

North Carolina Department of Transportation

Level III

Design of Erosion & Sediment Control Plans

MODULE 1. Hydrology	page 7
MODULE 2. Soil Erosion	page 12
MODULE 3. Regulatory Issues	page 20
MODULE 4. Open Channel Design.....	page 21
MODULE 5. Sediment Retention BMPs	page 27
MODULE 6. Below Water Table Borrow Pits	page 30

CONVERSION FACTORS

1 acre = 43,560 ft²

1 mi² = 640 acres

1 ft³ of water = 7.48 gallons = 62.4 pounds

1 ft³/sec = 1 cfs = 448.9 gallons per minute (gpm)

1,000,000 gallons per day (1 MGD) = 695 gpm = 1.56 cfs

1 m = 100 cm = 1000 mm

SYMBOLS

MODULE 1. Hydrology

A	watershed drainage area in acres (ac)
A_{Jarrett}	Jarrett Maximum Area in acres (ac)
C	Rational Method runoff coefficient (decimal ranging from 0 to 1)
H	elevation change from most remote point to point of interest (ft)
i	rainfall intensity in inches per hour (in/hr)
L_{flow}	flow length from most remote point to point of interest (ft)
P	probability of a hydrologic event being exceeded in any year (decimal)
Q	peak runoff rate in cubic feet per second (cfs)
S	slope equal to elevation change over length (ft/ft)
T	return period for a specific hydrologic event (years)
t_c	time of concentration in minutes (min)

MODULE 2. Erosion

A_{erosion}	annual soil interrill + rill erosion in tons per acre per year (tons/ac-yr),
C_{ditch}	regression constant for secondary roads dependent on ditch side slopes
CP	conservation practices factor (dimensionless)
K	soil erodibility factor (dimensionless)
LS	slope-length factor (dimensionless)
R	rainfall factor (dimensionless)
S_{ditch}	slope of secondary road ditch (ft/ft)
V_{ditch}	secondary road sediment volume expected in cubic feet per acre (ft ³ /ac)

MODULE 4. Open Channel Design

τ	average tractive force acting on the channel lining (lbs/ft ²),
γ	unit weight of water, assumed to be 62.4 lbs/ft ³ ,
d_{chan}	depth of flow in the channel (ft),
S_{chan}	slope of the channel (ft/ft).

MODULE 5. Sediment Retention BMPs

A_{basin}	surface area of a sediment retention basin in square feet (ft ²)
D_{orifice}	diameter of the skimmer orifice in inches (in)
H_{skim}	driving head at the skimmer orifice from Table 5.1 in feet (ft)
Q_{skim}	basin outflow rate in cubic feet per day (ft ³ /day)
t_{dewater}	dewatering time for a BMP (days)
V_{basin}	volume of a sediment retention basin in cubic feet (ft ³)
V_{skim}	basin volume to be dewatered in cubic feet (ft ³)

MODULE 6. Below Water Table Borrow Pits

V_{still}	volume of stilling basin in cubic feet (ft ³)
Q_{still}	pumping rate entering the stilling basin in gallons per minute (gpm)

Soils Prone to Flooding in North Carolina Counties (Not for Infiltration Basins)

Anson

Chewacla (ChA)
Chewacla and Chastain
(CmA)
Johnston (JoA)

Beaufort

Currituck (Cu)
Dorovan (Do)
Muckalee (Me)

Bertie

Bibb and Johnston (Bb)
Chewacla (Ch)
Dorovan (Dk)
Roanoke (Ro)
Wehadkee (WE)

Bladen

Congaree (Cn)
Croatan (CT)
Dorovan (DO)
Johnston (JO)
Pamlico (PC)
Wilbanks (WN)

Brunswick

Bohicket (BO)
Carteret (CA)
Chowan (CH)
Dorovan (DO)
Longshoal (LA)
Muckalee (Mk)

Camden

Chowan (CwA)
Dorovan (DoA)
Gertie (GtA)

Carteret

Carteret (CH, CL)
Deloss (Dm)
Dorovan (Do)
Duckston (Du)

Lafitte (LF)
Masontown (MA)

Chowan

Chowan (CO)
Dorovan (DO)

Columbus

Brookman (Br)
Dorovan (Do)
Meggett (Me)
Muckalee (Mk)
Wilbanks (Wn)

Craven

Dorovan (Do)
Lafitte (LF)

Cumberland

Chewacla (CH)
Johnston (JT)

Currituck

Currituck (Cu)
Dorovan (Do)

Dare

Carteret (CeA)
Currituck (CuA)
Hobonny (HoA)

Duplin

Bibb and Johnston (BbA)
Muckalee (MkA)

Edgecombe

Chewacla (Cc)
Johnston (JS)
Meggett (Me)
Wehadkee (Wh)

Franklin

Chewacla and Wehadkee
(ChA)

Riverview and Buncombe
(RmA)
Wehadkee (WvA)

Gates

Chowan (ChA)
Dorovan (DoA)
Nawney (NaA)

Greene

Bibb (Bb)
Johnston (JS)
Kinston (KN)

Halifax

Chastain and Bibb (CbA)
Chewacla and Wehadkee
(CwA)

Harnett

Bibb (Bb)
Polawana (Pn)
Wehadkee (Wh0)

Hertford

Bibb and Johnston (BB)
Dorovan (DO)
Wehadkee (We)
Wilbanks (WN)

Hoke

Chewacla (Ch)
Johnston (JT)

Hyde

Backbay (BaA)
Carteret (CaA)
Delway (DeA)
Dorovan (DoA)
Engelhard (EnA)
Longshoal (LfA)
Newholland (NhA)
Weeksville (WkA)

Jones

Hobonny (Ho)
Muckalee (Mk)

Lee

Chewacla (Ch)
Congaree (Cp)
Wehadkee (Wn)

Lenoir

Bibb (Bb)
Chewacla (Ch)
Johnston (JS)
Kinston (Kn)
Pamlico (Pc)

Martin

Bibb (Bb)
Chastain (Ch)
Dorovan (Do)
Roanoke (Ro)

Montgomery

Bibb (BhA)
Chastain (CkA)
Chenneby (CnA)
Johnston (JoA)
Oakboro (OKA)

Moore

Bibb (Bb)
Chewacla (Ch)
Congaree (Co)
Wehadkee (We)

Nash

Bibb (Bb)
Congaree (Co)
Meggett (Me)
Wehadkee (Wh)

New Hanover

Dorovan (Do)
Johnston (JO)
Pamlico (Pm)
Bohicket (TM)

Northampton

Chastain and Bibb (CbA)
Chewacla and Wehadkee
(CwA)

Onslow

Bohicket (Bo)
Carteret (Ca)
Dorovan (Da)
Masontown (Md)
Muckalee (Mk)

Pamlico

Brookman (Bm)
Hobucken (HN)
Lafitte (LF)
Masontown (MA)
Stockade (Sm)

Pasquotank

Chowan (CwA)
Dorovan (DoA)
Hobonny (HoA)

Pender

Bohicket (Bo)
Carteret (Ca)
Chewacla (Ch)
Meggett (Me)
Muckalee (Mk)

Perquimans

Chowan (CO)
Dorovan (DO)

Pitt

Bibb (Bb)
Cape Fear (Ca)
Leaf (Le)
Pantego (Pg)
Rains (Ra)
Swamp (Sw)

Richmond

Chewacla (ChA)

Johnston (JmA)

Robeson

Bibb and Johnston (BB)
Johnston (JT)
Meggett (Me)
Osier (Pm)

Sampson

Bibb and Johnston (BH)
Johnston (JT)
Pamlico (Pm)

Scotland

Bibb (BaA)
Johnston (JmA)

Tyrrell

Chowan (Ch)
Dorovan (Do)

Wake

Buncombe (BuB)
Chewacla (CmA)
Congaree (CoA)
Wehadkee (WnA)

Warren

Chewacla and Wehadkee
(ChA)

Washington

Dorovan (Do, Dr)
Muckalee (Me)

Wayne

Chewacla (Ch)
Johnston (Js)
Kinston (Kn)
Pamlico (Pa)

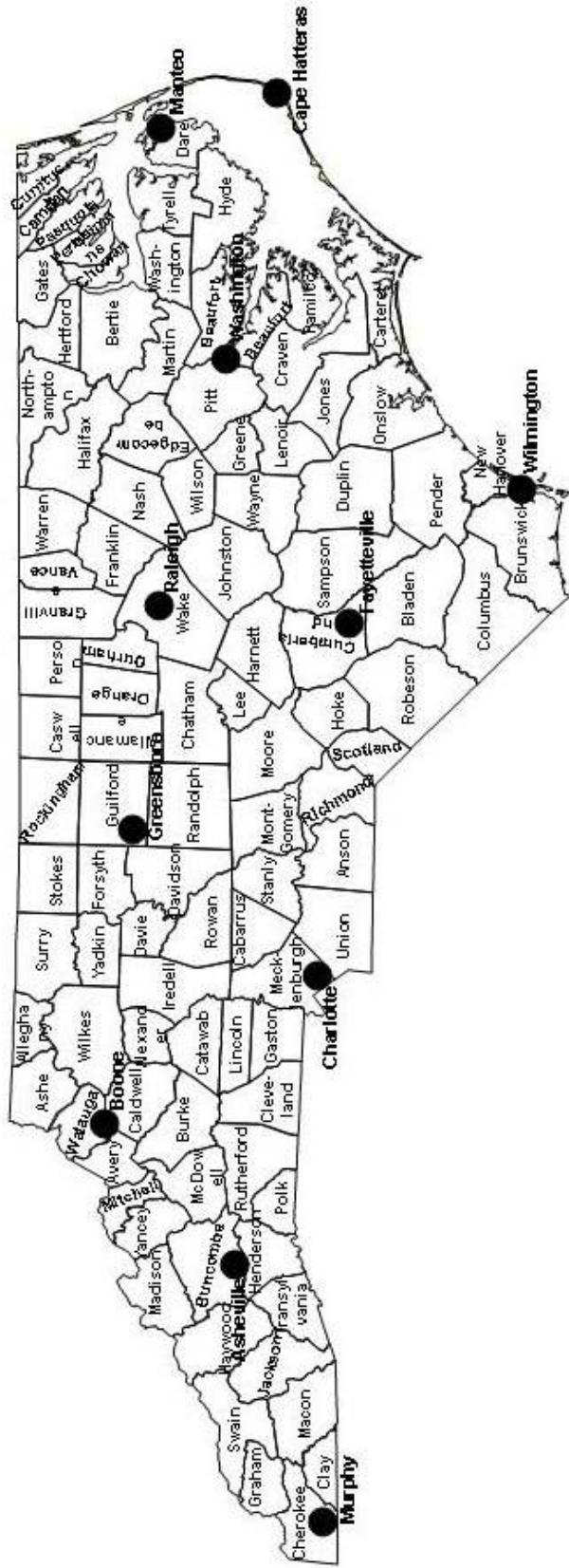
Wilson

Bibb (Bb)
Wehadkee and Chewacla
(Wh)
Wilbanks (Wk)

