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Appendices

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APPENDICES

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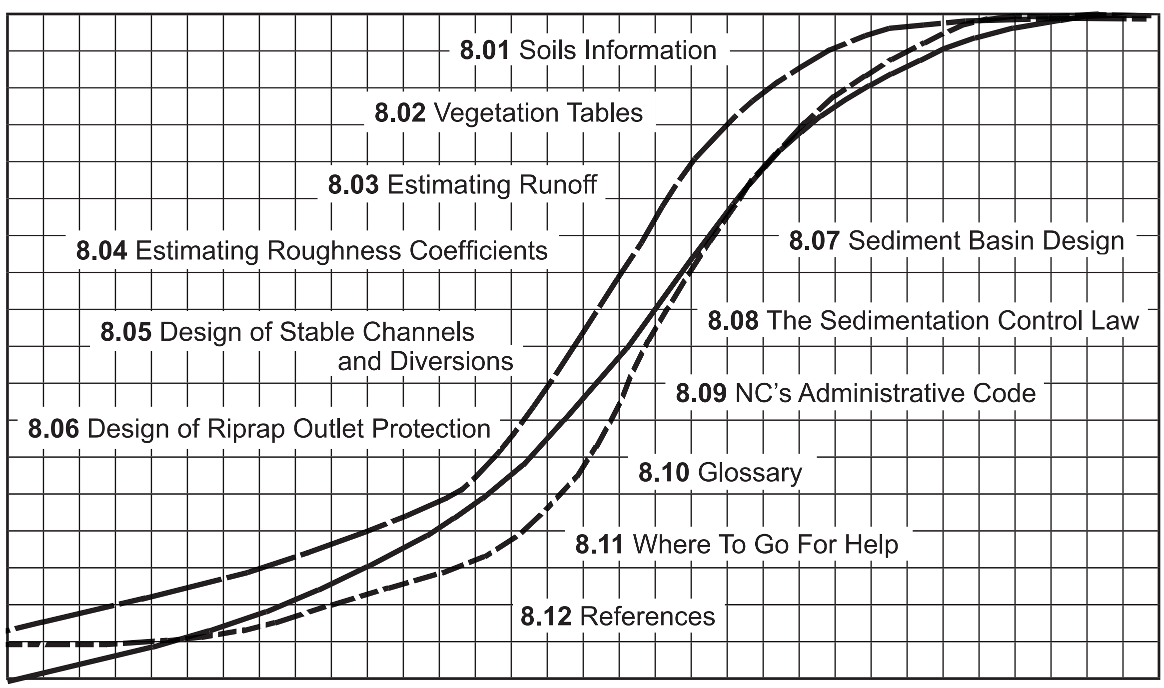
Appendices

The following appendices supplement material presented in earlier sections of the manual. The first seven appendices provide technical information to aid in the design and installation of structural and vegetative practices. These appendices include general information on soil properties and on the selection of vegetation as well as detailed guidelines on estimating runoff rates and roughness coefficients and on the design of channels and diversions, sediment basins and stable outlets. The final four appendices are less technical in nature and include the text of the law and regulations governing sediment control in North Carolina, a glossary, a list of offices readers may contact to obtain additional information, and a list of references.



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8.01

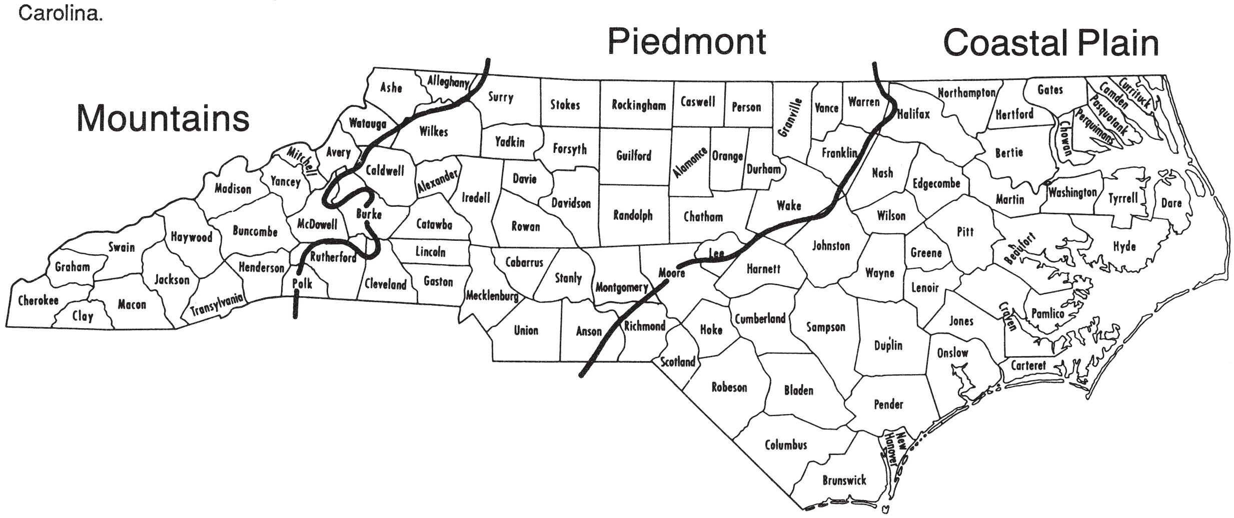
SOILS INFORMATION

A basic knowledge of soils can aid in preparing development plans. Selection of vegetation to be grown on the site for landscaping and erosion control also requires knowledge of the soils, and selection of other erosion control practices may depend on soil characteristics. In general, erosion control can be designed more cost effectively if soils are considered.

North Carolina is divided into three major soil regions (Coastal Plain, Piedmont, and Mountains) in which geology, geomorphology, and climate are the major factors determining soil characteristics (Figure 8.01a). Other site-specific factors such as moisture, temperature, organic matter, and vegetation also influence these characteristics.

About 45% of the land area of North Carolina is in the Coastal Plain. Elevations range from sea level to about 650 feet. Topography is flat to rolling, with soils that vary from sandy, droughty sandhills to large, wet pocosins, which are composed of sandy to clayey unconsolidated marine and fluvial deposits. About 39% of the state is in the Piedmont, in a rolling to hilly area between the Coastal Plain and the Mountains. Elevations range from 300 feet to 1500 feet. About 16% of the state is in the Mountains, with elevations ranging from 1500 to 6680 feet. Within each region the soils are numerous and often complex. Transition zones between the major regions are composed of mixed soils with variable characteristics.

Figure 8.01a Major soil regions of North Carolina.



USING SOIL SURVEYS

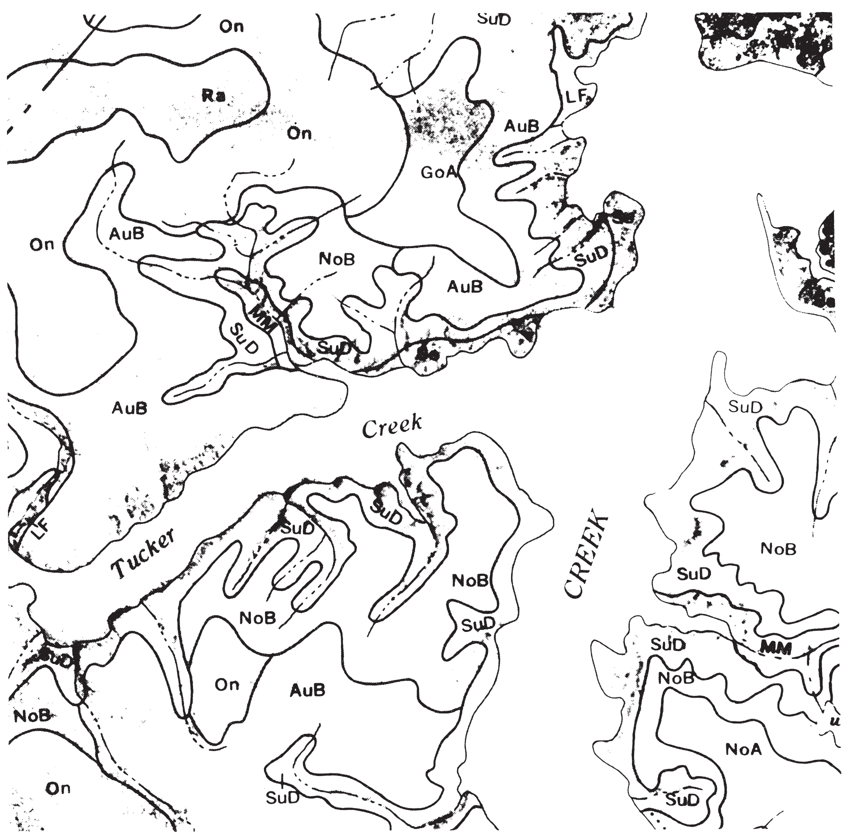
Information on soils may be obtained from soil surveys, but should be verified by on-site investigation. Soil surveys are available for most counties and can be obtained from the local Soil Conservation Service. The survey includes soil maps, soil descriptions, and soil interpretations.

A soil survey map is shown in Figure 8.01b. Boundaries of the different kinds of soils are delineated, showing their location and extent in relation to streams, roads, buildings, and other landscape features. Soil properties are determined from soil samples taken throughout the survey area and from laboratory analyses of selected samples.

Soils are named according to a nationwide uniform procedure. The classification system discussed here is that developed by the Soil Survey Staff of the U.S. Department of Agriculture (1975), published as Soil Taxonomy. The primary bases for identifying different classes in this system are the properties of soils as found in the field–properties that can be measured quantitatively. Another significant feature of this system is the nomenclature employed. The family names, for instance, define the major soil characteristics. Families are divided into lower-level groups called series. Soil series are commonly named for towns, or other geographic features near the place where they were first observed and mapped. A soil series is made up of soils that have similar profiles, major horizons, or layers that are similar in thickness, arrangement, and other important characteristics. A description of each soil type commonly found in North Carolina is given in Table 8.01d (found at the end of this appendix).

A series is divided into phases based on differences in surface layer texture, slope, stoniness, and other characteristics that affect use of the soils. The phase name indicates a feature that affects management. A Cecil sandy loam, 3 to 5% slope, and a Wedowee sandy loam, 8 to 15% slope, stony, are examples of soils in which phase distinctions are made.

Figure 8.01b Detail of soil survey map of Craven County.



NC0069 SOIL INTERPRETATIONS RECORD

MLRA(S): 133A, 136, 153A, 148, 153B, 153C
REV. RAC,WEH, 7-87
TYPIC HAPLUDULTS, FINE-LOAMY, MIXED, THERMIC

WICKHAM SERIES

THE WICKHAM SERIES CONSISTS OF NEARLY LEVEL TO MODERATELY STEEP, WELL DRAINED SOILS ON STREAM TERRACES IN THE PIEDMONT AND STREAM TERRACES AND LOW MARINE TERRACES IN THE COASTAL PLAIN. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS BROWN SANDY LOAM ABOUT 9 INCHES THICK. THE SUBSOIL IS YELLOWISH RED AND STRONG BROWN. IT EXTENDS TO 51 INCHES AND IS SANDY CLAY LOAM IN THE UPPER PART; SANDY CLAY LOAM AND SANDY LOAM IN THE MIDDLE PART; SANDY LOAM AND LOAMY SAND IN THE LOWER PART. THE UNDERLYING LAYER TO 70 INCHES IS GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 25 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT 3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-9	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-4	0	95-100	90-100	70-100	45-80	25	NP-7
0-9	LS, LFS	SM	A-2	0	95-100	90-100	55-80	15-30	-	NP
0-9	SCL, CL	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7-6	0	95-100	90-100	75-100	30-70	20-41	5-15
9-40	SCL, CL, L	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7-6	0	95-100	90-100	75-100	30-70	20-41	5-15
40-70	VAR									

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-9	8-15	1.45-1.65	2.0-6.0	0.11-0.16	4.5-6.0	-	LOW	.24	5	-	.5-2	MODERATE	HIGH
0-9	4-10	1.60-1.70	2.0-6.0	0.05-0.08	4.5-6.0	-	LOW	.15	5	-	.5-1		
0-9	18-35	1.30-1.50	0.6-2.0	0.12-0.17	4.5-6.0	-	LOW	.24	4	-	.5-1		
9-40	18-35	1.30-1.50	0.6-2.0	0.12-0.17	4.5-6.0	-	LOW	.24					
40-70													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE-RARE			6.0			-		60		-		B	-

SANITARY FACILITIES (B)		CONSTRUCTION MATERIAL (B)	
SEPTIC TANK ABSORPTION FIELDS	0-8% NONE: MODERATE-PERCS SLOWLY 8-15% NONE: MODERATE-SLOPE,PERCS SLOWLY 0-8% RARE: MODERATE-FLOODING,PERCS SLOWLY 8-15% RARE: MODERATE-FLOODING,PERCS SLOWLY 15+%: SEVERE-SLOPE	ROADFILL	0-15%: GOOD 15+%: FAIR-SLOPE
SEWAGE LAGOON AREAS	0-2%: MODERATE-SEEPAGE 2-7%: MODERATE-SEEPAGE,SLOPE 7+%: SEVERE-SLOPE	SAND	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (TRENCH)	0-8% NONE: MODERATE-TOO CLAYEY 8-15% NONE: MODERATE-SLOPE,TOO CLAYEY 0-8% RARE: MODERATE-FLOODING,TOO CLAYEY 8-15%RARE:MODERATE-FLOODING,SLOPE,TOO CLAYEY 15+%: SEVERE-SLOPE	GRAVEL	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (AREA)	0-8% NONE: SLIGHT 8-15% NONE: MODERATE-SLOPE 0-8% RARE: MODERATE-FLOODING 8-15% RARE: MODERATE-FLOODING,SLOPE 15+%: SEVERE-SLOPE	TOPSOIL	0-8%: FAIR-TOO CLAYEY,SMALL STONES 8-15%: FAIR-TOO CLAYEY,SMALL STONES,SLOPE 15+%: POOR-SLOPE

Figure 8.01c Typical soil interpretation sheet describing soil properties and suitability for various uses.

Each soil series is described on an interpretation sheet, such as that shown in Figure 8.01c. Interpretation sheets list properties and typical site conditions that are important in erosion and sedimentation control planning for construction sites: texture, erodibility, slope, plasticity, permeability, and depth to and hardness of bedrock. The interpretation sheet also lists other ratings and limitations that are important for site selection and development, such as shrink-swell potential, risk of corrosion, engineering properties, and hydrologic soil group.

Limitations of the survey must also be understood to make accurate interpretations. First, data generally do not represent soil material below 5 or 6 feet. Also, small soil areas that differ from the dominant soil may not be delineated in the map because the map scale limits the size of areas that can be shown. The ranges given for soil properties are often too wide for the design needs of a small development. Therefore, on-site investigation is needed in conjunction with a soil survey to evaluate many specific soil characteristics.

Properties included on the soils interpretation sheet that affect erosion most are soil texture, soil erodibility factor, slope, plasticity index, liquid limit, permeability, depth to bedrock, soil reaction, seasonal high water table, hydrologic group, and engineering classification. A description of each follows.

Soil Texture

Soil survey interpretation sheets indicate the USDA texture class for each soil, expressed as a relative proportion by weight of soil particle size classes finer than 2 mm. The basic texture classes, in decreasing particle size are sands, loams and clays. On the basis of these classes, additional class names are used such as loamy sand, sandy clay, and silty clay. Sands, loamy sands, and sandy loams may be further subdivided as very coarse, coarse, fine, or very fine. Soil description by particle size analysis, which is used by USDA as a guide to textural classifications, is shown in Figure 8.01d. Symbols used in classifying soils according to texture are provided at the bottom of the figure with corresponding descriptions.

Soil texture is defined by the proportions of different size groups of particles. The size limits of different soil particles are listed in Table 8.01a.

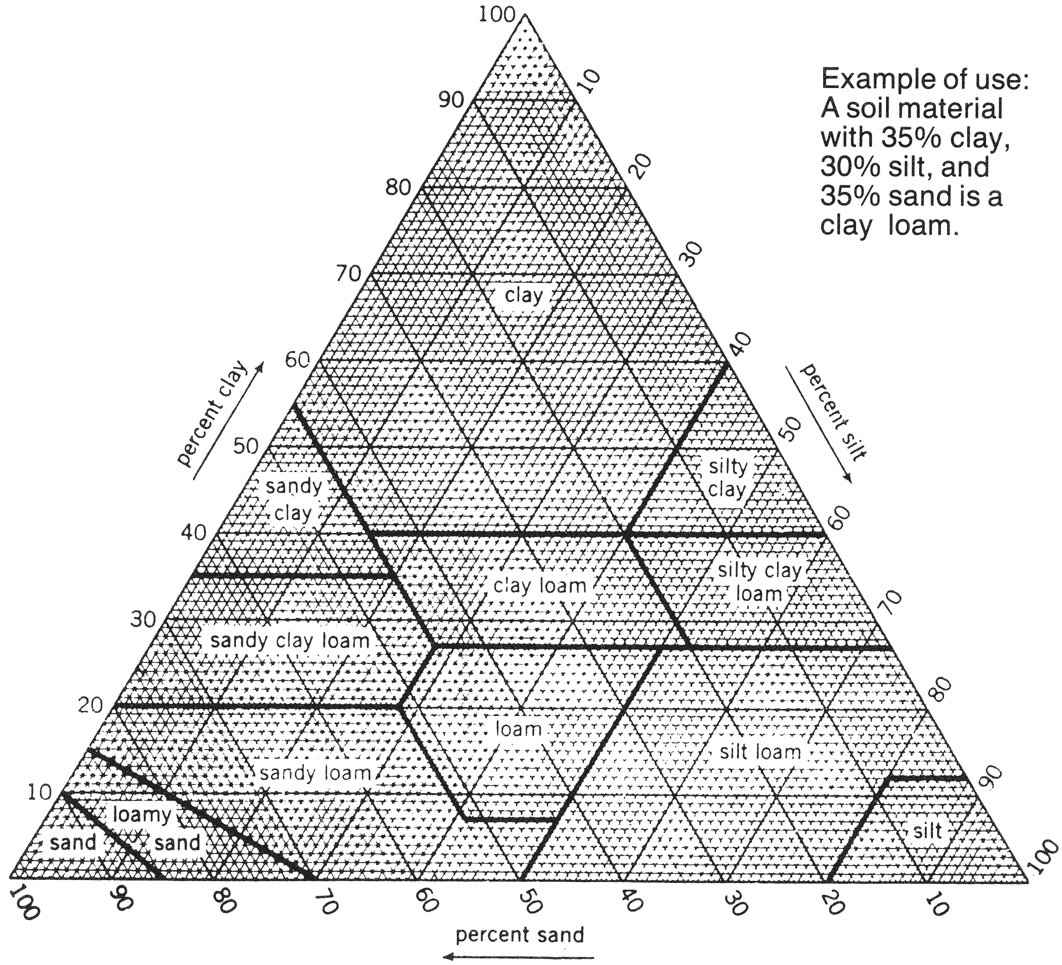
Table 8.01a Size Limits of Soil Particles

Soil Particle	Size
Cobble	0.3 - 0.15m
Gravel	0.15 - 2.0 mm
Sand	2.0 - 0.05 mm
Silt	0.05 - 0.002 mm
Clay	<0.002 mm

The physical properties and chemical composition of large soil particles differ from small soil particles. Since most physical and chemical reactions occur on the surface of small particles, clay (which has much more surface per unit mass than silt or sand) affects soil properties to a much greater extent than do coarser particles. Sand and rock fragments retain water and nutrients poorly because the voids between particles allow water and air to move freely. Therefore, soils with a large percentage of sand-size particles are generally poorly aggregated, well-drained, and well-aerated.

Silt particles are barely visible to the naked eye and are intermediate in many properties between sand and clay. Silt is characterized by its plasticity and stickiness. Silt content is an important characteristic for determining erodibility because silt-sized particles are small enough to reduce the water intake or infiltration rate, and because they are easily detached and transported in runoff. The small particle size makes silt difficult to capture in traps or basins.

There are two major types of clays, kaolinite and montmorillonite. Kaolinite (referred to as a 1:1 clay) is the most common clay in North Carolina soils. It is relatively inactive and fairly stable. Montmorillonite (referred to as a 2:1 clay) is a very active clay that shrinks when dry and swells when wet. These characteristics affect the permeability of soils and are very important to their use and management. Clayey soils retain water that is available for plant



Texture modifier:

CB	Cobbly
CBA	Angular Cobbly
CBV	Very Cobbly
CBX	Extremely cobbly
CN	Channery
CNV	Very channery
CNX	Extremely channery
GR	Gravelly
GRC	Coarse gravelly
GRF	Fine gravelly
GRV	Very gravelly
GRX	Extremely gravelly
MK	Mucky
PT	Peaty
SH	Shaly
SHV	Very shaly
SHX	Extremely shaly
SHR	Stratified
ST	Stony
STV	Very Stony
STX	Extremely Stony

Texture terms:

COS	Coarse sand
S	Sand
FS	Fine Sand
VFS	Very fine sand
LCOS	Loamy coarse sand
LS	Loamy sand
LFS	Loamy fine sand
LVFS	Loamy very fine sand
COSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
SI	Silt
SCL	Sandy clay loam
CL	Clay loam
SICL	Silty clay loam
SC	Sandy clay
SIC	Silty clay
C	Clay

Terms used in lieu of texture:

G	Gravel
MARL	Marl
MPT	Mucky-peat
MUCK	Muck
PEAT	Peat
SG	Sand and gravel
UWB	Unweathered bedrock
VAR	Variable
WB	Weathered bedrock

Note: These are boundary classifications. Soils possessing characteristics of two or more groups are designated by combinations of group symbols. For example, SR-S-FS is a stratified sand fine sand.

Figure 8.01d Guide for USDA Textural Classification and symbols (source: National Soils Handbook).

growth, but these soils are often dense, hard, wet, airtight, acidic and infertile. They may restrict root growth even though water holding capacity and potential rooting depth are adequate. Urban uses of clayey soils may be limited due to cracking of foundations and failure of septic drain fields.

Soil texture information for soils commonly found in North Carolina is given in Table 8.01

Soil Erodibility Factor, (K)

The soil erodibility factor, K, provides a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The principal factors affecting K are texture, organic matter, structure, and permeability. If minimal grading or compaction is expected, K from the soil interpretation sheet, which provides K for a range of depths, can be used (Table 8.01d). Erodibility increases with increasing K. Subsoils exposed during construction, however, may be too deep to be included on the survey. In this case, an on-site investigation is necessary to flag erosion-prone areas. The soil erodibility nomograph, in Figure 8.01e, can be used to estimate K from the percentage of sand, percentage of organic matter, soil structure, and soil permeability.

Slope

The erosion potential increases with slope length and gradient. Long and steep slopes have high potential for soil loss due to surface runoff.

Plasticity Index and Liquid Limit

Both the plasticity index and the liquid limit indicate the effect of water on the strength and consistency of soil and are most important in fine-grained soils. Soils with greater plasticity generally have higher cohesion and resistance to erosion than soils with lower plasticity. These indexes are used in both the Unified and the American Association of State Highway and Transportation Officials (AASHTO) soil classification systems, which are described in more detail later. They are also used as indicators in making general predictions of soil behavior.

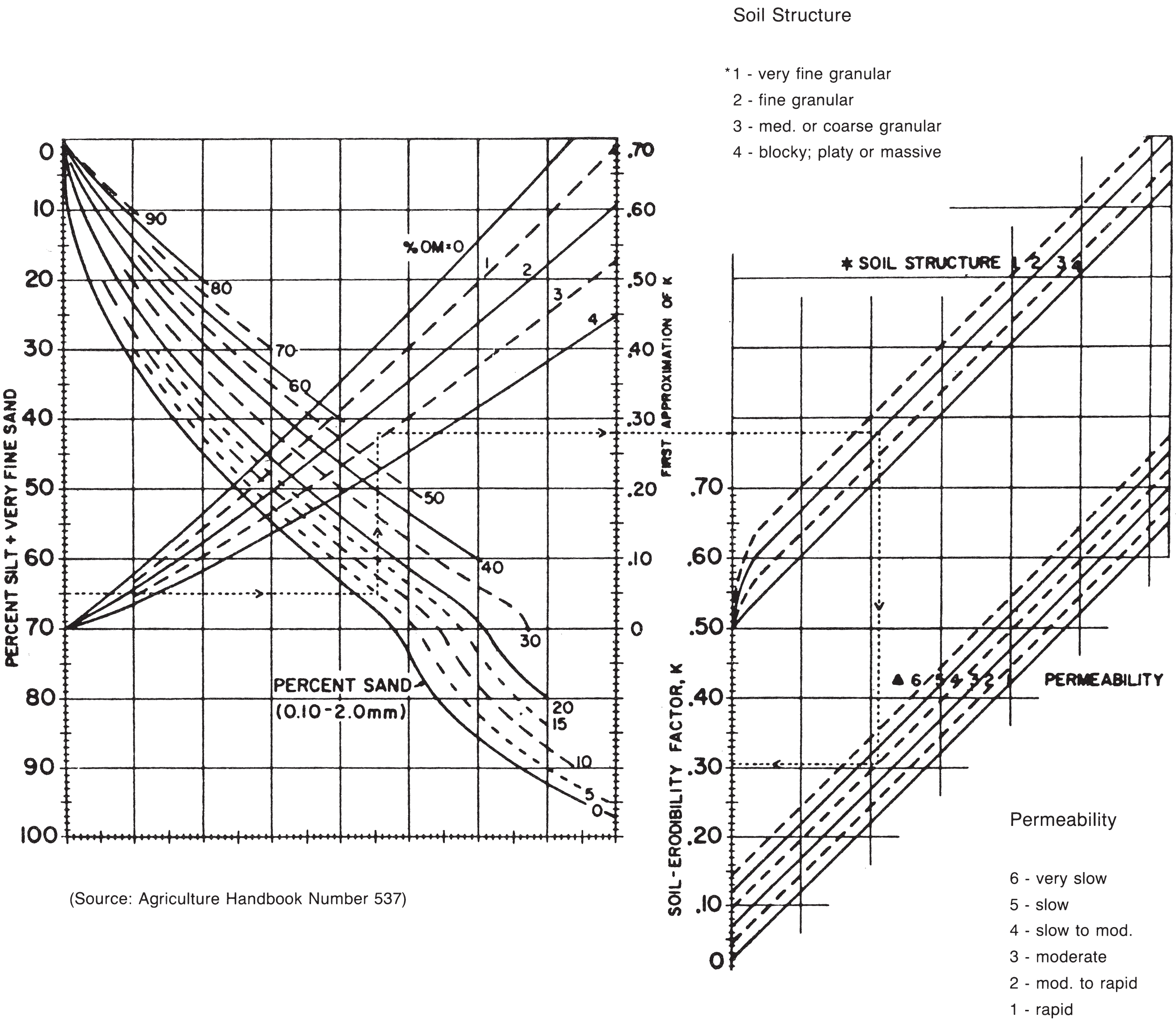
Information on plasticity of soils commonly found in North Carolina is given in Table 8.01d

Permeability

Permeability is a major factor influencing erosion. It refers to the soil's ability to transmit water or air and depends on both the size and volume of pores. Deep, permeable soils are less erodible because more rainfall soaks in, reducing surface runoff. Because permeability varies with depth, excavation may expose layers that are more or less permeable than the original surface. Compaction reduces permeability.

Depth to Bedrock

Soil survey interpretation sheets generally provide an estimate of depth to and hardness of bedrock, the solid (fixed) rock underlying soil. This information is helpful in determining time and cost of excavation as well as potential erodibility of the subsoil material. Hardness classes, "soft" and "hard", indicate the ease of excavating into the bedrock. "Soft" rock is likely to be sufficiently soft, thinly bedded, or fractured so that excavation can be made with trenching machines, backhoes, small ripper, or other equipment common in construction of pipelines, sewer lines, cemeteries, dwellings, or small buildings.



(Source: Agriculture Handbook Number 537)

Procedure: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0mm), % organic matter, structure and permeability, **in that sequence**. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: silt + vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Figure 8.01e Soil-erodibility nomograph

"Hard" rock is likely to require blasting or special equipment beyond what is considered normal in this type of construction.

Bedrock at shallow depths limits plant growth by restricting root penetration. There is frequently a correlation between bedrock depth and water holding capacity.

Soil Reaction, (pH)

Soil reaction represents the degree of acidity or alkalinity of a soil, expressed as pH. The pH in soils is directly related to parent material. The principal value of soil pH measurement is the knowledge it gives about associated soil characteristics, such as phosphorus availability or base saturation. A pH of approximately 6 to 7 indicates readily available plant nutrients.

Leaching removes bases, causing a pH decline. Therefore, the amount of rainfall, rate of percolation, return movement of moisture by capillary action, and evaporation affect pH. The pH is higher in soils of arid regions than in humid regions, higher in younger soils than older soils, higher on steep slopes than on flap topography, and higher under prairie than under timber.

Soil reaction is also used as an indicator of corrosivity or dispersivity. In general, soils that are either very alkaline or very acid are likely to be highly corrosive to steel. Soils that are acid are likely to be corrosive to concrete.

The range of pH for soils commonly found in North Carolina is given in Table 8.10d.

Seasonal High Water Table

A seasonal high water table is a zone of saturation at the highest average depth during the wettest season of the year. It is at least 6 inches thick, persists in the soil for more than a few weeks, and is within 6 feet of the soil surface. Soils that have a seasonal high water table are classified according to depth to the water table, kind of water table, and time of year when the water table is highest. Depth and duration of high water may limit soils for uses, such as septic tank absorption fields, roadfill, and topsoil. A water table near the surface during the growing season is detrimental to many plants and must be considered in vegetation plans.

Hydrologic Group

Hydrologic group identifies soils as having the same runoff potential under similar storm and cover conditions. Soil properties that determine the hydrologic groups include the following: seasonal high water table, water intake rate and permeability after prolonged wetting, and depth to the slowly permeable layer. The influence of ground cover is not considered. The soils in the U.S. and Caribbean area are placed into four groups (A, B, C, and D) and three dual classes (A/D, B/D, C/D). In the definition of classes, infiltration rate is the rate at which water enters the soil at the surface, controlled by surface conditions. Transmission rate is the rate water moves in the soil, controlled by the permeability of deeper horizons. The hydrologic group for soils commonly found in North Carolina is given in Table 8.01d. Definitions of the groups are listed below.

- **Group A** (low runoff potential)—Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

- **Group B**—Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

- **Group C**—Soils having slow infiltration rates when thoroughly wetted. Group C soils often have a layer that impedes downward movement of water, or may consist of moderately fine to fine-textured particles. These soils have a slow rate of water transmission.

- **Group D** (high runoff potential)—Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of clay soils with high swelling potential. These soils frequently have a permanent high water table, or a claypan or clay layer at or near the surface. Other soils in this group consist of shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

- **Dual hydrologic groups**, A/D, B/D, and C/D, are indicated for certain wet soils that can be drained. The first letter applies to the drained condition, the second to the undrained condition. Only soils that are rated D in their natural condition are assigned to a group.

Engineering Classification

Soils are classified according to engineering properties by two classification systems in the soil survey: (1) the AASHTO system and (2) the Unified Soil Classification System. Engineering classification for soils commonly found in North Carolina is given in Table 8.01d.

AASHTO System

The AASHTO system classifies soils according to the properties that affect roadway construction and maintenance. The fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of grain-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in silt and clay. Soils in group A-7 are fine grained. Highly organic soils in Group A-8 are classified on the basis of visual inspection. The AASHTO classification system is summarized in Table 8.01b.

Unified System

The Unified System classifies soils according to suitability for construction material: grain-size distribution, plasticity index, liquid limit, and organic matter content. This classification is based on that portion of soil having particles smaller than 3 inches in diameter. Classes include coarse-grained soils (GW, GP, GM, GC, SW, SP, SM, SC), fine-grained soils (ML, CL, OL, MH, CH, OH), and highly organic soils (PT). Borderline soils require a dual classification symbol. Table 8.01c provides classification descriptions for each class in the Unified System.

Table 8.01b
AASHTO Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or less passing 0.075 mm)							Silt-Clay Materials (More than 35% passing 0.075 mm)			
Group Classification	A - 1		A - 3	A - 2				A - 4	A - 5	A - 6	A - 7 A - 7 - 5 A - 7 -6
	A - 1- a	A - 1 - b		A - 2 - 4	A - 2 - 5	A - 2 - 6	A - 2 - 7				
Sieve Analysis, Percent Passing:											
2.00 mm (No. 10)	50 max										
0.425 mm (No. 40)	30 max	50 max	51 min								
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of Fraction Passing 0.425 mm (No. 40)											
Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		N.P.	10 max	10 max	11 min	11min	10 max	10 max	11 min	11 min[a]
Usual Types of Significant Constituent Materials	Stone Fragments Gravel and Sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
General Ratings as Subgrade	Excellent to Good							Fair to Poor			

[a] Plasticity index of A - 7 -5 subgroup is equal to or less than LL minus 30.
Plasticity index of A-7-6 subgroup is greater than LL minus 30.

FIELD TESTS

Although soil textures are defined in terms of the particle-size distribution determined by mechanical analysis in the laboratory, it is often desirable and necessary to estimate the textural class in the field. Field estimates of texture are influenced by consistency, structure, organic matter content, kind of clay and absorbed cations, and particle size.

Classification of soils in the field involves several different tests. Screening and weighing the samples are not necessary. Field tests described here include tests to (1) determine texture as coarse- or fine-grained, (2) classify coarse-grained materials, (3) classify fine-grained materials, and (4) determine if the soil has high organic matter content, high plasticity, or high clay content.

Determining Texture as Coarse- or Fine-grained

TEST 1
Spread the sample on a flat surface, and examine the particles to determine approximate grain size by visual inspection. If more than 50% of the sample has individual grains that are visible to the naked eye, the material is coarse; if less than 50%, it is fine.

Aggregated dry particles may appear to be sand-sized. Saturating the sample will break these aggregated particles down. By rubbing the wetted soil between the thumb and forefinger, sand-sized grains can be detected as they will feel rough and gritty. Practice with samples with known percentages of sand is helpful in establishing sand content.

TEST 2
Fill a straight-sided glass bottle to approximately 0.4 of its height with the sample, then nearly fill the bottle with water. Shake until all the material is in suspension. Estimate the percentage that settles in 25 seconds. If more than 50%

Table 8.01c
Classification of Materials for the Unified System

Group Symbol	Description of Material Classification
Coarse-grained	
GW	Well-graded gravels and gravel-sand mixture little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
GM	Silty gravels, gravel-sand-silt mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.
GC	Clayey gravels, gravel-sand clay mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.
SW	Well-graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
SP	Poorly graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.
SM	Silts sands, sand-silt mixtures. More than 50% passes No. 4 sieve. More than 50% retained on No. 200 sieve.
SC	Clayey sands, sand-clay mixtures. More than 50% passes No. 4 sieve. More than 50% retained on No. 200 sieve.
Fine-grained	
OL	Organic silts and organic silty clays of low plasticity. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. Liquid limit 50% or less. 50% or more passes No. 200 sieve.
MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
CH	Inorganic clays of high plasticity, fat clays. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
OH	Organic clays of medium to high plasticity. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.
Highly organic	
PT	Peat, muck, and other highly organic soils.

NOTE: These are boundary classifications. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC is a well-graded, gravel-sand mixture with clay binder.
All sieve sizes on this table are U.S. Standard.

of the material settles in 25 seconds, the material is coarse-grained; if less than 50% of the material settles in 25 seconds, the material is fine-grained.

Classifying Coarse-Grained Materials

Spread a representative sample on a flat surface. Determine whether more than one-half of the visible grains by weight are pea size or larger. If they are, it is a gravel; if not, it is a sand.

After determining if the material is a gravel of a sand, it is further classified according to the properties of the fine content of the material. Remove the coarse material by spreading a thin layer of material on a sheet of paper and tapping the coarse material to the edge. Saturate the remaining material, and work it into the hands. The hands will not be stained if there is less than 5% fines. It will be GW or GP if the material is a gravel, or SW or SP if the material is a sand. The hands will be stained if there is more than 12% fines. Weak casts can be formed from moist material. It will be GM or GC if the material is a gravel, SM, or SC if the material is a sand.

Dual symbol materials (5 to 12% fines) cannot be readily classified by field procedures.

Use a second sample if there is less than 5% fines. Spread it out an observe the grain size distribution. If the coarse material consists of fairly well-distributed particles, the material is a well-graded gravel or sand (GW or SW). If the coarse material consists chiefly of single-sized particles or of large and small particles with in-between sizes missing, the material is a poorly graded gravel or sand (GP or SP).

When there are more than 12% fines in a coarse-grained material, make the plasticity tests on the fines described below under **Classifying Fine-grained Materials** to determine whether the material is clayey or silty.

The material will be GC or SC if clayey and GM or SM if silty.

Classifying Fine-Grained Materials

TEST 1
Prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water to make the soil soft, but not sticky. Place pat in the open palm of the hand and shake it horizontally. Presence of fine-grained material is indicated by the appearance of water on the surface of the pat, giving the sample a glossy appearance. The water and gloss will disappear from the surface when the pat is squeezed between the thumb and forefinger. The rapidity of the appearance of water during shaking and its disappearance when squeezed identifies the character of the fines. An ML will have a rapid reaction; an MH and CL, a slow reaction; and a CH, no reaction.

TEST 2
Dry crushing strength is estimated by crushing a dry clod between the fingers. A block of soil at least 3/4 inch in smallest dimension should be used, as smaller samples may give erroneous results. CH material is almost impossible to break. Easily crushed material of low strength is classified ML. Medium strength material is either CL or MH.

TEST 3
The toughness test uses the same procedures that are used in the laboratory to determine the plastic limit (PL). Wet and mold a soil sample so that it can be rolled into a thread without crumbling. The material will not stick to the hands if the correct amount of water is added. Roll the moist soil with the palm of the hand on any clean, smooth surface such as a piece of paper, to form a 1/8 inch diameter thread. Gradually reduce the moisture content by breaking up the sample and remolding and rolling it until the 1/8 inch thread breaks into approximately 3/4 inch long pieces. The material is then at its plastic limit. Circumferential breaks in the thread indicate a CH or CL material. Longitudinal cracks and diagonal breaks indicate an MH material.

Remold the sample into a coarse thread and pull it apart. A tough thread indicates high plasticity (CH or CL). A medium tough thread indicates an MH material. A weak thread indicates an ML material.

TEST 4
The ribbon test uses a sample with moisture content at or slightly below the plastic limit. The ribbon is formed by squeezing and working the sample between thumb and forefinger.

A weak ribbon that breaks easily indicates an ML soil. A hard ribbon that breaks fairly readily indicates an MH soil. A flexible ribbon with medium strength indicates a CL soil. A strong, flexible ribbon indicates a CH soil.

TEST 5
A test for stickiness can be made by saturating the material and letting it dry on the hands. An ML soil will brush off with little effort. A CL or MH soil rubs off with moderate effort when dry. A CH soil requires rewetting to completely remove it from the hands.

TEST 6
The Liquid Limit (LL) test takes a pat of moist soil with volume about one-half cubic inch and enough water to make the soil soft, but not sticky. Rapidly add enough water to cover the surface. Break the pat open immediately. If water penetrates, the LL is low. If water does not penetrate, LL is high. Visual observation of this phenomenon is much easier in direct sunlight.

Determining Other Conditions

Tests are also available to identify high organic matter content, plasticity, and clay content, as described below.

- **Odor test**—to determine high organic matter content. Fresh, damp organic soils have a distinctive, pungent, musty odor.

- **Shine test**—to determine plasticity. In making the shine test, be sure soil is not micaceous. Rub a small clod of air-dry soil with a knife blade. A shiny surface indicates high plasticity. You are seeing the shine of the dry, highly plastic fines.

- **Malachite-green test**—to determine clay content. The staining agent used is a saturated nitrobenzene solution of malachite green. Clay minerals of the kaolinite group merely absorb the dye, becoming blue to green-blue after application of this solution. Montmorillonite becomes yellow-red, and illite becomes purple-red to purple.

