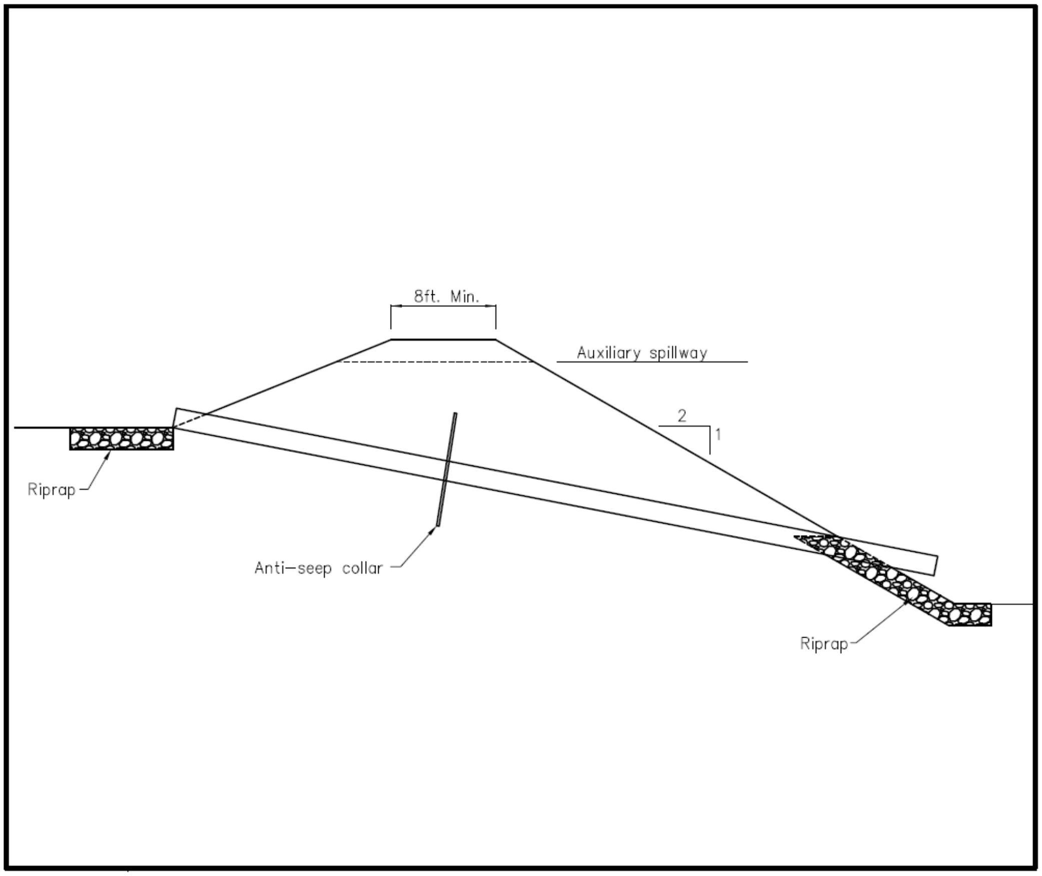


Figure DS-1 Straight Pipe Structure

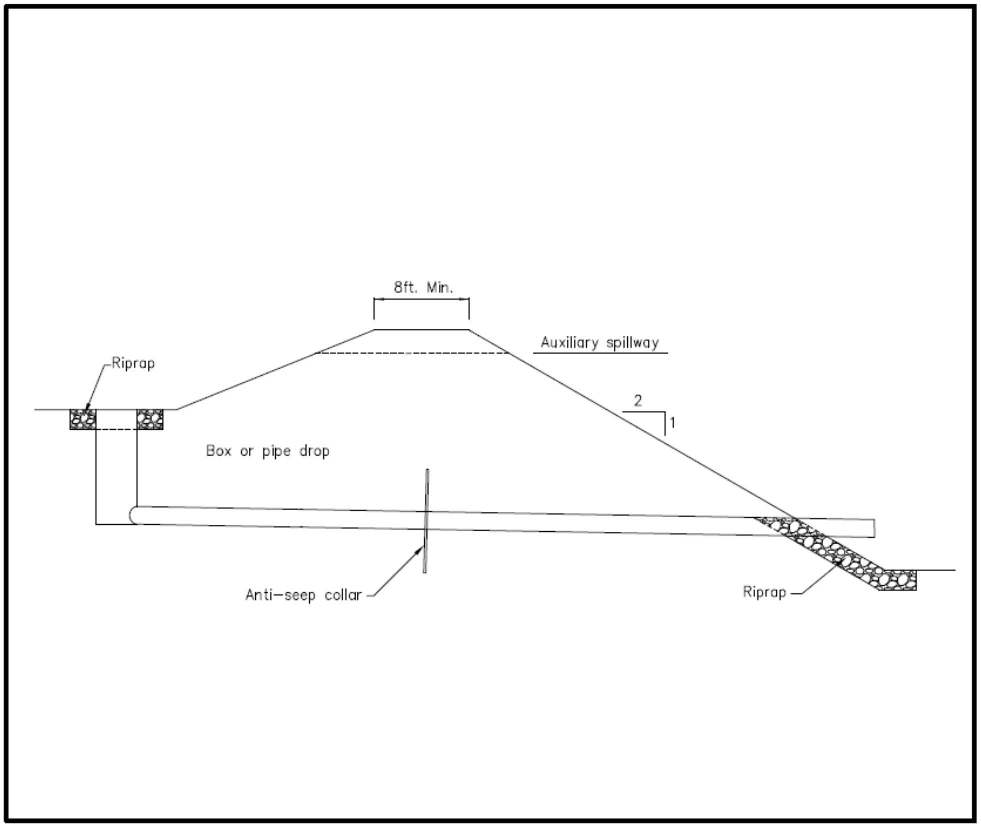


Figure DS-2 Pipe Drop Structure

Grass Swale (GS)

Practice Description

A grass swale is a natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff without causing damage to the channel by erosion. This practice applies to sites where concentrated runoff will cause erosion damage, a vegetative lining provides sufficient stability for the channel as designed, and space is available for a relatively large cross section. Typical situations where concentrated flow areas are addressed with a grass swale include roadside ditches, channels at property boundaries, outlets for diversions and other concentrated flow areas subject to channel erosion. Grassed swales are generally considered permanent structures but may be used as a temporary measure.

Planning Considerations

Grass swales should be carefully built to the design cross section, shape and dimensions. Swales are hydraulic structures and as such depend upon the hydraulic parameters to function satisfactorily. Vegetated swales should be well established before large flows are permitted in the channel.

The design of a channel cross section and lining is based primarily upon the volume and velocity of flow expected in the channel. This practice covers grassed swales with low velocity flows (generally less than 5 ft/sec). Where high velocities are anticipated lined swales should be used (see Lined Swale practice or Riprap-lined Swale practice). Lined swales should also be used where there is continuous flow in the swale, which would prevent establishment of vegetation within the flow area.

Besides the primary design considerations of capacity and velocity, a number of other important factors should be taken into account when selecting a cross section (Figure GS-1). These factors include land availability, compatibility with land use and surrounding environment, safety, maintenance requirements outlet conditions, etc.

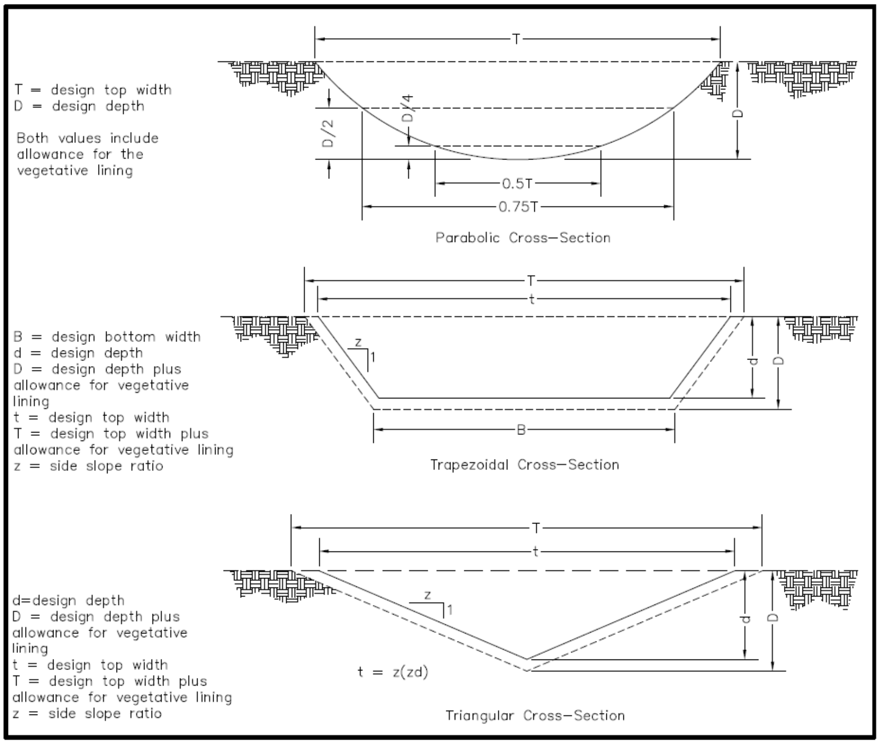


Figure GS-1 Typical Grass Swale Cross section

Triangular Shaped Ditches

Triangular shaped ditches are generally used where the quantity of water to be handled is relatively small, such as along roadsides. A triangular grass swale will suffice where velocities in the ditch are low.

Parabolic Channels

Parabolic channels are often used where the quantity of water to be handled is larger and where space is available for a wide, shallow channel with low velocity flow.

Trapezoidal Channels

Trapezoidal channels are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity. Trapezoidal ditches lined with concrete, riprap, or others similar materials are considered lined swales or riprap lined swales. In some cases, erosion control blankets (see Erosion Control Blanket practice) and high end hydraulic mulch (see Mulching practice) can be used to establish vegetation.

Other Considerations

Outlet conditions for all channels should be considered. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour at the outlet of the swale.

Grass swales should be protected from erosion by concentrated flows. The methods of protecting grass swales would include, but not be limited to the following:

- Vegetation.
- Biodegradable linings and vegetation.

The type and intensity of the protective linings will determine the design of the grass swale.

If velocities exceed stable velocities, for vegetated swales or vegetation with biodegradable linings, then other linings should be used (see Lined Swale or Riprap-lined Swale practice).

The time of the year should be considered when planning grass swales. Grass swales that are seeded to establish vegetation should not be planned for construction during late fall, winter or early spring. Grass swales constructed during mid-summer to early fall may need temporary seeding followed by permanent seeding at the recommended times. The vegetation species should be recommended for the area of the state that it is planned.

Design Criteria

Capacity

Note: This design example uses the Permissible Velocity approach. Grass swale design using the Tractive Stress approach can also be used but is not discussed in this document.

Grass swales shall be designed to convey the peak rate of runoff as shown in Table GS-1. Adjustments should be made for release rates from structures and other drainage facilities. Grass swales shall also be designed to comply with local stormwater ordinances. Grass swales should be designed for greater capacity whenever there is danger of flooding or out of bank flow cannot be tolerated.

Table GS-1 Design Frequency for Grassed Swale

Grass Swale Type	Typical Area of Protection	24 Hour Design Storm Frequency
Temporary Swale	Construction Areas	2-year
	Building Sites	5-year
Permanent Swale	Agricultural Land	10-year
	Reclaimed Mined Land	10-year
	Isolated Buildings	10-year
	Urban areas, Residential, School, Industrial Areas, Recreation Areas, etc.	10-year

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.
- Natural Resources Conservation Service formerly Soil Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds.
- Other comparable methods.

Grade of Grass Swale

After selecting a location for the grassed swale that will minimize the impacts to the site and maximize the intended use, the grade in the grass swales should be determined. The grade in feet per 100 feet of length can be determined from a topographic map of the site or from a detailed survey of the planned grassed swale location.

Retardance

The grass species used and the degree of maintenance planned for the vegetation determines the retardance of the swale (see Table GS-2).

Generally, the retardance used for the design of grassed swales should be “D” and “C” to produce a stable velocity and adequate capacity to carry the design storm.

Table GS-2 Retardance for Grassed Swales

Retardance	Species [1]	Cover Condition
A	Reed Canarygrass	Excellent stand, tall (average 36")
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36")
B	Smooth Bromegrass	Good stand, mowed (average 12 to 15")
	Bermudagrass	Good stand, tall (average 12)
	Native Grass mixture (Little Bluestem, Blue Grama, and other long and short Midwest Grasses)	Good stand, unmowed
	Tall Fescue	Good stand, unmowed (average 18")
	Lespedeza Sericea	Good stand, not woody, tall (average 19")
	Grass-Legume mixture- Timothy, smooth Bromegrass, or Orchardgrass	Good stand, uncut (average 20")
	Reed Canarygrass	Good stand, mowed (average 12 to 15")
	Tall Fescue, with Bird's Foot Trefoil or Ladino Clover	Good stand, uncut (average 18")
	Blue Grama	Good stand, uncut (average 13")
C	Bahiagrass	Good stand, uncut (average 6 to 8")
	Bermudagrass	Good stand, mowed (average 6")
	Redtop	Good stand, headed (15 to 20)
	Grass-legume mixture- summer (Orchardgrass, Redtop, Italian Ryegrass, and Common Lespedeza)	Good stand, uncut (6 to 8")
	Centipedegrass	Very dense cover (average 6")
	Kentucky Bluegrass	Good stand, headed (6 to 12")
D	Bermudagrass	Good stand, cut to 2.5" height
	Red Fescue	Good stand, headed (12 to 18")
	Buffalograss	Good stand, uncut (3 to 6")
	Grass-Legume mixture-fall, spring (Orchard Grass, Redtop, Italian Ryegrass, and Common Lespedeza)	Good stand, uncut (4 to 5")
	Lespedeza Sericea	After cutting to 2" height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5" height.
	Bermudagrass	Burned stubble

1/ Species to establish should be selected based on suitability of soil and expected management.

Velocities

Classify the soil where the swale is to be constructed into erosion resistant cohesive (clayey) fine and coarse grained soils or easily eroded noncohesive silt, clays and sands.

Determine the type of vegetative cover to be established in the swale.

Use the swale grade, cover and soil erodibility to determine permissible velocity using Table GS-3.

Table GS-3 Permissible Velocities in Grassed Swales

Cover	Slope Range[2]	Permissible Velocity[1] Erosion Resistant Soils[3] (clayey)	Easily Eroded Soils[4] (sandy)
	percent	ft/sec	ft/sec
Bermudagrass	< 5	8	6
	5-10	7	4
	over 10	6	3
Bahiagrass Tall Fescue	<5	7	5
	5-10	6	4
	over 10	5	3
Sericea Lespedeza Weeping Lovegrass	<5[5]	3.5	2.5

[1]Use velocities exceeding (5ft/sec) only where good covers and proper maintenance can be obtained.
[2]Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
[3]Cohesive (clayey) fine-grain soils and coarse-grain soils with cohesive fines with a plasticity index of 10 to 40 (CL, CH, SC, and CG).
[4] Soils that do not meet requirements for erosion-resistant soils.
[5] Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

Swale Dimensions

The swale may be triangular shaped, parabolic or trapezoidal as discussed in the planning considerations of this standard and shown in Figure GS-1.

Using the peak discharge, swale grade, permissible velocity and retardance, parabolic dimensions can be determined using Table GS-4, Sheets 1 through 14.

Design dimensions for triangular shaped and trapezoidal shaped swales can be determined using Manning's equation or other accepted engineering designs.

The design water surface elevation of a channel receiving water from other tributary sources shall be equal to or less than the design water surface elevation of the contributing source. The design water surface elevation of contributing and receiving waters should be the same, whenever practical.

A minimum depth may be necessary to provide adequate outlets for subsurface drains and tributary channels.

Drainage

Polyethylene drainage tubing, tile or other suitable subsurface drainage measures shall be provided for sites having high water tables or seepage problems.

Freeboard

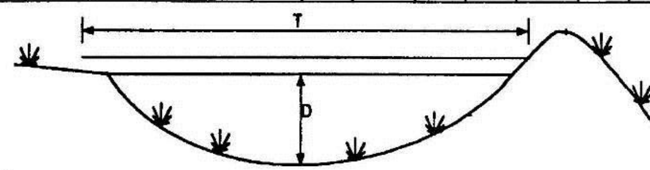
The minimum freeboard is 0.25 feet in depth. Freeboard is not required on grass swales with less than 1% slope and where out-of-bank flow will not be damaging and can be tolerated in the normal operation at the site.

Table GS-4 Parabolic Grass Swale Design Sheet 1 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.25 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15																											
20																											
25	9.3	2.3	1.7																								
30	11.7	2.2	1.8																								
35	14.1	2.1	1.7																								
40	16.3	2.1	1.8																								
45	18.5	2.1	1.8	10.4	2.8	2.3																					
50	20.7	2.1	1.8	12.3	2.6	2.3																					
55	22.9	2.1	1.8	13.8	2.6	2.3																					
60	25.0	2.0	1.8	15.3	2.5	2.3																					
65	27.2	2.0	1.8	16.8	2.5	2.3	10.4	3.4	2.8																		
70	29.3	2.0	1.8	18.2	2.5	2.3	12.1	3.1	2.8																		
75	31.9	2.0	1.7	19.7	2.4	2.3	13.5	3.0	2.8																		
80	34.0	2.0	1.7	21.1	2.4	2.3	14.7	2.9	2.8																		
85	36.1	2.0	1.7	22.5	2.4	2.3	15.8	2.9	2.8																		
90	38.2	2.0	1.7	23.9	2.4	2.3	16.9	2.8	2.8																		
95	40.3	2.0	1.7	25.3	2.4	2.3	18.0	2.8	2.8																		
100	42.4	2.0	1.7	26.7	2.4	2.3	19.1	2.8	2.8																		
105	44.6	2.0	1.7	28.1	2.4	2.3	20.2	2.8	2.8																		
110	46.7	2.0	1.7	29.5	2.4	2.3	21.3	2.8	2.8	12.9	3.8	3.4															
115	48.8	2.0	1.7	30.8	2.4	2.3	22.3	2.8	2.8	14.0	3.7	3.4															
120	50.9	2.0	1.7	32.2	2.4	2.3	23.4	2.8	2.8	15.3	3.5	3.4															
125	53.0	2.0	1.8	33.6	2.4	2.3	24.4	2.8	2.8	16.1	3.5	3.4															
130	55.1	2.0	1.8	35.0	2.4	2.3	25.5	2.8	2.8	16.9	3.4	3.4															
135	57.3	2.0	1.8	36.4	2.4	2.3	26.5	2.7	2.8	17.7	3.4	3.4															
140	59.4	2.0	1.8	38.3	2.4	2.3	27.6	2.7	2.8	18.5	3.4	3.4															
145	61.5	2.0	1.8	39.7	2.4	2.3	28.6	2.7	2.8	19.3	3.3	3.4															
150	63.6	2.0	1.8	41.1	2.4	2.3	29.6	2.7	2.8	20.1	3.3	3.4															



T = Top width, tall vegetation
D = Depth, tall vegetation
V2 = Design velocity, tall vegetation
V1 = Permissible velocity, short vegetation

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 2 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	8.4	1.6	1.7																								
20	11.7	1.5	1.7	7.1	2.0	2.2																					
25	14.9	1.5	1.7	9.7	1.8	2.2																					
30	18.0	1.5	1.7	12.0	1.7	2.2																					
35	21.0	1.5	1.7	14.2	1.7	2.2	9.3	2.1	2.7																		
40	24.4	1.5	1.7	16.3	1.7	2.2	10.9	2.0	2.7																		
45	27.4	1.5	1.7	18.5	1.7	2.2	12.5	2.0	2.7																		
50	30.5	1.5	1.7	20.6	1.7	2.2	14.1	1.9	2.7	8.7	2.6	3.3															
55	33.5	1.5	1.7	22.7	1.7	2.2	15.7	1.9	2.7	10.4	2.4	3.3															
60	36.6	1.5	1.7	24.8	1.7	2.2	17.2	1.9	2.7	11.7	2.3	3.3															
65	39.6	1.5	1.7	27.3	1.7	2.2	18.8	1.9	2.7	12.9	2.3	3.3															
70	42.6	1.5	1.7	29.4	1.7	2.2	20.3	1.9	2.7	14.0	2.2	3.3	9.8	2.8	3.8												
75	45.7	1.5	1.7	31.4	1.7	2.2	21.8	1.9	2.7	15.2	2.2	3.3	11.3	2.7	3.8												
80	48.7	1.5	1.7	33.5	1.7	2.2	23.3	1.9	2.7	16.3	2.2	3.3	12.2	2.6	3.8												
85	51.7	1.5	1.7	35.6	1.6	2.2	24.8	1.9	2.7	17.4	2.2	3.3	13.2	2.5	3.8												
90	54.8	1.5	1.7	37.7	1.6	2.2	26.3	1.9	2.7	18.5	2.2	3.3	14.2	2.5	3.8												
95	57.8	1.5	1.7	39.8	1.6	2.2	27.8	1.9	2.7	19.6	2.2	3.3	15.1	2.5	3.8												
100	60.9	1.5	1.7	41.9	1.6	2.2	29.7	1.9	2.7	20.7	2.2	3.3	16.0	2.5	3.8	11.0	3.2	4.3									
105	63.9	1.5	1.7	44.0	1.6	2.2	31.2	1.9	2.7	21.8	2.2	3.3	16.9	2.5	3.8	12.3	3.0	4.3									
110	66.9	1.5	1.7	46.1	1.6	2.2	32.6	1.9	2.7	22.9	2.2	3.3	17.8	2.4	3.8	13.1	2.9	4.3									
115	70.0	1.5	1.7	48.1	1.6	2.2	34.1	1.9	2.7	24.0	2.1	3.3	18.7	2.4	3.8	13.9	2.9	4.3									
120	73.0	1.5	1.7	50.2	1.6	2.2	35.6	1.9	2.7	25.1	2.1	3.3	19.6	2.4	3.8	14.6	2.9	4.3									
125	76.1	1.5	1.7	52.3	1.6	2.2	37.1	1.9	2.7	26.2	2.1	3.3	20.5	2.4	3.8	15.4	2.8	4.3									
130	79.1	1.5	1.7	54.4	1.6	2.2	38.5	1.9	2.7	27.3	2.1	3.3	21.3	2.4	3.8	16.1	2.8	4.3									
135	82.1	1.5	1.7	56.5	1.6	2.2	40.0	1.9	2.7	28.4	2.1	3.3	22.2	2.4	3.8	16.9	2.8	4.3									
140	85.2	1.5	1.7	58.6	1.6	2.2	41.5	1.9	2.7	29.4	2.1	3.3	23.1	2.4	3.8	17.6	2.8	4.3									
145	88.2	1.5	1.7	60.7	1.6	2.2	43.0	1.9	2.7	30.5	2.1	3.3	24.0	2.4	3.8	18.3	2.8	4.3	12.3	3.7	4.9						
150	91.3	1.6	1.7	62.8	1.6	2.2	44.5	1.9	2.7	31.6	2.1	3.3	24.8	2.4	3.8	19.0	2.7	4.3	13.1	3.5	4.9						

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 3 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.75 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	7.0	1.3	1.6																								
15	11.0	1.3	1.6	7.1	1.5	2.1																					
20	14.9	1.3	1.6	9.9	1.4	2.1	6.1	1.9	2.6																		
25	18.9	1.2	1.6	12.7	1.4	2.1	8.6	1.6	2.7																		
30	22.7	1.2	1.6	15.3	1.4	2.1	10.6	1.6	2.6	6.7	2.1	3.2															
35	26.5	1.2	1.6	18.0	1.4	2.1	12.6	1.6	2.7	8.7	1.9	3.2															
40	30.2	1.2	1.6	20.6	1.4	2.1	14.5	1.6	2.7	10.3	1.8	3.2															
45	34.0	1.2	1.6	23.5	1.4	2.1	16.4	1.5	2.7	11.8	1.8	3.2	7.8	2.3	3.8												
50	37.8	1.2	1.6	26.1	1.4	2.1	18.3	1.5	2.7	13.2	1.8	3.2	9.5	2.1	3.8												
55	41.5	1.2	1.6	28.7	1.4	2.1	20.2	1.5	2.7	14.7	1.7	3.2	10.7	2.0	3.8												
60	45.3	1.2	1.6	31.3	1.4	2.1	22.1	1.5	2.7	16.1	1.7	3.2	11.8	2.0	3.8												
65	49.1	1.2	1.6	33.9	1.4	2.1	24.3	1.5	2.6	17.6	1.7	3.2	13.0	2.0	3.8	8.5	2.6	4.4									
70	52.9	1.2	1.6	36.5	1.4	2.1	26.2	1.5	2.6	19.0	1.7	3.2	14.1	2.0	3.8	10.0	2.4	4.3									
75	56.6	1.2	1.6	39.1	1.4	2.1	28.0	1.5	2.6	20.4	1.7	3.2	15.2	2.0	3.8	11.0	2.4	4.4									
80	60.4	1.2	1.6	41.7	1.4	2.1	29.9	1.5	2.6	21.8	1.7	3.2	16.3	1.9	3.8	11.9	2.3	4.4									
85	64.2	1.2	1.6	44.3	1.4	2.1	31.8	1.5	2.6	23.2	1.7	3.2	17.4	1.9	3.8	12.8	2.3	4.4	9.1	2.9	4.8						
90	67.9	1.2	1.6	46.9	1.4	2.1	33.6	1.5	2.6	24.6	1.7	3.2	18.5	1.9	3.8	13.7	2.3	4.4	10.3	2.7	4.8						
95	71.7	1.2	1.6	49.5	1.4	2.1	35.5	1.5	2.6	26.0	1.7	3.2	19.6	1.9	3.8	14.6	2.2	4.4	11.4	2.6	4.8						
100	75.5	1.2	1.6	52.1	1.4	2.1	37.3	1.5	2.6	27.8	1.7	3.2	20.7	1.9	3.8	15.4	2.2	4.4	12.2	2.6	4.8						
105	79.3	1.2	1.6	54.7	1.4	2.1	39.2	1.5	2.6	29.1	1.7	3.2	21.8	1.9	3.8	16.3	2.2	4.4	12.9	2.5	4.8						
110	83.0	1.2	1.6	57.3	1.4	2.1	41.1	1.5	2.6	30.5	1.7	3.2	22.8	1.9	3.8	17.2	2.2	4.4	13.7	2.5	4.8						
115	86.8	1.2	1.6	59.9	1.4	2.1	42.9	1.5	2.6	31.9	1.7	3.2	23.9	1.9	3.8	18.0	2.2	4.4	14.4	2.5	4.8	10.5	3.1	5.3			
120	90.6	1.2	1.6	62.5	1.4	2.1	44.8	1.5	2.7	33.3	1.7	3.2	25.0	1.9	3.8	18.9	2.2	4.4	15.2	2.5	4.8	11.4	3.0	5.3			
125	94.3	1.2	1.6	65.1	1.4	2.1	46.7	1.5	2.7	34.7	1.7	3.2	26.0	1.9	3.8	19.7	2.2	4.4	15.9	2.4	4.8	12.4	2.9	5.3			
130	98.1	1.2	1.6	67.7	1.4	2.1	48.5	1.5	2.7	36.0	1.7	3.2	27.1	1.9	3.8	20.5	2.2	4.4	16.6	2.4	4.8	13.0	2.8	5.3			
135	101.9	1.2	1.6	70.3	1.4	2.1	50.4	1.5	2.7	37.4	1.7	3.2	28.2	1.9	3.8	21.4	2.2	4.4	17.3	2.4	4.8	13.7	2.8	5.3			
140	105.7	1.2	1.6	72.9	1.4	2.1	52.2	1.5	2.7	38.8	1.7	3.2	29.3	1.9	3.8	22.2	2.2	4.4	18.0	2.4	4.9	14.3	2.8	5.3			
145	109.4	1.2	1.6	75.5	1.4	2.1	54.1	1.5	2.7	40.2	1.7	3.2	30.8	1.9	3.7	23.1	2.2	4.4	18.7	2.4	4.9	14.9	2.7	5.3			
150	113.2	1.2	1.6	78.1	1.4	2.1	56.0	1.5	2.7	41.6	1.7	3.2	31.9	1.9	3.7	23.9	2.1	4.4	19.4	2.4	4.9	15.5	2.7	5.3			

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 4 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	8.2	1.2	1.6	5.2	1.4	2.0																					
15	12.6	1.1	1.6	8.7	1.3	2.1	5.5	1.6	2.6																		
20	17.1	1.1	1.6	11.8	1.2	2.1	8.2	1.4	2.6																		
25	21.4	1.1	1.6	14.9	1.2	2.1	10.5	1.4	2.6	7.3	1.6	3.1															
30	25.7	1.1	1.6	18.0	1.2	2.1	12.8	1.4	2.6	9.1	1.6	3.2															
35	29.9	1.1	1.6	21.2	1.2	2.1	15.0	1.3	2.6	10.9	1.5	3.1	7.8	1.8	3.7												
40	34.2	1.1	1.6	24.3	1.2	2.1	17.3	1.3	2.6	12.6	1.5	3.1	9.2	1.7	3.7												
45	38.5	1.1	1.6	27.3	1.2	2.1	19.5	1.3	2.6	14.3	1.5	3.1	10.6	1.7	3.7	7.2	2.2	4.3									
50	42.7	1.1	1.6	30.3	1.2	2.1	21.9	1.3	2.6	16.0	1.5	3.2	11.9	1.7	3.7	8.8	2.0	4.3									
55	47.0	1.1	1.6	33.3	1.2	2.1	24.1	1.3	2.6	17.7	1.5	3.2	13.3	1.7	3.7	9.9	1.9	4.3									
60	51.3	1.1	1.6	36.3	1.2	2.1	26.3	1.3	2.6	19.3	1.5	3.2	14.6	1.7	3.7	11.0	1.9	4.3									
65	55.5	1.1	1.6	39.4	1.2	2.1	28.5	1.3	2.6	21.0	1.5	3.2	15.9	1.6	3.7	12.1	1.9	4.3	8.0	2.5	4.9						
70	59.8	1.1	1.6	42.4	1.2	2.1	30.7	1.3	2.6	22.7	1.5	3.2	17.1	1.6	3.7	13.2	1.9	4.3	9.5	2.3	4.8						
75	64.1	1.1	1.6	45.4	1.2	2.1	32.9	1.3	2.6	24.6	1.5	3.1	18.5	1.6	3.7	14.2	1.8	4.3	10.4	2.2	4.9						
80	68.3	1.1	1.6	48.4	1.2	2.1	35.0	1.3	2.6	26.2	1.5	3.1	19.8	1.6	3.7	15.2	1.8	4.3	11.3	2.2	4.9						
85	72.6	1.1	1.6	51.5	1.2	2.1	37.2	1.3	2.6	27.9	1.5	3.1	21.0	1.6	3.7	16.3	1.8	4.3	12.1	2.2	4.9	8.8	2.7	5.4			
90	76.9	1.1	1.6	54.5	1.2	2.1	39.4	1.3	2.6	29.5	1.5	3.1	22.3	1.6	3.7	17.3	1.8	4.3	13.0	2.1	4.9	9.8	2.6	5.4			
95	81.1	1.1	1.6	57.5	1.2	2.1	41.6	1.3	2.6	31.1	1.5	3.1	23.6	1.6	3.7	18.3	1.8	4.3	13.8	2.1	4.9	10.9	2.5	5.3			
100	85.4	1.1	1.6	60.5	1.2	2.1	43.8	1.3	2.6	32.7	1.5	3.1	24.9	1.6	3.7	19.3	1.8	4.3	14.6	2.1	4.9	11.6	2.4	5.4			
105	89.7	1.1	1.6	63.6	1.2	2.1	46.0	1.3	2.6	34.4	1.5	3.1	26.5	1.6	3.7	20.3	1.8	4.3	15.4	2.1	4.9	12.4	2.4	5.4	9.7	2.8	5.8
110	94.0	1.1	1.6	66.6	1.2	2.1	48.2	1.3	2.6	36.0	1.5	3.1	27.7	1.6	3.7	21.3	1.8	4.3	16.2	2.1	4.9	13.1	2.4	5.4	10.8	2.6	5.8
115	98.2	1.1	1.6	69.6	1.2	2.1	50.4	1.3	2.6	37.6	1.5	3.1	29.0	1.6	3.7	22.3	1.8	4.3	17.0	2.1	4.9	13.8	2.3	5.4	11.5	2.6	5.8
120	102.5	1.1	1.6	72.6	1.2	2.1	52.5	1.3	2.6	39.3	1.5	3.1	30.2	1.6	3.7	23.3	1.8	4.3	17.9	2.1	4.9	14.5	2.3	5.4	12.2	2.6	5.8
125	106.8	1.1	1.6	75.7	1.2	2.1	54.7	1.3	2.6	40.9	1.5	3.1	31.5	1.6	3.7	24.3	1.8	4.3	18.7	2.1	4.9	15.2	2.3	5.4	12.8	2.5	5.8
130	111.0	1.1	1.6	78.7	1.2	2.1	56.9	1.3	2.6	42.5	1.5	3.1	32.7	1.6	3.7	25.3	1.8	4.3	19.4	2.1	4.9	15.9	2.3	5.4	13.4	2.5	5.8
135	115.3	1.1	1.6	81.7	1.2	2.1	59.1	1.3	2.6	44.2	1.5	3.1	34.0	1.6	3.7	26.3	1.8	4.3	20.2	2.0	4.9	16.6	2.3	5.4	14.1	2.5	5.8
140	119.6	1.1	1.6	84.7	1.2	2.1	61.3	1.3	2.6	45.8	1.5	3.1	35.2	1.6	3.7	27.3	1.8	4.3	21.0	2.0	4.9	17.2	2.3	5.4	14.7	2.5	5.8
145	123.8	1.1	1.6	87.8	1.2	2.1	63.5	1.3	2.6	47.5	1.5	3.1	36.5	1.6	3.7	28.7	1.8	4.3	21.8	2.0	4.9	17.9	2.3	5.4	15.3	2.5	5.8
150	128.1	1.1	1.6	90.8	1.2	2.1	65.7	1.3	2.6	49.1	1.5	3.1	37.8	1.6	3.7	29.7	1.8	4.3	22.6	2.0	4.9	18.6	2.3	5.4	15.9	2.4	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 5 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.25 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	4.1	1.2	1.5																								
10	9.4	1.0	1.5	6.3	1.2	2.0																					
15	14.3	1.0	1.6	9.9	1.1	2.0	6.8	1.3	2.6																		
20	19.4	1.0	1.5	13.4	1.1	2.0	9.5	1.2	2.6	6.7	1.4	3.1															
25	24.2	1.0	1.5	17.0	1.1	2.0	12.1	1.2	2.6	8.8	1.4	3.1	5.9	1.7	3.6												
30	29.0	1.0	1.6	20.4	1.1	2.0	14.6	1.2	2.6	10.7	1.4	3.1	7.8	1.6	3.7												
35	33.8	1.0	1.6	23.8	1.1	2.0	17.1	1.2	2.6	12.7	1.3	3.1	9.4	1.5	3.7	6.5	1.9	4.2									
40	38.6	1.0	1.6	27.1	1.1	2.0	19.8	1.2	2.5	14.6	1.3	3.1	10.9	1.5	3.7	8.1	1.7	4.2									
45	43.5	1.0	1.6	30.5	1.1	2.0	22.3	1.2	2.5	16.5	1.3	3.1	12.5	1.5	3.7	9.4	1.7	4.2									
50	48.3	1.0	1.6	33.9	1.1	2.0	24.8	1.2	2.5	18.3	1.3	3.1	13.9	1.5	3.7	10.6	1.7	4.2	7.7	2.0	4.8						
55	53.1	1.0	1.6	37.3	1.1	2.0	27.2	1.2	2.6	20.5	1.3	3.1	15.4	1.5	3.7	11.8	1.6	4.3	9.0	1.9	4.8						
60	57.9	1.0	1.6	40.7	1.1	2.0	29.7	1.2	2.6	22.3	1.3	3.1	16.9	1.5	3.7	13.0	1.6	4.3	10.1	1.9	4.8						
65	62.8	1.0	1.6	44.1	1.1	2.0	32.2	1.2	2.6	24.2	1.3	3.1	18.3	1.5	3.7	14.2	1.6	4.3	11.1	1.8	4.8	8.0	2.3	5.3			
70	67.6	1.0	1.6	47.5	1.1	2.0	34.6	1.2	2.6	26.0	1.3	3.1	19.8	1.4	3.7	15.4	1.6	4.3	12.0	1.8	4.8	9.3	2.1	5.3			
75	72.4	1.0	1.6	50.8	1.1	2.0	37.1	1.2	2.6	27.9	1.3	3.1	21.2	1.4	3.7	16.5	1.6	4.3	13.0	1.8	4.8	10.1	2.1	5.3			
80	77.2	1.0	1.6	54.2	1.1	2.0	39.6	1.2	2.6	29.7	1.3	3.1	23.0	1.4	3.6	17.7	1.6	4.3	14.0	1.8	4.8	11.0	2.0	5.3			
85	82.1	1.0	1.6	57.6	1.1	2.0	42.0	1.2	2.6	31.6	1.3	3.1	24.4	1.4	3.6	18.8	1.6	4.3	14.9	1.8	4.8	11.8	2.0	5.3			
90	86.9	1.0	1.6	61.0	1.1	2.0	44.5	1.2	2.6	33.5	1.3	3.1	25.8	1.4	3.6	20.0	1.6	4.3	15.9	1.8	4.8	12.6	2.0	5.3	9.1	2.5	5.9
95	91.7	1.0	1.6	64.4	1.1	2.0	47.0	1.2	2.6	35.3	1.3	3.1	27.3	1.4	3.6	21.1	1.6	4.3	16.8	1.8	4.8	13.4	2.0	5.4	10.2	2.4	5.9
100	96.6	1.0	1.6	67.8	1.1	2.0	49.4	1.2	2.6	37.2	1.3	3.1	28.7	1.4	3.6	22.3	1.6	4.3	17.7	1.8	4.8	14.2	2.0	5.4	10.9	2.3	5.9
105	101.4	1.0	1.6	71.2	1.1	2.0	51.9	1.2	2.6	39.0	1.3	3.1	30.1	1.4	3.6	23.4	1.6	4.3	18.7	1.8	4.8	15.0	2.0	5.4	11.6	2.3	5.9
110	106.2	1.0	1.6	74.6	1.1	2.0	54.4	1.2	2.6	40.9	1.3	3.1	31.6	1.4	3.6	24.6	1.6	4.3	19.6	1.7	4.8	15.8	2.0	5.4	12.3	2.3	5.9
115	111.0	1.0	1.6	78.0	1.1	2.0	56.8	1.2	2.6	42.7	1.3	3.1	33.0	1.4	3.6	26.1	1.6	4.2	20.5	1.7	4.8	16.6	1.9	5.4	13.0	2.2	5.9
120	115.9	1.0	1.6	81.3	1.1	2.0	59.3	1.2	2.6	44.6	1.3	3.1	34.4	1.4	3.6	27.2	1.6	4.2	21.5	1.7	4.8	17.3	1.9	5.4	13.6	2.2	5.9
125	120.7	1.0	1.6	84.7	1.1	2.0	61.8	1.2	2.6	46.4	1.3	3.1	35.9	1.4	3.6	28.3	1.6	4.2	22.4	1.7	4.8	18.1	1.9	5.4	14.3	2.2	5.9
130	125.5	1.0	1.6	88.1	1.1	2.0	64.3	1.2	2.6	48.3	1.3	3.1	37.3	1.4	3.7	29.5	1.6	4.2	23.3	1.7	4.8	18.9	1.9	5.4	14.9	2.2	5.9
135	130.3	1.0	1.6	91.5	1.1	2.0	66.7	1.2	2.6	50.2	1.3	3.1	38.7	1.4	3.7	30.6	1.6	4.2	24.2	1.7	4.8	19.6	1.9	5.4	15.6	2.2	5.9
140	135.2	1.0	1.6	94.9	1.1	2.0	69.2	1.2	2.6	52.0	1.3	3.1	40.2	1.4	3.7	31.7	1.6	4.2	25.1	1.7	4.8	20.4	1.9	5.4	16.2	2.2	5.9
145	140.0	1.0	1.6	98.3	1.1	2.0	71.7	1.2	2.6	53.9	1.3	3.1	41.6	1.4	3.7	32.9	1.6	4.2	26.1	1.7	4.8	21.2	1.9	5.4	16.9	2.2	5.9
150	144.8	1.0	1.6	101.7	1.1	2.0	74.1	1.2	2.6	55.7	1.3	3.1	43.0	1.4	3.7	34.0	1.6	4.2	27.0	1.7	4.8	21.9	1.9	5.4	17.5	2.2	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 6 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	4.9	1.0	1.5																								
10	10.5	0.9	1.5	7.1	1.1	2.0	4.6	1.3	2.5																		
15	16.0	0.9	1.5	10.9	1.0	2.0	7.8	1.1	2.5	5.3	1.4	3.1															
20	21.3	0.9	1.5	14.7	1.0	2.0	10.6	1.1	2.5	7.7	1.3	3.1	5.1	1.6	3.6												
25	26.6	0.9	1.5	18.6	1.0	2.0	13.4	1.1	2.5	9.9	1.2	3.1	7.3	1.4	3.6												
30	31.9	0.9	1.5	22.3	1.0	2.0	16.2	1.1	2.5	12.0	1.2	3.1	9.0	1.4	3.6	6.6	1.6	4.2									
35	37.3	0.9	1.5	26.0	1.0	2.0	19.1	1.1	2.5	14.1	1.2	3.1	10.7	1.4	3.6	8.1	1.5	4.2									
40	42.6	0.9	1.5	29.7	1.0	2.0	21.8	1.1	2.5	16.2	1.2	3.1	12.4	1.3	3.6	9.5	1.5	4.2	6.9	1.8	4.7						
45	47.9	0.9	1.5	33.4	1.0	2.0	24.5	1.1	2.5	18.3	1.2	3.1	14.0	1.3	3.6	10.8	1.5	4.2	8.3	1.7	4.7						
50	53.2	0.9	1.5	37.1	1.0	2.0	27.3	1.1	2.5	20.6	1.2	3.0	15.7	1.3	3.6	12.1	1.5	4.2	9.4	1.7	4.8						
55	58.5	0.9	1.5	40.8	1.0	2.0	30.0	1.1	2.5	22.7	1.2	3.0	17.3	1.3	3.6	13.4	1.5	4.2	10.5	1.6	4.8	8.1	1.9	5.3			
60	63.8	0.9	1.5	44.5	1.0	2.0	32.7	1.1	2.5	24.7	1.2	3.0	18.9	1.3	3.6	14.7	1.4	4.2	11.6	1.6	4.8	9.1	1.9	5.3			
65	69.2	0.9	1.5	48.2	1.0	2.0	35.4	1.1	2.5	26.8	1.2	3.1	20.8	1.3	3.6	16.0	1.4	4.2	12.7	1.6	4.8	10.0	1.8	5.3			
70	74.5	0.9	1.5	51.9	1.0	2.0	38.2	1.1	2.5	28.8	1.2	3.1	22.4	1.3	3.6	17.3	1.4	4.2	13.7	1.6	4.8	10.9	1.8	5.3	8.2	2.2	5.8
75	79.8	0.9	1.5	55.6	1.0	2.0	40.9	1.1	2.5	30.9	1.2	3.1	23.9	1.3	3.6	18.6	1.4	4.2	14.8	1.6	4.8	11.8	1.8	5.3	9.3	2.1	5.8
80	85.1	0.9	1.5	59.4	1.0	2.0	43.6	1.1	2.5	32.9	1.2	3.1	25.5	1.3	3.6	19.9	1.4	4.2	15.8	1.6	4.8	12.7	1.8	5.3	10.1	2.0	5.9
85	90.4	0.9	1.5	63.1	1.0	2.0	46.3	1.1	2.5	35.0	1.2	3.1	27.1	1.3	3.6	21.2	1.4	4.2	16.9	1.6	4.8	13.6	1.8	5.3	10.9	2.0	5.9
90	95.8	0.9	1.5	66.8	1.0	2.0	49.0	1.1	2.5	37.1	1.2	3.1	28.7	1.3	3.6	22.8	1.4	4.1	17.9	1.6	4.8	14.5	1.8	5.3	11.6	2.0	5.9
95	101.1	0.9	1.5	70.5	1.0	2.0	51.8	1.1	2.5	39.1	1.2	3.1	30.3	1.3	3.6	24.0	1.4	4.2	18.9	1.6	4.8	15.3	1.7	5.3	12.4	2.0	5.9
100	106.4	0.9	1.5	74.2	1.0	2.0	54.5	1.1	2.5	41.2	1.2	3.1	31.9	1.3	3.6	25.3	1.4	4.2	20.0	1.6	4.8	16.2	1.7	5.3	13.1	1.9	5.9
105	111.7	0.9	1.5	77.9	1.0	2.0	57.2	1.1	2.5	43.2	1.2	3.1	33.5	1.3	3.6	26.5	1.4	4.2	21.0	1.6	4.8	17.0	1.7	5.3	13.9	1.9	5.9
110	117.0	0.9	1.5	81.6	1.0	2.0	59.9	1.1	2.5	45.3	1.2	3.1	35.1	1.3	3.6	27.8	1.4	4.2	22.0	1.6	4.8	17.9	1.7	5.3	14.6	1.9	5.9
115	122.4	0.9	1.5	85.3	1.0	2.0	62.6	1.1	2.5	47.3	1.2	3.1	36.7	1.3	3.6	29.1	1.4	4.2	23.1	1.6	4.8	18.8	1.7	5.3	15.3	1.9	5.9
120	127.7	0.9	1.5	89.0	1.0	2.0	65.4	1.1	2.5	49.4	1.2	3.1	38.3	1.3	3.6	30.3	1.4	4.2	24.1	1.6	4.8	19.6	1.7	5.3	16.1	1.9	5.9
125	133.0	0.9	1.5	92.7	1.0	2.0	68.1	1.1	2.5	51.4	1.2	3.1	39.9	1.3	3.6	31.6	1.4	4.2	25.4	1.6	4.8	20.5	1.7	5.3	16.8	1.9	5.9
130	138.3	0.9	1.5	96.4	1.0	2.0	70.8	1.1	2.5	53.5	1.2	3.1	41.4	1.3	3.6	32.8	1.4	4.2	26.4	1.6	4.8	21.3	1.7	5.3	17.5	1.9	5.9
135	143.6	0.9	1.5	100.1	1.0	2.0	73.5	1.1	2.5	55.6	1.2	3.1	43.0	1.3	3.6	34.1	1.4	4.2	27.4	1.6	4.8	22.2	1.7	5.3	18.2	1.9	5.9
140	149.0	0.9	1.5	103.9	1.0	2.0	76.3	1.1	2.5	57.6	1.2	3.1	44.6	1.3	3.6	35.3	1.4	4.2	28.5	1.6	4.8	23.0	1.7	5.3	18.9	1.9	5.9
145	154.3	0.9	1.5	107.6	1.0	2.0	79.0	1.1	2.5	59.7	1.2	3.1	46.2	1.3	3.6	36.6	1.4	4.2	29.5	1.6	4.8	23.8	1.7	5.3	19.7	1.9	5.9
150	159.6	0.9	1.5	111.3	1.0	2.0	81.7	1.1	2.5	61.7	1.2	3.1	47.8	1.3	3.6	37.9	1.4	4.2	30.5	1.6	4.8	24.7	1.7	5.3	20.4	1.9	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

