Chapter 8. EROSION AND SEDIMENT CONTROL

8.1. Introduction

Natural erosion has been occurring since the earth was formed. This process, which generally occurs at a relatively slow rate, has shaped and molded the earth's surface in the form we recognize today. Man-made erosion, on the other hand, occurs at a quicker rate.

Man-made erosion caused by inappropriate management of storm water runoff from development sites contributes greatly to urban land breakdown and water pollution. It is estimated that erosion on unprotected construction sites may average up to 30 tons per acre per year. Construction-generated storm water runoff often contains sediment, toxic chemicals, oil and grease, pesticides (herbicides, insecticides, or rodenticides), trace metals, and other contaminants which serve as a significant source of water pollution and threatens public health, fish and other wildlife. Nutrients from fertilizers containing nitrogen, phosphorous, and potassium are carried by eroded sediment. These nutrients fuel weed and algae growth, and make outdoor water areas unattractive for swimming and other recreational activities. The resulting water and environmental damage caused by construction-related erosion is often extensive, long-term, costly and time consuming to correct.

Erosion

In Greenville County, water is the primary cause of most of the erosion experienced. Water has an affinity for sediment; therefore, most streams transport a bedload of sediment. This sediment is deposited, detached and transported over and over again. Studies have found that the bedload can harbor fecal matter and reproduction occurs in the bedload. Once a storm event occurs the fecal is released into the water column as the bedload is re-suspended.

Through proper management, the impacts from land disturbance activities can be reduced. Construction site disturbances are typically for development to improve the quality of life and to produce income. It is imperative that these disturbances are controlled and their impacts to water quality of Waters of the State are minimized. Therefore, the implementations of erosion prevention techniques are very critical to meeting this objective.

Erosion on most disturbed sites occurs in the following forms:

- Sheet
- Rill and interrill
- Gully

There are two concepts that must work together to begin the erosion process. The first is detachment. As raindrops fall and strike the ground, energy is released in the collision. This energy is transferred to the soil particles and they are moved. When the water flows over the surface it will transport these soil particles to a point downstream. This is the second part of the process known as transport. The flowing water also has energy that will dislodge soil particles. It is important to note that clear water has a greater affinity for sediment than does sediment-laden flow. Also remember that runoff and resulting transport does not occur until rainfall intensities exceed infiltration rates of the soil media.

Sheet erosion is a result of overland flow from disturbed areas. As this flow concentrates, interrills and rills begin to form. Once the flow concentrates into a single point, a gully may begin to form. Usually, sheet erosion is found on flatter slopes with rills and interrills forming as the slope increases. Then often times gully erosion is formed on the steeper sections of the slope.

There are two primary means to prevent erosion from occurring on sites that are disturbed. The most desirable alternative but, not always possible, is source protection. This protection encompasses a wide range of techniques most of which are management issues. The other approach is to provide flow control. This is a structural engineering solution. Often times it translates to diverting flow away from disturbed areas. From an application standpoint a combination of these to solutions can be very effective in reducing erosion.

Sedimentation

Since it is impossible to prevent all soil erosion, it is necessary to develop sediment control techniques. Soil erosion is a result of detachment and transport of the soil particles. Sediment does not accumulate until deposition occurs. Deposition occurs because velocities decrease and soil particles in the flow are heavy enough to settle. Once runoff starts, the quantity and size of the material transported increases with the velocity of the flow. Eventually the runoff will reach a point where the velocity will decrease and the transport capacity will also decrease. Any factor that reduces velocity in a flow segment increases deposition.

In general, larger sized particles and aggregates will settle at higher flow velocities while smaller sized particles will require a much lower flow velocity to settle out. Therefore, the particle size distributions of the soil have an enormous effect on the trapping efficiency of a sediment control structure. Typically civil engineers develop particle size distributions by using a dispersing agent. When considering the erosion and sedimentation phenomena the eroded particle size distribution (EPSD) should be used. The eroded particle size distribution has a direct effect on the required settling velocities. This in turn has a direct effect on the required detention area and detention time. Eroded sediment will be deposited starting first with the larger particles and aggregates, while smaller particles will be carried further downstream until their required settling velocity is reached. Therefore, the eroded particle size distribution and aggregate composition of a particular soil has a major impact on the soil erosion-deposition process.

The eroded particle size distribution of a particular soil is not the same as the primary particle size distributions. The primary particle sizes are based on the soil in a dry condition and represent the percentages of sand, silt and clay in the soil. Since sediment from eroded soils includes both primary soil particles and aggregates, eroded particle size distributions can not be accurately inferred from primary particle distributions, but can be estimated from the primary distributions.

Extensive research has been done on primary particle size distributions of soils. Primary particle distributions can be used in empirical equations to determine the eroded particle size distributions of the soil. Equations used in the CREAMS (Chemicals, Runoff and Erosion in Agricultural Management Systems) model are one set of equations designed to convert primary particle sizes into eroded particle sizes. The eroded particle size distributions listed in Appendix B were determined using the CREAMS based equations and primary particle sizes from Greenville County soils surveys. If site specific data is available, it should be used.

The critical shear stress or critical tractive force determines a soil's resistance to the shearing forces of concentrated flows. When the shearing forces of the water flow exceed the critical tractive force of the soil, erosion takes place. For non-cohesive soils, Shields diagram is commonly used to determine the critical tractive force for individual soil particles. For cohesive soils, the critical tractive force has been related to the following:

- Soil shear strength,

- Soil salinity,
- Moisture content,
- Percent clay,
- Mean particle size,
- Dispersion ratio,
- Vane shear strength ,
- Percent organic matter,
- Cation Exchange Capacity (CEC),
- Calcium-Sodium ratio, and
- Plasticity index.

Soil erosion by water is measured by the soil lost from a given area, usually described on a per unit area basis. Sediment yield is the amount of sediment that passes a certain point in a watershed. The ratio between soil loss and the sediment yield is the delivery ratio. Most often we consider two delivery ratios. Delivery ratio one is the amount of sediment delivered from the overland flow, delivery ratio two is the amount of sediment delivered to the sub-watershed outlet by concentrated flow.

Typical erosion prediction models like the USLE (universal soil loss equation) and RUSLE (revised universal soil loss equation) do not include delivery ratios or channel erosion. Both of the models determine soil loss over an extended period of time such as months and years in units of weight measure. Another useful model is MUSLE (modified universal soil loss equation) which estimates sediment yield for single storm events. This approach does account for delivery ratio one but does not include delivery ratio two or channel erosion. Acceptable computerized versions of these models include but are not limited to SEDIMOTII (University of Kentucky) and SEDCAD4 (Civil Software Design, Ames, Iowa). Greenville County has developed SEDIMOTIV and it is available to users in Greenville County.