Table 1. BMP Selection

BMP	Location	Catchment	Structure	Sed. Ctl. Stone	Surface Area	Volume	Function
T. Rock Sed. Dam A	Swale/large ditch	< 1 ac.	Class I	Yes	435Q ₁₀	3600 ft ² /ac	Remove sand
T. Rock Sed. Dam B	Drainage outlet	< 1 ac.	Class B	Yes	435Q ₁₀	3600 ft ² /ac	Remove sand
Silt Basin B	Drainage outlet/ Adjacent to inlet	< 3 ac.	Earth	No	435Q ₁₀ (325Q ₁₀ @ inlets)	3600 ft ² /ac (1800 ft ² /ac @ inlets)	Remove sand
Skimmer Basin	Drainage outlet	< 10 ac.	Earth	No	325Q ₁₀	1800 ft ² /ac	Remove sand
Infiltration Basin	Drainage outlet	< 10 ac.	Earth	No	325Q ₁₀	1800 ft ² /ac	Remove sand
Riser Basin(non-perforated riser w/ skimmer)	Drainage outlet	< 100 ac.	Earth	No	435Q ₁₀	1800 ft ² /ac	Remove silt, clay
Stilling Basin/Pumped	Near Borrow Pit/Culvert	N/A	Earth and Stone	No	2:1 L:W ratio	Based on dewatering	Remove silt, clay
Sp. Stilling Basin(Silt Bag)	Near stream	N/A	Filter Fabric	Yes	N/A	Variable	Remove sand
Rock Pipe Inlet Sed. Trap A	Pipe inlet	< 1 ac.	Class B	Yes	N/A	3600 ft ² /ac	Remove sand
Rock Pipe Inlet Sed. Trap B	Pipe inlet	< 1 ac.	Class A	Yes	N/A	3600 ft ² /ac	Remove sand
Slope Drain w/ Berm	Fill Slopes	< 1/2 ac.	12-inch pipe	No	N/A	N/A	Convey concentrated runoff
Rock Inlet Sed. Trap A	Stormwater Inlet	< 1 ac.	Class B	Yes	N/A	3600 ft ² /ac	Remove sand
Rock Inlet Sed. Trap B	Stormwater Inlet	< 1 ac.	Class A	Yes	N/A	3600 ft ² /ac	Remove sand
Rock Inlet Sed. Trap C	Stormwater Inlet	< 1 ac.	1/4" wire mesh	Yes	N/A	N/A	Remove sand
T. Rock Silt Check A	Drainage outlet	< 1 ac.	Class B	Yes	435Q ₁₀	3600 ft ² /ac	Remove sand
T. Rock Silt Check B	Channel	< 1/2 ac.	Class B	No	N/A	N/A	Reduce flow velocity
Temporary Earth Berm	Project perimeter	< 5 ac.	Earth	No	N/A	N/A	Divert offsite runoff
Temporary Silt Fence	Bottom of slope	< 1/4 acre per 100 feet <2%*	Silt fence	No	N/A	N/A	Create small basin; Remove sand, silt
Special Sediment Control Fence	Bottom of slope	< 1/2 ac.	1/4" wire mesh	Yes	N/A	N/A	Remove sand
Temporary Silt Ditch	Bottom of slope	< 5 ac.	Earth	No	N/A	N/A	Carry sediment/water
Temporary Diversion Earth Berm	Project & Stream perimeter	< 5 ac.	Earth	No	N/A	N/A	Divert turbid water
Clean Water Diversion Construction Entrance	Project perimeter Exit to road	<5 ac. N/A	Earth & Fabric Class A	No	N/A	N/A	Divert clean or turbid water
Safety Fence	Permitted Areas	N/A	Orange fence	No	N/A	N/A	Divert clean water Clean truck tires
Borrow Pit Dewatering Basin	Adjacent to Borrow Pits	N/A	Earth	No	N/A	N/A	Define permitted boundary Remove Sand and reduce turbidity
Wattle/Coir Fiber Wattle	Channel	< 1/2 ac.	Natural Fibers	No	N/A	N/A	Incorporate PAM
Silt Check A with Matting and PAM	Channel	< 1/2 ac.	Class B	Yes	N/A	N/A	Reduce flow velocity and incorporate PAM

*Contributing land slope must be <2%



Locations of NC DOT Regional Offices.

MODULE 1. Hydrology

Hydrology is the study of water movement through the water cycle. The peak runoff/discharge rate in response to rainfall is required to design erosion and sediment control best management practices (BMPs). The rainfall-runoff relationship for a watershed is shown in Figure 1.1, including a hydrograph showing runoff rate in relation to time. During a rainfall event, the runoff rate increases as more land produces runoff water. As rainfall continues, more remote land areas contribute runoff, and eventually the entire watershed produces runoff at the time of concentration, t_c , producing the peak runoff rate, Q .

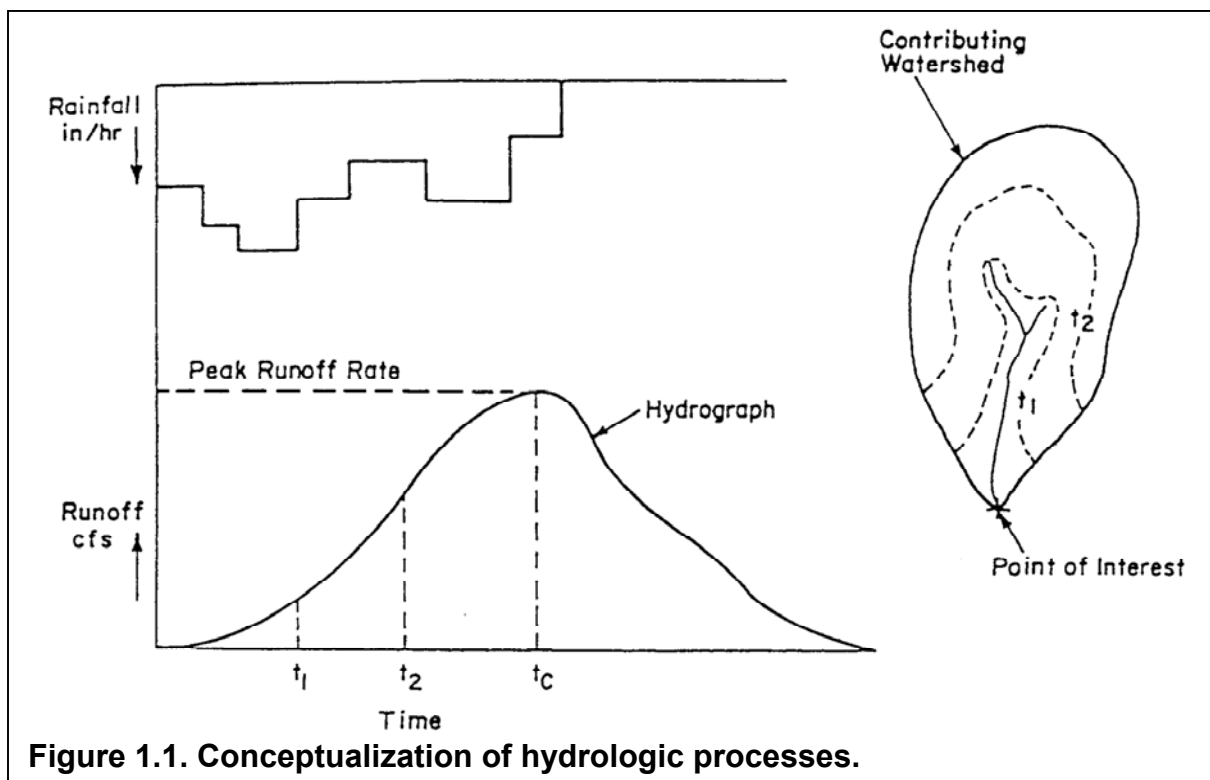


Figure 1.1. Conceptualization of hydrologic processes.

Rational Method for Estimating Peak Runoff Rate

The Rational Method (Water Pollution Control Federation, 1969) for predicting peak runoff rate is appropriate for designing small structures and channels in small watersheds:

$$Q = (C) (i) (A) \quad \text{(Equation 1.1)}$$

where:

- Q = peak runoff rate for a given return period in cubic feet per second (cfs),
- C = Rational Method runoff coefficient (decimal ranging from 0 to 1),
- i = rainfall intensity for a given return period in inches per hour (in/hr), and
- A = watershed drainage area in acres (ac).

Long-term records of rainfall and runoff at a specific location can be used to estimate the probability of a certain hydrologic event being exceeded in any year and the return period for a specific hydrologic event:

$$T = 1 / P \quad \text{(Equation 1.2)}$$

where:

P = probability of a hydrologic event being exceeded in any year (decimal), and
T = return period for a specific hydrologic event (years).

Most erosion control structures are designed for 10-year or 25-year return periods, which have 0.1 and 0.04 probabilities of being exceeded each year, respectively.

Time of Concentration

The time of concentration, t_c , is defined by USDA-NRCS (1986), as the time required for runoff water to travel from the watershed's most remote point to the point-of-interest. Many methods can be used to estimate t_c (Kirpich, 1940; USDA-SCS, 1972b; USDA-SCS, 1986). The most conservative design approach is to use the lowest predicted t_c in sizing a basin since it will result in the highest design rainfall intensity and largest basin size.

Jarrett Method for Small Drainage Areas

Jarrett (2005) determined that time of concentration, t_c , is approximated as 5 minutes for watersheds smaller than the Jarrett Maximum Area based on watershed slope:

$$S = H / L_{\text{flow}} \quad \text{(Equation 1.3)}$$

where:

S = average watershed slope (ft/ft),
H = elevation change from most remote point to point of interest (ft), and
 L_{flow} = flow length from most remote point to point of interest (ft).

$$A_{\text{Jarrett}} = 460 (S) \quad \text{(Equation 1.4)}$$

where:

A_{Jarrett} = Jarrett Maximum Area in acres (ac), and
S = average watershed slope (ft/ft).

Example: For a watershed drainage area of 5 acres with an elevation drop of 10 ft over a flow length of 500 ft, what is the average slope and the Jarrett Maximum Area?

Slope, $S = H / L_{\text{flow}} = 10 / 500 = 0.02 \text{ ft/ft}$

Jarrett Max Area, $A_{\text{Jarrett}} = 460 (0.02) = 9.2 \text{ acres}$

Since the watershed drainage area of 5 acres < 9.2 acres, then use $t_c = 5 \text{ minutes}$.

NRCS Segmental Method

For watersheds larger than the Jarrett Maximum Area, an appropriate method for estimating t_c is the NRCS Segmental Method (USDA-SCS, 1986). This method is based on the premise that runoff from the most remote point will travel as sheet flow, then become shallow concentrated flow as it travels over the longest path, and finally enter a channel where Manning's equation describes flow hydraulics. Since most of a small watershed's flow path is best classified as shallow concentrated flow, it is appropriate to use the following equations for estimating t_c based on slope and flow length:

$$\text{Unpaved Areas:} \quad t_c = 0.001 (L_{\text{flow}}) / S^{0.53} \quad (\text{Equation 1.5})$$

$$\text{Paved Areas:} \quad t_c = 0.0008 (L_{\text{flow}}) / S^{0.53} \quad (\text{Equation 1.6})$$

where:

t_c = time of concentration in minutes (min),

L_{flow} = flow length from most remote point to point of interest (ft),

S = average watershed slope (ft/ft).

Example: For a construction site watershed drainage area of 10 acres with an elevation drop of 14 ft over a flow length of 1000 ft, estimate time of concentration.

$$\text{Slope, } S = H / L_{\text{flow}} = 14 / 1000 = 0.014 \text{ ft/ft}$$

Assume that the area is unpaved, therefore use Equation 1.5:

$$t_c = L_{\text{flow}} * 0.001 / (S^{0.53}) = 1000 * 0.001 / (0.014^{0.53}) = 9.7 \text{ minutes}$$

Round to nearest whole number $t_c = 10$ minutes.