GaSWCC (Ame

Table GS-4 Parabolic Grass Swale Design Sheet 7 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.75 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.4	0.9	1.5																								
10	11.4	0.9	1.5	7.7	1.0	2.0	5.4	1.1	2.5																		
15	17.3	0.9	1.5	11.8	1.0	2.0	8.6	1.1	2.5	6.2	1.2	3.0															
20	23.1	0.9	1.5	16.0	0.9	2.0	11.6	1.0	2.5	8.6	1.2	3.0	6.3	1.3	3.6												
25	28.8	0.9	1.5	20.0	0.9	2.0	14.6	1.0	2.5	10.9	1.1	3.0	8.2	1.3	3.6	5.9	1.5	4.1									
30	34.6	0.9	1.5	24.0	0.9	2.0	17.8	1.0	2.5	13.2	1.1	3.0	10.1	1.2	3.6	7.6	1.4	4.2									
35	40.3	0.9	1.5	28.0	0.9	2.0	20.7	1.0	2.5	15.5	1.1	3.0	11.9	1.2	3.6	9.1	1.4	4.2	6.9	1.6	4.7						
40	46.1	0.9	1.5	32.0	0.9	2.0	23.7	1.0	2.5	18.0	1.1	3.0	13.7	1.2	3.6	10.6	1.4	4.2	8.2	1.6	4.7						
45	51.9	0.9	1.5	36.0	0.9	2.0	26.6	1.0	2.5	20.2	1.1	3.0	15.4	1.2	3.6	12.0	1.3	4.2	9.4	1.5	4.7	7.0	1.8	5.3			
50	57.6	0.9	1.5	40.0	0.9	2.0	29.6	1.0	2.5	22.4	1.1	3.0	17.2	1.2	3.6	13.5	1.3	4.1	10.6	1.5	4.7	8.3	1.7	5.3			
55	63.4	0.9	1.5	44.0	0.9	2.0	32.5	1.0	2.5	24.7	1.1	3.0	19.2	1.2	3.6	14.9	1.3	4.1	11.8	1.5	4.7	9.3	1.7	5.3	6.7	2.1	5.8
60	69.1	0.9	1.5	48.0	0.9	2.0	35.5	1.0	2.5	26.9	1.1	3.0	20.9	1.2	3.6	16.3	1.3	4.1	12.9	1.5	4.7	10.3	1.6	5.3	8.1	1.9	5.8
65	74.9	0.9	1.5	52.0	0.9	2.0	38.4	1.0	2.5	29.2	1.1	3.0	22.7	1.2	3.6	17.7	1.3	4.1	14.1	1.5	4.7	11.3	1.6	5.3	9.0	1.9	5.8
70	80.7	0.9	1.5	56.0	0.9	2.0	41.4	1.0	2.5	31.4	1.1	3.0	24.4	1.2	3.6	19.1	1.3	4.1	15.2	1.5	4.7	12.3	1.6	5.3	9.8	1.8	5.8
75	86.4	0.9	1.5	60.0	0.9	2.0	44.3	1.0	2.5	33.6	1.1	3.0	26.1	1.2	3.6	20.5	1.3	4.1	16.4	1.4	4.7	13.2	1.6	5.3	10.7	1.8	5.8
80	92.2	0.9	1.5	63.9	0.9	2.0	47.3	1.0	2.5	35.9	1.1	3.0	27.9	1.2	3.6	22.2	1.3	4.1	17.5	1.4	4.7	14.2	1.6	5.3	11.5	1.8	5.8
85	97.9	0.9	1.5	67.9	0.9	2.0	50.2	1.0	2.5	38.1	1.1	3.0	29.6	1.2	3.6	23.5	1.3	4.1	18.6	1.4	4.7	15.1	1.6	5.3	12.3	1.8	5.8
90	103.7	0.9	1.5	71.9	0.9	2.0	53.2	1.0	2.5	40.3	1.1	3.0	31.4	1.2	3.6	24.9	1.3	4.1	19.8	1.4	4.7	16.1	1.6	5.3	13.1	1.8	5.8
95	109.5	0.9	1.5	75.9	0.9	2.0	56.1	1.0	2.5	42.6	1.1	3.0	33.1	1.2	3.6	26.3	1.3	4.1	20.9	1.4	4.7	17.0	1.6	5.3	13.9	1.7	5.8
100	115.2	0.9	1.5	79.9	0.9	2.0	59.1	1.0	2.5	44.8	1.1	3.0	34.8	1.2	3.6	27.7	1.3	4.1	22.0	1.4	4.7	17.9	1.6	5.3	14.7	1.7	5.8
105	121.0	0.9	1.5	83.9	0.9	2.0	62.0	1.0	2.5	47.1	1.1	3.0	36.6	1.2	3.6	29.0	1.3	4.1	23.4	1.4	4.7	18.9	1.6	5.3	15.5	1.7	5.8
110	126.8	0.9	1.5	87.9	0.9	2.0	65.0	1.0	2.5	49.3	1.1	3.0	38.3	1.2	3.6	30.4	1.3	4.1	24.5	1.4	4.7	19.8	1.6	5.3	16.3	1.7	5.8
115	132.5	0.9	1.5	91.9	0.9	2.0	67.9	1.0	2.5	51.5	1.1	3.0	40.1	1.2	3.6	31.8	1.3	4.1	25.6	1.4	4.7	20.7	1.6	5.3	17.1	1.7	5.9
120	138.3	0.9	1.5	95.9	0.9	2.0	70.9	1.0	2.5	53.8	1.1	3.0	41.8	1.2	3.6	33.2	1.3	4.1	26.8	1.4	4.7	21.7	1.6	5.3	17.9	1.7	5.9
125	144.0	0.9	1.5	99.9	0.9	2.0	73.8	1.0	2.5	56.0	1.1	3.0	43.5	1.2	3.6	34.6	1.3	4.1	27.9	1.4	4.7	22.6	1.6	5.3	18.7	1.7	5.9
130	149.8	0.9	1.5	103.9	0.9	2.0	76.8	1.0	2.5	58.3	1.1	3.0	45.3	1.2	3.6	35.9	1.3	4.1	29.0	1.4	4.7	23.5	1.6	5.3	19.4	1.7	5.9
135	155.6	0.9	1.5	107.9	0.9	2.0	79.7	1.0	2.5	60.5	1.1	3.0	47.0	1.2	3.6	37.3	1.3	4.1	30.1	1.4	4.7	24.5	1.6	5.3	20.2	1.7	5.9
140	161.3	0.9	1.5	111.9	0.9	2.0	82.7	1.0	2.5	62.7	1.1	3.0	48.8	1.2	3.6	38.7	1.3	4.1	31.2	1.4	4.7	25.7	1.6	5.3	21.0	1.7	5.9
145	167.1	0.9	1.5	115.9	0.9	2.0	85.6	1.0	2.5	65.0	1.1	3.0	50.5	1.2	3.6	40.1	1.3	4.1	32.3	1.4	4.7	26.6	1.6	5.3	21.8	1.7	5.9
150	172.8	0.9	1.5	119.9	0.9	2.0	88.6	1.0	2.5	67.2	1.1	3.0	52.2	1.2	3.6	41.5	1.3	4.1	33.4	1.4	4.7	27.5	1.6	5.3	22.6	1.7	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second.
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 8 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.9	0.9	1.5																								
10	12.4	0.8	1.5	8.1	0.9	2.0	5.9	1.0	2.5																		
15	18.5	0.8	1.5	12.3	0.9	2.0	9.3	1.0	2.5	6.8	1.1	3.0	4.7	1.4	3.5												
20	24.7	0.8	1.5	16.7	0.9	2.0	12.5	1.0	2.5	9.4	1.1	3.0	7.0	1.2	3.6	4.7	1.5	4.1									
25	30.8	0.8	1.5	20.8	0.9	2.0	15.9	1.0	2.4	11.8	1.1	3.0	9.0	1.2	3.5	6.8	1.3	4.1									
30	37.0	0.8	1.5	25.0	0.9	2.0	19.0	1.0	2.5	14.3	1.1	3.0	11.0	1.2	3.5	8.5	1.3	4.1	6.4	1.5	4.7						
35	43.2	0.8	1.5	29.1	0.9	2.0	22.2	1.0	2.5	16.9	1.0	3.0	12.9	1.1	3.5	10.1	1.3	4.1	7.8	1.4	4.7						
40	49.3	0.8	1.5	33.3	0.9	2.0	25.3	1.0	2.5	19.3	1.0	3.0	14.8	1.1	3.5	11.6	1.3	4.1	9.1	1.4	4.7	7.1	1.6	5.2			
45	55.5	0.8	1.5	37.4	0.9	2.0	28.5	1.0	2.5	21.7	1.0	3.0	16.7	1.1	3.5	13.1	1.3	4.1	10.4	1.4	4.7	8.2	1.6	5.2			
50	61.7	0.8	1.5	41.6	0.9	2.0	31.7	1.0	2.5	24.1	1.0	3.0	18.8	1.1	3.5	14.7	1.2	4.1	11.7	1.4	4.7	9.3	1.5	5.3	7.1	1.8	5.8
55	67.8	0.8	1.5	45.7	0.9	2.0	34.8	1.0	2.5	26.5	1.0	3.0	20.7	1.1	3.5	16.2	1.2	4.1	12.9	1.4	4.7	10.4	1.5	5.3	8.2	1.7	5.8
60	74.0	0.8	1.5	49.9	0.9	2.0	38.0	1.0	2.5	28.9	1.0	3.0	22.6	1.1	3.5	17.7	1.2	4.1	14.1	1.4	4.7	11.4	1.5	5.3	9.2	1.7	5.8
65	80.2	0.8	1.5	54.0	0.9	2.0	41.1	1.0	2.5	31.4	1.0	3.0	24.5	1.1	3.5	19.5	1.2	4.1	15.4	1.3	4.7	12.4	1.5	5.3	10.1	1.7	5.8
70	86.3	0.8	1.5	58.2	0.9	2.0	44.3	1.0	2.5	33.8	1.0	3.0	26.3	1.1	3.5	21.0	1.2	4.1	16.6	1.3	4.7	13.5	1.5	5.3	11.0	1.6	5.8
75	92.5	0.8	1.5	62.3	0.9	2.0	47.5	1.0	2.5	36.2	1.0	3.0	28.2	1.1	3.5	22.4	1.2	4.1	17.8	1.3	4.7	14.5	1.5	5.3	11.8	1.6	5.8
80	98.7	0.8	1.5	66.5	0.9	2.0	50.6	1.0	2.5	38.6	1.0	3.0	30.1	1.1	3.5	23.9	1.2	4.1	19.0	1.3	4.7	15.5	1.5	5.3	12.7	1.6	5.8
85	104.8	0.8	1.5	70.6	0.9	2.0	53.8	1.0	2.5	41.0	1.0	3.0	32.0	1.1	3.5	25.4	1.2	4.1	20.3	1.3	4.7	16.5	1.5	5.3	13.6	1.6	5.8
90	111.0	0.8	1.5	74.8	0.9	2.0	57.0	1.0	2.5	43.4	1.0	3.0	33.8	1.1	3.5	26.9	1.2	4.1	21.8	1.3	4.6	17.5	1.5	5.3	14.4	1.6	5.8
95	117.2	0.8	1.5	78.9	0.9	2.0	60.1	1.0	2.5	45.8	1.0	3.0	35.7	1.1	3.5	28.4	1.2	4.1	23.0	1.3	4.6	18.6	1.5	5.3	15.3	1.6	5.8
100	123.3	0.8	1.5	83.1	0.9	2.0	63.3	1.0	2.5	48.2	1.0	3.0	37.6	1.1	3.5	29.9	1.2	4.1	24.2	1.3	4.6	19.6	1.5	5.3	16.2	1.6	5.8
105	129.5	0.8	1.5	87.3	0.9	2.0	66.4	1.0	2.5	50.6	1.0	3.0	39.5	1.1	3.5	31.4	1.2	4.1	25.4	1.3	4.6	20.6	1.5	5.3	17.0	1.6	5.8
110	135.7	0.8	1.5	91.4	0.9	2.0	69.6	1.0	2.5	53.0	1.0	3.0	41.3	1.1	3.5	32.9	1.2	4.1	26.6	1.3	4.7	21.6	1.4	5.3	17.9	1.6	5.8
115	141.8	0.8	1.5	95.6	0.9	2.0	72.8	1.0	2.5	55.4	1.0	3.0	43.2	1.1	3.5	34.4	1.2	4.1	27.9	1.3	4.7	22.6	1.4	5.3	18.7	1.6	5.8
120	148.0	0.8	1.5	99.7	0.9	2.0	75.9	1.0	2.5	57.9	1.0	3.0	45.1	1.1	3.5	35.9	1.2	4.1	29.1	1.3	4.7	23.9	1.4	5.2	19.5	1.6	5.8
125	154.1	0.8	1.5	103.9	0.9	2.0	79.1	1.0	2.5	60.3	1.0	3.0	47.0	1.1	3.5	37.4	1.2	4.1	30.3	1.3	4.7	24.8	1.4	5.2	20.4	1.6	5.8
130	160.3	0.8	1.5	108.0	0.9	2.0	82.3	1.0	2.5	62.7	1.0	3.0	48.8	1.1	3.5	38.9	1.2	4.1	31.5	1.3	4.7	25.8	1.4	5.3	21.2	1.6	5.8
135	166.5	0.8	1.5	112.2	0.9	2.0	85.4	1.0	2.5	65.1	1.0	3.0	50.7	1.1	3.5	40.3	1.2	4.1	32.7	1.3	4.7	26.8	1.4	5.3	22.1	1.6	5.8
140	172.6	0.8	1.5	116.3	0.9	2.0	88.6	1.0	2.5	67.5	1.0	3.0	52.6	1.1	3.5	41.8	1.2	4.1	33.9	1.3	4.7	27.8	1.4	5.3	22.9	1.6	5.8
145	178.8	0.8	1.5	120.5	0.9	2.0	91.8	1.0	2.5	69.9	1.0	3.0	54.5	1.1	3.5	43.3	1.2	4.1	35.1	1.3	4.7	28.8	1.4	5.3	23.7	1.6	5.8
150	185.0	0.8	1.5	124.6	0.9	2.0	94.9	1.0	2.5	72.3	1.0	3.0	56.4	1.1	3.5	44.8	1.2	4.1	36.3	1.3	4.7	29.8	1.4	5.3	24.6	1.6	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 9 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 3.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	7.4	0.7	1.4	4.9	0.8	1.9	3.2	1.0	2.3																		
10	15.1	0.7	1.4	10.2	0.8	1.9	7.6	0.8	2.4	5.7	0.9	2.9	4.0	1.1	3.4												
15	22.6	0.7	1.4	15.6	0.8	1.9	11.5	0.8	2.4	8.8	0.9	2.9	6.7	1.0	3.4	5.1	1.1	4.0									
20	30.1	0.7	1.4	20.7	0.8	1.9	15.5	0.8	2.4	11.8	0.9	2.9	9.2	0.9	3.4	7.2	1.0	4.0	5.5	1.2	4.6						
25	37.6	0.7	1.4	25.9	0.8	1.9	19.4	0.8	2.4	15.0	0.9	2.9	11.6	0.9	3.4	9.2	1.0	4.0	7.2	1.1	4.6	5.6	1.3	5.1			
30	45.1	0.7	1.4	31.1	0.8	1.9	23.3	0.8	2.4	18.0	0.9	2.9	14.0	0.9	3.4	11.1	1.0	4.0	8.9	1.1	4.6	7.1	1.2	5.2	5.3	1.5	5.7
35	52.7	0.7	1.4	36.2	0.8	1.9	27.1	0.8	2.4	21.0	0.9	2.9	16.5	0.9	3.4	13.0	1.0	4.0	10.5	1.1	4.6	8.4	1.2	5.2	6.7	1.4	5.7
40	60.2	0.7	1.4	41.4	0.8	1.9	31.0	0.8	2.4	24.0	0.9	2.9	18.9	0.9	3.4	14.9	1.0	4.0	12.0	1.1	4.6	9.8	1.2	5.2	7.9	1.3	5.7
45	67.7	0.7	1.4	46.6	0.8	1.9	34.9	0.8	2.4	27.0	0.9	2.9	21.2	0.9	3.4	17.0	1.0	4.0	13.6	1.1	4.6	11.1	1.2	5.2	9.1	1.3	5.7
50	75.2	0.7	1.4	51.8	0.8	1.9	38.8	0.8	2.4	29.9	0.9	2.9	23.6	0.9	3.4	18.9	1.0	4.0	15.2	1.1	4.6	12.4	1.2	5.2	10.2	1.3	5.7
55	82.8	0.7	1.4	56.9	0.8	1.9	42.6	0.8	2.4	32.9	0.9	2.9	25.9	0.9	3.4	20.8	1.0	4.0	16.7	1.1	4.6	13.7	1.2	5.2	11.3	1.3	5.7
60	90.3	0.7	1.4	62.1	0.8	1.9	46.5	0.8	2.4	35.9	0.9	2.9	28.3	0.9	3.4	22.7	1.0	4.0	18.5	1.1	4.5	14.9	1.2	5.2	12.4	1.3	5.7
65	97.8	0.7	1.4	67.3	0.8	1.9	50.4	0.8	2.4	38.9	0.9	2.9	30.6	0.9	3.4	24.6	1.0	4.0	20.0	1.1	4.5	16.2	1.2	5.2	13.5	1.3	5.7
70	105.3	0.7	1.4	72.4	0.8	1.9	54.3	0.8	2.4	41.9	0.9	2.9	33.0	0.9	3.4	26.4	1.0	4.0	21.5	1.1	4.5	17.5	1.2	5.2	14.5	1.3	5.7
75	112.8	0.7	1.4	77.6	0.8	1.9	58.1	0.8	2.4	44.9	0.9	2.9	35.3	0.9	3.4	28.3	1.0	4.0	23.1	1.1	4.5	19.1	1.2	5.1	15.6	1.3	5.7
80	120.4	0.7	1.4	82.8	0.8	1.9	62.0	0.8	2.4	47.9	0.9	2.9	37.7	0.9	3.4	30.2	1.0	4.0	24.6	1.1	4.5	20.3	1.2	5.1	16.7	1.3	5.7
85	127.9	0.7	1.4	88.0	0.8	1.9	65.9	0.8	2.4	50.9	0.9	2.9	40.1	0.9	3.4	32.1	1.0	4.0	26.1	1.1	4.5	21.6	1.2	5.1	17.8	1.2	5.7
90	135.4	0.7	1.4	93.1	0.8	1.9	69.8	0.8	2.4	53.9	0.9	2.9	42.4	0.9	3.4	34.0	1.0	4.0	27.7	1.1	4.5	22.9	1.2	5.1	18.9	1.2	5.7
95	142.9	0.7	1.4	98.3	0.8	1.9	73.6	0.8	2.4	56.9	0.9	2.9	44.8	0.9	3.4	35.9	1.0	4.0	29.2	1.1	4.5	24.1	1.2	5.1	20.2	1.2	5.7
100	150.5	0.7	1.4	103.5	0.8	1.9	77.5	0.8	2.4	59.9	0.9	2.9	47.1	0.9	3.4	37.8	1.0	4.0	30.7	1.1	4.5	25.4	1.2	5.1	21.2	1.2	5.7
105	158.0	0.7	1.4	108.7	0.8	1.9	81.4	0.8	2.4	62.8	0.9	2.9	49.5	0.9	3.4	39.6	1.0	4.0	32.3	1.1	4.5	26.7	1.2	5.1	22.3	1.2	5.7
110	165.5	0.7	1.4	113.8	0.8	1.9	85.3	0.8	2.4	65.8	0.9	2.9	51.8	0.9	3.4	41.5	1.0	4.0	33.8	1.1	4.6	27.9	1.2	5.1	23.3	1.2	5.7
115	173.0	0.7	1.4	119.0	0.8	1.9	89.1	0.8	2.4	68.8	0.9	2.9	54.2	0.9	3.4	43.4	1.0	4.0	35.4	1.1	4.6	29.2	1.2	5.1	24.4	1.2	5.7
120	180.5	0.7	1.4	124.2	0.8	1.9	93.0	0.8	2.4	71.8	0.9	2.9	56.5	0.9	3.4	45.3	1.0	4.0	36.9	1.1	4.6	30.5	1.2	5.1	25.5	1.2	5.7
125	188.1	0.7	1.4	129.4	0.8	1.9	96.9	0.8	2.4	74.8	0.9	2.9	58.9	0.9	3.4	47.2	1.0	4.0	38.4	1.1	4.6	31.7	1.2	5.1	26.5	1.2	5.7
130	195.6	0.7	1.4	134.5	0.8	1.9	100.8	0.8	2.4	77.8	0.9	2.9	61.2	0.9	3.4	49.1	1.0	4.0	40.0	1.1	4.6	33.0	1.2	5.1	27.6	1.2	5.7
135	203.1	0.7	1.4	139.7	0.8	1.9	104.6	0.8	2.4	80.8	0.9	2.9	63.6	0.9	3.4	51.0	1.0	4.0	41.5	1.1	4.6	34.3	1.2	5.1	28.6	1.2	5.7
140	210.6	0.7	1.4	144.9	0.8	1.9	108.5	0.8	2.4	83.8	0.9	2.9	66.0	0.9	3.4	52.8	1.0	4.0	43.0	1.1	4.6	35.6	1.2	5.1	29.7	1.2	5.7
145	218.2	0.7	1.4	150.1	0.8	1.9	112.4	0.8	2.4	86.8	0.9	2.9	68.3	0.9	3.4	54.7	1.0	4.0	44.6	1.1	4.6	36.8	1.2	5.1	30.7	1.2	5.7
150	225.7	0.7	1.4	155.2	0.8	1.9	116.3	0.8	2.4	89.8	0.9	2.9	70.7	0.9	3.4	56.6	1.0	4.0	46.1	1.1	4.6	38.1	1.2	5.1	31.8	1.2	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dir sions are in feet; Velocity measurements are in feet per second; includ lowance for freeboarc settlement.

Table GS-4 Parabolic Grass Swale Design   Sheet 10 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	8.5	0.6	1.4	5.9	0.7	1.8	4.1	0.8	2.3																		
10	17.2	0.6	1.4	12.1	0.7	1.8	8.8	0.7	2.3	6.7	0.8	2.8	5.2	0.9	3.3	3.8	1.0	3.9									
15	25.8	0.6	1.4	18.1	0.7	1.8	13.4	0.7	2.3	10.3	0.8	2.8	8.1	0.8	3.4	6.4	0.9	3.9	4.9	1.0	4.5						
20	34.4	0.6	1.4	24.2	0.7	1.8	17.8	0.7	2.3	13.9	0.8	2.8	10.9	0.8	3.4	8.7	0.9	3.9	6.9	1.0	4.5	5.5	1.1	5.0			
25	43.0	0.6	1.4	30.2	0.7	1.9	22.3	0.7	2.3	17.4	0.8	2.8	13.8	0.8	3.3	10.9	0.9	3.9	8.8	1.0	4.5	7.1	1.0	5.1	5.7	1.2	5.6
30	51.6	0.6	1.4	36.3	0.7	1.9	26.7	0.7	2.3	20.8	0.8	2.8	16.5	0.8	3.3	13.2	0.9	3.9	10.7	0.9	4.5	8.7	1.0	5.1	7.1	1.1	5.6
35	60.2	0.6	1.4	42.3	0.7	1.9	31.1	0.7	2.3	24.3	0.8	2.8	19.3	0.8	3.4	15.6	0.9	3.9	12.5	0.9	4.5	10.3	1.0	5.0	8.4	1.1	5.6
40	68.8	0.6	1.4	48.3	0.7	1.9	35.6	0.7	2.3	27.8	0.8	2.8	22.0	0.8	3.4	17.8	0.9	3.9	14.4	0.9	4.5	11.8	1.0	5.0	9.8	1.1	5.7
45	77.4	0.6	1.4	54.4	0.7	1.9	40.0	0.7	2.4	31.2	0.8	2.8	24.8	0.8	3.4	20.0	0.9	3.9	16.4	0.9	4.4	13.3	1.0	5.0	11.1	1.1	5.7
50	86.0	0.6	1.4	60.4	0.7	1.9	44.5	0.7	2.4	34.7	0.8	2.8	27.5	0.8	3.4	22.2	0.9	3.9	18.2	0.9	4.4	14.9	1.0	5.0	12.3	1.1	5.7
55	94.6	0.6	1.4	66.5	0.7	1.9	48.9	0.7	2.4	38.2	0.8	2.8	30.3	0.8	3.4	24.4	0.9	3.9	20.0	0.9	4.4	16.6	1.0	5.0	13.6	1.1	5.7
60	103.2	0.6	1.4	72.5	0.7	1.9	53.4	0.7	2.4	41.7	0.8	2.8	33.0	0.8	3.4	26.6	0.9	3.9	21.8	0.9	4.5	18.1	1.0	5.0	14.9	1.1	5.7
65	111.8	0.6	1.4	78.5	0.7	1.9	57.8	0.7	2.4	45.1	0.8	2.8	35.8	0.8	3.4	28.9	0.9	3.9	23.6	0.9	4.5	19.6	1.0	5.0	16.2	1.1	5.7
70	120.4	0.6	1.4	84.6	0.7	1.9	62.3	0.7	2.4	48.6	0.8	2.8	38.6	0.8	3.4	31.1	0.9	3.9	25.4	0.9	4.5	21.1	1.0	5.0	17.7	1.1	5.6
75	129.0	0.6	1.4	90.6	0.7	1.9	66.7	0.7	2.4	52.1	0.8	2.8	41.3	0.8	3.4	33.3	0.9	3.9	27.2	0.9	4.5	22.6	1.0	5.0	19.0	1.1	5.6
80	137.6	0.6	1.4	96.7	0.7	1.9	71.2	0.7	2.4	55.5	0.8	2.8	44.1	0.8	3.4	35.5	0.9	3.9	29.1	0.9	4.5	24.1	1.0	5.0	20.2	1.1	5.6
85	146.2	0.6	1.4	102.7	0.7	1.9	75.6	0.7	2.4	59.0	0.8	2.8	46.8	0.8	3.4	37.7	0.9	3.9	30.9	0.9	4.5	25.6	1.0	5.0	21.5	1.1	5.6
90	154.8	0.6	1.4	108.7	0.7	1.9	80.0	0.7	2.4	62.5	0.8	2.8	49.6	0.8	3.4	39.9	0.9	3.9	32.7	0.9	4.5	27.1	1.0	5.0	22.8	1.1	5.6
95	163.4	0.6	1.4	114.8	0.7	1.9	84.5	0.7	2.4	65.9	0.8	2.8	52.3	0.8	3.4	42.2	0.9	3.9	34.5	0.9	4.5	28.6	1.0	5.0	24.0	1.1	5.6
100	172.0	0.6	1.4	120.8	0.7	1.9	88.9	0.7	2.4	69.4	0.8	2.8	55.1	0.8	3.4	44.4	0.9	3.9	36.3	0.9	4.5	30.1	1.0	5.0	25.3	1.1	5.6
105	180.6	0.6	1.4	126.9	0.7	1.9	93.4	0.7	2.4	72.9	0.8	2.8	57.8	0.8	3.4	46.6	0.9	3.9	38.1	0.9	4.5	31.6	1.0	5.0	26.5	1.1	5.6
110	189.2	0.6	1.4	132.9	0.7	1.9	97.8	0.7	2.4	76.3	0.8	2.8	60.6	0.8	3.4	48.8	0.9	3.9	39.9	0.9	4.5	33.1	1.0	5.0	27.8	1.1	5.6
115	197.8	0.8	1.4	138.9	0.7	1.9	102.3	0.7	2.4	79.8	0.8	2.8	63.3	0.8	3.4	51.0	0.9	3.9	41.7	0.9	4.5	34.6	1.0	5.0	29.0	1.1	5.6
120	206.4	0.6	1.4	145.0	0.7	1.9	106.7	0.7	2.4	83.3	0.8	2.8	66.1	0.8	3.4	53.3	0.9	3.9	43.6	0.9	4.5	36.1	1.0	5.0	30.2	1.1	5.7
125	215.0	0.6	1.4	151.0	0.7	1.9	111.2	0.7	2.4	86.8	0.8	2.8	68.8	0.8	3.4	55.5	0.9	3.9	45.4	0.9	4.5	37.6	1.0	5.0	31.5	1.1	5.7
130	223.7	0.6	1.4	157.1	0.7	1.9	115.6	0.7	2.4	90.2	0.8	2.8	71.6	0.8	3.4	57.7	0.9	3.9	47.2	0.9	4.5	39.1	1.0	5.0	32.7	1.1	5.7
135	232.3	0.6	1.4	163.1	0.7	1.9	120.1	0.7	2.4	93.7	0.8	2.8	74.3	0.8	3.4	59.9	0.9	3.9	49.0	0.9	4.5	40.6	1.0	5.0	34.0	1.1	5.7
140	240.9	0.6	1.4	169.1	0.7	1.9	124.5	0.7	2.4	97.2	0.8	2.8	77.1	0.8	3.4	62.1	0.9	3.9	50.8	0.9	4.5	42.1	1.0	5.0	35.2	1.1	5.7
145	249.5	0.6	1.4	175.2	0.7	1.9	129.0	0.7	2.4	100.6	0.8	2.8	79.8	0.8	3.4	64.3	0.9	3.9	52.6	0.9	4.5	43.6	1.0	5.0	36.5	1.1	5.7
150	258.1	0.6	1.4	181.2	0.7	1.9	133.4	0.7	2.4	104.1	0.8	2.8	82.6	0.8	3.4	66.6	0.9	3.9	54.4	0.9	4.5	45.1	1.0	5.0	37.8	1.1	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 11 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 5.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	9.5	0.6	1.4	6.7	0.6	1.8	4.7	0.7	2.3	3.5	0.8	2.8															
10	19.0	0.6	1.4	13.7	0.6	1.8	9.7	0.7	2.3	7.6	0.7	2.8	6.0	0.8	3.3	4.7	0.8	3.8	3.4	1.0	4.4						
15	28.5	0.6	1.4	20.5	0.6	1.8	14.8	0.7	2.3	11.7	0.7	2.8	9.2	0.7	3.3	7.3	0.8	3.8	5.9	0.9	4.4	4.7	1.0	5.0			
20	38.0	0.6	1.4	27.3	0.6	1.8	19.7	0.7	2.3	15.5	0.7	2.8	12.4	0.7	3.3	9.9	0.8	3.8	8.0	0.9	4.4	6.5	0.9	4.9	5.3	1.0	5.5
25	47.5	0.6	1.4	34.1	0.6	1.8	24.6	0.7	2.3	19.4	0.7	2.8	15.5	0.7	3.3	12.6	0.8	3.8	10.1	0.8	4.4	8.3	0.9	5.0	6.8	1.0	5.6
30	57.0	0.6	1.4	40.9	0.6	1.8	29.5	0.7	2.3	23.3	0.7	2.8	18.6	0.7	3.3	15.1	0.8	3.8	12.2	0.8	4.4	10.1	0.9	5.0	8.3	1.0	5.6
35	66.5	0.6	1.4	47.7	0.6	1.8	34.4	0.7	2.3	27.2	0.7	2.8	21.7	0.7	3.3	17.6	0.8	3.8	14.5	0.8	4.4	11.8	0.9	5.0	9.8	1.0	5.6
40	76.0	0.6	1.4	54.6	0.6	1.8	39.4	0.7	2.3	31.0	0.7	2.8	24.8	0.7	3.3	20.1	0.8	3.8	16.5	0.8	4.4	13.6	0.9	5.0	11.3	1.0	5.5
45	85.5	0.6	1.4	61.4	0.6	1.8	44.3	0.7	2.3	34.9	0.7	2.8	27.9	0.7	3.3	22.6	0.8	3.8	18.6	0.8	4.4	15.5	0.9	4.9	12.8	1.0	5.5
50	95.0	0.6	1.4	68.2	0.6	1.8	49.2	0.7	2.3	38.8	0.7	2.8	31.0	0.7	3.3	25.1	0.8	3.8	20.6	0.8	4.4	17.2	0.9	4.9	14.3	1.0	5.5
55	104.6	0.6	1.4	75.0	0.6	1.8	54.1	0.7	2.3	42.7	0.7	2.8	34.1	0.7	3.3	27.6	0.8	3.8	22.7	0.8	4.4	18.9	0.9	4.9	15.9	0.9	5.5
60	114.1	0.6	1.4	81.8	0.6	1.8	59.0	0.7	2.3	46.6	0.7	2.8	37.2	0.7	3.3	30.1	0.8	3.8	24.7	0.8	4.4	20.6	0.9	4.9	17.3	0.9	5.5
65	123.6	0.6	1.4	88.6	0.6	1.8	63.9	0.7	2.3	50.4	0.7	2.8	40.3	0.7	3.3	32.6	0.8	3.8	26.8	0.8	4.4	22.3	0.9	4.9	18.8	0.9	5.5
70	133.1	0.6	1.4	95.5	0.6	1.8	68.9	0.7	2.3	54.3	0.7	2.8	43.4	0.7	3.3	35.1	0.8	3.8	28.9	0.8	4.4	24.0	0.9	4.9	20.2	0.9	5.5
75	142.6	0.6	1.4	102.3	0.6	1.8	73.8	0.7	2.3	58.2	0.7	2.8	46.5	0.7	3.3	37.7	0.8	3.8	30.9	0.8	4.4	25.7	0.9	4.9	21.6	0.9	5.5
80	152.1	0.6	1.4	109.1	0.6	1.8	78.7	0.7	2.3	62.1	0.7	2.8	49.6	0.7	3.3	40.2	0.8	3.8	33.0	0.8	4.4	27.4	0.9	4.9	23.1	0.9	5.5
85	161.6	0.6	1.4	115.9	0.6	1.8	83.6	0.7	2.3	65.9	0.7	2.8	52.7	0.7	3.3	42.7	0.8	3.8	35.0	0.8	4.4	29.1	0.9	5.0	24.5	0.9	5.5
90	171.1	0.6	1.4	122.7	0.6	1.8	88.5	0.7	2.3	69.8	0.7	2.8	55.8	0.7	3.3	45.2	0.8	3.8	37.1	0.8	4.4	30.9	0.9	5.0	26.0	0.9	5.5
95	180.6	0.6	1.4	129.6	0.6	1.8	93.4	0.7	2.3	73.7	0.7	2.8	58.9	0.7	3.3	47.7	0.8	3.8	39.2	0.8	4.4	32.6	0.9	5.0	27.4	0.9	5.5
100	190.1	0.6	1.4	136.4	0.6	1.8	98.4	0.7	2.3	77.6	0.7	2.8	62.0	0.7	3.3	50.2	0.8	3.8	41.2	0.8	4.4	34.3	0.9	5.0	28.8	0.9	5.5
105	199.6	0.6	1.4	143.2	0.6	1.8	103.3	0.7	2.3	81.5	0.7	2.8	65.1	0.7	3.3	52.7	0.8	3.8	43.3	0.8	4.4	36.0	0.9	5.0	30.3	0.9	5.5
110	209.1	0.6	1.4	150.0	0.6	1.8	108.2	0.7	2.3	85.3	0.7	2.8	68.2	0.7	3.3	55.2	0.8	3.8	45.3	0.8	4.4	37.7	0.9	5.0	31.7	0.9	5.5
115	218.6	0.6	1.4	156.8	0.6	1.8	113.1	0.7	2.3	89.2	0.7	2.8	71.3	0.7	3.3	57.7	0.8	3.8	47.4	0.8	4.4	39.4	0.9	5.0	33.2	0.9	5.5
120	228.1	0.6	1.4	163.6	0.6	1.8	118.0	0.7	2.3	93.1	0.7	2.8	74.3	0.7	3.3	60.2	0.8	3.8	49.5	0.8	4.4	41.1	0.9	5.0	34.6	0.9	5.5
125	237.6	0.6	1.4	170.5	0.6	1.8	123.0	0.7	2.3	97.0	0.7	2.8	77.4	0.7	3.3	62.7	0.8	3.8	51.5	0.8	4.4	42.8	0.9	5.0	36.0	0.9	5.5
130	247.1	0.6	1.4	177.3	0.6	1.8	127.9	0.7	2.3	100.8	0.7	2.8	80.5	0.7	3.3	65.2	0.8	3.8	53.6	0.8	4.4	44.6	0.9	5.0	37.5	0.9	5.5
135	256.6	0.6	1.4	184.1	0.6	1.8	132.8	0.7	2.3	104.7	0.7	2.8	83.6	0.7	3.3	67.8	0.8	3.8	55.6	0.8	4.4	46.3	0.9	5.0	38.9	0.9	5.5
140	266.1	0.6	1.4	190.9	0.6	1.8	137.7	0.7	2.3	108.6	0.7	2.8	86.7	0.7	3.3	70.3	0.8	3.8	57.7	0.8	4.4	48.0	0.9	5.0	40.4	0.9	5.5
145	275.6	0.6	1.4	197.7	0.6	1.8	142.6	0.7	2.3	112.5	0.7	2.8	89.8	0.7	3.3	72.8	0.8	3.8	59.8	0.8	4.4	49.7	0.9	5.0	41.8	0.9	5.5
150	285.1	0.6	1.4	204.6	0.6	1.8	147.5	0.7	2.3	116.4	0.7	2.8	92.9	0.7	3.3	75.3	0.8	3.8	61.8	0.8	4.4	51.4	0.9	5.0	43.2	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 12 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.6	0.5	1.3	7.3	0.6	1.8	5.3	0.6	2.3	4.0	0.7	2.8	2.9	0.8	3.2												
10	21.1	0.5	1.3	14.7	0.6	1.8	10.9	0.6	2.3	8.4	0.7	2.8	6.6	0.7	3.2	5.3	0.8	3.8	4.2	0.8	4.3						
15	31.6	0.5	1.3	22.1	0.6	1.8	16.3	0.6	2.3	12.7	0.6	2.7	10.1	0.7	3.3	8.2	0.7	3.8	6.6	0.8	4.3	5.4	0.9	4.9	4.3	1.0	5.5
20	42.1	0.5	1.3	29.5	0.6	1.8	21.7	0.6	2.3	17.0	0.6	2.7	13.6	0.7	3.2	11.1	0.7	3.7	9.0	0.8	4.3	7.4	0.8	4.9	6.1	0.9	5.5
25	52.7	0.5	1.3	36.8	0.6	1.8	27.1	0.6	2.3	21.2	0.6	2.8	17.0	0.7	3.2	13.9	0.7	3.8	11.3	0.8	4.3	9.3	0.8	4.9	7.8	0.9	5.5
30	63.2	0.5	1.3	44.2	0.6	1.8	32.5	0.6	2.3	25.4	0.6	2.8	20.4	0.7	3.2	16.6	0.7	3.8	13.7	0.8	4.3	11.3	0.8	4.9	9.4	0.9	5.5
35	73.7	0.5	1.3	51.6	0.6	1.8	38.0	0.6	2.3	29.7	0.6	2.8	23.8	0.7	3.2	19.4	0.7	3.8	16.0	0.8	4.3	13.4	0.8	4.9	11.1	0.9	5.5
40	84.2	0.5	1.3	58.9	0.6	1.8	43.4	0.6	2.3	33.9	0.6	2.8	27.2	0.7	3.3	22.2	0.7	3.8	18.3	0.8	4.3	15.3	0.8	4.9	12.7	0.9	5.5
45	94.8	0.5	1.3	66.3	0.6	1.8	48.8	0.6	2.3	38.2	0.6	2.8	30.7	0.7	3.3	24.9	0.7	3.8	20.6	0.8	4.3	17.2	0.8	4.9	14.5	0.9	5.4
50	105.3	0.5	1.3	73.6	0.6	1.8	54.2	0.6	2.3	42.4	0.6	2.8	34.1	0.7	3.3	27.7	0.7	3.8	22.8	0.8	4.3	19.1	0.8	4.9	16.1	0.9	5.4
55	115.8	0.5	1.3	81.0	0.6	1.8	59.7	0.6	2.3	46.6	0.6	2.8	37.5	0.7	3.3	30.5	0.7	3.8	25.1	0.8	4.3	21.0	0.8	4.9	17.7	0.9	5.4
60	126.4	0.5	1.3	88.4	0.6	1.8	65.1	0.6	2.3	50.9	0.6	2.8	40.9	0.7	3.3	33.3	0.7	3.8	27.4	0.8	4.3	22.9	0.8	4.9	19.3	0.9	5.4
65	136.9	0.5	1.3	95.7	0.6	1.8	70.5	0.6	2.3	55.1	0.6	2.8	44.3	0.7	3.3	36.0	0.7	3.8	29.7	0.8	4.3	24.8	0.8	4.9	20.9	0.9	5.4
70	147.4	0.5	1.3	103.1	0.6	1.8	75.9	0.6	2.3	59.3	0.6	2.8	47.7	0.7	3.3	38.8	0.7	3.8	32.0	0.8	4.3	26.7	0.8	4.9	22.5	0.9	5.4
75	158.0	0.5	1.3	110.5	0.6	1.8	81.3	0.6	2.3	63.6	0.6	2.8	51.1	0.7	3.3	41.6	0.7	3.8	34.3	0.8	4.3	28.6	0.8	4.9	24.1	0.9	5.4
80	168.5	0.5	1.3	117.8	0.6	1.8	86.8	0.6	2.3	67.8	0.6	2.8	54.5	0.7	3.3	44.3	0.7	3.8	36.5	0.8	4.3	30.5	0.8	4.9	25.7	0.9	5.5
85	179.0	0.5	1.3	125.2	0.6	1.8	92.2	0.6	2.3	72.0	0.6	2.8	57.9	0.7	3.3	47.1	0.7	3.8	38.8	0.8	4.3	32.4	0.8	4.9	27.3	0.9	5.5
90	189.6	0.5	1.3	132.6	0.6	1.8	97.6	0.6	2.3	76.3	0.6	2.8	61.3	0.7	3.3	49.9	0.7	3.8	41.1	0.8	4.3	34.3	0.8	4.9	28.9	0.9	5.5
95	200.1	0.5	1.3	139.9	0.6	1.8	103.0	0.6	2.3	80.5	0.6	2.8	64.7	0.7	3.3	52.6	0.7	3.8	43.4	0.8	4.3	36.2	0.8	4.9	30.5	0.9	5.5
100	210.6	0.5	1.3	147.3	0.6	1.8	108.5	0.6	2.3	84.8	0.6	2.8	68.1	0.7	3.3	55.4	0.7	3.8	45.7	0.8	4.3	38.1	0.8	4.9	32.1	0.9	5.5
105	221.1	0.5	1.3	154.6	0.6	1.8	113.9	0.6	2.3	89.0	0.6	2.8	71.5	0.7	3.3	58.2	0.7	3.8	47.9	0.8	4.3	40.0	0.8	4.9	33.7	0.9	5.5
110	231.7	0.5	1.3	162.0	0.6	1.8	119.3	0.6	2.3	93.2	0.6	2.8	74.9	0.7	3.3	60.9	0.7	3.8	50.2	0.8	4.3	41.9	0.8	4.9	35.3	0.9	5.5
115	242.2	0.5	1.3	169.4	0.6	1.8	124.7	0.6	2.3	97.5	0.6	2.8	78.3	0.7	3.3	63.7	0.7	3.8	52.5	0.8	4.3	43.8	0.8	4.9	36.9	0.9	5.5
120	252.7	0.5	1.3	176.7	0.6	1.8	130.2	0.6	2.3	101.7	0.6	2.8	81.7	0.7	3.3	66.5	0.7	3.8	54.8	0.8	4.3	45.7	0.8	4.9	38.5	0.9	5.5
125	263.3	0.5	1.3	184.1	0.6	1.8	135.6	0.6	2.3	106.0	0.6	2.8	85.1	0.7	3.3	69.3	0.7	3.8	57.1	0.8	4.3	47.6	0.8	4.9	40.1	0.9	5.5
130	273.8	0.5	1.3	191.5	0.6	1.8	141.0	0.6	2.3	110.2	0.6	2.8	88.5	0.7	3.3	72.0	0.7	3.8	59.4	0.8	4.3	49.5	0.8	4.9	41.7	0.9	5.5
135	284.3	0.5	1.3	198.8	0.6	1.8	146.4	0.6	2.3	114.4	0.6	2.8	91.9	0.7	3.3	74.8	0.7	3.8	61.6	0.8	4.3	51.4	0.8	4.9	43.3	0.9	5.5
140	294.9	0.5	1.3	206.2	0.6	1.8	151.8	0.6	2.3	118.7	0.6	2.8	95.3	0.7	3.3	77.6	0.7	3.8	63.9	0.8	4.3	53.3	0.8	4.9	44.9	0.9	5.5
145	305.4	0.5	1.3	213.6	0.6	1.8	157.3	0.6	2.3	122.9	0.6	2.8	98.7	0.7	3.3	80.3	0.7	3.8	66.2	0.8	4.3	55.2	0.8	4.9	46.5	0.9	5.5
150	315.9	0.5	1.3	220.9	0.6	1.8	162.7	0.6	2.3	127.1	0.6	2.8	102.1	0.7	3.3	83.1	0.7	3.8	68.5	0.8	4.3	57.1	0.8	4.9	48.1	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 13 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH' (D), AND V2 FOR RETARDANCE "C"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.0	0.5	1.3	8.5	0.5	1.7	6.2	0.5	2.2	4.6	0.6	2.7	3.7	0.6	3.2	2.9	0.7	3.6									
10	24.1	0.5	1.3	16.9	0.5	1.7	12.6	0.5	2.2	9.6	0.6	2.7	7.8	0.6	3.2	6.3	0.6	3.7	5.1	0.7	4.2	4.2	0.8	4.8	3.2	0.9	5.3
15	36.1	0.5	1.3	25.3	0.5	1.7	18.9	0.5	2.2	14.4	0.6	2.7	11.8	0.6	3.2	9.7	0.6	3.7	7.9	0.7	4.2	6.5	0.7	4.8	5.4	0.8	5.3
20	48.1	0.5	1.3	33.8	0.5	1.7	25.2	0.5	2.2	19.2	0.6	2.7	15.8	0.6	3.2	12.9	0.6	3.7	10.7	0.7	4.2	8.8	0.7	4.8	7.4	0.8	5.3
25	60.1	0.5	1.3	42.2	0.5	1.7	31.5	0.5	2.2	24.0	0.6	2.7	19.7	0.6	3.2	16.2	0.6	3.7	13.4	0.7	4.2	11.2	0.7	4.7	9.3	0.8	5.3
30	72.1	0.5	1.3	50.6	0.5	1.7	37.8	0.5	2.2	28.8	0.6	2.7	23.6	0.6	3.2	19.4	0.6	3.7	16.1	0.7	4.2	13.5	0.7	4.8	11.3	0.7	5.3
35	84.1	0.5	1.3	59.1	0.5	1.7	44.1	0.5	2.2	33.6	0.6	2.7	27.6	0.6	3.2	22.6	0.6	3.7	18.7	0.7	4.2	15.7	0.7	4.8	13.3	0.7	5.3
40	96.2	0.5	1.3	67.5	0.5	1.7	50.4	0.5	2.2	38.4	0.6	2.7	31.5	0.6	3.2	25.8	0.6	3.7	21.4	0.7	4.2	17.9	0.7	4.8	15.2	0.7	5.3
45	108.2	0.5	1.3	76.0	0.5	1.7	56.7	0.5	2.2	43.2	0.6	2.7	35.4	0.6	3.2	29.0	0.6	3.7	24.1	0.7	4.2	20.2	0.7	4.8	17.1	0.7	5.3
50	120.2	0.5	1.3	84.4	0.5	1.7	63.0	0.5	2.2	48.0	0.6	2.7	39.4	0.6	3.2	32.3	0.6	3.7	26.8	0.7	4.2	22.4	0.7	4.8	19.0	0.7	5.3
55	132.2	0.5	1.3	92.8	0.5	1.7	69.3	0.5	2.2	52.8	0.6	2.7	43.3	0.6	3.2	35.5	0.6	3.7	29.4	0.7	4.2	24.7	0.7	4.8	20.9	0.7	5.3
60	144.2	0.5	1.3	101.3	0.5	1.7	75.6	0.5	2.2	57.6	0.6	2.7	47.2	0.6	3.2	38.7	0.6	3.7	32.1	0.7	4.2	26.9	0.7	4.8	22.8	0.7	5.3
65	156.3	0.5	1.3	109.7	0.5	1.7	81.8	0.5	2.2	62.4	0.6	2.7	51.2	0.6	3.2	41.9	0.6	3.7	34.8	0.7	4.2	29.1	0.7	4.8	24.7	0.7	5.3
70	168.3	0.5	1.3	118.2	0.5	1.7	88.1	0.5	2.2	67.2	0.6	2.7	55.1	0.6	3.2	45.2	0.6	3.7	37.5	0.7	4.2	31.4	0.7	4.8	26.6	0.7	5.3
75	180.3	0.5	1.3	126.6	0.5	1.7	94.4	0.5	2.2	72.0	0.6	2.7	59.0	0.6	3.2	48.4	0.6	3.7	40.1	0.7	4.2	33.6	0.7	4.8	28.5	0.7	5.3
80	192.3	0.5	1.3	135.0	0.5	1.7	100.7	0.5	2.2	76.8	0.6	2.7	63.0	0.6	3.2	51.6	0.6	3.7	42.8	0.7	4.2	35.9	0.7	4.8	30.3	0.7	5.3
85	204.3	0.5	1.3	143.5	0.5	1.7	107.0	0.5	2.2	81.6	0.6	2.7	66.9	0.6	3.2	54.9	0.6	3.7	45.5	0.7	4.2	38.1	0.7	4.8	32.2	0.7	5.3
90	216.4	0.5	1.3	151.9	0.5	1.7	113.3	0.5	2.2	86.4	0.6	2.7	70.8	0.6	3.2	58.1	0.6	3.7	48.1	0.7	4.2	40.3	0.7	4.8	34.1	0.7	5.3
95	228.4	0.5	1.3	160.3	0.5	1.7	119.6	0.5	2.2	91.2	0.6	2.7	74.8	0.6	3.2	61.3	0.6	3.7	50.8	0.7	4.2	42.6	0.7	4.8	36.0	0.7	5.3
100	240.4	0.5	1.3	168.8	0.5	1.7	125.9	0.5	2.2	96.0	0.6	2.7	78.7	0.6	3.2	64.5	0.6	3.7	53.5	0.7	4.2	44.8	0.7	4.8	37.9	0.7	5.3
105	252.4	0.5	1.3	177.2	0.5	1.7	132.2	0.5	2.2	100.8	0.6	2.7	82.6	0.6	3.2	67.8	0.6	3.7	56.2	0.7	4.2	47.1	0.7	4.8	39.8	0.7	5.3
110	264.4	0.5	1.3	185.7	0.5	1.7	138.5	0.5	2.2	105.6	0.6	2.7	86.6	0.6	3.2	71.0	0.6	3.7	58.8	0.7	4.2	49.3	0.7	4.8	41.7	0.7	5.3
115	276.5	0.5	1.3	194.1	0.5	1.7	144.8	0.5	2.2	110.4	0.6	2.7	90.5	0.6	3.2	74.2	0.6	3.7	61.5	0.7	4.2	51.5	0.7	4.8	43.6	0.7	5.3
120	288.5	0.5	1.3	202.5	0.5	1.7	151.1	0.5	2.2	115.2	0.6	2.7	94.4	0.6	3.2	77.4	0.6	3.7	64.2	0.7	4.2	53.8	0.7	4.8	45.5	0.7	5.3
125	300.5	0.5	1.3	211.0	0.5	1.7	157.4	0.5	2.2	120.0	0.6	2.7	98.4	0.6	3.2	80.7	0.6	3.7	66.9	0.7	4.2	56.0	0.7	4.8	47.4	0.7	5.3
130	312.5	0.5	1.3	219.4	0.5	1.7	163.7	0.5	2.2	124.8	0.6	2.7	102.3	0.6	3.2	83.9	0.6	3.7	69.5	0.7	4.2	58.3	0.7	4.8	49.3	0.7	5.3
135	324.5	0.5	1.3	227.9	0.5	1.7	170.0	0.5	2.2	129.6	0.6	2.7	106.2	0.6	3.2	87.1	0.6	3.7	72.2	0.7	4.2	60.5	0.7	4.8	51.2	0.7	5.3
140	336.6	0.5	1.3	236.3	0.5	1.7	176.3	0.5	2.2	134.4	0.6	2.7	110.2	0.6	3.2	90.3	0.6	3.7	74.9	0.7	4.2	62.7	0.7	4.8	53.1	0.7	5.3
145	348.6	0.5	1.3	244.7	0.5	1.7	182.6	0.5	2.2	139.2	0.6	2.7	114.1	0.6	3.2	93.6	0.6	3.7	77.6	0.7	4.2	65.0	0.7	4.8	55.0	0.7	5.3
150	360.6	0.5	1.3	253.2	0.5	1.7	188.9	0.5	2.2	144.0	0.6	2.7	118.0	0.6	3.2	96.8	0.6	3.7	80.2	0.7	4.2	67.2	0.7	4.8	56.9	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second
Depth "D" does not include allowance for freeboard or settlement