These models are used to determine the amount of sediment that will enter an erosion control structure. The design sediment storage volume is directly related to the amount of soil lost from the site during the design life of the structure. The use of these models also helps in determining the cleaning schedule of the sediment control structure. The models will be able to predict the amount of sediment entering the structure over a given period of time. When this amount equals the design sediment storage, the structure must be cleaned free of the stored sediment.

Sediment control structures are designed to keep eroded soils from having adverse off-site impacts that includes adjacent properties and Waters of the State. There are three major types of sediment control structures:

- Detention structures that provide enough surface area and storage volume to slow the flow of the sediment-laden runoff and allow the desired particle sizes to settle out so a desired trapping efficiency is met.

- Structures that filter out eroded sediment particles, and

- Structures that add chemical agents that promote particle flocculation and settling.

Most all of the BMPs employed today function primarily by Stokes Law of quiescent settling. Filtering is not an efficient control because of the particle size variations and the filter media clogging and becoming ineffective. Chemical treatment is the least desirable due to the impacts to the impacted water pH variations.

8.2. Purpose

This chapter of the Design Manual provides the user with the tools to meet the requirements of the Greenville County Storm Water Management Ordinance. Some of the information contained in this chapter, such as the application forms and checklists are available in digital format and can be downloaded from the Greenville County Webpage.

This chapter also establishes requirements to be used when preparing plans for minimizing soil erosion and sedimentation during and after construction of any land development, improvement or retrofit project. Guidelines on how to select and design EPSC BMPs for specific construction activities have been developed in accordance with several references from across the country. Suggested uses for EPSC and Storm Water Control BMPs are summarized in Appendix E. An EPSC BMP selection flowchart is provided in Appendix E.

8.3. Erosion Protection and Sediment Control Requirements

The Greenville Storm Water Ordinance requires that an EPSC plan be developed and approved, prior to initiating construction on land disturbing activities that are in excess of 5,000 square feet or require a building permit or as directed by a General Permit.

The Ordinance also establishes standards for the design of EPSC plans to minimize the adverse impact and off-site degradation that may result from construction site runoff.

8.3.1 EPSC Development Standards

EPSC plans shall be developed to achieve an **80 percent** design removal efficiency of total suspended solids (TSS) goal. Simply applied, when a site is completely denuded of vegetation, the structural and nonstructural EPSC measures are designed to trap 80 percent of the TSS that are generated by the site. The design storm event associated with this level of control is the **10-year 24-hour SCS Type II storm event**.

SCS procedures should be used to determine runoff amounts. It is important to note that when a BMP is designed for the 10-year 24-hour storm event, the BMP will have a greater trapping efficiency for more frequent events such as the 2-year 24-hour storm event.

Each EPSC Plan must delineate the following elements:

- All Sensitive Features (including steep slopes 30%)
- Sources of sediment that may potentially leave the site
- The location and depth of all structural and nonstructural BMPs necessary to achieve the 80 percent design removal efficiency goal to protect receiving water bodies, off-site areas and all Sensitive Features
- Installation and maintenance of required BMPs
- The sequencing of construction activities to be utilized on the project

The following nonstructural site management practices shall be utilized on the plans where applicable:

- Minimize site disturbance to preserve and maintain existing vegetative cover.
- Limit the number of temporary access points to the site for land disturbing activities.
- Phase and sequence construction activities to minimize the extent and duration of disturbed soil exposure.
- Locate temporary and permanent soil disposal areas, haul roads and construction staging areas to minimize erosion, sediment transport and disturbance to existing vegetation.

Detailed EPSC plans shall comply with the following specific standards and review criteria:

- <u>Sediment Tracking Control</u>. Stabilized construction entrances shall be located and utilized at all points of ingress/egress on a construction site. The transfer of soil, mud and dust onto public rights-of-ways shall be prevented.
- <u>Crossings</u> of waterways during construction should be minimized and must be approved by the Greenville County Storm Water Plan Review Agency. Encroachment into stream buffers, riparian areas and wetlands should be avoided when possible.
- <u>Topsoil shall be stockpiled</u> and preserved from erosion or dispersal both during and after site grading operations when applicable.
- <u>Temporary Stabilization Measures</u>. Where construction or land disturbance activity will or has temporarily ceased on any portion of a site, temporary site stabilization measures shall be required as soon as practicable, but no later than 14 calendar days after the activity has ceased.
- <u>Final Stabilization</u>. Final Stabilization of the site shall be required within 14 calendar days of construction completion.
- <u>Temporary Structural Controls</u> installed during construction shall be designed to accomplish maximum stabilization and control of erosion and sedimentation, and shall be installed, maintained, and removed according to the specifications set forth in the Design Manual, Standard Specifications and Standard Drawings. All temporary structural controls shall be designed to control the peak runoff resulting from the storm event identified in the Design Manual, Standard Specifications and Standard Drawings.
- <u>All Permanent Structural Controls</u>, including drainage facilities such as channels, storm sewer inlets, and detention basins, shall be designed according to the standards set forth in the Design Manual, Standard Specifications and Standard Drawings.

8.3.2 Alternative Erosion Prevention and Sediment BMPs

To encourage the development and testing of innovative alternative EPSC BMPs, alternative management practices that are not included in the Design Manual, Standard Specifications and Standard Drawings may be allowed upon review and approval. To use an alternative BMP, the design professional shall submit substantial evidence that the proposed measure will perform at least equivalent to currently approved BMPs contained in the Design Manual, Standard Specifications and Standard Drawings. Evidence may include, but is not limited to:

- Supporting hydraulic and trapping efficiency calculations.
- Peer-review by a panel of licensed professional engineers.
- Research results as reported in professional journals.
- Manufacturer literature.

To justify the efficiency of innovated EPSC BMPs, the owner may be required to monitor the trapping efficiency of the structure. If satisfactory results showing that trapping efficiencies of greater than 80 percent are obtained, the innovative BMP may be used and no other monitoring studies shall be required. If monitoring shows that a certain BMP is not sufficient or if Greenville County finds that a BMP fails or is inadequate to contain sediment, other upstream and downstream BMPs shall be implemented to reach the required efficiency.

8.3.3 Basic Design Procedures

Control of sedimentation from construction sites may be accomplished through the utilization of a variety of erosion and sediment control BMPs. The complexity of the erosion and sediment control plan will vary depending on the individual site conditions. The goal of implementing the erosion control plan is to limit the quantity of sediment being eroded from, and leaving a construction site. This may be partially accomplished through the implementation of sediment control BMPs. However, these sediment trapping controls typically only remove a small portion of the clay particles eroded from the site. The best protection is provided by a combination of practices including temporary and permanent stabilization, flow diversions, and streambank protection, all which minimize the amount of soil that is eroded from the site.

All land development shall be planned in such a way to control and limit erosion and sediment discharge from construction sites using, but not limited to, the BMPs listed in this chapter. The goal of these erosion and sediment control BMPs shall be to:

- Minimize the extent and duration of disturbed soil exposure.
- Protect off-site and downstream locations, drainage systems and natural waterways from the impacts of erosion and sedimentation.
- Limit the exit velocities of the flow leaving the site to non-erosive or pre-development conditions.
- Design and implement an ongoing inspection and maintenance plan.