Table 8.01d
Soil Characteristics for Common Soils in North Carolina.

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
ALAGA	0-6	4.5-6.0	0.17	A	NP	LS, LFS, FS	SM, SW-SM, SP-SM	A-2, A-1-B
	6-80	4.5-6.0	0.17	A	NP-4	LS, LFS, FS	SM, SW-SM, SP-SM	A-2
ALAMANCE	0-11	4.5-7.3	0.43	B	NP-10	L, SIL,VFSL	ML	A-4
	0-11	4.5-7.3	0.28	B	NP-5	GR-L, GR-SIL, GR-VFSL	ML	A-4
	11-35	4.5-5.5	0.43	B	7-20	CL, SICL, SIL	CL, ML	A-4, A-6, A-7
	35-46	4.5-5.5	0.43	B	5-15	L, SIL, VFSL	CL, ML, CL-ML	A-4, A-6, A-7
	46-84	4.5-6.0	0.32	B	NP-12	VFSL	ML	A-4, A-6
	64-80			B		Var		
ALBANY	0-48	3.6-6.5	0.10	C	NP	S, FS	SM	A-2
	0-48	3.6-6.5	0.10	C	NP	LS	SM	A-2
	48-56	4.5-6.0	0.20	C	NP	SL	SM	A-2
	56-88	4.5-6.0	0.24	C	NP-17	SCL, SL, FSL	SC, SM, SM-SC	A-2, A-4, A-6
ALTAVISTA	0-12	4.5-6.0	0.20	C	NP	LS, SL	SM	A-2
	0-12	4.5-6.0	0.24	C	NP-7	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	12-42	4.5-6.0	0.24	C	5-28	CL, SCL, L	CL, CL-ML, SC, SM-SC	A-4, A-6, A-7
	42-60			C	NP	Var		
AMERICUS	0-7	4.5-5.5	0.10	A	NP	LS, S, LFS	SM, SP-SM	A-2
	7-47	4.5-5.5	0.17	A	NP	LS, LFS	SM	A-2
	47-72	4.5-5.5	0.20	A	NP-7	SL, LS, FSL	SM, SM-SC	A-2
APPLING	0-9	4.5-5.5	0.24	B	NP-5	FSL, SL, LS	SM, SM-SC	A-2
	0-9	4.5-5.5	0.15	B	NP	GR-SL, GR-COSL	GM, GP-GM, SM, SP-SM	A-1
	0-9	4.5-5.5	0.20	B	6-20	SCL	CL, SC, CL-ML, SM-SC	A-6, A-4
	9-35	4.5-5.5	0.20	B	15-30	SC, CL, C	MH, ML	A-7
	35-46	4.5-5.5	0.24	B	8-22	SC, CL,SCL	SC, CL	A-4, A-6, A-7
	45-65			B	NP	Var		
ARAPAHOE	0-17	3.6-5.5	0.15	B/D	NP	LFS, LS	SM	A-2, A-4
	0-17	3.6-5.5	0.15	B/D	NP-4	FSL, L	SM	A-2, A-4
	17-42	3.6-7.8	0.15	B/D	NP	FSL, L, SL	SM	A-2, A-4
	42-80	5.6-7.8	0.10	B/D	NP-4	SR,-LS-S	SM, SP-SM	A-2, A-3, A-4
ASHE	0-7	4.5-6.0	0.24	B	NP-7	L, SL, FSL	SM, SM-SC, ML, CL-ML	A-4
	0-7	4.5-6.0	0.17	B	NP-7	GR-L, GR-SL, GR-FSL	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.17	B	NP-7	ST-L, ST-SL, ST-FLS	SM, SM-SC	A-2, A-4
	7-25	4.5-6.0	0.17	B	NP-7	L, SL, FSL	SM, SM-SC	A-4
	25-30	4.5-6.0	0.17	B	NP	SL	SM	A-2, A-4
	30			B		UWB		
AUGUSTA	0-9	4.5-6.0	0.24	C	NP-10	SIL, L	ML, CL-ML	A-4
	9-60	4.5-6.0	0.24	C	5-25	SCL, CL, L	CL, CL-ML	A-4, A-6, A-7
	60-70	4.5-6.0	0.24	C	NP-5	COSL, L, GR-LS	SM,SP-SM, ML, SM-SC	A-2, A-4, A-1
AUTRYVILLE	0-26	4.5-6.5	0.10	A	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	26-41	4.5-5.5	0.10	A	NP-3	SL, SCL, FSL	SM	A-2
	41-58	4.5-5.0	0.10	A	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	58-85	4.5-5.5	0.17	A	NP-10	SL, SCL, FSL	SM, SC, SM-SC	A-2, A-4
AYCOCK	0-12	4.5-6.0	0.37	B	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-80	4.5-5.5	0.43	B	8-30	CL. SICL, L	CL	A-4, A-6, A-7

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
AYERSVILLE	0-8	4.5-6.0	0.32	B	NP-11	L, SIL, SICL	ML, CL-ML, CL, SC	A-4, A-6
	0-8	4.5-6.0	0.28	B	4-25	GR-L, GR-SIL, GR-SICL	SM, SM-SC, ML, SC	A-4, A-6
	8-22	4.5-5.5	0.28	B	4-25	GR-SIL, GR-L, L	CL, CL-ML, ML	A-4, A-6, A-7
	22-26	4.5-5.5	0.28	B	NP-10	GR-SIL, GR-L	CL, CL-ML, ML	A-4
	26-30			B	NP			
	30			B	NP			
BADIN	0-6	3.6-6.5	0.24	C	NP-10	CN-SIL, CN-VFSL, CN-L	ML, CL, CL-ML, GM	A-4
	6-25	3.6-5.5	0.24	C	15-35	SIC, SICL, CN-SICL	CL, CH	A-6, A-7
	25-40			C	NP	WB		
	40			C	NP	UWB		
BALLAHACK	0-9	4.5-5.5	0.10	D	NP-10	FSL, SL, L	SM, SC. CL, ML	A-4
	9-35	4.5-5.5	0.10	D	8-20	SCL, L	SC, CL	A-4, A-6
	35-74	4.5-5.5	0.17	D	NP-10	SR-S-SC	SM, SC, ML, CL	A-2, A-4
BARCLAY	0-57	4.5-6.0	0.43	C	NP-7	L, SIL, VFSL	CL-ML, ML	A-4
	57-72	4.5-6.0	0.43	C	NP	FS, LS, FSL	SM, SP-SM	A-2
BAYBORO	0-14	4.5-5.5	0.15	D	NP-7	FSL	SM-SC, SM, CL-ML, ML	A-4
	0-14	4.5-5.5	0.17	D	4-20	L, CL	CL, ML, CL-ML	A-6, A-7
	14-64	4.5-5.5	0.32	D	20-40	CL, SC, C	CL, CH	A-7
BAYMEADE	0-36	4.5-6.5	0.10	A	NP	FS, S	SM, SP-SM	A-2, A-3
	0-36	4.5-6.5	0.10	A	NP	LS, LFS	SM	A-2-4
	36-49	4.5-6.5	0.10	A	2-9	FSL, SCL, SL	SC, SM, SM-SC	A-2, A-4
	49-78	4.5-6.5	0.10	A	NP	LFS, S, LS	SM, SP-SM	A-2, A-3
BELHAVEN	0-26	4.5		D	NP	MUCK	PT	
	26-32	3.6-5.5	0.24	D	NP-10	SL, FSL	SM, SC, SM-SC	A-2, A-4
	32-65	3.6-6.5	0.24	D	4-15	L, CL, SCL	CL, CL-ML, SC, SM-SC	A-4, A-6
	65-72	3.6-6.5	0.15	D	NP	SR-S, FS	SM, SP-SM	A-2, A-3
BERTIE	0-17	4.5-6.5	0.17	B	NP-4	LS, LFS	SM	A-2
	0-17	4.5-6.5	0.20	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	17-42	4.5-6.5	0.24	B	4-16	SCL, CL, SL	SC, CL, SM-SC, CL-ML	A-2, A-4,A-6
	42-57	4.5-6.0	0.24	B	NP-8	FSL, SL, SCL	SM, SM-SC	A-2, A-4
	57-85	4.5-6.0	0.17	B	NP-6	SL, LFS, FS	SM, SM-SC, SP-SM	A-2, A-4
BIBB	0-12	4.5-5.5	0.20	C	NP-7	SL, FSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	0-12	4.5-5.5	0.28	C	NP-7	L, SIL	ML, CL-ML	A-4
	0-12	4.5-5.5	0.15	C	NP	S, LS	SM, SP-SM	A-2, A-3
	12-60	4.5-5.5	0.37	C	NP-7	SL, L, SIL	SM, SM-SC, ML, CL-ML	A-2, A-4
BILTMORE	0-10	5.1-7.8	0.15	A	NP-4	FSL, SL, LFS	SM	A-2, A-4
	10-60	5.1-7.8	0.10	A	NP	LS, LFS, S	SM, SP-SM	A-2
BLADEN	0-14	3.6-5.5	0.24	D	NP	FSL, SL	SM	A-2, A-4
	0-14	3.6-5.5	0.37	D	NP-10	L, SIL	CL, ML, CL-ML	A-4
	14-41	3.6-5.5		D	23-45	C, SC	CL, CH	A-7
	41-62	3.6-5.5		D	8-35	C, SC, CL	CL, CH, SC	A-4, A-6, A-7
	62-80			D	NP	Var		
BLANEY	0-25	4.5-6.0	0.15	B	NP	S, LS	SM, SP-SM	A,2, A-3
	0-25	4.5-6.0	0.10	B	NP	COS, LCOS	SM, SP-SM	A-2, A-3, A-1-B
	25-50	4.5-5.5	0.28	B	NP-20	SCL, SL	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B
	50-65	4.5-5.5	0.28	B	NP-14	SL, SCL, LS	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
BLANTON	0-58	4.5-6.0	0.10	A	NP	S, FS, COS	SP-SM	A-3, A-2-4
	0-58	4.5-6.0	0.15	A	NP	LS, LFS	SM	A-2-4
	0-58	4.5-6.0	0.05	A	NP	GR-S	SP-SM	A-1, A-2-4, A-3
	58-62	4.5-5.5	0.15	A	NP-3	SL, LS, LCOS	SM	A-2-4
	62-80	4.5-5.5	0.20	A	3-22	SCL, SL, FSL	SM, SM-SC, SM	A-4, A-2-4, A-2-6, A-6
BOWIE	0-12	5.1-6.5	0.32	B	NP-6	FSL	SM, SM-SC, ML	A-2-4, A-4
	12-42	4.5-5.5	0.32	B	8-25	SCL, CL, FSL	SC, CL	A-4, A-6
	42-78	4.5-5.5	0.28	B	8-30	SCL, CL, FSL	SC, CL	A-4, A-6, A-7
BRADDOCK	0-9	3.6-5.5	0.32	B	NP-10	L, FSL, SL	CL, SM, ML, SC	A-2, A-4
	0-9	4.5-5.5	0.32	B	15-25	CL, SICL, GR-CL	ML, CL	A-6, A-7
	9-48	4.5-5.5	0.24	B	15-23	CL, GR-SC, C	MH, CH, CL, SC	A-7, A-2
	48-80	4.5-5.5	0.24	B	8-28	L, SCL, CBV-C	SC, CL	A-2, A-4, A-6, A-7
BRADSON	0-6	4.5-6.0	0.20	B	NP-15	L, FSL, SL	SC, SM, ML	A-4, A-6
	0-6	4.5-6.0	0.15	B	NP-15	GR-L, GR-FSL, GR-SL	SM, SM-SC, SC	A-2
	6-65	4.5-6.0	0.24	B	11-25	CL, SC, C	ML, MH	A-7
	65-75	4.5-6.0	0.32	B	NP-10	L, SCL, SL	ML, CL-ML, CL	A-4
BRAGG	0-6	4.5-5.5	0.20	C	NP-4	LS, SL, SCL	SM	A-2, A-4
	6-30	4.5-5.5	0.28	C	3-25	SR-SL, CL	SM-SC, SC, CL	A-2, A-4, A-6, A-7-6
	30-72	4.5-5.5	0.28	C	3-18	SL, SCL, SC	SM, SC, ML, CL	A-4, A-6
	72-80			C	NP	Var		
BRANDYWINE	0-8	3.6-5.5	0.24	C	2-11	L	ML, SM	A-4, A-6
	0-8	3.6-5.5	0.20	C	2-11	GR-L	ML, SM, GM	A-2, A-4, A-6
	8-12	3.6-5.5	0.28	C	NP-10	GR-L, L	SM, ML, GM, GL-ML	A-2, A-4
	12-60	3.6-5.5	0.17	C	NP	GR-VCOS, GR-LS	GW, GP, GM-SP	A-1
BREVARD	0-4	4.5-6.0	0.24	B	NP-10	L, SIL	ML, CL, CL-ML	A-4
	0-4	4.5-6.0	0.15	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	4-76	4.5-6.0	0.24	B	5-15	SCL, CL, SICL	CL, CL-ML	A-4, A-6
	76-80	4.5-6.0		B	NP	GR-L	GM	A-1
BUCKS	0-15	4.5-5.5	0.32	B	3-10	SIL	ML, CL, CL-ML	A-4
	15-35	4.5-5.5	0.37	B	3-15	SIL, SICL, SH-L	ML, CL, SM, SC	A-4, A-6
	35-44	4.5-5.5	0.32	B	NP-10	SH-SIL, SIL, SICL	ML, CL, GM, SM	A-4, A-2
	44			B	NP	UWB		
BUNCOMBE	0-10	6.1-6.5	0.10	A	NP	LS, S	SM, SP-SM	A-2, A-3
	10-55	4.5-6.0	0.10	A	NP	LS, S	SM, SP-SM	A-2, A-3
	55-65			A	NP	Var		
BURTON	0-12	3.6-6.0	0.24	B	NP-7	L, FSL, SL	SM, SM-SC	A-2, A-4
	12-21	3.6-6.0	0.15	B	NP-7	L, FSL, SL	SM, SM-SC	A-2, A-4
	21-28	3.6-6.0	0.15	B	NP-3	FSL, SL	SM, GM, SP-SM	A-2, A-1-B
	28-29			B	NP	UWB		
BYARS	0-13	3.6-5.5	0.20	D	NP-7	SL, FSL	SM, ML	A-4
	0-13	3.6-5.5	0.28	D	11-23	SICL, CL, L	CL	A-6, A-7-6
	0-13	3.6-5.5	0.37	D	11-23	SIL	CL	A-6, A-7-6
	13-43	3.6-5.5	0.32	D	17-42	C, CL, SC	CL, CH	A-7-5, A-7-6, A-6
	43-73	3.6-5.5	0.32	D	8-20	C, SICL, SIC	CL	A-6, A-7, A-4
	73-79			D		Var		
CAHABA	0-9	4.5-6.0	0.24	B	NP	SL, FSL	SM	A-4, A-2-4
	0-9	4.5-6.0	0.15	B	NP	LS, LFS	SM	A-2
	0-9	4.5-6.0	0.28	B	NP-7	L	ML, CL-ML	A-4
	9-53	4.5-6.0	0.28	B	8-15	SCL, L, CL	SC, CL	A-4, A-6
	53-80	4.5-6.0	0.24	B	NP	S, LS, SL	SM, SP-SM	A-2-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
CAPE FEAR	0-16	4.5-6.5	0.15	D	3-15	L, SIL	ML. CL-ML, CL	A-4, A-6
	0-16	4.5-6.5	0.17	D	NP-10	FSL, VFSL	SM, SC, SM-SC	A-4
	16-52	4.5-6.0	0.32	D	15-35	CL, C, SIC	ML, CL, MH, CH	A-7
	52-62			D	NP	Var		
CAROLINE	0-9	3.6-5.5	0.43	C	NP-5	FSL, SL	SM, ML, CL-ML, SM-SC	A-2, A-4
	0-9	3.6-5.5	0.43	C	NP-7	L, SIL	ML, CL-ML	A-4
	0-9	3.6-5.5	0.43	C	15-40	CL, SCL	CL, CH	A-6, A-7
	9-84	3.6-5.5	0.32	C	18-40	CL, C, SIC	CL, CH	A-7
	84-99	3.6-5.5	0.32	C	5-40	CL, C, GR-FSL	SM-SC, SC, CL, CH	A-4, A-6, A-7
CARTECAY	0-9	5.1-6.5	0.24	C	NP	SL, LS	SM	A-2, A-4
	0-9	5.1-6.5	0.32	C	NP-15	L, SIL, SICL	ML, CL, CL-ML	A-4, A-6
	0-9	5.1-6.5	0.24	C	NP-5	VFSL, FSL	SM, SM-SC, ML	A-2, A-4
	9-40	5.1-6.5	0.24	C	NP-10	SL, FSL, L	SM, SC, SM-SC	A-2, A-4
	40-60	5.1-6.5	0.15	C	NP	LS, S, SL	SM, SP-SM	A-2, A-1
CARTERET	0-80	5.6-8.4	0.15	D	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-80	5.6-8.4	0.15	D	NP	S, FS	SP, SP-SM	A-3
CATAULA	0-7	5.1-6.5	0.17	B	NP-7	LS	SM, SM-SC	A-2
	0-7	5.1-6.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-7	5.1-6.5	0.32	B	NP-20	SCL, CL	CL, ML, SC, SM	A-4, A-6, A-7
	7-27	4.5-6.0	0.24	B	11-30	C, CL,SC	MH, ML, CL	A-7, A-6
	27-55	4.5-6.0	0.24	B	2-30	SCL, SC, CL	MH, ML	A-5, A-7
	55-75	4.5-6.0	0.32	B	20	SCL, CL, L	CL, ML, CL-ML, SC	A-4, A-6
CECIL	0-7	4.5-6.0	0.28	B	NP-6	SL, FSL, L	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.15	B	NP-4	GR-SL	GM, GM-GC, SM, SM-SC	A-2, A-1
	0-7	4.5-6.0	0.28	B	3-15	SCL, CL	SM, SC, CL, ML	A-4, A-6
	7-11	4.5-6.0	028	B	3-15	SCL, CL	SM, SC, ML, CL	A-4, A-6
	11-50	4.5-5.5	0.28	B	9-37	C	MH, ML	A-7, A-5
	50-75			B	NP	Var		
CHANDLER	0-4	4.5-6.0	0.15	B	12-26	L, FSL, SIL	ML, MH	A-7
	0-4	4.5-6.0	0.17	B	NP-7	ST-L, ST-FSL, ST-SIL	SM	A-4
	4-66	4.5-6.0	0.15	B	12-26	L, FSL, SIL	ML, MH	A-7
CHAPANOKE	0-6	3.6-6.5	0.43	C	NP-7	SIL, L	ML, CL-ML	A-4
	0-6	3.6-6.5	0.37	C	NP-7	FSL, VFSL	SM, ML, CL-ML, SM-SC	A-4
	6-50	3.6-6.5	0.43	C	6-30	SICL, L, CL	CL, CL-ML, ML	A-4, A-6, A-7
	50-62	3.6-6.5	0.37	C	NP-7	FSL, LFS	SM, SM-SC, ML	A-2, A-4
	62-80	3.6-6.5	0.20	C	NP-7	SR-S-L	SM, ML, SM-SC, CL-ML	A-2, A-4
CHASTAIN	0-5	4.5-6.0	0.32	D	3-18	SICL, SIL, L	ML, CL, CL-ML	A-4, A-6, A-7
	0-5	4.5-6.0	0.28	D	12-40	SIC, CL, C	ML, CL, MH, CH	A-6, A-7
	5-52	4.5-6.0	0.37	D	12-40	SICL, SIC, C	CL, CH, ML, MH	A-6, A-7
	52-72	4.5-6.0	0.10	D	NP	LS, S.FS	SP, SM, SP-SM	A-2, A-3
CHESTER	0-15	4.5-5.5	0.32	B	8-12	SIL, L	ML, CL	A-4, A-6, A-7
	0-15	4.5-5.5	0.28	B	8-12	CN-L, CN-SIL	ML, CL	A-4, A-6, A-7
	15-36	4.5-5.5	0.43	B	8-17	SICL, SIL, CN-L	ML, CL, SM, SC	A-4, A-6, A-7
	36-62	4.5-5.5	0.49	B	16	L	SM, SC, ML	A-2, A-4, A-7
CHEWACLA	0-8	4.5-6.5	0.24	C	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-8	4.5-6.5	0.28	C	4-20	SIL, L	ML, CL, CL-ML	A-4, A-6, A-7
	8-24	4.5-6.5	0.32	C	4-22	SIL, SICL, CL	ML, CL	A-4, A-6, A-7
	24-34	4.5-6.5	0.28	C	NP-7	SCL, L, SL	SM, CL-ML, SM-SC, ML	A-4
	34-58	4.5-6.5	0.32	C	4-28	SIL, CL, SICL	ML, MH	A-4, A-6, A-7
	58-70			C	NP	Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	----------Textural Classification[1]---------- USDA	Unified	AASHTO
CHIPLEY	0-6	3.6-6.0	0.10	C	NP	S, FS	SP-SM	A-3, A-2-4
	6-77	4.5-6.5	0.10	C	NP	S, FS	SP-SM	A-3, A-2-4
CHOWAN	0-6	3.6-6.0	0.32	D	4-24	L, SIL, SICL	CL-ML, ML, MH	A-7-5, A-4, A-6
	6-27	3.6-6.0	0.32	D	6-30	S, SIL, SICL	CL, MH, ML	A-7-5, A-4, A-6
	27-80	3.6-5.0		D	NP	SP	PT	
CLIFTON	0-5	4.5-6.5	0.17	B	NP-10	L, FSL	ML, CL, CL-ML	A-4
	0-5	4.5-6.5	0.17	B	5-12	CL	ML, CL, CL-ML	A-4, A-6
	0-5	4.5-6.5	0.17	B	NP-7	ST-L, ST-FSL	SM, CL-ML, SM-SC	A-4
	5-10	4.5-6.5	0.17	B	12-20	L, CL, SCL	SC, SM-SC	A-4, A-6
	10-45	4.5-6.5	0.17	B	12-25	C, CL	ML, MH	A-7
	45-65	4.5-6.5	0.17	B	NP-18	FSL, L	SM, ML, CL, SC	A-4
CODORUS	0-18	4.5-6.0	0.49	C	2-12	SIL, L	ML, CL, CL-ML	A-4, A-6
	18-54	5.1-6.5	0.37	C	2-12	SIL, L, SICL	ML, CL, CL-ML	A-4, A-6
	54-60	5.1-6.5	0.24	C	NP-7	SR-S-SI	SM, GM, ML	A-1, A-2, A-4
COLFAX	0-12	4.5-5.5	0.37	C	NP-10	L, SIL	ML, CL, CL-ML	A-4
	0-12	4.5-5.5	0.28	C	NP-10	SL, FSL	SM, SM-SC	A-2, A-4
	12-30	4.5-5.5	0.28	C	7-25	SCL, CL, L	SC, CL	A-4, A-6, A-7-6
	30-46	4.5-5.5	0.28	C	NP-20	SL, FSL, CL	ML, CL, SM, SC	A-2, A-4, A-6
	46-50	4.5-5.5	0.28	C	NP-10	SL	SM, SC, SM-SC	A-2, A-4
	50			C	NP	WB		
COMUS	0-30	4.5-6.0	0.43	B	6-15	SIL, L, FSL	ML, SM, CL, SC	A-2, A-4, A-6
	30-60	4.5-6.0	0.28	B	NP-20	SR-GR, SL-SICL	GM, SM, ML, CL	A-1, A-2, A-4, A-6
CONABY	0-13	3.6-5.5		B/D	NP	MUCK	PT	
	13-21	3.6-5.5	0.10	B/D	NP	S, LS, LFS	SM, SP-SM	A-2, A-3
	21-33	3.6-5.5	0.15	B/D	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-4
	33-74			B/D	NP	Var		
CONETOE	0-25	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-25	4.5-6.0	0.15	A	NP	S, FS	SM, SP-SM	A-2, A-3
	25-41	4.5-6.0	0.15	A	NP-10	SL, SCL	SM, SC, SM-SC	A-2, A-4
	41-80	4.5-6.0	0.10	A	NP	LS, S	SM, SP, SP-SM	A-2, A-3, A-1
CONGAREE	0-8	4.5-7.3	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-8	4.5-7.3	0.37	B	3-10	L, SIL	CL-ML, ML, CL	A-4
	8-38	4.5-7.3	0.37	B	3-22	SICL, FSL, L	SC, ML, CL, SM	A-4, A-6, A-7
	38-80			B	NP	Var		
COROLLA	0-72	5.6-7.8	0.10	D	NP	S, FS	SW, SP-SM, SP	A-2, A-3
COWARTS	0-8	4.5-5.5	0.15	C	NP	LS, LFS	SM	A-2
	0-8	4.5-5.5	0.24	C	NP-5	FSL, SL	SM, SM-SC	A-2, A-4
	8-19	4.5-5.5	0.28	C	NP-15	FSL, SL, SCL	SM-SC, SC, SM	A-2, A-4, A-6
	19-25	4.5-5.5	0.28	C	11-23	SCL, SC, CL	SM-SC, SM, SC	A-6, A-7
	25-60	4.5-5.5	0.24	C	5-20	SL, SCL, CL	SM-SC, SC, CL-ML, CL	A-2, A-4, A-6, A-7
COXVILLE	0-11	3.6-5.5	0.24	D	3-15	FSL, SL, L	SM, ML, CL-ML, CL	A-4, A-6, A-7
	11-72	3.6-5.5	0.32	D	12-35	CL, SC, C	CL, CH	A-6, A-7
	72-80			D	NP	Var		
CRAVEN	0-9	4.5-6.5	0.37	C	NP-7	L, FSL, SIL	ML, CL-ML, SM, SM-SC	A-4
	9-54	3.6-5.5	0.32	C	24-43	C, SIC, SICL	CH	A-7
	54-80	3.6-5.5	0.32	C	NP-15	SCL, LS, SL	SM, SM-SC, SC	A-2, A-4, A-6
CREEDMOOR	0-8	3.6-5.5	0.28	C	NP-7	SL, FSL, L	SM, SM-SC	A-4, A-2
	0-8	3.6-5.5	0.20	C	NP	LS	SM	A-2
	8-19	3.6-5.5	0.32	C	20-30	SCL, CL	CL	A-7
	19-56	3.6-5.5	0.32	C	25-49	C, SIC, SC	CH	A-7
	56-77	3.6-5.5	0.37	C	4-21	SL, SCL, L	ML, CL-ML, SM, SM-SC	A-7, A-6, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	----------Textural Classification[1]---------- USDA	Unified	AASHTO
CROATAN	0-28	4.5		D	NP	MUCK	PT	
	28-38	3.6-6.5	0.17	D	NP-10	SL, FSL, MK-SL	SM, SC, SM-SC	A-2, A-4
	38-60	3.6-6.5	0.24	D	4-15	L, CL, SCL	CL, CL-ML, SC, SM-SC	A-4, A-6
	60-80			D	NP	Var		
CURRITUCK	0-14	4.5-5.5		D	NP	MUCK, MPT	PT	A-8
	14-28	3.6-5.5		D	NP	MUCK	PT	A-8
	28-60	3.6-5.5		D	NP	LS, S	SM, SP-SM	A-2, A-3
DARE	0-70	3.6-4.4		D	NP	MUCK	PT	
	70-80	3.6-6.0	0.15	D	NP	SR-FS, LS	SM, SP-SM	A-2, A-3
DAVIDSON	0-7	4.5-6.5	0.28	B	3-15	L	CL, CL-ML, ML	A-4, A-6
	0-7	4.5-6.5	0.28	B	5-18	CL, SCL	CL, SC, CL-ML, SM-SC	A-6, A-4
	7-12	4.5-6.0	0.32	B	11-25	CL	CL	A-6
	12-53	4.5-6.0	0.24	B	12-33	C	CL, CH, ML, MH	A-7, A-6
	53-72	4.5-6.0	0.28	B	7-30	C, CL, SCL	CL, ML, MH	A-4, A-6, A-7
DELANCO	0-11	3.6-5.5	0.37	C	NP-15	SIL, FSL	ML, CL, SM ,SC	A-4, A-6
	11-36	3.6-5.5	0.32	C	10-25	SICL, CL, L	CL, ML	A-6, A-7
	36-50	3.6-5.5	0.28	C	NP-15	SR-GR-SL-SICL	ML, CL, SM, SC	A-2, A-4, A-6
DELOSS	0-18	4.5-6.5	0.15	B/D	NP-4	LFS	SM	A-2
	0-18	4.5-6.5	0.24	B/D	NP-7	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-2, A-4
	18-56	4.5-5.5	0.24	B/D	4-22	SCL, CL, FSL	SM-SC, SC, CL-ML, CL	A-4, A-6, A-7
	56-80			B/D	NP	Var		
DOROVAN	0-3	3.6-4.4		D	NP	MPT, MUCK	PT	
	3-74	3.6-4.4		D	NP	MUCK	PT	
	74-99	4.5-5.5		D	NP-7	S, LS,L	SP-SM, SM-SC, SM	A-1, A-3, A-4, A-2-4
DOTHAN	0-13	4.5-5.5	0.15	B	NP	LFS, LS	SM	A-2
	0-13	4.5-5.5	0.24	B	NP-5	FSL, SL	SM, SM-SC	A-2, A-4
	13-33	4.5-5.5	0.28	B	NP-16	SCL, SL, FSL	SM-SC, SC, SM	A-2, A-4, A-6
	33-60	4.5-5.5	0.28	B	4-23	SCL, SC	SM-SC, CL-ML, CL	A-2, A-4, A-6, A-7
DRAGSTON	0-9	4.5-5.5	0.20	C	NP-8	FSL, SL, L	SM, SC, SM-SC, CL-ML	A-2, A-4
	0-9	4.5-5.5	0.17	C	NP-7	LFS, LS	SM, SM-SC	A-2
	9-37	4.5-5.5	0.17	C	NP-10	FSL, SL, L	SM, SC, SM-SC, CL-ML	A-2, A-4
	37-66	4.5-6.5	0.17	C	NP-7	S, LS, FSL	SM, SP-SM, SM-SC	A-1, A-2, A-3
DUCKSTON	0-72	3.6-8.4	0.10	A/D	NP	S, FS	SP-SM, SP	A-3
DUNBAR	0-8	4.5-5.5	0.32	D	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-4
	8-80	3.6-5.5	0.32	D	18-35	SC, CL, C	CL, CH	A-6, A-7
DUPLIN	0-8	5.1-7.3	0.24	C	NP-7	SL, FSL, LS	SM, SM-SC	A-2, A-4
	8-80	4.5-5.5	0.28	C	13-35	SC, CL, C	CL, CH, SC	A-6, A-7
DURHAM	0-16	4.5-6.0	0.17	B	NP-3	LCOS, LS	SM	A-2
	0-16	4.5-6.0	0.24	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	16-36	4.5-5.5	0.20	B	10-25	SCL, CL	SC, CL	A-2, A-6, A-7
	36-42	4.5-5.5	0.20	B	13-28	CL, SC, SCL	SC, CL	A-6, A-7
	42-48	4.5-5.5	0.20	B	NP-10	SCL, SL	SM, SC, SM-SC	A-2, A-4
	48-60	4.5-5.5	0.17	B	NP-7	LS, SL, SCL	SM, SM-SC	A-2, A-4
EDNEYVILLE	0-10	4.5-6.0	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-10	4.5-6.0	0.28	B	NP-10	L, SIL	ML, CL-ML, CL	A-4
	10-60	4.5-6.0	0.20	B	6-15	FSL, SL, L	SM, SM-SC	A-2, A-4, A-6

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
ELBERT	0-11	4.5-5.5	0.49	D	14.20	SIL, L, SICL	CL	A-6
	11-41	4.5-5.5	0.24	D	55-65	C	CH	A-7
	41-52	6.1-7.3	0.24	D	26-32	SC, CL, C	MH, CH, SC, SM	A-7
	52-61	6.1-7.3	0.24	D	12-18	SL, GR-SL	SCL, SC	A2
	61			D	NP	WB		
ELIOAK	0-15	4.5-6.0	0.32	C	5-20	SIL, CL, FSL	ML, CL, SM	A-4, A-6, A-7
	15-42	4.5-5.5	0.28	C	11-26	SICL, CL, SIC	CL, CH, MH, ML	A-6, A-7
	42-60	4.5-5.5	0.49	C	NP-10	SIL, L, GR-FSL	ML, SM, GM	A-4, A-5, A-2
ELSINBORO	0-15	4.5-5.5	0.37	B	5-10	SIL, L, SL	ML, CL, SM, SC	A-2, A-4
	15-36	4.5-5.5	0.28	B	2-20	SICL, SIL, L	ML, CL	A-4, A-6, A-7
	36-60	4.5-5.5	0.17	B	2-20	SR, GR-SL, SCL	SM, SC, ML, CL	A-2, A-4, A-6, A-7
ENGLEHARD	0-72	3.6-5.5	0.49	B/D	NP-4	SI, SIL,VFSL	ML	A-4
ENON	0-8	5.1-6.5	0.28	C	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	0-8	5.1-6.5	0.24	C	4-20	L, CL, SCL	CL, CL-ML	A-4, A-6
	8-33	5.1-7.8	0.28	C	25-52	CL, C	CH	A-7-6
	33-75			C	NP	WB		
EUSTIS	0-6	4.5-5.5	0.10	A	NP	S, FS	SP-SM, SM	A-3, A-2-4
	0-6	4.5-5.5	0.10	A	NP	LS, LFS	SP-SM, SM	A-3, A-2-4
	6-24	4.5-5.5	0.17	A	NP	S, FS, LFS	SP-SM, SM	A-3, A-2-4
	24-76	4.5-5.5	0.17	A	NP	LFS, LS	SM	A-2-4
	76-98	4.5-5.5	0.17	A	NP	S, FS	SP-SM	A-3, A-2-4
EXUM	0-12	4.5-6.0	0.37	C	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-80	4.5-5.5	0.37	C	8-30	L, CL, SICL	CL	A-4, A-6, A-7
FACEVILLE	0-5	4.5-5.5	0.17	B	NP	LS, LFS	SM	A-2
	0-5	4.5-5.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-5	4.5-5.5	0.32	B	NP-7	SCL	SM, CL-ML, ML, SM-SC	A-4
	5-11	4.5-5.5	0.37	B	NP-13	SCL, SC	SC, ML, CL, SM	A-4, A-6
	11-72	4.5-6.0	0.37	B	11-25	SC, C, CL	CL, SC, CH	A-6, A-7
FANNIN	0-7	4.5-6.0	0.24	B	8-18	L, SIL, FSL	CL, SC	A-4, A-6
	0-7	4.5-6.0	0.24	B	NP-10	CB-L, CB-SIL, CB-FSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	7-32	4.5-6.0	0.24	B	5-23	CL, SCL, SICL	ML, MH, SM	A-4, A-7
	32-60	4.5-6.0	0.24	B	NP-10	L, SL, FSL	SM, ML	A-2, A-4
FLETCHER	0-11	4.5-5.5	0.43	B	3-8	SIL	ML, CL-ML, CL	A-4
	11-32	4.5-5.5	0.43	B	5-15	SIL, SICL	CL, CL-ML	A-4, A-6
	32-44	4.5-5.5	0.43	B	3-8	SIL	CL, CL-ML, CL	A-4
	44			B	NP	UWB		
FRENCH	0-12	5.1-6.5	0.28	C	4-18	L	CL-ML, SM-SC, CL	A-4, A-6
	0-12	5.1-6.5	0.24	C	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	12-30	5.1-6.5	0.32	C	7-25	FSL, SCL, CL	SM, SM-SC, SC, CL	A-4, A-6, A-7
	30-60			C	NP	SR-S-G		
FUQUAY	0-34	4.5-6.0	0.15	B	NP	LS, LFS	SP-SM, SM	A-2, A-3
	0-34	4.5-6.0	0.10	B	NP	S, FS	SP-SM, SM	A-1, A-2, A-3
	34-45	4.5-6.0	0.20	B	NP-13	SL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	45-96	4.5-6.0	0.20	B	4-12	SCL	SC, SM-SC, CL-ML	A-2, A-4, A-6, A-7-6
	96-99			B	NP	Var		
GEORGEVILLE	0-6	4.5-6.0	0.32	B	NP-10	SIL, L, VFSL	ML	A-4
	0-6	4.5-6.0	0.32	B	11-20	SICL, CL	CL, ML	A-6, A-7
	6-10	4.5-5.5	0.32	B	8-20	SICL, CL	CL, ML	A,6, A-7, A-4
	10-53	4.5-5.5	0.28	B	15-35	C, SIC, SICL	MH, ML	A-7
	53-63	4.5-5.5	0.32	B	NP-12	SICL, L, SIL	ML, CL, CL-ML	A-4, A-6