Table GS-4 Parabolic Grass Swale Design Sheet 14 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	13.3	0.4	1.3	9.4	0.5	1.7	6.8	0.5	2.2	5.3	0.5	2.6	4.1	0.6	3.2	3.4	0.6	3.6	2.6	0.7	4.1						
10	26.6	0.4	1.3	18.7	0.5	1.7	13.8	0.5	2.2	10.9	0.5	2.6	8.5	0.6	3.2	7.1	0.6	3.6	5.9	0.6	4.1	4.9	0.7	4.7	4.0	0.7	5.3
15	39.9	0.4	1.3	28.0	0.5	1.7	20.7	0.5	2.2	16.3	0.5	2.6	12.8	0.6	3.2	10.9	0.6	3.6	9.0	0.6	4.1	7.5	0.6	4.7	6.3	0.7	5.2
20	53.2	0.4	1.3	37.4	0.5	1.7	27.6	0.5	2.2	21.7	0.5	2.7	17.0	0.6	3.2	14.5	0.6	3.6	12.1	0.6	4.1	10.2	0.6	4.6	8.5	0.7	5.2
25	66.5	0.4	1.3	46.7	0.5	1.7	34.5	0.5	2.2	27.1	0.5	2.7	21.3	0.6	3.2	18.1	0.6	3.6	15.1	0.6	4.1	12.7	0.6	4.7	10.8	0.7	5.2
30	79.8	0.4	1.3	56.1	0.5	1.7	41.4	0.5	2.2	32.5	0.5	2.7	25.5	0.6	3.2	21.7	0.6	3.6	18.1	0.6	4.1	15.2	0.6	4.7	12.9	0.7	5.2
35	93.1	0.4	1.3	65.4	0.5	1.7	48.3	0.5	2.2	37.9	0.5	2.7	29.8	0.6	3.2	25.3	0.6	3.6	21.1	0.6	4.1	17.8	0.6	4.7	15.1	0.7	5.2
40	106.4	0.4	1.3	74.7	0.5	1.7	55.2	0.5	2.2	43.3	0.5	2.7	34.0	0.6	3.2	29.0	0.6	3.6	24.1	0.6	4.1	20.3	0.6	4.7	17.2	0.7	5.2
45	119.7	0.4	1.3	84.1	0.5	1.7	62.1	0.5	2.2	48.8	0.5	2.7	38.3	0.6	3.2	32.6	0.6	3.6	27.2	0.6	4.1	22.8	0.6	4.7	19.4	0.7	5.2
50	133.0	0.4	1.3	93.4	0.5	1.7	69.0	0.5	2.2	54.2	0.5	2.7	42.5	0.6	3.2	36.2	0.6	3.6	30.2	0.6	4.1	25.4	0.6	4.7	21.5	0.7	5.2
55	146.3	0.4	1.3	102.8	0.5	1.7	75.9	0.5	2.2	59.6	0.5	2.7	46.8	0.6	3.2	39.8	0.6	3.6	33.2	0.6	4.1	27.9	0.6	4.7	23.7	0.7	5.2
60	159.6	0.4	1.3	112.1	0.5	1.7	82.8	0.5	2.2	65.0	0.5	2.7	51.0	0.6	3.2	43.4	0.6	3.6	36.2	0.6	4.1	30.5	0.6	4.7	25.9	0.7	5.2
65	172.9	0.4	1.3	121.4	0.5	1.7	89.7	0.5	2.2	70.4	0.5	2.7	55.3	0.6	3.2	47.1	0.6	3.6	39.2	0.6	4.1	33.0	0.6	4.7	28.0	0.7	5.2
70	186.2	0.4	1.3	130.8	0.5	1.7	96.6	0.5	2.2	75.8	0.5	2.7	59.5	0.6	3.2	50.7	0.6	3.6	42.2	0.6	4.1	35.5	0.6	4.7	30.2	0.7	5.2
75	199.5	0.4	1.3	140.1	0.5	1.7	103.5	0.5	2.2	81.2	0.5	2.7	63.8	0.6	3.2	54.3	0.6	3.6	45.2	0.6	4.1	38.1	0.6	4.7	32.3	0.7	5.2
80	212.8	0.4	1.3	149.5	0.5	1.7	110.5	0.5	2.2	86.7	0.5	2.7	68.0	0.6	3.2	57.9	0.6	3.6	48.3	0.6	4.1	40.6	0.6	4.7	34.5	0.7	5.2
85	226.1	0.4	1.3	158.8	0.5	1.7	117.4	0.5	2.2	92.1	0.5	2.7	72.3	0.6	3.2	61.5	0.6	3.6	51.3	0.6	4.1	43.1	0.6	4.7	36.6	0.7	5.2
90	239.4	0.4	1.3	168.1	0.5	1.7	124.3	0.5	2.2	97.5	0.5	2.7	76.5	0.6	3.2	65.2	0.6	3.6	54.3	0.6	4.1	45.7	0.6	4.7	38.8	0.7	5.2
95	252.7	0.4	1.3	177.5	0.5	1.7	131.2	0.5	2.2	102.9	0.5	2.7	80.8	0.6	3.2	68.8	0.6	3.6	57.3	0.6	4.1	48.2	0.6	4.7	40.9	0.7	5.2
100	266.0	0.4	1.3	186.8	0.5	1.7	138.1	0.5	2.2	108.3	0.5	2.7	85.0	0.6	3.2	72.4	0.6	3.6	60.3	0.6	4.1	50.7	0.6	4.7	43.1	0.7	5.2
105	279.3	0.4	1.3	196.2	0.5	1.7	145.0	0.5	2.2	113.7	0.5	2.7	89.3	0.6	3.2	76.0	0.6	3.6	63.3	0.6	4.1	53.3	0.6	4.7	45.2	0.7	5.2
110	292.6	0.4	1.3	205.5	0.5	1.7	151.9	0.5	2.2	119.2	0.5	2.7	93.5	0.6	3.2	79.6	0.6	3.6	66.4	0.6	4.1	55.8	0.6	4.7	47.4	0.7	5.2
115	305.9	0.4	1.3	214.9	0.5	1.7	158.8	0.5	2.2	124.6	0.5	2.7	97.8	0.6	3.2	83.3	0.6	3.6	69.4	0.6	4.1	58.3	0.6	4.7	49.5	0.7	5.3
120	319.2	0.4	1.3	224.2	0.5	1.7	165.7	0.5	2.2	130.0	0.5	2.7	102.0	0.6	3.2	86.9	0.6	3.6	72.4	0.6	4.1	60.9	0.6	4.7	51.7	0.7	5.3
125	332.5	0.4	1.3	233.5	0.5	1.7	172.6	0.5	2.2	135.4	0.5	2.7	106.3	0.6	3.2	90.5	0.6	3.6	75.4	0.6	4.1	63.4	0.6	4.7	53.8	0.7	5.3
130	345.8	0.4	1.3	242.9	0.5	1.7	179.5	0.5	2.2	140.8	0.5	2.7	110.5	0.6	3.2	94.1	0.6	3.6	78.4	0.6	4.1	66.0	0.6	4.7	56.0	0.7	5.3
135	359.1	0.4	1.3	252.2	0.5	1.7	186.4	0.5	2.2	146.2	0.5	2.7	114.8	0.6	3.2	97.7	0.6	3.6	81.4	0.6	4.1	68.5	0.6	4.7	58.1	0.7	5.3
140	372.4	0.4	1.3	261.6	0.5	1.7	193.3	0.5	2.2	151.7	0.5	2.7	119.0	0.6	3.2	101.3	0.6	3.6	84.4	0.6	4.1	71.0	0.6	4.7	60.3	0.7	5.3
145	385.7	0.4	1.3	270.9	0.5	1.7	200.2	0.5	2.2	157.1	0.5	2.7	123.3	0.6	3.2	105.0	0.6	3.6	87.5	0.6	4.1	73.6	0.6	4.7	62.5	0.7	5.3
150	399.0	0.4	1.3	280.2	0.5	1.7	207.1	0.5	2.2	162.5	0.5	2.7	127.5	0.6	3.2	108.6	0.6	3.6	90.5	0.6	4.1	76.1	0.6	4.7	64.6	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

This Page Intentionally Left Blank

Lined Swale (LS)

Practice Description

A lined swale is a constructed channel with a permanent lining designed to carry concentrated runoff to a stable outlet. This practice applies where grass swales are unsuitable because of conditions such as steep channel grades, prolonged flow areas, soils that are too erodible or not suitable to support vegetation or insufficient space and where riprap-lined swales are not desired. The purpose of a lined swale is to conduct stormwater runoff without causing erosion problems in the area of channel flow.

The material that provides the permanent lining may be concrete, manufactured concrete products, or turf reinforcement mat (TRM).

Planning Considerations

A lined swale is used to convey concentrated runoff to a stable outlet in situations where a grass swale is inadequate. A lined swale can be lined with concrete, manufactured concrete products or TRM. Concrete-lined swales are the only type of lining covered in this practice. The practice Erosion Control Blanket should be referenced for criteria on TRM. Product manufacturers and qualified design professional should be consulted for design requirements for manufactured concrete linings. Concrete lined swales are generally used in areas where riprap-lined swales are not desired due to aesthetics, safety, or maintenance concerns. Concrete lined swales allow easy maintenance of surrounding vegetation with normal lawn care equipment. The concrete generally provides a more visually pleasing structure than the riprap linings. Concrete lined swales are especially desirable in areas accessed by small children.

In areas where stormwater infiltration is preferred, riprap and manufactured products should be considered rather than the concrete lining.

Design Criteria

Capacity

Lined swales should be capable of passing the peak flow expected from a 10-year 24-hour duration storm.

Adjustments should be made for release rates from structures and other drainage facilities. Swales shall also be designed to comply with local stormwater ordinances, and should be designed for greater capacity whenever there is danger of flooding or out of bank flow cannot be tolerated.

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, Engineering Field Manual for Conservation Practices, Chapter 2 Estimating Runoff.

- Natural Resources Conservation Service formerly Soil Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds.

- Other comparable methods.

Slope

This practice only applies to paved flumes that are installed on slopes of 25% or less. Slopes steeper than this should be designed by a qualified design professional.

The slope in feet per 100 feet of length can be determined from a topographic map of the site or from a detailed survey of the planned lined swale location.

Cross Section

With peak flow (capacity) and slope known, the paved flume cross section can be determined by using Figure LS-l through LS-3

Concrete

Flumes should be constructed of concrete with a minimum 28 day compressive strength of 3,000 psi. Flumes shall have a minimum concrete thickness of 4”.

Cutoff Walls

Cutoff walls shall be constructed at the beginning and end of every flume except where the flume connects with a catch basin or inlet.

Alignment

Keep paved flumes as straight as possible because they often carry supercritical flow velocities.

Inlet Section

The inlet section to the paved flume should be at least 6 feet long and have a bottom width equal to twice the bottom width of the flume itself. The bottom width should transition from twice the flume bottom width to the flume bottom width over the 6 feet length.

Outlet

Outlets of paved flumes shall be protected from erosion. The standard for Outlet Protection can be used to provide this protection. A method to dissipate the energy of low flows is to bury the last section of the flume in the ground. This will usually force the development of a “scour hole” which will stabilize and serve as a plunge basin. For the design of large capacity flumes it may be necessary to design a larger energy dissipater at the outlet.

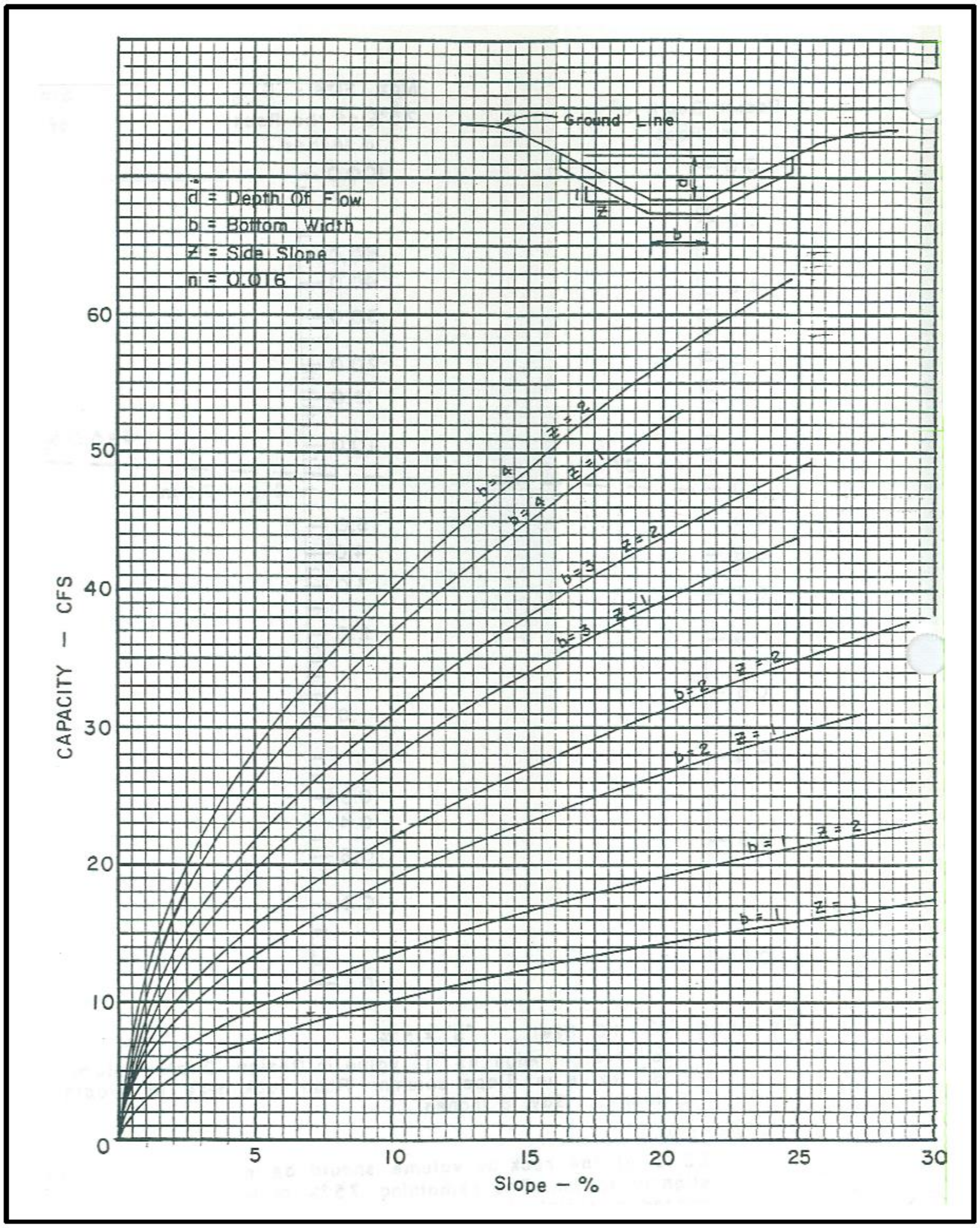


Figure LS-1 Capacity Graph For Concrete Flumes
Depth of Flow = 0.50 Feet

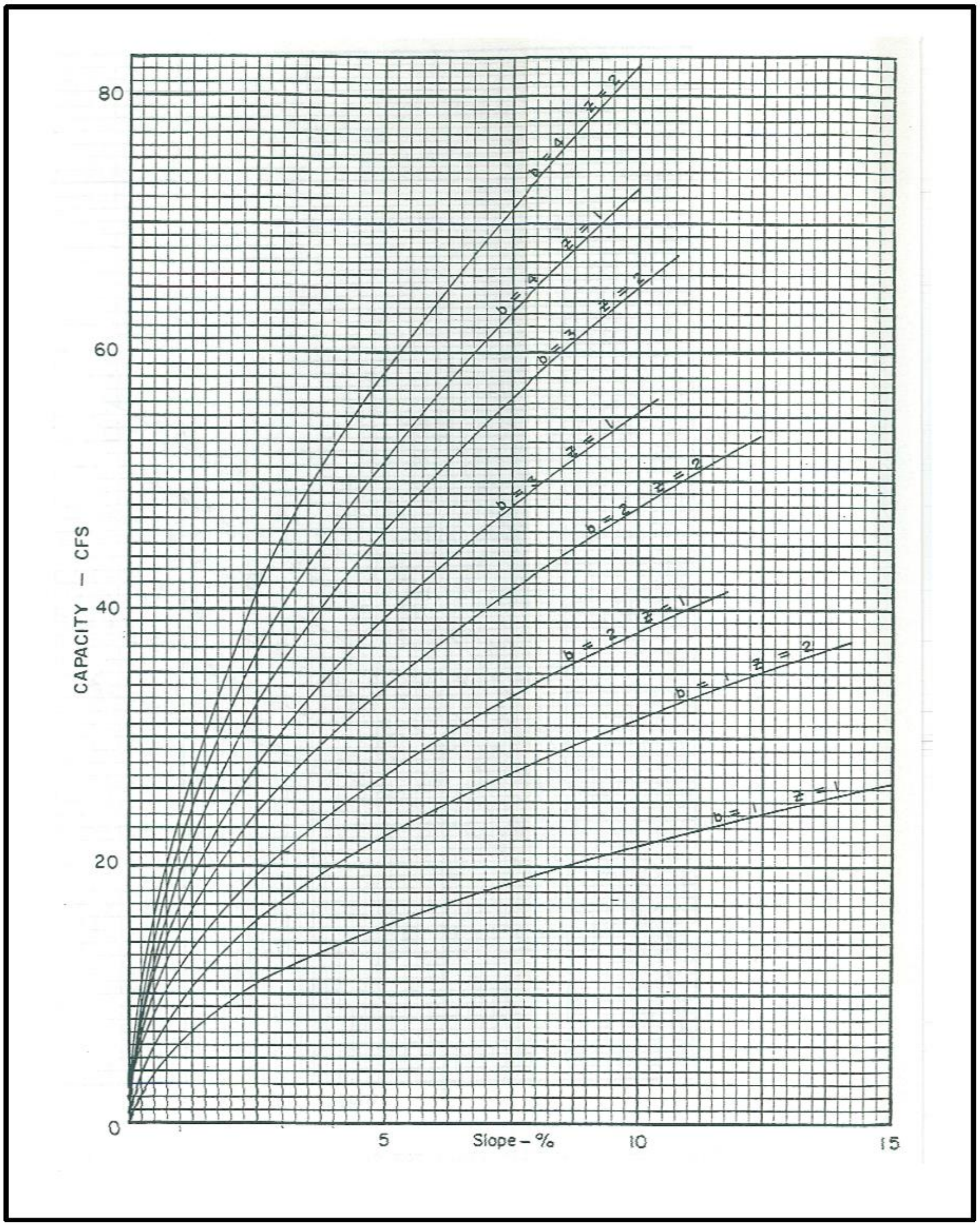


Figure LS-2 Capacity Graph for Concrete Flumes
Depth of Flow = 0.75 Feet

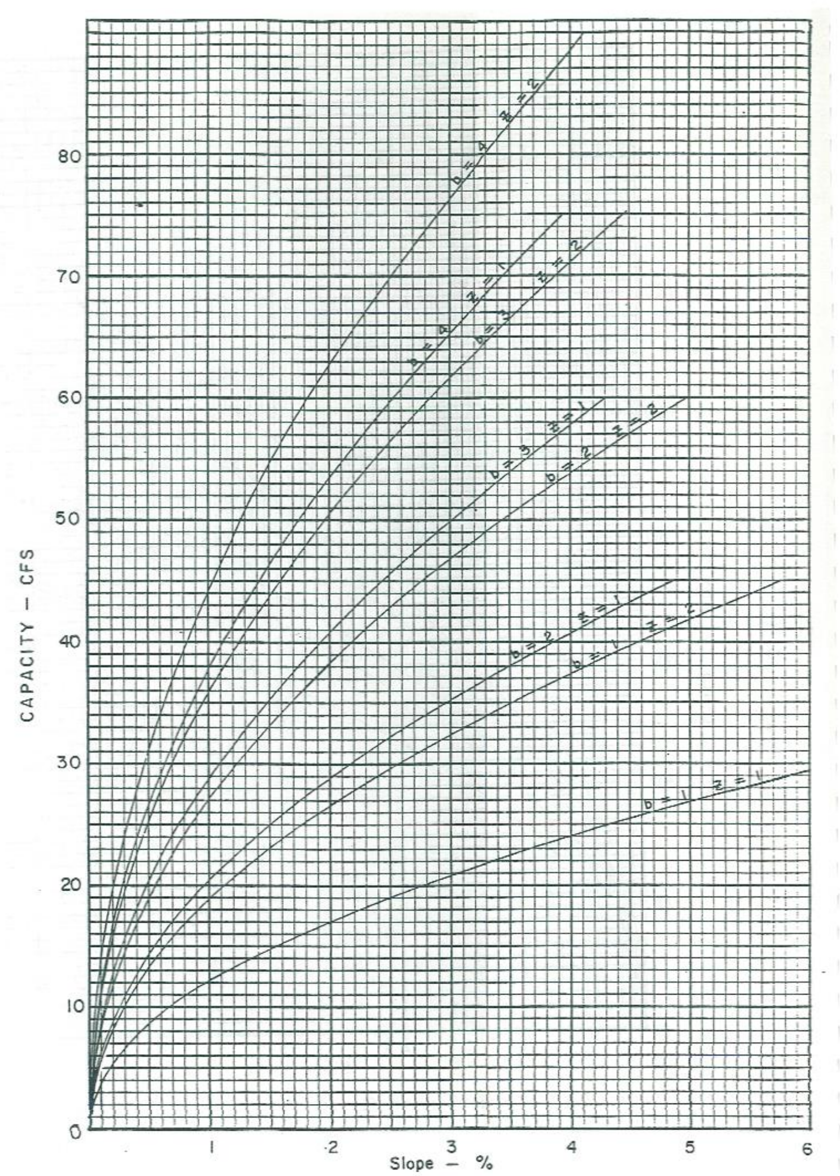


Figure LS-3 Capacity Graph for Concrete Flumes
Depth of Flow = 1.00 Feet

Outlet Protection (OP)

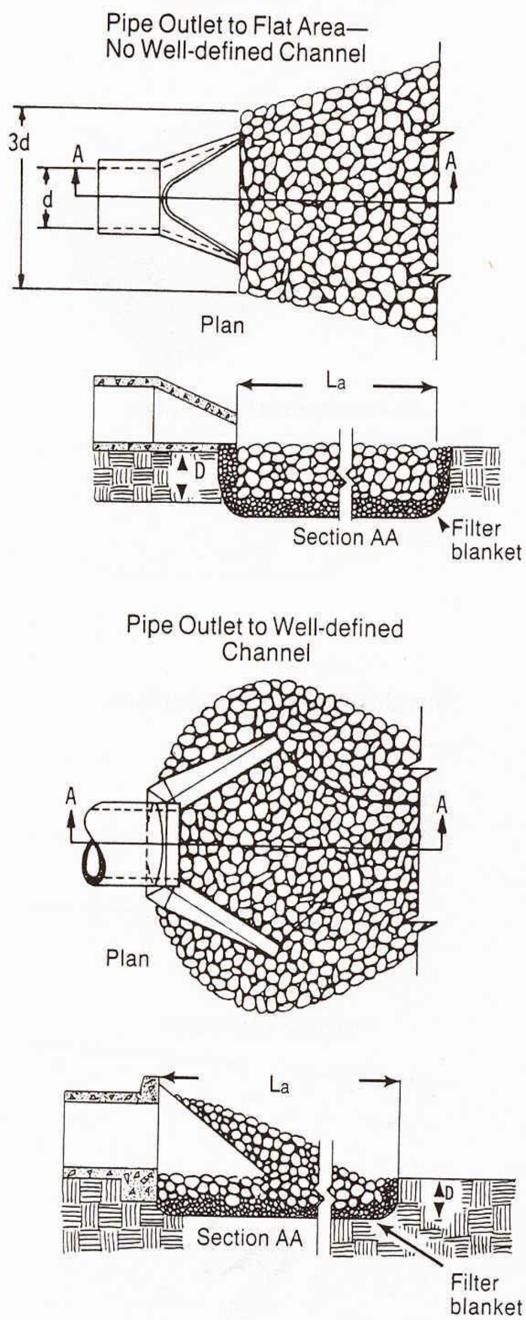
Practice Description

This practice is designed to prevent erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy. Outlet protection measures usually consist of a riprap-lined apron, a reinforced concrete flume with concrete baffles, a reinforced concrete box with chambers or baffles and possibly pre-manufactured products. This practice applies wherever high velocity discharge must be released on erodible material.

Planning Considerations

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the ability of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is required which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area of discharge.

The most commonly used structure for outlet protection is an erosion resistant lined apron. These aprons are generally lined with loose rock riprap, grouted riprap or concrete. They are constructed at zero grade for a distance which is related to the outlet flow rate and the tailwater level. Criteria for designing these structures are contained in this practice. Several outlet conditions are shown in Figure OP-1. Example design problems for outlet protection are found at the end of this practice.



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 OP-1 Pipe Outlet Conditions

Where the flow is excessive for the economical use of an apron, excavated stilling basins may be used. Acceptable designs for stilling basins may be found in the following documents available from the U. S. Government Printing Office.

1) Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulics Engineering Circular No.14, U. S. Department of Transportation, Federal Highway Administration.

2) Hydraulic Design of Stilling Basins and Energy Dissipaters, Engineering Monograph No.25 U. S. Department of Interior-Bureau of Reclamation.

Design Criteria

Structurally lined aprons at the outlets of pipes and paved channel sections should be designed according to the following criteria:

Pipe Outlets

Capacity

The structurally lined apron should have the capacity to carry the peak stormflow from the 25-year 24-hour frequency storm or the storm specified in state laws or local ordinances or the design discharge of the water conveyance structure, whichever is greatest.

Tailwater

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. Manning's Equation may be found in the practice Grass Swales. If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter, it shall be classified as a Maximum Tailwater Condition. Pipes which outlet to flat areas, with no defined channel, may be assumed to have a Minimum Tailwater Condition.

Apron Length

The apron length should be determined from Figure OP-2 or OP-3 according to the tailwater condition.

Apron Thickness

The apron thickness should be determined by the maximum stone size (dmax), when the apron is lined with riprap. The maximum stone size shall be 1.5 x d_{50} (median stone size), as determined from Figure OP-2 or OP-3. The apron thickness shall be 1.5 x dmax.

When the apron is lined with concrete, the minimum thickness of the concrete shall be 4".

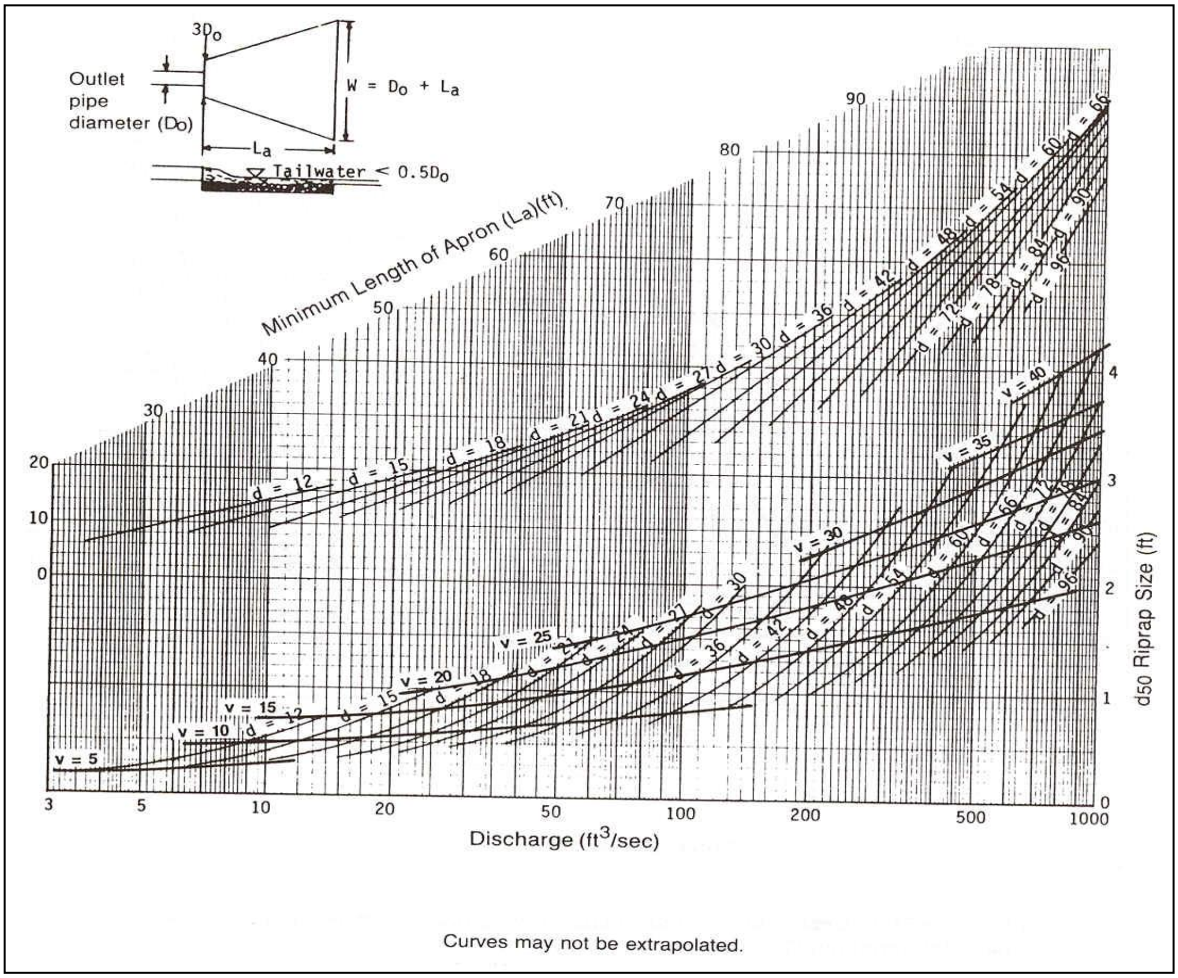


Figure OP-2 Outlet Protection Design for Tailwater < 0.5 Diameter

Apron Width

If the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation 1foot above the maximum tailwater depth or to the top of the bank, whichever is the least.

If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows:

- The upstream end of the apron, adjacent to the pipe, should have a width 3 times the diameter of the outlet pipe.
- For a Minimum Tailwater Condition, the downstream end of the apron should have a width equal to the pipe diameter plus the length of the apron obtained from the figures.
- For a Maximum Tailwater Condition, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron from Figures OP-2 or OP-3.

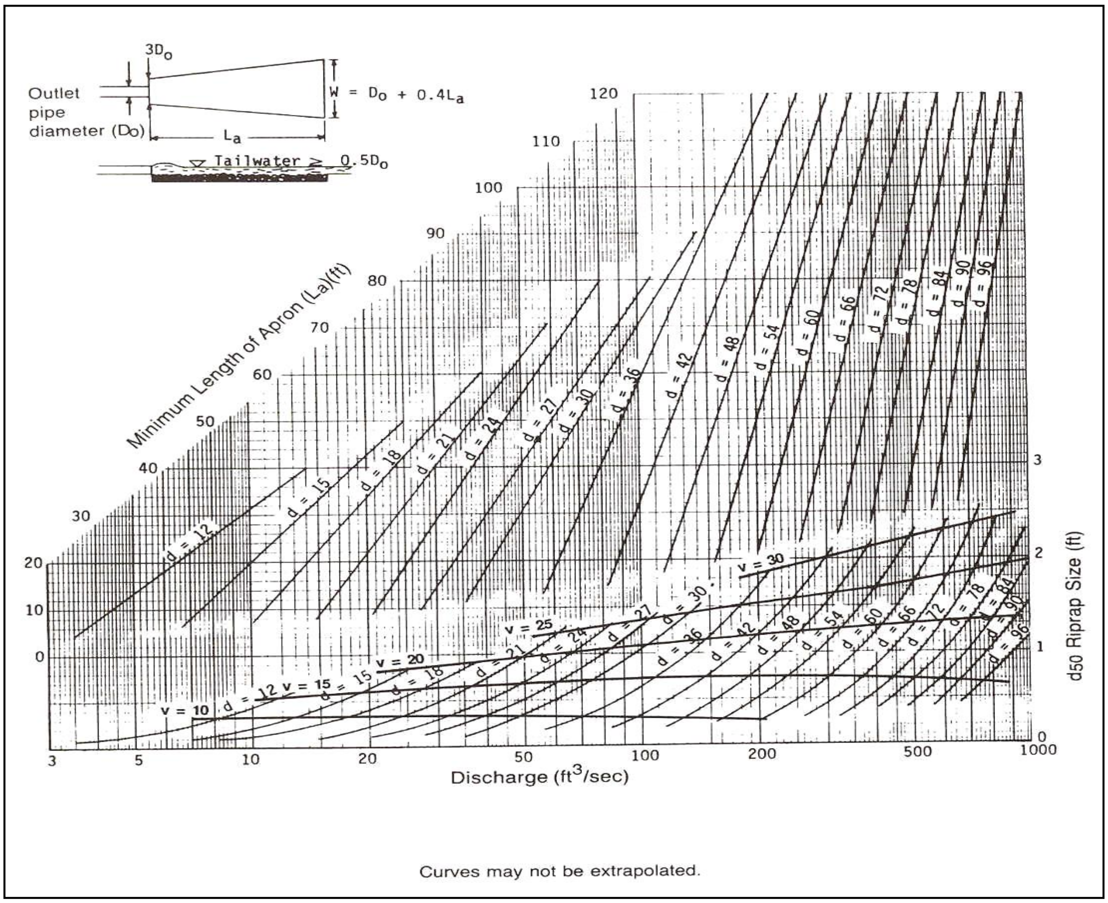


Figure OP-3 Outlet Protection Design for Tailwater ≥ 0.5 Diameter

Bottom Grade

The apron should be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

Side Slope

If the pipe discharges into a well-defined channel, the side slopes of the channel should not be steeper than 2:1 (Horizontal:Vertical).

Alignment

The apron should be located so that there are no bends in the horizontal alignment.

Geotextile

When riprap is used to line the apron, non-woven geotextile should be used as a separator between the graded stone, the soil subgrade, and the abutments. Geotextile should be placed immediately adjacent to the subgrade without any voids between the fabric and the subgrade. The geotextile will prevent the migration of soil particles from the subgrade into the graded stone. The geotextile shall be of the strength and durability required for the project to ensure the aggregate and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

Materials

The apron may be lined with loose rock riprap, grouted riprap, or concrete. The median sized stone for riprap should be determined from the curves on Figure OP-2 and OP-3 according to the tailwater condition.

After the median stone size is determined, the gradation of rock to be used should be specified using Tables OP-2 and OP-3. Table OP-2 is used to determine the weight of the median stone size (d_{50}). Using this median weight, a gradation can be selected from Table OP-3, which shows the commercially available riprap gradations as classified by the Alabama Department of Transportation.

Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

When the apron is lined with concrete, the concrete should have a minimum compressive strength at 28 days of 3000 pounds per square inch. American Concrete Institute guidelines should be used to design concrete structures and reinforcement. As a minimum, the concrete should be reinforced with steel welded wire fabric.

Table OP-2 Size of Riprap Stones

Weight	Mean Spherical Diameter (feet)	**Rectangular Shape** Length	Width, Height (feet)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	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

Table OP-3 Graded Riprap

Class	**Weight (lbs.)**					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

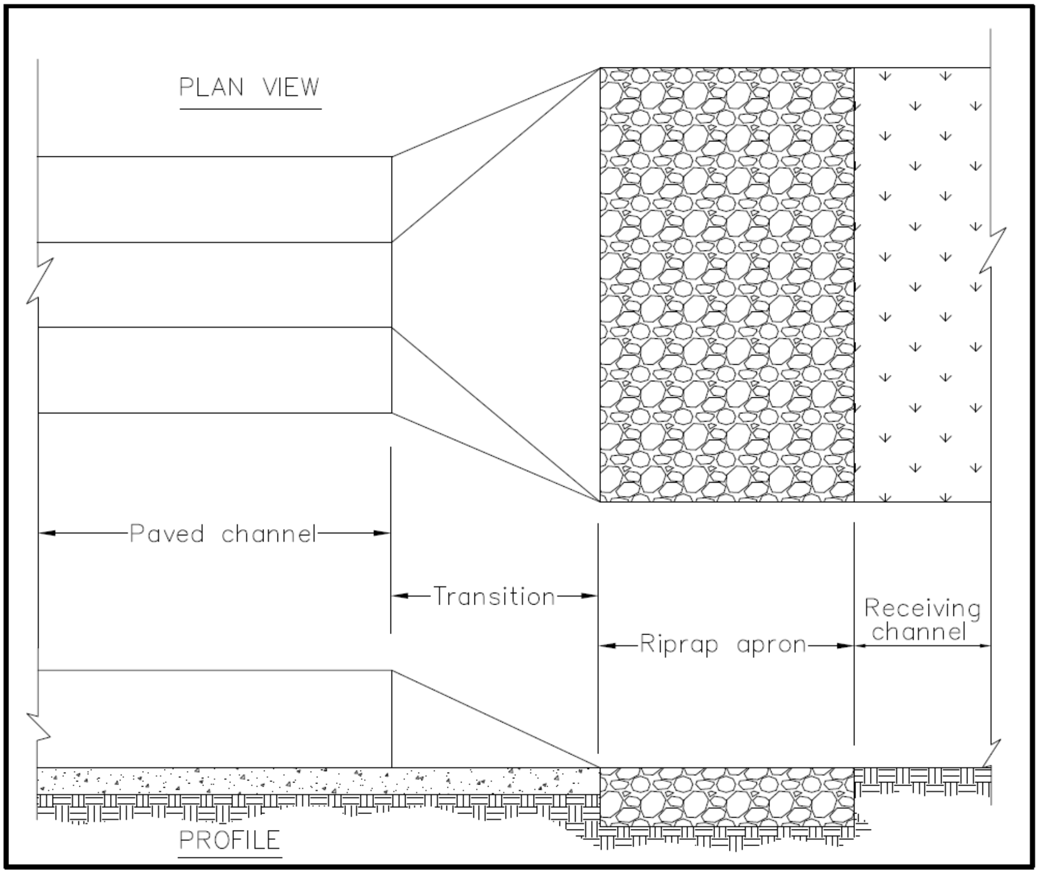


Figure OP-4 Paved Channel Outlet

1) The flow velocity at the outlet of paved channels flowing at design capacity should not exceed the velocity, which will cause erosion and instability in the receiving channel.

2) The end of the paved channel should merge smoothly with the receiving channel section. There should be no overfall at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section should be provided. The maximum side divergence of the transition shall be 1 in 3F where

   F = v/gd, and
   F = Froude no.
   V = Velocity at beginning of transition (ft./sec.)
   d = Dept of flow at beginning of transition (feet.)
   g = 32.2 ft./sec.^{2}

3) Bends or curves in the horizontal alignment of the transition are not allowed unless the Froude no. (F) is 0.8 or less, or the section is specifically designed for turbulent flow.

Example Design Problems

Example 1

Given: An 18" pipe discharges 24 cu. ft/sec at design capacity onto a grassy slope (no defined channel).

Find: The required length, width and median stone size (d_{50}) for a riprap-lined apron.

Solution

Since the pipe discharges onto a grassy slope with no defined channel, a Minimum Tailwater Condition may be assumed.

From Figure OP-2, an apron length (La) of 20 feet and a median stone size (d_{50}) of 0.8 feet is determined.

The upstream apron width equals 3 times the pipe diameter: 3 x 1.5 feet = 4.5 feet.

The downstream apron width equals the apron length plus the pipe diameter:
20 feet + 1.5 foot = 21.5 feet.

Example 2

Given: The pipe in example No. 1 discharges into a channel with a triangular cross section, 2 feet deep and 2:1 side slopes. The channel has a 2% slope and an "n" coefficient of 0.045.

Find: The required length, width and the median stone size (d_{50}) for a riprap lining.

Solution

Determine the tailwater depth using Manning's Equation and the Continuity Equation.

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

$$24 = 1.49/n \, [2d/4.47]^{2/3} \, (.02)^{1/2} \, (2d^2)$$

where, d = depth of tailwater
d = 1.74 feet. *

*Since d is greater than half the pipe diameter, a Maximum Tailwater Condition exists.

From Figure OP-3, a median stone size (d_{50}) of 0.5 feet. and an apron length (La) of 41 feet. is determined.

The entire channel cross section should be lined, since the maximum tailwater depth is within 1 foot of the top of the channel.