8.4. Erosion Prevention Measures

Erosion prevention measures shall be used during and after construction site preparation in order to safely convey clean water to storm drains or adequate watercourses. One or more measures and BMPs should be utilized as appropriate during the project's construction phase. Such measures may include phasing and construction sequencing.

In addition to site-specific erosion control measures, the grading plan should include the following general measures as a minimum:

- The finished cut and fill slopes to be vegetated should not be steeper than 3H:1V. The finished grades of cut and fill slopes to be vegetated with vines and/or groundcovers should not be steeper than 1H:1V.
- Cuts or fills should not be so close to property lines as to endanger adjoining property without adequately protecting such properties against erosion, sedimentation, slippage, settlement, subsidence, or other damages.
- Subsurface drainage should be provided in areas having a high water table to intercept seepage that would affect slope stability, bearing strength or create undesirable wetness.
- No fill shall be placed where it can slide or wash onto another property.
- Fill shall not be placed adjacent to channel banks where it can create bank failure, reduce the capacity of the stream, or result in downstream sediment deposition.
- All borrow and disposal areas should be included as part of the grading plan.
- Adequate channels and floodways should be provided to safely convey increased runoff from the developed area to an adequate outlet without causing significant channel degradation, or increased off-site flooding.

Greenville County technical specification and details for Erosion Prevention Measures are located Appendix F and include:

- EC-01 Surface Roughening
- EC-02 Bench Terracing
- EC-03 Seeding (Temporary and Permanent Stabilization, Sod, Mulch)
- EC-04 Rolled Erosion Control Products (RECPs)
- EC-05 Hydraulic Erosion Control Products (HECPs)
- EC-06 Riprap or Aggregate
- EC-07 Outlet Protection
- EC-08 Dust Control
- EC-09 Transition Mats
- EC-10 Slope Interruption Devices
- EC-11 Compost
- EC-12 Biological Growth Stimulant

8.4.1 RECP Design

Designing RECPs Example

Given:	Peak flow rate carried by channel:	80 cfs
	Bottom width of design channel B_o:	4-feet

Manning's n of matting:	0.025
Side slopes of design channel:	2:1
Channel bed slope (ft/ft):	0.01

Find: Temporary Erosion Control Blanket (ECB) that will meet the maximum shear stress requirements with no establishment of vegetation.

Solution: The normal depth of flow in the channel (d_n) shall be calculated.

- Manning's Equation can be utilized to determine the normal flow depth, or
- The graphical procedure outlined in Section 6.1.8 may be used.

Solve for $AR^{2/3}$

$$AR^{2/3} = \frac{(Q*n*)}{b_o^{8/3} * S^{1/2}} = \frac{(80*0.025)}{4^{8/3}*(.01)^{1/2}} = 0.50$$

For Side Slopes 2:1, **Figure 6-1**. Reads: d_n/B_o = 0.43

Solve for $d_n = (0.43 * B_o) = (0.43 * 4)$ = 1.72-feet.
The maximum shear stress is then calculated.

Solve for $\tau = \gamma\, d_n\, S = (62.4 * 1.72 * .01)$ = 1.1 (# / ft^2)

Select an appropriate ECB or TRM for the design conditions.

Select a Erosion Control Blanket that can handle a maximum shear stress of 1.1 pounds/ square foot from the list of ECBs and TRMs.

8.4.2 Design of Riprap Channel Linings

Design of erosion protection within the channel should be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape flow depth and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

8.4.2.1 Straight Channel Sections:

1. Enter the graph of **Figure 8-1** with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line <u>above</u> the point of intersection)

2. If the channel side slopes are steeper than 3H:1V, continue with Step 3; if not, the procedure is complete.

3. Enter the graph in **Figure 8-2** with the side slope and the base width to maximum depth ratio (B/d).

Where the two lines intersect, move horizontally left to read K1.

4. Determine from the graph in **Figure 8-3** the angle of repose for the d50 stone size and the channel side slope. (Use an angle of 42o for d50 >10-inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Enter graph in **Figure 8-4** with the side slope of the channel and the angle of repose for the d50 stone size. Where the two lines intersect, move vertically down to read K2.

6. Compute d50 x K1/K2 = d50 to determine the correct size stone for the bottom and side slopes of straight sections of channel.

8.4.2.2 Curved Channel Sections:

1. Enter the graph of **Figure 8-1** with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line above the point of intersection.)

2. Determine the radius of the curved section (RO) in feet.

3. Calculate the top width of the riprap at the design water surface (BS) in feet.

B_S	=	$B_O + 2(Z*D)$
B_O	=	Bottom width of channel (feet)
Z	=	Channel sides slopes defined as ZH:1V
D	=	Depth of riprap (feet)

4. Calculate the Ratio B_S / R_O

5. Knowing the value of the BS/RO ratio from step 4, use the graph in **Figure 8-5** and read the corresponding value of K3.

6. Compute (d50 x K3) = d50 to determine the correct size stone for the bottom and side slopes of curved channel sections.

8.4.2.3 Straight Channel Section Design Example

Given: A trapezoidal channel has a depth (D) of 3-feet, a bottom width (B_o) of 8-feet, side slopes (Z) 2:1, and a 2 percent slope.

Find: A stable riprap size for the bottom and side slopes of the channel.

Solution:

1. From **Figure 8-1**, for a 3-foot-deep channel over a 2 percent grade,
   Read d_{50} = 0.75-feet or 9-inches.

2. Since the side slopes are steeper than 3:1, continue with step 3

**If side slopes were less than 3:1, the process would be complete.

3. From **Figure 8-2**, BO/d = 8/3 = 2.67, Side slopes Z = 2,
   Read K_1 = 0.82.

4. From **Figure 8-3**, for d50 = 9-inches,
   Read Angle of Repose = 41

5. From **Figure 8-4**, side slopes Z = 2, and Angle of Repose = 41 ,
   Read K_2 = 0.73.

6. Stable Riprap = d_{50} x (K_1/K_2) = 0.75 x (0.82/0.73) = 0.84-feet or 10-inches

8.4.2.4 Curved Channel Section Design Example

Given: The preceding straight channel example has a curved section with a radius of 50-feet.

Find: A stable riprap size for the bottom and side slopes of the curved channel section.

Solution:

1. R_O = 50-feet.

2. Calculate Channel Top Width of Water Surface
   $B_S = B_O + 2(Z*D) = 8 + 2(2*3) = 20$-feet.

3. Calculate the Ratio B_S / R_O
   = 20/50 = 0.40

4. From **Figure 8-5**, for B_S / R_O = 0.40
Read K_3 = 1.1

5. d_{50} x K_3 = (0.84-ft. x 1.1) = 0.92-feet or 11-inches.