If the elevation drop for this site was 30 ft, the calculated value for t_c would be 6.6 minutes. In that case, use a t_c value of 5 minutes for determining rainfall intensity since the lower t_c produces a higher rainfall intensity and a more conservative estimate of peak runoff rate and basin size.

Precipitation Data

The rainfall intensity data required to predict runoff rates using the Rational Method are available on the National Weather Service web site and summarized in Table 1.1:

http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html

Table 1.1. Rainfall Intensity Data for North Carolina for the Rational Method.

T (Yrs)	5 min	10 min	15 min	30 min	60 min
Murphy					
10	6.40	5.12	4.32	3.13	2.04
25	7.41	5.90	4.99	3.69	2.46
Asheville					
10	6.96	5.57	4.70	3.40	2.22
25	8.03	6.40	5.41	4.00	2.67
Boone					
10	7.34	5.87	4.95	3.59	2.34
25	8.43	6.72	5.68	4.20	2.80
Charlotte					
10	7.19	5.74	4.85	3.51	2.29
25	8.00	6.37	5.38	3.99	2.65
Greensboro					
10	6.80	5.44	4.59	3.32	2.16
25	7.46	5.94	5.02	3.72	2.48
Raleigh					
10	6.97	5.58	4.70	3.41	2.22
25	7.72	6.16	5.20	3.85	2.56
Fayetteville					
10	7.84	6.27	5.29	3.83	2.49
25	8.86	7.05	5.96	4.41	2.94
Wilmington					
10	9.60	7.68	6.48	4.69	3.05
25	10.91	8.70	7.35	5.44	3.62
Washington					
10	8.04	6.43	5.43	3.93	2.56
25	9.13	7.28	6.15	4.56	3.03
Manteo					
10	8.23	6.59	5.55	4.02	2.62
25	9.35	7.45	6.29	4.66	3.10

Rational Method Runoff Coefficient, C

The watershed characteristics affecting peak runoff rate are summarized in the runoff coefficient, C, a dimensionless parameter between 0.0 and 1.0. The value of C depends on soil infiltration rate, land use, and land slope. Sandy soils with rapid infiltration have low C values, while clay soils with slow infiltration have higher C values. Vegetation increases water infiltration, resulting in lower C values. For construction sites, land conditions are similar to disturbed agricultural watersheds. Table 1.4 summarizes typical C values based on soil texture, land use, and slope.

Table 1.2. Rational Method C for Agricultural Areas (Schwab et al, 1971).

Vegetation Slope	Runoff Coefficient, C		
	Sandy Loam ¹	Clay & Silt Loam ²	Tight Clay ³
Forest			
0-5% slope	0.10	0.30	0.40
5-10% slope	0.25	0.35	0.50
10-30% slope	0.30	0.50	0.60
Pasture			
0-5% slope	0.10	0.30	0.40
5-10% slope	0.16	0.36	0.55
10-30% slope	0.22	0.42	0.60
Cultivated			
0-5% slope	0.30	0.50	0.60
5-10% slope	0.40	0.60	0.70
10-30% slope	0.52	0.72	0.82

¹Equivalent to Soil-Cover-Complex Hydrologic Soil Group A

²Equivalent to Soil-Cover-Complex Hydrologic Soil Group B and C

³Equivalent to Soil-Cover-Complex Hydrologic Soil Group D

If a watershed has more than one soil type with multiple land uses and slopes, it is necessary to determine the weighted average runoff coefficient that represents variability.

Example: Determine the weighted average runoff coefficient, C, for a 4-acre watershed with 1 acre of grassy field on clay soil at 3% slope and 3 acres of active construction on clay soil at a 4% slope.

Land Use	A	C	(A) (C)
Pasture	1	0.40	0.40
Bare soil	3	0.60	1.80
	sum = 4 ac		sum = 2.20

Weighted Runoff Coefficient: $C = 2.20 / 4 = 0.55$

For this example, estimate Q if rainfall intensity, $i = 5.80$ in/hr:

$$Q = (C) (i) (A) = (0.55) (5.80) (4) = 12.8 \text{ ac-in/hr} = 12.8 \text{ cfs}$$

MODULE 2. Soil Erosion

Erosion is defined as the process by which soil particles are detached and transported to a new location. Detachment is the breaking free of soil particles, caused by:

- Raindrops hitting the soil surface,
- Flow of water over the soil surface that can lift and detach particles,
- Movement of wind over the soil surface,
- Breaking of rock and soil aggregates caused by freezing and thawing,

After soil particles have been detached, they may be transported by various methods:

- Water flowing over the area where detached soil particles exist,
- Wind blowing over the area where detached particles exist,
- Raindrops impacting the surface and splashing detached soil to a new location, or

Splash erosion is the movement of soil that occurs when a raindrop impacts the exposed soil surface. The kinetic energy of a falling raindrop is dependent upon the drop's diameter and the velocity at which it impacts the soil. The greatest impact of splash erosion is its ability to detach soil particles.

Interrill Erosion is the erosion that occurs as a result of raindrop energy and a thin sheet flow of runoff. As soon as the rainfall rate exceeds the soil's infiltration rate, runoff begins flowing downslope as a thin sheet and carrying with it soil particles that have been dislodged.

Rill Erosion occurs when the runoff water from interrill areas enters small channels called rills. Rills are usually linear and are oriented in a direction perpendicular to the contour (straight down the hill). As the flow moves down slope, rills tend to grow deeper and wider until small channels are visible. Typically, rills are small enough to be removed by tillage operations.

Gully Erosion occurs in channels that cannot be eliminated by tillage operations. The erosion process in gullies or gully erosion is similar to rill erosion in that soil particles are detached by the shear forces of water flowing in the gully. Gully erosion is also often enhanced by sloughing and headcuts.

Channel Erosion is the detachment and transport of soil particles from the walls and sides of a channel usually by the shearing force of water and sediment, generally on a larger scale than gully erosion. Sloughing of banks may also contribute to channel erosion.

Factors Influencing Erosion

The primary driving force of erosion on upland land areas is precipitation. Rainfall amount and intensity, both of which contribute to the energy of detachment, varies by location and

time of year. Soil characteristics affect soil erodibility. Clay particles are cohesive and difficult to detach, but are easily transported long distances. Silty soils are generally well-aggregated, but large aggregates often fall apart when wetted resulting in small aggregates and individual soil particles, which are more easily transported. Sand-sized soil particles, because of their relatively large size, are difficult to transport even though they are easily detached. Land shape affects erosion potential as typically the steeper the land slope and the longer the length-of-slope the greater is the erosion potential. Land use and conservation practices affect the potential for erosion.

Predicting Soil Erosion

USDA-ARS developed the Revised Universal Soil Loss Equation (RUSLE) to estimate the long-term annual erosion potential on agricultural land. The equation is based on four factors affecting soil erosion potential:

$$A_{\text{erosion}} = (R) (K) (LS) (CP) \quad (\text{Equation 2.1})$$

where:

- A_{erosion} = annual soil interrill + rill erosion in tons per acre per year (tons/ac-yr),
- R = rainfall factor (dimensionless),
- K = soil erodibility factor (dimensionless),
- LS = slope-length factor (dimensionless),
- CP = conservation practices factor (dimensionless).

Rainfall Factor, R is a measure of the erosive forces of rainfall for an area. It is based on a combination of rainfall intensity and accumulation. Annual R values for North Carolina are shown in Figure 2.1. However, because construction projects often do not last a year, it is necessary to compute partial-year R values. Partial-year R values are shown in Table 2.1. The partial-year R factor can be computed by summing the monthly values in Table 2.1

Table 2.1. Partial-Year Cumulative R Distributions (Renard et al, 1993).

Month	Geographic Region, Figure 2.2	
	110 & 116	117
Jan	0.03	0.02
Feb	0.04	0.02
Mar	0.05	0.03
Apr	0.06	0.04
May	0.07	0.06
Jun	0.11	0.14
Jul	0.20	0.23
Aug	0.21	0.20
Sep	0.11	0.15
Oct	0.05	0.06
Nov	0.04	0.03
Dec	0.03	0.02

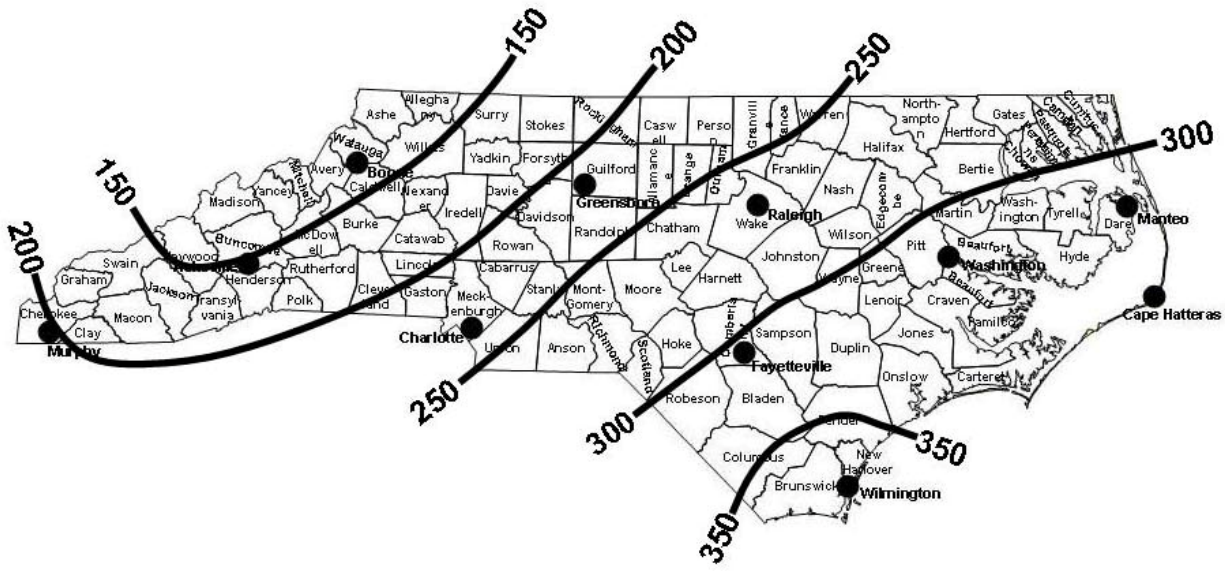


Figure 2.1. Annual Rainfall Factor, R, for North Carolina.