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
GILEAD	0-5	4.5-5.5	0.17	C	NP	LS, GR-LS	SP-SM, SM	A-2
	0-5	4.5-5.5	0.20	C	NP-4	SL, GR-SL	SM	A-2, A-4
	5-8	4.5-5.5	0.24	C	4-16	SL, SCL	SM-SC, SC	A-2, A-4, A-6
	8-42	4.5-5.5	0.28	C	18-30	SC, CL, C	SC, CL	A-6, A-7
	42-72	4.5-5.5	0.24	C	11-20	SL, SCL	SC, CL	A-2, A-6
	72-82	4.5-5.5		C		Var		
GOLDSBORO	0-15	4.5-6.0	0.20	B	NP-14	LS, SL, FSL	SM, SM-SC, SC	A-2, A-4, A-6
	15-45	4.5-5.5	0.24	B	4-18	SCL, SL	SM-SC, SC, CL-ML, CL	A-2, A-4, A-6
	45-65	4.5-5.5	0.24	B	6-32	SCL, CL, SC	SC, CL, CL-ML, CH	A-4, A-6, A-7-6
	65-76			B	NP	Var		
GOLDSTON	0-16	3.6-5.5	0.15	C	NP-10	CN-SIL, CN-VFSL	GM, GM-GC, SM,ML	A-2-4, A-4
	0-16	3.6-5.5	0.20	C	NP-7	CNV-SIL, CNV-VFSL	GM, GM-GC, SM, ML	A-2-4, A-4
	16-36			C	NP	WB		
	36			C	NP	UWB		
GRANTHAM	0-11	4.5-5.5	0.37	D	NP-7	VFSL, L, SIL	ML, CL-ML	A-4
	11-80	3.6-5.5	0.43	D	8-30	L, CL, SICL	CL	A-4, A-6, A-7
GRANVILLE	0-16	4.5-5.5	0.17	B	NP	LS, COSL	SM	A-2, A-1
	0-16	4.5-5.5	0.24	B	NP-3	SL, FSL	SM	A-2, A-4, A-1
	16-45	4.5-5.5	0.20	B	9-25	CL, SCL	SC	A-4, A-6, A-7
	45-60	4.5-5.5	0.17	B	NP-7	SL, L, SCL	SM, SM-SC	A-2, A-4
GRIFTON	0-15	4.5-6.5	0.20	D	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-15	4.5-6.5	0.17	D	NP-4	LS, LFS	SM, SP-SM	A-2
	15-58	4.5-6.5	0.24	D	8-15	SL, SCL, CL	SC, CL	A-4, A-6
	58-70			D	NP	Var		
GROVER	0-9	4.5-6.5	0.24	B	NP-10	SL, FSL, COSL	SM, SM-SC, SC	A-4
	0-9	4.5-6.5	0.28	B	7-20	SCL	SC, CL	A-4, A-6
	9-38	4.5-5.5	0.32	B	12-30	SCL, CL	SM, ML, MH	A-6, A-7
	38-68	4.5-5.5	0.32	B	NP-7	SL, L, SCL	SM, SM-SC	A-4
GWINNETT	0-7	5.1-6.5	0.28	B	NP-15	SL, L	SM, SC, SM-SC, ML	A-2, A-4, A-6
	0-7	5.1-6.5	0.28	B	4-12	SCL, CL	SC, ML, SM-SC, CL-ML	A-4, A-6
	0-7	5.1-6.5	0.17	B	NP-15	GR-SL, GR-SCL	SM, SC, SM-SC	A-2, A-4, A-6, A-1-B
	7-35	5.1-6.5	0.28	B	16-30	C, SC	MH, ML, CL, CH	A-7, A-6
	35-45			B	NP	WB		
HARTSELLS	0-13	3.6-5.5	0.28	B	NP-7	FSL, L	SM, ML, SM-SC, CL	A-4
	13-30	3.6-5.5	0.32	B	NP-15	FSL, L, SCL	SM-SC, SC, CL-ML, CL	A-4, A-6
	30-36	3.6-5.5	0.32	B	NP-15	SL, L, SCL	SM-SCSC, CL-MLCL	A-2, A-4, A-6
	36			B	NP	UWB		
HATBORO	0-9	4.5-7.3	0.49	D	2-12	SIL, L, SL	ML, CL, SC, SM	A-4, A-6
	9-44	4.5-7.3	0.32	D	2-12	SIL, SICL, SCL	ML, CL, CL-ML	A-4, A-6
	44-56	5.6-6.5	0.20	D	2-10	SCL, SL, SIL	ML, CL, SC, SM	A-4
	56-70	5.6-6.5	0.20	D	NP-14	SR-C-GS	SM, SC, GM,GC	A-1, A-2
HAYESVILLE	0-5	4.5-6.0	0.20	B	NP-10	L, FSL, VFSL	SM, SC, ML, CL	A-4
	5-38	4.5-6.0	0.24	B	11-35	CL, C	ML, MH, CH, CL	A-6, A-7
	38-48	4.5-6.0	0.20	B	11-25	SCL, CL	SM, ML, MH, CL	A-6, A-7
	48-60	4.5-6.0	0.17	B	NP-12	FSL, L, SCL	SM, ML, CL, SC	A-4, A-6
HAYWOOD	0-60	5.1-6.5	0.24	B	NP-10	SL, FSL, L	SM, ML, SC, CL	A-4
	0-60	5.1-6.5	0.15	B	NP-7	GR-L, GR-FSL, GR-SL	SM, ML, SM-SC, CL-ML	A-2-4, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
HELENA	0-12	4-5-6.0	0.15	C	NP-9	SL, FSL, L	SM, SM-SC, SC	A-2, A-4
	0-12	4.5-6.0	0.20	C	NP	LS, LCOS	SM	A-2, A-1-B
	0-12	4.5-6.0	0.28	C	15-25	SCL, CL	CL	A-6, A-7
	12-19	4.5-5.5	0.28	C	15-26	SCL, CL, SL	CL, SC	A-6, A-7
	19-43	4.5-5.5	0.28	C	24-50	CL, SC, C	CH	A-7
	43-60			C	NP	Var		
HERNDON	0-9	4.5-6.5	0.24	B	NP-5	ST-L, ST-SIL, ST-VFSL	ML	A-4
	0-9	4.5-6.5	0.43	B	NP-12	L, SIL, VFSL	ML, CL, CL-ML	A-4, A-6
	0-9	4.5-6.5	0.49	B	11-20	SICL	CL, ML	A-6, A-7
	9-48	3.6-5.5	0.28	B	13-30	SICL, SIC, C	MH, ML	A-7
	48-68	3.6-5.5	0.32	B	9-36	SIL, L, FSL	MH, ML	A-7, A-5
HIBRITEN	0-8	4.5-5.5	0.20	C	NP-10	CBV-SL, CB-SL	GM	A-2, A-1-B
	0-8	4.5-5.5	0.20	C	NP-10	CBV-FSL, CB-FSL	GM	A-2
	8-12	4.5-5.5	0.20	C	NP-18	CBV-FSL, CBV-SL, CBV-SCL	GM, GC, SM	A-2, A-1-B
	12-22	4.5-5.5	0.20	C	NP-18	CBV-CL, CBV, SCL	GC, SM	A-2, A-2-4
HIWASSEE	0-7	4.5-6.5	0.28	B	NP-7	SL, FSL	SM, SM-SC	A-4, A-2
	0-7	4.5-6.5	0.32	B	NP-7	SIL	ML	A-4, A-2
	0-7	4.5-6.5	0.28	B	5-23	CL, SCL, L	CL, ML, CL-ML	A-7-6, A-6, A-4
	7-61	4.5-6.5	0.28	B	12-36	C, SIC, CL	CL, ML, MH	A-7-5, A-7-6, A-6
	61-70	4.5-6.5	0.28	B	4-20	SL, L, SCL	SM, ML, SM-SC, ML	A-4, A5, A-6, A-7
HULETT	0-13	4.5-6.0	0.32	B	NP-7	FSL, SL, L	SM, SM-SC, ML	A-2, A-4
	0-13	4.5-6.0	0.15	B	NP-7	GR-FSL, GR-SL, GR-L	SM, SM-SC, ML	A-2, A-4
	0-13	4.5-6.0	0.32	B	4-17	SCL, CL	ML, CL, CL-ML	A-4
	36-60			B	NP	WB		
HYDE	0-17	3.6-5.5	0.17	B/D	NP-7	L, SIL, VFSL	CL-ML, ML	A-4
	17-54	3.6-5.5	0.43	B/D	7-20	CL, L, SICL	CL	A-6, A-4, A-7
	54-72			B/D	NP	Var		
IOTLA	0-10	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	10-31	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	31-35	5.1-7.3	0.10	B	NP	LS, S	SM, SP-SM	A-2
	35-60	5.1-7.3	0.15	B	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
IREDELL	0-7	5.1-7.3	0.24	C/D	2-10	GR-L, ST-L	SM, SC, ML, GM	A-2-4, A-4
	0-7	5.1-7.3	0.28	C/D	NP-9	FSL, SL	SM, SM-SC, SC	A-2-4, A-4
	0-7	5.1-7.3	0.32	C/D	5-12	L, SIL, CL	ML, CL-ML, CL	A-4, A-6
	7-24	6.1-7.3	0.20	C/D	29-85	C	CH	A-7
	24-27	6.1-7.8	0.28	C/D	20-39	L, SCL, CL	CL, CH, SC	A-7
	27-62			C/D	NP	Var		
IUKA	0-13	5.1-6.0	0.17	C	NP	LS, LFS	SM	A-2
	0-13	5.1-6.0	0.24	C	NP-7	FSL, SL	SM, SM-SC, ML, CL-ML	A-4, A-2
	0-13	5.1-6.0	0.37	C	NP-7	L, SIL	ML, CL-ML	A-4
	13-22	4.5-5.5	0.28	C	NP-7	FSL, L, SL	SM, SM-SC, ML, CL-ML	A-4
	22-60	4.5-5.5	0.20	C	NP-7	SL, FSL, L	SM, ML	A-2, A-4
IZAGORA	0-11	3.6-6.0	0.28	C	NP-5	VFSL, FSL, SL	SM, SM-SC, ML, CL-ML	A-4
	0-11	3.6-6.0	0.20	C	NP	LS, LFS	SM, SP-SM	A-2, A-4
	0-11	3.6-6.0	0.37	C	NP-10	L, SIL	CL, CL-ML, ML	A-4
	11-46	3.6-5.5	0.32	C	8-25	L, CL, SICL	CL	A-4, A-6, A-7
	46-91	3.6-5.5	0.32	C	20-40	CL, C	CL, CH	A-6, A-7
JOHNS	0-15	4.5-5.5	0.15	C	NP	LS, LFS	SM, SM-SC	A-2, A-4
	0-15	4.5-5.5	0.20	C	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	15-32	4.5-5.5	0.24	C	5-25	SCL, SL, CL	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6, A-7
	32-60	4.5-5.5	0.10	C	NP	S, LS	SM, SP-SM, SP	A-2, A-3

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
JOHNSTON	0-30	4.5-5.5	0.17	D	2-14	MK-L	OL, ML, CL-ML	A-8, A-4,A-5
	0-30	4.5-5.5	0.20	D	NP-10	L, SL, FSL	ML, SM	A-2, A-4
	30-34	4.5-5.5	0.17	D	NP	SR-S-S	SM, SP-SM	A-2, A-3
	34-60	4.5-5.5	0.17	D	NP-10	SR-FSL-SL	SM	A-2, A-4
KALMIA	0-14	4.5-6.0	0.15	B	NP	LS, LFS	SM, SM-SC, SC	A-2
	0-14	4.5-6.0	0.20	B	NP-10	SL, FSL	SM, SM-SC, SC	A-2, A-4
	14-32	4.5-5.5	0.24	B	4-15	SCL	SC, SM-SC	A-2, A-4, A-6
	32-60	4.5-5.5	0.10	B	NP	LS, S	SM, SP-SM, SP	A-2, A-3
KENANSVILLE	0-24	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-1, A-2
	0-24	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM	A-2, A-2
	24-36	4.5-6.0	0.15	A	NP-10	SL, FSL	SM, SC, SM-SC	A-2, A-4
	36-80	4.5-6.0	0.10	A	NP	S, LS	SP-SM, SM	A-1, A-2, A-3
KERSHAW	0-80	4.5-6.0	0.10	A	NP	S, COS, FS	SP, SP-SM, SW	A-2, A-3
KINSTON	0-12	4.5-6.0	0.24	B/D	NP-10	FSL	SM, SC SM-SC	A-2, A-4
	0-12	4.5-6.0	0.37	B/D	4-15	L, SIL	ML, CL, CL-ML	A-4, A-6
	12-60	4.5-5.5	0.32	B/D	8-22	L, CL, SCL	CL	A-4, A-6, A-7
	60-72			B/D	NP	Var		
KUREB	0-80	4.5-7.3	0.10	A	NP	S, COS, FS	SP, SP-SM	A-3
LAKELAND	0-43	4.5-6.0	0.10	A	NP	S, FS	SP-SM	A-3, A-2-4
	43-80	4.5-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3, A-2-4
LEAF	0-9	3.6-5.5	0.32	D	5-15	SIL, VFSL	ML, CL	A-4, A-6
	0-9	3.6-5.5	0.28	D	5-12	FSL, L	ML	A-4, A-6
	9-72	3.6-5.5	0.32	D	20-38	SICL, SIC, C	CL, CH	A-7
LEAKSVILLE	0-9	5.1-6.5	0.43	D	6-16	SIL, L, SICL	ML, CL-ML	A-4, A-6
	9-18	6.1-7.8	0.24	D	35-75	CL, C, SIC	CH	A-7
	18-24	6.1-7.8	0.24	D	20-45	CL, SICL	CL, CH	A-7
	24-30			D		WB		
	30			D		UWB		
LENOIR	0-8	4.5-5.5	0.37	D	4-10	L, SIL, VFSL	ML, CL, CL-ML	A-4
	8-75	4.5-5.5	0.32	D	11-35	C, SIC, CL	CL, CH	A-6, A-7
LEON	0-15	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
	15-30	3.6-5.5	0.15	B/D	NP	S, FS, LS	SM, SP-SM, SP	A-3, A-2-4
	30-80	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
LIDDELL	0-8	4.5-5.5	0.43	B/D	2-10	L, SIL, VFSL	ML, CL-ML	A-4
	8-65	4.5-5.5	0.43	B/D	2-10	L, SIL, VFSL	ML, CL-ML	A-4
LILLINGTON	0-16	4.5-6.0	0.15	B	NP	GR-LS, GR-SL	GM, GP-GM, SM, SP-SM	A-1, A-2
	16-44	4.5-5.5	0.15	B	NP-10	GR-SCL, GR-CL	GM, GC, SM, SC	A-1, A-2, A-4
	44-80	4.5-5.5	0.10	B	NP	SR-GRV-LS-GRV-SCL	GM, SM	A-1, A-2
LOCKHART	0-6	5.1-6.5	0.15	B	NP	GR-LS, GR-SL	GM, GP-GM, SM, SP-SM	A-1, A-2
	6-54	5.1-6.5	0.17	B	5-15	GR-SCL, GR-L	GC, GM-GC, SC, SM-SC	A2, A-4, A-6
	54-72			B		Var		
LOUISA	0-4	4.5-6.0	0.17	B	NP	GR-L, GR-SL, GR-FSL	SM	A-1, A-2, A-4
	0-4	4.5-6.0	0.28	B	NP	L, SL, FSL	SM, ML	A-2, A-4
	4-15	4.5-6.0	0.24	B	NP	GR-L, GR-SL	SM	A-2, A-4
	15-60			B		WB		
LOUISBURG	0-7	4.5-6.0	0.10	B	NP	LS, LCOS	SM	A-2, A-1-B
	0-7	4.5-6.0	0.24	B	NP-6	SL, FSL	SM, SM-SC	A-2
	7-24	4.5-6.0	0.24	B	NP-7	SL	SM, SM-SC	A-2, A-4
	24-60			B		WB		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
LUCY	0-24	5.1-6.0	0.15	A	NP	LS, S, LFS	SM, SP-SM	A-2
	24-35	4.5-5.5	0.24	A	NP-15	SL, FSL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	35-70	4.5-5.5	0.28	A	3-20	SL, SCL, CL	SC, SM-SC, SM	A-2, A-6, A-4
LUMBEE	0-14	4.5-5.5	0.24	B/D	NP-7	LS, SL, FSL	SM, SM-SC	A-2, A-4
	14-36	4.5-5.5	0.32	B/D	7-25	SCL, SL, CL	SC, CL	A-4, A-6, A-7
	36-60	4.5-5.5	0.10	B/D	NP	LS, S. FS	SP, SM, SP-SM	A-2, A-3
LYNCHBURG	0-10	3.6-5.5	0.15	C	NP-4	LS, LFS	SM, SP-SM	A-2
	0-10	3.6-5.5	0.20	C	NP-7	SL, FSL, L	SM, ML, SM-SC, CL-ML	A-2, A-4
	10-62	3.6-5.5	0.20	C	4-18	SCL, SL, CL	SM-SC, SC, CL, CL-ML	A-2, A-4, A-6
LYNN HAVEN	0-16	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM, SM	A-3, A-2-4
	16-30	3.6-5.5	0.15	B/D	NP	S, FS, LS	SM, SP-SM	A-3, A-2-4
	30-75	3.6-5.5	0.10	B/D	NP	S, FS	SP, SP-SM	A-3, A-2-4
MADISON	0-6	4.5-6.0	0.24	B	NP-8	FSL, SL	SM, SM-SC	A-2, A-4
	0-6	4.5-6.0	0.15	B	NP-7	GR-FSL, GF-SL	SM, SM-SC	A-2, A-4
	0-6	4.5-6.0	0.28	B	7-20	CL, SCL	CL	A-4, A-6
	6-30	4.5-5.5	0.32	B	12-43	C, CL, SC	MH, ML	A-7
	30-35	4.5-6.0	0.28	B	7-20	L, SCL, CL	CL	A-4, A-6
	35-66			B		WB		
MANTACHIE	0-11	4.5-5.5	0.37	C	NP-10	SIL	ML, CL-ML, CL	A-4
	0-11	4.5-5.5	0.28	C	5-15	CL	CL-ML, CL	A-4, A-6
	0-11	4.5-5.5	0.28	C	NP-5	FSL, SL, L	CL-ML, SM-SC, SM, ML	A-4
	11-61	4.5-5.5	0.28	C	5-15	L, CL, SCL	CL, SC, SM-SC, CL-ML	A-4, A-6
MANTEO	0-6	3.6-5.5	0.28	C/D	2-15	CN-SIL, CN-L	GM, ML, CL, GC	A-4
	0-6	3.6-5.5	0.28	C/D	2-15	CN-VSIL, CN-VL	GM, ML, CL, GC	A-1, A-2, A-4, A-6
	6-15	3.6-5.5	0.28	C/D	2-20	CN-VSIL, CN-SIL, CN-CL	GM GC , ML, CL	A-1, A-2, A-4, A-6
	15			C/D		UWB		
MARLBORO	0-9	5.1-6.5	0.15	B	NP-4	LS, LFS	SM	A-2
	0-9	5.1-6.5	0.20	B	NP-7	SL, FSL, VFSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	9-60	4.5-6.0	0.20	B	6-20	SC, CL,C	CL, ML, CL-ML	A-4, A-6, A-7
	60-72	4.5-6.0	0.20	B	6-20	SCL, SC, C	CL, ML, SM-SC	A-4, A-6, A-7
MASADA	0-10	4.5-5.5	0.32	C	NP-8	FSL, L	ML, SM, SC, CL	A-4, A-6
	10-55	4.5-5.5	0.24	C	20-35	CL, C, GR-C	CH, CL	A-7, A-6
	55-72	4.5-5.5	0.24	C	15-25	L, CL, GR-SCL	CL, ML	A-6, A-7, A-4
MATTAMUSKEET	0-22	4.5		D	NP	MUCK	PT	
	22-72	3.6-5.5		D	NP	LS, S, FS	SM, SP-SM	A-2, A-3
MAXTON	0-12	4.5-6.0	0.20	B	NP-7	SL, FSL	SM, SM-SC	A-2
	0-12	4.5-6.0	0.15	B	NP	LS, LFS	SM, SP-SM	A-2
	12-33	4.5-5.5	0.24	B	4-15	SCL, SL	SC, SM-SC	A-4, A-6, A-2
	33-60	4.5-5.5	0.10	B	NP	SR-LS-S	SM, SP-SM, SP	A-2, A-3
MAYODAN	0-12	4.5-6.0	0.24	B	NP-5	SL, FSL, SIL	SM, ML, SM-SC	A-2, A-4
	0-12	4.5-6.0	0.15	B	NP-4	GR-SL, GR-FSL	GP-GM, GM ,SM, SP-SM	A-1
	0-12	4.5-6.0	0.32	B	7-26	CL, SCL	CL, SC	A-4, A-6, A-7-6
	12-18	4.5-6.0	0.32	B	7-26	SICL, CL, SCL	CL, ML, SC	A-4, A-6, A-7-6
	18-47	4.5-5.5	0.28	B	15-45	C, SC, SIC	MH, CH, CL, ML	A-7
	47-60	4.5-5.5		B		Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
MCCOLL	0-9	4.5-7.3	0.24	D	4-12	SL, FSL	SC, SM-SC	A-2
	0-9	4.5-7.3	0.24	D	5-20	SCL, CL, L	SC, CL-ML, CL, SM-SC	A-4, A-6
	9-13	4.5-5.5	0.24	D	8-23	CL, SC, C	SC, CL	A-4, A-6, A-7
	13-42	4.5-5.5	0.24	D	3-15	SCL, CL, SC	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6
	42-80	4.5-5.5	0.32	D	3-22	SCL, SL, SC	SM, SC, SM-SC	A-2, A-4, A-6, A-7
MECKLENBURG	0-8	5.6-7.3	0.24	C	NP-15	L, FSL, SL	ML, SM	A-4, A-6, A-7-6
	0-8	5.6-7.3	0.17	C	NP-12	GR-L, GR-SL, GR-FSL	GM, SM, GP-GM, SP-SM	A-2, A-1
	0-8	5.6-7.3	0.28	C	11-25	CL, SCL	CL	A-6, A-7-6
	8-25	5.6-7.3	0.32	C	24-45	C	CH, MH	A-7
	25-36	5.6-7.3	0.32	C	11-25	L, SCL, CL	CL, ML	A-4, A-6, A-7
	36-60			C		WB		
MEGGETT	0-8	4.5-6.5	0.24	D	NP	FSL, SL, LS	SM	A-2, A-4
	0-8	4.5-6.5	0.28	D	NP-10	L, CL	ML, CL-ML	A-4
	8-16	5.1-8.4	0.32	D	20-30	C, SC, CL	CH, MH, CL	A-6, A-7
	16-52	6.1-8.4	0.32	D	20-30	C, SC, CL	CH, MH, CL	A-6, A-7
	52-65	6.1-8.4	0.28	D	NP-25	SC, CL, SCL	CL, SC, SM	A-4, A-6
MISENHEIMER	0-14	3.6-5.5	0.20	B	NP-10	CN-SIL, CN-L	GM, SM, ML	A-4
	14-25			B		WB		
	25			B		UWB		
MOLENA	0-7	4.5-6.5	0.10	A	NP	S, LS	SM, SP-SM	A-2, A-3
	7-51	4.5-6.0	0.17	A	NP	LFS, LS	SM, SP-SM	A-2, A-3
	51-60	4.5-6.0	0.15	A	NP	S, COS, GR-S	SP, SP-SM	A-2, A-3
MURVILLE	0-8	3.6-5.5	0.10	A/D	NP	FS, S, LFS	SP-SM, SM	A-2, A-3
	8-45	3.6-5.5	0.10	A/D	NP	FS, S, LFS	SM, SP-SM	A-2
	45-56	3.6-5.5	0.10	A/D	NP	FS, S	SP-SM, SP	A-2, A-3
	56-70			A/D		Var		
MUSELLA	0-4	5.1-6.5	0.20	B	NP-10	GR-CL, GR-SCL	SM, SC, SM-SC	A-2, A-4
	0-4	5.1-6.5	0.32	B	NP-10	CL, SCL	SM, SC, SM-SC, ML	A-4
	4-14	5.1-6.5	0.32	B	11-20	GR-CL, CL	ML, CL, SM, SC	A-6, A-7
	14-18	5.1-6.5	0.28	B	8-15	CRV-CL	SM, SC, GC	A-4, A-6
	18-60			B		WB		
MYATT	0-10	4.5-6.0	0.28	D	NP-5	FSL, SL, VFSL	SM, SM-SC, ML, CL-ML	A-2, A-4
	0-10	4.5-6.0	0.32	D	NP-5	SIL, L	ML, CL-ML	A-4
	0-10	4.5-5.5	0.20	D	NP-4	LS, LFS	SM, SM-SC, CL-ML	A-2
	10-50	3.6-5.5	0.28	D	NP-10	L, SCL, CL	SM, SC, ML, CL	A-4
	50-72	3.6-5.5	0.24	D	5-20	GR, FSL, SCL, CL	SM-SC, SC, CL-ML, CL	A-6, A-4, A-2
NAHUNTA	0-12	4.5-6.0	0.43	C	NP-10	VFSL, L, SIL	ML, CL-ML, CL	A-4
	12-79	3.6-5.5	0.43	C	8-30	L, CL, SICL	CL	A-4, A-6, A-7
NASON	0-9	4.5-6.5	0.37	C	NP-10	L, SIL, FSL	ML, CL-ML, SM	A-4
	0-9	4.5-6.5	0.37	C	11-20	SICL	CL	A-6, A-7
	9-38	4.5-5.5	0.28	C	15-30	SICL, SIC, C	CL, CH, MH	A-7
	38-50	4.5-5.5	0.28	C	4-12	CN-SIL, SIL, L	CL-ML, SC, GM-GC	A-2, A-4, A-6
	50			C		WB		
NEWHAN	0-64	3.6-7.8	0.10	A	NP	FS, S	SP	A-3
NIXONTON	0-34	5.1-6.5	0.37	B	NP-7	VFSL, L, SIL	CL-ML, ML	A-4
	34-80	5.1-6.5	0.32	B	NP	LFS, LS, FS	SM, SP-SM	A-2

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
NORFOLK	0-17	4.5-6.0	0.17	B	NP-14	SL, FSL	SM, SM-SC, SC	A-2
	0-17	4.5-6.0	0.20	B	NP	LS, LFS	SM	A-2
	17-38	4.5-5.5	0.24	B	4-15	SL, SCL, CL	SC, SM-SC, CL, CL-ML	A-2, A-4, A-6
	38-70	4.5-5.5	0.24	B	4-23	SCL, SC, CL	SC, SM-SC, CL, CL-ML	A-4, A-6, A-7-6
	70-99			B		Var		
OAKBORO	0-10	4.5-6.5	0.28	C	NP-10	SIL, L	ML, CL-ML, CL	A-4, A-6
	10-46	4.5-6.5	0.28	C	NP-15	L, SIL, SICL	ML, CL-ML, CL	A-4, A-6
	46			C		UWB		
OCHLOCKONEE	0-6	4.5-5.5	0.20	B	NP-5	FSL, SL	SM, ML, SM-SC, CL-ML	A-4, A-2
	0-6	4.5-5.5	0.24	B	NP-7	SIL, L	ML, CL-ML	A-4
	0-6	4.5-5.5	0.17	B	NP	LS, LFS	SM	A-2, A-4
	6-44	4.5-5.5	0.20	B	NP-9	FSL, SL, SIL	SM, SL, SC, CL	A-4
	44-72	4.5-5.5	0.17	B	NP-9	LS, SL, SIL	SM, ML, CL, SC	A-4, A-2
OCILLA	0-28	4.5-5.5	0.10	C	NP	LS, LFS, S	SM, SP-SM	A-2, A-3
	28-67	4.5-5.5	0.24	C	NP-18	SL, SCL	SM, CL, SC	A-2, A-4, A-6
OLUSTEE	0-8	3.6-5.5	0.10	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	8-21	3.6-5.5	0.15	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	21-35	4.5-5.5	0.10	B/D	NP	S, FS	SP-SM, SM	A-3, A-2-4
	35-62	4.5-5.5	0.24	B/D	8-15	SCL, SL	SC	A-2, A-4, A-6
	62-74	4.5-5.5	0.28	B/D	15-25	SC	SC, CL	A-6, A-7
ONSLOW	0-17	3.6-5.5	0.17	B	NP	LFS, LS	SM-SP-SM	A-2, A-3, A-4
	0-17	3.6-5.5	0.20	B	NP-10	FSL, SL	SM, ML, SC, CL	A-2, A-4
	17-53	3.6-5.5	0.24	B	NP-14	SCL, SL, CL	SM, CL, SM-SC, SC	A-2, A-4, A-6
	53-80			B		Var		
ORANGE	0-10	5.1-6.5	0.49	D	NP-10	SIL, L	SM, ML, CL-ML, SM-SC	A-4
	0-10	5.1-6.5	0.32	D	NP-7	FSL, SL	SM, ML, CL-ML, SM-SC	A-4
	10-38	5.1-6.5	0.28	D	45-70	C, SLC, SICL	CH	A-7
	38-58	5.6-7.8	0.28	D	10-25	SIL, CNV-SIL, SCL	SC, CL, GC	A-6, A-7
	58			D		UWB		
ORANGEBURG	0-7	4.5-6.0	0.10	B	NP	LS, LFS, S	SM	A-2
	0-7	4.5-6.0	0.20	B	NP	SL, FSL	SM	A-2
	0-7	4.5-6.0	0.24	B	3-16	SCL	SM, SM-SC, SC	A-4, A-6
	7-12	4.5-6.0	0.20	B	NP-4	SL	SM	A-2
	12-54	4.5-5.5	0.24	B	3-19	SCL, SL	SC, CL, SM, SM-SC	A-6, A-4
	54-64	4.5-5.5	0.24	B	8-21	SCL, SC, SL	SC, CL	A-6, A-4, A-7
OSIER	0-8	3.6-6.0	0.10	A/D	NP	S, LS, FS	SP-SM	A-2, A-3
	0-8	3.6-6.0	0.15	A/D	NP	FSL, LFS	SM	A-2
	8-48	3.6-6.0	0.10	A/D	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
	48-75	3.6-6.0	0.05	A/D	NP	COS, S, FS	SP, SP-SM	A-1, A-3, A-2-4
OTEEN	0-6	5.1-7.3	0.24	C	NP-7	FSL, SL, L	ML, CL-ML, SM-SC, SM	A-2, A-4
	0-6	5.1-7.3	0.17	C	NP-7	GR-FSL, GR-L, GR-SL	SM, SM-SC	A-2, A-4, A-1
	6-17	5.1-7.3	0.32	C	11-30	L, CL, C	CL	A-6, A-7
	17-60			C		WB		
PACOLET	0-3	4.5-6.5	0.20	B	NP-7	SL, FSL, L	SM, SM-SC	A-2, A-1-B
	0-3	4.5-6.5	0.24	B	4-17	CL, SCL	SM-SC, SC	A-4, A-6
	0-3	4.5-6.5	0.15	B	NP-3	LS	SM	A-2
	3-29	4.5-6.0	0.28	B	11-30	SC, CL, C	ML, MH	A-6, A-7
	29-52	4.5-6.0	0.28	B	5-15	CL, SCL, SL	CL, CL-ML, SM-SC, SC	A-2, A-4, A-6
	52-70	4.5-6.0	0.28	B	NP-6	SL, FSL, L	SM, SM-SC	A-4, A-2-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
PACTOLUS	0-40	4.5-6.0	0.10	A/C	NP	LS, LFS, S	SM	A-2
	40-80	4.5-5.5	0.10	A/C	NP	S, LS, LFS	SP-SM, SM	A-2, A-3
PAMLICO	0-30	3.6-4.4		D	NP	MUCK	PT	
	30-60	3.6-5.5	0.10	D	NP	LS, S, LFS	SM, SP-SM	A-2, A-3
PANTEGO	0-18	3.6-5.5	0.10	B/D	NP-10	MK-L	CL, SM, ML, SM-SC	A-2, A-4
	0-18	3.6-5.5	0.15	B/D	NP-10	L, FSL, SL	SM, SM-SC, CL, ML	A-2, A-4
	0-18	3.6-5.5	0.10	B/D	NP	LFS, LS	SM	A-2
	18-42	3.6-5.5	0.28	B/D	4-16	SCL, SL, CL	SC, CL, SM-SC, CL-ML	A-4, A-6, A-2
	42-65	3.6-5.5	0.28	B/D	11-24	CL, SC, SCL	CL, SC	A-6, A-7
PASQUOTANK	0-17	4.5-6.0	0.43	B/D	NP-7	SIL, L, VFSL	CL-ML, ML	A-4
	17-56	4.5-5.5	0.43	B/D	NP-7	L, VFSL, SIL	CL-ML, ML	A-4
	56-80	4.5-5.5	0.32	B/D	NP	LS, LFS, FS	SM, SP-SM	A-2
PELHAM	0-27	4.5-5.5	0.10	B/D	NP	LS	SM	A-2
	0-27	4.5-5.5	0.10	B/D	NP	S, FS	SM	A-2
	27-56	4.5-5.5	0.24	B/D	2-12	SCL, SL	SM, SC, SM-SC	A-2, A-4, A-6
	56-68	4.5-5.5	0.24	B/D	5-20	SCL, SL, SC	SC, SM-SC, ML, CL	A-2, A-4, A-6, A-7
PENDER	0-13	4.5-6.5	0.24	C	NP-14	SL, FSL	SM, SM-SC, SC	A-2
	0-13	4.5-6.5	0.15	C	NP-10	LS, LFS	SM, SP-SM	A-2
	13-54	5.6-7.3	0.24	C	4-20	SL, SCL, CL	SC, SH-SC, CL, CL-ML	A-2, A-4, A-4
	54-62			C		Var		
PENN	0-8	3.6-5.5	0.32	C		SIL, L	ML	A-4
	0-8	3.6-5.5	0.28	C		SH-SIL, SH-L	ML, GM	A-4
	8-21	3.6-6.0	0.24	C	1-10	SH-SIL, SH-L, SH-SICL	ML, SM, GM	A-4, A-2
	21-34	5.1-6.5	0.24	C	3-10	SH-SIL, SHVL	ML, CL, SM, GM	A-4, A-2, A-1
	34			C		UWB		
PERQUIMANS	0-8	4.5-6.5	0.37	D	NP-7	SIL, L, VFSL	ML, CL-ML	A-4
	8-50	4.5-6.0	0.43	D	8-30	L, SICL, CL	CL	A-4, A-6, A-7
	50-62	4.5-6.0	0.37	D	NP-7	SIL, L, SL	ML, CL-ML	A-4
PETTIGREW	0-15	3.6-5.5		B/D	NP	MUCK	PT	
	15-26	3.6-5.5	0.17	B/D	11-25	L, CL, SICL	CL	A-6, A-7
	26-50	3.6-5.5	0.32	B/D	20-40	CL, C, SIC	CL, CH	A-7
	50-74	5.6-7.8		B/D		Var		
PINKSTON	0-8	4.5-6.5	0.32	B	NP-10	FSL, SL	CL, ML, SM, SC	A-2, A-4
	0-8	4.5-6.5	0.32	B	NP-10	SIL, L, VFSL	CL, ML, SM-SC	A-4
	8-19	4.5-5.5	0.24	B	NP-10	L, SL, SIL	SC, CL, ML, SM	A-2, A-4, A-1
	19-26	4.5-5.5	0.24	B	3-15	GR-SL, L, SIL	CL, GM, GP-GM, ML	A-1, A-2, A-4, A-6
	26			B		WB		
PLUMMER	0-50	3.6-5.5	0.10	B/D	NP	S, FS, LS	SM, SP-SM	A-2-4, A-3
	50-72	3.6-5.5	0.15	B/D	NP-10	SL, SCL, FSL	SM, SC, SM-SC	A-2-4, A-2-6, A-4
POCALLA	0-23	4.5-6.5	0.15	A	NP	S, LS	SP-SM, SM	A-2, A-3
	23-36	4.5-5.5	0.10	A	NP-4	SL	SM	A-2
	36-46	4.5-5.5	0.10	A	NP	S, LS	SP-SM, SM	A-2, A-3
	46-72	4.5-5.5	0.15	A	3-15	SCL, SL	SM-SC, SC, SM	A-2, A-4, A-6
POCOMOKE	0-28	3.6-5.5	0.28	B/D	3-10	SL, FSL, LS	SM, SC, CL-ML	A-2, A-4
	28-40	3.6-5.5	0.20	B/D	NP-8	LS, S	SM, SP-SM	A-2, A-3
POMELLO	0-42	4.5-6.0	0.10	C	NP	COS, S, FS	SP, SP-SM	A-3
	42-64	4.5-6.0	0.15	C	NP	COS, S, FS	SP- SM, SM	A-3, A-2-4
	64-80	4.5-6.0	0.10	C	NP	COS, S, FS	SP, SP-SM	A-3
PONZER	0-24	3.6-4.4		D	NP	MUCK	PT	
	24-52	3.6-6.5	0.24	D	NP-20	L, SCL, SIL	SM, ML, SC, CL	A-2, A-4, A-6
	52-72			D		Var		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
PORTERS	0-7	4.5	0.24	B	NP-10	FSL, SL	SM, SM-SC	A-2, A-4
	0-7	4.5-6.0	0.28	B	NP-10	L, SIL	ML, CL, CL-ML	A-4
	7-42	4.5-6.0	0.24	B	NP-7	L, SL, FSL	SM, SM-SC	A-2, A-4
	42-60			B		UWB		
PORTSMOUTH	0-19	3.6-5.5	0.24	B/D	NP-7	SL, FSL, L	SM, SM-SC, ML	A-2, A-4
	19-35	3.6-5.5	0.28	B/D	7-18	L, SCL, CL	SC, CL-ML, CL	A-4, A-6
	35-38	3.6-5.5	0.17	B/D	NP-4	LS, SL	SM	A-2
	38-72	3.6-6.0	0.17	B/D	NP	SR-COS-LS	SP-SM, SP, SM	A-1, A-2, A-3
PUNGO	0-72	4.5		D	NP	MUCK	PT	
	72-84	3.6-7.3	0.24	D	15-35	C, SIC, SC	CH, CL,SC	A-7, A-6
RABUN	0-9	5.1-6.5	0.32	B	3-20	L, CL, SIL	ML, CL, SM, SC	A-6, A-7, A-4
	0-9	5.1-6.5	0.20	B	3-12	GR-L, GR-CL	SM, SC, SM-SC	A-6, A-4
	9-37	5.1-6.5	0.28	B	12-30	CL, C, SIC	ML, CL, MH, CH	A-7
	37-48	5.1-6.5	0.28	B	11-23	C, CL, SICL	ML, CL	A-7, A-6
	48-62			B		WB		
RAINS	0-12	4.5-6.5	0.10	B/D	NP	S, FS	SP-SM	A-3, A-2-4
	12-62	4.5-5.5	0.24	B/D	8-18	SCL	SC	A-2-6, A-2-4
	62-85	4.5.5	0.20	B/D	NP-7	LS, LFS, SL	SM, SM-SC	A-2-4
RAMSEY	0-5	4.5-5.5	0.24	D	NP-7	L, SL, FSL	SM, CL-ML, ML, SM-SC	A-4, A-2
	5-18	4.5-5.5	0.17	D	NP-7	L, SL, FSL	SM, CL-ML, ML, SM-SC	A-4, A-2
	18			D		UWB		
RANGER	0-6	4.5-5.5	0.24	C	2-8	CN-SIL	ML, CL-ML, CL	A-4
	6-26	4.5-5.5	0.24	C	2-10	CN-SIL, CN-SICL, CNV-SIL	GM,CG, GM-GC	A-4, A-2
RIDGELAND	0-8	3.6-6.5	0.10	B/D	NP	S, FS, LFS	SP-SM, SM	A-2, A-3
	8-15	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP-SM, SP, SM	A-2, A-3
	15-35	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP, SM, SP, SM	A-2, A-3
	35-80	3.6-6.5	0.15	B/D	NP	S, FS, LFS	SP-SM, SP, SM	A-2, A-3
RIMINI	0-58	3.6-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	58-70	3.6-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	70-80	36.-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
ROANOKE	0-7	3.6-5.5	0.28	D	NP-7	FSL	SM, ML, CL-ML, SM-SC	A-2, A-4
	0-7	3.6-5.5	0.37	D	5-16	SIL, L	SM-SC, CL-ML, CL, SC	A-4, A-6
	0-7	3.6-5.5	0.37	D	14-20	SICL, CL	CL	A-6, A-7
	7-12	3.6-5.5	0.24	D	14-20	CL, SICL	CL	A-6, A-7
	12-50	3.6-5.5	0.24	D	22-40	C, SIC, CL	CH, CL	A-7
	50-72	3.6-6.5	0.24	D	NP-40	SR, SC-C	CL-ML, GM-GC, CL, ML	A-2, A-4, A-6, A-7
ROPER	0-15	3.6-5.5		B/D	NP	MUCK	PT	
	15-42	3.6-5.5	0.43	B/D	8-25	SIL, SICL, L	CL	A-4, A-6
	42-55	5.6-7.8	0.43	B/D	8-25	SIL, SICL, L	CL	A-4, A-6
	55-72	5.6-7.8		B/D		Var		
ROSMAN	0-50	5.1-6.5	0.24	B	4-15	L, FSL, SIL	ML, CL-ML	A-4
	50-60	5.1-6.5	0.10	B	NP-7	SR-GR-S-GR-C	SM, ML, CL-ML, SM-SC	A-4
RUMFORD	0-17	3.6-5.5	0.17	B	NP	LFS, LS	SM	A-2, A-1
	0-17	3.6-5.5	0.24	B	NP-6	FSL, SL	SM, SM-SC	A-2, A-4
	17-37	3.6-6.0	0.17	B	NP-12	FSL, SL, SCL	SM, SC, SM-SC	A-2, A-4, A-6
	37-60	3.6-6.5	0.17	B	NP-6	SR-SL-GR-S	SM, SP, GP, GM	A-1, A-2, A-3, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
RUSTON	0-16	4.5-6.5	0.15	B	NP-3	GR-FSL, GR-SL, GR-L	SM	A-2, A-1-B
	0-16	4.5-6.5	0.28	B	NP-3	FSL, SL	SM, ML	A-4, A-2-4
	0-16	4.5-6.5	0.20	B	NP-3	LFS	SM	A-2-4
	41-47	4.5-6.0	0.32	B	NP-7	FSL, SL, LS	SM, ML, CL-ML, SM-SC	A-4, A-2-4
	47-80	4.5-6.0	0.28	B	11-20	SCL, L, CL	SC, CL	A-6
SCRANTON	0-7	4.5-6.5	0.15	A/D	NP	LS, LFS	SM, SP-SM	A-2, A-4
	0-7	4.5-6.5	0.10	A/D	NP	S, FS	SP-SM, SM	A-2, A-3
	7-41	4.5-5.5	0.10	A/D	NP	LS, S, FS	SP-SM, SM	A-2, A-3
	41-72	4.5-5.5	0.10	A/D	NP	S, FS	SP-SM, SM	A-2, A-3
SEABROOK	0-9	4.5-6.5	0.10	C	NP	LFS, LS, FS	SM, SP-SM	A-2, A-3
	9-60	4.5-6.5	0.10	C	NP	LFS, FS, S	SM, SP-SM	A-2, A-3
SEAGATE	0-12	3.6-6.0	0.10	A/D	NP	FS, S	SM, SP-SM	A-2, A3
	12-28	3.6-6.0	0.15	A/D	NP	FS, LFS, S	SM, SP-SM	A-2
	28-36	3.6-6.0	0.10	A/D	NP	FS, S	SM, SP-SM	A-2, A-3
	36-40	3.6-6.0	0.28	A/D	NP-7	SL, SCL	SM- SM-SC	A-2, A-4
	40-64	3.6-6.0	0.32	A/D	16-27	CL, SCL	CL	A-6, A-7
SEDGEFIELD	0-13	4.5-6.5	0.17	C	NP	LS	SM	A-2
	0-13	4.5-6.5	0.28	C	5-20	FSL, SL, SCL	SM, SM-SC, CL	A-2, A-4, A-6
	13-33	4.5-6.5	0.28	C	25-60	SC, CL, C	CL, CH	A-7
	33-37	5.6-8.4	0.28	C	8-25	SL, SCL, CL	SC, CL	A-6, A-7, A-4
	37-65			C		UWB		
STALLINGS	0-12	3.6-5.5	0.10	C	NP	LS, LFS, FS	SM	A-2
	0-12	3.6-5.5	0.20	C	NP-3	SL, FSL	SM	A-2, A-4
	12-42	3.6-5.5	0.17	C	NP-3	SL, FSL	SM	A-2, A-4
	42-80	3.6-5.5	0.17	C	NP-4	SL, LS, LFS	SM, SP-SM, SM-SC	A-2, A-4
STARR	0-10	5.1-6.5	0.24	C	NP-7	SL, FSL	SM, SM-SC	A-4, A-2
	0-10	5.1-6.5	0.28	C	3-12	L	ML, CL-ML, CL	A-4, A-6
	0-10	5.1-6.5	0.28	C	3-23	SIL, SICL, SCL	ML, CL-ML, CL	A-4, A-6, A-7
	10-53	5.1-6.5	0.28	C	3-23	CL, SCL, SICL	ML, CL-ML, CL	A-4, A-6, A-7
	53-70	5.1-6.5	0.28	C	NP-15	GR-SL, SCL, CL	SM, SM-SC, SC	A-2, A-4, A-6
STATE	0-10	4.5-5.5	0.28	B	NP-7	FSL, SL	SM, ML CL-ML, SM-SC	A-2, A-4
	0-10	4.5-5.5	0.38	B	NP-15	SIL, L	L, SM, SC, ML, CL	A-4, A-6
	0-10	4.5-5.5	0.28	B	NP-6	LS, LFS	SM, SM-SC	A-2, A-1
	10-45	4.5-5.5	0.28	B	8-22	L, CL, SCL	CL, SC	A-4, A-6
	45-60	4.5-6.0	0.17	B	NP-7	SR-S-FSL	SM, SM-SC, SP-SM	A-1, A-2, A-3, A-4
STONEVILLE	0-5	4.5-6.0	0.32	B	6-16	L, SIL, CL	SM-SC, CL, ML, CL-ML	A-4, A-6
	5-13	4.5-6.0	0.32	B	11-25	CL, SICL, L	CL	A-6, A-7-6
	13-38	4.5-6.0	0.28	B	20-50	C, CL, SIC	CL, CH, MH	A-6, A-7
	38-48	4.5-6.0	0.24	B	11-31	CL, SICL, L	CL, MH, ML	A-6, A-7
	48-72			B		WB		
SUNCOOK	0-7	4.5-6.5	0.17	A	NP	LFS, LS, SL	SM	A-2
	7-42	4.5-6.5	0.17	A	NP	SR-LFS-COS	SP, SM	A-2, A-3
	42-60	4.5-6.5	0.10	A	NP	SR-LFS-GR-COS	SP, SM	A-1, A-2, A-3
TALLADEGA	0-9	4.5-5.5	0.28	C	NP-10	CN-SIL, CN-L	SM, SC, SM-SC, GM	A-4, A-2, A-1
	0-9	4.5-5.5	0.32	C	NP-10	SIL, L	SM, SC, ML, SM-SC	A-4
	9-22	4.5-5.5	0.28	C	8-15	CN-CL, CN-SIL, CN-SICL	GM, GC, SC, SM	A-4, A-6, A-2
	22-26			C		Var		
	26			C		WB		