8.4.3 Outlet Protection Design Example

Given: An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel)

Find: The required length, width and median stone size (d_{50}) for riprap lined protection.

Solution:

1. Since the pipe discharges onto a grassy slope with no defined channel, a **Minimum Tailwater Condition** is assumed. Figures for design of outlet protection for Minimum and Maximum Tailwater Conditions are provided in **Figure 8-6** and **Figure 8-7**

2. From **Figure 8-6**, the intersection of a discharge of 24 cfs and a pipe diameter (d) of 18-inches,

Gives a protection length (L_a) of 20-feet.

3. From **Figure 8-6**, the intersection of a discharge of 24 cfs and a pipe diameter (d) of 18-inches.

   Gives a median stone size (d_{50}) of 0.8-ft.

4. The upstream protection width equals 3 times the pipe diameter (3Do)

   = 3 x 1.5-feet = 4.5-feet

5. The downstream protection width equals the apron length + the pipe diameter;

   = 20-feet + 1.5-feet = **21.5-feet**

8.5. Temporary Sediment Control Measures

Greenville County emphasizes erosion prevention in EPSC plans. However there are always instances where erosion cannot be prevented. For these situations temporary sediment controls and BMPs must be implemented to control the migration of eroded sediment off site. The following sediment control measures are applicable as temporary practices for use during construction. One or more of the measures and BMPs should be utilized as appropriate during the project's construction phase. A discussion of the planned measures will be required during the Preliminary Plan Review phase for sites containing sensitive features.

Greenville County technical specifications and details for Temporary Sediment Control Measures are located Appendix F and include:

- SC-01 Surface Outlet and Baffle Sediment Basin / Multipurpose Basins
- SC-02 Temporary Sediment Trap
- SC-03 Silt Fence
- SC-04 Rock Ditch Check
- SC-05 Sediment Tube Ditch Check
- SC-06 Stabilized Construction Entrances
- SC-07 Storm Drain Inlet Protection
- SC-08 Rock Sediment Dikes
- SC-09 Construction DeWatering
- SC-10 Floating Skimmer
- SC-11 Porous Baffles
- SC-12 Perimeter Control for Small Sites
- SC-13 Polymer/ Flocculant / Coagulant for Sediment Control

8.5.1 Sediment Storage Volumes and Maintenance Schedules

Calculating the appropriate sediment storage volume is very important un sediment basin and sediment trap design. This volume is the storage occupied by the sediment deposited over the given design period. Design periods may be the life of the basin, or the time between scheduled clean outs. Using computed sediment yields from the Universal Soil Loss Equation (USLE), along with the sediment bulk density, the sediment storage volume can be calculated by

$$V_S = \frac{Y_D}{W * 43,560}$$

Where $\mathbf{V_S}$ is the sediment storage volume (acre-feet), $\mathbf{Y_D}$ is the sediment deposited over the design period (pounds), and **W** is the weight density (bulk density) of the deposited sediment (lbs./ft^3). **W** can be found from soil survey data (usually given in grams/cm^3) or by the equation

$$W = W_c P_c + W_m P_m + W_s P_s$$

Where W_c, W_m, and W_s are unit weights of clay, silt, and sand in (lbs./ft^3) taken from Table 8-1, and P_c, P_m, and P_s are the primary soil matrix percent clay, silt, and sand as listed in soil survey (used as a decimal).

Table 8-1. Unit Weight Values of Basin Sediment

Type of Basin Operation	Wc (#/ft^3)	Wm (#/ft^3)	Ws (#/ft^3)
Sediment always submerged (Wet Pond)	26	70	97
Basin normally empty (Dry Pond)	40	72	97

8.5.1.1 R Factors and EI Values

When designing for sediment storage volume, the sediment deposited over the design period $\mathbf{Y_D}$, must be calculated. This value can be obtained by converting the sediment yield calculated by the Universal Soil Loss Equation (USLE) into pounds of sediment.

One of the variables used in the USLE is the R factor. R is the factor in the USLE that accounts for the damaging effects of rainfall. The R factor indicates the erositivity of the rainfall, not the average annual precipitation in a locality. The R factor is defined as the number of erosion index (EI) values in a normal year's rain. The EI index value of a given storm is equal to the kinetic energy of the storm (hundreds of foot-tons per acre) multiplied by its maximum 30-minute intensity (inches/hour). The EI values of individual storms may be summed to get an EI value for a month, six months, or for any period of time. When EI values are summed and averaged over a period of years, they become R factors.

The distribution of EI values become important when soil losses need to be calculated for a period of time less than one year, such as a construction season. The distribution of the EI values over a known period of time is used to calculate an R factor for that time period. Table 8-2 of this chapter shows the distribution of EI values for Greenville County as a percentage of the R factor for Greenville County. This design procedure shall require a minimum EI value of 50 for any construction period.

Table 8-2. Average Example Distribution of Rainfall Erosion Index (EI Curves) for Greenville County

Date	Percent of EI Value
January 1	0.0
January 15	1.0
February 1	3.0
February 15	5.0
March 1	7.0
March 15	9.0
April 1	12.0
April 15	15.0
May 1	18.0
May 15	21.0
June 1	25.0
June 15	29.0
July 1	36.0
July 15	45.0
August 1	56.0
August 15	68.0
September 1	77.0
September 15	83.0
October 1	88.0
October 15	91.0
November 1	93.0
November 15	95.0
December 1	97.0
December 15	99.0
January 1	100.0

The minimum EI value for any construction period shall be 50.

The annual R factor value for Greenville County is 300.

8.5.1.2 Factors and EI Value Example Problem

- The annual R factor value for Greenville County is **300**.
- If construction of a particular site is scheduled to take place for 5 months from January 1 to June 1, the EI Curve value would be,
- 25.0 – 0.0 = **25.0**
- The corresponding R factor for this time period is calculated to be

  0.25 * 300 = **75.0.**

- If construction of a particular site is scheduled to take place for 5 months from March 1 to August 1, the EI Curve value would be,

  56.0 – 7.0 = **49.0**

- The corresponding R factor for this time period is calculated to be

  0.49 * 300 = **147.0**

8.5.1.3 Calculating Sediment Storage Volumes

The following steps are used to determine the storage volume for a sediment trapping structure. All Universal Soil Loss Equation input values are found in Appendix B of this Design Manual.

1. Determine the sediment yield from the site using the Universal Soil Loss Equation

$$A = R \bullet K \bullet LS \bullet CP$$

Where :

A	=	Average soil loss per unit area (tons/acre/specified design period),
R	=	Rainfall erosive index (100-ft-tons/acre x in/hr) (EI Value for given design period * average annual R Value)
K	=	Soil erodibility factor (tons/acre per unit R),
LS	=	Length-slope steepness factor (length is the slope distance from the point of origin of overland flow to the point of concentrated flow or until deposition occurs (dimensionless), and
CP	=	Control practice factor (dimensionless).