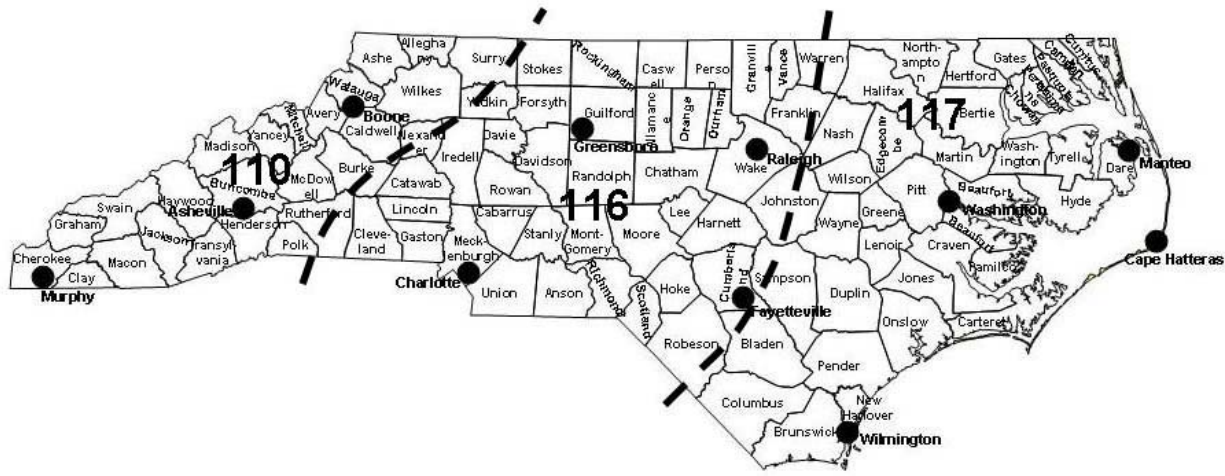


Figure 2.2. Regions for Determining Partial-Year R Values.

- Soil Erodibility Factor, K** is related to soil properties (Wischmeier et al, 1971):
- Percent silt (MS; 0.002 to 0.05 mm) and very fine sand (VFS; 0.05 to 0.1 mm),
 - Percent sand (SA; 0.1 to 2 mm),
 - Percent organic matter (OM),
 - Soil structure (S_1), and
 - Soil permeability (P_1).

These soil parameters have been used to determine K values for most soils as listed in Table 2.2 and in other references such as Table 8.01d (NCDENR, 2006).

Table 2-2. Hydrologic Soil Group (HSG), Permeability, K and T values.

Soil Series	HSG	Permeability in/hr	RUSLE T	B-Horizon		
				RUSLE K(A)	RUSLE K(B)	RUSLE K(C)
Ailey	B	0.6 to 2.0	2	0.15	0.24	0.24
Appling	B	0.6 to 2.0	4	0.24	0.28	0.28
Autryville	A	2.0 to 6.0	5	0.10	0.10	0.10
Badin	B	0.6 to 2.0	3	0.15	0.24	0.15
Belhaven	D	0.2 to 6.0	--	--	0.24	0.24
Cecil	B	0.6 to 2.0	4	0.24	0.28	--
Centenary	A	6.0 to 20.0	5	0.10	0.10	0.10
Chastain	D	0.06 to 0.2	4	0.28	0.37	--
Chewacla	C	0.15 to 0.24	5	0.28	0.32	0.28
Cowee	B	0.6 to 2.0	3	0.28	0.28	0.28
Creedmoor	C	0.2 to 0.6	3	0.28	0.32	0.32
Emporia	C	3.0 to 6.0	5	0.28	0.17	0.28
Evard	B	0.6 to 2.0	5	0.24	0.24	0.24
Fannin	B	0.6 to 2.0	3	0.32	0.32	0.32
Goldsboro	B	0.6 to 2.0	3	0.20	0.24	0.24
Goldston	C	2.0 to 6.0	2	0.15	0.05	--
Gritney	C	0.06 to 0.2	3	0.32	0.32	0.20
Helena	C	0.06 to 0.2	4	0.24	0.28	
Hiwassee	B	0.6 to 2.0	5	0.28	0.28	0.28
Hyde	B/D	0.2 to 0.6	5	0.17	0.43	--
Johnston	D	1.25 to 1.45	5	0.17	0.17	--
Lynn Haven	B/D	1.35 to 1.6	5	0.10	0.15	--
Madison	B	0.6 to 2.0	3	0.28	0.32	0.32
Mayodan	B	0.6 to 2.0	4	0.24	0.32	0.28
Norfolk	B	1.30 to 1.75	5	0.17	0.24	--
Pacolet	B	0.12 to 0.16	3	0.15	0.28	0.28
Polkton	D	1.15 to 1.60	2	0.37	0.37	0.37
Portsmouth	B/D	0.6 to 2.0	5	0.24	0.28	0.17
Rains	B/D	1.30 to 1.60	5	0.20	0.24	--
Rion	B	0.6 to 2.0	3	0.24	0.24	0.24
Roanoke	D	< 0.02	4	0.37	0.24	0.24
Roper	B/D	0.16 to 0.46	--	--	0.43	0.43
State	B	0.6 to 2.0	5	0.28	0.28	0.17
Tatum	B	1.10 to 1.60	4	0.37	0.28	--
Tomotley	A	0.6 to 2.0	5	0.20	0.20	0.20
Torhunta	C	1.35 to 1.60	5	0.10	0.15	0.10
Vance	C	0.06 to 0.2	3	0.24	0.28	--
Wakulla	B/D	0.4 to 1.6	5	0.10	0.10	0.10
Wedowee	B	0.6 to 2.0	3	0.24	0.28	0.28
Weeksville	B/D	0.6 to 2.0	5	0.43	0.32	--
White Store	D	0.06 to 0.6	3	0.37	0.37	0.32
Woodington	A	0.6 to 2.0	5	0.10	0.20	0.10

Length-Slope Factor, LS is a single factor based on average land slope and the length of the uninterrupted slope over which water flows. The LS value is determined from Figure 2.3 for a known slope length and slope in %. For example, a slope length of 300 ft with slope of 0.05 ft/ft (5%) produces an LS value of 1.3.

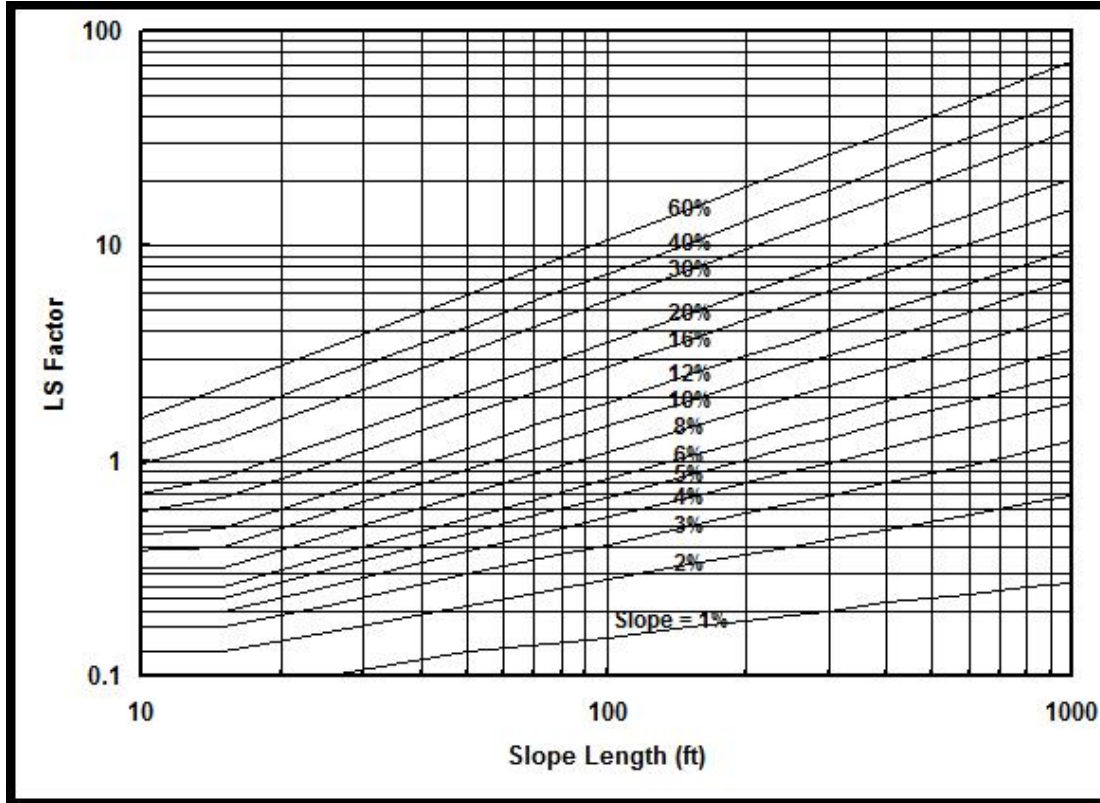


Figure 2.3. LS factors for construction and mining site land uses that have a high ratio of rill to interrill erosion. (Adapted from Renard et al., 1997).

Conservation Practice Factor, CP accounts for the influences of protective vegetation and plant roots on erosion processes. The variations in earth-moving activities and their influence on erosion potential are shown in Table 2.3.

Table 2.3 CP Values for Earth Disturbance Sites.

Bare soil condition	CP
Fill	
Packed, smooth	1.00 a
Fresh disked	0.95 a
Rough (offset disk)	0.85 a
Cut	
Loose to 12 inches, smooth	0.90 b
Loose to 12 inches, rough	0.80 b
Compacted by bulldozer	1.00 b
Compacted by bulldozer and tracked parallel to the contour	0.50 c
Rough, irregular tracked all directions	0.90 b

Surface Condition with No Cover	
Compact and smooth, scraped w/ bulldozer or scraper up / down hill	1.3 d
Compact and smooth, raked w/ bulldozer root rake up and down hill	1.2 d
Compact and smooth, scraped w/bulldozer or scraper across slope	1.2 d
Compact and smooth, raked w/bulldozer root rake across slope	0.9 d
Loose as a disked plow layer	1.0 d
Ryegrass (perennial type)	0.05 d
Small Grain	0.05 d
Sod (freshly placed)	0.08 b
Hay (1.0 tons/acre)	0.13 d
Hay (2.0 tons/acre)	0.02 d
Straw, 1 ton/acre, 69% cover when placed, 50% cover at 3 months	0.24 a
Straw, 2 tons/acre, 91% cover when placed, 84% cover at 3 months	0.10 a
Wood chips (2.0 tons/acre)	0.70 e
Wood chips (4.0 tons/acre)	0.42 e
Bark mulch (25 tons/acre of 2.5-in chips)	0.06 c
Stone (200 tons/acre)	0.21 b
Stone (400 tons/acre)	0.10 b

a. Adapted from Toy and Foster, 1998.

b. Adapted from Israelson et al. (1980).

c. Adapted from Jarrett et al. (1984).

d. Adapted from USDA-NRCS, Connecticut Technical Guide

e. Transportation Research Board (1980)

Example: Estimate erosion from a 5-acre site in Raleigh during March-May with R = 49. The site is 600 ft long with elevation drop of 48 ft, and soil type is Creedmoor.

Average slope = $48 / 600 = 0.08$ ft/ft (8% slope)

Table 2.2: K value is 0.32 (assume B Horizon – subsoil)

Figure 2.3: LS value is 3.5 (slope length = 600 ft; slope = 8%)

Table 2.3: CP value is 1.0 (assume loose surface with no cover)

Erosion per acre = $(49) (0.32) (3.5) (1.0) = 54.4$ tons/acre (3 months, March-May)

Total erosion for 5 acres = $(54.4) (5) = 272$ tons during the 3-month period

If the construction period is July-September (partial-year R = 140):

Erosion per acre = $(140) (0.32) (3.5) (1.0) = 157$ tons/acre (3 months, Jul-Sep)

Total erosion for 5 acres = $(157) (5) = 786$ tons during the 3-month period

Erosion Volume Estimates from Secondary Roads

Based on the RUSLE2 analysis results, following is a shortcut equation that estimates the eroded sediment volume expected from secondary roads based on a 30-foot roadway including the road ditch:

$$V_{\text{ditch}} = (C_{\text{ditch}}) (R) (K) (S_{\text{ditch}}) \quad \text{(Equation 2.2)}$$

where:

V_{ditch} = secondary road sediment volume expected in cubic feet per acre (ft³/ac),
 C_{ditch} = regression constant for secondary roads dependent on ditch side slopes,
 R = Rainfall Factor for the duration of construction,
 K = Soil Erodibility Factor (B or C horizon, whichever is higher),
 S_{ditch} = slope of secondary road ditch (ft/ft).