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasticity	Textural Classification[1] USDA	Unified	AASHTO
TALLAPOOSA	0-4	4.5-5.0	0.32	C	1-9	L, SIL	SM, ML	A-4, A-5
	0-4	4.5-5.0	0.28	C	NP-7	FSL, SL	SM, ML	A-4, A-2
	4-10	4.5-5.0	0.37	C	8-14	SICL, CL, L	ML, CL	A-4, A-6
	10-19	4.5-5.0	0.20	C	NP-6	L	ML, SM	A-4
	19-60			C	NP	WB		
TARBORO	0-40	5.1-6.5	0.10	A	NP	LS, S	SM, SP-SM, SW-SM	A-2, A-3, A-1
	40-80	5.1-6.5	0.10	A	NP	S, COS, LS	SP, SP-SM, SW-SM, SM	A-2, A-3, A-1
TATE	0-7	5.1-6.0	0.24	B	NP-13	L, FSL	CL, ML, SM, SC	A-4, A-6
	0-7	5.1-6.0	0.24	B	NP-13	ST-L, ST-FSL	CL, ML, SM, SC	A-4, A-6
	7-46	5.1-6.0	0.28	B	2-12	CL, SCL, L	CL, ML, CL-ML	A-4, A-6
	46-72	5.1-5.5	0.17	B	NP-7	GR-FSL	GM, GM-GC	A-4, A-2-4
TATUM	0-8	4.5-5.5	0.37	C	NP-10	SIL, L, VFSL	ML, CL, SM	A-4
	0-8	4.5-5.5	0.37	C	12-20	SICL	CL	A-6, A-7
	8-45	4.5-5.5	0.28	C	10-36	SICL, SIC, C	MH	A-7
	45-47	4.5-5.5	0.28	C	12-20	SIL, L, SICL	CL	A-6, A-7
	47			C		WB		
THURMONT	0-9	4.5-5.5	0.24	B	NP-10	GR-SL, GR-FSL, GR-L	SM, SC, SM-SC, CL	A-1, A-2, A-4
	0-9	4.5-5.5	0.24	B	NP-10	CB-SL, CB-FSL, CB-L	SM, SC, SM-SC, CL	A-1, A-2, A-4
	9-36	4.5-5.5	0.20	B	12-20	CL, L, GR-SCL	SC, CL	A-2, A-6, A-7
	36-48	4.5-5.5	0.20	B	12-25	SL, SCL, GR-SCL	SC	A-2, A-6, A-7
	48-60	4.5-5.5	0.20	B	NP-7	CB-SL, GR-SCL	SM, SM-SC	A-1, A-2
TOCCOA	0-10	5.1-6.5	0.24	B	NP-4	FSL, L, SIL	SM, ML	A-2, A-4
	0-10	5.1-6.5	0.10	B	NP-4	SL, LS	SM	A-2, A-4
	10-60	5.1-6.5	0.10	B	NP-4	SL, L	SM, ML	A-2, A-4
TOISNOT	0-13	4.5-5.5	0.28	B/D	5-15	L, SIL	CL-ML, CL, ML	A-4, A-6
	0-13	4.5-5.5	0.10	B/D	NP-10	LS, SL	SM, SM-SC, SC	A-2, A-4
	13-28	4.5-5.5	0.32	B/D	NP-10	SL, FSL, SIL	SM, SM-SC, SC, ML	A-2, A-4
	28-45	4.5-5.5	0.43	B/D	NP-7	LS, SL	SM, SM-SC	A-2, A-4
	45-80	4.5-5.5	0.37	B/D	4-20	SCL, SC, L	CL, SC, CL-ML	A-4, A-6
TOMAHAWK	0-24	4.5-5.5	0.10	A	NP	LS, LFS, S	SM-SP-SM	A-2-4, A-1-B
	24-42	4.5-5.5	0.15	A	NP-10	SL, FSL	SM, SC, SM-SC	A-2-4, A-4
	42-80	4.5-6.5	0.10	A	NP	FS, S, LS	SM, SP-SM	A-2-4, A-1-B, A-3
TORHUNTA	0-15	3.6-5.5	0.10	C	NP-4	MK-L, MK-FSL	SM	A-2-4, A-4
	0-15	3.6-5.5	0.15	C	NP-4	FSL, L, LFS	SM	A-2, A-4
	15-40	3.6-5.5	0.15	C	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	40-80	3.6-6.5	0.10	C	NP-4	LS, S, SL	SM, SP-SM	A-2, A-3
TOXAWAY	0-36	5.1-6.5	0.17	B/D	6-22	SIL, L	CL, ML, CL-ML	A-4, A-6, A-7
	36-72	5.1-6.5	0.17	B/D	NP-15	SR-SCL-S	CL, ML, SM, SC	A-2, A-4, A-6
TRANSYLVANIA	0-27	4.5-6.0	0.37	B	7-20	SIL, L	ML, MH	A-4, A-6
	27-60	4.5-6.0	0.32	B	7-20	SICL, CL, L	ML, MH	A-4, A-6, A-7
	60-70			B		Var		
TROUP	0-53	4.5-6.0	0.17	A	NP	LS, LFS	SM, SP-SM	A-2, A-3, A-4
	0-53	4.5-6.0	0.10	A	NP	S, FS	SM, SP-SM	A-2
	53-80	4.5-5.5	0.20	A	4-13	SCL, SL, FSL	SC, SM-SC, CL-ML, CL	A-4, A-2
TUCKERMAN	0-9	4.5-6.0	0.24	D	NP-3	FSL	ML, SM	A-4, A-2
	9-18	4.5-6.0	0.24	D	NP-5	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	18-34	4.5-6.0	0.32	D	5-15	SCL, L	CL, CL-ML, SC, SM-SC	A-4, A-6
	34-52	4.5-6.0	0.24	D	NP-5	FSL, L	ML, CL-ML, SM, SM-SC	A-4
	52-62	4.5-6.0	0.20	D	NP-3	LFS, FSL, SL	SM-ML	A-2, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
TUSQUITTEE	0-10	4.5-6.0	0.24	B	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-10	4.5-6.0	0.28	B	NP-7	L, SIL	ML, CL-ML, CL, SM	A-4, A-5
	10-48	4.5-6.0	0.20	B	6-15	L, SL, FSL	SM-SC, SM	A-4
	48-60	4.5-6.0	0.20	B	NP-7	GR-SL, GR-FSL	GM, SM-SC, SM, GM-GC	A-4, A-1, A-2
UNISON	0-9	4.5-6.0	0.32	B	2-15	L, SIL, FSL	CL, ML, CL-ML, SM	A-4, A-6
	9-50	4.5-6.0	0.24	B	15-35	CL, C, GR-SIC	CL, CH	A-6, A-7
	50-72	4.5-6.0	0.28	B	5-20	CB-CL, SICL, GRV-L	CL-ML, CL, ML, GM-GC	A-1, A-2, A-6, A-7
VALHALLA	0-21	4.5-6.0	0.15	A	NP	LFS, LS	SM	A-2
	0-21	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM, SP	A-2, A-3
	21-30	4.5-6.0	0.24	A	NP-10	FSL, SL, SCL	SM, SC, SM-SC	A-2, A-4
	30-99	4.5-6.0	0.15	A	NP	FS, S	SM, SP-SM	A-2, A-3
VANCE	0-5	4.5-6.0	0.24	C	NP-7	FSL, SL, COSL	SM, SM-SC	A-2, A-4
	0-5	4.5-6.0	0.15	C	NP-7	GR-SL, GR-COSL	SM, GM, GM-GC	A-1, A-2, A-4
	0-5	4.5-6.0	0.28	C	8-20	SCL, CL	CL, SC	A-6, A-4
	5-29	4.5-5.5	0.37	C	25-48	CL, SC, C	CH	A-7
	29-72			C		WB		
VARINA	0-14	4.5-6.5	0.15	C	NP-3	LS	SM, SP-SM	A-2
	0-14	4.5-6.5	0.17	C	NP-7	SL	SM, SM-SC	A-2, A-4
	14-38	4.5-5.5	0.28	C	11-25	SC, CL, C	SC, MH, ML, SM	A-6, A-7
	38-80	4.5-5.5	0.28	C	8-26	SC, CL, C	SC, CL, CH	A-4, A-6, A-7
VAUCLUSE	0-15	4.5-6.0	0.15	C	NP	LS, S. LCOS	SM, SP-SM	A-2,A-3
	0-15	4.5-6.0	0.24	C	NP-7	FSL, SL	SM, SM-SC	A-2, A-4
	0-15	4.5-6.0	0.32	C	NP-7	SCL	SM, CL-ML, ML, SM-SC	A-4
	15-29	3.6-5.5	0.24	C	5-18	SCL, SL	SC, SM-SC	A-2, A-4, A-6
	29-58	3.6-5.5	0.24	C	NP-20	SCL, SL, SC	SC, SM-SC, SM	A-2, A-4, A-6
	58-72	3.6-5.5	0.17	C	NP-12	SL, SCL, LS	SM, SC, SM-SC	A-2, A-4, A-6
WAGRAM	0-24	4.5-6.0	0.15	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-24	4.5-6.0	0.10	A	NP	FS, S	SP-SM, SM	A-1, A-2, A-3
	24-75	4.5-6.0	0.20	A	8-25	SCL, SL	SC	A-2, A-4, A-6, A-7
WAHEE	0-11	4.5-6.0	0.24	D	NP-7	SL, FSL	SM, SM-SC	A-2, A-4
	0-11	4.5-6.0	0.28	D	2-10	L, SIL, VFSL	ML, CL-ML, CL	A-4
	11-56	3.6-5.5	0.28	D	18-42	S, CL, SIC	CL, CH	A-6,A-7
	56-65	3.6-5.5	0.28	D		Var		
WAKE	0-15	4.5-6.0	0.20	D	NP	GR-LCOS, GR-LS, LS	SP-SM, SM, GM, GP-GM	A-2, A-3, A-1
WAKULLA	0-24	4.5-6.0	0.10	A	NP	LS, LFS	SM, SP-SM	A-2, A-3
	0-24	4.5-6.0	0.10	A	NP	S, FS	SP, SP-SM	A-3
	24-42	4.5-6.0	0.10	A	NP	LS, LFS	SM, SP-SM	A-2
	42-80	4.5-6.0	0.10	A	NP	S, FS	SM, SP-SM	A-2, A-3
WANDO	0-8	5.6-7.3	0.10	A	NP	LFS, FS	SP-SM, SM	A-2, A-3
	8-99	5.6-7.3	0.10	A	NP	S, FS	SP, SP-SM, SM	A-2, A-3
WASDA	0-14	3.6-5.5		B/D	NP	MUCK	PT	
	14-42	4.5-5.5	0.20	B/D	NP-10	CL, SCL, SL	ML, CL, CL-ML	A-4
	42-60	5.6-7.8	0.24	B/D	NP-7	SL, L	ML, SM, CL-ML, SM-SC	A-4
	60-74	5.6-7.8	0.15	B/D		S	SP-SM, SM	A-2, A-3

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	Textural Classification[1] USDA	Unified	AASHTO
WATAUGA	0-7	4.5-6.0	0.24	B	NP-10	L, FSL, SIL	SM, SM-SC, SC, ML	A-4
	0-7	4.5-6.0	0.17	B	NP-7	CB-L, CB-FSL, CB-SIL	SM, SM-SC, ML, CL-ML	A-2, A-4
	7-28	4.5-6.0	0.28	B	12-25	CL, L, SCL	SC, CL	A-6, A-7
	28-72	4.5-6.0	0.24	B	NP	L, SL, FSL	SM	A-2, A-4
WEDOWEE	0-10	4.5-5.5	0.24	B	NP-6	SL, FSL, L	SM, SM-SC	A-4, A-2-4
	0-10	4.5-5.5	0.15	B	NP-6	GR-SL, GR-FSL, GR-L	SM, SM-SC	A-4, A-2, A-1
	0-10	4.5-5.5	0.28	B	5-15	SCL, CL	SC, CL	A-4, A-6
	10-14	4.5-5.5	0.28	B	NP-15	L, SCL	SM, SC, CL, ML	A-4, A-6
	14-32	4.5-5.5	0.28	B	10-25	SC, CL, C	SC, ML, CL, SM	A-6, A-7
	32-60	4.5-5.5	0.28	B	5-15	SCL, CL, SL	SC, SM-SC, CL	
WEEKSVILLE	0-42	4.5-5.5	0.43	B/D	NP-7	SIL, VFSL, L	CL-ML, ML	A-4
	42-56	4.5-5.5	0.43	B/D	NP-3	FSL, SL	SM	A-2, A-4
	56-72	4.5-5.5	0.32	B/D	NP	S, LS, LFS	SM, SP-SM	A-2
WEHADKEE	0-8	4.5-6.5	0.24	D	NP-10	FSL, L, SL	SM, SC, SM-SC	A-2, A-4
	0-8	4.5-6.5	0.32	D	10-24	SIL, SICL	CL, MH, ML	A-6, A-7
	8-40	4.5-6.5	0.32	D	7-25	L, SCL, CL	ML, CL, CL-ML	A-6, A-7, A-4
	40-50			D		Var		
WESTON	0-9	4.5-6.0	0.24	D	NP-3	FSL, SL	ML, SM	A-4
	0-9	4.5-6.0	0.20	D	NP-3	LFS	SM	A2, A-4
	9-44	4.5-5.0	0.24	D	NP-5	SL, L, FSL	SM, SM-SC, ML, CL-ML	A-4
	44-54	4.5-5.0	0.32	D	NP-15	SR-S-C	SM, ML, CL, CL-ML	A-4, A-6
WHITE STORE	0-6	5.6-6.0	0.28	D	NP-7	SL, FSL	ML, CL-ML	A-4
	0-6	5.6-6.0	0.43	D	NP-7	L, SIL	ML, CL-ML	A-4
	0-6	4.5-5.5	0.37	D	25-45	CL, C	CH, CL	A-7
	6-35	4.5-5.5	0.37	D	45-65	C	CH	A-7
	35-60			D		Var		
WICKHAM	0-9	4.5-6.0	0.24	B	NP-7	SL, FSL, L	SM, SM-SC, ML, CL-ML	A-4
	0-9	4.5-6.0	0.15	B	NP	LS	SM	A-2
	9-40	4.5-6.0	0.24	B	5-15	SCL, CL, L	CL-ML, CL, SC, SM-SC	A-2, A-4, A-6, A-7
	40-70			B		Var		
WICKSBURG	0-26	4.5-6.0	0.10	B	NP	GR-COS	SP, SP-SM	A-1
	0-26	4.5-6.0	0.17	B	NP	LS, LFS	SM	A-2
	0-26	4.5-6.0	0.15	B	NP	S, FS	SM, SP-SM	A-2, A-3
	26-30	4.5-5.5	0.20	B	NP-15	SCL, CL	SC, SM-SC, CL, CL-ML	A-4, A-6
WILBANKS	0-5	3.6-5.5	0.20	D	6-20	FSL, SIL, L	ML, CL-ML, CL	A-4
	5-39	3.6-5.5	0.24	D	18-35	SIC, C, CL	CH, MH	A-7
	39-78			D		Var		
WILKES	0-6	5.1-6.5	0.24	C	NP-7	SL, L	ML, SM, SM-SC	A-2, A-4
	0-6	5.1-6.5	0.28	C	10-25	SCL, CL	CL, SC	A-6, A-7
	0-6	5.1-6.5	0.17	C	NP-7	GR-SL, GR-L	SM, SM-SC	A-2, A-4, A-1-B
	6-13	6.1-7.8	0.32	C	11-35	CL, C, SCL	CL, CH	A-6, A-7
	13-48			C		WB		
WOODINGTON	0-12	3.6-5.5	0.10	B/D	NP	LS, LFS	SM	A-2
	0-12	3.6-5.5	0.20	B/D	NP-3	SL, FSL	SM	A-2, A-4
	12-47	3.6-5.5	0.20	B/D	NP-3	SL, FSL	SM	A-2, A-4
	47-85	3.6-5.5	0.10	B/D	NP-3	SL, LS, LFS	SM, SP-SM	A-2, A-4

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

Table 8.01d (continued)

Name	Depth	pH	K	Hydrology Group	Plasti-city	---Textural Classification[1]--- USDA	Unified	AASHTO
WORSHAM	0-8	4.5-5.5	0.28	D	NP-9	FSL, SL	SM, SC, ML, CL	A-2, A-4
	0-8	4.5-5.5	0.37	D	4-12	L, SIL	CL, CL-ML	A-4, A-6
	8-50	4.5-5.5	0.28	D	22-40	SCL, SC, C	SC, CH, CL	A-2, A-7
	50-70	4.5-5.5	0.28	D	8-30	SL, SCL, CL	SC, CL	A-2, A-4, A-6, A-7
WRIGHTSBORO	0-9	4.5-6.0	0.17	C	NP	LS, LFS	SM	A-2
	0-9	4.5-6.0	0.28	C	NP-3	SL, FSL	SM	A-2, A-4
	9-48	4.5-6.0	0.32	C	11-25	SCL, CL, L	SC, CL	A-6, A-7
	48-65	4.5-6.0	0.43	C	25-45	C	CH	A-7

[1]See Tables 8.01b, 8.01c and Figure 8.01d for definition of symbols.

8.02

VEGETATION TABLES

Table 8.02a is a listing of grasses and legumes referred to in this manual, along with characteristics useful in their selection. Most of these plants are discussed in detail in *Chapter 3, Vegetative Considerations*. This table is intended for use as a reference and should not be used as a substitute for seeding mixture specifications given in *Practice Standards and Specifications 6.10, Temporary Seeding,* and *6.11, Permanent Seeding*.

Table 8.02b is a reference for selecting trees and shrubs native to North Carolina. It is the master list developed by the NC DENR Ecosystem Enhancement Program. Appropriate riparian species may be selected from this list for reforestation of stream buffers. These plants are considered separately from grasses and herbaceous legumes because of the longer time required to produce effective cover and the different planting methods used in their establishment. Light and moisture requirements are given for each plant to assist in fitting it to a specific use and site. Region refers to the physiographic provinces of the state where a plant is climatically suited.

There are many excellent sources of information on plant materials. The USDA Natural Resources Conservation Service maintains a Plants Database at http://plants.usda.gov/index.html. The Federal Highway Administration maintains a list of Native Plants for Landscape Use in North Carolina at http://www.fhwa.dot.gov/environment/rdsduse/nc.htm. Appendix Three of this reference lists 129 dominant plant communities within the United States, with a species list for each plant community at http://www.fhwa.dot.gov/environment/rdsduse/rdus3_20.htm This is a valuable tool in selecting appropriate species to plant together to recreate a natural plant community.

Table 8.02a
Grasses and Legumes for Use in Stabilization of Disturbed Soils In North Carolina

Grasses

Common name:	AMERICAN BEACHGRASS
Botanical name:	*Ammophila breviligulata* Fernald
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	20-60 inches
pH range:	—
Seeds per lb (x 1000):	Not seeded
Applications:	Dune building
Adaptations:	Excessively drained soils
Recommended variety:	Hatteras
Notes:	Transplant sprigs or potted plants in spring Native

Common name:	BAHIAGRASS
Botanical name:	*Paspalum notatum* Flugge
Life cycle:	Perennial
Growth form:	Spreads by rhizomes and stolons
Season of growth:	Warm
Height:	15-30 inches
pH range:	4.5-7.0
Seeds per lb (x 1000):	273
Applications:	Fine turf, waterways and critical areas, Coastal Plain and Southern Piedmont
Adaptations:	Traffic, heat, drought
Recommended varieties:	Pensacola and Wilmington
Notes:	Tall seed heads may be aesthetically objectionable

Common name:	BERMUDAGRASS
Botanical name:	*Cynodon dactylon* (L.) Pers
Life cycle:	Perennial
Growth form:	Spreads by rhizomes and stolons
Season of growth:	Warm
Height:	4-16 inches
pH range:	4.5-7.5
Seeds per lb (x 1000):	1,586 (unhulled), 2,071 (hulled)
Applications:	Waterways and other critical areas in the Coastal Plain and Southern Piedmont; hybrids used for fine turf
Adaptations:	Traffic, drought, flooding, salinity
Recommended varieties:	Coastal in the Coastal Plain; Tifway, Tifway II, and Tifton-44 for fine turf in the Piedmont and Coastal Plain; Vamont and Midiron for Piedmont lawns.
Notes:	Common Bermudagrass is an agressive invader and potential pest.

Common name:	BIG BLUESTEM
Botanical name:	*Andropogon geradii*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer
Height:	6 feet
pH range:	6-7.5
Seeds per lb (x 1000):	144
Applications:	Riparian areas, erosion control, prairie restoration
Adaptations:	Full sun, well drained soils
Recommended varieties:	Roundtree, Kaw, Earl
Notes:	Native

Common name:	BITTERPANICUM
Botanical name:	*Panicum amarum* Ell.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	3-4 feet
pH range:	5.0-7.5
Seeds per lb (x 1000):	Does not produce viable seed
Applications:	Dune building
Adaptations:	Excessively drained soils
Notes:	Transplants better than sea oats; spreads slowly. Should not be confused with *P. amarulum*, a seed-producing bunchgrass

Common name:	CENTIPEDEGRASS
Botanical name:	*Eremochloa ophiuroides* (Munro.) Hack.
Life cycle:	Perennial
Growth form:	Spreads by stolons
Season of growth:	Warm
Height:	4-12 inches
pH range:	5-5-6.0
Seeds per lb (x 1000):	800
Applications:	Dry sites—Coastal Plains and Piedmont
Adaptations:	Drought

Common name:	CORDGRASS, GIANT
Botanical name:	*Spartina cynosuroides* (L.) Roth
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	To 9 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Irregularly flooded estuarine areas of moderate salinity
Notes:	Transplant nursery-grown potted plants in spring Native

Common name:	CORDGRASS, SALTMEADOW(MARSHHAY CORDGRASS)
Botanical name:	*Spartina patens* (Ait.) Muhl.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	1-4 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Dunes, sand flats, and channel banks along the coast
Adaptations:	Poor drainage; salinity
Notes:	Transplanted by sprigs or potted plants Native

Common name:	CORDGRASS, SMOOTH
Botanical name:	*Spartina alterniflora* Loisel
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	1-6 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Salt marsh restoration
Adaptations:	Regularly flooded, organic and mineral soils along the coast
Notes:	Transplant sprigs or potted plants in spring Native

Common name:	CREEPING BENTGRASS
Botanical name:	*Agrostis stolonifera*
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Cool
Height:	2 feet
pH range:	5.1-7.5
Seeds per lb (x 1000):	6,130
Applications:	Works well in mixtures; waterways
Adaptations:	Drought, acid soils, flooding
Notes:	Native

Common name:	DEERTONGUE
Botanical name:	*Dichanthelium clandestinum*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring, Summer
Height:	2 feet
pH range:	4-7.5
Seeds per lb (x 1000):	350
Applications:	Mine reclamation, erosion control
Adaptations:	Full sun, drought tolerant, acidic soils
Recommended varieties:	
Notes:	Native

Common name:	EASTERN BOTTLEBRUSH GRASS
Botanical name:	*Elymus hystrix*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring, Summer
Height:	2-5 feet
pH range:	--
Seeds per lb (x 1000):	--
Applications:	Riparian areas, erosion control, moist woods
Adaptations:	Partial sun to shade, moist soils
Recommended varieties:	
Notes:	Native

Common name:	FESCUE, CHEWINGS RED
Botanical name:	*Festuca rubra* var. *commutata* Gaud.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	1-2 feet
pH range:	4.5-7.5
Seeds per lb (x 1000):	449
Applications:	Waterways
Adaptations:	Shade, traffic, and flooding
Notes:	Stands thin with age

Common name:	FESCUE, HARD
Botanical name:	*Festuca brevipila*
Life cycle:	Perennial
Growth form:	Bunchgrass
Season of growth:	Cool
Height:	1-2 feet
pH range:	4.5-8.0
Seeds per lb (x 1000):	592
Applications:	Shaded, high maintenance areas in the Mountains and Upper Piedmont
Adaptations:	Partial shade

Common name:	FESCUE, RED, (CREEPING RED FESCUE)
Botanical name:	*Festuca rubra* L.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	To 18 inches
pH range:	4.5-7.5
Seeds per lb (x 1000):	365
Applications:	Waterways; used in turf grass mixtures for the Mountains and Piedmont
Adaptations:	Shade, traffic, and flooding
Recommended varieties:	Fortress and Pennlawn for fine turf

Common name:	FESCUE, TALL
Botanical name:	*Festuca arundinacea* Schreb.
Life cycle:	Perennial
Growth form:	Bunch
Season of growth:	Cool
Height:	3-4 feet
pH range:	4.8-8.2
Seeds per lb (x 1000):	200
Applications:	Waterways and lawns
Adaptations:	Shade, traffic, drought, and flooding
Recommended varieties:	KY-31; for fine turf: Rebel, Falcon and many others

Common name:	FOX SEDGE
Botanical name:	*Carex vulpinoidea*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	3.2 feet
pH range:	6.8-8.9
Seeds per lb (x 1000):	1297
Applications:	Riparian areas, wetlands
Adaptations:	Full sun to partial shade, wet soils
Recommended varieties:	--
Notes:	Native

Common name:	INDIAN GRASS
Botanical name:	*Sorghastrum nutans*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer, Fall
Height:	6 feet
pH range:	4.8-7.5
Seeds per lb (x 1000):	175
Applications:	Riparian Areas
Adaptations:	Full sun, tolerant of poorly to excessively drained soils
Recommended varieties:	Rumsey, Osage, Cheyenne, Lomenta
Notes:	Native

Common name:	INDIAN SEAOATS (INDIAN WOODOATS)
Botanical name:	*Chasmanthium latifolium*
Life Cycle:	Perennial
Growth habit:	Rhizomatous
Season of growth:	Spring
Height:	4.6 feet
pH range:	5-7

Seeds per lb (x 1000):	900
Applications:	Riparian areas
Adaptations:	Shade tolerant, streambanks, shaded slopes and bottomland forests
Recommended varieties:	--
Notes:	Native

Common name:	KENTUCKY BLUEGRASS
Botanical name:	*Poa pratensis* L.
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Cool
Height:	4-32 inches
pH range:	5.0-8.0
Seeds per lb (x 1000):	1,022-1,758
Applications:	Waterways and turf—Western Piedmont and Mountains
Adaptations:	Flooding
Recommended varieties:	Many varieties available

Common name:	LITTLE BLUESTEM
Botanical name:	*Schizachyrium scoparium*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Summer, Fall
Height:	3 feet
pH range:	5-8.4
Seeds per lb (x 1000):	241
Applications:	Riparian areas, erosion control, prairie restoration
Adaptations:	Full sun, well drained, infertile soils
Recommended varieties:	Aldous, Cimmaron, Common
Notes:	Native

Common name:	MAIDENCANE
Botanical name:	*Panicum hemitomon* Shultes
Life cycle:	Perennial
Growth form:	Rhizomatous
Season of growth:	Warm
Height:	2-6 feet
pH range:	6-7.5
Seeds per lb (x 1000):	—
Applications:	Shoreline stabilization, wetlands
Adaptations:	Shallow water, periodically flooded sites
Recommended varieties:	Halifax
Notes:	Transplant dormant rhizomes from existing beds. Very sensitive to salinity; excellent forage for livestock. Native

Common name:	MILLET, GERMAN (FOXTAIL MILLET)
Botanical name:	*Setaria italica* (L.) Beauvois
Life cycle:	Annual
Season of growth:	Warm
Height:	2-3 feet
pH range:	4.5-7.0
Seeds per lb (x 1000):	184-249
Applications:	Temporary seedings in spring and summer on the Coastal Plain
Adaptations	—
Notes:	Watch List of Exotic Invasive Plants

Common name:	PARTRIDGE PEA
Botanical name:	*Chamaecrista fasciculata*
Life Cycle:	Annual

Growth form: Bunch
Season of growth: Spring
Height: 2.4 feet
pH range: 5.5-7.5
Seeds per lb (x 1000): 65
Applications: Native legume for erosion control on disturbed areas
Adaptations: Partial shade, well drained soils
Recommended varieties: --
Notes: Native, Not suitable for pasture or hay

Common name: CREEPING BENTGRASS
Botanical name: *Agrostis stolonifera*
Life cycle: Perennial
Growth form: Stoloniferous
Season of growth: Cool
Height: 2 feet
pH range: 5.1-7.5
Seeds per lb (x 1000): 6,130
Applications: Works well in mixtures; waterways
Adaptations: Drought, acid soils, flooding
Notes: Native

Common name: REED CANARYGRASS
Botanical name: *Phalaris arundinacea* L.
Life cycle: Perennial
Growth form: Rhizomatous
Season of growth: Spring, Summer, Fall
Height: To 5 feet
pH range: 5.5-8
Seeds per lb (x 1000): 538
Applications: Stabilization of pond shorelines, drainage ditches and streambanks, Mountains and Western Piedmont
Adaptations: Low, wet areas to upland sites; drought resistant
Notes: Plant freshly cut stem slips or rhizome fragments; stems root at the nodes. Native

Common name: RICE CUTGRASS
Botanical name: *Leersia oryzoides (Persia oryzoides)*
Life Cycle: Perennial
Growth form: Rhizomatous
Season of growth: Summer
Height: 4.9 feet
pH range: 5.1-8.8
Seeds per lb (x 1000): --
Applications: Wetland restoration, shoreline stabilization
Adaptations: Sun to partial shade, wet soil, mud flats, low pH
Recommended varieties: --
Notes: Native

Common name: RYE(WINTER RYE, CEREAL RYE GRAIN)
Botanical name: *Secale cereale* L.
Life cycle: Annual
Season of growth: Cool
Height: To 4 feet
pH range: 5-5-7.0
Seeds per lb (x 1000): 18
Applications: Temporary fall and winter seedings; nurse plant
Adaptations: Cold, drought

Common name:	SAINT AUGUSTINE GRASS
Botanical name:	*Stenotaphrum secundatum* (Walter) Kuntze
Life cycle:	Perennial
Growth form:	Stoloniferous
Season of growth:	Warm
Height:	4-5 inches (seedheads)
pH range:	6.5-7.0
Seeds per lb (x 1000):	Propagated vegetatively
Applications:	High maintenance turf, Coastal Plain, and Southern Piedmont
Adaptations:	Sun or shade and close mowing; not cold hardy; withstands salt spray.
Recommended variety:	Raleigh
Notes:	Not seeded; sod or plug on 12-inch centers

Common name:	SEA OATS
Botanical name:	*Uniola paniculata* L.
Life cycle:	Perennial
Growth habit:	Rhizomatous
Season of growth:	Warm
Height:	3-4 feet
pH range:	—
Seeds per lb (x 1000):	—
Applications:	Dune stabilization
Adaptations:	Salinity; dune sands
Notes:	Transplant by sprigs or potted plants; flourishes in drifting and accumulating sand. Native

Common name:	SHALLOW SEDGE
Botanical name:	*Carex lurida*
Life Cycle:	Perennial
Growth form:	Bunch
Season of growth:	Spring
Height:	3.2 feet
pH range:	4.9-6.8
Seeds per lb (x 1000):	--
Applications:	Riparian areas, wetlands
Adaptations:	Full sun to partial shade, wet soils
Recommended varieties:	--
Notes:	Native

Common name:	SOFT RUSH (COMMON RUSH)
Botanical name:	*Juncus effusus*
Life Cycle:	Perennial
Growth form:	Bunch, Rhizomatous
Season of growth:	Spring
Height:	6.6 feet
pH range:	5.5-7.0
Seeds per lb (x 1000):	--
Applications:	Freshwater marshes, swamps, seasonal wetlands
Adaptations:	Full sun, shallow water, low pH
Recommended varieties:	--
Notes:	Native

Common name:	SUDANGRASS
Botanical name:	*Sorghum bicolor* (L.) Moench *(previously S. sudanense)*
Life cycle:	Annual
Season of growth:	Warm
Height:	3-6 feet
pH range:	4.5-7.5
Seeds per lb (x 1000):	38-51
Applications:	Temporary seedings; nurse plant

Adaptations: Acidity; fine soils
Notes: Use only small-stemmed varieties; do not substitute sorghum-Sudan hybrids

Common name: SWEET WOODREED
Botanical name: *Cinna arundinacea*
Life Cycle: Perennial
Growth form: Bunch
Season of growth: Spring
Height: 4.9 feet
pH range: 4-8.5
Seeds per lb (x 1000): --
Applications: Riparian areas, moist woodlands, floodplains
Adaptations: Shade tolerant, wet soils
Recommended varieties:
Notes: Native

Common name: SWITCHGRASS
Botanical name: *Panicum virgatum*
Life Cycle: Perennial
Growth form: Rhizomatous
Season of growth: Summer
Height: 5 feet
pH range: 4.5-8
Seeds per lb (x 1000): 259
Applications: Riparian areas, erosion control
Adaptations: Full sun, somewhat dry to poorly drained soils
Recommended varieties: Cave-in-Rock, Blackwell, Shelter, Carthage, Kanlow, Alamo
Notes: Native

Common name: VIRGINIA WILD RYE
Botanical name: *Elymus virginicus*
Life Cycle: Perennial
Growth form: Bunch
Season of growth: Spring
Height: 2.5 feet
pH range: 5-7
Seeds per lb (x 1000): 100
Applications: Riparian areas, moist woods
Adaptations: Shade tolerant, moist soils
Recommended varieties: --
Notes: Native

Common name: WEEPING LOVE GRASS
Botanical name: *Eragrostis curvula* (Schrader) Nees.
Life cycle: Perennial
Growth form: Bunch
Season of growth: Warm
Height: 3 feet
pH range: 4.5-8.0
Seeds per lb (x 1000): 1,482
Applications: Steep, dry slopes
Adaptations: Drought
Notes: Quick summer cover; frequently short-lived, and best used with sericea lespedeza. Bunch growth is a problem in pure stands.