This Page Intentionally Left Blank

Riprap-lined Swale (RS)

Practice Description

A riprap-lined swale is a natural or constructed channel with an erosion-resistant rock lining designed to carry concentrated runoff to a stable outlet. This practice applies where grass swales are unsuitable because of conditions such as steep channel grades, prolonged flow areas, soils that are too erodible or not suitable to support vegetation or insufficient space.

Planning Considerations

Swales should be carefully built to the design cross section, shape and dimensions. Swales are hydraulic structures and as such depend upon the hydraulic parameters to serve satisfactorily. Swales may be used to:

- Serve as outlets for diversions and sediment control basins and stormwater detention basins.
- Convey water collected by road ditches or discharged through culverts.
- Rehabilitate natural draws and gullies carrying concentrations of runoff.

The design of a swale cross section and lining is based primarily upon the volume and velocity of flow expected in the swale. Riprap lined swales should be used where velocities are in the range of 5 to 10 ft/sec.

Besides the primary design considerations of capacity and velocity, a number of other important factors should be taken into account when selecting a cross section. These factors include land availability, compatibility with land use and surrounding environment, safety, maintenance requirements and outlet conditions, etc.

Riprap lined swales are trapezoidal in shape. Trapezoidal swales are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity.

Outlet conditions for all swales should be considered. This is particularly important for the transition from the riprap lining to a vegetative lining. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour of the receiving swale.

Design Criteria

Capacity

Lined swales shall be designed to convey the peak rate of runoff from a 10-year 24-hour rainfall event. Adjustments should be made for release rates from structures and other drainage facilities. Swales should also be designed to comply with local stormwater ordinances.

Swales should be designed for greater capacity whenever there is danger of flooding or out of bank flow cannot be tolerated. The maximum capacity of the swale flowing at design depth should be 200 cubic ft/sec.

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.
- Natural Resources Conservation Service formerly Soil Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds.
- Other comparable methods.

Cross section

The swale cross section should be trapezoidal in shape. The steepest permissible side slope of the swale should be 2:1. A bottom width should be selected based on area available for installation of the swale and available rock sizes. The bottom width will be used in determining stable rock size and flow depth.

Depth

Design flow depth should be determined by the following formula:

$z = [n(q)/1.486(S)^{0.50}]^{3/5}$
S = Bed slope, ft./ft.
z = Flow depth, ft.
q = Unit discharge, $ft^3/s/ft$
(Total discharge ÷ Bottom width)
n = Manning's coefficient of roughness (see formula under velocities)

The design water surface elevation of a swale receiving water from other tributary sources should be equal to or less than the design water surface elevation of the contributing source. The design water surface elevation of contributing and receiving waters should be the same, whenever practical. A minimum depth may be necessary to provide adequate outlets for subsurface drains and tributary swales.

Freeboard

The minimum freeboard is 0.25 feet. Freeboard is not required on swales with less than 1% slope and where out-of-bank flow will not be damaging and can be tolerated from an operational point of view.

Stable Rock Size

Stable rock sizes, for rock lined swales having gradients between 2 percent and 40 percent should be determined using the following formulas from Design of Rock Chutes by Robinson, Rice, and Kadavy.

For swale slopes between 2% and 10%: $d_{50} = [q\,(S)^{1.5}/4.75(10)^{-3}]^{1/1.89}$

For swale slopes between 10% and 40%: $d_{50} = [q\,(S)^{0.58}/3.93(10)^{-2}]^{1/1.89}$

d_{50} = Particle size for which 50 % of the sample is finer, inch
S = Bed slope, ft./ft.
q = Unit discharge, $ft^3/s/ft$
(Total discharge ÷ Bottom width)

After the stable median stone size is determined, the gradation of rock to be used should be specified using Tables RS-1 and RS-2. Table RS-1 is used to determine the weight of the median stone size (d_{50}). Using this median weight, a gradation can be selected from Table RS-2, which shows the commercially available riprap gradations as classified by the Alabama Department of Transportation.

Table RS-1 Size of Riprap Stones

Weight (lbs)	Mean Spherical Diameter (feet)	Rectangular Shape	
		Length	Width, Height (feet)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	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

Table RS-2 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Velocities

Velocities should be computed by using Manning's Formula with a coefficient of roughness, "n", as follows: $n = 0.047(d_{50} \cdot S)^{0.147}$

Applies on slopes between 2 and 40% with a rock mantle thickness of 2 x d_{50} where:

d_{50} = median rock diameter (inch), S = lined section slope (ft./ft.) ($.02 \leq S \leq .4$)

Velocities exceeding critical velocity should be restricted to straight reaches.

Waterways or outlets with velocities exceeding critical velocity should discharge into an outlet protection structure to reduce discharge velocity to less than critical (see Outlet Protection practice).

Lining Thickness

The minimum lining thickness should be equal to the maximum stone size of the specified riprap gradation plus the thickness of any required filter or bedding.

Lining Durability

Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

Geotextiles

Non- woven geotextiles should be used where appropriate as a separator between rock and soil to prevent migration of soil particles from the subgrade, through the lining material. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

Filters or Bedding

Filters or bedding should be used where needed to prevent piping. Filters should be designed according to the requirements contained in the Subsurface Drain Standard. The minimum thickness of a filter or bedding should be 6".

This Page Intentionally Left Blank

Subsurface Drain (SD)

Practice Description

A subsurface drain is a perforated pipe or continuous layer of porous material installed below the ground surface that intercepts, collects and carries excessive groundwater to a stable outlet. Subsurface drains by themselves do not provide erosion control. The purpose of a subsurface drain is to improve soil moisture conditions, vegetation growth and ground stability. Subsurface drains may reduce wet ground from interfering with construction activities. Drains may be constructed using a gravel-filled trench, perforated pipe in gravel bedding or manufactured drain panel products. This practice applies where groundwater is at or near the ground surface or where adequate drainage cannot be provided for surface runoff.

Planning Considerations

In order to properly design and install this practice, a detailed site investigation will be required. This investigation should include a site survey to determine the location of the area to be drained, the depth of the area to be drained, topography of the area to be drained and the outlet of the drain system, and soils at the site.

When considering use of this practice, the qualified design professional should consider the intended use of the area to be drained. Base flow and interflow of groundwater may increase with installation of this practice due to excess soil water being removed. Groundwater recharge may also be reduced by this practice. Finally, surface runoff may increase due to this practice reducing deep percolation at the site.

All federal, state, and local laws and regulations should be adhered to when planning and installing this practice.

Design Criteria

Layout and Depth

In the absence of site specific information, a depth of 3 feet and a spacing of 50 feet for drains should be adequate. However, it is recommended that site specific information be obtained. Typical details of subsurface drain construction can be seen in Figures SD-1 and SD-2. The following guidelines should be followed.

Depth
The depth the drain is installed will determine how much the water table is lowered.

The minimum depth for the drain is 2 feet under normal conditions.

The maximum depth is limited by the depth of the impermeable layer, and if a pipe is used in the drain, by the allowable load on the pipe used.

Spacing
The permeability of the soil at the site and the depth of the drain will determine the spacing of the drain.

Multiple Drains

In some cases more than one drain will be needed to achieve the desired results. The first drain should be installed and additional drains should only be added if seepage or high water table problems continue.

Location

Drains should be located a minimum of 50 feet from any trees to prevent damage to the trees.

Grade

In areas where sedimentation is not likely, the minimum grades should be based on site conditions and a velocity of not less than 0.5 ft/sec. Where a potential for sedimentation exists, a velocity of not less than 1.4 ft/sec should be used to establish the minimum grades if site conditions permit. Otherwise, provisions should be made for prevention of sedimentation by filters or collection and periodic removal of sediment from installed traps. Steep grades should be avoided.

Gravel Bedding

Typically 3” or more of gravel is placed completely around the drain and graded to prevent the infiltration of fine-grained soils into the drain.

Filters and Filter Material

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter will be determined by the characteristics of the surrounding soil material (i.e. permeability), site conditions, and the velocity of flow in the conduit.

A suitable filter should be specified if:

- Local experience indicates a need.
- Soil materials surrounding the conduit are dispersed clay, low plasticity silts, or fine sands (ML or SM with P.I. less than 7).
- Where deep soil cracking is expected.
- Where the method of installation may result in voids between the conduit and backfill material.

The filter can be non-woven geotextile filter fabric, sand, gravel or sand-gravel combination. If a geotextile is used it should meet the requirements of the material table found in the Outlet Protection practice. Caution should be used when selecting geotextile filter fabric since small soil particles can clog the fabric causing the drain to be ineffective. If a sand-gravel filter is specified, the filter gradation will be based on the gradation of the base material surrounding the conduit within the following limits:

- D_{15} size smaller than 7 times d_{95} size, but not smaller than 0.6 mm.
- D_{15} size larger than 4 times d_{15} size.
- Less than 5% passing No. 200 sieve.
- Maximum size smaller than 1.5".

D represents the filter material and d represents the surrounding base material. The number following each letter is the percent of the sample, by weight, that is finer than that size. For example, D_{15} size means that 15 percent of the filter material is finer than that size.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3" of filter material except that the top of the conduit and side filter material may be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required.

Clean-outs

In long sections of drain and in areas where sedimentation is concerned, clean-outs should be installed in the drain to facilitate removal of sediment deposits.

Outlet and Protection

The outlet must be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain. A continuous section of rigid pipe without open joints or perforations will be used at the outlet end of the line and must discharge above the normal elevation of low flow in the outlet ditch. Corrugated plastic tubing is not suitable for the outlet section.

Materials

Pipe should be perforated, continuous closed-joint pipes of corrugated plastic, concrete, corrugated metal or bituminous fiber. The pipe should have sufficient strength to withstand the load to be placed on it under the planned installation design. Manufacturer's recommendations should be followed in designing the pipe to withstand design loads.

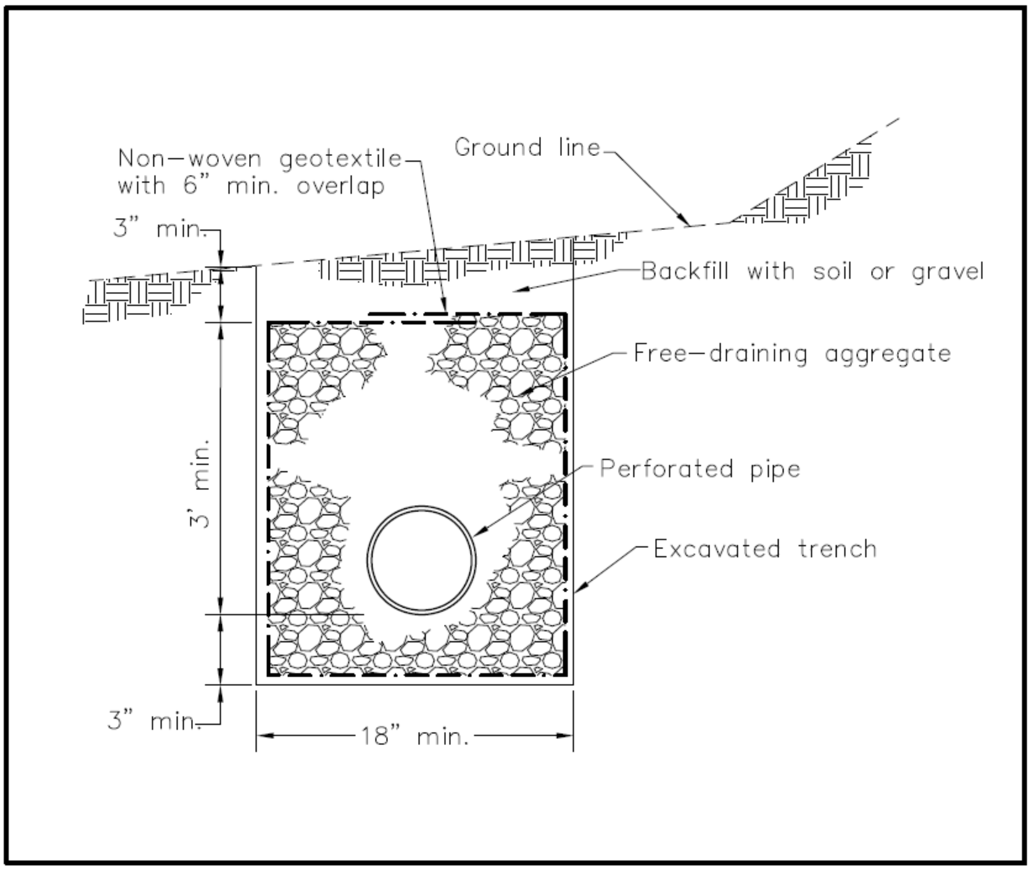


Figure SD-1 Details of Typical Subsurface Drain Construction

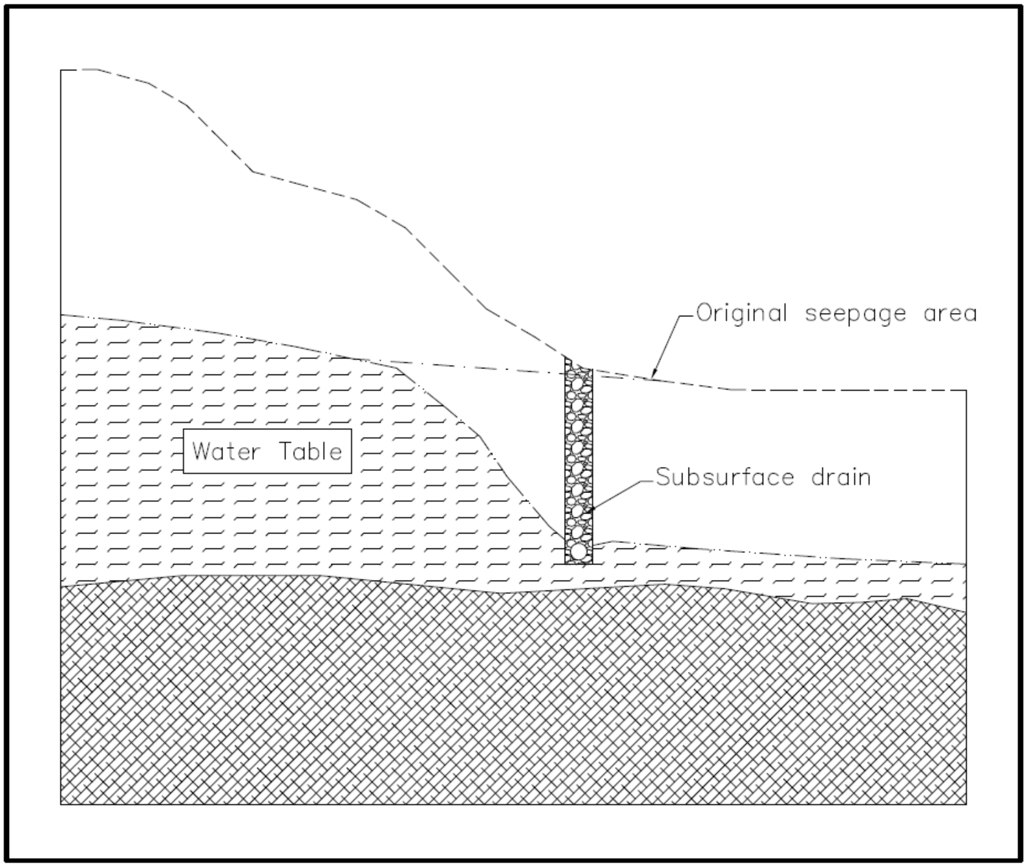


Figure SD-2 Details of Subsurface Drain Construction

This Page Intentionally Left Blank

Temporary Slope Drain (TSD)

Photo courtesy of CPESC. Inc.

Practice Description

A temporary slope drain is a pipe or other conduit designed to convey concentrated runoff down the face of a cut or fill slope without causing erosion. This practice applies wherever concentrated stormwater runoff must be conveyed down a steep slope.

Planning Considerations

There is often a significant lag between the time a cut or fill slope is completed and the time a permanent runoff conveyance system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached. Temporary slope drains, sometimes called “downdrains”, can provide valuable protection of exposed slopes until permanent runoff conveyance structures can be installed. See Figure TSD-1 for typical details of a Temporary Slope Drain.

When used in conjunction with diversions, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion. It is very important that these temporary structures be installed properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be securely staked. Prior approval may be required from local regulatory agencies if the downdrain outlet is tied into an existing storm sewer or in areas where municipal stormwater is regulated.

Design Criteria

Drainage Area

The maximum allowable drainage area per drain is 5 acres.

Flexible Conduit

The downdrain should consist of heavy duty flexible material designed for this purpose. The diameter of the downdrain should be equal over its entire length. Reinforced hold-down grommets should be spaced at 10 feet (or less) intervals with the outlet end securely fastened in place. The conduit should extend beyond the toe of the slope.

Downdrains may be sized according to the table TSD-1.

Table TSD-1 Flexible Conduit Diameters

Maximum Drainage Area (Acres)	Pipe Diameter (D) (Inches)
0.5	12
1.5	18
2.5	21
3.5	24
5.0	30

Drains should be designed to convey the peak rate of runoff from a 10-year 24-hour rainfall whenever it is desired to individually design each installation.

Entrance Sections

The entrance to the downdrain (Figures TSD-2 and TSD-3) should consist of a Standard Flared End-Section for Metal Pipe culverts. All fittings should be watertight.

The toe plate should be a minimum of 8” deep.

Extension collars should consist of 12” long corrugated metal pipe. Avoid use of helical pipe. Securing straps should be fabric, metal or other material well suited to providing a watertight connection. The strap should secure at least one corrugation of the extension collar.

Diversion Design

An earthen diversion should be used to direct stormwater runoff into the slope drain and should be constructed according to the Diversion Standard.

The height of the diversion at the centerline of the inlet should be equal to at least the diameter of the pipe (D) plus 12”. Where the dike height is greater than 18” at the inlet, it should be level for 3 feet each side of the pipe and be sloped at the rate of 3:1 or flatter to transition with the remainder of the dike.

Outlet Protection

The outlet of the downdrain should be protected from erosion as detailed in the Outlet Protection Standard.

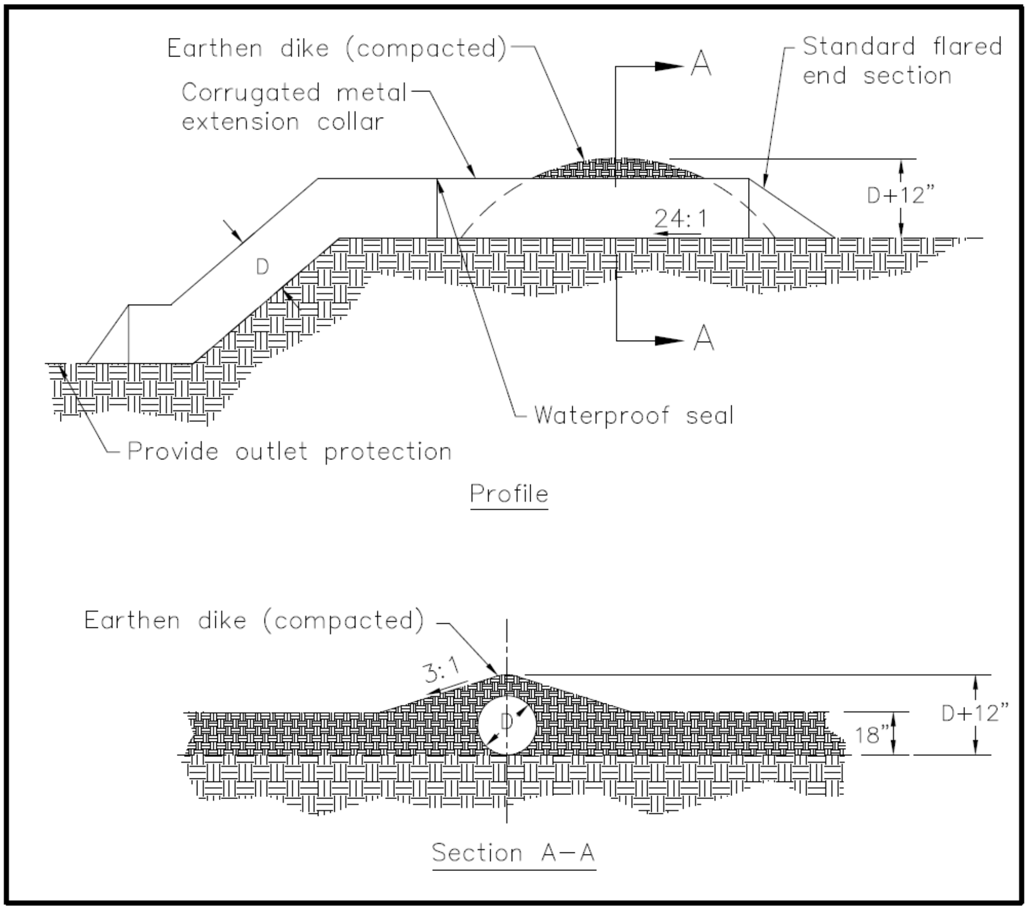


Figure TSD-1 Typical Temporary Slope Drain Detail

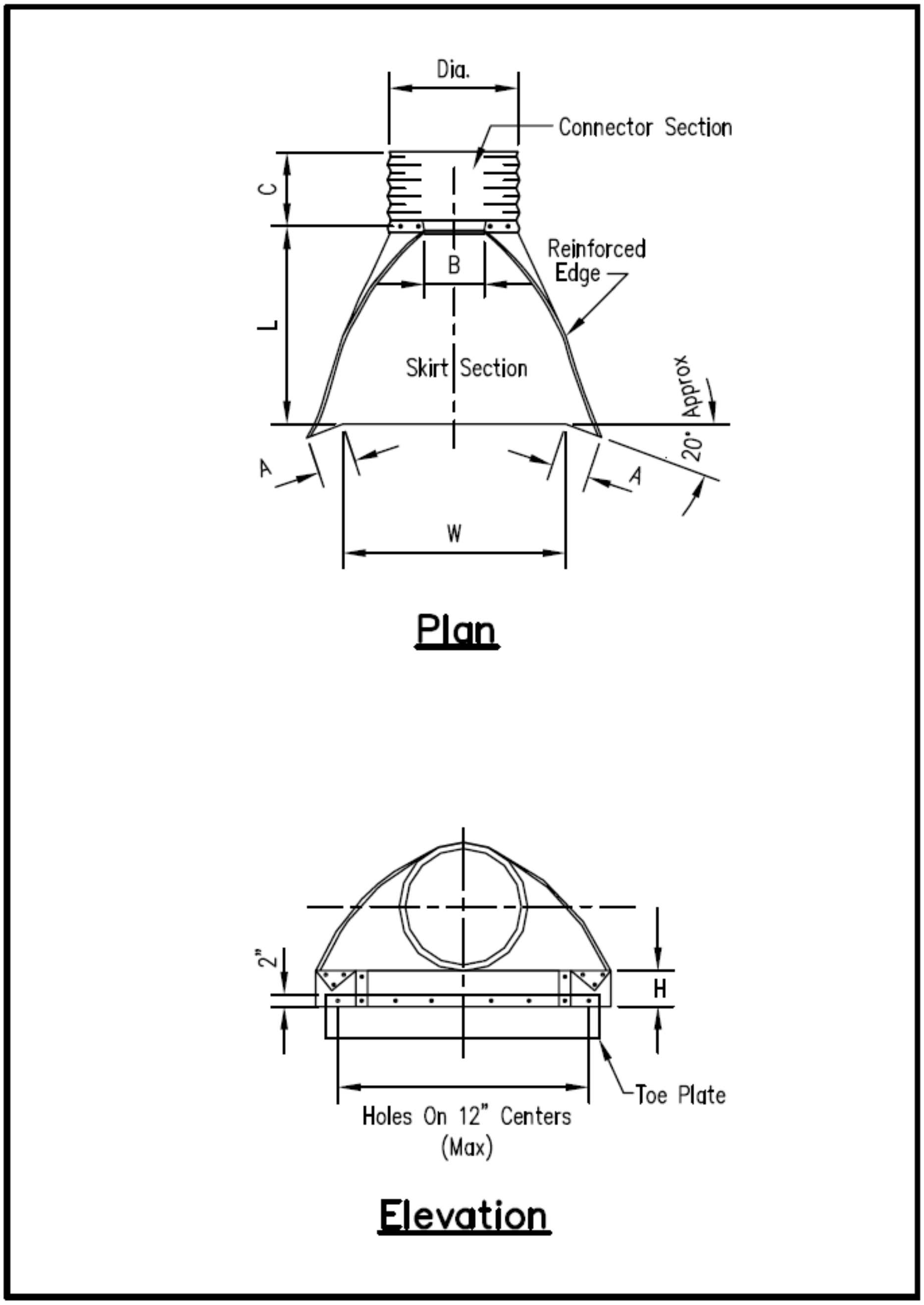
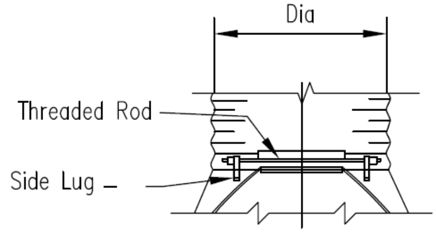


Figure TSD-2 Flared End-Section Detail



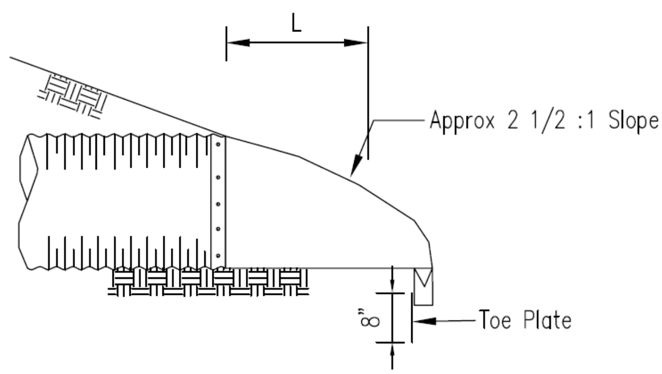
Alternate Connection

PIPE DIA	SHEET THICKNESS	A ± 1"	B MAX	H ± 1"	L ± 1-1/2"	W ± 2"	C
		DIMENSIONS					
12"	.064"	6"	6"	6"		24"	2'-0"
15"	.064"	7"	8"	6"	26"	30"	24"
18"	.064"	8"	10"	6"	31"	36"	24"
24"	.064"	10"	13"	6"	41"	48"	24"
30"	.079"	12"	16"	8"	51"	60"	24"
36"	.079"	14"	19"	9"	60"	72"	36"
42"	.109"	16"	22"	11"	69"	84"	36"
48"	.109"	18"	27"	12"	78"	90"	36"
54"	.109"	18"	30"	12"	84"	102"	36"
60"	.109"-.138"	18"	33"	12"	87"	114"	36"

± = Tolerance Plus or Minus

NOTES:

1. Toe plate, where needed, to be punched to match holes in skirt lip. 3/8" galvanized bolts to be furnished. Length of toe plate is W+10" for 12" to 30" diameter pipe and W+22" for 36" to 60" diameter pipe.
2. Skirt section for 12" to 30" diameter pipe to be made in one piece.
3. Skirt section for 36" to 54" pipe to be made from two sheets joined by riveting or bolting on center line. 60" may be constructed in 3 pieces.
4. Connector section, corner plate and toe plate to be same sheet thickness as skirt.
5. End sections and fittings are to be galvanized steel or aluminum alloy for use with like pipe.
6. Where flared end sections are to be used with bituminous coated and paved metal pipe, they are to be galvanized only.



Typical Cross-Section

Figure TSD-3 Flared End-Section Details (continued)

This Page Intentionally Left Blank

Block and Gravel Inlet Protection (BIP)

Photo courtesy of EnviroCert International, Inc.

Practice Description

Block and gravel inlet protection is a sediment control barrier formed around a storm drain inlet by the use of standard concrete block and gravel. The purpose is to help minimize sediment entering storm drains during construction. This practice applies where use of the storm drain system is necessary during construction and inlets have a drainage area of 1 acre or less and an approach slope of 1% or less. The practice will pond water causing hazardous conditions to motorists and should only be used when there is no public transportation allowed on the street.

Planning Considerations

Storm sewers which are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

This practice is for drainage areas of less than 1 acre. Runoff from large disturbed areas should be routed through a Sediment Basin. This method is for areas where heavy flows are expected and where overflow capacity is necessary to prevent excessive ponding around the structure.

The best way to prevent sediment from entering the storm sewer system is to minimize erosion by leaving as much of the site undisturbed as possible and disturbing the site in small increments, if possible. After disturbance, stabilize the site as quickly as possible to prevent erosion and sediment delivery.

Design Criteria

Drainage Area

Drainage area should be less than 1 acre per inlet.

Capacity

The design storm for the inlet should be able to enter the inlet without bypass flow.

Approach

The approach to the block and gravel structure should be less than 1%.

Height

The height of the block structure should be 1 to 2 feet.

Side Slopes

Gravel placed around the concrete block structure should have 2:1 side slopes or flatter.

Dewatering

Place a minimum of 1 block on the bottom row (more as needed) on its side to allow for dewatering the pool.

Block Placement

The foundation for the blocks should be excavated at least 2” below the crest of the storm drain. The bottom row of blocks should be placed against the edge of the storm drain for lateral support and to avoid washouts when overflow occurs. If needed, lateral support may be given to subsequent rows by placing 2” x 4” wood studs through block openings.

Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of 4”, 8” and 12” wide blocks. The barrier of blocks should be at least 12” high and no greater than 24” high.

The top elevation of the structure must be at least 6” 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 dikes below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

Wire mesh should be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Hardware cloth or comparable wire mesh with ½” openings should be used.

Gravel

Stone should be piled against the wire to the top of the block barrier, as shown in the typical details in Figure BIP-1. Alabama Highway Department No. 57 Coarse Aggregate or similar gradations should be used.

If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

Maintenance

Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to ½ the design depth. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.

The sediment trap shall be removed and the area stabilized when the constructed drainage area has been properly stabilized.

Safety

Do not use this practice when there is public transportation allowed on the street. Provide protection to prevent children from entering the area.

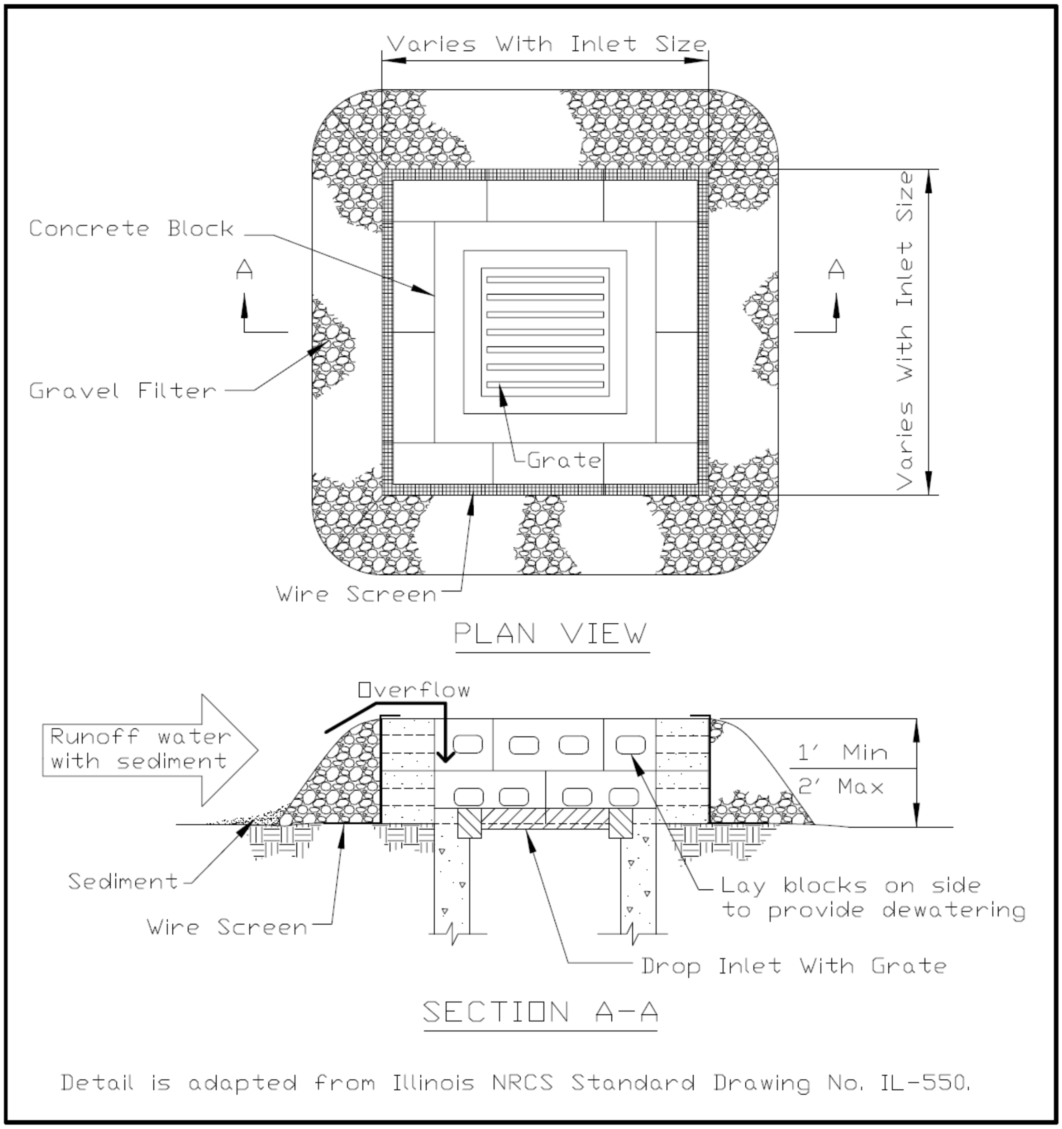


Figure BIP-1 Typical Details of Block and Gravel Inlet Protection

Brush/Fabric Barrier (BFB)

Practice Description

A brush/fabric barrier is a dam-like structure constructed from woody residue and faced with a non-woven geotextile fabric to provide a temporary sediment basin. This practice is applicable on sites with a small drainage area where brush and other woody debris are available from a clearing and grubbing operation.

Planning Considerations

This practice is intended to be a temporary sediment basin with a limited life span and applicable only for small drainage areas.

The barrier should be located downslope from areas with potential sheet and rill erosion, with adequate storage volume in front of the barrier, and with no more than 2 acres of drainage area.

Adequate woody material from clearing and grubbing required on the site must be available for the construction of the barrier.

The practice should be located and designed so adequate storage volume and detention time can be obtained, and that failure of the barrier will not result in hazard to the public or damage to either work on-site or off-site property.

Design Criteria

Drainage Area

Brush/fabric barriers should be designed with no more than 2 acres of drainage area. A sediment basin should be considered for larger drainage areas (see Sediment Basin).

Structure Life

The design life of the structure should be 1 year or less. The barrier should be removed and sediment accumulations properly stabilized prior to completion of the construction project.

Sediment Storage

The barrier should be designed to provide 67 cubic yards of sediment storage per acre of disturbed drainage area. Sediment should be removed and properly utilized on site when ½ the sediment storage volume has been filled.

Site Location and Preparation

The site for the barrier should be located so that a basin capable of providing the sediment storage required can be obtained or created. The site for the barrier should be smoothed prior to placement of the brush.

Brush Placement

The barrier should be mostly on a contour or constant elevation with each end of the barrier turned up to a higher elevation so that excessive flows will overtop the barrier instead of bypassing the barrier. Brush should be placed in a longitudinal dense pile with main stems oriented perpendicular to the direction of flow. Generally, the barrier should be at least 3 feet tall, but no more than 6 feet tall. The width of the barrier perpendicular to the direction of flow should be at least 5 feet at its base. Small stems and limbs protruding from the bundle that could damage the fabric should be trimmed.

Fabric

The fabric used to face the upstream surface of the brush should be non-woven geotextile. The geotextile shall be of the strength and durability required for the project. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

The fabric to be used should be supplied in lengths and widths to minimize vertical splices and eliminate horizontal splices. The minimum vertical splice overlap should be 3 foot. Vertical splices must be securely fastened to each other so that flows will not short-circuit through the splice.

The fabric should be securely buried at the bottom of an excavated trench that is at least 6" deep in front of the barrier. Prior to compacting backfill in the trench, the fabric should be securely staked at 3-foot centers with wooden stakes a minimum of 18” long.

The top edge of the fabric should be secured so that it will not sag below the designed storage elevation. The upper edge can be anchored with twine fastened to the fabric and secured to stakes behind the barrier.

This Page Intentionally Left Blank

Fabric Drop Inlet Protection (FIP)

Practice Description

Fabric drop inlet protection is a structurally supported geotextile barrier placed around or over a drop inlet to prevent sediment from entering storm drains during construction. This practice applies where early use of the storm drain system is necessary prior to stabilization of the disturbed drainage area. This practice is suitable for inlets with a drainage area of less than 1 acre and a gentle approach slope generally of 1% or less. This practice will cause runoff water to pond. If used at a storm drain for a road, the practice could cause hazardous conditions to motorists and should only be used when there is no public transportation allowed on the street.

Planning Considerations

Storm sewers which are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainage ways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets which discharge directly to waters of the state.

The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source. Sediment is best treated by preventing erosion. Leave as much of the site undisturbed as possible in the total site plan. Clear and disturb the site in small increments, if possible.

Numerous products have been developed to facilitate the capture of suspended soil particles at inlets. The Design Criteria for performance should be considered when evaluating alternative products. Products that will likely not meet performance goals or that usually fail under storm conditions should not be selected.

Design Criteria

Drainage Area

Drainage area should be less than 1 acre per inlet.

Height

The height of the structurally supported geotextile should be at least 1 foot but no more than 2.5 foot. The base of the fabric should be buried with compacted earth fill at least 12" into the soil or extend horizontally and be adequately secured with ballast material according to the manufacturer's recommendations. Ensure the height of the structure when fully ponded does not cause unintentional damage or hazards to adjacent areas.

Approach

The approach to the inlet protection practice should generally be less than 1% slope.

Sediment Storage

The basin created at the inlet should provide 67 cubic yards per disturbed acre of sediment storage.

Structural Frame

The structural frame should be designed to withstand soil and hydrostatic loads without failure due to buckling, fabric sagging, or undermining.

Performance

Either the system of protection for the project or the drop inlet protection that discharges directly to the outfall of the project must be designed to meet the NTU requirements for discharge.

Maintenance

When sediment has accumulated to ½ the height of the structure, it should be removed and properly disposed of.

Safety

Protection should be provided to prevent children from entering open-top structures. Do not use the practice if it ponds water on roads used by motorist

Filter Strip (FS)

Practice Description

A filter strip is a wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants, and reduce stormwater flow and velocity. Filter strips are similar to grassed swales except that they are designed to intercept overland sheet flow (not channel flow). They cannot treat high velocity flows. Surface runoff must be evenly distributed across the filter strip. Vegetation may consist of existing cover that is preserved and protected or be planted to establish the strip. Once a concentrated flow channel forms in the filter strip, the filter strip is no longer effective. This practice applies on construction sites and other disturbed areas.

Planning Considerations

Filter strips provide their maximum benefit when established as early as possible after disturbances begin. This concept should receive strong consideration during the scheduling of practices to be installed. In some instances the existing vegetation may be preserved to serve as a filter strip.

Filter strips should be strategically located on the contour to reduce runoff, and increase infiltration. They should be situated downslope from the disturbed site and where runoff water enters environmentally sensitive areas.

Overland flow entering filter strips should be primarily sheet flow. All concentrated flow should be dispersed prior to entering the filter strip.

Flow length should be based on slope percent and length, predicted amount and particle size distribution of sediment delivered to the filter strip, density and height of the filter strip vegetation, and runoff volume.

The slope of the drainage area above a filter strip should be greater than 1% but less than 10%. The ratio of the drainage area to the filter strip area should be less than 10:1. The minimum width of an effective filter strip is 15 feet.

Existing vegetation may be used if it meets stand density and height requirements and has uniform flow through the existing vegetation. The existing vegetation strip must be on a contour to be effective.

Site preparation for filter strips requires that the filter strip be placed on the contour. Variation in placement on the contour should not exceed a 0.5% longitudinal (perpendicular to the flow length) gradient.

All soil amendments should be applied according to a soil test recommendation for the planned vegetation.

The vegetation for filter strips must be permanent herbaceous vegetation of a single species or a mixture of grasses or legumes, which have stiff stems and a high stem density near the ground surface. Stem density should be such that the stem spacing does not exceed 1”.

Design Criteria

Installation (preservation of existing vegetation)

Designate the areas for preserving vegetation on the design plan map.

Indicate in the plan that the designated areas will be fenced or flagged and will not be disturbed. This includes avoiding surface disturbances that affect sheet flow of stormwater runoff and not storing debris from clearing and grubbing, and other construction waste material in the filter strips during construction.

Installation (planting)

Site Preparation
If the upper edge of the filter strip does not have a level edge, remove any obstructions and grade the upper edge of the filter strip so that runoff evenly enters the filter strip.
Fill and smooth any rills and gullies that exist over the filter strip area to ensure that overland flow will discharge across the filter strip along a smooth surface

Seedbed Preparation
Grade and loosen soil to a smooth firm surface to enhance rooting of seedlings and reduce rill erosion. If existing, break up large clods and loosen compacted, hard or crusted soil surfaces with a disk, ripper, chisel, harrow or other tillage equipment. Avoid preparing the seedbed under excessively wet conditions.

For broadcast seeding and drilling, tillage should adequately loosen the soil to a depth of at least 6”, alleviate compaction, and smooth and firm the soil for the proper placement of seed.

For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction. If compaction exists, the area should be chiseled across the slope to a depth of at least 6”.

Applying Soil Amendments

Liming
Follow soil test recommendation. If a soil test is not available, use 2 tons/acre of ground agricultural lime on clayey soils (approximately 90 lbs/1000 ft^2) and 1 ton/acre on sandy soils (approximately 45 lbs/1000 ft^2). Exception: If the cover is tall fescue and clover, use the 2 tons/acre rate (90 lbs/1000 ft^2) on both clayey and sandy soils.

Spread the specified amount of lime and incorporate into the top 6” of soil after applying fertilizer.

Fertilizing
Apply fertilizer at rates specified in the soil test recommendation. In the absence of soil tests, use the following as a guide:

Grass alone: 8-24-24 or equivalent - 400 lbs/acre (9.2 lbs/1000 ft^2). When vegetation has emerged to a stand and is growing, 30 to 40 lbs/acre (0.8 lb/1000 ft^2) of additional nitrogen fertilizer should be applied.

Grass-Legume Mixture: 8-24-24 or equivalent-400 lbs/acre (9.2 lbs/1000 ft^2). When vegetation has emerged to a stand and is growing, 30 to 40 lbs (0.8 lb/1000 ft^2) of additional nitrogen fertilizer should be applied.

Legume alone: 0-20-20 or equivalent-500 lbs/acre (11.5 lbs/1000 ft^2).

Incorporate lime and fertilizer to a minimum depth of at least 6” or more by disking or chiseling on slopes of up to 3:1.

Planting

Select adapted species from Figure FS-1 and Table FS-1.

Apply seed uniformly using a cyclone seeder, drill seeder, cultipacker seeder or hydroseeder.

When using a drill seeder, plant grasses and legumes ¼” to ½” deep. Calibrate equipment in the field.

When planting by methods other than a drill seeder or hydroseeder, cover seed by raking, or dragging a chain, brush or mat. Then firm the soil lightly with a roller. Seed can also be covered with hydro-mulched wood fiber and tackifier. Legumes require inoculation with nitrogen-fixing bacteria to ensure good growth. Purchase inoculum specific for the seed and mix with seed prior to planting.

Table FS-1 Commonly Used Plants for Permanent Cover

Species	Seeding Rates/Ac	North	Central	South
	PLS[1]		Seeding Dates	
Bahiagrass, Pensacola	40 lbs	--	Mar 1-July 1	Feb 1-Nov 1[1]
Bermudagrass, Common	10 lbs	Apr 1-July 1	Mar 15-July 15	Mar 1-July 15
Bahiagrass, Pensacola Bermudagrass, Common	30 lbs 5 lbs	--	Mar 1-July 1	Mar 1-July 15
Bermudagrass, Hybrid (Lawn Types)	Solid Sod	Anytime	Anytime	Anytime
Bermudagrass, Hybrid (Lawn Types)	Sprigs 1/sq ft	Mar 1-Aug 1	Mar 1-Aug 1	Feb 15 - Sep 1
Fescue, Tall	40-50 lbs	Sep 1-Nov 1	Sep 1-Nov 1	--
Sericea	40-60 lbs	Mar 15-July 15	Mar 1-July 15	Feb 15 -July 15
Sericea & Common Bermundagrass	40 lbs 10 lbs	Mar 15 -July 15	Mar 1-July 15	Feb 15-July 15
Switchgrass, Alamo	4 lbs	Apr 1-Jun 15	Mar 15-Jun 15	Mar 15-Jun 15

[1] PLS means pure live seed and is used to adjust seeding rates. For example, to plant 10 lbs of a species with germination of 80% and with purity of 90%, PLS = 0.8 x 0.9 = 72%, 10 PLS = 10/0.72 = 13.9 lbs

[2] A late fall planting of Bahiagrass should include 45 lbs./ac. of small grain to provide cover during winter months.

Mulching

Cover approximately 75% of the surface with the specified mulch materials. Crimp, tack or tie down straw mulch with netting. Mulching is extremely important for successful seeding (See Mulching practice for more details).

Figure FS-1 Geographical Areas for Species Adaptation and Seeding Dates

Note: Site conditions related to soils and aspect in counties adjacent or close to county boundaries may justify adjustments in planting dates by qualified design professionals.