The values of C_s are determined using Table 2.4 depending on road ditch side slope.

Table 2.4. Regression Constant, C_{ditch} to be used in Equation 2.2.

Ditch Side Slope	Constant C_{ditch}
4:1	291
3:1	399
2.5:1	467
2:1	549
1.5:1	659
1:1	808

Example: Estimate erosion volume from a 2-acre secondary roadway construction during June-July in Carteret County with Goldsboro soil. The road ditch has a slope of 0.05 ft/ft and 2:1 side slopes.

Figures 2.1 and 2.2: Annual R = 340, and Carteret County is in Region 117.

Table 2.1: During June-July, partial-year R = (0.14 + 0.23) (340) = 126

Table 2.2: K value is 0.24 (assume B Horizon – subsoil)

Table 2.4: C_{ditch} is 549 for 2:1 ditch side slopes

$V_{\text{ditch}} = (549) (126) (0.24) (0.05) = 830$ cubic ft per acre (Jun-Jul)

Total erosion for 2 acres = (830) (2) = 1,660 cubic ft (Jun-Jul)

To convert to cubic yards: Erosion = 1,660 / 27 = 61 cubic yards

MODULE 3. Regulatory Issues

The North Carolina Department of Transportation is regulated by many different environmental laws and regulations. Current requirements are posted on the NCDOT web site:

<http://ncdot.gov/doh/operations/dp%5Fchief%5Feng/roadside/fieldops/>

The current NC DENR Division of Water Quality General Permit NCG010000 to discharge stormwater under the NPDES for Construction Activities is effective August 3, 2011 to July 31, 2016. A critical part of this permit is the ground cover stabilization requirement as outlined in the table below.

Site Area Description	Time Frame	Stabilization Time Frame Exceptions
Perimeter dikes, swales, ditches and slopes	7 days	None
High Quality Water (HQW) Zones	7 days	None
Slopes steeper than 3:1	7 days	If slopes are 10 ft or less in height and are not steeper than 2:1, then 14 days are allowed
Slopes 3:1 or flatter	14 days	7-days for slopes greater than 50 feet in length
All other areas with slopes flatter than 4:1	14 days	None (except for perimeters and HQW Zones)

MODULE 4. Open Channel Design

Open channel flow occurs due to gravity in natural water courses, channels, diversions, and culverts. Two limiting criteria for designing stable open channels are velocity and tractive force (sometimes termed shear stress). Both parameters increase with channel slope and depth of water. The basic design approach is to calculate the maximum allowable velocity and/or tractive force and then establish a liner that can withstand the minimum design parameters and will not erode. This module will focus on tractive force as the limiting criteria for open channel design on construction sites.

Tractive force, τ , is a measure of the frictional resistance to flow in a channel and is calculated using:

$$\tau = (\gamma) (d_{\text{chan}}) (S_{\text{chan}}) \quad \text{(Equation 4.1)}$$

where:

- τ = average tractive force acting on the channel lining (lbs/ft²),
- γ = unit weight of water, assumed to be 62.4 lbs/ft³,
- d_{chan} = depth of flow in the channel (ft),
- S_{chan} = slope of the channel (ft/ft).

The maximum tractive force in a channel occurs where the depth of flow is greatest, typically the center of channel flowing full. By comparing the maximum tractive force from Equation 4.1 with the maximum allowable tractive forces from the tables below, the appropriate channel lining can be selected to resist erosion. The NCDOT guidelines for selecting road ditch linings are listed in Table 4.1. Rock rip rap size gradations are listed in Table 4.2. Allowable tractive forces for various channel liners are listed in Tables 4.3 and 4.4. Table 4.4 also lists allowable hill slopes for liner applications.

Table 4.1. NCDOT guidelines for selecting channel linings.

Channel Slope (%)	Recommended Channel Lining
< 1.5	Seed and Mulch
1.5 to 4.0	Temporary Liners
> 4.0	Turf Reinforced Mats (TRM) or Hard

Table 4.2. Rock Rip Rap Size Gradation.

Class or #	Graded Rock Size (inches)		
	Maximum	D ₅₀	Minimum
#57	1	½	No. 8
#5	1	¾	¾
A	6	4	2
B	12	8	5
1	17	10	5
2	23	14	9

Table 4.3. Allowable Tractive Forces for Channel Linings (PADEP, 2000).¹

Channel Lining Category	Lining Type	Allowable Tractive Force, τ (lbs/ft²)
Unlined – Erodible Soils (K > 0.37)	Silts, Fine – Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Erosion Resistant Soils (K < 0.37)	Sandy loam	0.02
	Gravelly, Stony, Channery loam	0.05
	Stony or Channery silt loam	0.07
	Loam	0.07
	Sandy clay loam	0.10
	Silt loam	0.12
	Silty clay loam	0.18
	Clay loam	0.25
	Shale & Hardpan	1.00
	Durable Bedrock	2.00
RECP	Jute Netting	0.45
	Geocoir/Dekowe; Straw; RS-1	0.83
	Profile; Futerra	1.00
	Am. Excelsior Co.; Curlex Net Free	1.00
	Am. Excelsior Co.; Straw; 1 net	1.25
	Geocoir/Dekowe; Straw; RS-2	1.25
	E. Coast Ero. Blank.; Straw/Coir, 2 Jute nets	1.35
	Am. Excelsior Co.; Straw; 2 nets	1.50
	Am. Excelsior Co.; Curlex I.73; 1 net	1.55
	E. Coast Ero. Blank.; Straw, 1 net	1.55
	E. Coast Ero. Blank.; Coir, 2 Jute nets	1.63
	Am. Excelsior Co.; Curlex I.98; 1 net	1.65
	Am. Excelsior Co.; Curlex II.73; 2 nets	1.75
	N. Am. Green; Straw; double net	1.75
	E. Coast Ero. Blank.; Excelsior, 1 net	1.80
	NAG; 70% straw: 30% Coconut; double net	2.00
	NAG; Polypropylene; double net; Bare soil	2.00
	Am. Excelsior Co.; Curlex II.98; 2 nets	2.00
Geocoir/Dekowe; Coconut, RSC-4	2.00	
E. Coast Ero. Blank.; Excelsior, 2 nets	2.00	
E. Coast Ero. Blank.; Straw, Jute net	2.10	
E. Coast Ero. Blank.; Straw, 2 nets	2.10	
N. Am. Green; Coconut; double net	2.25	

	Am. Excelsior Co.; Curlex III; 2 nets	2.30
	Am. Excelsior Co.; Curlex Enforcer; 2 nets	2.30
	E. Coast Ero. Blank.; Straw/Coir, 2 nets	2.60
	Am. Excelsior Co.; Curlex High Velocity; 2 nets	3.00
	Geocoir/Dekowe; 400	3.10
	E. Coast Ero. Blank.; Coir, 2 nets	3.20
	E. Coast Ero. Blank.; Polypropylene, 2 nets	3.21
	Geocoir/Dekowe; 700	4.46
	Geocoir/Dekowe; 900	4.63
	NAG; Polypropylene; double net; Vegetated	8.00
Turf Reinforced Mats (TRM)	North Am. Green SC250; Bare soil	2.50
	North Am. Green C350; Bare soil	3.00
	North Am. Green P550; Bare soil	3.25
	E. Coast Ero. Blank.; Coir, 3 nets	3.50
	Profile/Enkamat; 7003 (BFM)	5.00
	Profile/Enkamat; 7010, seed and hydromulch	6.00
	Profile/Enkamat; 7010 – 7220, seed, BFM; Veg	6.0-8.0
	Profile/Enkamat; 7010 - 7220, seed, BFM; Bare	6.7-11.2
	Profile/Enkamat; 7018, seed and hydromulch	7.00
	North Am. Green SC250; Vegetated	8.00
	Profile/Enkamat; 7020, seed and hydromulch	8.00
	Profile/Enkamat II; seed and BFM; Vege.	8.00
	Profile/Enkamat; 7920, seed and BFM; Vege.	8.00
	North Am. Green C350; Vegetated	10.0
	Profile/Enkamat II; seed and BFM; Bare	10.0
	Am. Excelsior Co.; Recyclex	10.0+
	North Am. Green P550; Vegetated	12.5
Grass Liners	Class D	0.60
	Class C	1.00
	Class B	2.10
Aggregate & Riprap	#57	0.25
	#5	0.50
	Class A	1.00
	Class B	2.00
	Class 1	3.00
	Class 2	4.00
Reno Mattress & Gabion		8.35
Concrete		100

Table 4.4. Allowable Tractive Force of RECPs. (Table 6.17a NCDENR (2006))¹

Category	Product Type	Max. Permissible Shear Stress (lbs/ft ²)	Slopes Up to
RECP	N. Am. Green; Straw; 1 net	1.55	3:1
	Am. Excelsior Co.; Curlex Net Free	1.00	3:1
	Am. Excelsior Co.; Straw; 1 net	1.25	3:1
	Geocoir/Dekowe; Straw; RS-1	0.83	3:1
	N. Am. Green; Straw; 2 nets	1.75	2:1
	Am. Excelsior Co.; Curlex I.73; 1 net	1.55	2:1
	Am. Excelsior Co.; Curlex I.98; 1 net	1.65	2:1
	Am. Excelsior Co.; Straw; 2 nets	1.50	2:1
	Geocoir/Dekowe; Straw; RS-2	1.25	2:1
	Geocoir/Dekowe; 70% Straw 30% Coconut; RSS/C-3	1.85	2:1
	Geocoir/Dekowe; Poly/Fiber; RSP-5	2.00	2:1
	Geocoir/Dekowe; Coconut, RSC-4	2.00	2:1
	Am. Excelsior Co.; Curlex II.73; 2 nets	1.75	1.5:1
	Am. Excelsior Co.; Curlex II.98; 2 nets	2.0	1.5:1
	Am. Excelsior Co.; Straw/Coconut; 2 nets		1.5:1
	NAG; 70% straw: 30% Coir; 2 nets	2.00	1:1
	N. Am. Green; Coconut; 2 nets	2.25	1:1
	Am. Excelsior Co.; Curlex III; 2 nets	2.3	1:1
	NAG; Polypropylene; 2 nets; Bare soil	2.0	1:1
	NAG; Polypropylene; 2 nets; Vegetated	8.0	1:1
	Am. Excelsior Co.; Coconut; 2 nets		1:1
	Am. Excelsior Co.; Curlex Enforcer; 2 nets		0.75:1
	Am. Excelsior Co.; Curlex High Velocity; 2 nets	3.0	0.75:1
TRM	Profile/Enka; 7003, Vege.	5.0	3.5:1
	Profile/Enka; 7010, 7210, 7910, Vege.	6.0	2:1
	Profile/Enka; 7220, 7020, Vege.	8.0	1.5:1
	Profile/Enkamat II	8.0	1:1
	Profile/Enka; 7520, Vege.	8.0	0.5:1
	Am. Excelsior Co.; Recyclex	10.0+	0.5:1
Degradable RECP's	Nets and Mulch	0.1 – 0.2	20:1
(Unvegetated)	Coir Mesh	0.4 – 3.0	3:1
	Blanket – Single Net	1.55 – 2.0	2:1
	Blanket – Double net	1.65 – 3.0	1:1
Nondegradable Turf Reinforce Mats	Unvegetated	2 – 4	1:1
	Partially Vegetated	4 – 6	>1:1
	Fully Vegetated	5 - 10	>1:1

Example: Select a suitable channel liner for a triangular road ditch with maximum depth of 1 ft and slope of 1%.