Common name: ZOYSIAGRASS (MANILAGRASS)
Botanical name: *Zoysia matrella* L. Merrill
Life cycle: Perennial
Growth form: Stoloniferous
Season of growth: Warm

Height: 4 inches (leaves)
pH range: 6.5-7.0
Seeds per lb (x 1000): 601
Applications: Fine turf, Coastal Plain and Piedmont
Adaptations: Drought
Notes: High-maintenance lawn grass. Not seeded; sod or plug on 12-inch centers

Legumes

Common name: CROWN VETCH
Botanical name: *Coronilla varia* L.
Life cycle: Perennial
Growth form: Low, spreading
Season of growth: Cool
Height: To 3 feet
pH range: 5.5-7.5
Seeds per lb (x 1000): 138
Applications: Steep roadbanks and other low-maintenance areas in the Mountains and on cool slopes in the Western Piedmont
Adaptations: Low pH, low fertility, and drought
Notes: Not very aggressive in the seedling stage, but a strong grower after establishment and very persistent. Does not compete well. Good in mixtures with tall fescue. Significant Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, KOBE (JAPANESE CLOVER)
Botanical name: *Lespedeza striata* (Thumb) H. & A.
Life cycle: Annual
Growth habit: Upright
Season of growth: Warm
Height: 4-16 inches
pH range: 5-7
Seeds per lb (x 1000): —
Applications: Nurse plant (Coastal Plain and Piedmont)
Adaptations: Drought
Notes: Heavy seeder and volunteer plant, Lesser Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, KOREAN
Botanical name: *Lespedeza stipulacea* Maxim.
Life cycle: Annual
Growth habit: Upright
Season of growth: Warm
Height: 4-12 inches
pH range: 5.5-7.5
Seeds per lb (x 1000): 238
Applications: Nurse plant (Mountains)
Adaptations: —
Notes: Volunteers, Lesser Threat List of Exotic Invasive Plants

Common name: LESPEDEZA, SERICEA (CHINESE LESPEDEZA)
Botanical name: *Lespedeza cuneata* (Dumont) G. Don
Life cycle: Perennial
Growth habit: Upright
Season of growth: Warm
Height: 2-4 feet
pH range: 5.0-7.0
Seeds per lb (x 1000): 372
Applications: Low maintenance slopes; works well in mixtures with tall fescue

Adaptations:	Low pH
Recommended varieties:	Appalow, Ambro, Caricea, Interstate, and Serala
Notes:	Severe Threat List of Exotic Invasive Species

Common name:	ROUNDHEAD LESPEDEZA
Botanical name:	*Lespedeza capitata*
Life Cycle:	Perennial
Growth form:	Multiple Stem
Season of growth:	Summer
Height:	2.6 feet
pH range:	5.7-8.2
Seeds per lb (x 1000):	275
Applications:	Native legume for use in upland seed mixes
Adaptations:	Full sun, drought tolerant
Recommended varieties:	--
Notes:	Native

Table 8.02b
Guide to the Selection of Native Trees and Shrubs

Adapted from the NC DENR Ecosystem Enhancement Program Publication *Guidelines for Riparian Buffer Restoration,* October, 2004

Master List of Native Plants

Native Regions	Light Requirements	Moisture Requirements
M= Mountains	S= Shade	L= Low Moisture
P= Piedmont	P= Partial Sun	M= Moderate Moisture
C= Coastal Plain	F= Full Sun	H= High Moisture
		A= Aquatic

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Medium to Large Trees											
Acer barbatum	Southern sugar maple		X	X	X	X			X		
Acer saccharinum	silver maple		X		X	X	X		X		
Acer saccharum	sugar maple	X				X	X		X		
Betula alleghaniensis	yellow birch	X			X	X			X		
Betula lenta	cherry birch, sweet birch	X			X	X			X		
Betula nigra	river birch	X	X	X		X	X		X	X	
Carya aquatica	water hickory			X		X	X			X	
Carya cordiformis	bitternut hickory	X	X	X	X	X	X		X	X	
Carya glabra	pignut hickory	X	X	X	X	X	X	X	X		
Carya ovata	shagbark hickory	X	X	X	X	X	X		X		
Carya tomentosa	mockernut hickory	X	X	X	X	X	X	X	X		
Celtis laevigata	sugarberry, hackberry		X	X	X	X			X		
Chamaecyparis thyoides	Atlantic white cedar			X		X	X		X	X	
Cladrastis kentuckea	yellowwood	X			X	X			X		
Diospyros virginiana	persimmon	X	X	X	X	X	X	X	X		
Fagus grandifolia	American beech	X	X	X	X	X			X		
Fraxinus americana	white ash	X	X	X	X	X			X		
Fraxinus pennsylvanica	green ash	X	X	X	X	X			X	X	
Fraxinus profunda	pumpkin ash, red ash		X	X		X				X	
Juglans nigra	black walnut	X	X	X	X	X			X		
Liriodendron tulipifera	tulip poplar, yellow poplar	X	X	X	X	X	X		X		
Magnolia acuminata	cucumber magnolia	X	X		X	X			X		
Magnolia fraseri	Fraser magnolia	X				X			X		
Nyssa aquatica	water tupelo			X	X	X	X			X	X
Nyssa sylvatica	black gum	X	X	X	X	X	X	X	X		

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Nyssa sylvatica var. biflora	swamp black gum			X	X	X	X			X	
Oxydendrum arboreum	sourwood	X	X	X		X	X	X	X		
Picea rubens	red spruce	X			X	X	X		X		
Pinus echinata	shortleaf pine	X	X	X		X	X	X			
Pinus palustris	longleaf pine		X	X			X	X	X		
Pinus rigida	pitch pine	X					X	X			
Pinus serotina	pond pine			X				X	X	X	
Pinus strobus	white pine	X	X			X	X		X		
Platanus occidentalis	sycamore	X	X	X		X	X		X	X	
Populus deltoides	eastern cottonwood		X	X			X			X	
Populus heterophylla	swamp cottonwood			X		X	X			X	
Prunus serotina	black cherry	X	X	X	X	X	X	X	X		
Quercus alba	white oak	X	X	X		X	X	X	X		
Quercus bicolor	swamp white oak		X		X	X				X	
Quercus coccinea	scarlet oak	X	X		X	X		X			
Quercus falcata	Southern red oak	X	X	X	X	X		X	X		
Quercus pagoda	cherrybark oak		X	X	X	X			X	X	
Quercus laurifolia	laurel oak			X	X	X	X		X	X	
Quercus lyrata	overcup oak		X	X	X	X				X	
Quercus margaretta	sand post oak			X		X	X	X			
Quercus marilandica	black jack oak	X	X	X	X	X		X			
Quercus michauxii	swamp chestnut oak		X	X	X	X	X		X	X	
Quercus nigra	water oak		X	X	X	X	X	X	X		
Quercus phellos	willow oak		X	X	X	X	X		X	X	
Quercus prinus	chestnut oak	X	X		X	X		X			
Quercus rubra	Northern red oak	X	X		X	X		X	X		
Quercus shumardii	shumard oak		X	X	X	X			X	X	
Quercus stellata	post oak	X	X	X	X	X		X			
Quercus velutina	black oak	X	X	X	X	X		X			
Quercus virginiana	live oak			X		X	X	X			
Robinia pseudoacacia	black locust	X	X	X		X	X		X		
Taxodium ascendens	pond-cypress			X		X	X				X
Taxodium distichum	bald-cypress			X		X	X				X
Tilia americana var. heterophylla	basswood	X	X		X	X			X		
Tsuga canadensis	Eastern hemlock	X	X		X	X	X		X		
Tsuga caroliniana	Carolina hemlock	X	X			X	X	X			
Ulmus alata	winged elm		X	X	X	X	X	X	X		
Ulmus americana	American elm	X	X	X	X	X			X		
Small Trees											
Amelanchier arborea	downy serviceberry, shadbush	X	X	X	X	X			X		
Amelanchier canadensis	Canada serviceberry			X			X		X	X	
Amelanchier laevis	smooth serviceberry	X				X	X	X	X		
Asimina triloba	pawpaw		X	X	X	X	X				X
Carpinus caroliniana	ironwood, American hornbeam	X	X	X	X	X			X	X	
Cercis canadensis	eastern redbud	X	X	X	X	X			X		
Chionanthus virginicus	white fringetree, old man's beard	X	X	X		X	X		X		
Cornus alternifolia	alternate-leaf dogwood	X			X	X			X		
Cornus florida	flowering dogwood	X	X	X	X	X		X	X		
Crateagus crus-galli	cockspur hawthorn	X	X	X		X	X	X	X		
Crateagus flabellata	fanleaf hawthorn	X	X			X			X		
Crateagus flava	October haw	X	X	X		X	X		X		
Cyrilla racemiflora	titi			X		X	X		X	X	
Fraxinus caroliniana	water ash			X	X	X				X	
Gordonia lasianthus	loblolly bay			X	X	X	X		X	X	
Halesia tetraptera (H. carolina)	common silverbell		X	X		X	X			X	
Ilex opaca	American holly		X	X	X	X	X		X	X	X
Juniperus virginiana	Eastern red cedar		X	X	X		X	X	X	X	

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Magnolia tripetala	umbrella tree		X	X		X				X	
Magnolia virginiana	sweetbay magnolia			X	X	X	X	X		X	X
Morus rubra	red mulberry		X	X	X	X	X			X	
Osmanthus americana	wild olive, devilwood				X	X	X			X	
Ostrya virginiana	Eastern hop-hornbeam		X	X		X	X			X	
Persea borbonia	red bay				X	X	X	X	X	X	
Persea palustris	swamp bay				X	X	X	X		X	X
Pinus pungens	table mountain pine		X					X	X		
Prunus americana	American wild plum		X	X			X			X	
Prunus caroliniana	Carolina laurel-cherry				X		X	X	X	X	
Quercus incana	bluejack oak				X		X	X	X		
Quercus laevis	turkey oak			X		X	X	X			
Rhus glabra	smooth sumac	X	X				X	X	X		
Rhus hirta (Rhus typhina)	staghorn sumac	X					X	X			
Salix caroliniana	swamp willow	X	X	X		X	X		X	X	
Salix nigra	black willow	X	X	X		X	X		X	X	
Sassafras albidum	sassafras	X	X	X		X	X	X	X		
Staphylea trifolia	bladdernut		X		X				X	X	
Symplocos tinctoria	horse-sugar, sweetleaf	X	X	X	X	X		X	X		
Ulmus rubra	slippery elm	X	X		X	X			X		
Shrubs											
Aesculus sylvatica	painted buckeye	X	X		X	X			X		
Alnus serrulata*	common alder	X	X	X	X	X	X			X	X
Aronia arbutifolia	red chokeberry	X	X	X	X	X			X	X	
Baccharis halimifolia	silverling		X	X			X	X	X	X	
Callicarpa americana	American beautyberry		X	X	X	X	X		X		
Calycanthus floridus	sweet-shrub	X	X		X	X			X		
Castanea pumila	Allegheny chinkapin	X	X	X	X	X	X	X			
Ceanothus americanus	New Jersey tea	X	X	X		X	X	X			
Cephalanthus occidentalis	buttonbush	X	X	X		X	X				X
Clethra acuminata	mountain sweet pepperbush	X			X	X			X		
Clethra alnifolia	sweet pepperbush			X	X	X			X	X	
Comptonia peregrina	sweet fern	X	X			X	X				
Cornus amomum	silky dogwood	X	X	X	X	X				X	X
Cornus stricta	swamp dogwood			X	X	X				X	
Corylus americana	American hazel, hazelnut	X	X		X	X			X		
Euonymus americanus	hearts-a-bustin', strawberry bush	X	X	X	X	X		X	X		
Fothergilla gardenii	witch-alder			X		X			X	X	
Gaylussacia frondosa	dangleberry			X	X	X	X		X	X	
Hamamelis virginiana	witch hazel	X	X	X	X	X		X	X		
Hydrangea arborescens	wild hydrangea	X	X		X	X			X		
Ilex coriacea	gallberry			X	X	X			X	X	
Ilex decidua	deciduous holly, possumhaw		X	X	X	X			X		
Ilex glabra	inkberry			X	X	X	X		X	X	
Ilex verticillata	winterberry	X	X	X	X	X	X		X	X	
Ilex vomitoria	yaupon holly			X	X	X	X	X			
Itea virginica	Virginia willow		X	X	X	X				X	
Kalmia angustifolia var. caroliniana	lamb-kill, sheep-kill			X		X	X		X	X	
Kalmia latifolia	mountain laurel	X	X		X	X		X	X		
Leucothoe axillaris	coastal dog-hobble			X	X	X			X		
Leucothoe fontanesiana	dog-hobble	X	X		X				X		
Leucothoe racemosa	fetterbush		X	X	X	X			X	X	
Lindera benzoin	spicebush	X	X		X				X		
Lyonia ligustrina	northern maleberry	X	X	X		X			X	X	
Lyonia lucida	shining fetterbush			X	X	X			X		
Myrica cerifera*	Southern wax-myrtle		X	X	X	X	X	X	X	X	

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Myrica cerifera var. pumila*	dwarf Southern wax-myrtle			X		X	X	X	X		
Myrica heterophylla*	bayberry, evergreen bayberry			X	X	X			X		
Pieris floribunda	evergreen mountain fetterbush	X					X	X	X		
Rhododendron atlanticum	dwarf azalea			X		X			X		
Rhododendron calendulaceum	flame azalea	X			X	X			X		
Rhododendron catawbiense	Catawba rhododendron	X	X		X	X	X	X	X		
Rhododendron maximum	rosebay rhododendron	X	X		X	X		X	X		
Rhododendron periclymenoides	pinxter flower, wild azalea	X	X	X	X	X			X		
Rhododendron viscosum	swamp azalea	X		X		X	X		X	X	
Rhus copallina	winged sumac	X	X	X		X	X	X	X		
Rosa carolina	pasture rose, Carolina rose	X	X	X		X	X	X	X		
Rosa palustris	swamp rose	X	X	X		X	X				X
Rubus allegheniensis	Alleghany blackberry	X	X				X	X			
Rubus cuneifolius	blackberry		X	X		X	X	X	X		
Rubus odoratus	purple flowering raspberry	X				X			X		
Salix humilis	prairie willow	X	X				X	X			
Salix sericea	silky willow	X	X	X		X	X				X
Sambucus canadensis	common elderberry	X	X	X			X		X	X	
Spiraea alba	narrow-leaved meadowsweet	X					X		X		
Spiraea latifolia	broad-leaved meadowsweet	X					X		X		
Spiraea tomentosa	meadowsweet	X	X	X		X	X			X	
Stewartia malacodendron	silky camellia			X	X	X			X		
Stewartia ovata	mountain camellia	X	X		X	X			X		
Styrax grandifolia	bigleaf snowbell		X	X	X	X			X		
Vaccinium arboreum	sparkleberry		X	X	X	X		X	X		
Vaccinium corymbosum	highbush blueberry	X	X	X	X	X	X	X	X	X	
Vaccinium crassifolium	creeping blueberry			X		X			X		
Vaccinium elliottii	mayberry			X	X				X		
Vaccinium stamineum	deerberry, gooseberry	X	X	X	X	X		X			
Vaccinium pallidum	lowbush blueberry	X	X		X	X		X			
Viburnum acerifolium	maple-leaf viburnum	X	X		X	X		X	X		
Viburnum dentatum	Southern arrowwood viburnum	X	X	X	X	X	X		X		
Viburnum nudum	possumhaw viburnum	X	X	X	X	X				X	
Viburnum prunifolium	blackhaw viburnum	X	X	X	X	X			X		
Viburnum rafinesquianum	downy arrowwood		X		X	X			X		
Viburnum rufidulum	rusty blackhaw		X	X	X	X		X			
Xanthorhiza simplicissima	yellowroot	X	X	X	X			X	X		

8.03

ESTIMATING RUNOFF

Estimating peak rate of runoff, volume of runoff, and soil loss are basic to the design of erosion and sedimentation control facilities.

There are a number of acceptable methods of determining runoff. Two acceptable methods, the rational method and the Natural Resources Conservation Service (NRCS), formally the SCS, peak discharge method, are described in this section.

The rational method is very simple in concept but relies on considerable judgement and experience to evaluate all factors properly. It is used primarily for small drainage areas (less than 50 acres). The NRCS method is more sophisticated hydrologically and offers a more accurate approximation of runoff, particularly for areas larger than 20 acres. Choice of method for small areas depends primarily on the experience of the designer.

Rational Method

The rational formula is:

$$Q = CIA$$

where:

Q = peak rate of runoff in cubic feet per second (cfs)
C = runoff coefficient, an empirical coefficient representing the relationship between rainfall rate and runoff rate
I = average intensity of rainfall in inches/hour, for a storm duration equal to the time of concentration, T_C
A = drainage area in acres

The general procedure for determining peak discharge using the rational formula is presented below and illustrated in Sample Problem 8.03a.

Step 1. Determine the drainage area in acres.

Step 2. Determine the runoff coefficient, C, for the type of soil/cover in the drainage area (Table 8.03b).

If the land use and soil cover is homogenous over the drainage area, a C value can be determined directly from Table 8.03b. If there are multiple soil cover conditions, a weighted average must be calculated, or the area may be subdivided.

Step 3. Determine the time of concentration, T_C, for the drainage area.

Shortcut to Time of Concentration, T_C, calculation:

As long as a watershed's area is less than 4.6S, $A_{(acres)} < 4.6\ S_{\%}$, where S is the slope in percent, the total time of concentration can be taken to be 5 minutes for bare soil. This is helpful to know because it will save the time of calculating time of concentration by other methods, including the Kinematic Wave Theory (below) which requires an iterative solution.

The Kinematic Wave Theory defines time of concentration as the "travel time of a wave to move from the hydraulically most distant point in the catchment to the outlet (Bedient and Huber, 1992)". The formula for the time of concentration for overland flow is:

$$T_C = \frac{\left[\dfrac{L}{\left(\dfrac{1.49 * S^{1/2}}{n}\right)\left(\dfrac{I_i * C}{43{,}200}\right)^{2/3}}\right]^{3/5}}{60}$$

where:

L = length of overland flow plane (feet)

S = slope (ft/ft)

n = Manning's roughness

Ii = rainfall intensity

C = rational runoff coefficient

Because both time of concentration and rainfall intensity are unknown variables in one equation, the solution must be found through iterations. The use of a spreadsheet is recommended. An example is shown in Table 8.03a.

Table 8.03a Time of Concentration

Solving for Time of Concentration (overland flow)
Kinematic Wave Theory

Length of overland flow:	100 feet
Manning's "n" surface:	0.020
Average watershed slope:	0.030 foot per foot
Rational Coefficient:	0.33

Surface Manning's "n"	
Smooth Surface:	0.011
Bare Earth:	0.020
Fallow:	0.050
Cultivated, < 20% residue:	0.060
Cultivated, > 20% residue:	0.170
Grass, short:	0.150
Grass, dense:	0.240
Grass, Bermuda:	0.410
Woods, light:	0.400
Woods, dense:	0.800

Trial Time of Duration T_r (minutes)	**Rainfall Intensity** i (inches/hour)	**Calculated Time of Concentration** T_C (minutes)
5	7.08	2.90
10	5.66	3.17
15	4.78	3.39
30	3.46	3.86
60 (1 hour)	2.25	4.58

Enter the Rainfall Intensity Values for the Corresponding Times of Duration from the Table 8.03c, Intensity Duration Frequency, or the NOAA Precipitation Frequency Data Server, http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html. Select the Trial Time of Duration that is equal to or less than the calculated Time of Concentration, or the Calculated Time of Concentration if less than 5 minutes. This is the overland flow component of the Time of Concentration.

In this example, there is no Trial Time of Duration that is less than corresponding Calculated Time of Concentration. In this case, select a Rainfall Intensity of 7.08 inches/hour and a Time of Concentration for Overland Flow of 2.90 minutes.

The above method estimates the time of concentration for **overland flow**. After short distances of 400 feet at most, sheet flow tends to concentrate in rills and then gullies of increasing proportions. Such flow is usually referred to as **shallow concentrated flow** (HEC-22, Urban Drainage Manual, FWHA). The NRCS TR-55 Manual (1986) assumed a maximum sheet flow of 300 feet, and the more recent WinTR-55 User Manual (2003) allowed no more than 100 feet of overland flow. Shallow concentrated flow is an important component in determining Time of Concentration.

Both the FWHA and NRCS procedures use similar formulas for the velocity of **shallow concentrated flow,** where...

$$V = 16.1345 * S^{1/2} \quad \text{(Unpaved)}$$

$$V = 20.3282 * S^{1/2} \quad \text{(Paved)}$$

where:

V = average velocity (ft/s), and
S = slope (ft/ft)

Flow in gullies empty into **open channels or pipes**. Cross-section geometry and roughness should be obtained for all channel reaches in the watershed. Manning's equation can be used to estimate average flow velocities in pipes and open channels as follows:

$$V = \frac{1.49}{n} (R)^{2/3} (S^{1/2})$$

where:

n = roughness coefficient
V = velocity (ft/s)
R = hydraulic radius (ft)
S = slope (ft)

For a circular pipe flowing full, the hydraulic radius is one-fourth of the diameter. For a wide rectangular channel (width > 10 * depth), the hydraulic radius is approximately equal to the depth.

The travel time for **shallow concentrated flow** and **open channels and pipes** is then calculated from the velocities of those travel segments by the following equation:

$$T_i = \frac{L}{(60 * V)}$$

where:

T_i = travel time for segment i, minutes
L = flow length for segment i, (ft)

For short flow lengths, the time of travel in open channels or pipes may not significantly add to the time of concentration. For longer flow lengths, it may be more accurate to calculate the kinematic wave speed in the open channel or pipe rather than the velocity.

The wave travel time in an open channel can be estimated by calculating the kinematic wave speed in feet per second, converting to feet per minute, and dividing the length (ft) by the average velocity. The kinematic wave speed, C, in an open channel is determined by the following equation:

$$C = V + \left[\frac{32.2\ (A)}{W_T}\right]^{1/2}$$

where:

C = wave speed (ft/s)
V = velocity (ft/s)
A = the cross-sectional area of flow (ft^2)
W_T = the top width of the channel flow (ft)

$$T_C = \frac{L}{60\ (C)}$$

where:

T_C = Time of Concentration for open channel (minutes)
L = length of channel segment (ft)
C = wave speed (ft/s)

The total time of concentration is the sum of the overland, shallow concentrated and channel flow times.

Step 4. Determine the rainfall intensity, duration and frequency. The tables provided were excerpted from the "Precipitation-Frequency Atlas of the United Sates" NOAA Atlas 14, Volume 2, Version 2, G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M. Yekta, and D. Riley, NOAA, National Weather Service, Silver Spring, Maryland, 2004. An interactive web-site that includes many more observation records across North Carolina may be used to obtain data for a more specific locale at http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html .

Step 5. Determine peak discharge, Q (cubic feet per second), by multiplying the previously determined factors using the rational formula (Sample Problem 8.03a);

$$Q = CIA$$

Table 8.03b
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, ave., 2-7%	0.10-0.15
Residential:		Sandy soil, steep, 7%	0.15-0.20
Single-family areas	0.30-0.50	Heavy soil, flat, 2%	0.13-0.17
Multi units, detached	0.40-0.60	Heavy soil, ave., 2-7%	0.18-0.22
Multi units, Attached	0.60-0.75	Heavy soil, steep, 7%	0.25-0.35
Suburban	0.25-0.40		
Industrial:		Agricultural land:	
Light areas	0.50-0.80	Bare packed soil	
Heavy areas	0.60-0.90	Smooth	0.30-0.60
Parks, cemeteries	0.10-0.25	Rough	0.20-0.50
Playgrounds	0.20-0.35	Cultivated rows	
Railroad yard areas	0.20-0.40	Heavy soil no crop	0.30-0.60
Unimproved areas	0.10-0.30	Heavy soil with crop	0.20-0.50
Streets:		Sandy soil no crop	0.20-0.40
Asphalt	0.70-0.95	Sandy soil with crop	0.10-0.25
Concrete	0.80-0.95	Pasture	
Brick	0.70-0.85	Heavy soil	0.15-0.45
Drives and walks	0.75-0.85	Sandy soil	0.05-0.25
Roofs	0.75-0.85	Woodlands	0.05-0.25

NOTE: The designer must use judgement to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

Sample Problem 8.03a Determination of Peak Runoff Rate Using the Rational Method

Q = CIA

Given:

Drainage area:	20 acres
Graded areas:	12 acres
Woodland:	8 acres
Maximum slope length:	100 ft overland flow, 300 ft shallow concentrated flow
Average slope:	3%, area bare
Location:	Raleigh, NC

Find:

Peak runoff rate from 10-year frequency storm

Solution:

(1) Drainage area: 20 acres (given)

(2) Determine runoff coefficient, C.
Calculate Weighted Average

	Area		**C from Table 8.03b**		
Graded[1]	12	x	0.45	=	5.4
Woodland	8	x	0.15	=	1.2
	20				6.6

C = 6.6/20 = 0.33

(3) Find the overland time of concentration using iterations of the kinematic wave equation (Table 8.03a) using a slope length of 100 ft for overland flow and 300 feet for shallow concentrated flow (unpaved). The average watershed slope is 3%. Assume overland flow on bare earth. Work an example with the spreadsheet (pasted in below)

NOTE: Any time of flow in shallow concentrated flow or channel flow should be added to the overland flow to determine T_C.

To find the time of flow in shallow concentrated flow, use the procedures from FWHA and NRCS described on page 8.03.4.

First, calculate the velocity of the shallow concentrated flow:

$$V = 16.1345 * S^{1/2} \quad \text{(Unpaved)}$$

$$V = 16.1345 * (0.03)^{1/2} = 2.79 \text{ ft/s}$$

The travel time for shallow concentrated flow may then be calculated for the segment by:

$$T = \frac{L}{60 * V}$$

where T = travel time, minutes

L = flow length of segmer

$$T = \frac{300}{60 * 2.79} = 1.79 \text{ minutes}$$

The total time of concentration, T_C, may be found by summing the T_C for overland flow and the travel time in shallow concentrated flow:

$T_C = T_C$ (overland) + T_C (shallow concentrated) + T_C (channel)
T_C = 2.90 minutes + 1.79 minutes
T_C = 4.7 minutes, Use 5 minutes as the minimum T_C

I = 7.08 inches/hour (from Table 8.03C) using a 10-year storm, 5 minute duration.

(4) Q = CIA
Q = 0.33*7.08*20 = 46.7cfs, Use 47 cfs.

Watershed Basin Number	
Total Drainage Area	20
Rational Method for Flow	
Subarea A (acres)	12
Subarea A Runoff Coefficient	0.45
Subarea B (acres)	8
Subarea B Runoff Coefficient	0.15
Subarea C (acres)	
Subarea C Runoff Coefficient	
Subarea D (acres)	
Subarea D Runoff Coefficient	
Weighted Runoff Coefficient	**0.33**
2-year Rainfall Intensity (IDF)	0
10-year Rainfall Intensity (IDF)	7.08
Q2 Flow	**0**
Q10 Flow	**46.7**

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RUNOFF COEFFICIENT	
LAND USE	**C**
BUSINESS:	
DOWNTOWN AREAS	0.7-0.95
NEIGHBORHOOD AREAS	0.5-0.7
RESIDENTIAL:	
SINGLE FAMILY AREAS	0.3-0.5
MULTI UNITS, DETACHED	0.4-0.6
MULTI UNITS, ATTACHED	0.6-0.75
SUBURBAN	0.25-0.4
INDUSTRIAL:	
LIGHT AREAS	0.5-0.8
HEAVY AREAS	0.6-0.9
PARKS, CEMETARIES	0.1-0.25
PLAYGROUNDS	0.2-0.35
RAILROAD YARD AREAS	0.2-0.4
UNIMPROVED AREAS	0.1-0.3
STREETS:	
ASPHALT	0.7-0.95
CONCRETE	0.8-0.95
BRICK	0.7-0.85
DRIVES AND WALKS	0.75-0.85
ROOFS	0.75-0.85
LAWNS:	
SANDY SOIL, FLAT, 2%	0.05-0.1
SANDY SOIL, AVE., 2-7%	0.1-0.15
SANDY SOIL, STEEP, 7%	0.15-0.2
HEAVY SOIL, FLAT, 2%	0.13-0.17
HEAVY SOIL, AVE., 2-7%	0.18-0.22
HEAVY SOIL, STEEP, 7%	0.25-0.35
AGRICULTURAL LAND:	
BARE PACKED SOIL	
SMOOTH	0.3-0.6
ROUGH	0.2-0.5
CULTIVATED ROWS	
HEAVY SOIL NO CROP	0.3-0.6
HEAVY SOIL WITH CROP	0.2-0.5
SANDY SOIL NO CROP	0.2-0.4
SANDY SOIL WITH CROP	0.1-0.25
PASTURE	
HEAVY SOIL	0.15-0.45
SANDY SOIL	0.05-0.25
WOODLANDS	0.05-0.25

Solving for Time of Concentration
Kinematic Wave Theory

User Data | Calculated Value

Length of overland flow	100.000	feet
Mannings "n" for surface	0.020	
Average watershed slope	0.030	ft./ft.
Constant alpha	12.904	
Constant m	1.667	
Weighted Runoff Coefficient	0.33	

Surface Mannings n	
Smooth Surface	0.011
Bare Earth	0.020
Fallow	0.050
Cultivated, <= 20% Residue	0.060
Cultivated, > 20% Residue	0.170
Grass, Short	0.150
Grass, Dense	0.240
Grass, Bermuda	0.410
Woods, Light	0.400
Woods, Dense	0.800

Trail Time of Duration		Rainfall Intensity(IDF)	Calculation of Time of Concentration
tr (minutes)		i (Inches/hour)	tc (minutes)
http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html			
5		7.08	2.90
10		5.66	3.18
15		4.78	3.40
30		3.46	3.87
60	(1 hour)	2.25	4.60
120	(2 hours)	1.33	5.67
180	(3 hours)	0.95	6.49
360	(6 hours)	0.98	6.41
720	(12 hours)	0.34	9.79
1440	(24 hours)	0.21	11.87

Enter the Rainfall Intensity Values for the Corresponding Times of Duration from the NWS hyperlink provided.
Select the smallest Trial Time of Duration that is equal to or less than the calculated Time of Concentration, or the Calculated Time of Concentration if it is less than 5 minutes. This is the overland flow component of the Time of Concentration.

Overland Flow	tc (minutes)	**2.9**

Calculate the shallow concentrated flow component of the Time of Concentration.
Calculate the channel flow component of the Time of Concentration.
Sum these three components. This is the total Time of Concentration.

Shallow Concentrated Flow	
Paved	
Flow Length	0
Slope	0.03
tc (minutes)	**0.0**
Unpaved	
Flow Length	300
Slope	0.03
tc (minutes)	**1.8**

Channel Flow	
Flow Length	0
Slope	0.03
Hydraulic Radius	1
Mannings n	0.035
tc (minutes)	**0.0**

Total Time of Concentration	**4.7**

Al Jarrett Shortcut, for Bare Soil		
Average Watershed Slope	5	%
Total Drainage Area A	10	acres
4.6*S	23	
If A<4.6*S, Assume Tc=5 minutes		

Table 8.03c Intensity Duration Frequency

For use with Rational Method**

Murphy, North Carolina 35.0961N, 84.0239W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	4.93	3.94	3.30	2.28	1.43	0.89	0.62	0.38	0.24	0.15
10	6.78	5.42	4.57	3.31	2.16	1.29	0.92	0.55	0.34	0.21
25	7.90	6.29	5.31	3.94	2.62	1.57	1.13	0.68	0.41	0.25
100	9.62	7.64	6.44	4.93	3.40	2.06	1.50	0.90	0.53	0.33

Asheville, North Carolina 35.4358N, 82.5392W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.21	4.16	3.46	2.41	1.51	0.89	0.63	0.38	0.24	0.14
10	7.06	5.65	4.76	3.45	2.25	1.30	0.91	0.55	0.34	0.20
25	8.09	6.44	5.45	4.03	2.69	1.56	1.10	0.66	0.40	0.24
100	9.68	7.69	6.48	4.96	3.42	2.00	1.43	0.86	0.50	0.30

Boone, North Carolina 36.2167N, 81.6667W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.71	4.57	3.83	2.64	1.66	1.00	0.72	0.48	0.31	0.18
10	7.50	6.00	5.06	3.67	2.39	1.46	1.06	0.69	0.44	0.28
25	8.59	6.85	5.78	4.28	2.85	1.77	1.29	0.83	0.52	0.34
100	10.38	8.25	6.95	5.32	3.67	2.35	1.72	1.08	0.65	0.44

Charlotte, North Carolina, 35.2333N, 80.85W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.68	4.54	3.80	2.63	1.65	0.96	0.68	0.41	0.24	0.14
10	7.26	5.80	4.89	3.55	2.31	1.36	0.98	0.59	0.35	0.20
25	8.02	6.38	5.40	4.00	2.66	1.59	1.15	0.70	0.42	0.24
100	9.00	7.15	6.03	4.62	3.18	1.93	1.43	0.87	0.53	0.30

Greensboro, North Carolina 36.975N, 79.9436W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	5.46	4.36	3.66	2.52	1.58	0.93	0.66	0.40	0.23	0.14
10	6.85	5.48	4.62	3.35	2.18	1.30	0.92	0.56	0.33	0.20
25	7.39	5.89	4.98	3.69	2.46	1.49	1.06	0.65	0.39	0.23
100	7.93	6.30	5.31	4.07	2.80	1.75	1.24	0.78	0.48	0.29

* ARI is the Average Return Interval.

** Intensity Duration Frequency table is measured in inches per hour.

Raleigh, North Carolina 35.8706N, 78.7864W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	5.58	4.46	3.74	2.58	1.62	0.94	0.66	0.40	0.24	0.14
10	7.08	5.66	4.78	3.46	2.25	1.33	0.95	0.58	0.34	0.021
25	7.78	6.19	5.24	3.88	2.58	1.54	1.11	0.68	0.41	0.24
100	8.64	6.86	5.78	4.43	3.05	1.85	1.36	0.84	0.51	0.30

Fayetteville, North Carolina 35.0583N, 78.8583W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.11	4.88	4.09	2.83	1.77	1.04	0.74	0.44	0.26	0.15
10	7.96	6.36	5.36	3.88	2.53	1.54	1.10	0.66	0.39	0.23
25	8.94	7.13	6.02	4.46	2.97	1.83	1.32	0.80	0.47	0.28
100	10.44	8.29	6.99	5.35	3.69	2.29	1.69	1.03	0.62	0.36

Wilmington, North Carolina 34.2683N, 77.9061W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	7.39	5.92	4.96	3.42	2.15	1.28	0.91	0.56	0.33	0.19
10	9.70	7.75	6.54	4.74	3.08	1.94	1.39	0.87	0.51	0.30
25	10.98	8.75	7.40	5.48	3.65	2.38	1.73	1.08	0.64	0.38
100	12.92	10.27	8.65	6.63	4.56	3.18	2.37	1.49	0.89	0.53

Washington, North Carolina 35.5333N, 77.0167W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.41	5.12	4.29	2.96	1.86	1.10	0.78	0.47	0.27	0.16
10	8.38	6.70	5.65	4.09	2.66	1.64	1.19	0.72	0.42	0.25
25	9.48	7.55	6.38	4.73	3.15	1.99	1.46	0.88	0.52	0.31
100	11.16	8.87	7.47	5.72	3.94	2.58	1.93	1.18	0.70	0.42

Manteo Airport, North Carolina 35.9167N, 75.7000W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	6.46	5.16	4.32	2.99	1.87	1.08	0.79	0.48	0.29	0.17
10	8.47	6.77	5.71	4.14	2.69	1.62	1.20	0.74	0.44	0.27
25	9.56	7.62	6.44	4.77	3.17	1.96	1.47	0.91	0.54	0.33
100	11.26	8.95	7.54	5.77	3.98	2.54	1.95	1.21	0.73	0.44

Cape Hatteras, North Carolina, 35.2322N, 75.6225W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	7.20	5.75	4.82	3.33	2.09	1.29	0.94	0.58	0.34	0.20
10	9.41	7.52	6.35	4.60	2.99	1.93	1.43	0.89	0.53	0.31
25	10.66	8.49	7.18	5.31	3.54	2.33	1.75	1.09	0.65	0.38
100	12.53	9.95	8.39	6.42	4.42	3.03	2.32	1.45	0.88	0.51

SCS (NRCS) Peak Discharge Method

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met. The following excerpt presents the portion of TR-55 for determining peak discharge. New rainfall data from NOAA is presented in tabular form.

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is:

Equation 8.03a

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. Ia is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, Ia was found to be approximated by the following empirical equation:

Equation 8.03b

$$I_a = 0.2S$$

By removing Ia as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 8.03b into equation 8.03a gives:

Equation 8.03c

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

Equation 8.03d

$$S = \frac{1000}{CN} - 10$$

Figure 8.03a and Table 8.03d solve equations 8.03c and 8.03d for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 8.03b is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in Tables 8.03e-8.03g represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 8.03c assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced.

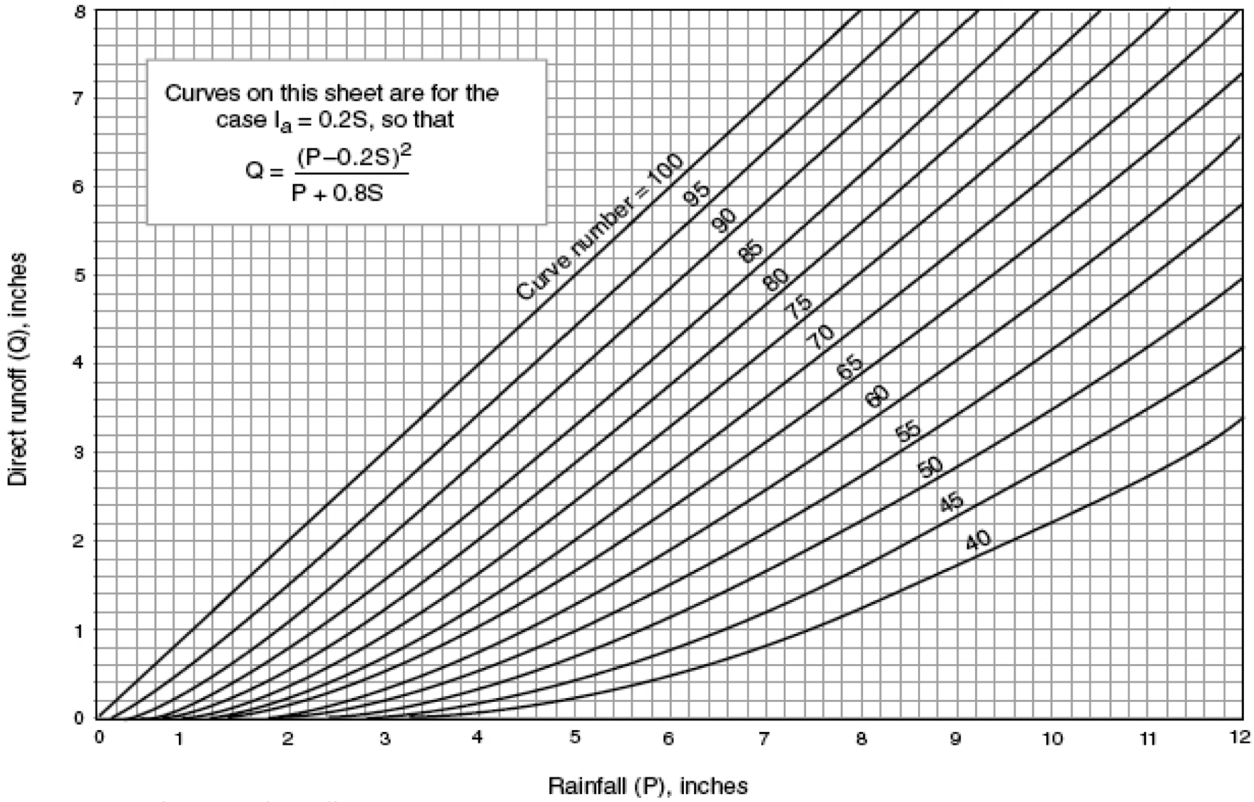


Figure 8.03a Solution of runoff equation

Cover type

Table 8.03e addresses most cover types, such as vegetation, bare soil, and impervious surfaces. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photographs, and land use maps.

Treatment

Treatment is a cover type modifier (used only in Table 8.03f) to describe the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage.