2. Determine the weight density **(W)** of the specific soil.

- Use the equation from Section 8.5.1, or
- Soil bore test and/or the Greenville County Soil Survey provide a soil bulk density usually given in grams/cm^3
- Convert (grams/cm^3) to (lbs/ ft^3) by multiplying by 62.43

W = (bulk density in grams/cm^3) x (62.43) = lbs/ft^3

3. Convert sediment yield from (tons/acre) to acre-feet of sediment storage.

- Determine the total disturbed area **DA** (acres)
- Determine the sediment yield in tons,

  Calculated by Multiplying **A** from step 1. * **DA** from step 3. (tons/acre * Acres = tons)

- Convert tons to pounds to get YD
  (**Y_D** = (tons) * (2000 lbs/ ton) = pounds)

$$V_S = \frac{Y_D}{W * 43{,}560} = acre - feet$$

4. The design professional can now determine what level the required sediment storage corresponds to, and require a clean out marking stake to be installed at this elevation. The contractor shall be

required to clean out the basin or trap when this level is reached. Or the designer can simply state that based on the calculations, the basin or trap will be required to be cleaned out on a time period basis such as weeks, months or years.

8.5.1.4 Sediment Storage Volume Example

Given: A 60-acre construction site is to be cleared to a bare soil condition and developed. The contributing runoff slope length is 400-feet with a 2.5 percent slope. The primary soil is Cecil Sandy Loam. A sediment basin is to be designed to be the primary sediment control structure on the site. Determine the required sediment storage volume if construction is to take place between March 1 and September 1

1. Determine the sediment yield form the site using the Universal Soil Loss Equation

$$A = R \bullet K \bullet LS \bullet CP$$

R = from Table 8-2, EI for September 1 = 77.0, and EI for March 1 = 7.0
(77.0 – 7.0) = 70% of 300 **= 210**
K = 0.28 for Cecil sandy loam soil
LS = 0.365 for 400 ft slope length with 2.5%
CP = 1.0 for a bare soil condition
A = (210) x (0.28) x (0.365) x (1.0) = 21.5 tons/acre

2. Determine the weight density (W) of the Cecil sandy loam soil.

- Soil boring tests give an average soil bulk density of 1.40 grams/cm3 for Cecil sandy loam soil
- Convert 1.40 (grams/cm3) to (# / ft3) by multiplying by 62.43

W = (1.40) x (62.43) = $\underline{87.4\ \#/ft^3}$

3. Convert sediment yield from (tons/acre) to acre-feet of sediment storage.

- Determine the total disturbed area (acres)
- Determine the sediment yield in tons

21.5 (tons/acre) * 60 (acres) = **1290 tons**

- Convert tons to pounds to get $\mathbf{Y_D}$
$\mathbf{Y_D}$ = (1290 tons) * (2000 # / ton) = 2,580,000 pounds

$$V_S = \frac{Y_D}{W * 43{,}560} = \frac{2{,}580{,}000}{87.4 \times 43{,}560} = 0.68\ acre - feet$$

8.6. Runoff Control and Conveyance Measures

The following flow control measures are applicable as temporary and/or permanent practices for use during construction. Greenville County technical specification and details for Runoff Control Measures are located Appendix F and include:

- RC-01 Pipe Slope Drains
- RC-02 Subsurface Drains
- RC-03 Runoff Conveyance Measures
- RC-04 Stream Crossings

8.6.1 Runoff Control and Conveyance Measures Design Example Problems

See **Figure 8-8**, **Figure 8-9** and **Figure 8-10** for Subsurface Drain Capacity for the given Manning's n value

Given: An interceptor subsurface drain is to be installed on a 1.0% grade, 700-feet in length, using corrugated plastic pipe.

Find: The required size of the drain pipe.

Solution:

- The required capacity of the drain pipe is 1.50 cfs per 1000-feet.
- The design capacity for this situation can be calculated by:

$$\text{Capacity} = \frac{700}{1000} \, x \, 1.50 \ \ cfs = \ 1.05 \ \ cfs$$

- The Manning's n value for corrugated plastic pipe is 0.015.
- From **Figure 8-9**, with the hydraulic gradient of 0.01 and a flow capacity of 1.05 cfs, read a pipe size of 8-inches.

Given: A relief drain system is designed to have a gridiron pattern of 8 laterals, 500-feet long, on a 0.50 percent grade spaced 50-feet on center, connected to a main pipe 400-feet in length on 0.50 percent grade. Smooth PVC pipe shall be used.

Find: The required size of the drain pipe.

Solution:

Lateral Design:

- The drainage area (DA) for each lateral is 25-feet on either side of the pipe multiplied by the length:

$$\text{DA}=\frac{(25ft+25ft) \ x \ 500ft.}{43{,}560 \ ft^2/acre} = \ 0.57 \ acres$$

- From Section 8.6.6.2, relief drains in a uniform pattern shall remove 1-inch of water in 24-hours (0.042 cfs/acre):

$$0.042 \ cfs \ x \ 0.57 \ acres \ = \ 0.02 \ cfs$$

- The Manning's n value for PVC pipe is 0.013.

- From **Figure 8-8**, with the hydraulic gradient of 0.005 and a flow capacity of 0.02 cfs, read a pipe size of 4-inches for each lateral.

Main Pipe Design:

- The drainage area (DA) of the main pipe will only drain 25-feet opposite the laterals:

$$\mathrm{DA} = \frac{(25\,ft) \ x \ 400\,ft.}{43{,}560 \ ft^2/} \ = \ 0.23 \ acres$$

- The drainage area from the 8 laterals (DAL) is calculated to be:

$$\mathrm{DAL} = 8 \ x \ 0.57 \ acres \ = \ 4.56 \ acres$$

- The total drainage area (TDA) to the main is:

$$\mathrm{TDA} = 0.23 acres \ + \ 4.56 \ acres \ = \ 4.79 \ acres$$

- Relief drains in a uniform pattern shall remove 1-inch of water in 24-hours (0.042 cfs/acre):

0.042 cfs x 4.79 acres = **0.20 cfs**

- The Manning's n value for PVC pipe is 0.013.

- From **Figure 8-8**, with the hydraulic gradient of 0.005 and a flow capacity of 0.2 cfs, read a pipe size of 5-inches for the main.

8.7. Engineering Design Aids and Design Guidelines for Sediment Controls

This section presents design aids that were developed for use in designing four types of sediment control structures; sediment basins, sediment traps, silt fences, and rock ditch checks for Greenville County South Carolina. Each of these design aids will be briefly described and then examples will be used to demonstrate their use in realistic problems. First however a common feature of each design aid settling velocity will be discussed.