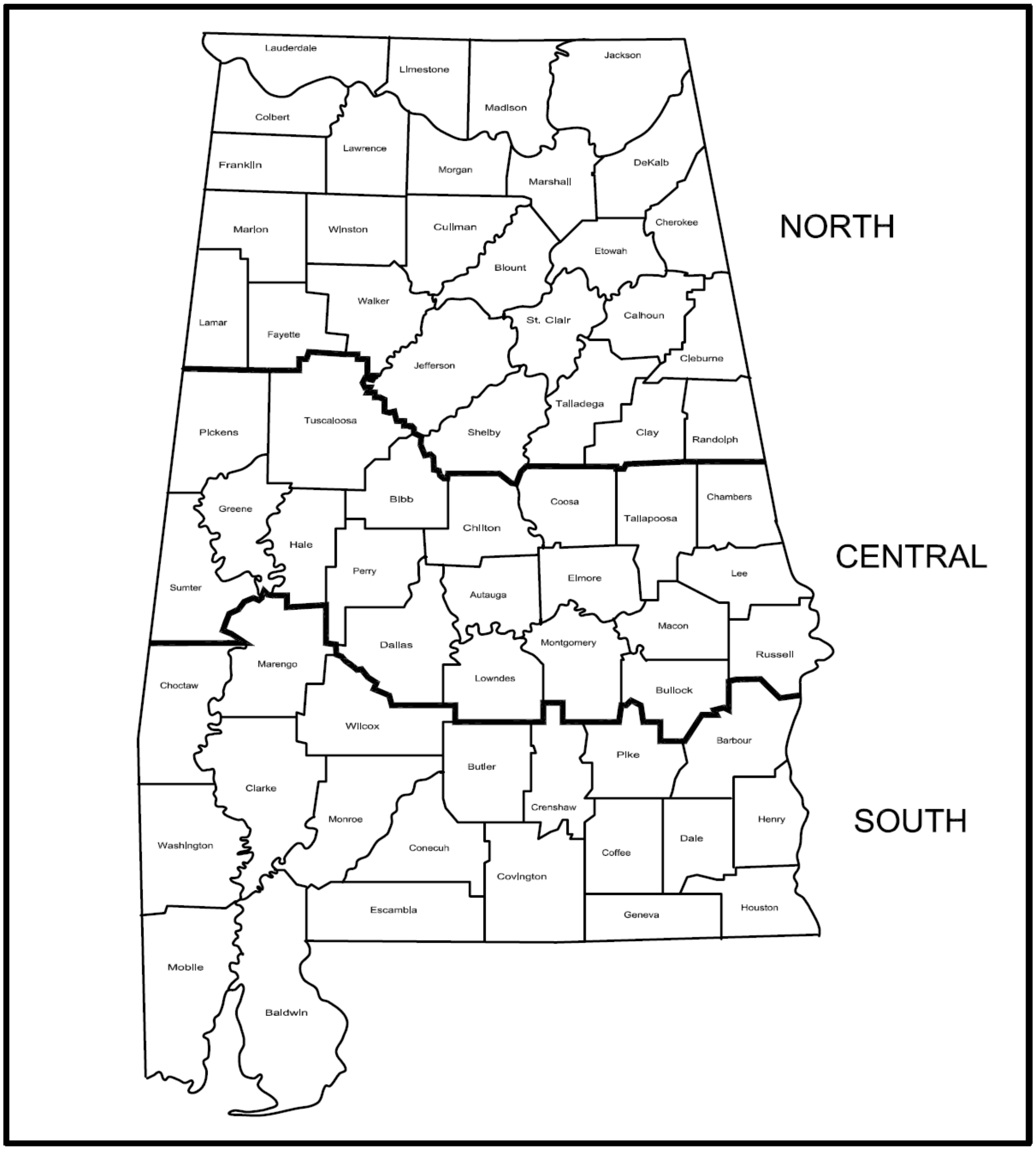


Figure FS-1 Geographical Areas for Species Adaptation and Seeding Dates

Note: Site conditions related to soils and aspect in counties adjacent or close to county boundaries may justify adjustments in planting dates by qualified design professionals.

This Page Intentionally Left Blank

Floating Turbidity Barrier (FB)

Practice Definition

A floating turbidity barrier consists of geotextile material (curtain) with floats on the top, weights on the bottom, and an anchorage system that minimizes sediment transport from a disturbed area that is adjacent to or within a body of water. The barrier provides sedimentation and turbidity protection for a watercourse from up-slope land disturbance activities where conventional erosion and sediment controls cannot be used or need supplemental sediment control, or from dredging or filling operations within a watercourse. The practice can be used in non-tidal and tidal watercourses where intrusion into the watercourse by construction activities has been permitted and subsequent sediment movement is unavoidable.

Planning Considerations

Soil loss into a watercourse results in long-term suspension of sediment. In time, the suspended sediment may travel long distances and affect widespread areas. A turbidity barrier is designed to deflect and contain sediment within a limited area and provide enough residence time so that soil particles will fall out of suspension and not travel to other areas.

Turbidity barrier types must be selected based on the flow conditions within the waterbody, whether it is a flowing channel, lake, pond, or a tidal watercourse. The specifications contained within this practice pertain to minimal and moderate flow conditions where the velocity of flow may reach 5 ft/sec (or a current of approximately 3 knots). For situations where there are greater flow velocities or currents, a qualified design professional and product manufacturer should be consulted.

Consideration must also be given to the direction of water movement in channel flow situations. Turbidity barriers are not designed to act as water impoundment dams and cannot be expected to stop the flow of a significant volume of water. They are designed and installed to trap sediment, not to halt the movement of water itself. In most situations, turbidity barriers should not be installed across channel flows. There is an exception to this rule. This occurs when there is a danger of creating a sediment buildup in the middle of a watercourse, thereby blocking access or creating a sediment bar. Curtains have been used effectively in large areas of moving water by forming a very long-sided, sharp “V” to deflect clean water around a work site, confining a large part of the sediment-laden water to the work area inside the “V” and direct much of the sediment toward the shoreline. Care must be taken, however, not to install the curtain perpendicular to the water current.

In tidal or moving water conditions, provisions must be made to allow the volume of water contained within the barrier to change. Since the bottom of the barrier is weighted and external anchors are frequently added, the volume of water contained within the curtain will be much greater at high tide verses low tide and measures must be taken to prevent the curtain from submerging. In addition to allowing slack in the curtain to rise and fall, water must be allowed to flow through the curtain if the curtain is to remain in roughly the same place and maintain the same shape. Normally, this is achieved by constructing part of the curtain from a heavy woven filter fabric. The fabric allows the water to pass through the curtain, but retains the sediment particles. Consideration should be given to the volume of water that must pass through the fabric and sediment particle size when specifying fabric permeability.

Sediment, which has been deflected and settled out by the curtain, may be removed if so directed by the on-site inspector or the permitting agency. However, consideration must be given to the probable outcome of the procedure, which may create more of a sediment problem by resuspension of particles and by accidental dumping of the material by the equipment involved. It is, therefore, recommended that the soil particles trapped by a turbidity curtain only be removed if there has been a significant change in the original contours of the affected area in the watercourse. Regardless of the decision made, soil particles should always be allowed to settle for a minimum of 6-12 hours before removal by equipment or before removal of a turbidity curtain.

It is imperative that all measures in the erosion control plan be used to keep sediment out of the watercourse. However, when proximity to the watercourse makes successfully mitigating sediment loss impossible, the use of the turbidity curtain during land disturbance is essential. Under no circumstances should permitted land disturbing activities create violations of water quality standards.

Design Criteria

Floating turbidity barriers are normally classified into 3 types:

- Type I (see Figure FB-1) is used in protected areas where there is no current and the area is sheltered from wind and waves.
- Type II (see Figure FB-1) is used in areas where there may be small to moderate current (up to 2 knots or 3.5 ft/sec) and/or wind and wave action can affect the curtain.
- Type III (see Figure FB-2) is used in areas where considerable current (up to 3 knots or 5 ft/sec) may be present, where tidal action may be present, and/or where the curtain is potentially subject to wind and wave action.

Turbidity curtains should extend the entire depth of the watercourse whenever the watercourse in question is not subject to tidal action and/or significant wind and wave forces. This prevents sediment-laden water from escaping under the barrier, scouring and resuspending additional sediments.

In tidal and/or wind and wave action situations, the curtain should never be so long as to touch the bottom. A minimum 1 foot gap should exist between the weighted, lower end of the skirt and the bottom at “mean” low water. Movement of the lower skirt over the bottom due to tidal reverses or wind and wave action on the flotation system may fan and stir sediments already settled out.

In tidal and/or wind and wave action situations, it is seldom practical to extend a turbidity curtain depth lower than 10 to 12 feet below the surface, even in deep water. Curtains which are installed deeper than this will be subjected to very large loads with consequent strain on curtain materials and the mooring system. In addition, a curtain installed in such a manner can "billow up" toward the surface under the pressure of the moving water, which will result in an effective depth which is significantly less than the skirt depth.

Turbidity curtains should be located parallel to the direction of flow of a moving body of water. Turbidity curtains should not be placed across the main flow of a significant body of moving water.

When sizing the length of the floating curtain, allow an additional 10-20% variance in the straight-line measurements. This will allow for measuring errors, make installing easier and reduce stress from potential wave action during high winds.

An attempt should be made to avoid an excessive number of joints in the curtain. A minimum continuous span of 50 feet between joints is a good “rule of thumb.”

For stability reasons, a maximum span of 100 feet between anchor or stake locations is also a good rule to follow.

The ends of the curtain, both floating upper and weighted lower, should extend well up onto the shoreline, especially if high water conditions are expected. The ends should be secured firmly to the shoreline to fully enclose the area where sediment may enter the water.

When there is a specific need to extend the curtain to the bottom of the watercourse in tidal or moving water conditions, a heavy woven pervious filter fabric may be substituted for the normally recommended impervious geotextile. This creates a "flow-through" medium, which significantly reduces the pressure on the curtain and will help to keep it in the same relative location and shape during the rise and fall of tidal waters.

Typical installation layouts of turbidity curtains can be seen in Figure FB-3. The number and spacing of external anchors will vary depending on current velocities and potential wind and wave action. Manufacturer's recommendations should be followed.

In navigable waters, additional permits may be required from the Corps of Engineers or other regulatory agencies if the barrier creates an obstruction to navigation.

Materials and Installation Requirements

Barriers should be a bright color (yellow or "international" orange) that will attract the attention of nearby boaters. The curtain fabric must meet the minimum requirements noted in Table FB-1.

Seams in the fabric should be either vulcanized welded or sewn, and should develop the full strength of the fabric.

Flotation devices should be flexible, buoyant units contained in an individual flotation sleeve or collar attached to the curtain. Buoyancy provided by the flotation units should be sufficient to support the weight of the curtain and maintain a freeboard of at least 3" above the water surface level.

Load lines must be fabricated into the bottom of all floating turbidity curtains. Type II and Type III curtains must have load lines also fabricated into the top of the fabric. The top load line should consist of woven webbing or vinyl-sheathed steel cable and should have break strength in excess of 10,000 pounds (5 t). The supplemental (bottom) load line should consist of a chain incorporated into the bottom hem of the curtain of sufficient weight to serve as ballast to hold the curtain in a vertical position. Additional anchorage should be provided as necessary. The load lines should have suitable connecting devices which develop the full breaking strength for connecting to load lines in adjacent sections (See Figures FB-1 and FB-2 which portray this orientation)

Table FB-1 Curtain Fabric Material Requirements for Floating Turbidity Barriers

Characteristic Test Method	16 Oz Nominal Laminated	18 Oz Laminated	22 Oz Coated	Geotextile Filter
Construction	Vinyl Laminate On 1300 Denier 9 X 9 Scrim	Vinyl Laminate On1300 Denier 9 X 9 Scrim	Vinyl Coated On Woven 6 Oz Polyester Base	Woven Polypropylene
Weight Astm D-751-95 Sec 16	Nominal 16 Oz/Sq Yd 376 Gr/Sq M	18 Oz/Sq Yd 423 Gr/Sq M	22 Oz/Sq Yd 517 Gr/Sq M	7.5 Oz/Sq Yd 176 Gr/Sq M
Adhesion Astm D-751-95 Sec 43.1.2	15 Lb/In 14 Dan/5 Cm	15 Lb/In 14 Dan/5 Cm	14 Lb/In 13 Dan/5 Cm	Not Applicable
Tensile Strength Astm D-751-95 Sec 12	324 X 271 Lb/In 308 X 258 Dan/5 Cm	397 X 373 Lb/In 378 X 363 Dan/5 Cm	500 X 400 Lb/In 476 X 389 Dan / 5 Cm	350 X 250 Lb/ In 333 X 230 Dan / 5 Cm
Tear Strength Astm D-751-95 Sec 29	76 X 104 Lb/In 72 X 99 Dan/5 Cm	96 X 86 Lb/In 91 X 82 Dan/5 CM	132 X 143 Lb/In 126 X 136 Dan / 5 Cm	95 X 55 Lb/In 90 X 52 Dan / 5 Cm
Hydrostatic Astm D-751-95 Sec 34.2	385 Lb/Sq In 2674 Kpa	385 Lb/Sq In 674 Kpa	881 Lb/Sq In 6118 Kpa	Not Applicable

External anchors may consist of 2” x 4” or 2½” minimum diameter wooden stakes, or 1.33 pounds/linear foot steel posts when Type I installation is used. When Type II or Type III installations are used, bottom anchors should be used.

Bottom anchors must be sufficient to hold the curtain in the same position relative to the bottom of the watercourse without interfering with the action of the curtain. The anchor may dig into the bottom (grappling hook, plow or fluke-type) or may be weighted (mushroom type) and should be attached to a floating anchor buoy via an anchor line. The anchor line would then run from the buoy to the top load line of the curtain. When used with Type III installations, these lines must contain enough slack to allow the buoy and curtain to float freely with tidal changes without pulling the buoy or curtain down and must be checked regularly to make sure they do not become entangled with debris. As previously noted, anchor spacing will vary with current velocity and expected wind and wave action. Manufacturer's recommendations should be followed. See orientation of external anchors and anchor buoys for tidal installation in Figure FB-2.

Installing 2 parallel curtains, separated at regular intervals by 10 feet long wooden boards or lengths of pipe can increase the effectiveness of the barrier.

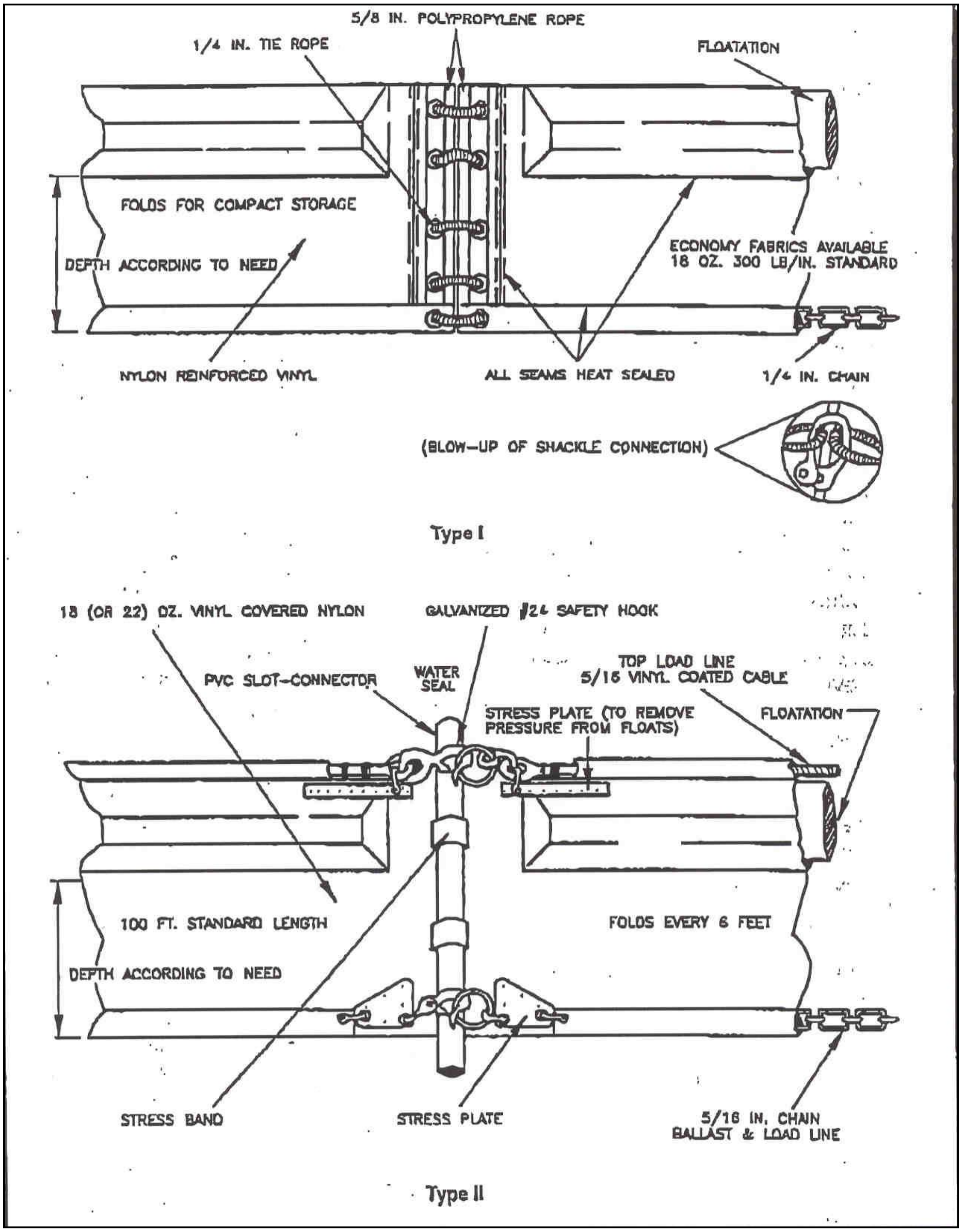


Figure FB-1 Type I and II Floating Turbidity Barriers
(Source: American Boom and Barrier Corp. product literature)

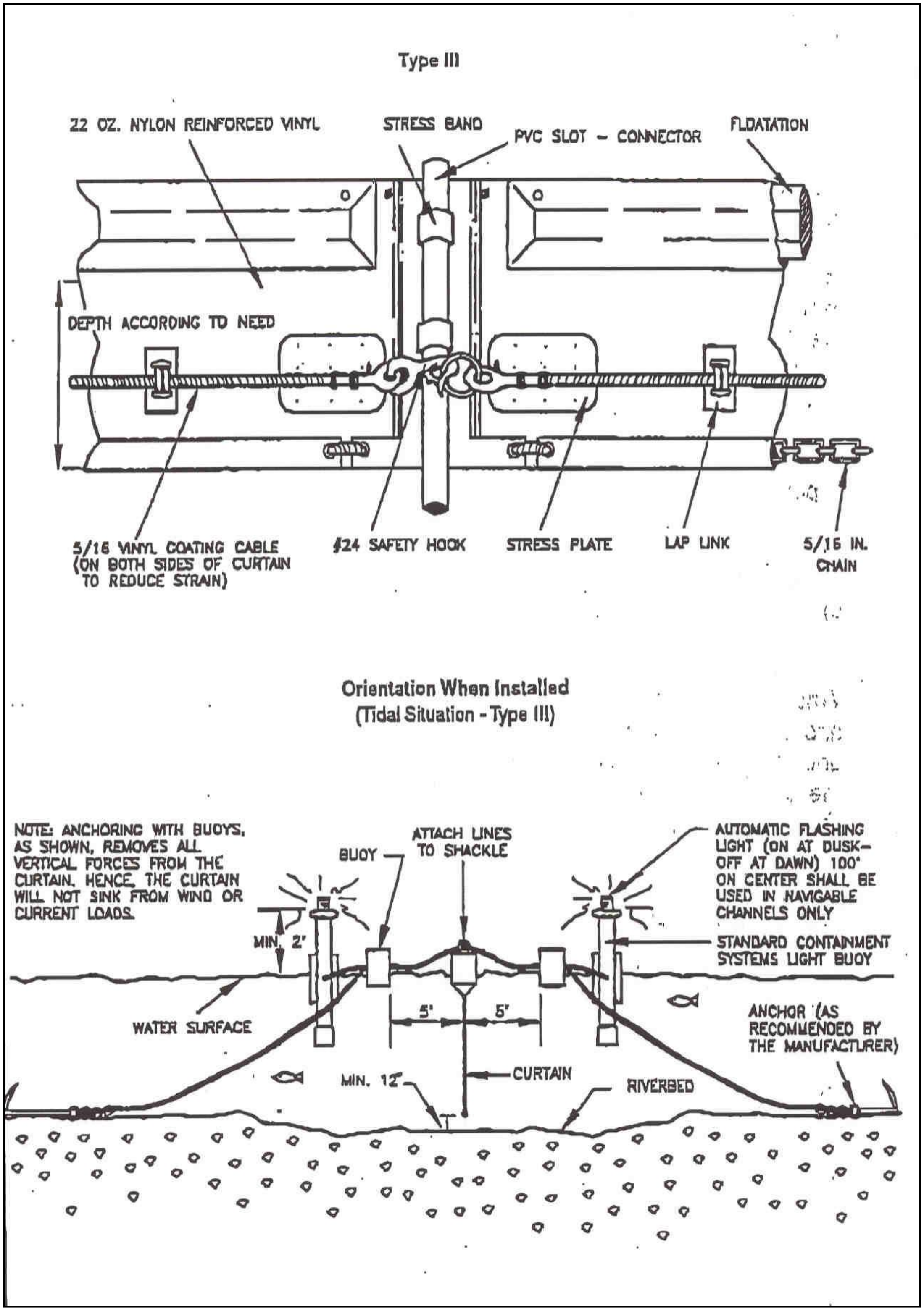


Figure FB-2 Type III Floating Turbidity Barrier
(Source: American Boom and Barrier Corp. product literature)

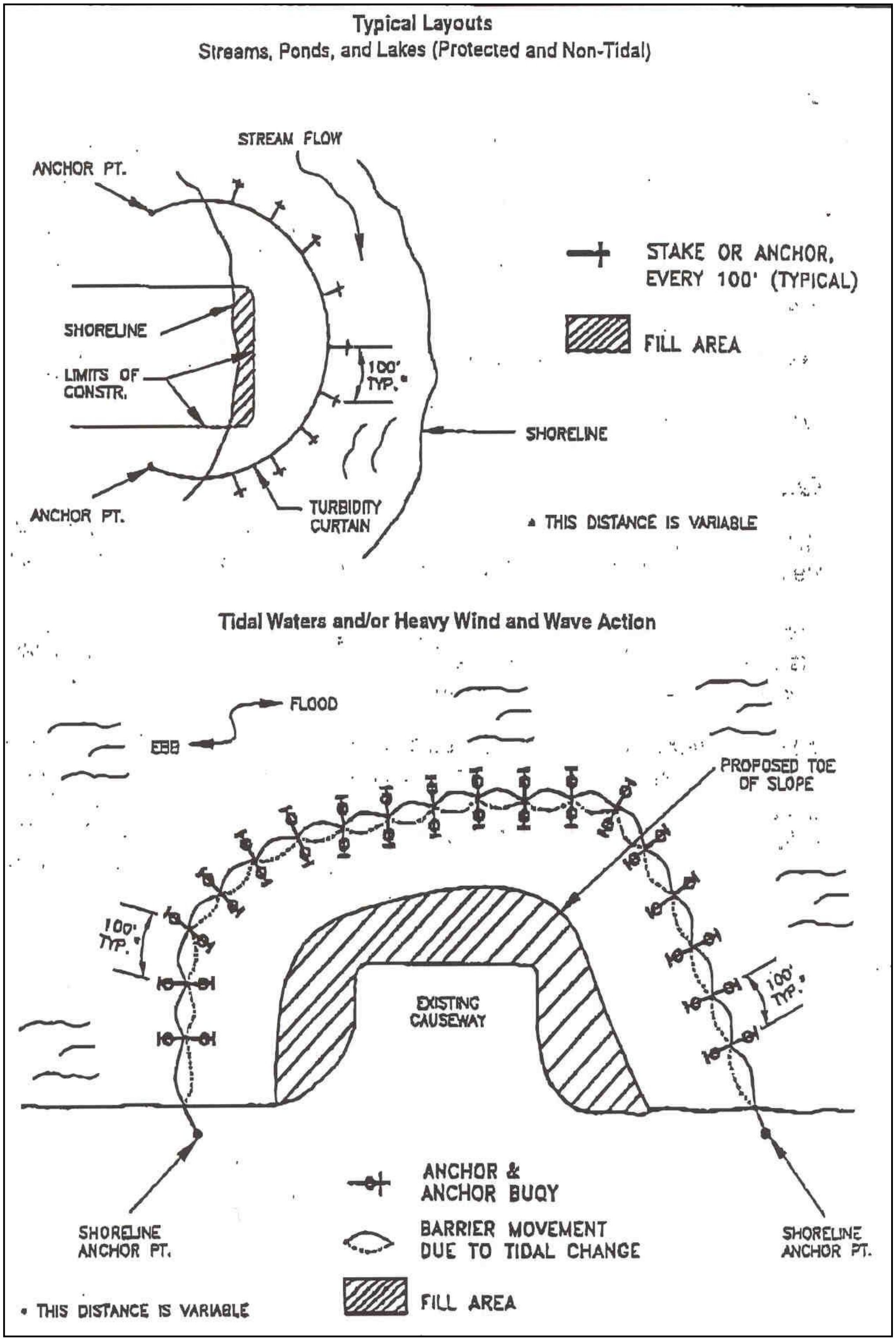


Figure FB-3 Typical Installation Layouts
(Source Florida Department of Transportation Road and Design Specifications)

Flocculant (FL)

Practice Definition

Flocculation is the chemical process of causing small, suspended soil particles to be drawn together to form “flocs”. These flocs more readily settle out compared to the individual particles due to their relatively greater mass. Products that cause flocculation of suspended soil particles (Flocculants) are often used to help polish, or minimize turbidity of stormwater runoff from construction sites. These products may contain both manufactured and natural polymers.

Planning Considerations

Products containing polyacrylamide (PAM) are commonly used in construction. PAM is a term describing a wide variety of chemicals based on the acrylamide unit. Products containing chitosan have also shown to be effective in reducing turbidity in stormwater runoff and are also commonly used in the US. Chitosan is a naturally occurring polymer.

When properly applied at the recommended rates, flocculants can be used as polishing agents to remove sediments from turbid runoff water on a construction site. If conventional erosion and sediment control are not being properly implemented to the fullest extent, flocculants will have little or no effect on the quality of the runoff from a construction site. Most flocculant products are available in emulsions, powders, gel bars, logs, tablets, and socks.

When including flocculant as a treatment option on a project, the following items must be addressed:

- Some states do not allow the use of flocculants for turbidity management. Flocculants are allowed in Alabama.
- Flocculant products should be tested for ecotoxicity and proven to not be toxic if used in accordance with the manufacturer's recommended application rates.
- Material Safety Data Sheets (MSDS) should be stored and available onsite.
- Areas where flocculant is applied must drain to a sediment basin or other BMP that promotes settling for final flocculation prior to discharging from the site.
- Adequate mixing is necessary for flocculant to be fully effective. Passive treatment using the turbulent flow of water in a channel or at the outlet of a pipe as the mixing method is encouraged.
- Adequate time and laminar flow (calm flow) or ponding is necessary to promote effective and efficient flocculation.
- Flocculant must be reapplied as it becomes bound with sediment particles with each rain event or other new flow.
- Flocculants that are water soluble dissolve slowly and may require considerable agitation and time to dissolve.
- Soil tests, such the "jar test", are required to ensure that the flocculant is properly matched with the anticipated soils suspended in the runoff.
- Manufacturer's application or dosage rates and application instructions should be followed closely based on specific site conditions and soils.

Design Criteria

Flocculants mixed with water after heavy sediment loads and particles have been removed can greatly reduce turbidity and suspended solids concentrations. Flocculants are commonly used to passively treat construction stormwater runoff in a conveyance, within sediment basins, or with other sediment traps, barriers or other practices. Flocculants may also be used in conjunction with erosion control practices and products to better manage raindrop and rill erosion. Flocculant is also used as a part of active treatment systems. It is critical that precautions are taken to minimize the potential for over application of flocculant or the release of flocs into receiving waters.

The following basic guidelines, at a minimum, should be followed when specifying or using flocculant:

1. Completely understand any regulatory requirements concerning the use of flocculants.
2. Choose the appropriate flocculant for the soil type.
3. Choose flocculants deemed non-toxic based on toxicity reports related to the planned use.
4. Adhere to manufacturer recommendations and MSDS for specification and application.

5. Use flocculants in conjunction with other appropriate BMPs. Pretreatment to remove heavy loads and larger particles should take place in advance of flocculant introduction when possible.
6. Do not apply flocculants directly to streams, wetlands, or other waters of the state.
7. Provide provisions for capturing flocs prior to their entering receiving waters.
8. Use of multiple types of flocculants in the same watershed should be avoided. Without a full understanding of the chemical interactions of each flocculant there is a possibility the two flocculants could interact with each other, reducing the overall effectiveness.
9. Dry form (powder) may be applied by hand spreader or mechanical spreader. Mixing with dry silica sand will aid in spreading. Pre-mixing of dry form flocculants into fertilizer, seed or other soil amendments is allowable.
10. Solid forms of flocculant shall be applied following site testing results to ensure proper placement and performance and shall meet or exceed state and federal water quality requirements. Logs, blocks, and tablets must be installed up gradient from the sediment capture BMP. Solid forms of flocculant should be protected from the sun and remain hydrated if possible.
11. Some flocculants involves a two-component system and generally are provided in the form of "socks." Manufacturer recommendations for installation and matching the components should be followed closely.

Materials and Installation Requirements

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 flocculant 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 flocculant. 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 capture BMP.

Another option for introducing flocculant into runoff involves running the water over a solid form of flocculant. Powders can be sprinkled on various practices such as check dams and materials, such as jute, coir, or other geotextiles. When wet, flocculants could 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.

Flocculant logs are designed to be placed in flowing water to dissolve the flocculant from the log somewhat proportionately to flow. While using these solid forms does not have the same challenges as liquid forms, they do have drawbacks. The amount of flocculant 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 flocculant blocks can be sticky when wet, it can accumulate materials from the runoff and become coated, releasing little flocculant. The solid forms also tend to harden when allowed to dry. This causes less flocculant 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 flocculant releases from the solid form:

- Reduce sediment load in the runoff upstream of the flocculant location. This avoids burying the flocculant under accumulated sediment.
- Create constant flow across or onto the solid flocculant. The flow will help dissolve and mix the flocculant as well as prevent suspended solids from sticking to the product.

Rock Filter Dam (RD)

Practice Description

A rock filter dam is a stone embankment designed to help capture sediment in natural or constructed drainageways on construction sites. This practice can be used as a fore bay to a sediment basin to help capture coarser particles of sediment. It is usually located so that it intercepts runoff primarily from disturbed areas, is accessible for periodic sediment removal and does not interfere with construction activities

Planning Considerations

Rock filter dams are used across drainageways to help remove coarser sediment particles and reduce off-site sediment delivery. Since rock filter dams are installed in flowing water, all local, state and federal laws and regulations must be followed during the design and construction process.

Dams should be designed so that impounded water behind the structures will not encroach on adjoining property owners or on other sediment and erosion control measures that outlet into the impoundment area.

Dams should be located so that the basin intercepts runoff primarily from disturbed areas, has adequate storage, and so that the basin can be accessed for sediment removal. Dams should also be located, as much as possible, in areas that do not interfere with construction activities.

Rock filter dams are not permanent structures. The design life of the structure is 3 years or less.

Design Criteria

Drainage Area

The drainage area above the dam should not exceed 10 acres.

Dam Height

The height of dam will be limited by the channel bank height or 8 feet, whichever is less. The dam height should also not exceed the elevation of the upstream property line. Water will bypass over the top of the dam and the back slope of the rock dam should be designed to be stable.

Spillway Capacity

The top of the dam should be designed to handle the peak runoff from a 10 year, 24 hour design storm with a maximum flow depth of 1 foot and freeboard of 1 foot. Therefore, the center portion of the dam should be at least 2 feet lower than the outer edges at the abutment. See Figure RD-1.

Dam Top Width

The minimum top width should be 6 feet. See Figure RD-2.

Dam Side Slopes

Side slopes should be 3:1 or flatter on the back slope and 2.5:1 or flatter on the front slope.

Outlet Protection

The downstream toe of the dam should be protected from erosion by placing larger stone on the back slope and a riprap apron at the toe. The apron should be placed on a zero grade with a riprap thickness of 1.5 feet. The apron should have a length equal to the height of the dam as a minimum and longer if needed to protect the toe of the dam.

Location

The dam should be located as close to the source of sediment as possible so that it will not cause water to back up onto adjoining property.

Basin Requirements

The basin behind the dam should provide a surface area that maximizes the sediment trapping efficiency. The basin should have a sediment storage capacity of 67 cubic yards per acre of drainage area.

Riprap Requirements

Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

The minimum median stone size should be 9”. The gradation of rock to be used should be specified using Tables RD-1 and RD-2. Table RD-1 is used to determine the weight of the median stone size (d50). Using this median weight, a gradation can be selected from Table RD-2, which shows the commercially available riprap gradations as classified by the Alabama Department of Transportation.

The dam should be faced with 1 foot of smaller stone (½” to ¾” gravel) on the upstream side to increase efficiency for trapping coarser particles. Geotextile can also be added between the smaller stone and rock.

Table RD-1 Size of Riprap Stones

Weight	Mean Spherical Diameter (ft)	Rectangular Shape	
		Length	Width, Height (ft)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	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

Geotextiles

Non-woven geotextiles should be used as a separator between the graded stone, the soil base and the abutments. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288. Geotextile should be placed immediately adjacent to the subgrade without any voids between the fabric and the subgrade.

Table RD-2 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

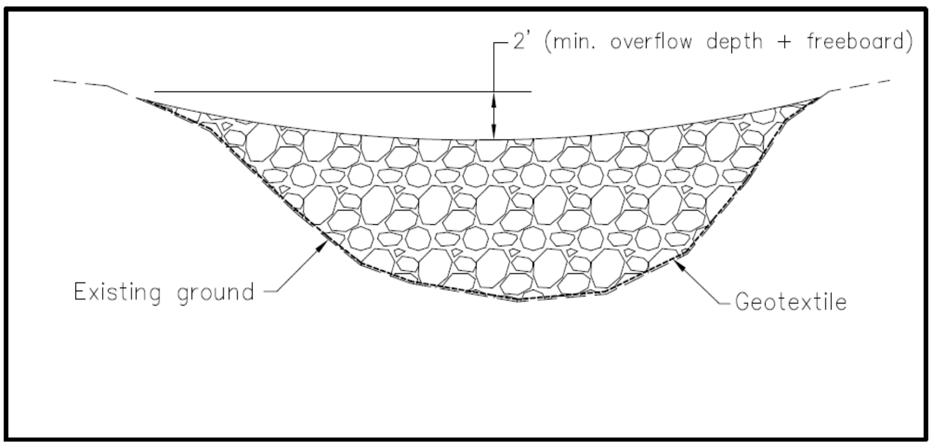


Figure RD-1 Typical Front View of Rock Filter Dam

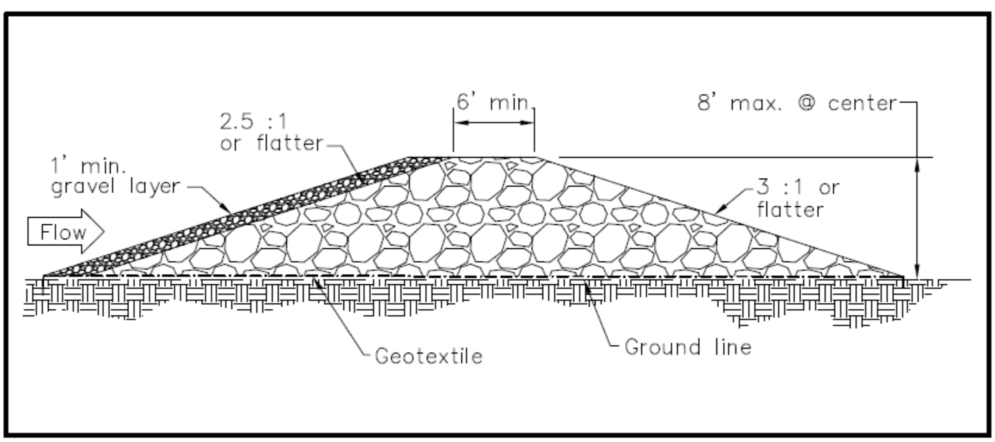


Figure RD-2 Typical Section of Rock Filter Dam

Sediment Barrier (SB)

Practice Description

A sediment barrier is a temporary structure used across a landscape mostly on the contour to reduce the quantity of sediment that is moving downslope. The most commonly used barrier is a silt fence (a geotextile fabric which is trenched into the ground and attached to supporting posts and possibly wire fence. Other barrier materials could include sand bags, wattles, and various man-made materials and devices that can be used in a similar manner as a silt fence.

This practice applies where sheet and rill erosion occurs on small disturbed areas. Barriers intercept runoff from upslope to form ponds that temporarily store runoff and allow sediment to settle out of the water and stay on the construction site.

Planning Considerations

Sediment barriers may be used on developing sites. It is most important that they be installed on the contour so that flow will not concentrate and cause bypassing by runoff going around the end of the barrier or overtopping because of lack of storage capacity.

The most commonly used sediment barriers are silt fences, and manufactured sediment logs (often referred to as wattles or sediment retention fiber roll). Manufactured sediment logs should be installed according to manufacturer's recommendations.

The success of silt fences depends on a proper installation (on the contour with each end turned up slope) that causes the fence to develop maximum efficiency of sediment trapping. Silt fences should be carefully installed to meet the intended purpose.

A silt fence is specifically designed to retain sediment transported by sheet flow from disturbed areas, while allowing water to pass through the fence. Silt fences should be installed to be stable under the flows expected from the site. Silt fences should not be installed across streams, ditches, waterways, or other concentrated flow areas.

Silt fences are composed of geotextile supported between steel or wooden posts. Silt fences are commercially available with geotextile attached to the post and can be rolled out and installed by driving the post into the ground. This type of silt fence is simple to install, but more expensive than some other installations. Silt fences must be trenched in at the bottom to prevent runoff from undermining the fence and developing rills under the fence. Locations with high runoff flows or velocities should use wire fence reinforcement.

A rather recent innovation that somewhat resembles a double silt fence and referred to as a “sediment retention barrier with flocculant” is used to reduce turbidity in the runoff that will reach sensitive sites. The measure consists of a double row of netting or high flow silt fences installed parallel with loose straw, woodchips or other organic fill spread between the rows and straw or other organic material laid on the ground adjacent to the downslope row (see following picture). An approved flocculant powder is added to the material between the rows and to the organic material below the downslope row prior to runoff events. The measure is located upstream of a filter strip or buffer zone and is installed on the contour. Design professionals should get details needed to design this measure from a qualified industry representative.

Sediment retention barriers may be used as a “last line of defense” against sediment leaving the construction site in sensitive areas. Do not use it in lieu of adequate erosion and sediment control practices.

Design Criteria (only for silt fence)

Silt fence installations are normally limited to situations in which only sheet or overland flow is expected because the practice cannot pass the volumes of water generated by channel flows. Silt fences are normally constructed of synthetic fabric (geotextile) and the life is expected to be the duration of most construction projects. Silt fence fabric should conform to the requirements of geotextile meeting the requirements found in ASSHTO M288.

The drainage area behind the silt fence should not exceed ¼ acre per 100 linear feet of silt fence for non-reinforced fence and ½ acre per 100 feet of wire reinforced fence. When all runoff from the drainage area is to be stored behind the fence (i.e. there is no stormwater disposal system in place) the maximum slope length behind the fence should not exceed those shown in Table SB-1.

Table SB-1 Slope Limitations for Silt Fence

Land Slope (Percent)	Maximum Slope Length Above Fence (Feet)
<2	100
2 to 5	75
5 to 10	50
10 to 20*	25
>20	15

*In areas where the slope is greater than 10%, a flat area length of 10 feet between the toe of the slope to the fence should be provided.

Type A Silt Fence

Type A fence is at least 32” above ground with wire reinforcements and is used on sites needing the highest degree of protection by a silt fence. The wire reinforcement is necessary because this type of silt fence is used for the highest flow situations and has almost 3 times the flow rate as Type B silt fence. Type A silt fence should be used where runoff flows or velocities are particularly high or where slopes exceed a vertical height of 10 feet. Staked tie backs on each end of a Type A silt fence may be necessary to prevent overturning.

Provide a riprap splash pad or other outlet protection device for any point where flow may overtop the sediment fence.

The silt fence should be installed as shown in Figure SB-1. Materials for posts and fasteners are shown in Tables SB-2 and SB-3. Details for overlap of Type A silt fence is available from The Alabama Department of Transportation construction drawings.

Table SB-2 Post Size for Silt Fence

	Minimum Length	Type of Post	Size of Post
Type A	5'	Steel "T" Post	1.3lb./ft. min.
Type B	4'	Soft Wood Oak Steel	3" diameter or 2X4 1.5" X 1.5" 1.3lb./ft. min.
Type C	3'	Soft Wood Oak Steel	2" diameter or 2X2 1" X 1" .75lb./ft. min.

Table SB-3 Wood Post Fasteners for Silt Fence

	Gauge	Crown	Legs	Staples/Post
Wire Staples	17 min.	¾" wide	½" long	5 min.
	Gauge	Length	Button Heads	Nail/Post
Nails	14 min.	1"	¾" long	4 min.

Type B Silt Fence

This 36" wide filter fabric should be used on developments where the life of the project is greater than or equal to 6 months.

The silt fence should be installed as shown in Figure SB-2. Materials for posts and fasteners are shown in Tables SB-2 and SB-3. Details for overlap of the silt fence and fastener placement are shown in Figure SB-4.

Type C Silt Fence

Though only 22" wide, this filter fabric allows the same flow rate as Type B silt fence. Type C silt fence should be limited to use on relatively minor projects, such as residential home sites or small commercial developments where permanent stabilization will be achieved in less than 6 months.

The silt fence should be installed as shown in Figure SB-3. Materials for posts and fasteners are shown in Tables SB-2 and SB-3. Details for overlap of the silt fence and fastener placement are shown in Figure SB-4.