Hydrologic condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. Good hydrologic condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are (a) canopy or density of lawns, crops, or other vegetative areas; (b) amount of year-round cover; (c) amount of grass or close-seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

Table 8.03d Runoff depth for selected CN's and rainfall amounts [1]

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0.00	0.00	0.00	0.00	0.00	0.00	.03	.07	.15	.27	.46	.74	.99
1.4	0.00	0.00	0.00	0.00	0.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	0.00	0.00	0.00	0.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	0.00	0.00	0.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	0.00	0.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	0.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

1 / Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Figure 8.03b Flow chart for selecting the appropriate figure or table for determining runoff curve numbers

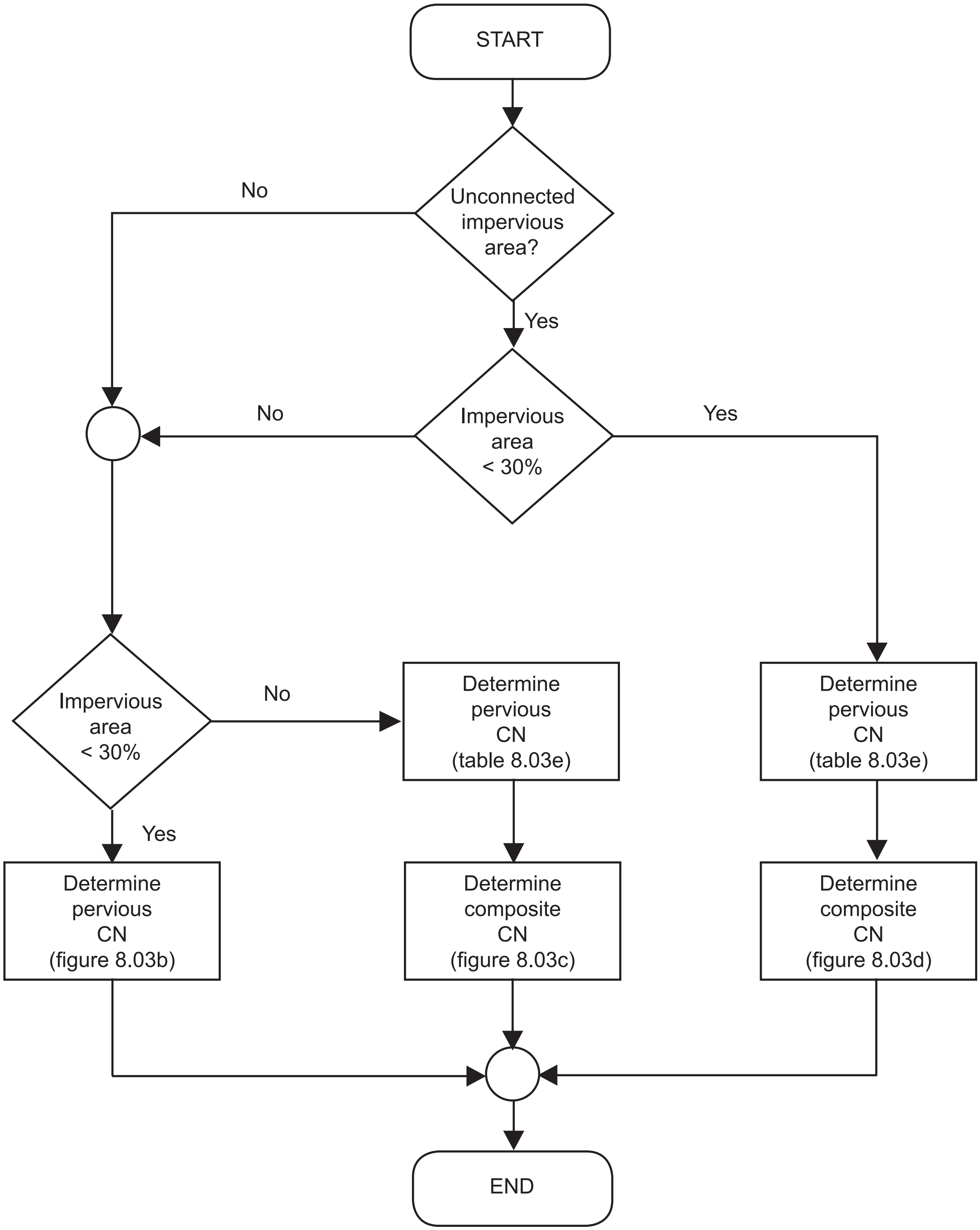


Table 8.03e Runoff curve numbers of urban areas[1]

Cover Description: Cover type and hydrologic condition	Average percent impervious area[2]	Curve number for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[4]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1. Average runoff condition, and Ia = 0.2S.
2. The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using Figure 8.03c or 8.03d.
3. CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4. Composite CN's to use for the design of temporary measures during grading and construction should be computed using Figure 8.03c or 8.03d based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 8.03f Runoff curve numbers for cultivated agriculture lands[1]						
---------------------------Cover description------------------------------			Curve numbers for --------------hydrologic soil groups-----------			
Cover type	Treatments[2]	Hydrologic conditions[3]	A	B	C	D
Fallow	Bare soil	————	77	86	91	94
Row crops	Straight row	Good	67	78	85	89
	Contoured & terraced	Good	62	71	78	81

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 8.03g Runoff curve numbers for other agriculture lands[1]

---Cover description---		Curve numbers for ---hydrologic soil groups---			
Cover type	Hydrologic conditions[3]	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN’s shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN’s for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Urban impervious area modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for urban areas (Rawls et al., 1981). For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

Connected impervious areas — An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area and then into the drainage system.

Urban CN's (Table 8.03e) were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN vales were developed on the assumptions that (a) pervious urban areas are equivalent to pasture in good hydrologic condition and (b) impervious areas have a CN of 98 and are directly connected to the drainage system. Some assumed percentages of impervious area are shown in Table 8.03e.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table 8.03e are not applicable, use Figure 8.03c to compute a composite CN. For example, Table 8.03e gives a CN of 70 for a 1/2-acre lot in HSG B, with assumed impervious area of 25 percent. However, if the lot has 20 percent impervious area and a pervious area CN of 61, the composite CN obtained from Figure 8.03c is 68. The CN difference between 70 and 68 reflects the difference in percent impervious area.

Unconnected impervious areas — Runoff from these areas is spread over a pervious area as sheet flow. To determine CN when all or part of the impervious area is not directly connected to the drainage system, (1) use Figure 8.03d if total impervious area is less than 30 percent or (2) use Figure 8.03c if the total impervious area is equal to or greater than 30 percent, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

When impervious area is less than 30 percent, obtain the composite CN by entering the right half of Figure 8.03d with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN. For example, for a 1/2-acre lot with 20 percent total impervious area (75 percent of which is unconnected) and pervious CN of 61, the composite CN from Figure 8.03d is 66. If all of the impervious area is connected, the resulting CN (from Figure 8.03c) would be 68.

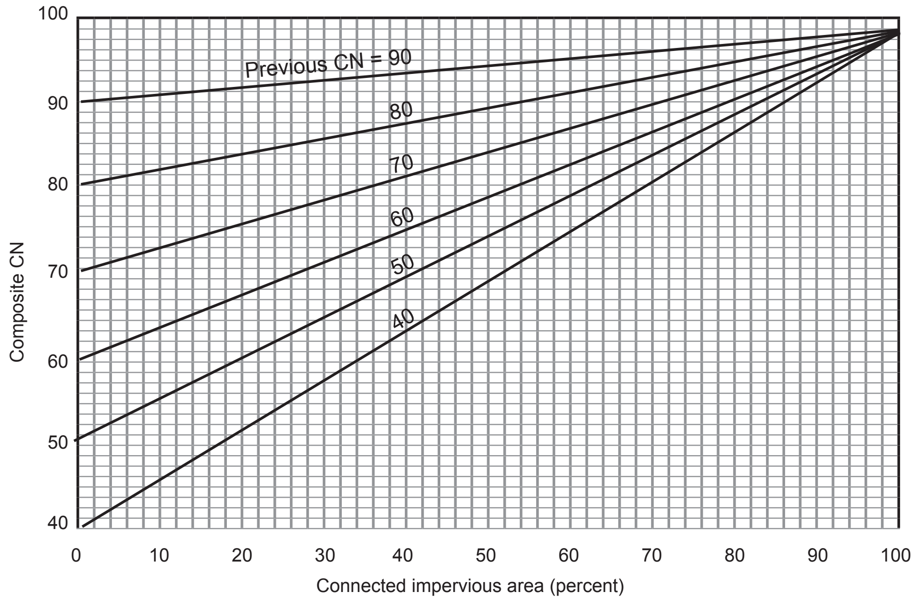


Figure 8.03c Composite CN with connected impervious area

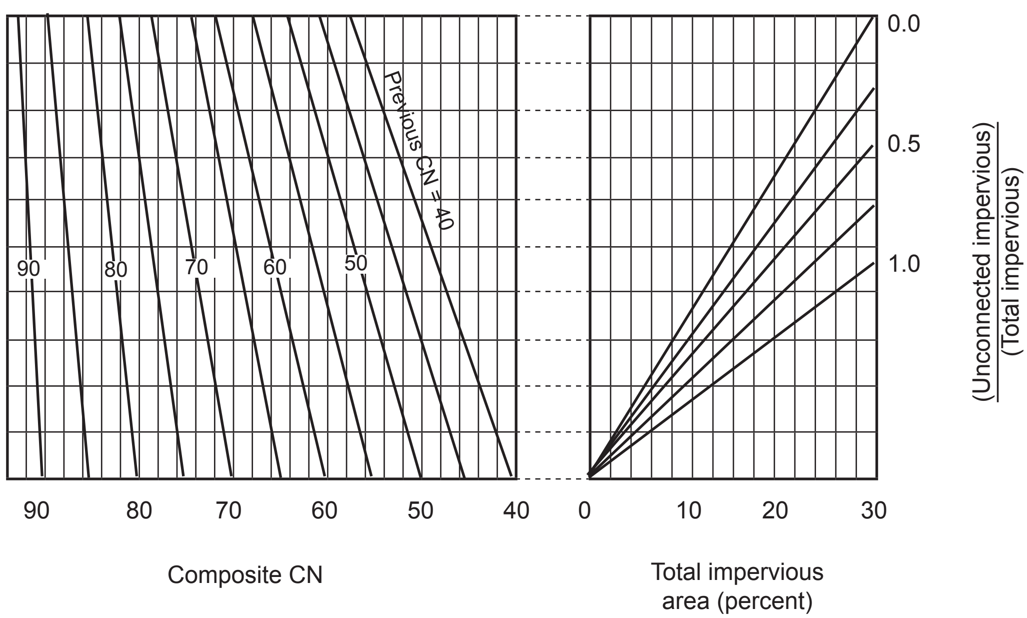


Figure 8.03d Composite CN with unconnected impervious areas and total impervious are less than 30%

Runoff

When CN and the amount of rainfall have been determined for the watershed, determine runoff depth by using Figure 8.03a, Table 8.03d, or equations 8.03c and 8.03d. The runoff is usually rounded to the nearest hundredth of an inch.

Limitations

- Curve numbers describe average conditions that are useful for design purposes. If the rainfall event used is a historical storm, the modeling accuracy decreases.
- Use the runoff curve number equation with caution when re-creating specific features of an actual storm. The equation does not contain an expression for time and, therefore, does not account for rainfall duration or intensity.
- The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place. The opposite effect, a greater initial loss, can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must redevelop equation 8.03c, Figure 8.03a, Table 8.03d, and Table 8.03e by using the original rainfall-runoff data to establish new S or CN relationships for each cover and hydrologic soil group.
- Runoff from snowmelt or rain on frozen ground cannot be estimated using these procedures.
- The CN procedure is less accurate when runoff is less than 0.5 inch. As a check, use another procedure to determine runoff.
- The SCS runoff procedures apply only to direct surface runoff: do not overlook large sources of subsurface flow or high ground water levels that contribute to runoff. These conditions are often related to HSG A soils and forest areas that have been assigned relatively low CN's in Table 8.03e. Good judgment and experience based on stream gage records are needed to adjust CN's as conditions warrant.
- When the weighted CN is less than 40, use another procedure to determine runoff.

Example 8.03a

The example below illustrates the procedure for computing runoff curve number (CN) and runoff (Q) in inches. Worksheet 2 is provided to assist TR-55 users.

The watershed covers 250 acres in Dyer County, northwestern Tennessee. Seventy percent (175 acres) is a Loring soil, which is in hydrologic soil group C. Thirty percent (75 acres) is a Memphis soil, which is in group B. The event is a 25-year frequency, 24-hour storm with total rainfall of 6 inches.

Seventy percent (175 acres) of the watershed, consisting of all the Memphis soil and 100 acres of the Loring soil, is 1/2-acre residential lots with lawns in good hydrologic condition. The rest of the watershed is scattered open space in good hydrologic condition. (See Figure 8.03e).

Figure 8.03e Worksheet 1 for example 8.03a

Worksheet 1: Runoff curve number and runoff

Project Heavenly Acres	By WJR	Date 10/1/2006
Location Dare County, North Carolina	Checked NM	Date 10/3/2006

Check one: ☐ Present ☒ Developed 175 Acres residential

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] (Table 8.03e / Figure 8.03c / Figure 8.03d)	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
Memphis, B	25% impervious 1/2 acre lots, good condition	70	75	5250
Loring, C	25% impervious 1/2 acre lots, good condition	80	100	8000
Loring, C	Open space, good condition	74	75	5550
1: Use only one CN source per line		**Totals ➡**	25	18,800

$$\text{CN (weighted)} = \frac{\text{total product}}{\text{total area}} = \frac{18,800}{2500} = 75.2$$

Use CN ➡ 75

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	25		
Rainfall, P (24-hr) .... in	6.0		
Runoff, Q .... in	3.28		

(Use P and CN with table 8.03d, figure 8.03a, or equations 8.03c and 8.03d)

Worksheet 1: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] Table 8.03e	CN [1] Figure 8.03c	CN [1] Figure 8.03d	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
1: Use only one CN source per line		**Totals ➡**				

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ______ = **Use CN ➡** ☐

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr			
Rainfall, P (24-hr) .... in			
Runoff, Q .... in			

(Use P and CN with table 8.03d, figure 8.03a, or equations 8.03c and 8.03d)

Time of Concentration and Travel Time

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors affecting time of concentration and travel time

Surface roughness

One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel shape and flow patterns

In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope

Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of travel time and time of concentration

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

Equation 8.03e

$$T_t = \frac{L}{3600V}$$

where:

T_t = Travel time (hr)
L = flow length (ft)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments:

Equation 8.03f

$$T_c = T_{t_1} + T_{t_2} + \ldots T_{t_m}$$

where:

T_c = time of concentration (hr)
m = number of flow segments

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 8.03h gives Manning's n values for sheet flow for various surface conditions.

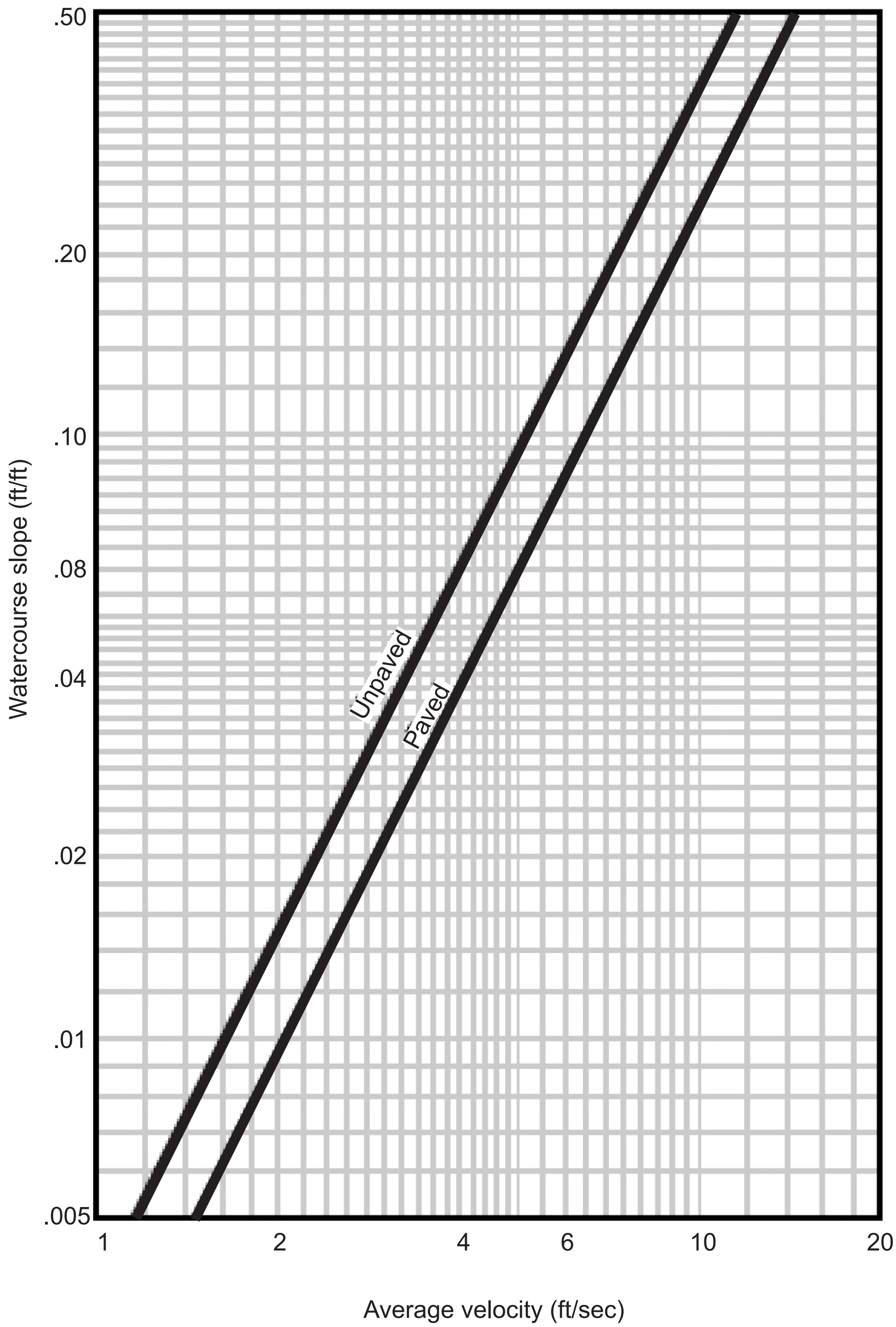


Figure 8.03f Average velocities for estimating travel time for shallow concentrated flow

Table 8.03h Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surface (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairies	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (nutral)	0.13
Woods: [3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

Equation 8.03g

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}s^{0.4}}$$

where:

T_t = Travel time (hr)
n = Manning's roughness coefficient (Table 8.03h)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure 8.03f, in which average velocity is a function of watercourse slope and type of channel. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in Figure 8.03f, use equation 8.03e to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation.

Manning's equation is:

Equation 8.03h

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$$

where:

V = average velocity (ft/s)
r = hydralic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of hydraulic grade line (land slope, ft/ft)
n = Manning's roughness coefficient for open channel flow

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 8.03h, T_t for the channel segment can be estimated using equation 8.03e.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 8.03g was developed for use with the four standard rainfall intensity-duration relationships.
- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.

- The minimum T_c used in TR-55 is 0.1 hour.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

Example 8.03b

The sketch below shows a watershed in Dyer County, northwestern Tennessee. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft; and length (L) = 100 ft. Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1,400 ft. Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (p_w) = 28.2 ft; s = 0.005 ft/ft; and L = 7,300 ft.

See Figure 8.03h for the computations made on worksheet 2.

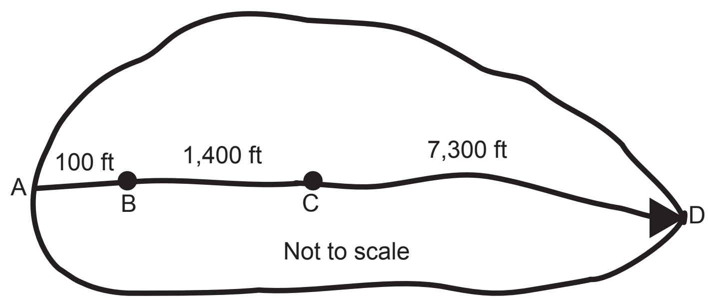


Figure 8.03g

Figure 8.03h Worksheet 2 for example 8.03b

Worksheet 2: Time of Concentration (T_c) or travel time (T_t)

Project Heavenly Acres	By DW	Date 10/6/2006
Location Dare County, North Carolina	Checked NM	Date 10/8/2006

Check one: [ ] Present [X] Developed

Check one: [X] T_c [ ] T_t through subarea

Note: Space for as many as two segments per flow can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Segment ID: AB			
1. Surface description (table 8.03h)	Dense Grass			
2. Manning's roughness coefficient, n (table 8.03h)	0.24			
3. Flow length, L (total L + 300ft) ...ft	100			
4. Two-year 24-hour rainfall, P_2 ...in	3.6			
5. Land slope, s ...ft/ft	0.01			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t ...hr	0.30	+		= 0.30

Shallow concentrated flow

	Segment ID: BC			
7. Surface description (paved or unpaved)	Unpaved			
8. Flow length, L ...ft	1400			
9. Watercourse slope, s ...ft/ft	0.01			
10. Average velocity, V (figure 3-1) ...ft/s	1.6			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ...hr	0.24	+		= 0.24

Channel flow

	Segment ID: CD			
12. Cross sectional flow area, a ...ft^2	27			
13. Wetted perimeter, P_w ...ft	28.2			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ...ft	0.957			
15. Channel slope, s ...ft/ft	0.005			
16. Manning's roughness coeficient, n	0.05			
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V ...ft/s	2.05			
18. Flow length, L ...ft	7300			
19. $T_t = \frac{L}{3600V}$ Compute T_t ...hr	0.99	+		= 0.99
20. Watershed or subarea or (add in step 6,11, and 19) ...Hr				1.53

Worksheet 2: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

Note: Space for as many as two segments per flow can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID:			
1. Surface description (table 8.03h)			
2. Manning's roughness coefficient, n (table 8.03h)			
3. Flow length, L (total L + 300ft) ... ft			
4. Two-year 24-hour rainfall, P_2 ... in			
5. Land slope, s ... ft/ft			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t ... hr		+	=

Shallow concentrated flow

Segment ID:			
7. Surface description (paved or unpaved)			
8. Flow length, L ... ft			
9. Watercourse slope, s ... ft/ft			
10. Average velocity, V (figure 3-1) ... ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr		+	=

Channel flow

Segment ID:			
12. Cross sectional flow area, a ... ft^2			
13. Wetted perimeter, P_w ... ft			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ... ft			
15. Channel slope, s ... ft/ft			
16. Manning's roughness coeficient, n ...			
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V ... ft/s			
18. Flow length, L ... ft			
19. $T_t = \frac{L}{3600V}$ Compute T_t ... hr		+	=
20. Watershed or subarea or (add in step 6,11, and 19) ... Hr			

Graphical Peak Discharge Method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is:

Equation 8.03i

$$q_p = q_u A_m Q F_p$$

where:

q_p = peak discharge (cfs)
q_u = unit peak discharge (csm/in)
A_m = discharge area (mi^2)
Q = runoff
F_p = pond and swamp adjustment factor

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi^2), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from Tables 8.03i. The CN is used to determine the initial abstraction (I_a) from Table 8.03h. I_a / P is then computed.

If the computed I_a / P ratio is outside the range in Figure 8.03k and 8.03l for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 8.03i illustrates the sensitivity of I_a / P to CN and P.

Peak discharge per square mile per inch of runoff (qu) is obtained from Figure 8.03k and 8.03l by using T_c, rainfall distribution type, and I_a / P ratio. The pond and swamp adjustment factor is obtained from Table 8.03j (rounded to the nearest table value). Use Worksheet 3 to aid in computing the peak discharge using the Graphical method.

Figure 8.03i Variation of I_a / P for P and CN

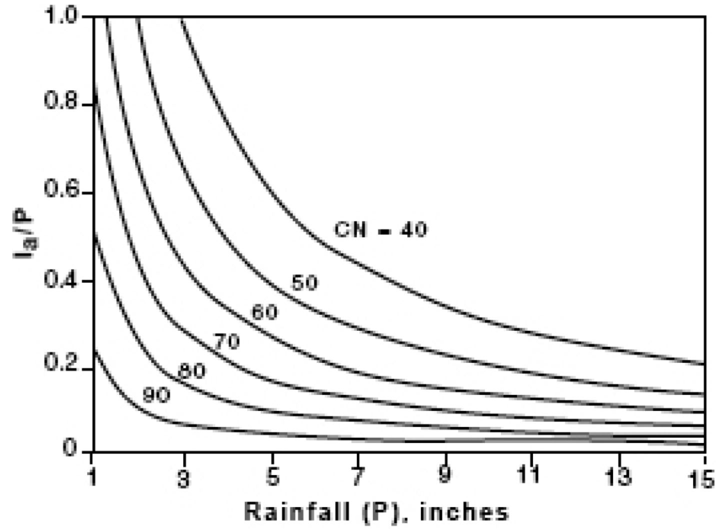


Table 8.03i I_a values for runoff curve number

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Table 8.03j Precipitation Frequency Estimates

For use with NRCS Method**

Murphy, North Carolina 35.0961N, 84.0239W										
ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.41	0.66	0.83	1.14	1.43	1.71	1.85	2.29	2.90	3.48
10	0.56	0.90	1.14	1.66	2.16	2.57	2.76	3.32	4.14	6.08
25	0.66	1.05	1.33	1.97	2.62	3.14	3.38	4.05	4.95	6.08
100	0.80	1.27	1.61	2.47	3.40	4.13	4.50	5.38	6.33	7.93

Asheville, North Carolina 35.4358N, 82.5392W										
ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.43	0.69	0.87	1.21	1.51	1.77	1.88	2.30	2.91	3.47
10	0.59	0.94	1.19	1.72	2.25	2.60	2.74	3.29	4.10	4.91
25	0.67	1.07	1.36	2.02	2.69	3.13	3.31	3.96	4.83	5.79
100	0.81	1.28	1.62	2.48	3.42	4.00	4.29	5.12	6.04	7.24

Boone, North Carolina 36.2167N, 81.6667W										
ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.48	0.76	0.96	1.32	1.66	2.00	2.18	2.85	3.77	4.39
10	0.62	1.00	1.26	1.83	2.39	2.92	3.18	4.10	5.28	6.61
25	0.72	1.14	1.45	2.14	2.85	3.55	3.87	4.94	6.21	8.07
100	0.86	1.38	1.74	2.66	3.67	4.69	5.15	6.47	7.82	10.65

Charlotte, North Carolina, 35.2333N, 80.85W										
ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.47	0.76	0.95	1.31	1.65	1.92	2.04	2.46	2.91	3.37
10	0.60	0.97	1.22	1.77	2.31	2.72	2.93	3.55	4.23	4.90
25	0.67	1.06	1.35	2.00	2.66	3.17	3.46	4.19	5.04	5.82
100	0.75	1.19	1.51	2.31	3.18	3.85	4.29	5.22	6.36	7.30

Greensboro, North Carolina 36.975N, 79.9436W										
ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.46	0.73	0.91	1.26	1.58	1.85	1.98	2.36	2.81	3.31
10	0.57	0.91	1.16	1.68	2.18	2.60	2.77	3.37	4.02	4.76
25	0.62	0.98	1.25	1.84	2.46	2.98	3.17	3.90	4.71	5.26
100	0.66	1.05	1.33	2.03	2.80	3.46	3.72	4.68	5.81	7.00

* ARI is the Average Return Interval.

**Precipitation Frequency Estimates are measured in inches.

Raleigh, North Carolina 35.8706N, 78.7864W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.47	0.74	0.94	1.29	1.62	1.88	1.99	2.42	2.87	3.42
10	0.59	0.94	1.19	1.73	2.25	2.66	2.85	3.46	4.14	4.93
25	0.65	1.03	1.31	1.94	2.58	3.08	3.34	4.06	4.90	5.83
100	0.72	1.14	1.45	2.21	3.05	3.69	4.10	5.01	6.13	7.25

Fayetteville, North Carolina 35.0583N, 78.8583W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.51	0.81	1.02	1.41	1.77	2.08	2.21	2.64	3.11	3.66
10	0.66	1.06	1.34	1.94	2.53	3.08	3.30	3.96	4.71	5.55
25	0.74	1.19	1.51	2.23	2.97	3.66	3.98	4.77	5.72	6.74
100	0.87	1.38	1.75	2.67	3.69	4.59	5.09	6.14	7.45	8.73

Wilmington, North Carolina 34.2683N, 77.9061W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.62	0.99	1.24	1.71	2.15	2.56	2.73	3.38	3.96	4.66
10	0.81	1.29	1.63	2.37	3.08	3.87	4.18	5.20	6.15	7.24
25	0.92	1.46	1.85	2.74	3.65	4.75	5.20	6.49	7.73	9.10
100	1.08	1.71	2.16	3.31	4.56	6.37	7.13	8.93	10.78	12.64

Washington, North Carolina 35.5333N, 77.0167W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.53	0.85	1.07	1.48	1.86	2.20	2.36	2.82	3.30	3.89
10	0.70	1.12	1.41	2.05	2.66	3.29	3.57	4.29	5.07	5.99
25	0.79	1.26	1.60	2.36	3.15	3.98	4.37	5.27	6.28	7.41
100	0.93	1.48	1.87	2.86	3.94	5.17	5.80	7.04	8.49	9.96

Manteo Airport, North Carolina 35.9167N, 75.7000W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.54	0.86	1.08	1.49	1.87	2.17	2.38	2.90	3.45	4.15
10	0.71	1.13	1.43	2.07	2.69	3.25	3.61	4.42	5.29	6.38
25	0.80	1.27	1.61	2.38	3.17	3.92	4.42	5.43	6.55	7.89
100	0.94	1.49	1.89	2.89	3.98	5.08	5.85	7.23	8.85	10.62

Cape Hatteras, North Carolina, 35.2322N, 75.6225W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.60	0.96	1.21	1.67	2.09	2.58	2.83	3.49	4.14	4.77
10	0.78	1.25	1.59	2.30	2.99	3.86	4.29	5.30	6.35	7.34
25	0.89	1.42	1.79	2.66	3.54	4.67	5.26	6.52	7.86	9.08
100	1.04	1.66	2.10	3.21	4.42	6.06	6.97	8.69	10.62	12.21

Table 8.03k Adjustment factor (F_p) for pond and swamp areas that are spread throughout the watershed

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Limitations

The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method. Use TR-20 if the watershed is very complex or a higher degree of accuracy is required.

- The watershed must be hydrologically homogeneous, that is, describable by one CN. Land use, soils, and cover are distributed uniformly throughout the watershed.
- The watershed may have only one main stream or, if more than one, the branches must have nearly equal T_c' s.
- The method cannot perform valley or reservoir routing.
- The F_p factor can be applied only for ponds or swamps that are not in the T_c flow path.
- Accuracy of peak discharge estimated by this method will be reduced if I_a / P values are used that are outside the range given in Figure 8.03k. The limiting I_a / P values are recommended for use.
- This method should be used only if the weighted CN is greater than 40.
- When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure for estimating T_c.
- T_c values with this method may range from 0.1 to 10 hours.

Example 8.03c

Compute the 25-year peak discharge for the 250-acre watershed described in examples 8.03a and 8.03b. Example 8.03c shows how Worksheet 3 is used to compute q_p as 345 cfs.

Figure 8.03j Worksheet 3 for example 8.03c

Worksheet 3: Graphical Peak Discharge Method

Project Heavenly Acres	By RHM	Date 10/15/06
Location Dare County, NC	Checked NM	Date 10/17/06

Check one: ☐ Present ☒ Developed

1. Data

Drainage area .... A_m = 0.39 mi^2 (acres/640)

Runoff curve number .... CN = 75 (From worksheet 1)

Time of concentration .... T_c = 1.53 hr (from worksheet 2)

Rainfall disturbance .... = II (I, IA, II, III)

Pond and swamp areas sprea throughout watershed .... = — — percent of Am (— — acres or mi^2 covered)

	Storm #1	Storm #2	Storm #3
2. Frequency ....yr	25		
3. Rainfall, P (24-hour) ....in	6.0		
4. Initial abstraction, I_a ....in (Use CN with table 8.03h)	0.667		
5. Compute I_a/P	0.11		
6. Unit peak discharge, q_u ....csm/in (Use T_c and I_a/P with figure 8.03k)	270		
7. Runoff, Q ....in (From worksheet 1) Figure 8.03e	3.28		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 8.03j. Factor is 1.0 for zero percent pond and swamp area.)	1.0		
9. Peak discharge, q_p ....ft^3/s (Where $q_p = q_u A_m Q F_p$)	345		

Worksheet 3: Graphical Peak Discharge Method

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Data

Drainage area .... A_m = ________________ mi^2 (acres/640)

Runoff curve number .... CN = __________________ (From worksheet 1)

Time of concentration .... T_c = ___________________ hr (from worksheet 2)

Rainfall disturbance .... = _____________________ (I, IA, II, III)

Pond and swamp areas sprea throughout watershed .... = _______________ percent of Am (______acres or mi^2 covered)

	Storm #1	Storm #2	Storm #3
2. Frequency ....yr			
3. Rainfall, P (24-hour) ....in			
4. Initial abstraction, I_a ....in (Use CN with table 8.03h)			
5. Compute I_a/P			
6. Unit peak discharge, q_u ....csm/in (Use T_c and I_a/P with figure 8.03k)			
7. Runoff, Q ....in (From worksheet 1) Figure 8.03e			
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 8.03j. Factor is 1.0 for zero percent pond and swamp area.)			
9. Peak discharge, q_p ....ft^3/s (Where $q_p = q_u A_m Q F_p$)			

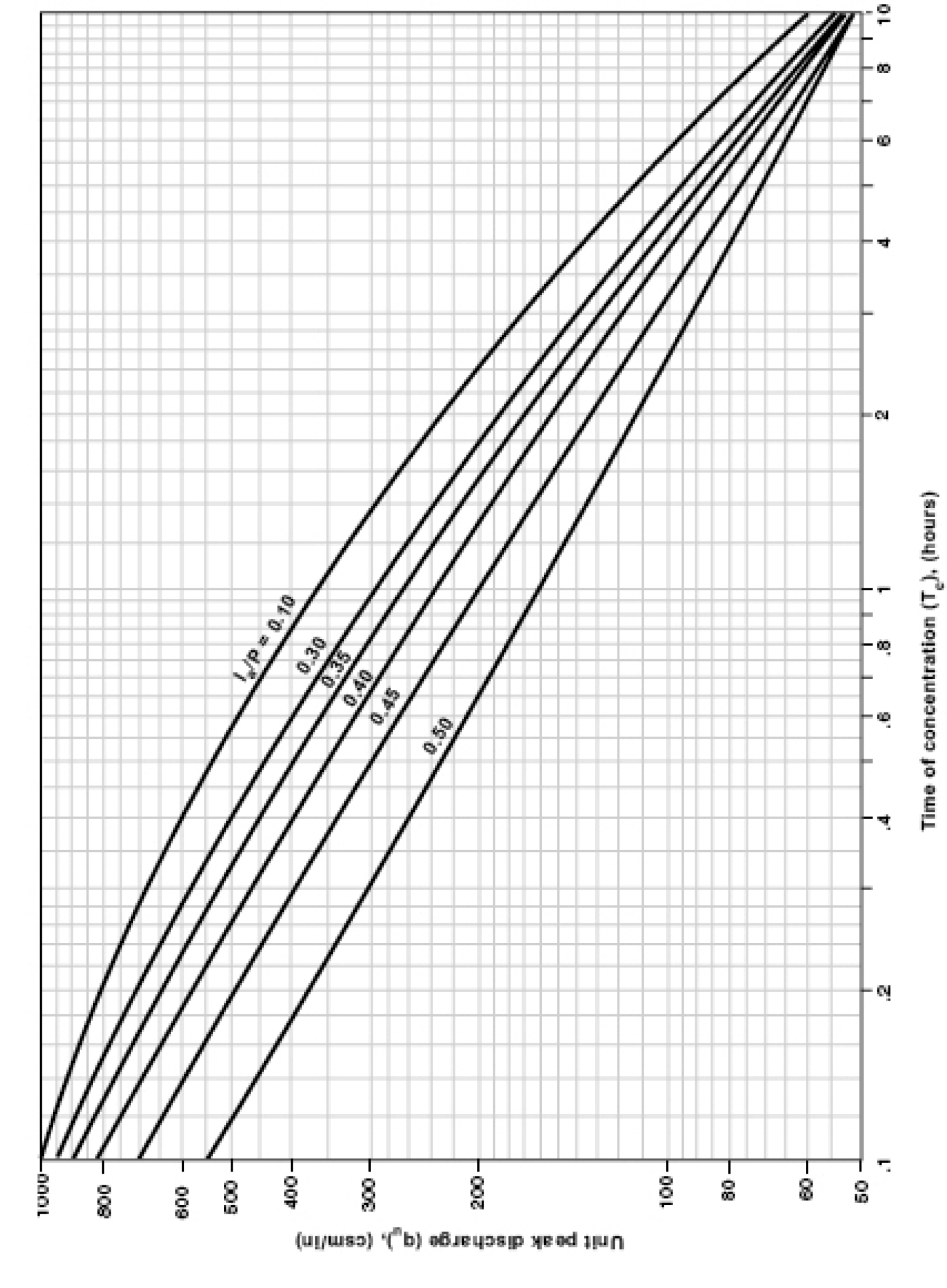


Figure 8.03k Unit peak discharge (q_u) for NRCS (SCS) type II rainfall distribution for NC except lower coastal plain.

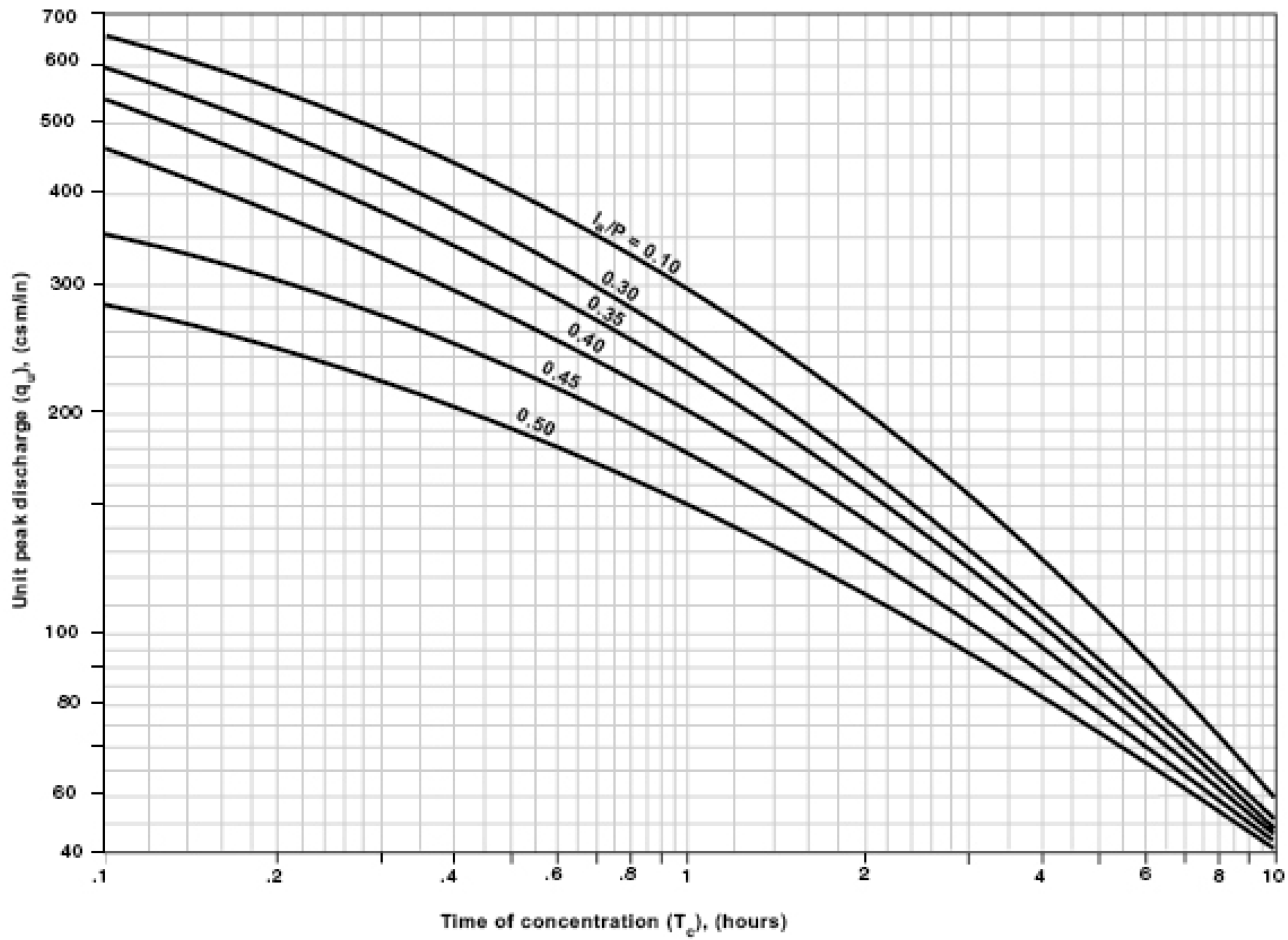


Figure 8.03l Unit peak discharge (q_u) for NRCS (SCS) type III rainfall distribution for lower coastal plain of North Carolina

8.04

ESTIMATING ROUGHNESS COEFFICIENTS

This section describes a method for estimating the roughness coefficient *n* for use in hydraulic computations associated with natural streams, floodways, and excavated channels. The procedure applies to the estimation of *n* in Manning's formula (*Appendix 8.05*).