8.7.1 Characteristic Settling Velocity and Eroded Particle Size

A common feature of each of the design aids is that a characteristic settling velocity for the eroded soil must be obtained. For Greenville County conditions, this velocity corresponds to an eroded size such that 15 percent of the sediment has particles smaller than the size specified. The procedure for empirically estimating eroded size distributions is best described by Hayes et. al (1996). The characteristic settling velocity corresponds to an eroded particle diameter that is referred to as D_{15}. This diameter represents the point on the eroded particle size distribution curve where 15 percent of the particles (by weight) are equal to or smaller than this size. Estimated eroded size distributions for Greenville County soils using an adaptation of the method described by Foster et al. (1985) were developed. The procedure uses the primary particle size information reported by the USDA Soil Conservation Service (SCS) as part of county soil surveys. This procedure may be used with USDA Soil Survey Data or site specific soil boring data. Other procedures are given by Haan et. al. (1994) for physically based estimating procedures. If D_{15} is less than 0.01 mm, then settling velocity based upon a simplified form of Stokes Law is:

$$\mathbf{V_s = 2.81d^2}$$

Where V_s is settling velocity in ft/sec and d is diameter in mm. If D_{15} is greater than or equal to 0.01 mm, then settling velocity should be found using:

$$\mathbf{\log_{10}V_s = -0.34246\ (\log_{10}d)^2 + 0.98912\ (\log_{10}d) - 0.33801}$$

Where V_s, is settling velocity in ft/sec and d is particle diameter in mm (Wilson et al., 1982). The characteristic settling velocity can be obtained using **Figure 8-11** and the eroded particle size (D_{15}) for soils found in Greenville County is provided in Appendix D.

It is important to remember that the eroded size distribution is the most critical parameter in sizing sediment controls. The eroded size distributions vary greatly from primary particle size distributions that are often determined as a result of soil strength investigations for construction purposes. Primary particle sizes will yield erroneous results and should not be used. The user should note that D_{15} is often smaller for coarse textured (more sandy soils) because of the reduced clay content and the lack of aggregation.

Table 8-3. Soil Classification by Texture

Greenville County Soil Classification by General Texture			
Texture	Coarse	Medium	Fine
Soil Type	Sandy Loam	Silt Loam	Clay Loam

8.7.2 Sediment Basin Design Aids

The Sediment Basin Design Aids are designed for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam). The design ratio should be less than or equal to the curve value at any given trapping efficiency. The sediment basin Design Aids have been developed for the following two separate conditions:

- Basins **not** located in low lying areas and/or not having a high water table, and
- Basin located in low lying areas and/or having a high water table.

8.7.2.1 Sediment Basin Design Aid Ratio

$$\text{Basin Ratio} = \frac{q_{po}}{A\,V_{15}}$$

Where:

q_{po} = Peak outflow rate from the basin for the 10-year 24-hour storm event (cfs),
A = Surface area of the pond at riser crest (acres),
V_{15} = Characteristic settling velocity (fps) of the characteristic D_{15} eroded particle (mm).

Constraints for use of Sediment Basin Design Aids:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 percent
- Outlet diameter less than or equal to 6-feet

Basin Ratios above the design curves are not recommended for any application of the design aids. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A basin **not** located in a low lying area and not having a high water table, has a basin ratio equal to **2.20 E5** at 80 percent trapping efficiency as shown in **Figure 8-12**.

A basin that **is** located in a low lying area or in an area that has a high water table, has a basin ratio equal to **4.70 E3** at 80 percent trapping efficiency as shown in **Figure 8-13**.

8.7.2.2 Sediment Basin Example Problems

Given:

A sediment basin is to be constructed on a 14-acre (0.0219 mi^2) disturbed site.

Peak discharge is to be limited to that of the current land use, established grass.

A pond site is available with an area at the riser crest of 0.75 ac. Soil in the area is an Edisto.

a) Estimate the basin's trapping efficiency for a 10-year, 24-hour storm if time of concentration is approximately 20 minutes.

b) If the desired trapping efficiency is 80 percent and the eroded diameter D15 equals 0.01mm, what is the required peak discharge for basin areas of 0.33, 0.50, 0.67, 0.75 and 1.0 acres

Solution:

Part (a)

1. Estimate the peak runoff allowed. The SCS curve number is found for a hydrologic soil group C with established grass as 74. Using a 10-year, 24-hour design storm of 6.0-inches, with this curve number yields a runoff volume of 3.2-inches using the SCS curve number method.

2. Using the SCS graphical method to estimate peak flow, the I_a/P ratio computes to approximately 0.12. Combining this and an estimated time of concentration equal to 0.33 hrs yields a q_u = 650 csm/in for a Type II storm distribution.

3. The peak discharge allowed is calculated by multiplying q_u times the runoff volume times the disturbed area in mi^2 and is approximately 46 cfs.

4. D_{15} for an Edisto sub-soil 0.0128. Using this diameter, V_{15} can be estimated as 3.7E-4 ft/sec.

5. The sediment basin ratio can now be calculated by calculating

   $q_{po} / (AV_{15}) = 46 / [(0.75)(3.7E\text{-}4)] = 1.70\ E5$

6. Going to the Sediment Basin Design Aid (**Figure 8-12**) with this sediment basin ratio, read across to the curve and then turn down to the x-axis. The trapping efficiency is estimated to be **81%.**

7. If the desired trapping efficiency was not obtained, the process would need to be repeated with a larger basin or decreased discharge until the desired trapping efficiency was found.

Part (b)

1. Determine the Sediment Basin Ratio. From the Sediment Basin Design Aid (**Figure 8-12**), the ratio for a design trapping efficiency of 80 percent is **2.20 E5 ft^2/acre.**

2. Determine the ratio of qpo/A required. Substituting the results from step 1 into equation 3,

   $$Basin\ Ratio = 2.2x10^5 = q_{po}/A/V_{15}$$

3. With D15 equal 0.01 mm, the corresponding V15 is **2.8E-4 ft/sec**. Hence,

   $2.2x10^5\ V_{15} = q_{po}/A = (2.2x10^5)(2.8x10^{-4})$ = **62 cfs /acre of pond.**

4. Determine q_{po} and A values. The following results can be tabulated for the acreage shown:

   q_{po} = 62 cfs/acre * (0.33 ac.) = **20.5 cfs.**

Continuing this calculation for basin areas of 0.67 and 1.0 acres, we have:

Pond Area (acres)	q_{po} (cfs)
0.33	20.5
0.50	31.0
0.67	41.5
0.75	46.5
1.00	62.0

Each of these combinations will give the desired 80 percent trapping efficiency for the specified eroded size. The depth will depend on the expected volume of sediment to be deposited during the life of the structure.

8.7.3 Rock Ditch Check Design Aids

Design aids for rock ditch checks were developed similarly to those for ponds. Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity. The ratio for ditch checks is defined by:

The Rock Ditch Design Aids have been designed for the following soil classifications:

- Coarse (sandy loam),
- Medium (silt loam), and
- Fine (clay loam).

The design ratio should be less than or equal to the curve value at any given trapping efficiency.