Table 4.1: NCDOT guidelines for 1% slope allow seed and mulch or RECP

$$\text{Equation 4.1: } \tau = (62.4 \text{ lbs/ft}^3) (1 \text{ ft}) (0.01 \text{ ft/ft}) = 0.6 \text{ lbs/ft}^2$$

Table 4.3: Apply seed and mulch or select a RECP channel lining with a maximum allowable tractive force greater than 0.6 lbs/ft².

Example: Select a suitable channel liner for a triangular road ditch with maximum depth of 1.5 ft and slope of 2%.

Table 4.1: NCDOT guidelines for 2% slope require a temporary liner.

$$\text{Equation 4.1: } \tau = (62.4 \text{ lbs/ft}^3) (1.5 \text{ ft}) (0.02 \text{ ft/ft}) = 1.9 \text{ lbs/ft}^2$$

Table 4.3: Select a channel lining with a maximum allowable tractive force greater than 1.9 lbs/ft². Table 4.3 lists several RECPs that work for this application.

Sizing Pipes for Open Channel Flow

Though circular channels obey the continuity and Manning's equations, the geometry of circular channels is much more complex. Therefore, it is suggested that you use Figure 4.1 for sizing pipes that have relatively smooth linings such as clay or concrete pipe or corrugated plastic pipe with the smooth inner lining. For corrugated plastic pipe, Figure 4.2 is appropriate. In both of these figures the pipe slope, in %, is located on the x-axis and the pipe discharge, in gpm, is located on the y-axis. The solid sloping lines (low on the left and rising toward the right) represent each pipe (diameter shown below the line) flowing full.

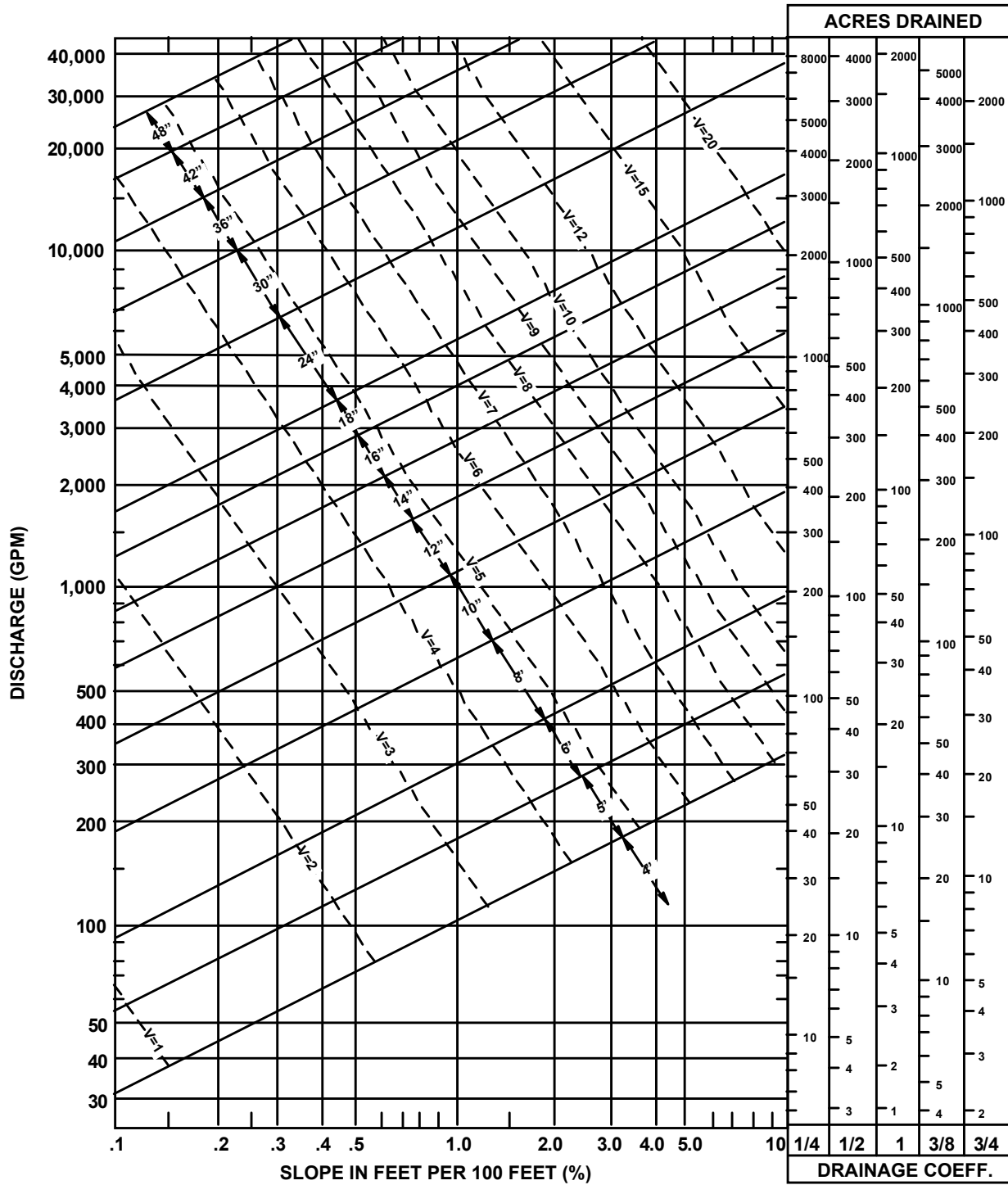


Figure 4.1. Pipe sizing chart for clay, concrete and corrugated plastic pipe with a smooth inner liner (Jarrett, 2000).

MODULE 5. Sediment Retention BMPs

Sediment retention best management practices (BMPs) are treatment systems designed to remove suspended sediment from runoff water before discharging to a receiving stream or a neighboring property. BMPs are designed to maximize sediment retention based on (1) impoundment volume to store runoff water and collected sediment; (2) detention time to remove water by gravity; and (3) length of flow path within the structure to maximize settling. BMP characteristics that improve effectiveness include:

- Stable interior sideslopes no steeper than 1.5:1,
- Plastic liner and/or vegetation established within the structure,
- Stable inlet(s) for water entering the structure to settle sediment,
- Baffles of porous jute or coir to divide the structure into 3 or more chambers,
- Surface dewatering device to remove cleaner water first, and
- Infiltration from the bottom of the basin if possible.

In North Carolina, sediment retention BMPs (basins or similar retention structures) are sized based on two criteria:

1. **Volume**, V_{basin} , in cubic feet (ft³):

$$V_{\text{basin}} \geq 3,600 \text{ ft}^3 \text{ per acre of disturbed land}$$

$$V_{\text{basin}} \geq 1,800 \text{ ft}^3 \text{ per acre of disturbed land (with a surface dewatering device)}$$

2. **Surface Area**, A_{basin} , in square feet (ft²):

$$A_{\text{basin}} \geq 435 Q_{10}$$

$$A_{\text{basin}} \geq 325 Q_{10} \text{ (with a surface dewatering device)}$$

For environmentally sensitive areas, use the 25-year peak runoff rate, Q_{25} .

Example: Calculate minimum volume and surface area for a skimmer basin serving a 6-acre construction site (all disturbed) with $Q_{10} = 20$ cfs.

Volume:

$$V_{\text{basin}} \geq 1,800 \text{ ft}^3 \text{ per acre of disturbed land}$$
$$V_{\text{basin}} \geq 1,800 \text{ ft}^3/\text{ac} (6 \text{ ac}) = 10,800 \text{ ft}^3$$

Surface Area:

$$A_{\text{basin}} \geq 325 Q_{10} \text{ (with a surface dewatering device)}$$
$$A_{\text{basin}} \geq 325 (20) = 6,500 \text{ ft}^2$$

Dewatering Sediment Retention BMPs

Sediment retention BMPs may have one or two spillways. The principal spillway is designed to pass all flows up to extreme conditions. The geometry and position of the principal spillway determine the discharge of water and the retention time for settling of suspended sediment. The design dewatering time ranges from less than a day up to several days to maximize settling while providing room for the next storm event. The principal spillway can be designed in many ways to facilitate the controlled removal of water from a sediment control structure. The most common dewatering devices are a rock section in the wall of the structure, a perforated riser, skimmer, or a flashboard riser.

Rock Spillway. This structure consists of a trapezoidal shaped stack of Class B structural rock with a 12-inch layer of #57 “sediment control stone” placed over the inside face of the Class B structural stone (see current NCDOT standard drawing). The water leaving the basin is expected to pass through the finer stone and be filtered leaving a substantial portion of the sediment inside the basin. In all but the largest runoff events, the water exits the basin as fast as it enters.

Skimmer Surface Dewatering Device. This device is designed to remove water from the surface of the water column to discharge the cleanest water first. The Faircloth Skimmer is commonly used as a surface outlet (see current NCDOT standard drawing). The "C" enclosure floats on the water surface suspending the water entry unit just below the water surface. An orifice located just below the water surface controls the flow rate of discharge water. The water is discharged from the arm assembly into the structure's barrel. Table 5.1 lists design dewatering rates for several sizes of Faircloth Skimmers.

Table 5.1. Faircloth Skimmer Dewatering Rates.

Skimmer Diameter (inches)	Q_{skim} Max Outflow Rate (ft ³ /day)	H_{skim} Driving Head (ft)
1.5	1,728	0.125
2.0	3,283	0.167
2.5	6,234	0.208
3.0	9,774	0.250
4.0	20,109	0.333
5.0	32,832	0.333
6.0	51,840	0.417
8.0	97,978	0.500

Table 5.1 is used to size the skimmer orifice located at the top of the water entry point. This orifice controls the basin outflow rate and must be sized carefully. The Faircloth skimmer is patented and is available from J. W. Faircloth and Sons, Inc at <http://www.fairclothskimmer.com> in specific sizes. The skimmer size refers to the diameter of the float and arm. The Faircloth Skimmer is sized by determining the required basin outflow rate as the water volume divided by the dewatering time:

$$Q_{skim} = V_{skim} / t_{dewater} \quad (\text{Equation 5.1})$$

where:

Q_{skim} = basin outflow rate in cubic feet per day (ft³/day),
 V_{skim} = basin volume to be dewatered in cubic feet (ft³),
 $t_{dewater}$ = dewatering time (days).

For NCDOT skimmer basins, the current design standard calls for dewatering the top 2 feet of volume in 3 days. For the design Q_{skim} , select a skimmer and orifice from Table 5.1 which meets or exceeds this rate. The Faircloth Skimmer comes with a plastic plug that can be drilled to provide an orifice to limit outflow to the desired rate. The diameter of the orifice is calculated using the discharge rate and the driving head:

$$D_{orifice} = \sqrt{\frac{Q_{skim}}{2310\sqrt{H_{skim}}}} \quad (\text{Equation 5.2})$$

where:

$D_{orifice}$ = diameter of the skimmer orifice in inches (in),
 Q_{skim} = basin outflow rate in cubic feet per day (ft³/day),
 H_{skim} = driving head at the skimmer orifice from Table 5.1 in feet (ft).