The coefficient of roughness *n* quantifies retardation of flow due to roughness of channel sides, bottom, and irregularities.

Estimation of *n* requires the application of subjective judgement to evaluate five primary factors:

- irregularity of the surfaces of the channel sides and bottom;
- variations in the shape and size of the channel cross sections;
- obstructions in the channel;
- vegetation in the channel; and
- meandering of the channel.

Procedure For Estimating *n*

The procedure for estimating *n* involves selecting a basic value for a straight, uniform, smooth channel in the existing soil materials, then modifying that value with each of the five primary factors listed above.

In selecting modifying values, it is important that each factor be examined and considered independently.

Step 1. Selection of basic value of *n*. Select a basic *n* value for a straight, uniform, smooth channel in the natural materials involved. The conditions of straight alignment, uniform cross section, and smooth side and bottom surfaces without vegetation should be kept in mind. Thus, basic *n* varies only with the material than forms the sides and bottom of the channel. Select the basic *n* for natural or excavated channels from Table 8.04a. If the bottom and sides of a channel consist of different materials, select an intermediate value.

Table 8.04a
Basic Value of Roughness Coefficient for Channel Materials

Soil Material	Basic *n*
Channels in earth	0.02
Channels in fine gravel	0.024
Channels cut into rock	0.025
Channels in coarse gravel	0.028

Step 2. Selection of modifying value for surface irregularity. This factor is based on the degree of roughness or irregularity of the surfaces of channel sides and bottom. Consider the actual surface irregularity, first in relation to the degree of surface smoothness obtainable with the natural materials involved, and second in relation to the depths of flow expected. If the surface irregularity is comparable to the best surface possible for the channel materials, assign a modifying value of zero. Irregularity induces turbulence that calls for increased modifying values. Table 8.04b may be used as a guide to selection of these modifying values.

Table 8.04b Modifying Value for Roughness Coefficient Due to Surface Irregularity of Channels

Degree of Irregularity	Surface Comparable	Modifying Value
Smooth	The best obtainable for the materials	0.000
Minor	Well-dredged channels; slightly eroded or scoured side slope of canals or drainage channels	0.005
Moderate	Fair to poorly dredged channels; moderately sloughed or eroded side slopes of canals or drainage channels	0.010
Severe	Badly sloughed banks of natural channels; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged and irregular surfaces of channels excavated in rock	0.020

Source for Tables b - f: Estimating Hydraulic Roughness Coefficients

Step 3. Selection of modifying value for variations in the shape and size of cross sections. In considering this factor, judge the approximate magnitude of increase and decrease in successive cross sections as compared to the average. Gradual and uniform changes do not cause significant turbulence. Turbulence increases with the frequency and abruptness of alternation from large to small channel sections.

Shape changes causing the greatest turbulence are those for which flow shifts from side to side in the channel. Select modifying values based on Table 8.04c.

Step 4. Selection of modifying value for obstructions. This factor is based on the presence and characteristics of obstructions such as debris deposits, stumps, exposed roots, boulders, and fallen and lodged logs. Take care that conditions considered in other steps not be double-counted in this step.

In judging the relative effect of obstructions, consider the degree to which the obstructions reduce the average cross-sectional area at various depths and the characteristics of the obstructions. Sharp-edged or angular objects induce more turbulence than curved, smooth-surfaced objects. Also consider the

Table 8.04c Modifying Value for Roughness Coefficient Due to Variations of Channel Cross Section

Character of Variation	Modifying Value
Changes in size or shape occurring gradually	0.000
Large and small sections alternating occasionally, or shape changes causing occasional shift of main flow from side to side	0.005
Large and small sections alternating frequently, or shape changes causing frequent shift of main flow from side to side	0.010 - 0.015

transverse and longitudinal position and spacing of obstructions in the reach. Select modifying values based on Table 8.04d.

Step 5. Selection of modifying value for vegetation. The retarding effect of vegetation is due primarily to turbulence induced as the water flows around and between limbs, stems, and foliage and secondarily to reduction in cross section. As depth and velocity increase, the force of flowing water tends to bend the vegetation. Therefore, the ability of vegetation to cause turbulence is related to its resistance to bending. Note that the amount and characteristics of foliage vary seasonally. In judging the retarding effect of vegetation, consider the following: height of vegetation in relation to depth of flow, its resistance to bending, the degree to which the cross section is occupied or blocked, and the transverse and longitudinal distribution of densities and heights of vegetation in the reach. Use Table 8.04e as a guide.

Step 6. Computation of n_s for the reach. The first estimate of roughness for the reach, n_s, is obtained by neglecting meandering and adding the basic n value obtained in step 1 and modifying values from steps 2 through 5.

$$n_s = n + \Sigma \text{ modifying values}$$

Step 7. Meander. The modifying value for meandering is not independent of the other modifying values. It is estimated from the n_s obtained in step 6, and the ratio of the meandering length to the straight length. The modifying value for meandering may be selected from Table 8.04f.

Step 8. Computation of *n* for a channel reach with meandering. Add the modifying value obtained in step 7, to n_s, obtained in step 6.

The procedure for estimating roughness for an existing channel is illustrated in Sample Problem 8.04a.

Out-of-Bank Condition Channel And Flood Plain Flow

Work with natural floodways and streams often requires consideration of a wide range of discharges. At higher stages, both channel and overbank or flood plain flow may occur. Usually, the retardance of the flood plain differs significantly from that of the channel, and the hydraulic computations can be improved by subdividing the cross section and assigning different n values for flow in the channel and the flood plain. If conditions warrant, the flood plain may be subdivided further. **Do not average channel *n* with flood plain *n*.** The n value for in-bank and out-of-bank flow in the channel may be averaged.

Table 8.04d Modifying Value for Roughness Coefficient Due to Obstructions in the Channel

Relative Effect of Obstructions	Modifying Value
Negligible	0.000
Minor	0.010 to 0.015
Appreciable	0.020 to 0.0.30
Severe	0.040 to 0.060

Table 8.04e Modifying Value for Roughness Coefficient Due to Vegetation in the Channel

Vegetation and Flow Conditions Comparable to:	Range in Modifying Value
Low Effect	
Dense growths of flexible turf grass or weeds, such as Bermudagrass and Kentucky bluegrass. Average depth of flow is 2 to 3 times the height of the vegetation	0.005 to 0.010
Medium Effect	
Turf grasses where the average depth of flow is 1 to 2 times the height of vegetation	0.010 to 0.025
Stemmy grasses, weeds or tree seedlings with moderate cover where the average depth of flow is 2 to 3 times the height of vegetation	
Brushy growths, moderately dense, similar to willows 1 to 2 years old, dormant season, along side slopes of channel with no significant vegetation along the channel bottom, where the hydraulic radius is greater than 2 feet	
High Effect	
Grasses where the average depth of flow is about equal to the height of vegetation	0.025 to 0.050
Dormant season, willow or cottonwood trees 8 - 10 years old, intergrown with some weeds and brush; hydraulic radius 2 to 4 feet	
1-year old, intergrown with some weeds in full foliage along side slopes; no significant vegetation along channel bottom; hydraulic radius 2 to 4 feet	
Grasses where average depth of flow is less than one-half the height of vegetation	
Very High Effect	
Growing season, bushy willows about 1-year old, intergrown with weeds in full foliage along side slopes; dense growth of cattails or similar rooted vegetation along channel bottom; hydraulic radius greater than 4 feet	0.050 to 0.100
Growing season, trees intergrown with weeds and brush, all in full foliage; hydraulic radius greater than 4 feet	

Table 8.04f Modifying Value for Roughness Coefficient Due to Meander in the Channel

Meander Ratio[1]	Degree of Meandering	Modifying Value
0.0 to 1.2	Minor	0.000
1.2 to 1.5	Appreciable	0.15 n_s
1.5 and greater	Severe	0.30 n_s

[1]Meander ratio is the total length of reach divided by the straight line distance.

To compute a roughness coefficient for flood plain flow, consider all factors except meandering. Flood plain *n* values normally are greater than channel values, primarily due to shallower depths of flow. The two factors requiring most careful consideration in the flood plain are obstructions and vegetation. Many flood plains have fairly dense networks of obstructions to be evaluated. Vegetation should be judged on the basis of growing-season conditions.

Sample Problem 8.04a Estimation of roughness coefficient for an existing channel

Description of reach:

Soil—Natural channel with lower part of banks and bottom yellowish gray clay, upper part light gray silty clay.

Side slopes—Fairly regular; bottom uneven and irregular.

Cross section—Very little variation in the shape; moderate, gradual variation is size. Average cross section approximately trapezoidal with side slopes about 1.5:1 and bottom width about 10 feet. At bankfull stage, the average depth is about 8.5 feet and the average top width is about 35 feet.

Vegetation—Side slopes covered with heavy growth of poplar trees, 2 to 3 inches in diameter, large willows, and climbing vines; thick, bottom growth of waterweed; summer condition with the vegetation in full foliage.

Alignment—Significant meandering; total length of meandering channel, 1120 feet; straight line distance, 800 feet.

Solution:

Step Number	Description	*n* Values
1	Soil materials indicate minimum basic *n*	0.02
	Modification for:	
2	Moderately irregular surface	0.01
3	Changes in size and shape judged insignificant	0.00
4	No obstructions indicated	0.00
5	Dense vegetation	<u>0.08</u>
6	Straight channel subtotal, n_s =	0.11
7	Meandering appreciable, meandering ratio: 1120/800 = 1.4 Select 0.15 from Table 8.04f	
8	Modified value = (0.15)(0.11) = 0.0165 or	<u>0.02</u>
	Total roughness coefficient *n* =	0.13

8.05

DESIGN OF STABLE CHANNELS AND DIVERSIONS

This section addresses the design of stable conveyance channels and diversions using flexible linings. A stable channel is defined as a channel which is nonsilting and nonscouring. To minimize silting in the channel, flow velocities should remain constant or increase slightly throughout the channel length. This is especially important in designing diversion channels and can be accomplished by adjusting channel grade. Procedures presented in this section address the problems of erosion and scour. More advanced procedures for permanent, unlined channels may be found elsewhere. (References: Garde and Ranga Raju, 1980)

Diversions are channels usually with a supporting ridge on the lower side. They are generally located to divert flows across a slope and are designed following the same procedures as other channels. Design tables for vegetated diversions and waterways are included at the end of this section.

Flexible channel linings are generally preferred to rigid linings from an erosion control standpoint because they conform to changes in channel shape without failure and are less susceptible to damage from frost heaving, soil swelling and shrinking, and excessive soil pore water pressure from lack of drainage. Flexible linings also are generally less expensive to construct, and when vegetated, are more natural in appearance. On the other hand, flexible linings generally have higher roughness and require a larger cross section for the same discharge.

EROSION CONTROL CRITERIA

The minimum design criteria for conveyance channels require that two primary conditions be satisfied: the channel system must have capacity for the peak flow expected from the 10-year storm and the channel lining must be resistant to erosion for the design velocity. In some cases, out-of-bank flow may be considered a functional part of the channel system. In these cases, flow capacities and design velocities should be considered separately for out-of-bank flows and channel flows.

Both the capacity of the channel and the velocity of flow are functions of the channel lining, cross-sectional area and slope. The channel system must carry the design flow, fit site conditions, and be stable.

STABLE CHANNEL DESIGN METHODS

Two accepted procedures for designing stable channels with flexible linings are: (1) the permissible velocity approach; and (2) the tractive force approach. Under the permissible velocity approach, the channel is considered stable if the design, mean velocity is lower than the maximum permissible velocity. Under the tractive force approach, erosive stress evaluated at the boundary between flowing water and lining materials must be less than the minimum unit tractive force that will cause serious erosion of material from a level channel bed.

The permissible velocity procedure is recommended for the design of vegetative channels because of common usage and the availability of reliable design tables. The tractive force approach is recommended for design of channels with temporary synthetic liners or riprap liners. The tractive force procedure is described in full in the U.S. Department of Transportation, Federal Highway Administration Bulletin, *Design of Roadside Channels with Flexible Linings*.

Permissible Velocity Procedure

The permissible velocity procedure uses two equations to calculate flow:

Manning's equation,

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

where:

V	=	average velocity in the channel in ft/sec.
n	=	Manning's roughness coefficient, based upon the lining of the channel
R	=	hydraulic radius, wetted cross-sectional area/wetted perimeter in ft
S	=	slope of the channel in ft/ft

and the continuity equation,

$$Q = AV$$

where:

Q	=	flow in the channel in cfs
A	=	cross-sectional area of flow within the channel in ft^2
V	=	average velocity in the channel in ft/sec.

Manning's equation and the continuity equation are used together to determine channel capacity and flow velocity. A nomograph for solving Manning's equation is given in Figure 8.05a.

Selecting Permanent Channel Lining

Channel lining materials include such flexible materials as grass, riprap and gabions, as well as rigid materials such as paving blocks, flag stone, gunite, asphalt, and concrete. The design of concrete and similar rigid linings is generally not restricted by flow velocities. However, flexible channel linings do have maximum permissible flow velocities beyond which they are susceptible to erosion. The designer should select the type of liner that best fits site conditions.

Table 8.05a lists maximum permissible velocities for established grass linings and soil conditions. Before grass is established, permissible velocity is determined by the choice of temporary liner. Permissible velocities for riprap linings are higher than for grass and depend on the stone size selected.

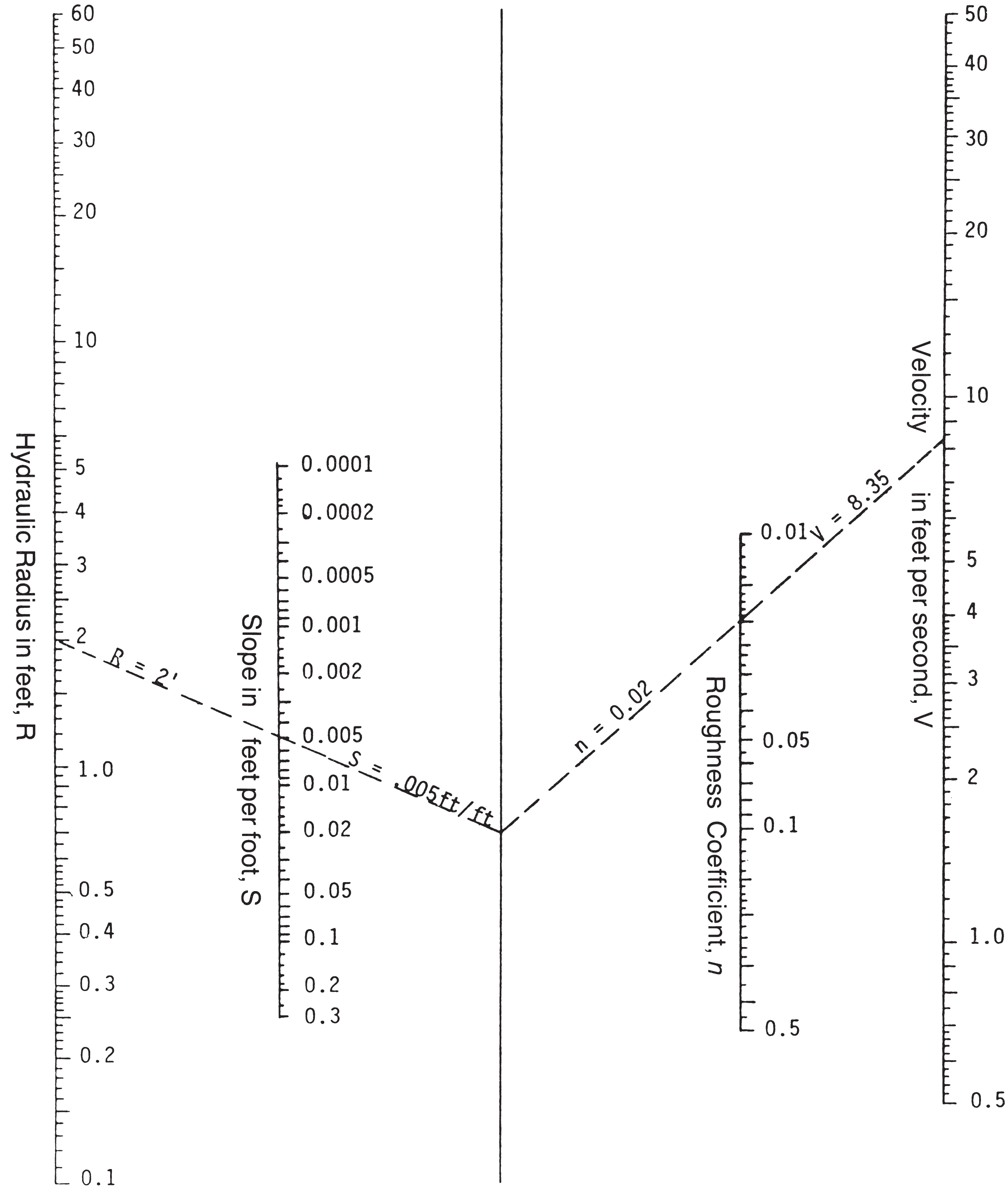


Figure 8.05a Nomograph for solution of Manning equation.

Table 8.05a
Maximum Allowable Design Velocities[1]
for Vegetated Channels

Typical Channel Slope Application	Soil Characteristics[2]	Grass Lining	Permissible Velocity[3] for Established Grass Lining (ft/sec)
0-5%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	5.0
		Tall fescue	4.5
		Bahiagrass	4.5
		Kentucky bluegrass	4.5
		Grass-legume mixture	3.5
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	6.0
		Tall fescue	5.5
		Bahiagrass	5.5
		Kentucky bluegrass	5.5
		Grass-legume mixture	4.5
5-10%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	4.5
		Tall fescue	4.0
		Bahiagrass	4.0
		Kentucky bluegrass	4.0
		Grass-legume mixture	3.0
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	5.5
		Tall fescue	5.0
		Bahiagrass	5.0
		Kentucky bluegrass	5.0
		Grass-legume mixture	3.5
>10%	Easily Erodible Non-plastic (Sands & Silts)	Bermudagrass	3.5
		Tall fescue	2.5
		Bahiagrass	2.5
		Kentucky bluegrass	2.5
	Erosion Resistant Plastic (Clay mixes)	Bermudagrass	4.5
		Tall fescue	3.5
		Bahiagrass	3.5
		Kentucky bluegrass	3.5

Source: USDA-SCS Modified

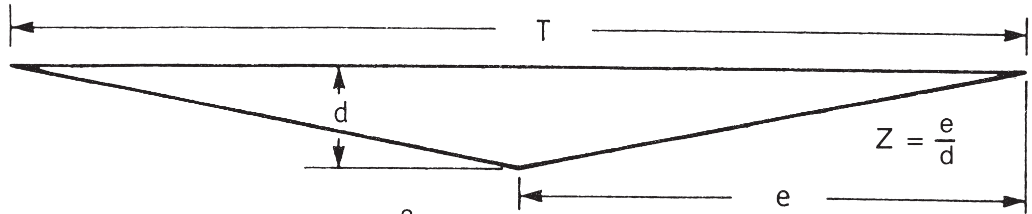
NOTE: [1]Permissible Velocity based on 10-year storm peak runoff
[2]Soil erodibility based on resistance to soil movement from concentrated flowing water.
[3]Before grass is established, permissible velocity is determined by the type of temporary liner used.

Selecting Channel Cross-Section Geometry

To calculate the required size of an open channel, assume the design flow is uniform and does not vary with time. Since actual flow conditions change throughout the length of a channel, subdivide the channel into design reaches, and design each reach to carry the appropriate capacity.

The three most commonly used channel cross-sections are "V"-shaped, parabolic, and trapezoidal. Figure 8.05b gives mathematical formulas for the area, hydraulic radius and top width of each of these shapes.

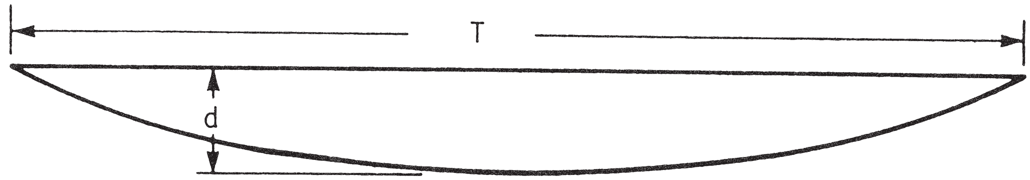
V-Shape



Cross-Sectional Area (A) = Zd^2
Top Width (T) = $2dZ$

Hydraulic Radius (R) = $\dfrac{Zd}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

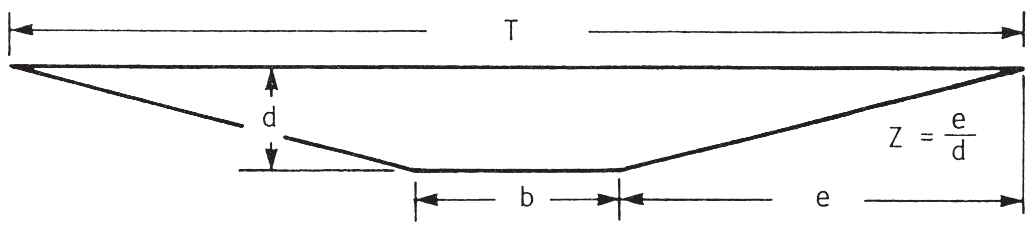


Cross-Sectional Area (A) = $\dfrac{2}{3}\,Td$

Top Width (T) = $\dfrac{1.5\,A}{d}$

Hydraulic Radius = $\dfrac{T^2d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $bd + Zd^2$
Top Width (T) = $b + 2dZ$

Hydraulic Radius = $\dfrac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Figure 8.05b Channel geometries for v-shaped, parabolic and trapezoidal channels.

Design Procedure- Permissible Velocity

The following is a step-by-step procedure for designing a runoff conveyance channel using Manning's equation and the continuity equation:

Step 1. Determine the required flow capacity, Q, by estimating peak runoff rate for the design storm (*Appendix 8.03*).

Step 2. Determine the slope and select channel geometry and lining.

Step 3. Determine the permissible velocity for the lining selected, or the desired velocity, if paved. (see Table 8.05a, page 8.05.4)

Step 4. Make an initial estimate of channel size—divide the required Q by the permissible velocity to reach a "first try" estimate of channel flow area. Then select a geometry, depth, and top width to fit site conditions.

Step 5. Calculate the hydraulic radius, R, from channel geometry (Figure 8.05b, page 8.05.5).

Step 6. Determine roughness coefficient *n*.

Structural Linings—see Table 8.05b, page 8.05.6.

Grass Lining:

a. Determine retardance class for vegetation from Table 8.05c, page 8.05.8. To meet stability requirement, use retardance for newly mowed condition (generally C or D). To determine channel capacity, use at least one retardance class higher.

b. Determine *n* from Figure 8.05c, page 8.05.7.

Step 7. Calculate the actual channel velocity, V, using Manning's equation (Figure 8.05a, pg. 8.05.3), and calculate channel capacity, Q, using the continuity equation.

Step 8. Check results against permissible velocity and required design capacity to determine if design is acceptable.

Step 9. If design is not acceptable, alter channel dimensions as appropriate. For trapezoidal channels, this adjustment is usually made by changing the bottom width.

Table 8.05b
Manning's *n* for Structural Channel Linings

Channel Lining	Recommended *n* values
Asphaltic concrete, machine placed	0.014
Asphalt, exposed prefabricated	0.015
Concrete	0.015
Metal, corrugated	0.024
Plastic	0.013
Shotcrete	0.017
Gabion	0.030
Earth	0.020

Source: American Society of Civil Engineers (modified)

Step 10. For grass-lined channels once the appropriate channel dimensions have been selected for low retardance conditions, repeat steps 6 through 8 using a higher retardance class, corresponding to tall grass. Adjust capacity of the channel by varying depth where site conditions permit.

NOTE 1: If design velocity is greater than 2.0 ft/sec., a temporary lining may be required to stabilize the channel until vegetation is established. The temporary liner may be designed for peak flow from the 2-year storm. If a channel requires a temporary lining, the designer should analyze shear stresses in the channel to select the liner that provides protection and promotes establishment of vegetation. For the design of temporary liners, use tractive force procedure.

NOTE 2: Design Tables—Vegetated Channels and Diversions at the end of this section may be used to design grass-lined channels with parabolic cross-sections.

Step 11. Check outlet for carrying capacity and stability. If discharge velocities exceed allowable velocities for the receiving stream, an outlet protection structure will be required (Table 8.05d, page 8.05.9).

Sample Problem 8.05a illustrates the design of a grass-lined channel.

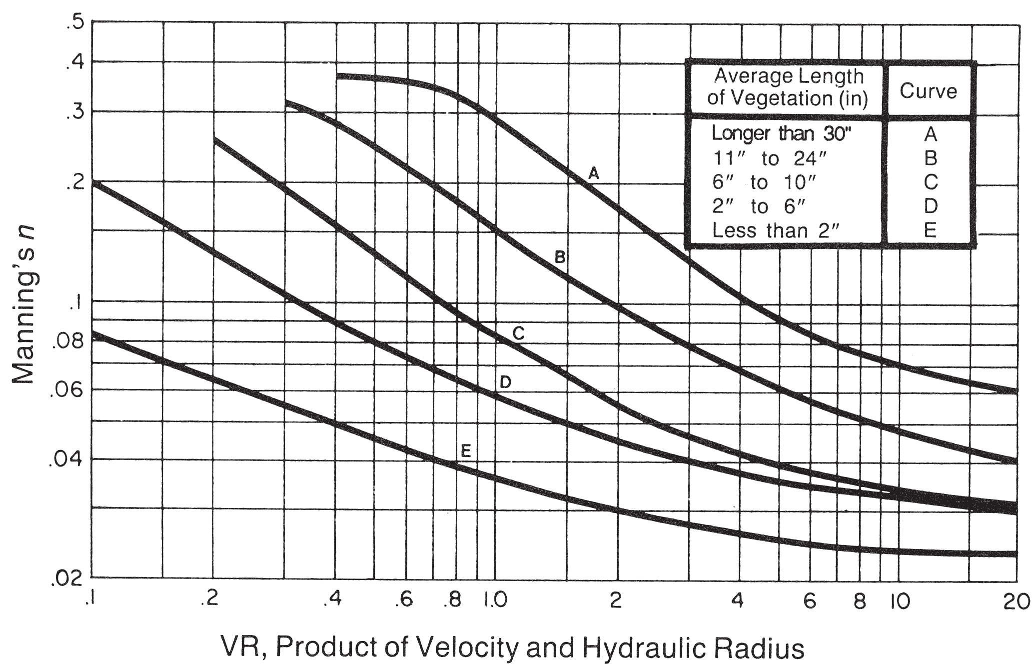


Figure 8.05c Manning's *n* related to velocity, hydraulic radius, and vegetal retardance.
Note: From Sample Problem 8.05a multiply Vp x Hydralulic Radius (4.5x0.54=2.43), then enter the product of VR and extend a straight line up to Retardance class "D", next project a straight line to the left to determine a trial manning's *n*.

Table 8.05c
Retardance Classification for Vegetal Covers

Retardance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36”)
	Weeping lovegrass	Excellent stand, tall (average 30”)
B	Tall fescue	Good stand, uncut, (average 18”)
	Bermudagrass	Good stand, tall (average 12”)
	Grass-legume mixture (tall fescue,red fescue, sericea lespedeza)	Good stand, uncut
	Grass mixture (timothy, smooth bromegrass or orchardgrass)	Good stand, uncut (average 20”)
	Sericea lespedeza	Good stand, not woody, tall (average 19”)
	Reed canarygrass	Good stand, cut, (average 12-15”)
	Alfalfa	Good stand, uncut (average 11”)
C	Tall fescue	Good stand (8-12”)
	Bermudagrass	Good stand, cut (average 6”)
	Bahiagrass	Good stand, uncut (6-8”)
	Grass-legume mixture-- summer (orchardgrass, redtop and annual lespedeza)	Good stand, uncut (6-8”)
	Centipedegrass	Very dense cover (average 6”)
	Kentucky bluegrass	Good stand, headed (6-12”)
	Redtop	Good stand, uncut (15-20”)
D	Tall fescue	Good stand, cut (3-4”)
	Bermudagrass	Good stand, cut (2.5”)
	Bahiagrass	Good stand, cut (3-4”)
	Grass-legume mixture-- fall-spring (orchardgrass, redtop, and annual lespedeza)	Good stand, uncut (4-5”)
	Red fescue	Good stand, uncut (12-18”)
	Centipedegrass	Good stand, cut (3-4”)
	Kentucky bluegrass	Good stand, cut (3-4”)
E	Bermudagrass	Good stand, cut (1.5”)
	Bermudagrass	Burned stubble

Modified from: USDA-SCS, 1969. Engineering Field Manual.

Table 8.05d Maximum Permissible Velocities for Unprotected Soils in Existing Channels.

Materials	Maximum Permissible Velocities (fps)
Fine Sand (noncolloidal)	2.5
Sand Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5

Sample Problem 8.05a Design of a Grass-lined Channel.

Given:

Design Q_{10} = 16.6 cfs

Proposed channel grade = 2%
Proposed vegetation: Tall fescue
Soil: Creedmoor (easily erodible)
Permissible velocity, V_p = 4.5 ft/s (Table 8.05a)
Retardance class: "B" uncut, "D" cut (Table 8.05c).
Trapezoidal channel dimensions:
designing for low retardance condition (retardance class D)
design to meet V_p.

Find:

Channel dimensions

Solution:

Make an initial estimate of channel size

A = Q/V, 16.6 cfs/4.5 ft/sec = 3.69 ft^2
Try bottom width = 3.0 ft w/side slopes of 3:1

$Z = 3$
$A = bd + Zd^2$
$P = b + 2d\sqrt{Z^2 + 1}$
$R = AP$

An iterative solution using Figure 8.05a to relate flow depth to Manning's *n* proceeds as follows: Manning's equation is used to check velocities.
*From Fig. 8.05c, pg. 8.05.7, Retardance Class d (VR=4.5x0.54=2.43)

d (ft)	A (ft^2)	R (ft)	*n	Vt (fps)	Q (cfs)	Comments
0.8	4.32	0.54	0.043	3.25	14.0	$V<V_p$ OK, $Q<Q_{10}$ (too small, try deeper channel)
0.9	5.13	0.59	0.042	3.53	18.10	$V<V_p$, OK, $Q>Q_{10}$, OK

Now design for high retardance (class B):

For the ease of construction and maintenance assume and try d = 1.5 ft and trial velocity V_t = 3.0 ft/sec

d (ft)	A (ft^2)	R (ft)	V_t (fps)	n	V (fps)	Q (cfs)	Comments
1.5	11.25	0.90	3.0	0.08	2.5	28	reduce V_t
			2.0	0.11	1.8	20	reduce V_t
			1.6	0.12	1.6	18	
			**1.5	0.13	1.5	17	$Q>Q_{10}$ OK

** These assumptions = actual V (fps.) (chart continued on next page)

**(continued)
Sample Problem 8.05a
Design of a
Grass-lined Channel.**

Channel summary:

Trapezoidal shape, Z = 3, b = 3 ft, d = 1.5 ft, grade = 2%

Note: In Sample Problem 8.05a the "n-value" is first chosen based on a permissible velocity and not a design velocity criteria. Therefore, the use of Table 8.05c may not be as accurate as individual retardance class charts when a design velocity is the determining factor.

Tractive Force Procedure

The design of riprap-lined channels and temporary channel linings is based on analysis of tractive force.

NOTE: This procedure is for uniform flow in channels and is *not* to be used for design of deenergizing devices and may not be valid for larger channels.

To calculate the required size of an open channel, assume the design flow is uniform and does not vary with time. Since actual flow conditions change through the length of a channel, subdivide the channel into design reaches as appropriate.

PERMISSIBLE SHEAR STRESS

The permissible shear stress, T_d, is the force required to initiate movement of the lining material. Permissible shear stress for the liner is not related to the erodibility of the underlying soil. However, if the lining is eroded or broken, the bed material will be exposed to the erosive force of the flow.

COMPUTING NORMAL DEPTH

The first step in selecting an appropriate lining is to compute the design flow depth (the normal depth) and determine the shear stress.

Normal depths can be calculated by Manning's equation as shown for trapezoidal channels in Figure 8.05d. Values of the Manning's roughness coefficient for different ranges of depth are provided in Table 8.05e for temporary linings and Table 8.05f for riprap. The coefficient of roughness generally decreases with increasing flow depth.

**Table 8.05e
Manning's Roughness
Coefficients for Temporary
Lining Materials**

Lining Type	*n* value for Depth Ranges* 0-0.5 ft	0.5-2.0 ft	>2.0 ft
Woven Paper Net	0.016	0.015	0.015
Jute Net	0.028	0.022	0.019
Fiberglass Roving	0.028	0.021	0.019
Straw with Net	0.065	0.033	0.025
Curled Wood Mat	0.066	0.035	0.028
Synthetic Mat	0.036	0.025	0.021

* Adapted from: FHWA-HEC 15, Pg. 37 - April 1988

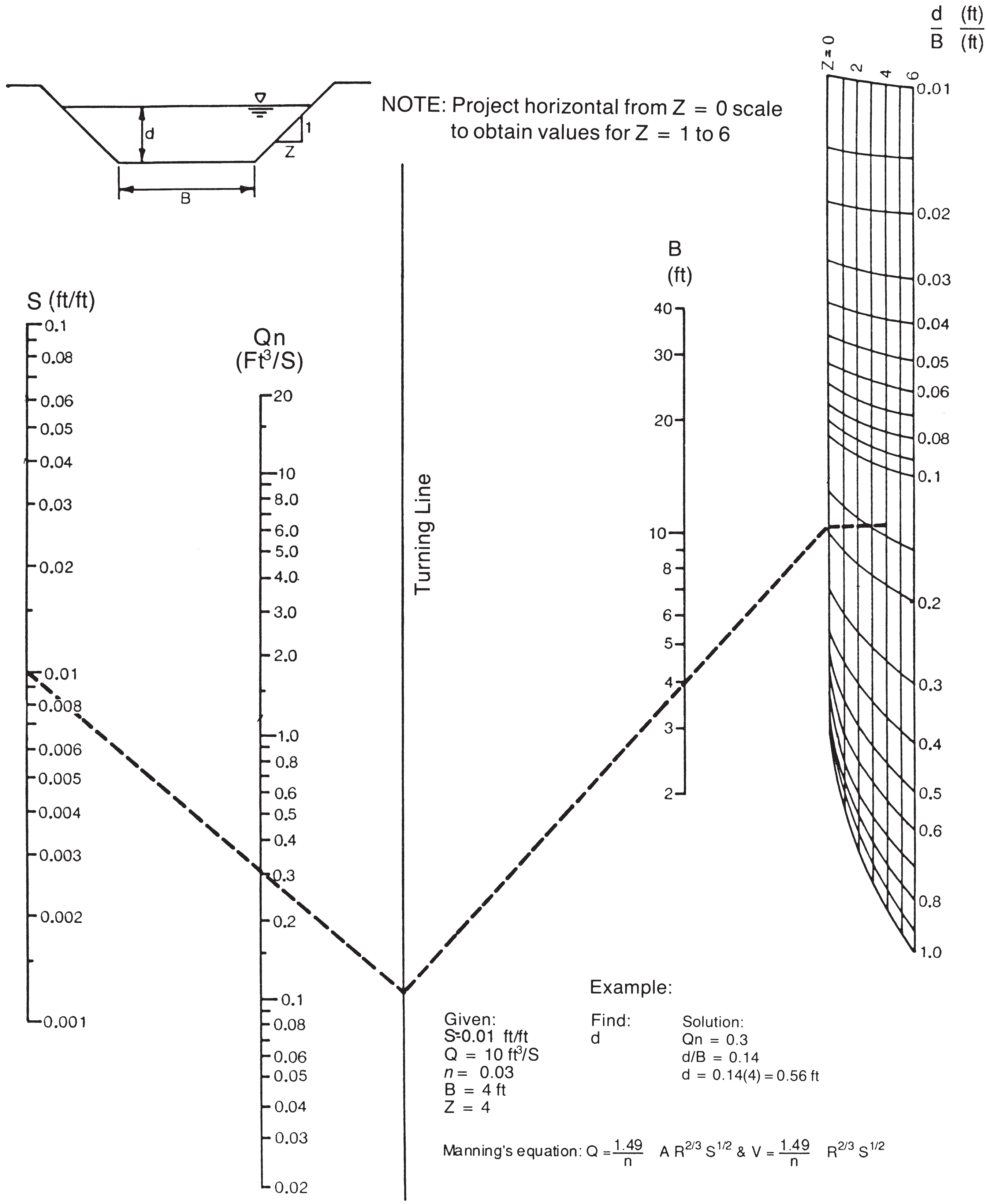


Figure 8.05d Solution of Manning's equation for trapezoidal channels of various side slopes.
Adapted from: FHWA-HEC. 15, Pg 40 - April 1988

Table 8.05f Manning's Roughness Coefficient

Lining Category	Lining Type	*n* - value *n* value for Depth Ranges 0-0.5 ft (0-15 cm)	 0.5-2.0 ft (15-60 cm)	 2.0 ft (>60 cm)
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Gravel Riprap	1-inch (2.5-cm) D_{50}	0.044	0.033	0.030
	2-inch (5-cm) D_{50}	0.066	0.041	0.034
Rock Riprap	6-inch (15-cm) D_{50}	0.104	0.069	0.035
	12-inch (30-cm) D_{50}	--	0.078	0.040

Note: Values listed are representative values for the respective depth ranges. Manning's roughness coefficients, *n*, vary with the flow depth.

DETERMINING SHEAR STRESS

Shear stress, T, at normal depth is computed for the lining by the following equation:

$$T = yds$$
$$T_d = \text{Permissible shear stress}$$

where:

- T = shear stress in lb/ft^2
- y = unit weight of water, 62.4 lb/ft^3
- d = flow depth in ft
- s = channel gradient in ft/ft

If the permissible shear stress, T_d, given in Table 8.05g is greater than the computed shear stress, the riprap or temporary lining is considered acceptable. If a lining is unacceptable, select a lining with a higher permissible shear stress and repeat the calculations for normal depth and shear stress. In some cases it may be necessary to alter channel dimensions to reduce the shear stress.

Computing tractive force around a channel bend requires special considerations because the change in flow direction imposes higher shear stress on the channel bottom and banks. The maximum shear stress in a bend, T_b, is given by the following equation:

$$T_b = K_b T$$

where:

- T_b = bend shear stress in lb/ft^2
- k_b = bend factor
- T = computed stress for straight channel in lb/ft^2

The value of k_b is related to the radius of curvature of the channel at its center line, R_c, and the bottom width of the channel, B, Figure 8.05e. The length of channel requiring protection downstream from a bend, L_p, is a function of the roughness of the lining material and the hydraulic radius as shown in Figure 8.05f.