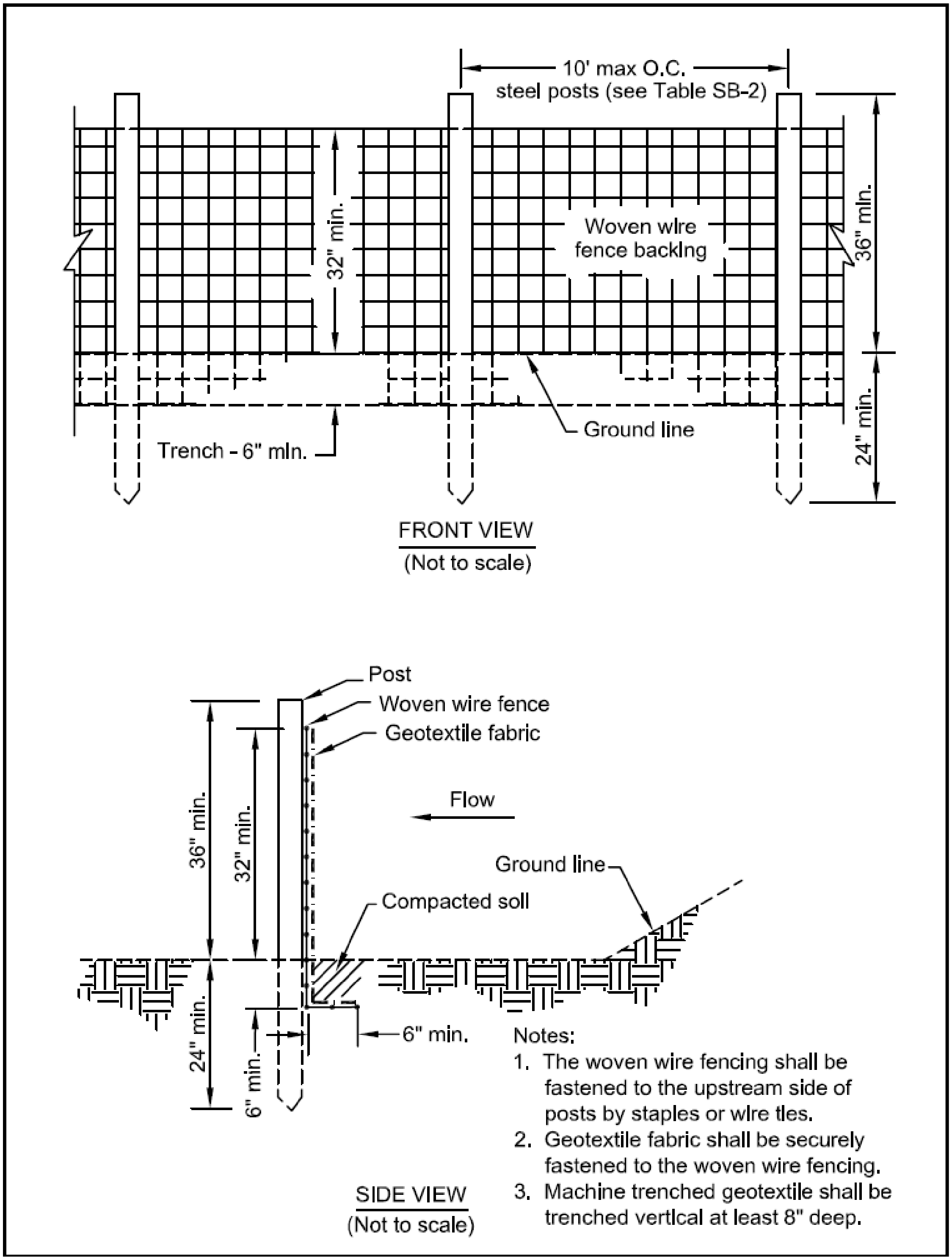


Figure SB-1 Silt Fence-Type A
(For post material requirements see Tables SB-2 and SB-3)

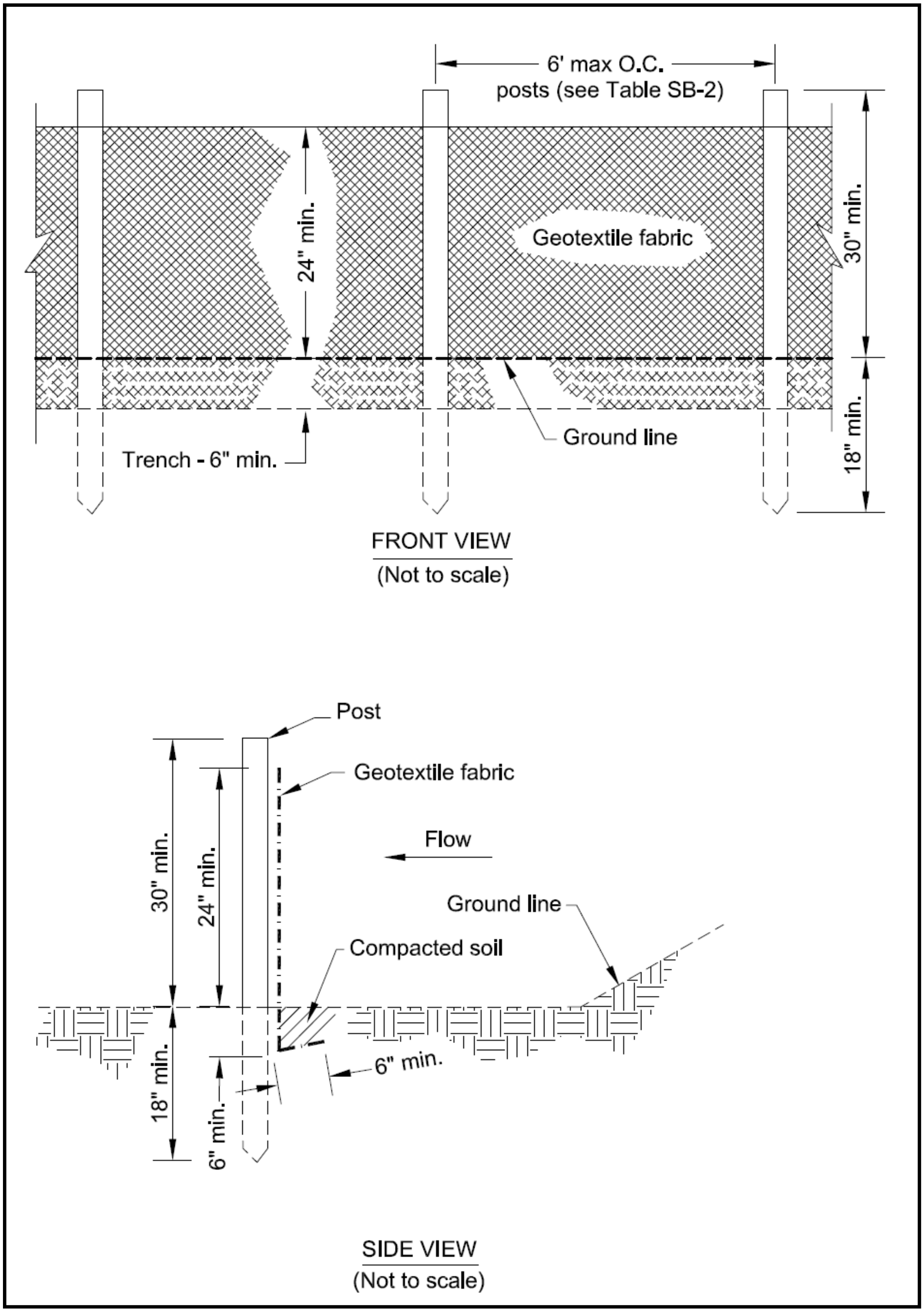


Figure SB-2 Silt Fence - Type B

(1) For post material requirements see Tables SB-2 and SB-3

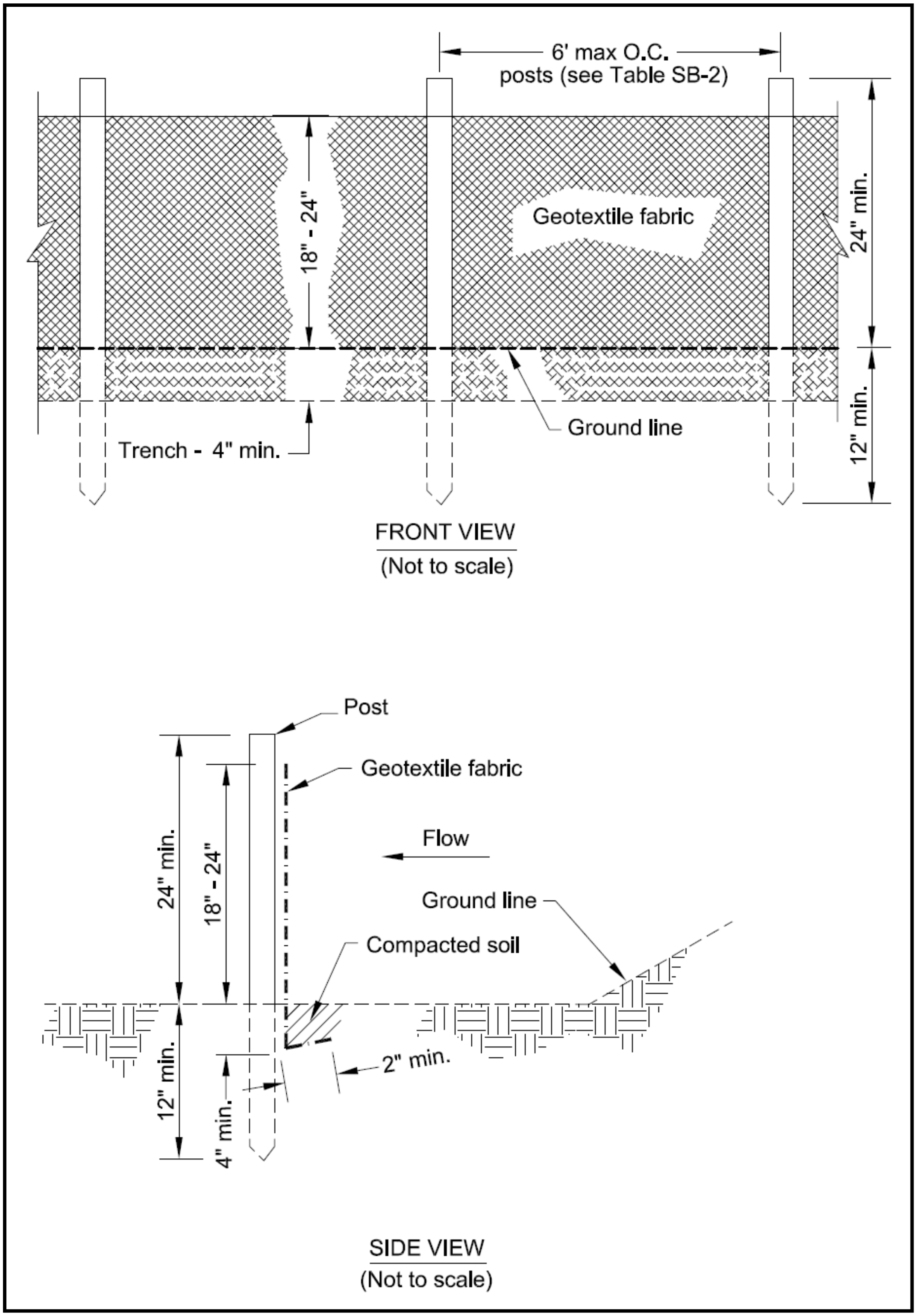


Figure SB-3 Silt Fence – Type C

(1) For post material requirements see Tables SB-2 and SB-3

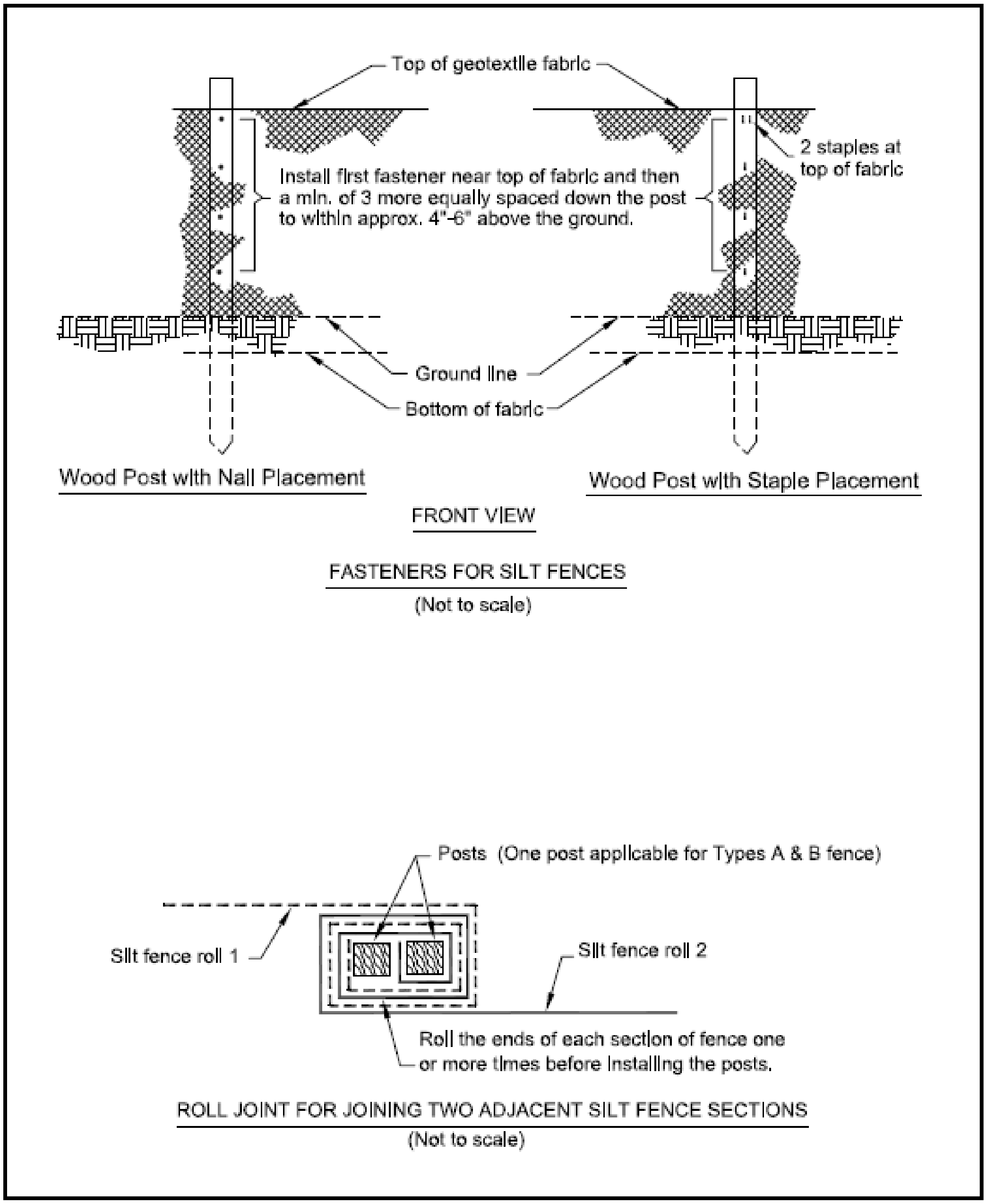


Figure SB-4 Silt Fence Installation Details

Sediment Basin (SBN)

Practice Description

An earthen embankment suitably located to capture runoff, with an emergency spillway lined to prevent spillway erosion, interior porous baffles to reduce turbulence and evenly distribute flows, and equipped with a floating skimmer or other approved surface dewatering device that removes water from the top of the basin. Flocculants are commonly used with a sediment basin to increase sediment capture.

Planning Considerations

Sediment basins are needed where drainage areas are too large for other sediment control practices.

Select locations for basins during initial site evaluation. Locate basin so that sudden failure should not cause loss of life or serious property damage. Install sediment basins before any site grading takes place within the drainage area.

Select 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.

Because the emergency spillway is actually used relatively frequently, it is generally stabilized using geotextile and riprap that can withstand the expected flows without erosive velocities. 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 ground (not over the embankment) to the greatest extent possible.

The use of approved flocculants properly introduced into the turbid runoff water at the inlet of the basin and/or at the first baffle should be considered to help polish the discharge from the basin for meeting turbidity requirements.

A fore bay or sump area prior to the basin should be considered for capture of heavier particles.

Baffles

Porous baffles effectively spread the flow across the entire width of a sediment basin or trap and cause increased deposition within the basin. 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 SBN-1). Spreading the flow in this manner utilizes the full cross section of the basin and reduces turbulence which shortens the time required for sediment to be deposited.

The installation should be similar to a sediment barrier (silt fence) (Figure SBN-2) utilizing posts and wire backing. The most proven material for a baffle is 700 - 900 g/m^2 coir erosion blanket (See following picture). Other materials proven by research to be equivalent in this application may be used. A support wire or rope across the top will help prevent excessive sagging if the material is attached to it with appropriate ties. Another option is to use a sawhorse type of support with the legs stabilized with rebar inserted into the basin floor. These structures work well and can be prefabricated off site and quickly installed.

Baffles need to be installed correctly in order to fully provide their benefits. Refer to Figure SBN-2 and the following key points:

- The baffle material needs to be secured at the bottom and sides by using staples or stakes, trenching, or securing horizontally to the bottom. Flow should not be allowed under the baffle.
- Most of the sediment will accumulate in the first bay, so this should be readily accessible for maintenance.

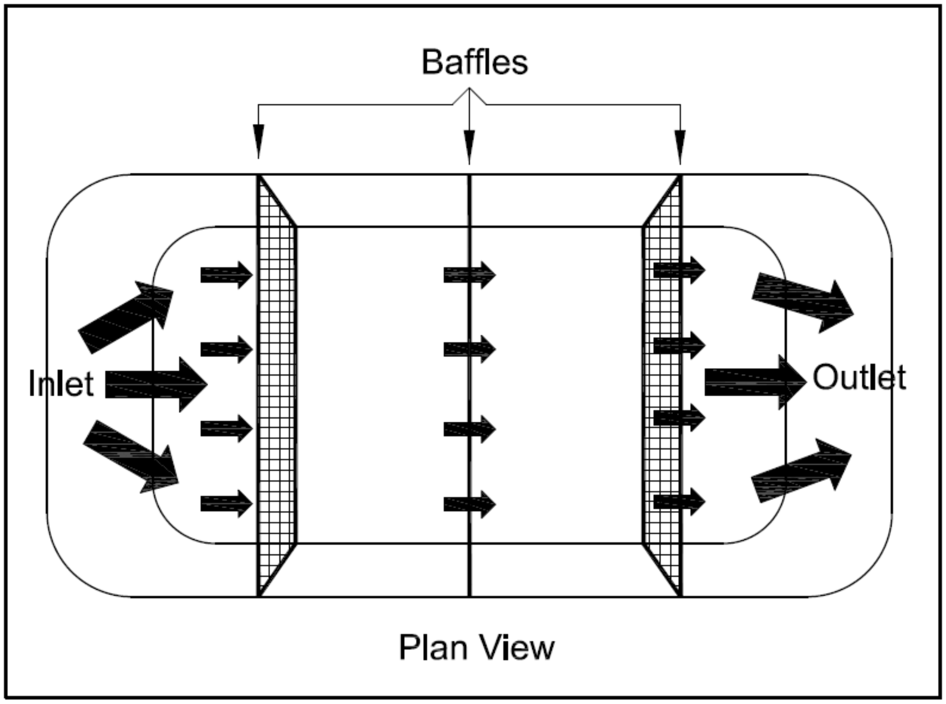


Figure SBN-1 Porous baffle in a sediment basin
(from North Carolina Erosion and Sediment Control Planning and Design Manual.)

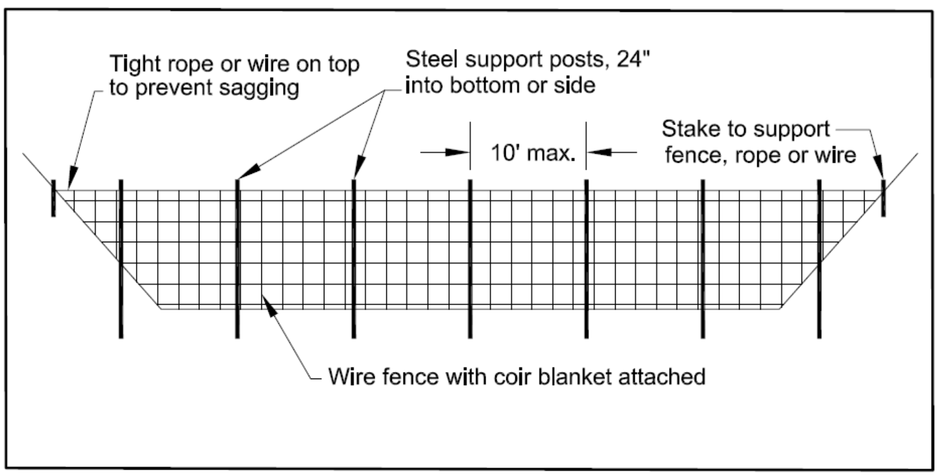


Figure SBN-2   Cross-section of a porous baffle in a sediment basin
Note there is no weir because the water flows through the baffle material
(from North Carolina Erosion and Sediment Control Planning and Design Manual.)

Example of porous baffle made of 700 g/m^2 coir erosion blanket as viewed from the inlet

Basin Dewatering

Sediment basins should be dewatered from the surface. A device often used for this is a skimmer that withdraws water from the basin's water surface, thus removing the highest quality water for delivery to the uncontrolled environment. One type of skimmer is shown in Figure SBN-3. By properly sizing the skimmer's control orifice, the skimmer can be made to dewater a design hydrologic event in a prescribed period.

An advantage of the skimmer is that it can be reused on future projects. Skimmers are generally maintenance free, but may require occasional maintenance to remove debris from the orifice.

All basin dewatering devices must dewater the basin from the top of the water surface. The rate of dewatering must be controlled. A dewatering time of 48 to 120 hours (2 to 5 days) is required for the basin to function properly.

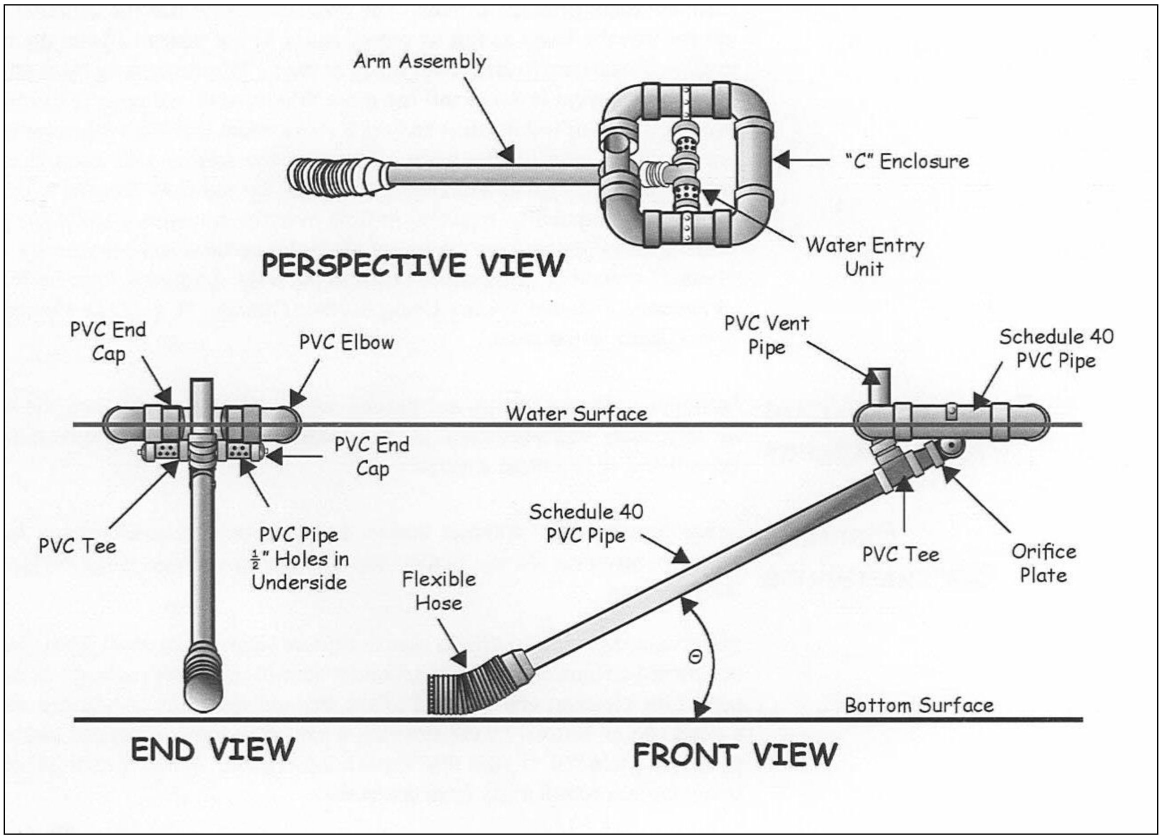


Figure SBN-3 Schematic of a skimmer
(from Pennsylvania Erosion and Sediment Pollution Control Manual, March, 2000)

Design Criteria

Summary:	**Temporary Sediment Trap**
Emergency Spillway:	Trapezoidal spillway with non-erosive lining. 10 – year, 24 – hour rainfall event
Recommended Maximum Drainage Area:	10 acres
Minimum Volume:	3,600 cubic feet per acre of drainage area
Minimum L/W Ratio:	2:1
Minimum Depth:	2 feet
Dewatering Mechanism:	Skimmer(s) or other approved basin dewatering device.
Dewatering Time:	2 – 5 days
Baffles Required:	3

Compliance with Laws and Regulations

Design and construction should comply with state and local laws, ordinances, rules and regulations.

Design Basin Life

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.

Dam Height

In order to ensure public safety, the maximum dam height should be 10 feet, measured from the designed (settled) top elevation of the dam to the lowest point at the downstream toe.

Drainage Area

In order to minimize risk to the public and environment, the maximum drainage area for each sediment basin should be minimized. The recommended maximum drainage area is 10 acres. The absolute maximum drainage area should be 100 acres.

Basin Locations

Select areas that:

- Are not intermittent or perennial streams
- Allow a maximum amount of construction runoff to be brought into the structure
- 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 2:1 or larger to improve trapping efficiency. Length is measured at the elevation associated with the minimum storage volume. Generally, the bottom of the basin should be level to ensure the baffles function properly. The area between the inlet and first baffle can be designed with reverse grade to improve the trapping efficiency.

Research has shown that the surface area of the basin should be maximized to improve trapping efficiency. Results of tests show that a surface area of 435 sq. ft. per CFS (peak discharge for the 10-year, 24-hour event), is needed for effective trapping efficiency.

Storage Volume

Ensure that the sediment storage volume of the basin is at least 3,600 cubic feet per acre for the area draining into the basin. Volume is measured below the emergency spillway crest. Remove sediment from the basin when approximately one-half of the storage volume has been filled.

Baffles

Space the baffles to create equal zones of volume within the basin.

The top of the baffle should be the same elevation as the maximum water depth flowing through the emergency spillway. Baffles are most effective at a height of 3 feet; however, site conditions may warrant taller baffles.

Baffles should be designed to go up the sides of the basin banks so water does not flow around the baffles. Most of the sediment will be captured in the inlet zone. Smaller particle size sediments are captured in the latter cells.

The design life of the fabric can be up to 3 years, but may need to be replaced more often if damaged or clogged.

Spillway Capacity

The emergency spillway system must carry the peak runoff from the 10-year 24-hour storm with a minimum 1 foot of freeboard (distance between the surface of the water with the spillway flowing full and the top of the embankment). Base runoff computations on the most severe soil cover conditions expected in the drainage area 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 skimmer apparatus will control the rate of dewatering. The skimmer should be sized to dewater the basin in 48-120 hours (2-5 days). The barrel pipe should be located under the embankment with at least one anti-seep collar at the center of the embankment projecting a minimum of 1.5 ft in all directions from the pipe. A drainage diaphragm can be used in lieu of an anti-seep collar. The barrel pipe outlet must be stable and not cause erosion.

Skimmer Orifice Diameter

Skimmer Selection Procedure

The manufacturer’s skimmer performance charts are recommended for use in selecting skimmers for use in dewatering sediment control basins. Always verify performance with the manufacturer’s information.

Required input data:
Basin volume = ________ ft^3
Desired dewatering time = ________ days

Procedure:

1. First use the basin volume (ft^3) and the desired dewatering time (days) and determine the required skimmer outflow rate in cubic feet per day (ft^3/d) from the following equation

$$Q = \frac{V}{t_d}$$

2. Scan the manufacturer’s skimmer performance charts and select the (a) skimmer size and (b) the skimmer orifice diameter (in inches) if desired.

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

Solution: First compute the required outflow rate as

$$Q = \frac{V}{t_d} = \frac{20000\,ft^3}{3d} = 6670\,ft^3/d$$

Now go to the manufacturer’s selection charts and select an appropriate skimmer. For example, a 2-inch skimmer with no orifice could have an outflow rate of 5,429 ft^3/d, which will require about 3.5 days to dewater the basin. A 4-inch skimmer with a 2.5 inch diameter orifice could have an outflow rate of 8,181 ft^3/d and dewater the basin in about 2.5 days.

Example: A More Precise Alternative: Most skimmers come with a plastic plug that can be drilled forming a hole that will limit the skimmer's outflow to any desired rate. Thus, for a specific skimmer the orifice that will dewater a basin in a more precisely chosen time can be determined. The flow through an orifice can be computed as

$$Q = CA\sqrt{2gH}$$

where C is the orifice coefficient (usually taken to be 0.6), A is the orifice cross-sectional area in ft^2, g is the acceleration of gravity (32.2 ft/sec^2), and H is the driving head on the orifice center in feet. The orifice equation can be simplified to yield the orifice flow in gpm using the diameter D (in inches) and the head in feet as

$$Q = 12D^2\sqrt{H} \text{ .}$$

Or the orifice flow in ft^3/d using the diameter D (in inches) and the head in feet as

$$Q = 2310D^2\sqrt{H} \text{ .}$$

If we solve the orifice equation for the orifice diameter using the desired outflow rate (6670 ft^3/d) and the head driving water through the skimmer (0.333 ft for a 4-inch skimmer) as

$$D = \sqrt{\frac{Q}{2310\sqrt{H}}} = \sqrt{\frac{6670}{2310\sqrt{0.333}}} = 2.24 inches$$

We see that if the plastic plug were drilled to a diameter of 2.24 inches and placed in a 4-inch skimmer, the dewater rate would be 6,670 ft^3/d and the 20,000 ft^3 basin would dewater in 3 days.

Outlet Protection

Provide outlet protection to ensure erosion does not occur at the pipe outlet.

Basin Emergency Spillway

The emergency spillway should carry the peak runoff from a 10-year storm. The spillway should have a minimum 10 foot bottom width, 0.5 foot flow depth, and 1 foot freeboard above the design water surface.

Construct the entire flow area of the spillway in undisturbed soil to the greatest extent possible. Cross section should be trapezoidal, with side slopes 3:1 or flatter for grass spillways (Figure SBN-4) and 2:1 for riprap. Select vegetated lining to meet flow requirements and site conditions.

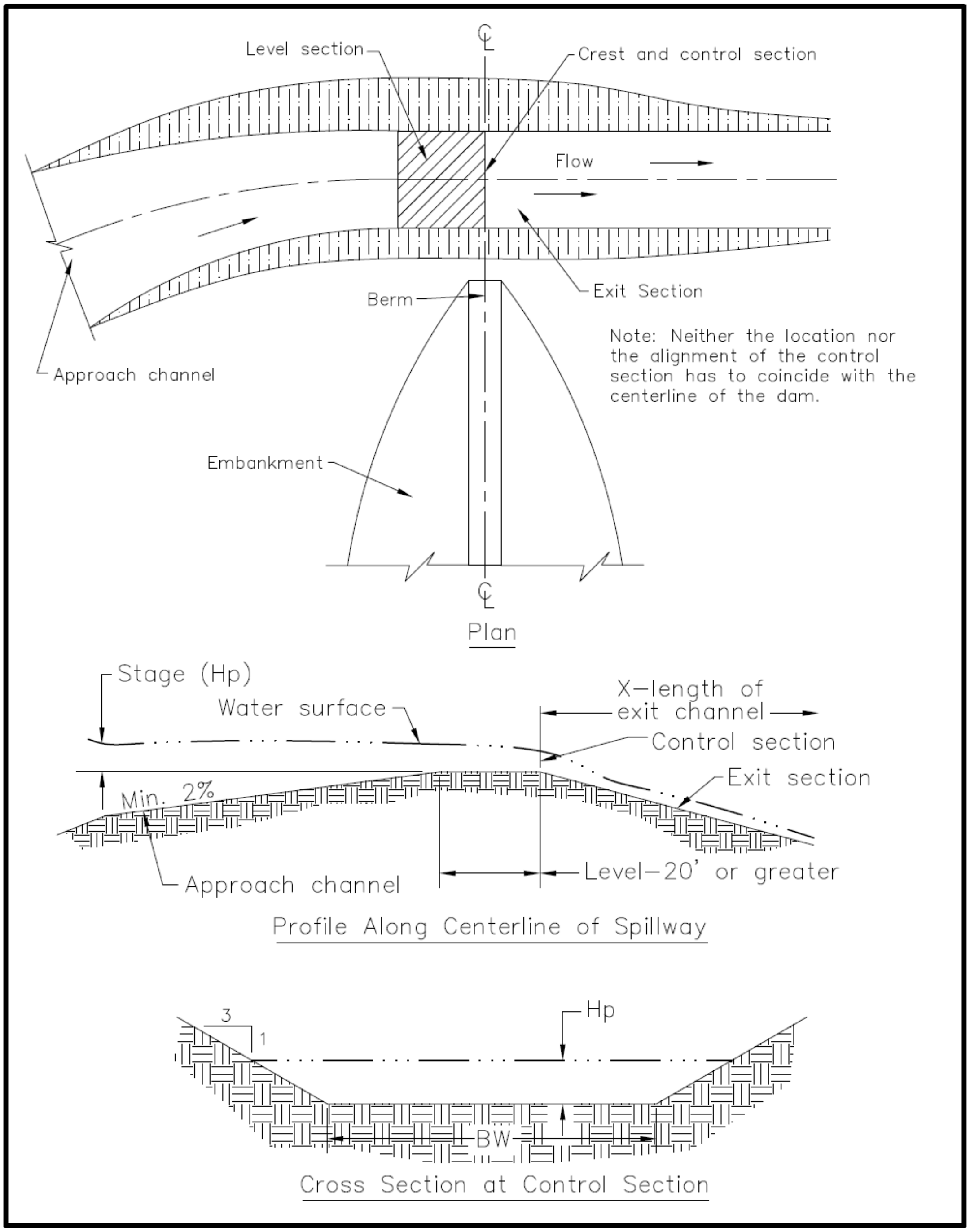


Figure SBN-4 Excavated grass spillway views

Inlet Section
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 inlet portion of the spillway may be curved to improve alignment.

The Control Section
The control section of the spillway should be level and straight and at least 20 ft long for grass spillways and 10 feet for riprap. 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
The outlet section of the spillway 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

Embankments should not exceed 10 feet in height, measured at the center line from the original ground surface to the designed (settled) top elevation of the embankment. Keep a minimum of 1 foot between the designed (settled) top of the dam and the design water level in the emergency spillway. 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 8 feet and side slopes of 2.5:1 or flatter.

There should be a cutoff trench in stable soil material under the dam at the centerline. The trench should be at least 2 feet deep with 1.5:1 side slopes, and sufficiently wide (at least 8 ft.) to allow compaction by machine.

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 9-inch layers through the length of dam and compact by routing construction hauling equipment over it. Maintain moisture and compaction requirements according to the plans and specifications. Hauling or compaction equipment must traverse each layer so that the entire surface has been compacted by at least one pass of the equipment wheels or tracks.

Excavation

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

Erosion Protection

Minimize the area disturbed during construction. Divert surface water from disturbed areas. When possible, delay clearing the sediment impoundment area until the dam is in place. Keep the remaining temporary pool area undisturbed. Stabilize the spillway, embankment, and all disturbed areas with permanent vegetation. The basin bottom should also be established to a vegetative cover as this promotes sediment deposition.

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. The shallower the pool, the better.
- Length—Maximize the length-to-width ratio of the basin to provide the longest flow path possible.
- 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 bottom should be stabilized by geotextile material, riprap with geotextile, a pipe drop, or other similar methods (Figure SBN-5 shows the area with rocks). Inlets to basin should be located the greatest distance possible from the spillway.
- Dewatering—Allow the maximum reasonable detention period before the basin is completely dewatered (at least 48 hours).
- Inflow rate—Reduce the inflow velocity to nonerosive rates and divert all sediment-free runoff
- Establish permanent vegetation in the bottom and side slopes of the basin.
- Introduce the appropriate PAM material either at the turbulent entrance of the runoff water into the basin and/or apply to the first baffle. Apply the PAM according to manufacturer’s recommendations.

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.

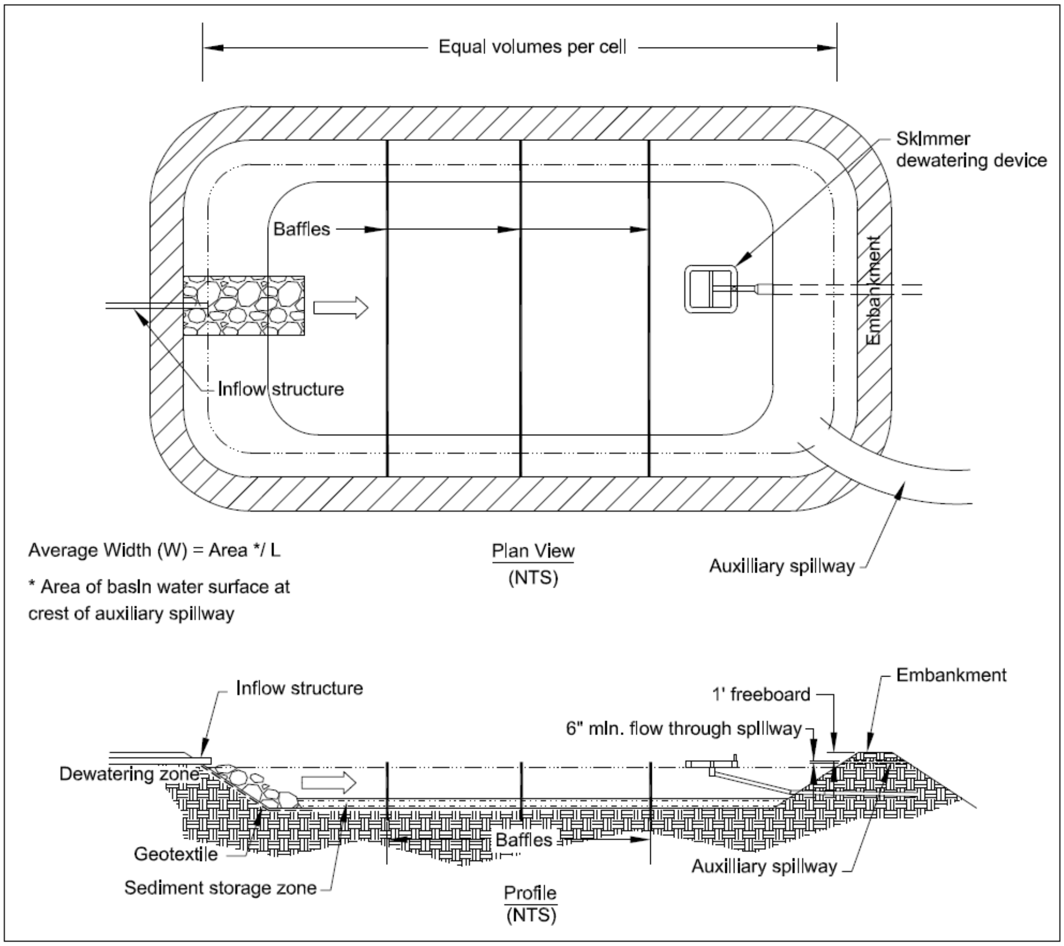


Figure SBN-5 Example of a sediment basin with a skimmer outlet and emergency spillway
(modified from Pennsylvania Erosion and Sediment Control Manual, March, 2000)

Design Procedure

Step 1. Determine peak flow, Q_{10}, for the basin drainage area utilizing the NRCS runoff curve number method.

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 (3,600 ft^3/acre of drainage area).
- Specify sediment cleanout level to be clearly marked (one-half the design volume). Specify that the basin area is to be cleared after the dam is built.

Step 4. Determine area of basin, shape of basin, and baffles:

- Check length/width ratio (should be 2:1 or larger) and the surface area (435 sq.ft./Qp10).
- Ensure the bottom of the basin is level.
- Design and locate a minimum of 3 coir baffles. The baffle spacing should produce equal volumes of storage within the basin when the basin if full. The top elevation of the baffles will be set in Step 7.

Step 5. Size the skimmer, skimmer orifice, and barrel pipe.

Use Table SBN-1 or the precise alternative design to size the orifice. Generally, a Schedule 40 PVC barrel pipe the same size as the skimmer arm is used under the embankment.

Step 6. Design the anti-seep collar.

Ensure that antiseep collar is no closer than 2 ft from a pipe joint and as close to the center of the embankment as possible. Collar must project at least 1.5 ft from the pipe and be watertight.

Step 7. Determine the emergency spillway dimensions.

Size the spillway bottom width and flow depth to handle the Q_{10} peak flow. Tables SBN-1 and SBN-2 can be used for the design process for grassed emergency spillways. Use appropriate design procedures for spillways with other surfaces. Set top of baffles at the elevation of the designed maximum flow depth of the emergency spillway.

Step 8. 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%.

Step 9. Spillway control section.

- Locate the control section in natural ground to the greatest extent possible.
- Keep a level area to extend at least 20 ft (grass) or 10 ft (riprap) upstream from the outlet end of the control section to ensure a straight alignment.
- Side slopes should be 3:1 (grass) or 2:1 (riprap).

Step 10. 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 11. 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.
- 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 remembering that the spillway cut may provide a significant amount of fill.

Step 12. Erosion control

- Select surface stabilization measures to control erosion.
- 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.
- Establish all disturbed areas including the basin bottom and side slopes to vegetation.

Step 13. Safety.

- Construct a fence and install warning signs as needed.

Table SBN-1 Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils (side slopes 3 horizontal: 1 vertical)

Discharge Q CFS	Slope Range		Bottom Width Feet	Stage Feet
	Minimum Percent	Maximum Percent		
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
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 Table Use:

Given: Discharge, Q_{10} = 87 cfs, Spillway slope (exit section) = 4%.
Find: Bottom Width and Stage in Spillway.
Procedure: Using a discharge of 90 cfs, note that the spillway (exit section) slope falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width of 32 ft, to minimize velocity. Stage in the spillway is 1.14 ft.
Note: Computations are based on: Roughness coefficient, n = 0.40 and a maximum velocity of 5.50 ft. per sec.

Table SBN-2 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 Table Use:

Given: Discharge, Q_{10} = 38 cfs, Spillway slope (exit section) = 4%.
Find: Bottom Width and Stage in Spillway.
Procedure: Using a discharge of 40 cfs, note that the spillway (exit section) slope falls within slope ranges corresponding to bottom widths of 36 and 40 ft. Use bottom width of 40 ft, to minimize velocity. Stage in the spillway is 0.64 ft.
Note: Computations are based on: Roughness coefficient, n = 0.40 and a maximum velocity of 3.50 ft. per sec.

This Page Intentionally Left Blank

Sediment Trap (ST)

Practice Description

A sediment trap is a temporary catch basin used for the purpose of intercepting and detaining small amounts of sediment to prevent it from leaving the construction site. This practice applies within disturbed areas with very small drainage basins that are subject to sheet erosion or in minor swales. Various materials may be used for sediment traps and include straw bales, sand bags, wattles, and various man-made materials and devices.

Planning Considerations

Note: Straw bales are the only sediment trap material covered in this handbook.

In certain situations, straw bales can be used as an alternative to silt fence for trapping sediment. The practice should only be used to trap sediment for a short duration from very small drainage areas. Straw bales comparatively low flow rate should be considered before choosing to use this practice. Ponding above the bales can occur rapidly due to the low flow rate. Overtopping and bypass of the bales can cause significant damage to the site. Additional measures should be used if turbidity leaving the site served by this practice is an issue.

Design Criteria

Drainage Area

For disturbed areas subject to sheet erosion the drainage area should be restricted to ¼ acre per 100 feet of trap. The slope length behind the trap should be restricted according to Table ST-1.

Table ST-1 Criteria for Straw or Hay Bale Placement

Land Slope (Percent)	**Maximum Slope Length Above Bale (Feet)**
<2	75
2 to 5	50
5 to 10	35
10 to 20	20
>20	10

Bale Size

Bales should be 14” x 18” x 36”.

Anchors

Two 36” long (minimum) 2” x 2” hardwood stakes should be driven through each bale after the bales are properly entranced. Alternate anchors can be 2 pieces of no.4 steel rebar, 36” long (minimum). See Figure ST-1 for details on proper installation of straw bales.

Effective Life

Straw and hay bales have a relatively short period of usefulness and should not be used if the project duration is expected to exceed 3 months. Bale placement should result in the twine or cord being on the side and not the bottom of the bale.

Location

This practice should be used on nearly level ground and be placed at least 10 feet from the toe of any slope. The barrier should follow the land contour. The practice should never be used in live streams or in swales where there is a possibility of washout. The practice should also not be used in areas where rock or hard surfaces prevent the full and uniform anchoring of the bales.

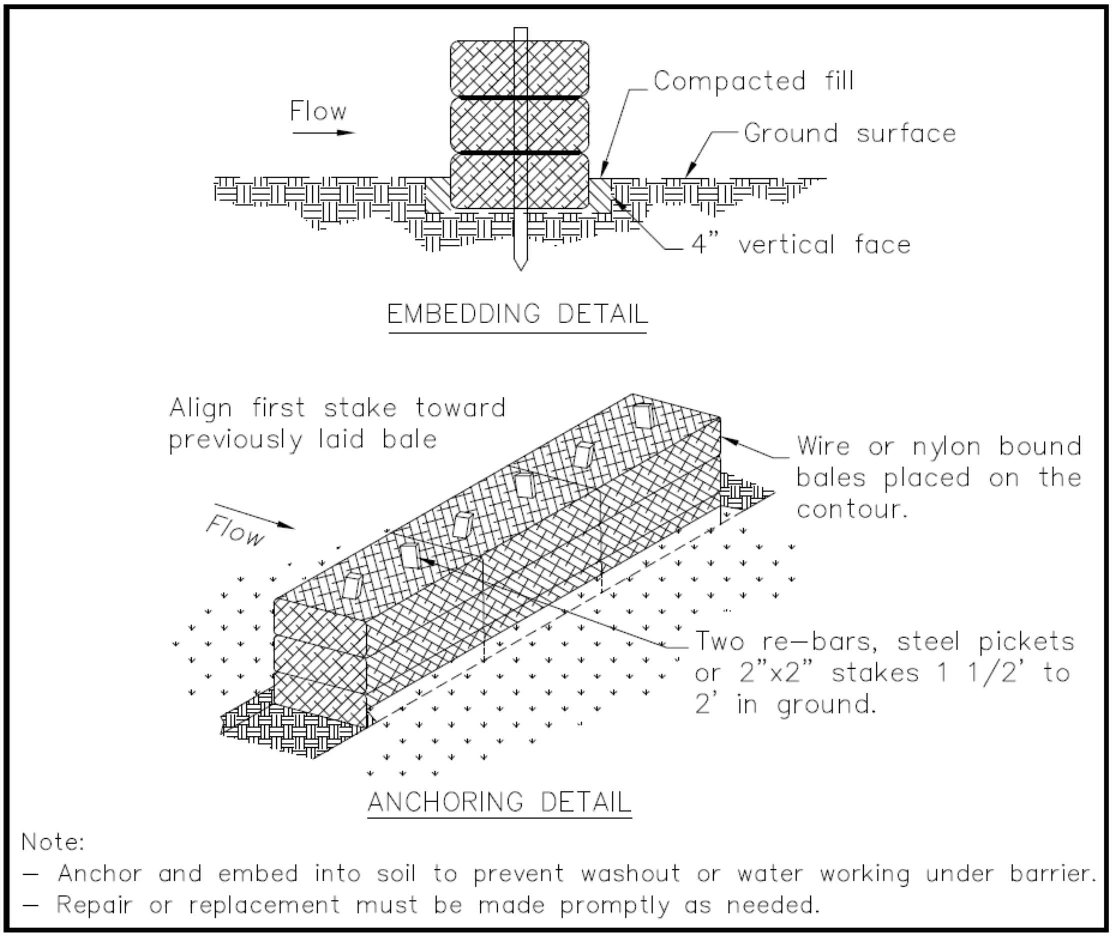


Figure ST-1 Anchoring Technique for Straw Bales

This Page Intentionally Left Blank

Bioretention Area (BA)

Source: Department of Environmental Resources, Prince George's County, MD

Practice Description

A bioretention area is a shallow, vegetated depression incorporated into a development's landscape. The purpose of bioretention is to restore, as much as possible, an area's pre-development hydrology and provide both water quantity and water quality benefits.

Stormwater is conveyed as sheet flow to the bioretention area that temporarily stores runoff. As stormwater percolates through the bioretention area, soils and plants remove pollutants. Filtered stormwater is then directed to the conveyance system or if underlying soils are appropriate, stormwater is allowed to infiltrate to the aquifer below and provide recharge.

A bioretention area is a suitable stormwater practice for commercial, transportation, industrial, and residential developments. Applications include parking lot islands, roadway medians, roadside swales, and residential gardens positioned to collect roof and parking lot runoff. Bioretention is particularly effective on sites of 1 acre or less. Bioretention is used on larger sites with multiple bioretention areas treating sub-drainages. In general, a bioretention area is a suitable stormwater management practice for residential subdivisions and high density/ultra urban sites but not for regional-scale control. [2]

Note: Only general guidance is provided for this practice. More specific information can be obtained from the Low Impact Development Handbook for the State of Alabama (www.aces.edu/lid).

Planning Considerations

Examples of bioretention area applications are illustrated in Figure BA-1.

A bioretention area is designed with one of the two basic configurations: (1) with an underdrain connected to a stormwater collection system; or (2) without an underdrain ("no-underdrain") and infiltration into a permeable soil profile, providing groundwater recharge. The underlying soil is the main factor determining which configuration is used. [2] The no-underdrain design is a better choice when feasible because of aquifer recharge. However, the underdrain design is likely to be more appropriate over much of Alabama because of the occurrence of clayey soils.

A typical underdrain bioretention area consists of (1) grass/gravel filter strip at the entrance, (2) ponding area, (3) native vegetation selected for tolerance to wet and dry conditions, (4) hardwood mulch layer, (5) planting soil layer amended to promote infiltration, (6) pea gravel diaphragm, (7) underdrain with outlet, and (8) overflow structure.[3] Premanufactured bioretention boxes are also available.

Properly designed, constructed and maintained bioretention areas have demonstrated excellent pollutant load removal. However, pollutant removal drastically declines when poorly designed or not sufficiently maintained. Information on pollutant removal by bioretention areas may be found in the National Pollutant Removal Performance Database, 2nd Edition (www.cwp.org) and the National Stormwater Best Management Practices (BMP) Database (www.bmpdatabase.org).

Native vegetation is preferred for use in bioretention areas. Ideally, native plant species should require less maintenance and provide better wildlife habitat than introduced species. Exotic invasive species should never be used and should be removed during annual maintenance.

Bioretention areas should be finished "last" during the construction phase to minimize sediment delivery to the bioretention facility.

- The non-engineered version of this practice is a Rain Garden and is not included in the Bioretention Area of this handbook, but is covered in the Low Impact Development Handbook for the State of Alabama [1].