Example: Select a skimmer that will dewater 20,000 ft³ of water in 3 days.

$$Q_{skim} = 20,000 \text{ ft}^3 / 3 \text{ days} = 6,670 \text{ ft}^3/\text{day}$$

From Table 5.1, select the 3-inch skimmer with an outflow rate of 9,774 ft³/day and a driving head of 0.25 ft. Since this outflow rate will dewater the basin in less than 3 days, an orifice smaller than 3 inches diameter can be drilled to slow the flow rate according to Equation 5.2.

$$D_{orifice} = \sqrt{\frac{6,670}{2310\sqrt{0.25}}} = 2.1 \text{ inches}$$

If the plastic is drilled to a diameter of 2.1 inches and placed in the 3-inch skimmer, the dewatering rate is 6,670 ft³/d and 20,000 ft³ will dewater in 3 days.

Flashboard Riser. This device can be managed to maintain a minimum water depth and provide for surface dewatering, see Figure 5.1.



Figure 5.1. Flashboard Riser for Dewatering a Sediment Retention Basin.

Infiltration Basin. If soil conditions are conducive to high infiltration rates, most or all of the water entering a basin can be discharged through infiltration. The infiltration rate can be obtained from USDA-NRCS County Soil Surveys where the permeability (sometimes called saturated hydraulic conductivity) is typically listed as a range of values (e.g. 0.6 to 2.0 in/hr). For a conservative design, choose the lower permeability of the soil horizon with the slowest permeability. For example, if a soil has “A”, “B”, and “C” horizons with published permeabilities of 0.6-2.0, 0.2-0.8, and 6.0-20, respectively, the value to be used for the basin’s infiltration design would be 0.2 in/hr. For NCDOT projects, the soil permeability must be at least 0.5 in/hr to meet the design criteria of dewatering 3 ft of water in 3 days or less.

Emergency Spillway

The emergency spillway on a sediment retention BMP should be capable of passing large storm flows with a maximum depth of flow over the emergency spillway of 1 ft. For NCDOT skimmer basins and infiltration basins, the weir length (ft) is calculated by dividing the peak discharge (Q_p in cfs) by 0.4, except for drainage areas <1 acre, which have a 4ft minimum weir length.

MODULE 6. Below Water Table Borrow Pits

Borrow pits are areas of suitable soil material excavated to provide necessary road building material. Between active borrow pit excavations, ground water may seep into the pit, and rainfall may produce runoff into the borrow pit, creating an impoundment that must be dewatered before additional borrow material can be removed. When a borrow pit is initially prepared to serve as a source of construction material, a rim ditch is dug around the perimeter, typically 10 to 25 ft wide at its bottom, dug to the lowest depth from which the borrow material will be removed. Because the rim ditch, and later all or part of the whole borrow pit area inside of the rim ditch, will fill with water at least to the depth of the regional water table, it is common practice for contractors to dewater rim ditches and borrow pits by placing a pump in the deepest rim ditch location. If the pumped water has a high turbidity level, the pumped borrow pit water must be treated.

Stilling basin for Pumped Borrow Pit Water

A common practice is to discharge the water pumped from the rim ditch into a stilling basin with a volume that provides sufficient time for settling. The required stilling basin volume can be calculated by multiplying the desired detention time by the pumping rate of water entering the basin. For NCDOT applications, the current design standard requires a detention time of at least 2 hours and a maximum pumping rate of 1,000 gpm. For a 2-hr detention time, the minimum stilling basin volume is:

$$V_{\text{still}} = 16 (Q_{\text{still}}) \quad \text{(Equation 6.1)}$$

where:

V_{still} = volume of stilling basin in cubic feet (ft³), and

Q_{still} = pumping rate entering the stilling basin in gallons per minute (gpm).

At the maximum NCDOT pumping rate of 1,000 gpm, the required stilling basin volume is 16,000 ft³.

If water pumped from the borrow pit has high turbidity, the water is most commonly discharged into a stilling basin located at the land surface. The stilling basin for pumped effluent is a rectangular-shaped basin with at least a 2:1 L:W shape, constructed from natural soil. The basin should receive sediment-laden water from a borrow pit excavation site where the water is pumped to the stilling basin for treatment. The maximum depth is 3 feet, and the embankment should have 1.5:1 interior and exterior side slopes. The basin is dewatered with a surface outlet device, most appropriately a 12-inch vertical riser pipe (with no perforations) set at the 3-ft water level. A flashboard riser system may also be used with the top flashboard set at 3 ft for normal operation. This system allows for dewatering by removing flashboards as necessary.

Polyacrylamide (PAM)

For high-turbidity water, a polyacrylamide (PAM) may be added to the pumped water as a flocculant to help settle sediment in the stilling basin system. When PAM is properly injected into the pumped water, the stilling basin can be designed to detain the water for as little as 2 hours. PAM is available in powder form and can be mixed with water to form a liquid suspension of PAM. Normal mixing rates are one pound of PAM added to 100 gallons of water. This liquid PAM solution can be injected into the positive side of the pump using an injection pump unit to produce a PAM concentration of about 1 mg/L. The liquid PAM application or injection rates needed to create a 1 mg/L PAM concentration in the sediment-laden water are shown in Figure 6.1.

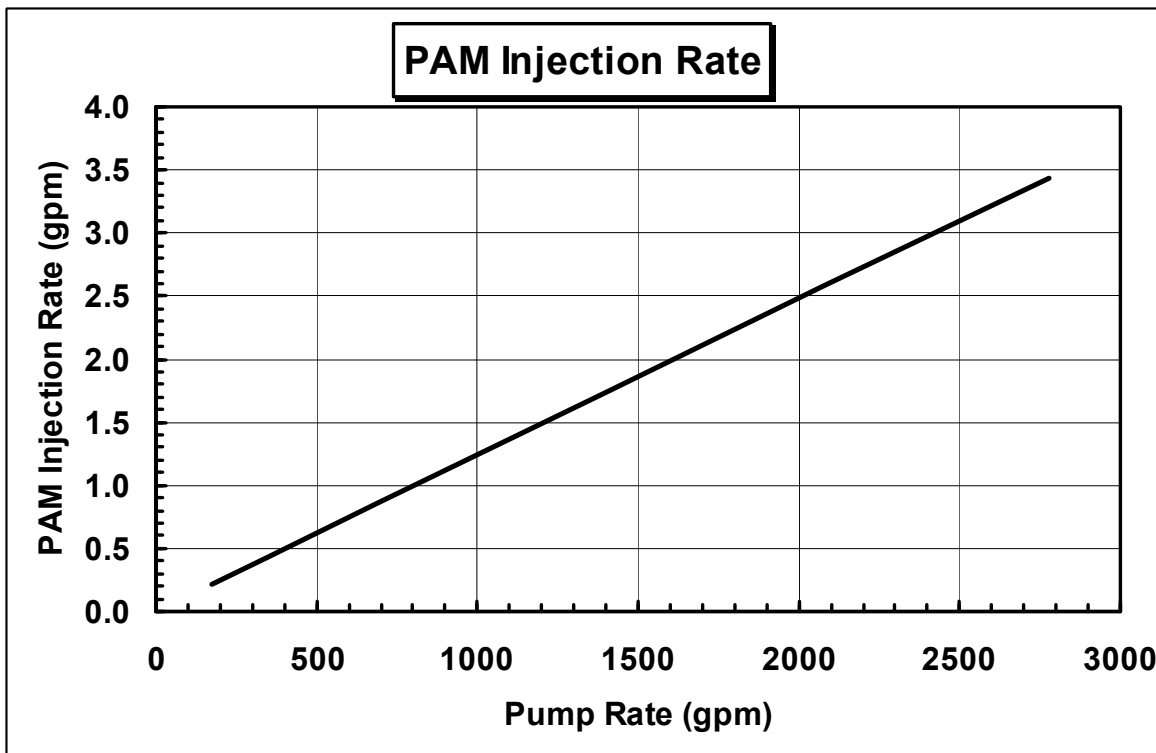


Figure 6.1. PAM injection rate related to pump rate to create 1 mg/L of PAM.

Borrow pit pump water that has had PAM applied will quickly develop clay flocs (large aggregates of clay particles) that must be removed from the water. Normally this water should be pumped directly into the inlet chamber of a stilling basin. Applied Polymer Systems recommend discharging the flocculent-laden water into a level (perpendicular to flow direction) shallow (not more than 0.1 ft deep) channel lined with jute or coir erosion control blanket. The flocs tend to be captured in the jute/coir pores and removed from the gently flowing water. When the jute/coir layer becomes filled with settled/captured soil flocs, just add another layer of jute/coir. This stripping approach may work well for borrow pit dewatering systems where the pump rate is 350 gpm or less.

Skaggs Method for Determining Wetlands Encroachment

Where borrow pits are located near wetlands, it is critical that excavation be managed so that wetland hydrology is not altered. A site has wetland hydrology if, during the growing season, the water table is normally within 1 ft of the soil surface for a continuous critical duration, defined as 5 to 12.5% of the growing season (USACE, 1987). The lower limit of 5% of the growing season was used in the Skaggs Method to predict lateral effects of borrow pit excavation on the water table.

The Skaggs Method is a procedure developed from simulating 50 years (1951-2000) of each county's meteorological data on the flow cross-section shown in Figure 6.2 using a local hydric soil to determine the distance from the borrow pit where, once every 2 years, the water table will drop below the 0.83 ft depth; shown in Figure 6.2 as the "Lateral Effect." During DRAINMOD simulations, a critical water table depth of 0.83 ft was used as a conservative approximation of the USACE (1987) 1-ft criterion. As boundary conditions for the DRAINMOD simulations, two additional parameters were used; (a) depth of water stored on the soil surface, either 1 or 2 inches; and (b) depth below surface where the borrow pit has ponded water, ranging from 1 to 6 ft. Other parameters for each county included depth from surface to impermeable layer, h_o , soil drainable porosity, f , and soil effective hydraulic conductivity, K_e .

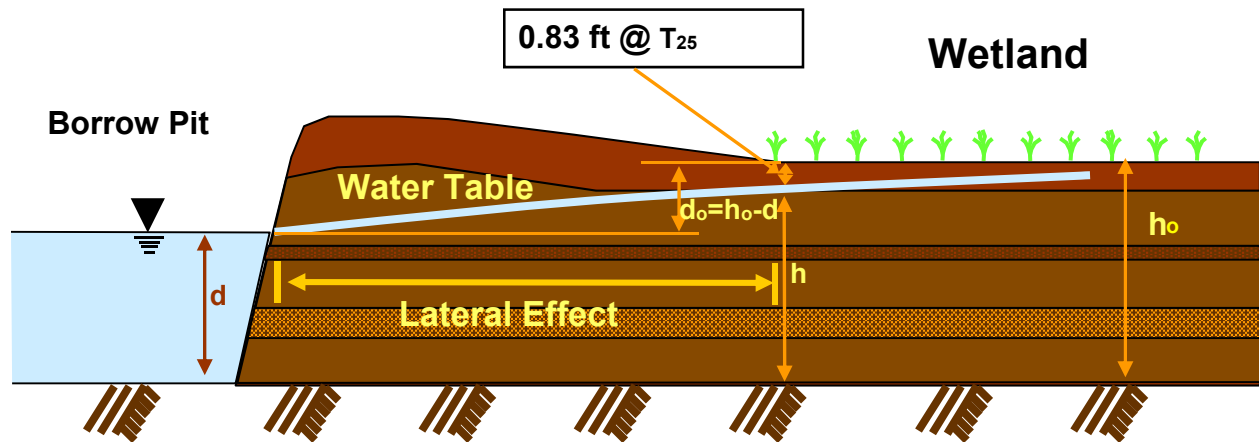


Figure 6.2. Borrow Pit with Lateral Effect on Wetland Hydrology.