8.7.3.1 Rock Ditch Check Design Aid Ratio

$$\text{Ditch Check Ratio} = \frac{Sq^{(1-b)}}{aV_{15}}$$

Where:

S = Channel slope (%),

q = Unit width flow through the check for the 10-year 24-hour storm event (cfs/ft),

V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Coefficients a and Exponent b can be interpolated from tables

Constraints for the use of Rock Ditch Check Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 15 percent
- Maximum depth of the ditch is less than or equal to 6-feet

Ditch Check Ratios above the design curves are not recommended for any application of the design aids.

If the ditch check ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A ditch check located on coarse soils has a ditch check ratio equal to **1.10 E3** at 80 percent trapping efficiency as shown in **Figure 8-14**.

A ditch check located on medium soils has a ditch check ratio equal to **5.80 E3** at 80 percent trapping efficiency as shown in **Figure 8-15**.

A ditch check located on fine soils has a ditch check ratio equal to **1.20 E4** at 80 percent trapping efficiency as shown in **Figure 8-16**.

8.7.3.2 Rock Ditch Check Example Problem

Given: A rock ditch with a channel slope of 1.0 percent is to be installed on an area having Cecil sandy loam soils. The eroded size distribution is for a medium texture soil since it is a sandy loam.

The runoff coefficient "C" for the rational method is estimated as 0.4 with an intensity of 6.75 in/hr for the design storm.

Drainage area to the ditch check is 4.4 ac.

Average rock diameter of the ditch check is 0.10 m (4 in.).

Average width (perpendicular to flow) is 6.7 ft and ditch check length is one meter (refer to Section 6.4 for procedures to calculate flow through a ditch check).

Find:

The trapping efficiency for the rock ditch check.

Solution:

A Cecil D_{15} topsoil is 0.0066 mm, and the settling velocity is found to be V_{15} = 1.2 E-4 fps.

Peak flow can be estimated from the given information by substituting into the rational formula so that

$q_p = C\ i\ A = 0.4\ (6.75)(4.4) = 11.9$ cfs

1. The flow rate should be converted to flow per unit width by dividing the peak flow by the check width to obtain the design q as

   $q = 11.9$ cfs/6.7 ft = 1.78 cfs/ft

2. Appropriate values of the coefficients a and b can be interpolated from Table 8-4.

   - Rock diameter of 0.10 m
   - Flow length of 1.0 m

   a = 4.13

b = 0.6651.

Substitute all values and calculate the ditch check ratio

$$Sq^{(1-b)} / a\, V_{15} = (1.0)(1.78^{(1-0.6651)})/(4.13)(1.2E\text{-}4) = 2448$$

3. Enter the Rock Ditch Check Design Aids for medium texture soil (**Figure 8-15**) on the y-axis with Ditch Check Ratio = 2.5E3, go to line and turn to the x-axis to read trapping efficiency.

Trapping efficiency equals **86%.**

Note: The ditch check must also be checked for overtopping since this is a common occurrence and results in total failure of the check. If the check overtops, the trapping efficiency is assumed to be zero. See Section 6.4 entitled Stage Discharge Equations for Rock Structures.

Table 8-4. Stone Flow Coefficient *a* and Exponent *b*

Stone Diameter(m)	Exponent b	Coefficient a dl= 1m	Coefficient a dl = 2m	Coefficient a dl = 3m
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

D_{50} = rock ditch check average stone diameter in meters.

***dl* = average flow length through the rock ditch check in meters.**

Source: Haan et. al. (1994) pg. 151.

8.7.4 Silt Fence Design Aids

This design aid for applies to silt fences placed in areas down slope from disturbed areas where it serves to retard flow and cause settling. Two conditions must be met for satisfactory design.

- Trapping efficiency must meet the desired level of control.
- Overtopping of the fence must not occur.

8.7.4.1 Silt Fence Design Aid Ratio

The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the ponds and rock checks. For the silt fence, the ratio is:

$$\text{Silt Fence Ratio} = \frac{q_{po}}{V_{15} P_{area}}$$

Where:

q_{po} = Peak outflow through the fence for the 10-year 24-hour storm event (cfs),
V15 = Characteristic settling velocity (fps), of the characteristic D15 eroded particle (mm),
P_{area} = Potential ponding area up slope of the fence (ft^2).

The ponding area can be estimated by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. The unit available area is calculated by multiplying the fence height by the ground slope. Multiply this unit area by the available fence length for ponding to obtain the potential ponding area.

Using the calculated ponding area, calculate the ratio and enter the value to **Figure 8-17** to determine the efficiency. Once an acceptable trapping efficiency is determined, a calculation for overtopping must be performed. The overtopping calculation must be performed using the slurry flow rate through the fence. This rate must be checked against the incoming flow to determine if enough storage exist behind the fence to prevent overtopping.

Constraints for the use of Silt Fence Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 6 percent
- Slurry flow rate through the fence is less than or equal to 10 gpm / ft
- Maximum height of the silt fence is less than or equal to 3-feet

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. If the silt fence ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A silt fence ratio equal to **0.23** has an 80 percent trapping efficiency as shown in **Figure 8-17**.

8.7.4.2 Silt Fence Example Problem

Given:

A wire-backed silt fence is to be built from 2.5 ft wide, silt fence fabric at the toe of a 2.0 percent slope draining a linear construction site.

Topography will cause runoff to drain through 400-feet of total fabric length.

Peak flow from the 1.0-acre upslope area is estimated at 2.5 cfs using the rational equation with "C" equal to 0.25 and intensity equal to 10.0 iph.

Freeboard allowance and installation will reduce the usable height of the fence from 2.5- to 1.5-feet that is usable above ground.

Slurry flow rate for the filter fabric is 10 gpm/ft^2 of fabric according to manufacturer specifications or other source.

Find:

A. The trapping efficiency if the soil is Lakeland Sand with an eroded size distribution having a D_{15} equal to 0.0463 mm.

B. The trapping efficiency if the soil is Cecil with an eroded size distribution having a D15 equal to 0.0066 mm.

Solution:

A:

1. The settling velocity of the D_{15} particle (0.0463 mm) can be estimated as V_{15} equal to 5.1 E-3 ft/sec.

2. The ponded area can be estimated using the geometry at the installation site. With a fence length of 400 ft, maximum depth equal to 1.5 ft based on the usable width of the fabric, and slope upstream of the fence equal to 2.0 percent, there will be ponded area of 75 ft^2/linear ft of fabric for a total ponded area of

   $$P_{area} = (75\ ft^2/ft)\ (400\ ft) = 30{,}000\ ft^2$$

   Based on this ponding calculation, a tie back of 75-feet is required to provide an adequate ponding area.

3. The filter fence ratio is calculated as

   $$\text{Silt Fence Ratio} = q_{po} / (V_{15}\ P_{area}) = 2.5/[(5.1E\text{-}3)(30{,}000)] = 0.017$$

4. Reading the trapping efficiency from the Silt Fence Design Aid (**Figure 8-17**) with the ratio equal to 0.017, the trapping efficiency is approximately 94 percent.