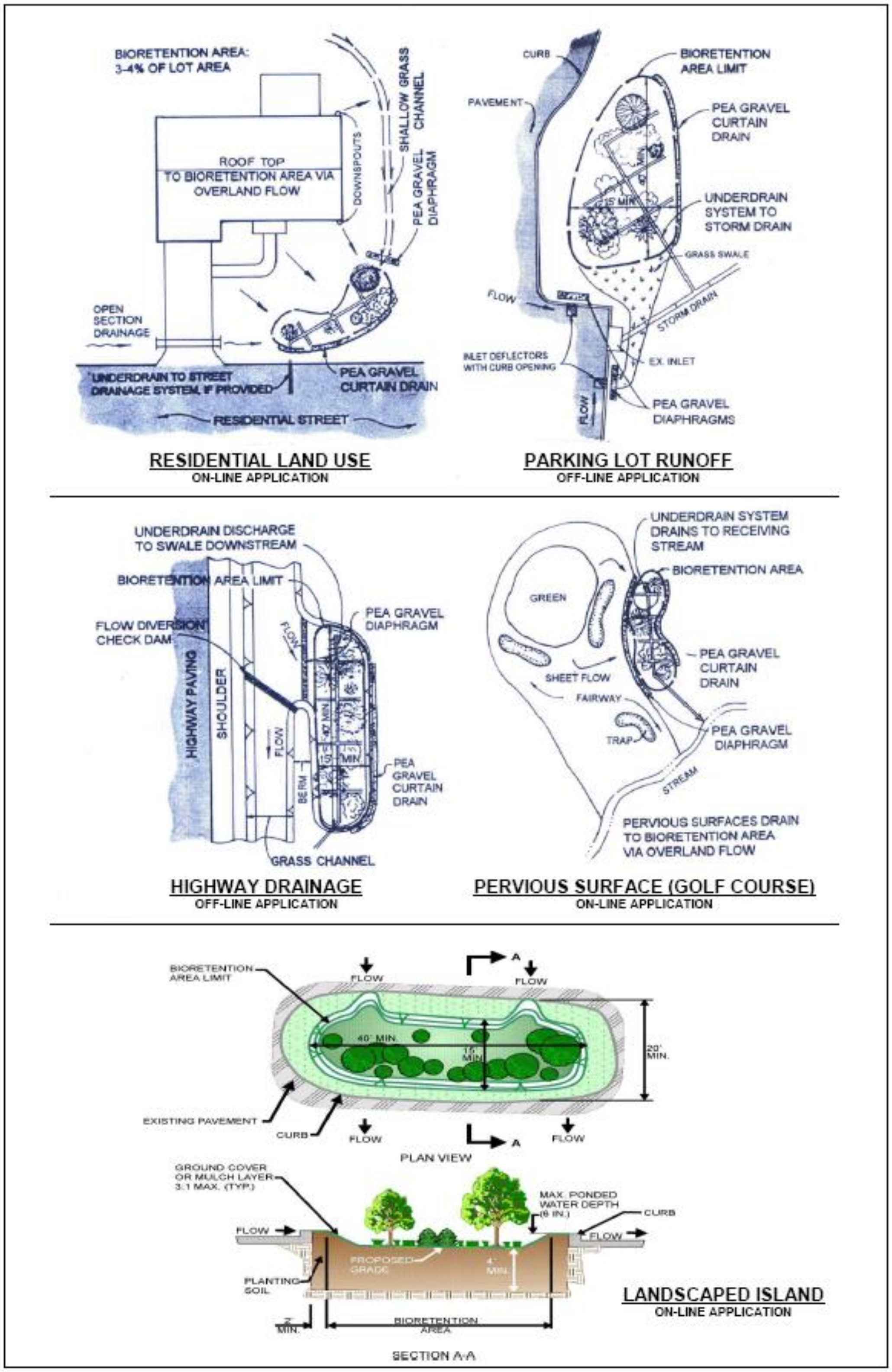


Figure BA-1 Applications of Bioretention Areas
(Source: Claytor and Schueler. 1996. Center for Watershed Protection.)

Design Criteria

Drainage Area

The drainage area contributing runoff to a bioretention area should be at maximum 5 acres and preferably between 0.5 and 2 acres. [2]

Slopes

Slopes in the bioretention area should be flatter than 6%. [2]

Space Required

A bioretention area requires approximately 5% of the impervious portion of its drainage area. A minimum area of 200 ft^2 (10 ft. x 20 ft.) is recommended for small sites. [2]

Water Table

A distance of 2 feet between the bottom of the bioretention basin and the seasonal high water table is recommended. If a bioretention area is installed at a potential stormwater pollutant hotspot, e.g. gas station or in karst topography, an impermeable liner should be installed to prevent runoff from potentially reaching and polluting an aquifer. [2]

In-situ Soils for No-Underdrain Design

In-situ soils should have an infiltration rate greater than 1” per hour for a no-underdrain bioretention area design. [3]

Soil Mixtures

The volumetric soil mixture for the bioretention area should consist of 85% washed sand, 3-5% organic (mulch, non-animal waste compost or peat moss) and 8-12% fines (silt and clay).

The planting soil for the bioretention soil mixture should be equivalent to loamy sand or sandy loam. Soil testing is recommended to determine fertilizer and lime needs. Proper soil fertility and pH is essential to support vigorous plant growth and to enhance pollutant removal.

Plant Materials

Plants should be tolerant of both extreme wet and dry conditions and include a mixture of evergreen and deciduous vegetation. Publications, such as the Low Impact Development Handbook for the State of Alabama [1] and Residential Rain Garden Handbook [5] by the Alabama Cooperative Extension System provide a listing of adapted species used in the region. The Alabama Cooperative Extension System specialists trained in bioretention technology can also provide plant selection guidance.

Facility Specifications

Minimum dimensions of a bioretention area are 10 feet wide by 20 feet long.
Wherever possible, sites should have a minimum length to width ratio of 2:1.
The planned ponding depth above the facility bottom should be 6 inches.
The planting soil layer should have a minimum depth of 2 feet.
Runoff should be pretreated before entering the facility by providing a grass filter strip with a gravel diaphragm (see Figures BA-2 and BA-3)
The recommended organic mulch layer is 3 inches of double shredded hardwood bark.

Stone for the diaphragm should be ASTM D 448 coarse aggregate size No. 6 or No. 57.

The underdrain system is 6-inch diameter perforated plastic pipe or tubing such as that conforming to ASTM F 405 (corrugated PE tubing) or ASTM F 758 (smooth wall PVC underdrain pipe). Perforations for PVC pipe should be 4 rows of 3/8-inch diameter holes, with holes spaced at a maximum of 6 inches along the row. Perforations should be located in the lower ½ of the pipe circumference. The minimum grade of the pipe is 0.5%. Underground pipes should be spaced at a maximum of 10 feet on center. See Figures BA-2, BA-3 and BA-4 for schematic representations of designs.

Outlet Structures

An outlet pipe should connect the underdrain system to a storm sewer outlet. When outlets empty into a drainage structure, the outlet pipe should be positioned a minimum of 6 inches above normal flow level and covered by a minimum of 18 inches of fill.

Emergency Spillway

Overflows from a bioretention area shall be diverted by an overflow structure and a stabilized overflow channel to a stable swale or other stable waterway. The inlet of the overflow system is placed in the bioretention area and is placed 6 inches above the mulch layer (see Figure BA-2). [2]

Maintenance

Bioretention areas must be kept accessible for inspection and maintenance.

Caution should be exercised during the application of fertilizers and pesticides in and around the bioretention area to prevent the possibility of surface and ground water contamination.

Landscaping

Proper attention to landscaping is vital to the performance of a bioretention area. Diversity of vegetation structure may include small trees, shrubs and herbaceous vegetation. Using combinations of small trees, shrubs or herbaceous vegetation is aesthetically pleasing and offers different levels of pollutant removal. Woody plants should not be placed near the facility inflow.

Design Procedures

Designs must be quite site-specific because of the variability in site conditions including soils, topography, use of the land in the drainage area, space for the facility and desired appearance of the facility. Because of these variables, no additional design procedures are provided. Instead, one should refer to other references[1, 2, 3] for more details.

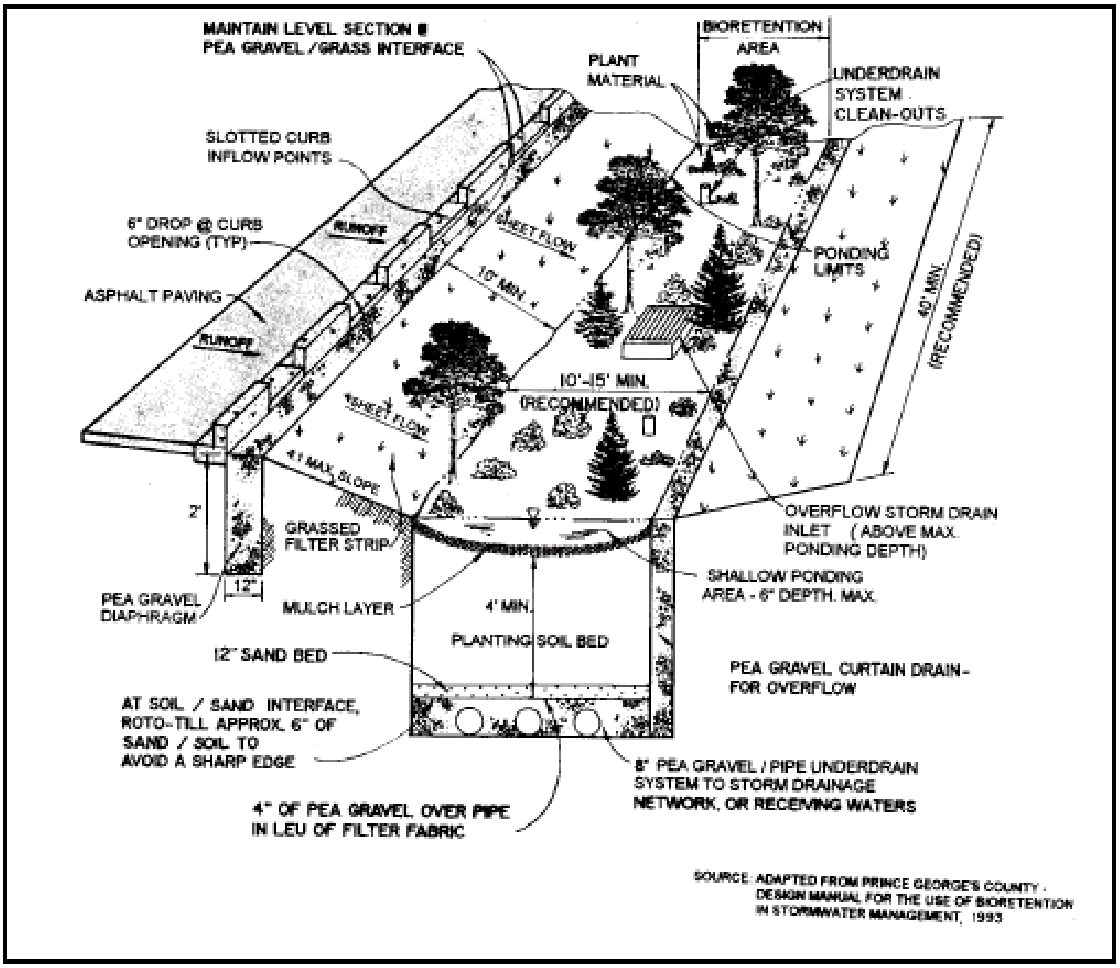


Figure BA-2 Typical Bioretention Area
(Source: Claytor and Schueler. 1996. Center for Watershed Protection.)

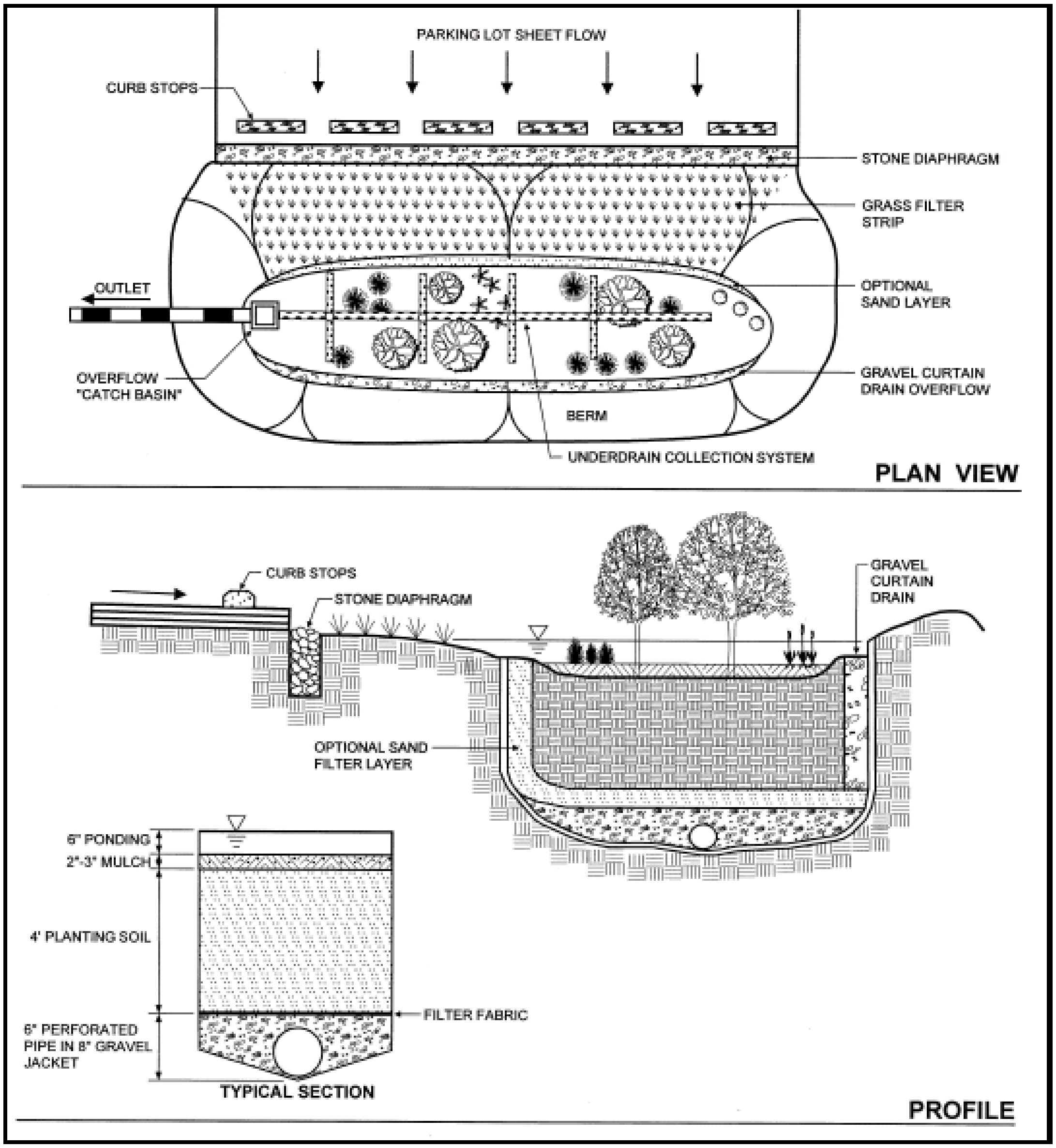


Figure BA-3 Typical On-line Bioretention Facility
(Source: Claytor and Schueler. 1996. Center for Watershed Protection.)

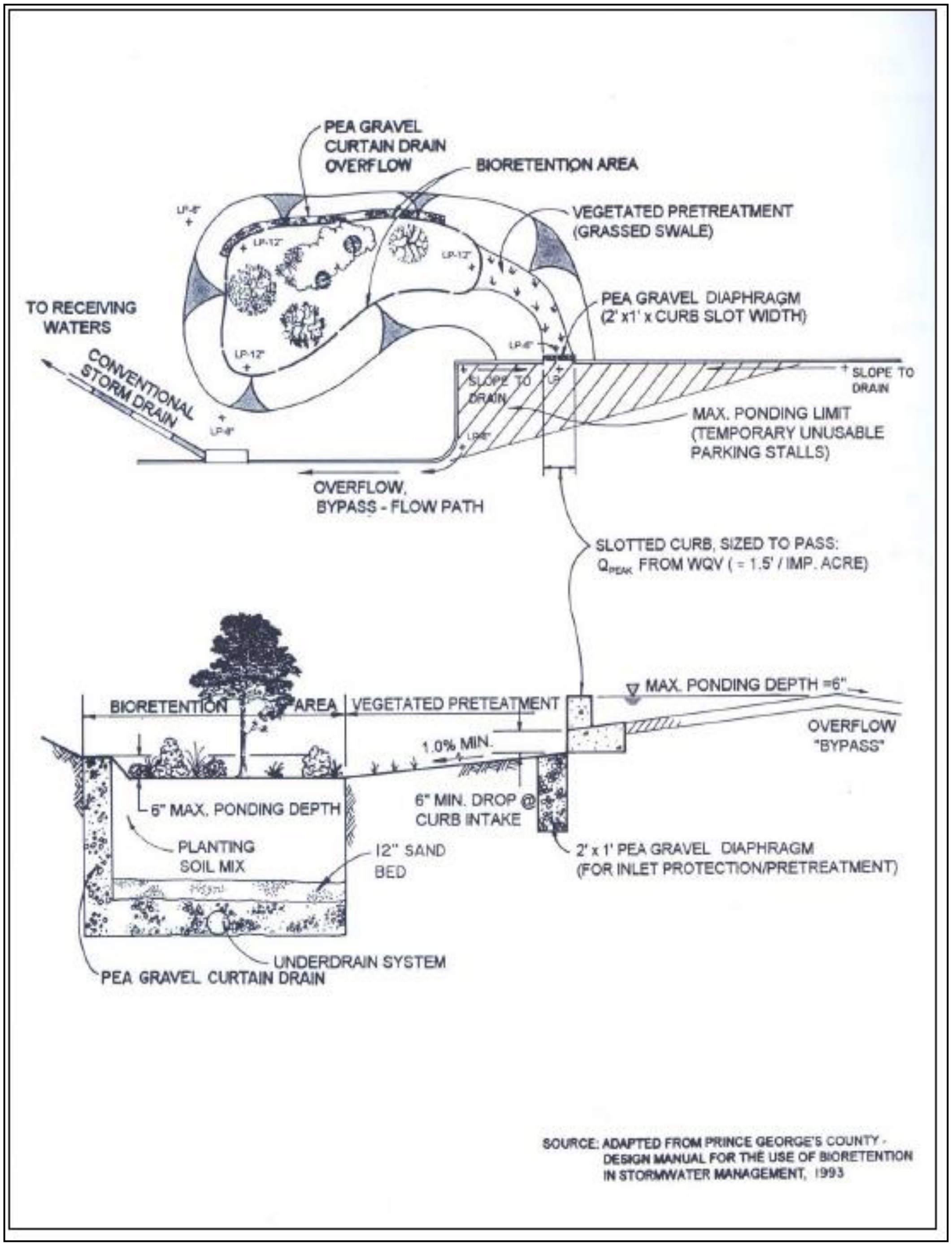


Figure BA-4 Typical Off-line Bioretention Facility
(Source: Claytor and Schueler. 1996. Center for Watershed Protection.)

References

[1] Low Impact Development Handbook for the State of Alabama. Alabama Department of Environmental Management, Alabama Cooperative Extension System and Auburn University, www.aces.edu/lid

[2] Georgia Stormwater Management Manual, Volume 2 – Technical Manual. Section 3.2.3 Bioretention Areas

[3] The Bioretention Manual. Prince George's County, Maryland

[4] Drainage-Bioretention Specifications website. Low-Impact Development Center

[5] Residential Rain Garden Handbook, Alabama Cooperative Extension System, www.aces.edu/raingarden

[6] Claytor, R. and T. Schuler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Ellicott City, MD.

This Page Intentionally Left Blank

Porous Pavement (PP)

Practice Description

Porous pavement is a permeable load-bearing layer that reduces runoff by providing infiltration, and can be underlain by a stone reservoir for stormwater storage. The practice with a stone reservoir is designed to intercept storm runoff and allow it to gradually infiltrate into the subsoil. In addition, porous pavement may provide groundwater recharge, augment low flow in streams during dry periods, reduce downstream flooding and protect water quality. The practice is applicable for areas with low traffic, such as overflow parking lots and lightly used access roads that are on relatively gentle slopes and permeable soils.

Porous pavement falls into three different categories based on the extent of storage provide by the stone reservoir: a full exfiltration system (stores the entire design storm), a partial exfiltration system (stores a portion of the design storm) and a water quality exfiltration system (provides infiltration only or stores the first flush or some portion of a design storm and conveys the excess runoff to a conventional stormwater management facility).

Concrete grids, modular pavement, or similar products will be considered as a part of this practice.

Note: Only general guidance is provided for this practice. More specific information can be obtained from the Alabama Low Impact Development (LID) Handbook.

Planning Considerations

This practice provides protection of water quality by reducing stormwater runoff through infiltration and/or storage in a buried stone reservoir. The practice is intended for areas with relatively flat slopes (less than 5%) where traffic volumes are low and the on-site soils are permeable. The practice also requires a higher degree of maintenance than normal paving materials.

When considering use of this practice the type and amount of traffic traversing the pavement must be considered. Soils and topography of the finished paving are also important. Since various levels of storage can be used, the area available for underground storage, as well as outlets for the storage area, needs to be considered in the design of the system. The seasonal high water table is an important consideration in the design of the stone storage reservoirs.

Design Criteria

Drainage Area

The drainage area contributing runoff to the stone storage reservoir should be between ¼ and 10 acres.

Slopes

Slopes in the area to receive porous paving should be flatter than 5%.

Pavement Thickness

If permeable asphalt is used the pavement thickness should be 2 to 4 inches. When using permeable concrete the thickness should be 4 to 6 inches. The thickness of concrete grids or modular pavers will be determined by the thickness of the product selected that is available from the manufacturer.

Water Table

This practice should be used in areas with deep water tables. As a minimum the seasonal high water table should be below the planned bottom of the stone storage reservoir.

Soils

Soils at the site where porous pavement is to be used should be permeable soils with combined silt/clay contents of less than 40%. Soils would generally be in NRCS hydrologic groups A, B, or C.

Stone Reservoir

The stone reservoir should be installed with a minimum of 2 feet (preferably 4 feet) of clearance between the bottom of the reservoir and bedrock. The stone reservoir should be designed so that it can be drained within 72 hours (see Figures PP-1 and PP-2).

Site Protection

Design of the porous pavement site should include measures to protect the site from being compacted by construction equipment and from erosion and sediment. Only tracked construction equipment should be used on the construction of the porous pavement subgrade. Construction traffic access routes should be routed around the site to prevent compaction by unnecessary traffic over the site. Diversions should be installed around the area to keep off-site runoff and sediment away from the site.

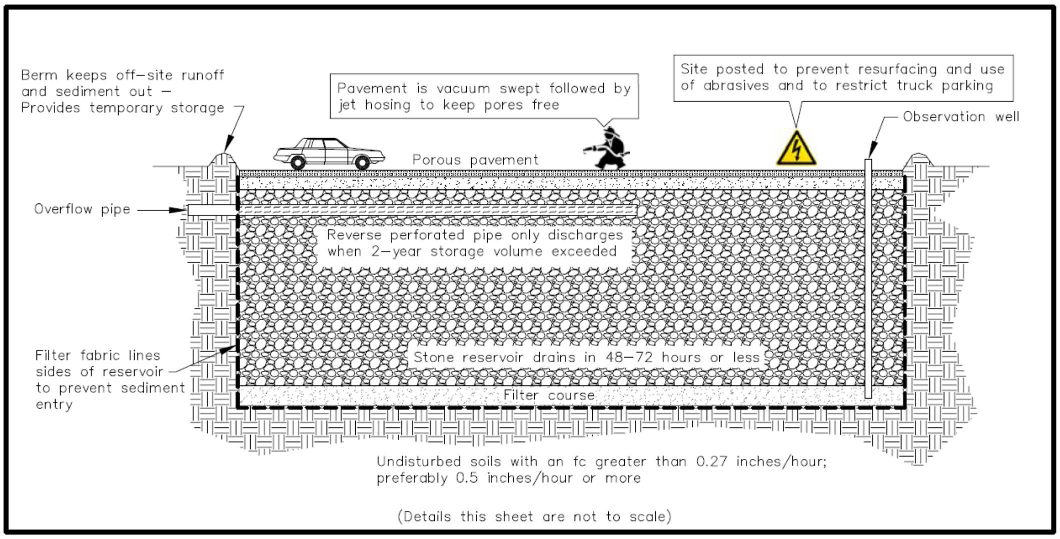


Figure PP-1 Typical Section of Porous Pavement with Buried Stone Reservoir

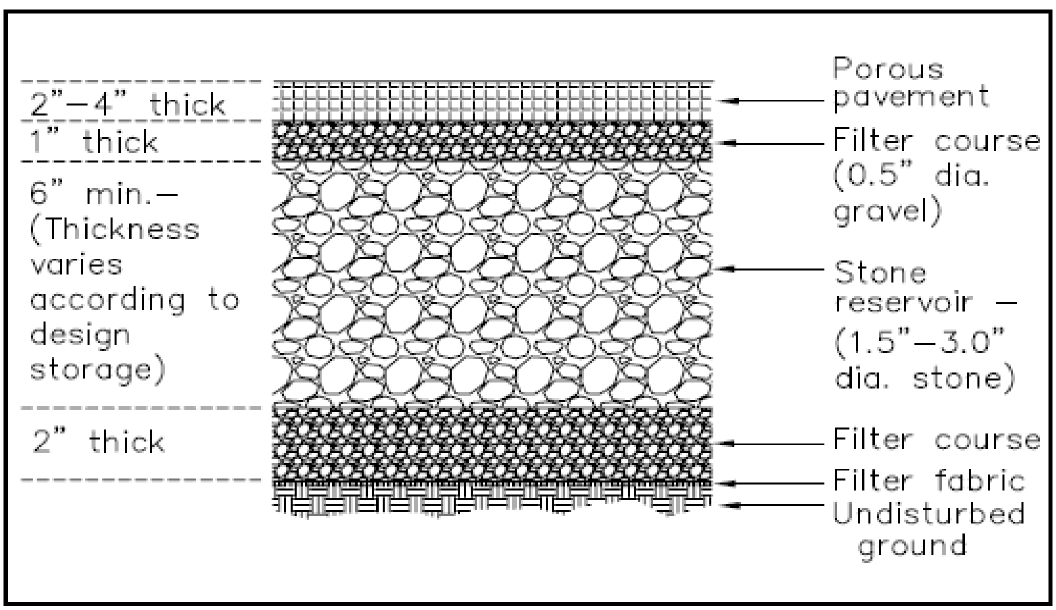


Figure PP-2 Typical Porous Pavement Design

This Page Intentionally Left Blank

Stormwater Detention Basin (SDB)

Practice Description

A stormwater detention basin is a dam-basin practice designed to hold stormwater runoff and release the water slowly to prevent downstream flooding and stream erosion. The practice is an extremely effective water quality and peak discharge reduction measure. Its usage is best suited to larger, more intensively developed sites. Structure life is 10 years or more. A stormwater detention basin can have a permanent pool of water or be designed to have a dry basin (typical). A detention basin can be designed to also serve as a sediment basin during the construction period.

Planning Considerations

The purpose of a stormwater detention basin is to intercept stormwater runoff and to protect drainageways, properties, and right-of-ways downstream of the structure. A qualified design professional engineer with expertise in hydrology and hydraulics should always design stormwater detention basins. This practice applies only to permanent basins on sites where:

- Failure of the dam will not result in loss of life; in damage to homes, commercial, or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities.
- The peak release rate of stormwater runoff from the design storm does not exceed the predevelopment runoff rate for the drainage area or the rate allowed by local ordinances, whichever is less.

- The drainage area does not exceed 50 acres. The peak flow through the principal spillway normally should not exceed 50 cfs. Structures should be designed as water impoundment structures utilizing inflow hydrographs, storage characteristics of the basin, and outflow hydrographs in the design process. Design criteria should be commensurate with the complexity of site conditions, including consideration of damages that would be caused by breaching of the embankment by overtopping.

A stormwater detention basin is appropriate where physical site conditions or land ownership restrictions preclude the installation of other stormwater measures to adequately control runoff. Where site conditions are suitable, low impact practices should be strongly considered to reduce the volume of stormwater runoff. The basin should be maintained throughout the life of the development which produced the need for the basin.

Design Criteria

Classification

Table SDB-1 shows the recommended design and classification criteria for three types of Stormwater Detention Basins.

Table SDB-1 Stormwater Detention Basin Classification

Type [1]	Max. W/S Size (acre)	Max. Dam Ht.[2] (feet)	Minimum Principal Spillway Design Storm Frequency[3]	Minimum Emergency Spillway Design Storm Frequency[3]	Freeboard [4] (feet)
1	20	7	5-yr 24-hr	10-yr 24-hr	1.0
2	20	10	5-yr 24-hr	10-yr 24-hr	1.0
3	50	15	10-yr 24-hr	25-yr 24-hr	1.0

[1] Type 1 basins may be used where site conditions prevent the construction of an emergency spillway on residual earth.
[2] Height is measured from the top of the dam to the low point on the original centerline survey of the dam.
[3] Runoff should be determined by NRCS methods or other methods accepted by local ordinances. Soil and cover conditions used should be based on those expected during the construction period.
[4] Vertical distance between basin water surface at maximum flow through the emergency spillway and top of dam.

Location

Locate the stormwater detention basin to obtain the maximum storage benefit from the terrain and for ease of cleanout of trapped sediment. It should be located to minimize interference with construction activities and construction of utilities. Whenever possible, locate detention basins out of floodplain areas and never in flowing streams. Detention basins can be an excavated basin type as well as an earthfill dam type or a combination of the two.

Entrance of Runoff into Basin

Protect the entrance points of surface runoff into the basins to prevent erosion of the basin walls. Install riprap check dams, grade stabilization structures, or other water control devices at main points of inflow to ensure direction of runoff and protect the points of entry into the basin. Locate points of entry so as to ensure maximum travel distance of runoff water through the basin to the point of exit from the basin.

Erosion and Sedimentation Control

Conduct construction operations in such a manner that erosion and sedimentation will be minimized. Comply with state and local laws concerning pollution abatement.

Safety

Stormwater detention basins should comply with any state laws related to Dam Safety.

Stormwater detention basins are attractive to children and can be very dangerous. Local ordinances and regulations must be adhered to regarding health and safety. The developer or owner should check with local building officials on applicable safety requirements. If fencing of basins is required, the location of and type of fence should be shown on the plans.

Storage

The minimum capacity of a stormwater detention basin below the crest of the principal spillway pipe should be ½ inch per acre of the potential disturbed portion of the drainage area plus the runoff volume from a 2-year frequency, 24-hour duration storm for the developed conditions.

Shape of the Basin

Design the stormwater detention basin to have a flow length to width ratio of 2:1 or greater, where flow length is the distance between the point of inflow and the point of outflow.

When the basin is used as for sediment control during construction, design the sediment storage portion of the basin to meet the requirements in the *Sediment Basin* practice.

Principal (Pipe) Spillway Design

Layout
The spillway should consist of a vertical riser joined at its bottom to a conduit (barrel) which extends through the embankment. Connections should be watertight.

Capacity
The maximum capacity of the pipe spillway should not exceed the peak rate of runoff from the drainage area in its pre-developed condition for all rainfall events up to and including the principal spillway design storm frequency. The minimum inside diameter of the barrel should be 8 inches. The diameter of the vertical inlet riser should be a minimum of 1.5 times greater than that of the barrel to ensure full barrel flow. Size the pipe to remove at least 50% of the runoff volume of the design storm within a 3 day period.

Inlet Data
The vertical inlet (riser) may be one of the following:

- A full round pipe.
- A half round pipe fitted for flashboards.
- A box-type riser fitted with flashboards.

Set the crest of the riser inlet at an elevation to provide the minimum storage requirement (runoff from a 2-year 24-hour storm for developed conditions and ½" sediment storage for the disturbed acreage). The riser should have a base (ballast) of sufficient weight to provide a 1.5:1 safety factor against flotation. Install an approved trash rack and anti-vortex device securely on top of the riser.

Anti-seep Collars
Install anti-seep collars around all conduits through earth fills according to the following criteria:

- Collars should be placed to increase the seepage length along the conduit by a minimum of 15 percent of the pipe length located within the saturation zone.
- Collar spacing should be between 5 and 14 times the vertical projection of each collar.
- All collars should be placed within the saturation zone.
- All anti-seep collars and their connection should be watertight.

A properly designed drainage diaphragm may be utilized in lieu of anti-seep collars.

Outlet
Provide protection of the barrel pipe outlet where needed to prevent outlet scour. Design outlet protection measures according to the *Outlet Protection* Standard.

Dewatering the Basin

Stormwater detention basins can serve a dual purpose as a sediment basin during construction and a stormwater detention basin after construction (See Figure SDB-1). Basins that serve only for the purpose of stormwater detention can be designed as either a dry pool (typical) or a wet pool (See Figures SDB-2 and SDB-3).

For basins designed to also serve as a sediment basin, dewatering the sediment basin volume (½" runoff for the disturbed acreage plus ½" runoff for the total drainage area) is best accomplished with a skimmer designed according to the *Sediment Basin* practice design criteria. Dewatering of the 2-year developed condition runoff above the sediment basin volume can be accomplished with a small 4 inch orifice (installed with trash protection) in the riser at the sediment storage elevation. After disturbed areas contributing runoff water to the basin have been stabilized, the skimmer dewatering device can be removed to allow the basin to operate only as a stormwater detention basin. If the purpose of the basin is to also treat the "first flush", the skimmer can be left as a permanent treatment measure. Any accumulation of sediments that would reduce stormwater detention storage should be removed and disposed of in a proper manner.

Dry basins that serve only as stormwater detention can be dewatered with a 4" orifice at the base of the riser.

Emergency spillways

Layout
Install earth emergency spillways for Type 2 and 3 basins only in undisturbed earth. Emergency spillways for Type 1 basins may be located on compacted earth fill selected for erosion resistance qualities. Other erosion control measures such as rock riprap may be required to ensure stable emergency spillways. Each spillway should have a longitudinal level section at least 25 feet long at its crest and a straight outlet section for at least 25 feet or ½ the base width of the embankment fill.

Capacity and Design

Spillways should be trapezoidal in cross section with minimum bottom widths of 10 feet and side slopes of 3:1. The elevation of the emergency spillway crest will be determined through routing procedures of the principal spillway design storm.

The capacity of the emergency spillway should be adequate to pass peak discharges of the emergency spillway design storm, taking into account the discharge through the principal spillway and the available storage. As a minimum, the designer should consider at least 0.5 foot of stage for flow through the emergency spillway. Spillways should be designed to pass designed discharges at non-erosive velocities for the types of protection used.

Embankment

The minimum top width should be 8 feet. Side slopes should be no steeper than 2½:1 (mowable surfaces should be 3:1 or flatter). On sites where relatively impermeable material (clay) is not available for a core, the downstream side slope should be increased to 4:1. Construct a keyway along the centerline of the dam. It should be at least 8 feet wide, have 1:5:1 or flatter side slopes, and should extend at least 2 feet below the normal ground surface. The core of the embankment should be at least 8 feet wide and consist of the most impermeable material available at the site. Extend this core from the bottom of the keyway to the crest of the emergency spillway.

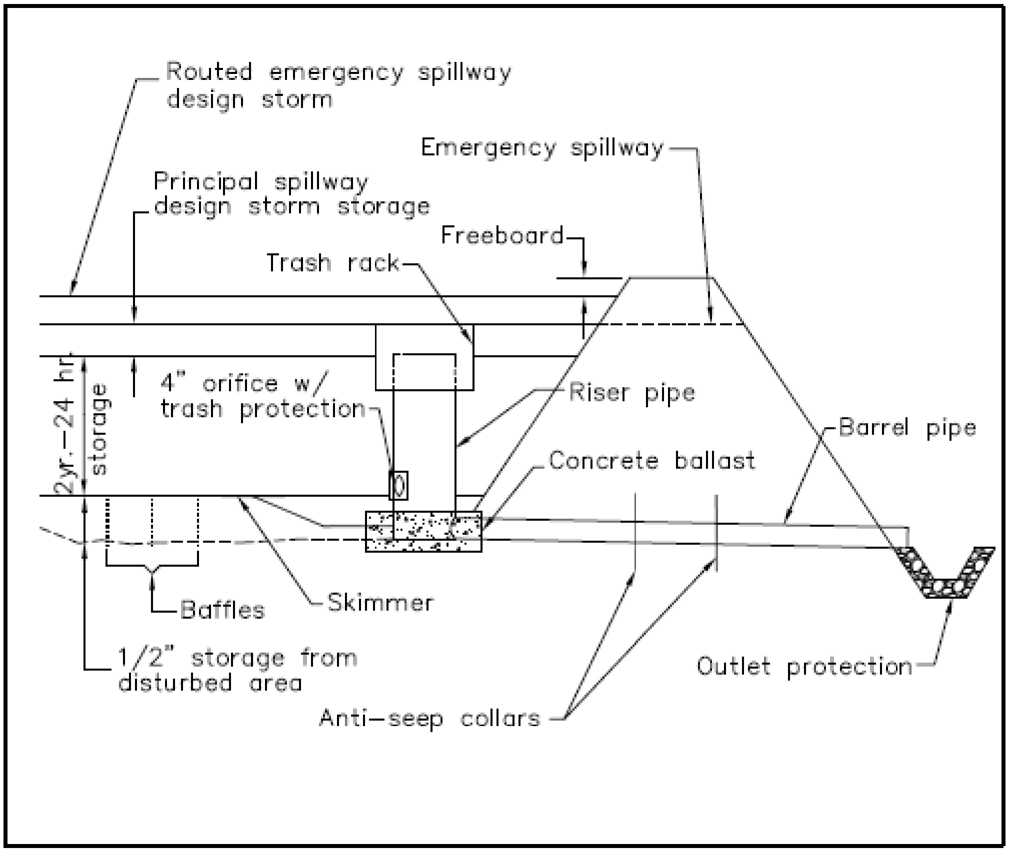


Figure SDB-1 Typical Stormwater Detention Basin / Sediment Basin Components.

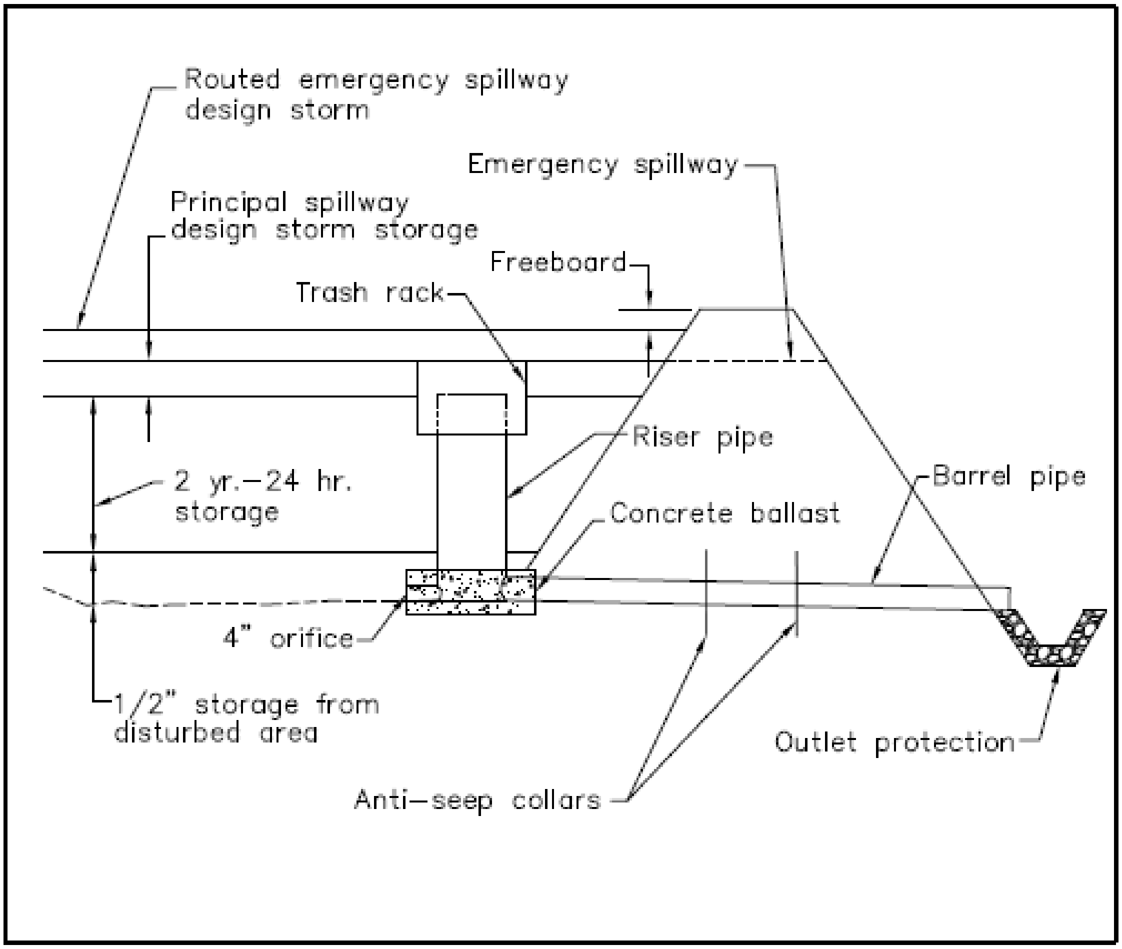


Figure SDB-2 Typical Dry Stormwater Detention Basin Components.

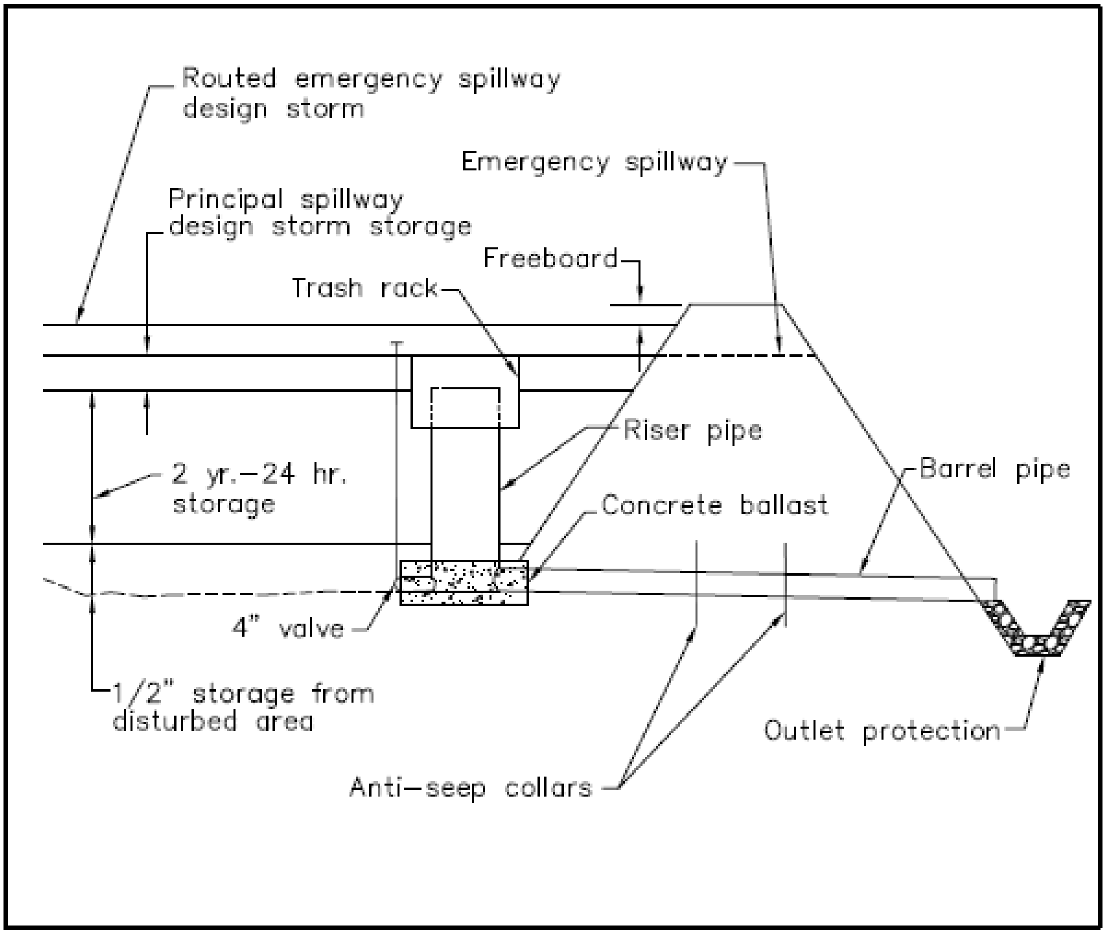


Figure SDB-3 Typical Wet Stormwater Detention Basin Components.

Buffer Zone (BZ)

Practice Description

A buffer zone is a strip of plants adjacent to land-disturbing sites or bordering streams, lakes, and wetlands which provides streambank stability, reduces scour erosion, reduces storm runoff velocities and filters sediment in stormwater. This practice applies on construction sites and other disturbed areas that can support vegetation and can be particularly effective on floodplains, next to wetlands, along streambanks and on steep, unstable slopes.

Planning Considerations

The width and plant composition of a buffer zone will determine its effectiveness.

There is no ideal width and plant community for buffer zones. A buffer zone 50 feet wide with desirable vegetation may provide significant protection of a perennial stream, water body or wetland. Adjustments can be made to account for the purpose(s) of the buffer and landscape characteristics.

Three zones are typically recognized in the buffer area. If planned to be 45 to 55 feet wide, the recommended width and plant categories are described in the following listings:

- Zone 1: the first 15 to 20 feet nearest the stream. Cover is close growing trees (commonly 6 to 10 feet apart).
- Zone 2: the next 10 to 15 feet. Cover is trees or trees and shrubs.
- Zone 3: the next 20 feet. Cover is grass or dense groundcover.

Note: All widths are for one side of the stream only and are measured from top of stream bank.

Existing vegetation should be considered for retention, especially hardwoods that are in Zones 1 and 2.

Buffer Zone 3 may be established with a grass planting or with close-growing groundcover that will provide dense cover to filter sediment. Where topography accommodates sheet flow from the adjacent landscape, Zone 3 should be retained or developed as a Filter Strip.

Necessary site preparation and planting for establishing new buffers should be done at a time and manner to insure survival and growth of selected species.

Buffer zones may become part of the overall landscape of the project.

The layout and density of the buffer should complement natural features and mimic natural riparian forests.

Design Criteria

Installation (Preservation)

Evaluate vegetation and landscape features in proposed buffer zone to determine potential for existing plant community to maintain streambank stability, prevent sheet, rill and scour erosion, reduce stormwater velocities and filter sediment.

Dedicate a vegetated zone to effectively minimize streambank and shoreline erosion, prevent sheet, rill and scour erosion in the buffer zone and remove sediment from sheet flow from the disturbed area. Initially estimate a width of 50 feet wide adjacent to the stream (each side), water body or wetland. Adjust the width to account for slope of the land adjacent to the stream and the purposes of the buffer. If the buffer is planned to trap sediment in sheet flow the width should be increased 2 feet for every 1% slope measured along a line perpendicular to the streambank and immediately downslope of the disturbed area. If the buffer is not planned to trap sediment and only bank stabilization is the purpose of the buffer only Zones 1 and 2 are required and the adjustment for slope of the adjacent land is not essential.

Installation (Plantings)

Width and Zone Requirements

Use guidance under Installation (Preservation) to determine width and zone requirements.

Site Preparation

Plan appropriate site preparation to provide a suitable planting medium for grass, or trees and shrubs.

Plan to install sediment and erosion control measures such as silt fence and diversions if zones are graded before seedbed preparation.