The effective hydraulic conductivity is the weighted average of conductivities of each soil layer above the impermeable layer:

$$K_e = \frac{K_1 d_1 + K_2 d_2 + \dots + K_n d_n}{d_1 + d_2 + \dots + d_n} \quad \text{(Equation 6.2)}$$

where K_1 , K_2 , etc are the hydraulic conductivities and d_1 , d_2 , etc are the thicknesses of soil layers 1, 2, etc, respectively.

The results of the county simulations are expressed in terms of T_{25} , the time in days required for the water table to be drawn down from the soil surface to a depth of 0.83 ft. The results of these simulations are shown in Table 6.1 for areas with 1 and 2 inches of surface depressional storage. The T_{25} value is used with other soil parameters to solve for the “Lateral Effect” distance, x :

$$x = \frac{\sqrt{\frac{Kh_o t}{f}}}{\frac{1}{\eta}} \quad (\text{Equation 6.3})$$

where:

- K_e = effective hydraulic conductivity in feet per day (ft/d),
- h_o = depth from soil surface to impermeable layer in feet (ft),
- t is T_{25} from Table 6.1 for appropriate depth of depressional storage (days),
- f = drainable porosity for the soil into which pit is excavated (decimal),
- $1/\eta$ = the value read from the x -axis of Figure 6.2 based on the parameters $H = h/h_o$ and $D = d/h_o$, where h is depth from critical water table depth (0.83 ft) to impermeable layer (ft) and d is depth from water surface in the borrow pit to impermeable layer.

Since critical water table depth is 0.83 ft, h is always $h = h_o - 0.83$, so

$$H = \frac{h_o - 0.83}{h_o} \quad (\text{Equation 6.4})$$

If d_o represents the “depth to water” in the borrow pit parameter, then $d = h_o - d_o$ and

$$D = \frac{h_o - d_o}{h_o} \quad (\text{Equation 6.5})$$

For NCDOT applications, the current design standard is to set the following parameters as constants:

$$f = 0.035 \quad \text{and} \quad d_o = 2 \text{ ft}$$

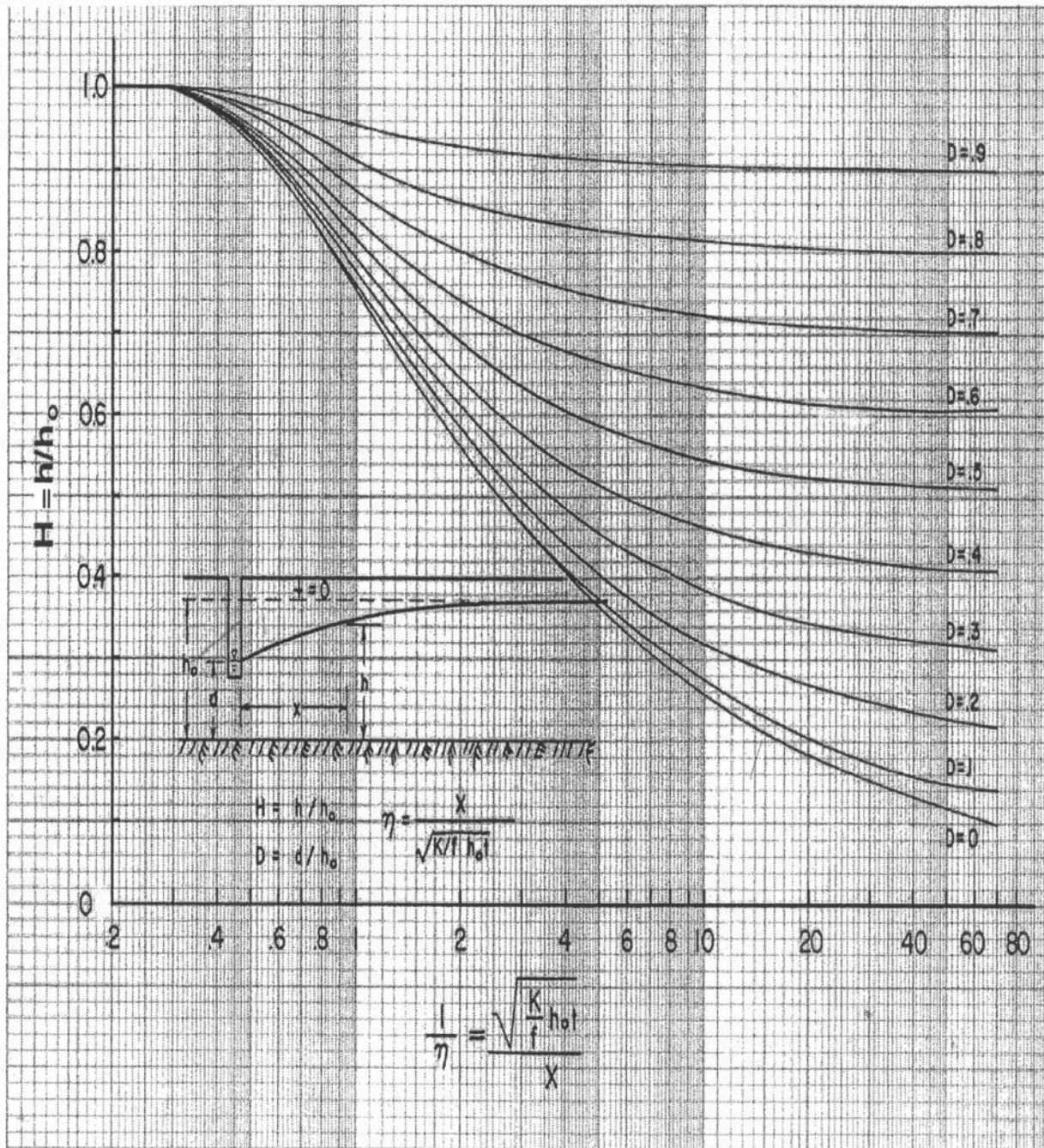


Figure 6.3. Nondimensional solutions to the Boussinesq Equation for water table drawdown due to drainage to a single ditch or borrow pit (after Skaggs, 1976).

Example: Determine the lateral effect of a borrow pit in Johnston County with Goldsboro soil, effective hydraulic conductivity of 4 ft/day, drainable porosity of 0.035, depth to impermeable layer of 15 ft, and surface depressional storage of 2 in. See schematic in Figure 6.4.

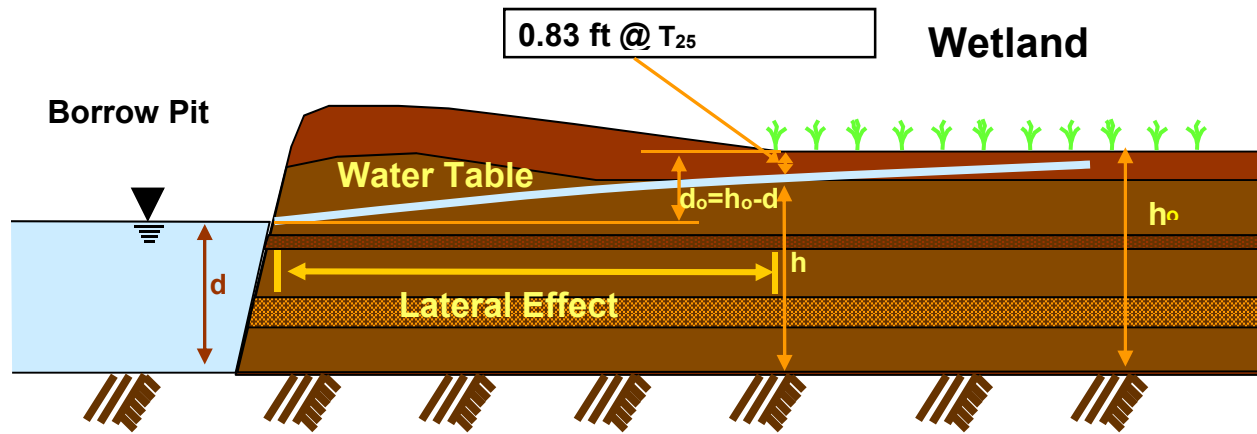


Figure 6.4. Example application of Skaggs Method.

Given: $f = 0.035$
 $d_o = 2 \text{ ft}$
 $K_e = 4.0 \text{ ft/day}$
 $h_o = 15 \text{ ft}$
 Table 6.1: $t = T_{25} = 5.2 \text{ days}$

$$H = \frac{h_o - 25}{h_o} = \frac{15 - 0.83}{15} = \frac{14.17}{15} = 0.94$$

$$D = \frac{h_o - d_o}{h_o} = \frac{15 - 2}{15} = \frac{13}{15} = 0.87$$

From Figure 6.3, use interpolation to find the x-axis value, $1/\eta = 1.07$

Solve Equation 6.3 for the "Lateral Effect", x as:

$$x = \frac{\sqrt{\frac{K h_o t}{f}}}{\frac{1}{\eta}} = \frac{\sqrt{\frac{4.0 \text{ ft} / \text{day} (15.0 \text{ ft}) (5.2 \text{ days})}{0.035}}}{1.07} = \frac{94.42}{1.07} = 88 \text{ ft}$$

The Lateral Effect is 88 ft. In other words the borrow pit can be placed 88 feet from the edge of the wetland area without causing drainage of the wetland and reducing its status as a wetland.

Table 6.1. T₂₅ (days) for 2-ft depth to water for 1 and 2 inch depressional storage.

County	1 inch storage	2 inches
Alamance	9.0	4.6
Alexander	5.6	3.5
Alleghany	5.7	3.5
Anson	8.5	4.6
Ashe	2.9	1.9
Avery	3.0	2.2
Bertie	8.7	4.1
Beaufort	6.2	3.7
Bladen	10.3	4.8
Brunswick	4.6	3.0
Buncombe	4.0	2.8
Burke	5.6	3.3
Cabarrus	6.7	3.9
Caldwell	5.1	2.9
Camden	6.0	3.8
Carteret	5.0	3.2
Caswell	8.2	4.5
Catawaba	5.6	3.5
Chatham	5.4	3.6
Cherokee	4.0	2.5
Chowan	7.1	4.0
Clay	2.8	1.7
Cleveland	5.2	3.2
Columbus	9.2	4.6
Craven	5.2	3.2
Cumberland	6.3	4.6
Currituck	6.0	3.8
Dare	5.7	3.2
Davidson	8.6	4.8
Davie	6.9	4.4
Duplin	5.5	3.4
Durham	7.1	4.0
Edgecombe	9.5	4.7
Forsyth	7.1	4.1
Gaston	7.0	3.7
Gates	6.2	3.7
Graham	4.8	3.1
Granville	9.7	4.6
Greene	8.6	4.0
Guilford	6.2	3.9
Halifax	7.9	4.6
Harnett	8.9	4.7
Haywood	10.4	5.7
Henderson	3.3	2.4
Hertford	6.2	3.7
Hoke	6.3	4.6
Hyde	7.2	3.6
Iredell	5.6	3.5