   - The fence must be checked for its ability to pass the design flow without overtopping.

5. Convert the peak flow from cfs to gpm so that

   $$q_{po} = (2.5\ ft^3/sec)(7.48\ gal/ft^3)(60\ sec/min) = 1122\ gpm$$

6. Required length of fabric to carry this flow can be found by dividing the peak flow rate by the effective height (1.5-ft) and the slurry flow rate of 10 gpm/ft2 of fabric. Hence, the length of fence required to carry the peak flow without overtopping is

   $$L = (1122)/\ (1.5)\ (10) = 75\ ft$$

7. Since 75 ft is less than the 400 ft available, the fence as designed should not overtop if it is properly maintained. Note: This analysis does not account for concentration of flows or strength of the posts, wire mesh, or fabric.

B.

1. A Cecil D_{15} topsoil is 0.0066 mm, and the settling velocity is found to be V_{15} = 1.2 E-4 fps.

2. The filter fence ratio is calculated as:
   Silt Fence Ratio = q_{po} /(V_{15} P_{area}) = 2.5/[(1.2E-4)(30,000)] = **0.70**

3. Reading the trapping efficiency from the Silt Fence Design Aid (**Figure 8-17**) with the ratio equal to 0.70, the trapping efficiency is approximately **70%.**

8.7.5 Sediment Trap Design Aids

Sediment traps, for the purposes of this document, are small excavated ponds with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure, thus the Design Aid is slightly different with the area defined as being the area at the bottom of the outlet structure. Trapping efficiencies for sediment traps are plotted in **Figure 8-18** as a function of the sediment trap ratio:

8.7.5.1 Sediment Trap Design Aid Ratio

The sediment trap design aid is a single line grouping all soil textures together. A similar procedure was used for the development of the ratio as used for basins. For the sediment trap, the ratio is:

$$\text{Sediment Trap Ratio} = \frac{q_{po}}{A\,V_{15}}$$

Where

$\mathbf{q_{po}}$	=	peak outflow for the 10-year 24-hour storm event (cfs),
A	=	surface area at the elevation equal to the **bottom** of the rock fill outlet (acres),
$\mathbf{V_{15}}$	=	characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Constraints for the use of Sediment Trap Design Aids are:

- Watershed area less than or equal to 5 acres
- Overland slope less than or equal to 20 percent
- Rock fill diameter greater than 0.2-feet and less than 0.6-feet
- Rock fill height less than 5-feet
- Top width of rock fill between 2- and 4-feet
- Maximum Side slopes 1:1 to 1.5:1.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. If the sediment trap ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A sediment trap ratio equal to **9.0 E4** has an 80 percent trapping efficiency

Storm flows shall be routed through the sediment trap to calculate the required depth and storage volume of the trap.

A sediment storage volume shall be calculated and provided below the bottom of the rock fill outlet structure.

8.7.5.2 Sediment Trap Example Problem

Given:

A sediment trap designed for a 10-year, 24-hour storm is to be constructed on a development site as a temporary sediment control measure for a 3-acre drainage area that is totally disturbed.
The outlet is to be a rock fill constructed of rock with a mean diameter of 0.5-feet.

The soil is a Cecil sandy loam, the slope of the watershed is 5 percent, and the time of concentration is 6 minutes.

a) If the desired trapping efficiency is 80 percent, what is the required peak discharge for trap areas of 0.10, 0.25, and 0.50 acres.

Solution:

1. Determine the Sediment Trap Ratio. From the Sediment Trap Design Aid (**Figure 8-18**), the ratio for a design trapping efficiency of 80 percent is 9.0E4 ft^2/acre.

2. Determine the ratio of qpo/A required from the Sediment Trap Ratio,

   $Sediment\ Trap\ Ratio = 9.0x10^4 = qpo/A*V15$

3. The D15 for a Cecil soil is 0.0066 mm, and the corresponding V15 for a Cecil sandy loam soil is 1.2E-4 ft/sec. Hence,

   $9.0x10^4\ V_{15} = qpo/A = (9.0x10^4)(1.2x10^{-4}) = 11\ cfs\ /acre\ of\ pond.$

4. Determine qpo/A values. The following results can be tabulated for the acreage shown:

Sediment Trap Bottom Area (acres)	qpo Through Rock Fill (cfs)
0.10	1.1
0.25	2.8
0.50	5.5

Each of these combinations will give the desired resulting 80 percent trapping efficiency.

The rock fill outlet structure must be designed to convey a peak flow of that shown in column two of the table above. See Section 6.4 for design details. If the check rock fill overtops, the trapping efficiency is assumed to be zero.

Storm flows shall be routed through the sediment trap to calculate the required depth and storage volume of the trap.

A sediment storage volume shall be provided below the bottom of the rock fill outlet structure.

8.8. Report Development

Specific requirements for the erosion and sediment control section of the Storm Water Management Permit Application shall include, but is not limited to the following items:

- The plans shall contain a description and location of the predominant soil types on the site.
- The plans shall show the location and delineation of vegetative covers that are not to be disturbed.
- The plans shall contain the location and dimensions of all storm water drainage and natural drainage systems on, and adjacent to the development site.
- The plans shall contain both existing and planned site topography.
- The plans shall contain the location and dimensions of all land disturbing activities.
- If applicable, the plans shall contain the potential location for soil stock-piles and the related stabilization structures or techniques for these stock piles.
- The plans shall include details, dimensions and descriptions of all temporary and permanent erosion and sediment control measures.
- Notes contained in the erosion and sediment control plan shall state that all erosion and sediment controls be inspected at least once every seven calendar days, or after any storm event the produces greater than ½-inches of rainfall during any 24-hour period.
- Notes contained in the erosion and sediment control plan shall state that when construction or land disturbance activities have temporarily ceased on any portion of a site, temporary site stabilization measures shall be required as soon as practicable, but no later than 14 calendar days after the activity has ceased.
- Notes contained in the erosion and sediment control plan shall state that final stabilization of the site shall be required within 14 calendar days of the completion of construction.
- Specifications for a sequence of construction operations shall be contained on all plans describing the relationship between the implementation and maintenance of sediment controls including permanent and temporary stabilization and the various phases of earth disturbance and construction. The specifications for the sequence of construction shall contain, at a minimum, the following:
  - Clearing and grubbing for those areas necessary for installation of perimeter controls
  - Installation of sediment basins and traps
  - Construction of perimeter controls
  - Remaining clearing and grubbing
  - Road grading
  - Grading for the remainder of the site
  - Utility installation and whether storm drains will be used or blocked until the completion of construction
  - Final grading, landscaping, or stabilization
  - Removal of sediment control structures.
- Design computation for all erosion and sediment control structures.
  - List of the trapping efficiency of each sediment control structure.
  - Calculation of required sediment storage volumes.

- Explanation of any computer models or software used with highlights of the output data.
- Description of required clean-out frequencies and maintenance schedules.