If significant compaction exists, plan for chiseling or subsoiling.

For Zone 3 plantings, clear area of clods, rocks, etc. that would interfere with seedbed preparation; smooth the area, to encourage sheet flow, before the soil amendments are applied and firm the soil after the soil amendments are applied. Follow guidelines in the Filter Strip practice Design Criteria if Zone 3 is to be used to filter sheet flow from the adjacent construction area.

Soil Amendments (lime and fertilizer)

Plan soil amendments using design criteria for the appropriate category (Permanent Seeding, Tree Planting on Disturbed Areas, and Shrub, Vine and Groundcover Planting). Incorporate amendments to a depth of 4” to 6” with a disk or chisel plow.

Plantings

Plan the vegetation for buffer zones using Design Criteria for Permanent Seeding, Tree Planting on Disturbed Areas, and/or Shrub, Vine and Groundcover Planting. No invasive species shall be used. If trees are planted, at least 2 hardwood species should be used.

Mulching

Plan to mulch shaped areas, and other areas that are bare using the Mulching practice Design Criteria.

This Page Intentionally Left Blank

Channel Stabilization (CS)

Practice Description

Channel stabilization is stabilizing a channel, either natural or artificial, in which water flows with a free surface. The purpose of this practice is to establish a non-erosive channel. This practice applies to the stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Methods of channel stabilization include rock riprap lining, concrete lining and grade stabilization structures.

Note: The design of open channel conveyance structures other than Grass Swale is beyond the scope of this edition of the Alabama Handbook and should be done by a qualified design professional and meet applicable state, federal and local regulatory requirements.

Planning Considerations

This practice applies to the improvement or stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Channels with drainage greater than 1 square mile will be designed with appropriate criteria. In all cases, channel stabilization design should be done by a qualified design professional experienced in hydrology and hydraulics. An adequate outlet for the channel must be available for discharge by gravity flow. Construction or other improvements to the channel should not adversely affect the environmental integrity of the area and must not cause significant erosion upstream or flooding and/or sediment deposition downstream.

The alignment and design of channels and stabilization structures shall give careful consideration to the preservation of valuable fish and wildlife habitat and trees of significant value for aesthetic purposes.

Where construction will adversely affect significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include in-stream structures such as pools, riffles, and woody structures, or streamside measures such as trees, shrubs, and other features that enhance wildlife habitat.

Due to the varied nature of these considerations an interdisciplinary team consisting of engineers, hydrologists, and wildlife biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits should be followed during the design and construction process.

Design Criteria

Realignment

The realignment of channels should be kept to an absolute minimum. Where realignment is unavoidable, the realigned channel should be designed to have a stable grade considering the soil type, vegetation, and new channel length.

Channel Capacity

The design capacity of open channels and stabilization structures should be determined by procedures applicable to the purposes to be served.

Hydraulic Requirements

Manning's formula should be used to determine velocities in channels. The "n" values for use in this formula should be estimated using currently accepted guides along with knowledge and experience regarding the conditions. Acceptable guides can be found in hydrology textbooks.

Channel Cross-Section

The required channel cross section of new or realigned channels is determined by the design capacity, the bed and bank materials, vegetation, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains and tributary channels. In order to enhance fisheries and wildlife, consider a channel cross section configuration that will ensure concentrated and unobstructed flow during periods of low flow.

Drop Structure

Drop structures are used to reduce or prevent excessive erosion by reduction of velocities in the watercourse or by providing structures that can withstand and reduce the higher velocities. They may be constructed of concrete, rock, masonry, steel, aluminum or non-toxic treated wood.

These structures are constructed where the capability of earth and vegetative measures is exceeded in the safe handling of water at permissible velocities, where excessive grades or overall conditions are encountered or where water is to be lowered structurally from one elevation to another. These structures should generally be planned and installed along with or as part of other erosion control practices. The structures must be designed hydraulically to adequately carry the channel discharge and structurally to withstand loadings imposed by the site conditions.

Channel Stability

All channel construction, improvement and modification should be in accord with a design expected to result in a stable channel which can be maintained.

Characteristics of a stable channel are:

- It neither aggrades nor degrades beyond tolerable limits.
- The channel banks do not erode to the extent that the channel cross section is changed appreciably.
- Excessive sediment bars do not develop.
- Excessive erosion does not occur around culverts, bridges or elsewhere.
- Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.
- The determination of channel stability considers “bankfull” flow.
- Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cutting through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

The design for channels in natural materials shall be considered stable if the check velocity is less than the allowable velocities shown in Table CS-l. The check velocity is defined as the lesser of the bankfull velocity or 10-year frequency peak discharge velocity.

Table CS-1 Allowable Velocities for Various Soil Textures

Soil Texture	Allowable Velocity (ft/sec.)
Sand and Sandy Loam (noncolloidal)	2.5
Silt Loam (also high lime clay)	3.0
Sandy Clay Loam	3.5
Clay Loam	4.0
Stiff Clay, Fine Gravel, Graded Loam to Gravel	5.0
Graded Silt to Cobbles (colloidal)	5.5
Shale, Hardpan and Coarse Gravel	6.0

Channel Linings and Structural Measures

Where channel velocities exceed safe velocities for bare soil, channel linings of rock, concrete or other durable material may be needed. Grade stabilization structures may also be needed.

Use one or more of the following methods to stabilize channels:

Rock Riprap Lining

Rock riprap should be designed to resist displacement when the channel is flowing at the bankfull discharge or the 10-year 24-hour frequency discharge whichever is the lesser. Rock riprap lining should not be used when channel velocities exceed 10 feet per second unless a detailed engineering analysis is performed using appropriate guidelines.

Use Figure CS-1 to determine the stable basic stone weight (d_{100}). Using the d_{100} size as a d_{90}, select a commercially available riprap gradation as classified by the Alabama Department of Transportation, from Table CS-2.

Dumped and machine placed riprap should be installed on slopes flatter than 2 horizontal to 1 vertical. Where riprap is placed by hand the slopes may be steeper. Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

A filter blanket should be placed between the riprap and base material, if needed. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. A filter blanket should be considered where soils have a high piping potential and/or there is significant seepage of groundwater from the bed or banks.

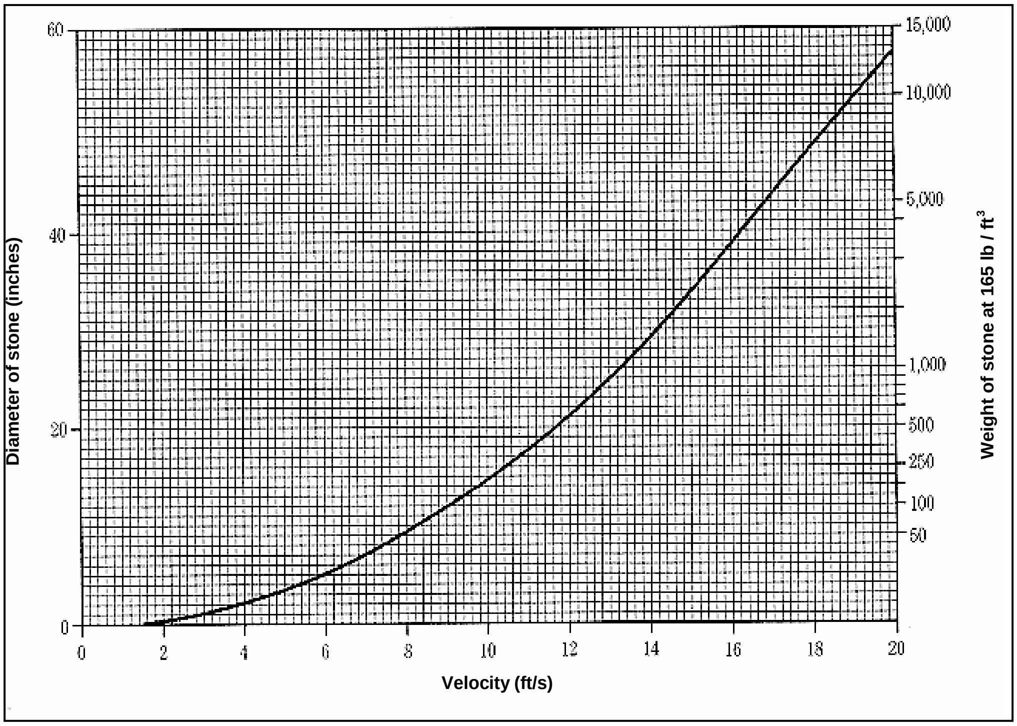


Figure CS-1 Ishbash Curve

1) Determine the design velocity.
2) Use design velocity and Figure CS-1 to determine d_{100} rock size.
3) Use d_{100} from Figure CS-1 as d_{90} to select rock gradation from Table CS-2.

Table CS-2 Commercially Available Riprap Gradations

Class	**Weight (lbs.)**					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

A filter blanket can be of 2 general forms: a gravel layer or a geotextile filter cloth. Gravel filter blankets are to be designed in accordance with the criteria below.

The following relationships must exist:

$$\frac{d_{15}\text{ filter}}{d_{85}\text{ base}} < 5 < \frac{d_{15}\text{ filter}}{d_{15}\text{ base}} < 40$$

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

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6” thick.

Non-woven geotextile filter cloth may be used in place of or in conjunction with gravel filters where appropriate as a separator between rock and soil to prevent migration of soil particles from the subgrade, through the lining material. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Concrete Lining

Concrete linings should be designed according to currently accepted guides for structural and hydraulic adequacy. They must be designed to carry the required discharge and to withstand the loading imposed by site conditions. Concrete linings are generally used when velocities exceed 10 ft/sec. Erosion at the outlet of concrete lined channels is generally a problem due to the high velocities. Measures should be taken to reduce the velocity and erosion potential at the outlet by use of outlet protection measures (see Outlet Protection practice).

Stream Diversion Channel (SDC)

Practice Description

A stream diversion channel is a temporary practice to convey stream flow in an environmentally safe manner around or through a construction site while a permanent structure or conveyance is being installed in the stream channel.

Planning Considerations

Construction projects often cross and impact live streams creating a potential for excessive sediment delivery into the stream. In cases where in-stream work is unavoidable, a temporary stream diversion channel should be planned. In-stream projects of this nature are subject to the rules and regulations of the U. S. Army Corps of Engineers for in-stream modifications (Clean Water Act Section 404 permit) and if applicable, ADEM CWA Section 401 water quality certification. Temporary stream diversions shall be used only on streams with a drainage area less than 1 square mile (640 acres). Detailed engineering analysis and design should be used for larger drainage areas to ensure a stable diversion channel. For sites with very small drainage areas, the designer may consider temporary blocking and overland pumping of the stream. In order to avoid crossing a live stream, the planner or designer should consider only allowing access for the construction of the permanent structure from the side opposite the stream diversion channel. At locations where access from both sides of the stream is required to construct the permanent structure in the stream channel, a Temporary Stream Crossing (TSC) may be necessary. It is best to locate this crossing either up or downstream of the stream diversion channel.

Vegetation along the existing stream channel should be left undisturbed and protected with effective sediment control practices until such time as the diversion channel is constructed and can safely convey stream flows. Construction equipment should not be allowed to operate in flowing waters and are to be operated and maintained according to the Groundskeeping (GK) practice. Excavated materials should be stockpiled away from the stream and diversion channel and protected to ensure the material does not erode and enter the stream system. The stream diversion channel should be planned and installed in such a manner and time (dry season) that the impact to fisheries and the aquatic environment is minimized. A pictorial representation of a stream diversion channel is shown in Figure SDC-1.

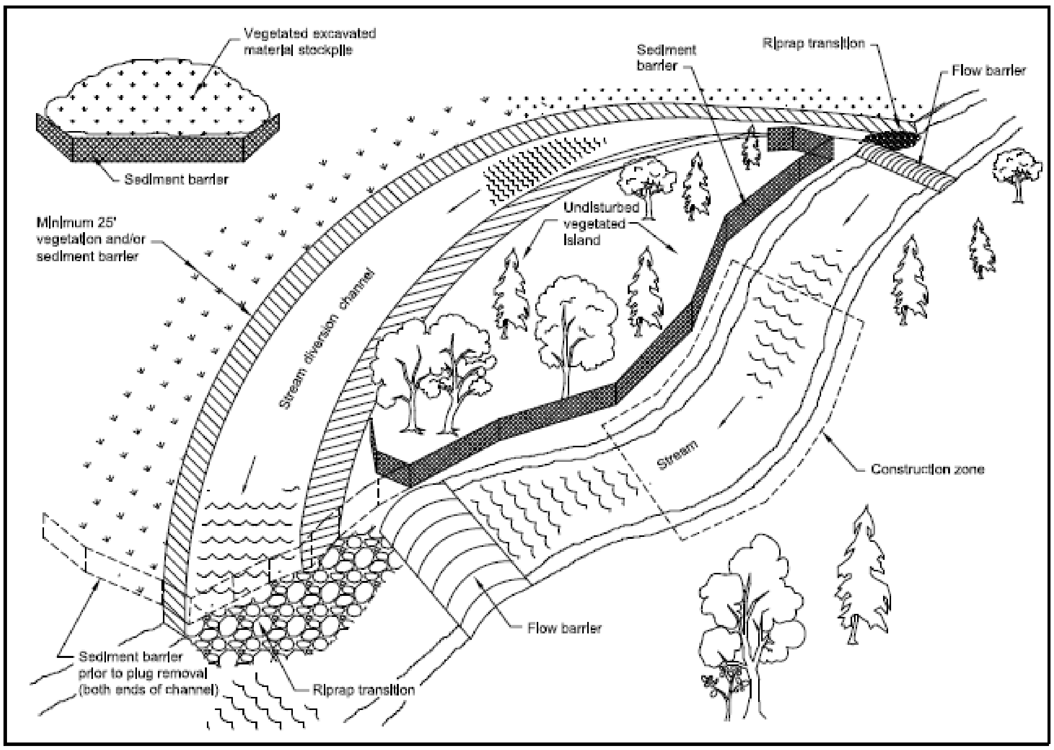


Figure SDC-1 Typical Stream Diversion Channel Layout

Design Criteria

Size

The combination of bottom width, depth, and gradient shall be sufficient to provide the required flow capacity. The minimum bottom width of the stream diversion channel shall be six feet or equal to the bottom width of the existing streambed, whichever is greater. The bottom surface should be shaped or configured to ensure adequate concentrated and unobstructed flow of water during periods of low flow.

Side Slope

Side slopes of the stream diversion channel shall be no steeper than 2 horizontal to 1 vertical (2:1).

Gradient

The diversion bottom grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion at velocities not exceeding the allowable velocities for the selected channel lining material. The stream diversion channel length should be the same or greater than the length of the stream diverted.

Capacity

The capacity of the stream diversion channel shall be at least bankfull capacity of the existing stream. Consideration should be given to providing greater capacity where construction is expected to extend over several weeks or months.

Channel Lining

The stream diversion channel shall be lined to prevent erosion of the channel and sedimentation in the stream. The lining should be selected based on the velocity at bankfull flow. Use Table SDC-1 for general guidance on the type of lining to be used. Pre-manufactured products like turf reinforcement mats (TRM), cellular blocks, and other similar products shall be designed and installed according to the manufacturer's recommendations.

Table SDC-1 Stream Diversion Channel Linings

Lining Materials	Acceptable Velocity Range
Geotextile fabric, polyethylene film, light weight TRM, block sod	0 – 2.5 fps
Geotextile fabric, heavy weight TRM,	2.5 – 9.0 fps
Class I Riprap and Geotextile, flexible concrete lining	9.0 – 13.0 fps

Riprap linings shall be designed in accordance with the guidance contained in the Channel Stabilization (CS) practice. Class I non-woven geotextile shall be used underneath riprap lining for high velocity applications.

When rolled products like polyethylene film or geotextile fabric are used as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes while also providing enough material for a minimum 6 inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top of bank to top of bank with additional trench anchorages of at least 1 ft. x 1 ft. at 50 foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet and occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and be capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Block sod shall be covered with erosion control netting and staked at minimal 3 ft. x 3 ft. spacing, and staked at the upstream edge of each piece of sod.

Transitions

Additional protection such as riprap may be needed at the entrance and exit portion of the stream diversion channel to ensure velocities do not scour the existing stream bed or bank.

Sequence of Construction

In order to minimize detrimental effects to the environment and the aquatic community, the stream diversion channel should be quickly and carefully installed, well maintained, and removed as soon as possible when the construction area is stable. A sequence of construction should be specified in the contract work. While the sequence of construction should be tailored to the specific site, the general process should be as follows:

- Install sediment barrier at locations alongside stream to intercept runoff from the construction of the stream diversion channel.
- Install sediment barrier around or downstream of stockpile location.
- Maintain vegetation around stream.
- Clear downstream portion of stream diversion channel except for the area of the temporary plug.
- Begin excavation of the stream diversion channel at least 25 ft. from the outlet and maintain this undisturbed plug.
- Stockpile excavated material at designated location and clear additional portions of the stream diversion channel as needed for excavation operations.
- Complete the excavation and leave at least a 25 ft. undisturbed plug at the entrance to the stream diversion channel.
- Dewater the excavated area as needed for installation of the lining and pump the dewatered material to a settling basin before any discharge is allowed.
- Install the lining in diversion channel.

- Excavate the downstream plug and install the transition riprap.
- Adjust sediment barrier locations as needed for stream protection.
- Excavate the upstream plug and install the transition riprap.
- Install an upstream flow barrier, forcing flow into the diversion channel.
- Allow time for aquatic organisms to move or migrate downstream.
- Install a downstream flow barrier if needed.
- Seed and mulch the stockpile and the disturbed area around the stream diversion channel.
- Complete the “in-stream” work.
- Divert flow into the completed “in-stream” conveyance system.
- Place sediment barriers for protection while decommissioning the stream diversion channel.
- Remove channel linings as needed, recycle or properly dispose of the material.
- Place excavated material into diversion channel
- Apply seed and mulch to disturbed areas.

This Page Intentionally Left Blank

Streambank Protection (SP)

Practice Description

Streambank protection is the stabilization of the side slopes of a stream. Streambank protection can be vegetative, structural or a combined method (bioengineering) where live plant materials are incorporated into a structure. Vegetative protection is the least costly and the most compatible with natural stream characteristics. Additional protection is required when hydrologic conditions have been greatly altered and stream velocities are excessively high. Streambank protection is often necessary in areas where development has occurred in the upstream watershed and full channel flow occurs several times a year.

Planning Considerations

Since there are several different methods of streambank protection the first step in the design process is a determination of the type protection to be used at the site. Items to consider include:

- Overall condition of the stream within and adjacent to the reach to be stabilized
- Current and future watershed conditions
- Amount of discharge at the site
- Flow velocity at the site
- Sediment load in the stream
- Channel slope
- Controls for bottom scour
- Soil conditions

- Present and anticipated channel roughness
- Compatibility of selected protection with other improvements at the site
- Changes in channel alignment
- Fish and wildlife habitat

Due to the varied nature of these considerations an interdisciplinary team consisting of engineers, hydrologists, and wildlife biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits should be followed during the design and construction process.

Design Criteria

Velocities

Use vegetation alone with velocities up to 6 ft/sec if the stream bottom is stable. Use structural protection for velocities greater than 6 ft/sec. The design velocity should be the velocity associated with the peak discharge of the design storm for the channel.

Channel Bottom

The channel bottom must be stabilized before installing bank protection. Grade control in the channel bottom may be needed to prevent downcutting (see Channel Stabilization practice).

Permits

All local, state, and federal laws should be complied with during the design and construction of bank protection. If fill is to be placed in wetlands or streams the Army Corps of Engineers should be contacted regarding a 404 permit for the work.

Vegetative Protection

This practice should be used only when velocities are less than 6 ft/sec. The design team should consider the natural zones of a streambank community when selecting vegetation for use in the protection design. Native plant materials should be used for establishment and long term success. No exotic or invasive species should be used.

Aquatic Zone

This area includes the stream bed and is normally submerged at all times (See Figure SP-1). No planting is required in this zone.

Shrub Zone

This zone is on the bank slopes above mean water level and is normally dry except during floods. Plants with high root densities, high root shear and tensile strength, and an ability to transpire water at high rates are recommended for this zone. Willows, silver maples, and poplars are examples of species to use here.

Normally, grasses are not used in this area, but they can be if velocities are low and the grass will not be submerged frequently or for long periods of time.

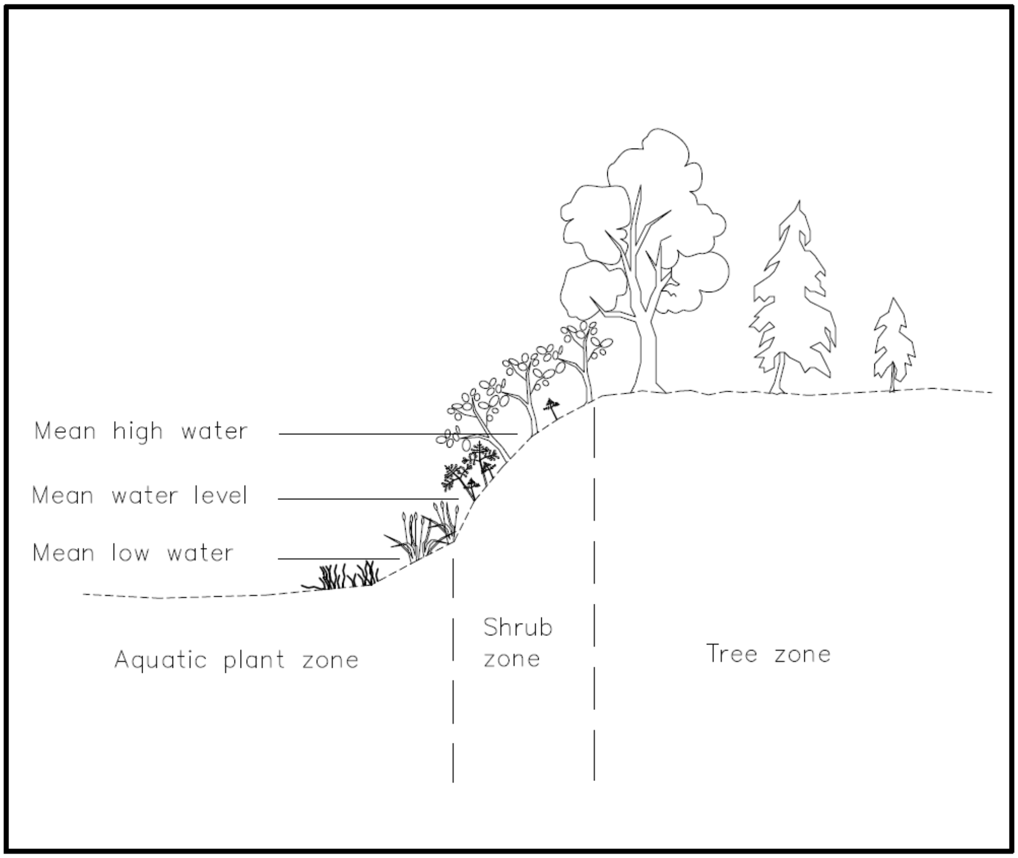


Figure SP-1 Vegetative Zones for Streambank Protection

Tree Zone

This area is at the top of the streambank. Plants in this area usually provide shade for the stream and riparian habitat for wildlife. Upland species should be planted in this location.

Structural Protection

Structural protection is used in areas where velocities exceed 6 feet per second, along channel bends, in areas with highly erodible soils and in areas of steep channel slopes. Common measures are riprap, gabions, fabric-formed revetments and reinforced concrete.

Riprap

This is the most commonly used material for streambank protection. The following criteria should be used when designing riprap bank protection:

- Riprap should be designed to be stable under the design flow conditions using the following procedure:

  1) Determine the design velocity.
  2) Use velocity and figure SP-2 to determine d_{100} rock size.
  3) Use d_{100} from Figure SP-2 as d_{90} to select rock gradation from Table SP-1.

- Streambanks should be sloped at 2:1 or flatter.

- Where needed to prevent movement of soil from the channel bank into the riprap, place a geotextile filter fabric between the soil and riprap. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

- The toe of the riprap should extend a minimum of 1 foot below the stream channel bottom or anticipated scour depth to prevent failure of the riprap protection.

- The top of the riprap should extend up to the 2-year water surface elevation as a minimum unless it is determined that a lesser height in combination with vegetative measures will provide the needed protection. The remainder of the bank above the riprap can be vegetated.

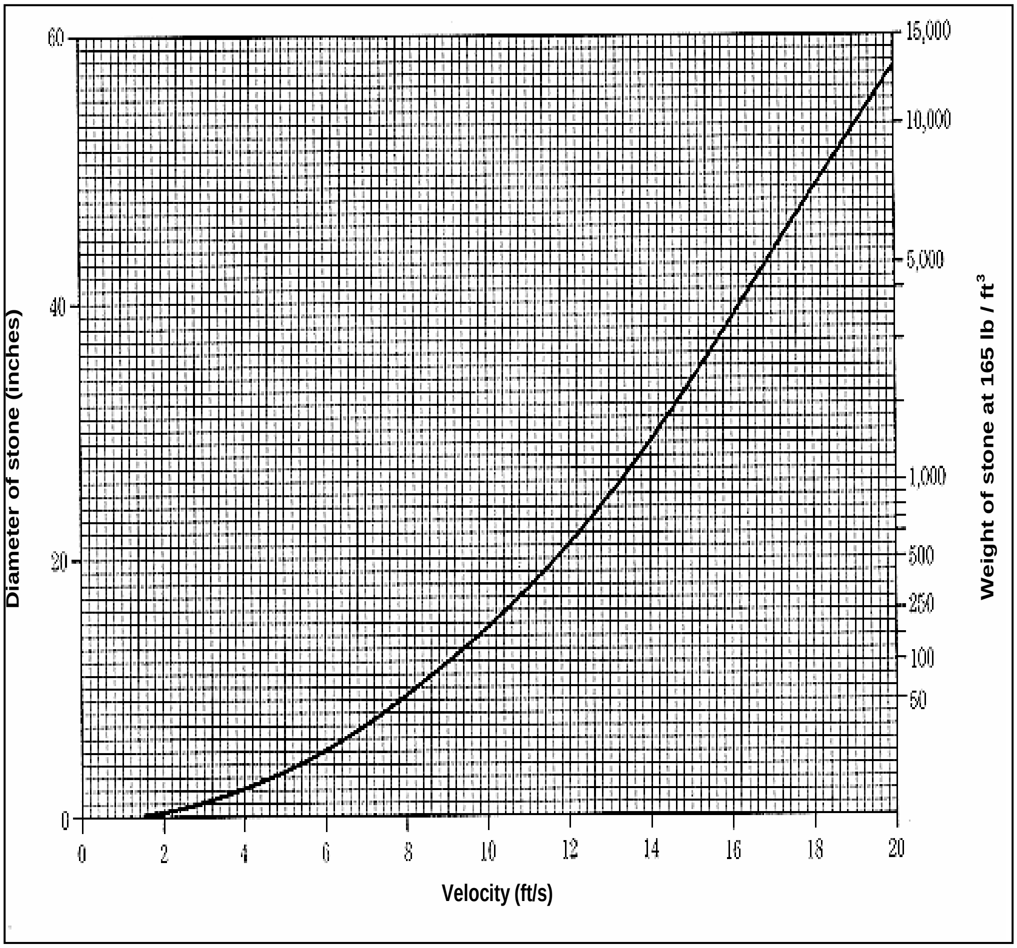


Figure SP-2 Isbash Curve

Table SP-1 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Gabions

These rock-filled wire baskets are very labor intensive to construct, but they are semi-flexible and permeable. Gabions should be designed and constructed according to manufacturer's guidelines and recommendations. They should be filled with durable rock. If needed, a filter fabric can be used between the gabions and the soil subgrade. Fabric will be selected from the table for geotextiles shown above.

Fabric-Formed Revetments

These are manufactured, large, quilted envelopes that can be sewn or zipped together at the site to form continuous coverage of the area to be protected. Once the fabric is in place, it is pumped full of grout to form a solid, hard and semi-impervious cover. Revetments should be designed and installed according to manufacturer's recommendations.

Reinforced Concrete

A qualified design professional using sound and accepted engineering procedures should design this protection method. The design should include a solid foundation for the retaining wall and a method of draining excess water from behind the wall.

All structural protection methods should begin and end along stable reaches of the stream.

Combined Methods of Protection

Combinations of vegetative and structural protection can be used in any area where a structural measure would be used. Common measures include cellular matrix confinement systems, grid pavers, and bioengineering techniques. As with structural measures all combined methods should begin and end along stable reaches of the stream.

Cellular Confinement Matrices

These are commercially available products made of heavy-duty polyethylene formed into a honeycomb type matrix. The product is flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel or cement. Where soil is used to fill the combs vegetation may also be established. These systems should be designed and installed according to manufacturer's recommendations.

Grid Pavers

These are modular concrete units with interspaced voids. They are used to armor the bank and provide an area for vegetation as well. Pavers come in a variety of shapes and sizes with various anchoring methods. They should be designed and installed according to manufacturer's recommendations.

Soil Bioengineering

This method uses live, woody vegetative cuttings to increase slope stability. It can either be a woody vegetation system alone or woody vegetation combined with simple inert structures. It is especially useful in areas with minimal access or environmentally sensitive areas. Following are some general requirements for this method:

Plant Species

Use native species that root easily such as willow and are suitable for the intended use and adapted to site conditions. Plants are usually harvested from a nearby local area.

Cutting Size

Normally ½" to 2" in diameter and from 2 to 6 feet long (length will depend on project requirements).

Harvesting

Cut plant materials at a blunt angle, 8" to 10" from the ground, leaving enough trunk so that cut plants will regrow.

Transportation and Handling

Bundle cuttings together on harvest site, removing side branches. Keep material moist. Handle carefully during loading and unloading to prevent damage. Cover to protect cuttings from drying out.

Installation Timing

Deliver to construction site within 8 hours of harvest and install immediately, especially when temperatures are above 50º F. Store up to 2 days if cuttings are submerged, "heeled in" moist soil, shaded and protected from wind.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids and maintain good branch cutting-to-soil contact.

Woody Protective Vegetation

Live staking, live fascines, brushlayers and branchpacking are soil bioengineering practices that use the stems or branches of living plants as a soil reinforcing and stabilizing material. Eventually the vegetation becomes a major structural component of the bioengineered system.

Live Staking

Live staking is the use of live, rootable vegetative cuttings, inserted and tamped into the ground. As the stakes grow, they create a living root mat that stabilizes the soil. Use live stakes to peg down surface erosion control materials. Most native willow species root rapidly and can be used to repair small earth slips and slumps in wet areas.

To prepare live material, cleanly remove side branches, leaving the bark intact. Use cuttings ½" to 1½" in diameter and 2 to 3 feet long. Cut bottom ends at an angle to insert into soil. Cut top square. Tamp the live stake into the ground at right angles to the slope, starting at any point on the slope face. Buds should point up. Install stakes 2 to 3 feet apart using triangular spacing with from 2 to 4 stakes per square yard. An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand). Four-fifths of the live stake should be underground with soil packed firmly around it after installation. Replace stakes that split during installation.

Live Fascines

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. They should be placed in shallow contour trenches and at an angle on wet slopes to reduce erosion and shallow face sliding. This practice is suited to steep, rocky slopes, where digging is difficult.

To prepare live materials, make cuttings from species such as young willows or shrub dogwoods that root easily and have long, straight branches. Make stakes 2 ½ feet long for cut slopes and 3 feet long for fill slopes. Make bundles of varying lengths from 5 to 30 feet or longer, depending on site conditions and limitations in handling. Use untreated twine for bundling. Completed bundles should be 6" to 8" in diameter. Orient growing tips in the same direction. Stagger cuttings so that root ends are evenly distributed throughout the length of the bundle. Install live fascine bundles the same day they are prepared. Prepare dead stakes 2 ½ feet long, untreated 2" by 4" lumber, cut diagonally lengthwise to make 2 stakes. Live stakes will also work. Beginning at the base of the slope, dig a trench on the contour large enough to contain the live fascine. Vary width of trench from 12" to 18", depending on angle of the slope. Trench depth will be 6" to 8", depending on size of the bundle. Place the live fascine into the trench. Drive the dead stakes directly through the bundle every 2 to 3 feet. Use extra stakes at connections or bundle overlap. Leave the top of the stakes flush with the bundle. Install live stakes on the downslope side of the bundle between the dead stakes.

Brushlayer

Brushlayering is similar to live fascine systems. Both involve placing live branch cuttings on slopes. However, in brushlayering, the cuttings are oriented at right angles to the slope contour. Use on slopes up to 2:1 in steepness and not over 15 feet in vertical height.

Starting at the toe of the slope, excavate benches horizontally, on the contour, or angled slightly down the slope to aid drainage. Construct benches 2 to 3 feet wide. Slope each bench so that the outside edge is higher than the inside.

Crisscross or overlap live branch cuttings on each bench. Place growing tips toward the outside of the bench. Place backfill on top of the root ends and compact to eliminate air spaces. Growing tips should extend slightly beyond the fill to filter sediment. Soil for backfill can be obtained from excavating the bench above. Space brushlayer rows 3 to 5 feet apart, depending upon the slope angle and stability.

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (no greater than 4 feet deep or 5 feet wide). Use for earth reinforcement and mass stability of small earthen fill sites.

Make live branch cuttings from ½” to 2” in diameter and long enough to reach from soil at the back of the trench to extend slightly from the front of the rebuilt slope face.

Make wooden stakes 5 to 8 feet long from 2” by 4” lumber or 3” to 4” diameter poles. Start at the lowest point and drive wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1½ feet apart. Place a layer of living branches 4” to 6” thick in the bottom of the hole, between the vertical stakes, and at right angles to the slope face. Place live branches in a crisscross arrangement with the growing tips oriented toward the slope face. Some of the root ends of the branches should touch the back of the hole. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the branch cuttings. The final installation should match the existing slope. Branches should protrude only slightly from the rebuilt slope face.

The soil should be moist or moistened to ensure that live branches do not dry out.

Woody Vegetation with Inert Structures

Live cribwalls, vegetated rock gabions and joint plantings are soil bioengineering practices that combine a porous structure with vegetative cuttings. The structures provide immediate erosion, sliding and washout protection. As the vegetation becomes established, the structural elements become less important.

Live Cribwall

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber. Use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness or where space is limited and a more vertical structure is required. It should be tilted back if the system is built on a smooth, evenly sloped surface.

Make live branch cuttings ½” to 2” in diameter and long enough to reach the back of the wooden crib structure. Build constructed crib of logs or timbers from 4” to 6” in diameter or width. The length will vary with the size of the crib structure. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability. Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour. Place the next set of logs or timbers at right angles to the slope on top of the previous set. Place each set of timbers in the same manner and nail to the preceding set. Place live branch cuttings on each set to the top of the cribwall structure with growing tips oriented toward the slope face. Backfill the cribwall, compact the soil for good root-to-soil contact, then apply seed and mulch.

Vegetated Rock Gabions

Vegetated gabions combine layers of live branches and gabions (rectangular baskets filled with rock). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Use where space is limited and a more vertical structure is required. Overall height, including the footing, should be less than 5 feet.

Make live branch cuttings from ½” to 1” in diameter and long enough to reach beyond the rock basket structure into the backfill. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting. Place the wire baskets in the bottom of the excavation and fill with rock. Backfill between and behind the wire baskets. Place live branch cuttings on the wire baskets at right angles to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it. Repeat the construction sequence until the structure reaches the required height.

Joint Planting

Joint planting or vegetated riprap involves tamping live cuttings into soil between the joints or open spaces in rocks that have previously been placed on a slope. Use where rock riprap is required. Joint planting is used to remove soil moisture, to prevent soil from washing out below the rock and to increase slope stability over riprap alone.

Make live branch cuttings from ½” to 1½” in diameter and long enough to extend into soil below the rock surface. Remove side branches from cuttings leaving the bark intact. Tamp live branch cuttings into the openings of the rock during or after construction. The root ends should extend into the soil behind the riprap. Mechanical probes may be needed to create pilot holes for the live cuttings. Place cuttings at right angles to the slope with growing tips protruding from the finished face of the rock.

This Page Intentionally Left Blank

Temporary Stream Crossing (TSC)

Photo courtesy of Steve Taylor, Auburn University Biosystems Engineering

Practice Description

A temporary stream crossing is a short term road crossing constructed over a stream for use by construction traffic to prevent turbidity and streambed disturbance caused by traffic. A temporary stream crossing can be a low water crossing, a culvert crossing, or a bridge with or without embankment approaches. Temporary stream crossings are applicable on construction sites where traffic must cross steams during construction.

Planning Considerations

A stream crossing can be an open ford, a pipe (culvert), or bridge crossing. Stream crossings can be a useful practice to provide a means for construction traffic to cross flowing streams without damaging the channel or banks or causing flooding, and to keep sediment generated by construction traffic out of the stream. Stream crossings are generally applicable to flowing streams with drainage areas less than 1 square mile. A qualified design professional should design permanent structures to handle flow from larger drainage areas.

Careful planning can minimize the need for stream crossings and the qualified design professional should always 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 are a direct source of water pollution; they may create flooding and safety hazards; they can be expensive to construct; and they cause costly construction delays if damaged by flooding.

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. However, these structures are also undesirable in that they could cause a channel constriction, which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

Fords made of stabilizing material such as rock are often used in steep areas subject to flash flooding, where normal flow is shallow (less than 3") or intermittent. Fords should only be used where crossings are infrequent. Fords are especially adapted for crossing wide, shallow watercourses. Generally do not use fords where bank height exceeds 5 ft. Rock material used for the ford may be washed out during large storm events and require the rock to be replaced. Mud and other contaminants are brought into the stream on vehicles using ford crossings unless crossings are limited to no flow conditions.

The criteria contained in this practice pertains primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the qualified design professional must also be sure that the structure is capable of withstanding the expected loads from heavy construction equipment. The qualified design professional must also be aware that such structures are subject to the rules and regulations of the U. S. Army Corps of Engineers for in-stream modifications (404 permits).

Design Criteria

Culvert Crossings or Spans (Bridges)

The structure should be large enough to convey the flow expected from a 2-year frequency, 24-hour duration storm without appreciably altering the stream flow characteristics. The structure may be a span or culvert. If culverts are used, see Table TSC-1 for aid in selecting the appropriate size. (Multiple culverts may be used in place of 1 large culvert if they have the equivalent capacity of the larger one). The minimum-sized culvert that may be used is 18".

Where culverts are installed (Figure TSC-1), compacted soil will be used to form the crossing. The depth of soil cover over the culvert should be equal to ½ the diameter of the culvert or 24", whichever is greater. To protect the sides of the fill from erosion, riprap shall be used and designed in accordance with the practice Outlet Protection.

The length of the culvert should be adequate to extend the full width of the crossing, including side slopes.

The grade of the culvert pipe should be at least 0.25" per foot.

Table TSC-1 Culvert Selection Guide (pipe, diameter, inches)

Drainage Area (Acres)	**Average Slope of Watershed**			
	1%	4%	8%	16%
1-25	30	30	36	36
26-50	30	36	42	48
51-100	36	48	48	54
101-150	42	48	60	60
151-200	42	54	72	72
201-250	48	60	72	72
251-300	48	60	72	72
301-350	48	60	72	2X60
351-400	54	72	2X60	2X60
401-450	54	72	2X60	2X60
451-500	54	72	2X60	2X72
501-550	60	72	2X60	2X72
551-600	60	72	2X60	2X72
601-640	60	72	2X60	2X72

Assumptions for determining USDA-NRCS Peak Discharge Method; CN=70; Rainfall depth (average for Alabama) = 4.3” for 2-year/24-hour storm; No tailwater exists; and the depth of water at the inlet invert is 1.5 X diameter.

The top of the compacted fill should be covered with 6” of Alabama Highway Department course aggregate No.1 stone (3/4” to 4”).

The approaches to the structure should consist of stone pads meeting the following specifications:

- Stone: Alabama Highway Department course aggregate No.1.
- Minimum thickness: 6”.
- Minimum width: equal to the width of the structure.
- Minimum approach lengths: 25 feet.

Culvert crossings and spans should be designed with features that will prevent damage, destruction or removal during major flood events (i.e. cabling, emergency bypass, etc.).

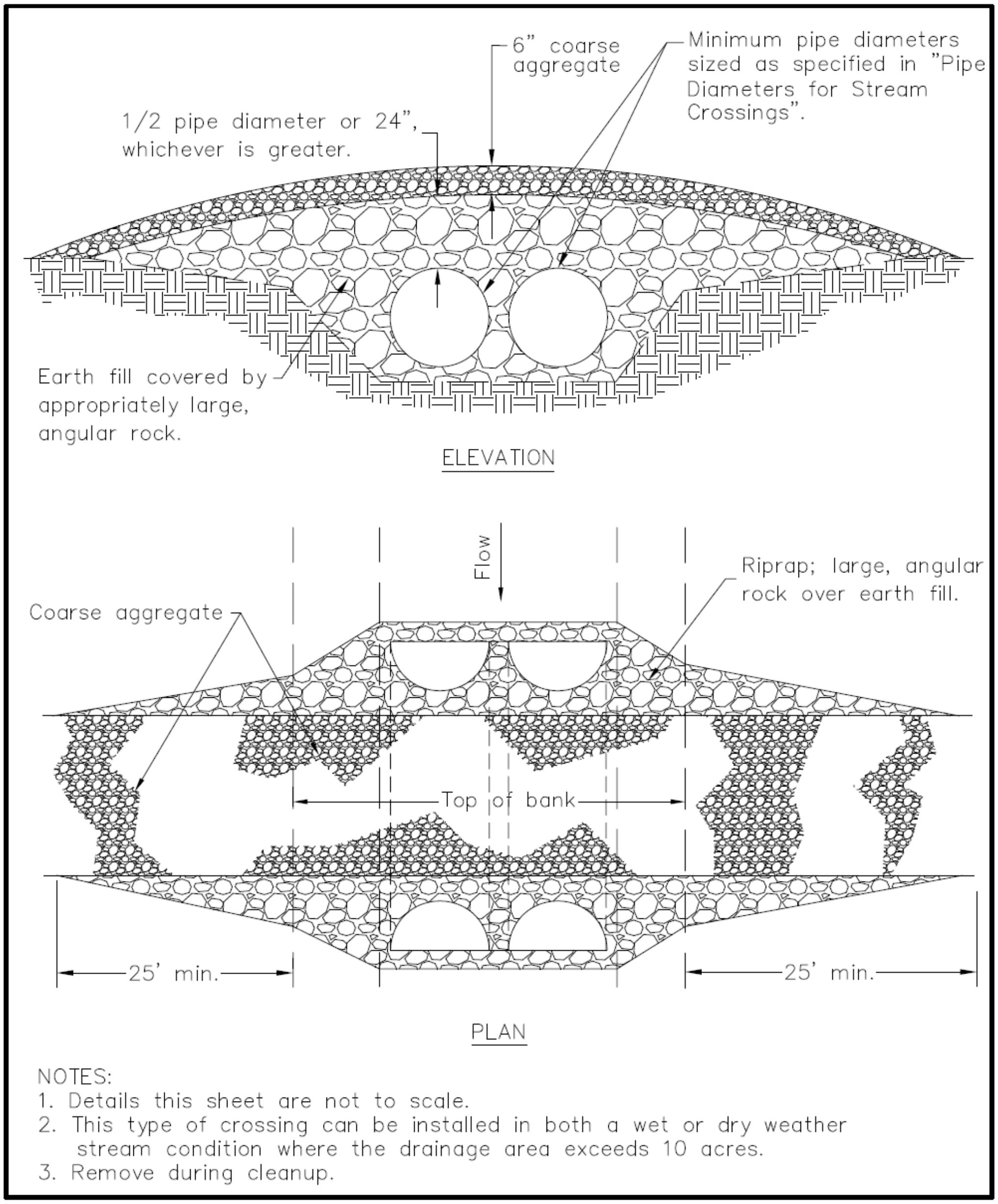


Figure TSC-1 Culvert Stream Crossing

Fords (See Figure TSC-2)

Stream banks should be excavated to provide approach sections of 5:1 or flatter.

The width of the ford crossings should be wide enough for the construction equipment to safely use.

Filter fabric material designed for use under riprap (see Channel Stabilization practice) should be installed on the excavated surface of the ford according to the manufacturer's recommendations. The fabric should extend across the bottom of the stream and at least 25 feet up each approach section. All edges of the fabric should be keyed in a minimum of 1 foot.

Alabama Highway Department course aggregate No.1 stone, 6" thick should be installed on the filter fabric and also should be used to fill the 1 foot keyed edges of the fabric.

The final surface of the stone in the bottom of the watercourse should be the same elevation as the watercourse bottom in order to eliminate any overfall and possible scour problems.

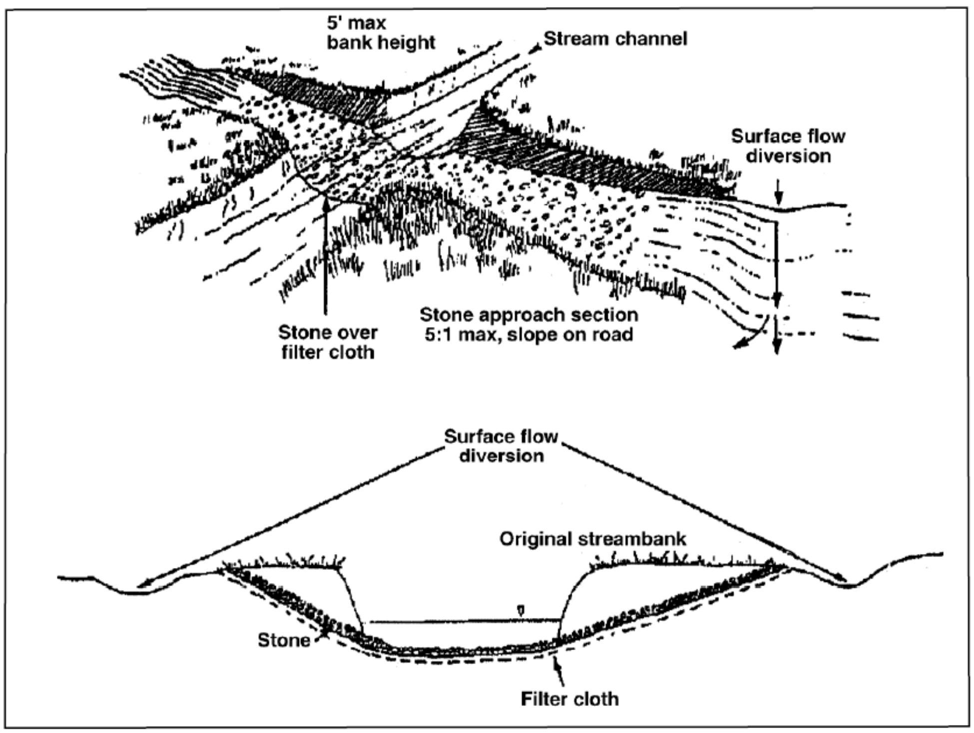


Figure TSC-2 Ford Stream Crossing