**Table 8.05g
Permissible Shear Stresses for Riprap and Temporary Liners**

Lining Category	Lining Type	Permissible Unit Shear Stress, T_d (lb/ft^2)
Temporary	Woven Paper Net	0.15
	Jute Net	0.45
	Fiberglass Roving:	
	Single	0.60
	Double	0.85
	Straw with Net	1.45
	Curled Wood mat	1.55
	Synthetic Mat	2.00
	d_{50} **Stone Size** (inches)	
Gravel Riprap	1	0.33
	2	0.67
Rock Riprap	6	2.00
	9	3.00
	12	4.00
	15	5.00
	18	6.00
	21	7.80
	24	8.00

Adapted From: FHWA, HEC-15, April 1983, pgs. 17 & 37.

Design Procedure-Temporary Liners

The following is a step-by-step procedure for designing a temporary liner for a channel. Because temporary liners have a short period of service, the design Q may be reduced. For liners that are needed for six months or less, the 2-year frequency storm is recommended.

Step 1. Select a liner material suitable for site conditions and application. Determine roughness coefficient from manufacturer's specifications or Table 8.05e, page 8.05.10.

Step 2. Calculate the normal flow depth using Manning's equation (Figure 8.05d). Check to see that depth is consistent with that assumed for selection of Manning's *n* in Figure 8.05d, page 8.05.11. For smaller runoffs Figure 8.05d is not as clearly defined. Recommended solutions can be determined by using the Manning equation.

Step 3. Calculate shear stress at normal depth.

Step 4. Compare computed shear stress with the permissible shear stress for the liner.

Step 5. If computed shear is greater than permissible shear, adjust channel dimensions to reduce shear, or select a more resistant lining and repeat steps 1 through 4.

Design of a channel with temporary lining is illustrated in Sample Problem 8.05b, page 8.05.14.

Sample Problem 8.05b Design of a Temporary Liner for a Vegetated Channel

Given:

Q_2 = 16.6 cfs
Bottom width = 3.0 ft
Z = 3
n = 0.02 (Use basic *n* value for channels cut in earth (Table 8.05b)
V_p = 2.0 ft/sec maximum allowable velocity for bare soil (pg. 6.30.1)
Channel gradient = 2%

Find:

Suitable temporary liner material

Solution:

Using Manning's equation:

b(ft)	d(ft)	A(ft²)	R(ft)	V(fps)	Q(cfs)	Comments
3.0	0.59	2.82	0.42	5.88	16.60	$V>V_p$, (needs protection) $Q \geq Q_2$, OK

Velocity >2.0 fps channel requires temporary liner:*

Calculate channel design with straw with net as temporary liner.
n = 0.033 (Table 8.05e). T_d = 1.45 (Table 8.05g, pg. 8.05.13)

b(ft)	d(ft)	A(ft²)	R(ft)	V(fps)	Q(cfs)	Comments
3.0	0.76	4.05	1.94	4.10	16.60	$V<T_d$, OK

Calculate shear stress for Q_2 conditions:

T = yds where: y = unit weight of water (62.4 lb/ft³)
d = flow depth in ft
s = channel gradient in ft/ft

T = (62.4)(0.76)(0.02) = 0.95 $T<T_d$, OK

Temporary liner: straw with net.

*In some cases the solution is not as clearly defined; the use of a more conservative material is recommended.

DESIGN OF RIPRAP LINING-MILD GRADIENT

The mild gradient channel procedure is applicable for channel grades less than 10%. The method assumes that the channel cross section has been designed properly, including undercut and that the remaining problem is to provide a stable riprap lining.

Side slope stability. As the angle of the side slope approaches the angle of repose of the channel lining, the lining material becomes less stable. The stability of a side slope is given by the tractive force ratio, K_2, a function of the side slope and the angle of repose of the rock lining material.

The rock size to be used for the channel lining can be determined by comparing the tractive force ratio, an indicator of side slope stability, to the shear stress on the sides and shear stress on the bottom of the channel. The angle of repose for different rock shapes and sized is shown in Figure 8.05g. The required rock size (mean diameter of the gradation, d_{50}) for the side slopes is determined from the following equation:

$$d_{50\,(sides)} = \frac{K_1}{K_2}\, d_{50\,(bottom)}$$

where:

K_1 = ratio of shear stress on the sides, T_s, and bottom, T, of a trapezoidal channel (Figure 8.05h),

K_2 = tractive force ratio (Figure 8.05i).

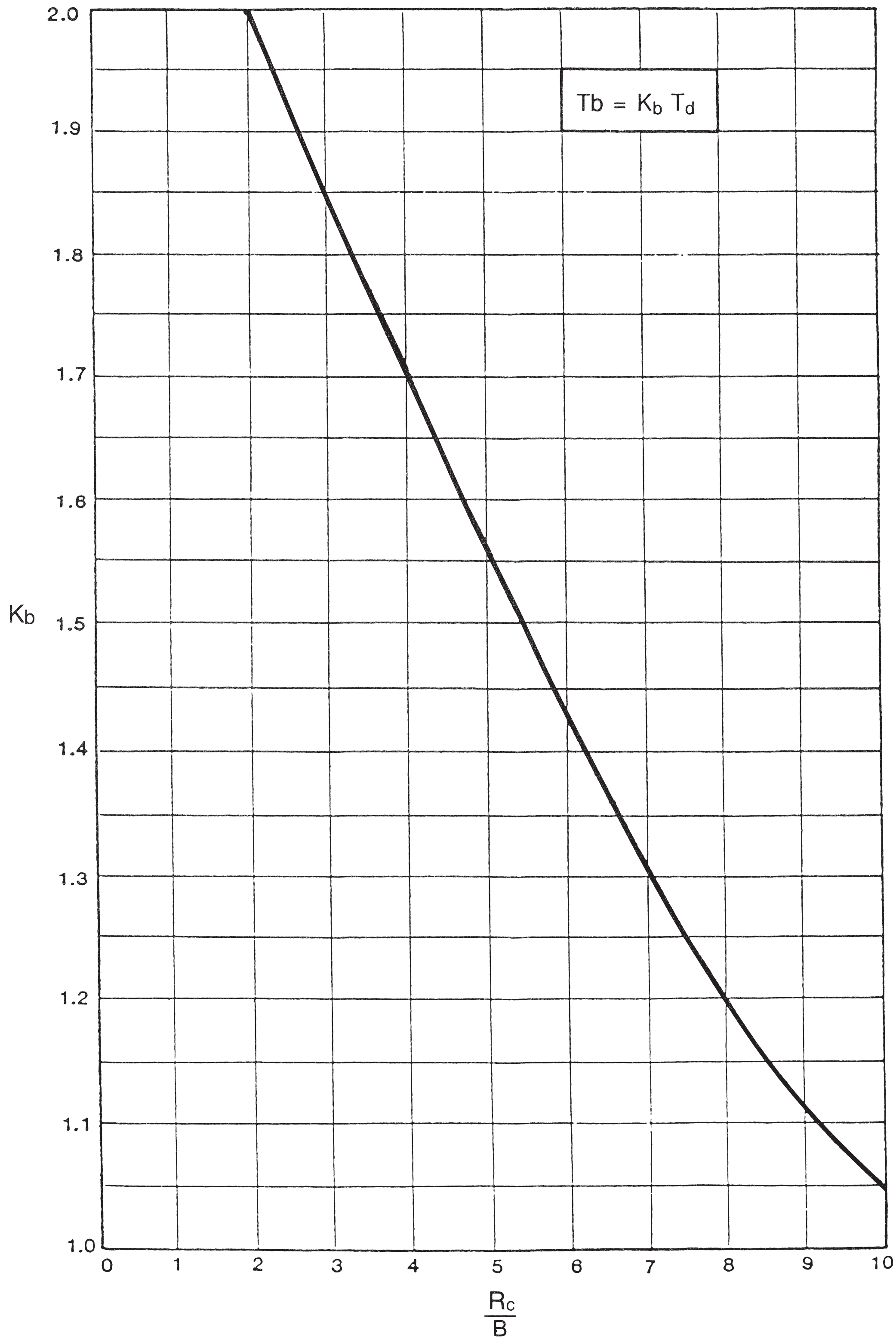


Figure 8.05e K_b factor for maximum shear stress on channel bends.
Adapted from: FHWA-HEC 15, Pg. 47 - April 1988

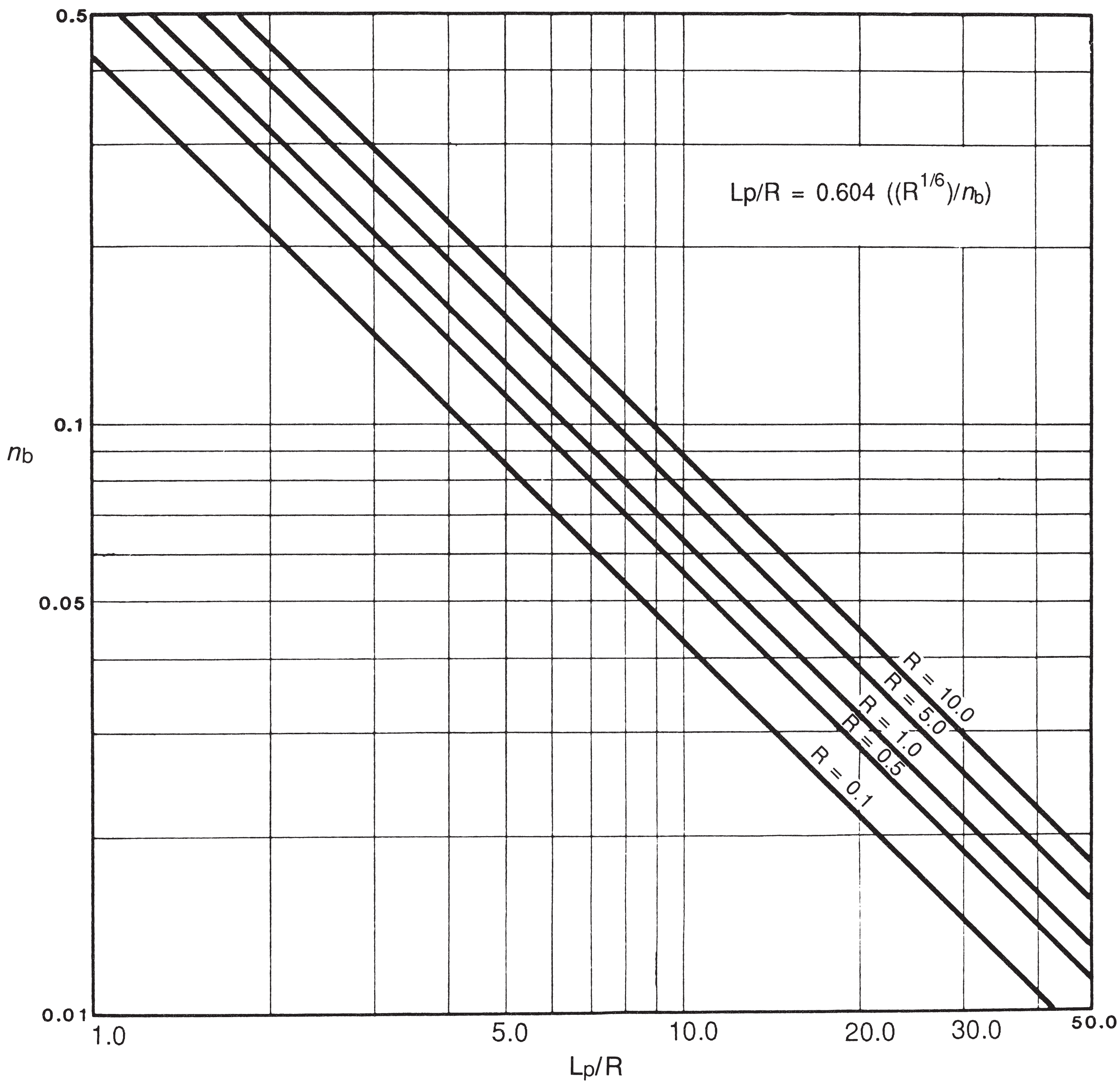


Figure 8.05f Protection length, L_p, downstream from a channel bend.
n_b = Manning Roughness of the lining material in the bend and the depth of flow (see tables 8.05e and f).
R = Hydraulic Radius = Area/wetted perimeter
Adapted from: FHWA-HEC 15, pg 48 - April 1988

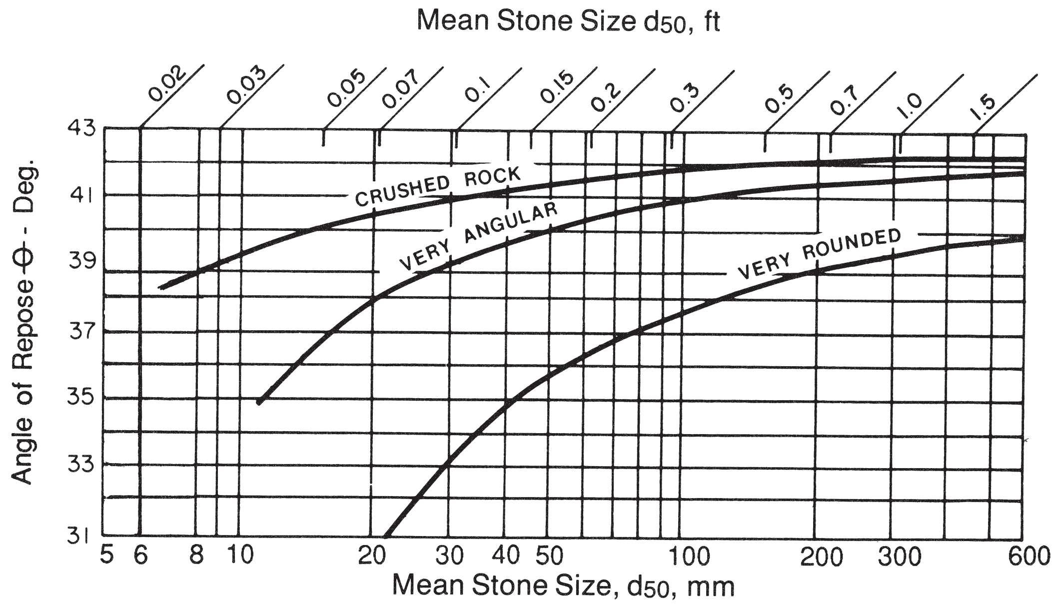


Figure 8.05g Angle of repose for different rock shapes and sizes.
Adapted from: FHWA, HEC-15, pg. 49 - April 1988

Selection of riprap gradation and thickness. Riprap gradation should have a smooth size distribution curve. The largest stone size in the gradation should not exceed 1.5 times the d_{50} size. The most important criterion is that interstices formed by larger stones be filled with smaller sizes in an interlocking fashion, preventing the formation of open pockets. These gradation requirements apply regardless of the type of filter design used.

In general, riprap constructed with angular stone performs best. Round stones are acceptable as riprap provided they are not placed on side slopes steeper than 3:1. Flat, slab-like stones should be avoided since they are easily dislodged by the flow. An approximate guide to stone shape is that neither the breadth nor the thickness of a single stone be less than one-third its length.

The thickness of a riprap lining should equal 1.5 times the diameter of the largest rock size in the gradation.

Filter design: When rock riprap is used, an appropriate underlying filter material must be selected. The filter material may be either a granular, gravel or sand filter blanket, or a geotextile fabric.

For a granular filter blanket, the following criteria must be met:

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

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

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

Where "filter" refers to the overlying riprap or gravel and "base" refers to the underlying soil, sand or gravel. The relationship must hold between the filter blanket and base material and between the riprap and filter blanket.

The minimum thickness for a filter blanket should not be less than 6 inches.

In selecting a filter fabric, the fabric should have a permeability at least equal to the soil and a pore structure that will hold back the base soil. The following properties are essential to assure performance under riprap:

- For filter fabric covering a base with granular particles containing 50 percent or less (by weight) of fine particles (less than U.S. Standard Sieve No. 200):
  a. d_{85} base (mm)/EOS* filter cloth (mm) > 1.
  b. Total open area of filter is less than 36%.

- Filter fabric covering other soils:
  a. EOS less than U.S. Standard Sieve No. 70.
  b. Total open area of filter less than 10%.

*EOS - Equivalent Opening Size to a U.S. Standard Sieve Size

Design Procedure-Riprap Lining, Mild Gradient

The following is a step-by-step procedure for designing a riprap channel lining with mild gradients. This procedure is designed for **smaller** channels that are generally used as erosion control measures, and is not intended for conveyance channels.

Additional design information for lined channels may be obtained from the National Technical Information Services (NTIS) by obtaining a copy of the National Cooperative Highway Research Program Report No. 108, titled "Tentative Design Procedure for Riprap - Lined Channels".

Step 1. Select a riprap size, and look up the Manning's *n* value (Table 8.05f) and permissible shear stress, T_d (Table 8.05g).

Step 2. Calculate the normal flow depth in the channel, using Manning's equation (Figure 8.05d). Check that the *n* value for the calculated normal depth is consistent with that determined in step 1.

Step 3. Calculate shear stress at normal depth.

Step 4. Compare the calculated shear stress with the permissible shear stress.

If the calculated shear stress is less than the permissible shear stress, then the selected riprap size is acceptable. Otherwise, the procedure must be repeated using a larger size riprap with a higher permissible shear stress.

Step 5. For riprap linings on side slopes steeper than 3:1, execute the supplemental procedure for steep side slope design presented below.

Supplemental Procedure for Riprap Channel With Steep Side Slopes. This procedure should be used when side slopes are steeper than 3:1.

Step 1. From Figure 8.05g, determine the angle of repose for the rock size and shape. NOTE: The side slopes selected for the channel must be stable for the soil conditions.

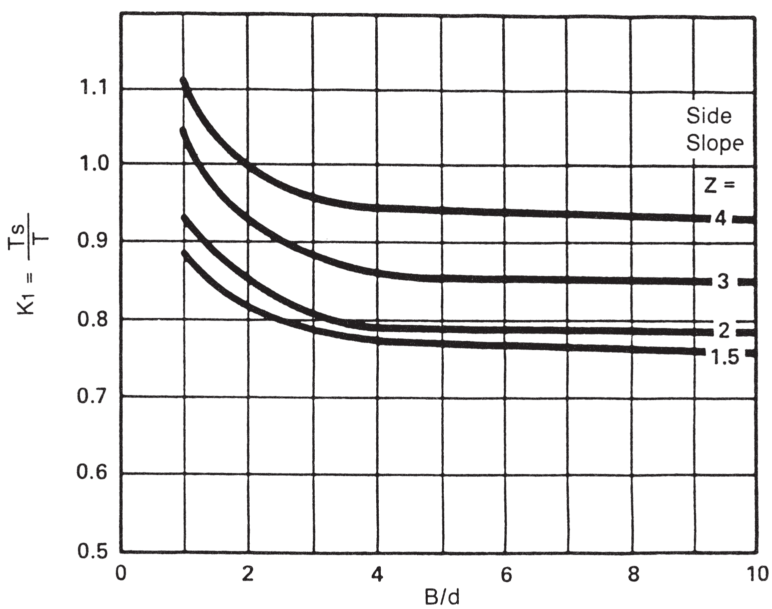


Figure 8.05h Ratio of side shear stress to bottom shear stress , K_1.

Step 2. From Figure 8.05h, determine K_1, the ratio of maximum side shear to maximum bottom shear for a trapezoidal channel, based on bottom width to depth ratio, b/d, and side slope, Z.

Step 3. From Figure 8.05i, determine K_2, the tractive force ratio, based on side slope and the stone angle of repose.

Step 4. The required d_{50} for side slopes is given by the following equation:

$$d_{50\ (sides)} = \frac{K_1}{K_2}\ d_{50\ (bottom)}$$

where:

K_1 = ratio of shear stress on the sides, T_s, and bottom, T, of a trapezoidal channel (Figure 8.05h),

K_2 = tractive force ratio (Figure 8.05i).

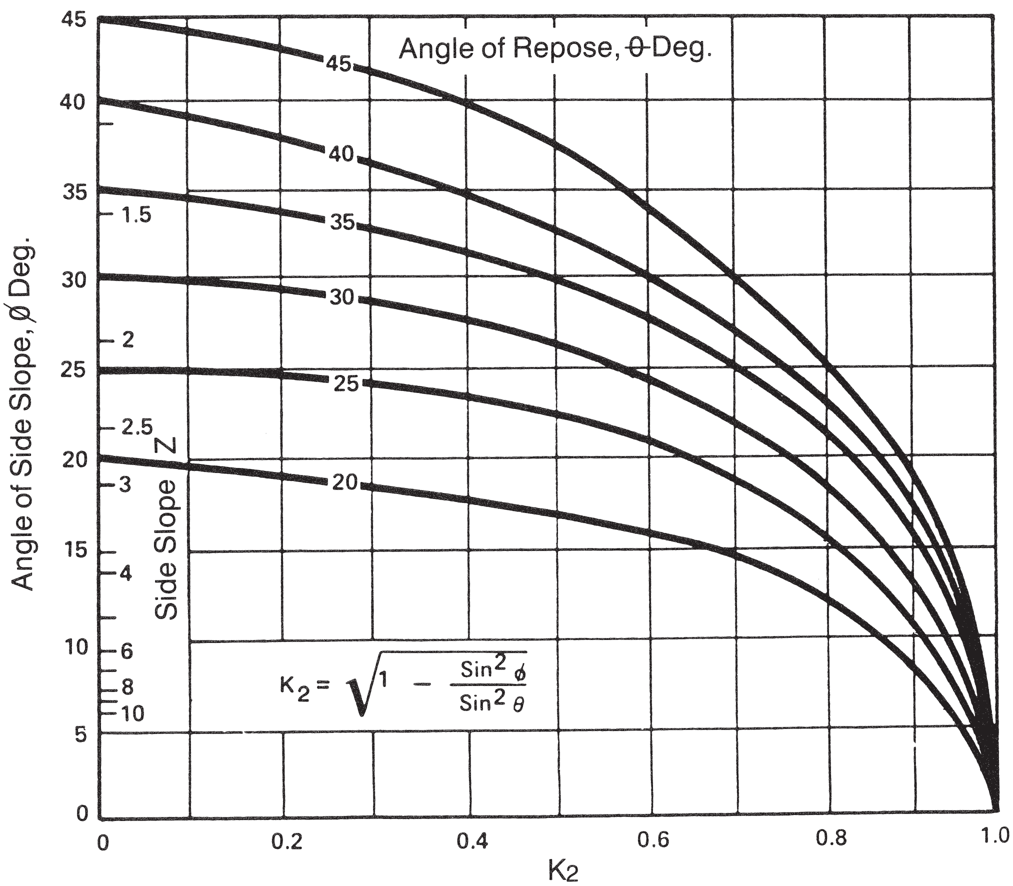


Figure 8.05i Tractive force ratio, K_2.
Adapted from: FHWA, HEC-15, pg. 51 - April 1988

Sample Problem 8.05c demonstrates the tractive force procedure for the design of mild gradient riprap channels.

DESIGN OF RIPRAP LINING-STEEP GRADIENTS

This section outlines the design of riprap channel lining for steep gradients. Achieving channel stability on steep gradients, 10% or more, usually requires some type of channel linings except where the channels can be constructed in durable bedrock.

Rigid channel linings may be more cost effective than riprap in steep slope conditions. Riprap stability on a steep slope depends on the average weight of the stones and the lift and drag forces induced by the flow. To resist these forces, steep channels require larger stones than mild slope channels, and the size of riprap linings increases quickly as discharge and channel gradient increases. The decision to select a rigid or flexible lining may be based on other site conditions, such as foundation material and maintenance requirements.

Transition sections protect transition regions of the channel both above and below the steep gradient section. The transition from a steep gradient to a culvert

Sample Problem 8.05c Design of a Mild Gradient Channel with Riprap Lining

Determine the mean riprap size and flow depth for a mild gradient channel:

Given:
Q = 22 cfs
s = 0.05 ft/ft
b = 4.0 ft
Z = 3

Find:
Flow depth and mean riprap size

Solution:

(1) Try d_{50} = 6 inches, depth 1.0 ft
From Table 8.05f; select *n* = 0.069
From Table 8.05g; permissible unit shear stress = 2.0 lb/ft^2

(2) From Figure 8.05d determine channel flow depth
Q*n* = (22)(0.069) = 1.52 d/b = 0.23 d = (0.23)(4.0) = 0.92 ft.
NOTE: Calculated depth is within selected depth range.

(3) Calculate shear stress
T = yds
T = (62.4 lb/ft^3)(0.92)(0.05) = 2.87 lb/ft^2
Exceeds allowable of 2.0 lb/ft^2

Try d_{50} = 1.0 ft, depth 1.0 ft

(1) *n* = 0.078; permissible unit shear stress = 4.0 lb/ft^2

(2) Q*n* = (22)(0.078) = 1.72; d/b = 0.245
d = (0.245)(4.0) = 0.98

(3) Shear stress (62.4)(0.98)(0.05) = 3.06 lb/ft^2 < 4.0 lb/ft^2 O.K.
Use d_{50} 1.0 ft

Determine maximum stone size and riprap thickness

(1) d_{max} = 1.5 x d_{50} = (1.5)(12 in) = 18 in, see pg. 8.05.17

(2) Thickness of riprap (installed *below* finished grade)
= 1.5 x d_{max} = (1.5) x (18 in) = 27 in

Continuing with the same problem
Given a channel bend of radius R_c = 30 ft (see pg. 8.05.12)

(1) R_c/B = 30/4.0 = 7.5

(2) K_b = 1.25 (Figure 8.05e, pg. 8.05.15)

(3) T_b = T x K_b = 3.06 lb/ft^2 x 1.25 = 3.83. This is less than the permissible shear stress for d_{50} = 1.0 ft O.K.

(4) For hydraulic radius, R = 0.67 and n_b = 0.078 the protection length downstream of the channel bend is found from Figure 8.05f, pg. 8.05.16. LP/R = 7.5, L_p = 5.0' The total length of protection is the sum of the length in the bend plus the length required for downstream protection.

Adapted from: FHWA, HEC-15, April 1988, pg. 26-29.

should allow room for some movement of riprap to prevent blockage of the culvert opening. Riprap should be placed flush with the invert of a culvert. The break between the steep slope and culvert entrance should equal three to five times the mean rock diameter. The transition from a steep gradient to a mild gradient channel may require an energy dissipation structure. The transition from a mild gradient to a steep gradient should be protected against local scour upstream from the transition for a distance approximately five times the uniform depth of flow in the downstream channel.

Channel alignment and freeboard. Bends should be avoided on steep gradient channels. A design requiring a bend in a steep channel should be redesigned if possible to eliminate the bend, or replaced by a conduit system.

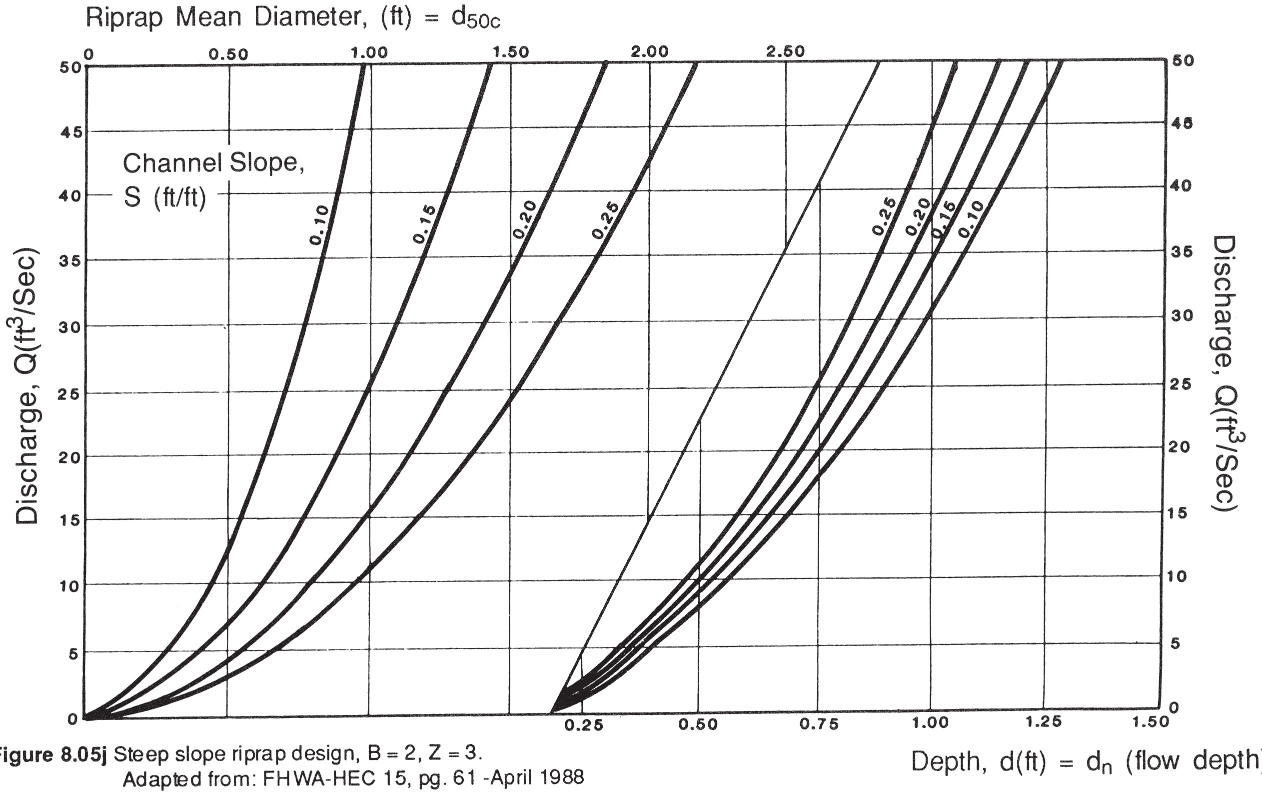


Figure 8.05j Steep slope riprap design, B = 2, Z = 3.
Adapted from: FHWA-HEC 15, pg. 61 -April 1988

Freeboard should be evaluated based on the consequences of overflow of the channel banks and may be affected by wave height, or super elevation of the flow in bends, of the channel

Riprap gradation, thickness and filter requirements. Riprap gradations, thickness and filter requirements are the same as those for mild slopes. It is important to note that riprap thickness is measured normal to the channel gradient.

Design Procedure-Riprap Lining, Steep Gradient

The design procedure for steep gradient channel linings is summarized below.

Step 1. Based on a known discharge and channel slope, use Figures 8.05j-8.05l to select a channel bottom width and channel size, and determine the mean riprap size and flow depth. For intermediate channel widths not given in these figures, interpolate between charts.

Step 2. To determine flow depth and riprap size for side slopes other than 3:1, proceed as follows:

a. Find the flow depth by the following equation:

$$d = \frac{A_3}{A_z} d_n$$

where values of the A_3/A_z ratio are found from Table 8.05h (the subscript refers to the side slope Z-value) and d_n is the flow depth from the design charts for side slopes of 3:1.

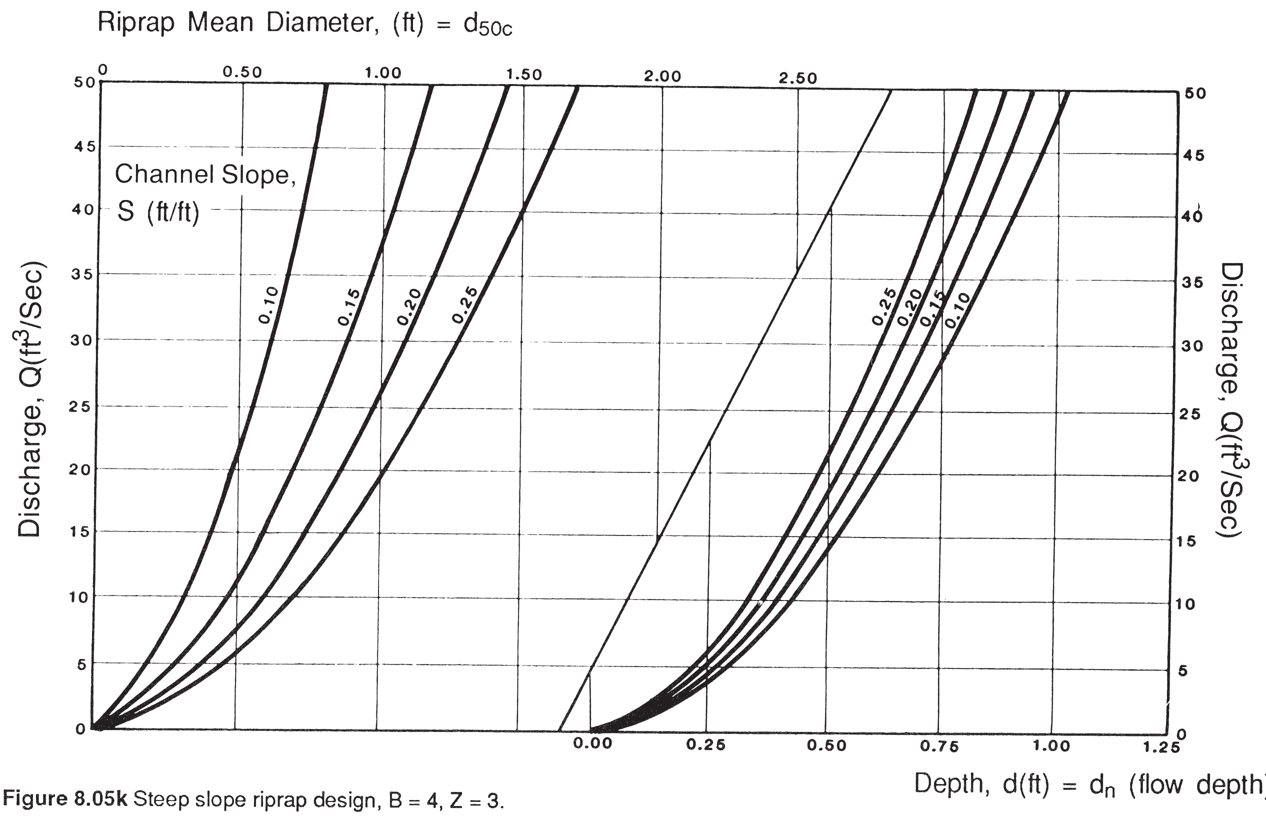


Figure 8.05k Steep slope riprap design, B = 4, Z = 3.

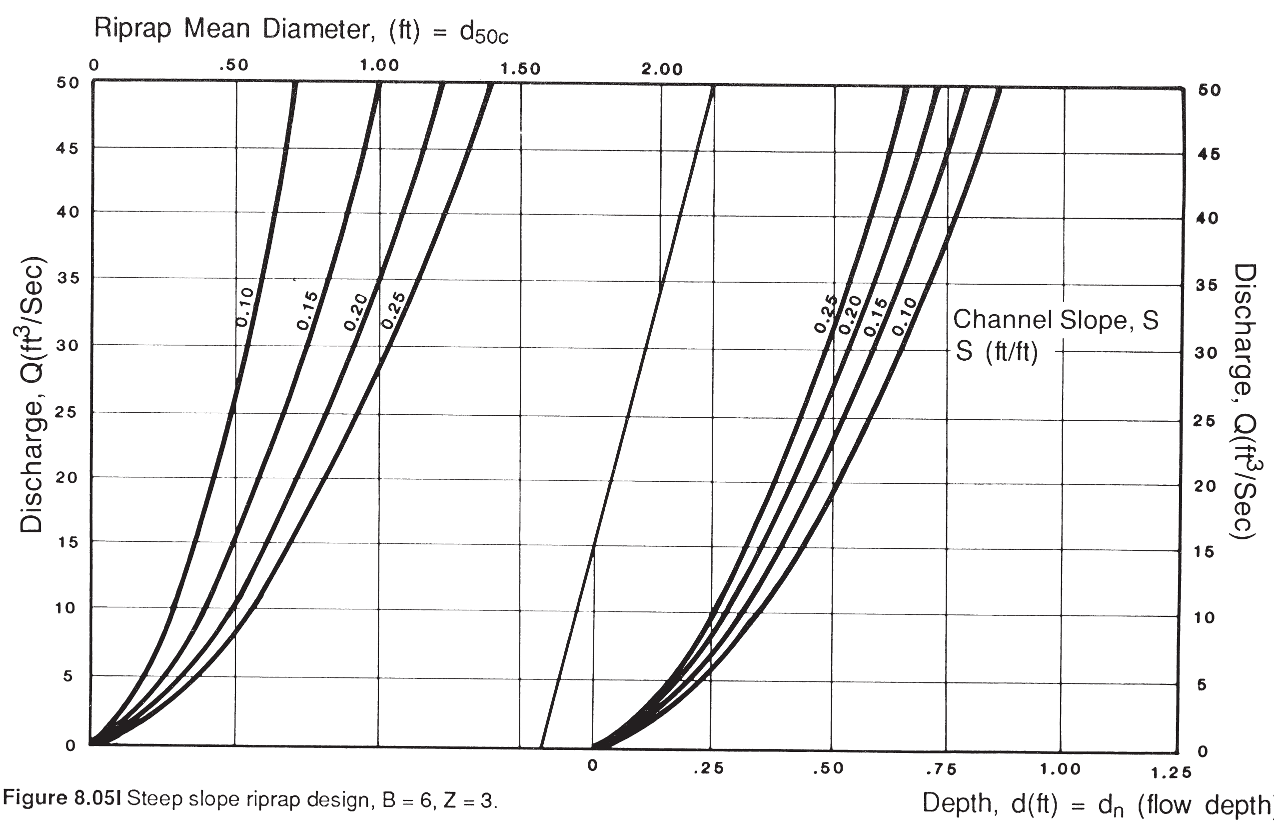


Figure 8.05l Steep slope riprap design, B = 6, Z = 3.

Table 8.05h
Values of A_3/A_z for Selected Side Slopes and Depth-to-Bottom Width Ratios[1]

	A_3/A_z				
d/b	**2:1**	**3:1**	**4:1**	**5:1**	**6:1**
0.10	1.083	1.000	0.928	0.866	0.812
0.20	1.142	1.000	0.888	0.800	0.727
0.30	1.187	1.000	0.853	0.760	0.678
0.40	1.222	1.000	0.846	0.733	0.647
0.50	1.250	1.000	0.833	0.714	0.625
0.60	1.272	1.000	0.823	0.700	0.608
0.70	1.291	1.000	0.815	0.688	0.596
0.80	1.307	1.000	0.809	0.680	0.586
0.90	1.321	1.000	0.804	0.672	0.578
1.00	1.333	1.000	0.800	0.666	0.571
1.10	1.343	1.000	0.796	0.661	0.565
1.20	1.352	1.000	0.793	0.657	0.561
1.30	1.361	1.000	0.790	0.653	0.556
1.40	1.368	1.000	0.787	0.650	0.553
1.50	1.378	1.000	0.785	0.647	0.550
1.60	1.381	1.000	0.783	0.644	0.547
1.70	1.386	1.000	0.782	0.642	0.544
1.80	1.391	1.000	0.780	0.640	0.542
1.90	1.395	1.000	0.779	0.638	0.540
2.00	1.400	1.000	0.777	0.636	0.538

[1]Based on the following equation:

$$A_3/A_z = \frac{1 + 3(d/b)}{1 + Z(d/b)}$$

Adapted from: FHWA-HEC 15, pg. 59 - April 1988

b. Find the riprap size using the following equation:

$$d_{50} = \frac{d}{d_n}\, d_{50c}$$

where d_n and d_{50c} are values from the design charts (Figures 8.05j, 8.05k, and 8.05l).

Sample problem 8.05d demonstrates the tractive force procedure for design of riprap channels on steep grade.

Stability Evaluation for Natural Channels

Determining flow capacity and velocity in a natural channel involves detailed analysis and evaluation. Variations in channel cross section, alignment, grade and roughness, and often changing conditions of in-bank and out-of-bank flow make accurate determination of channel capacity and velocity difficult.

The following procedure uses Manning's equation and the continuity equation to estimate stream channel capacity and velocity. Flow constrictions caused by culverts or bridges must be evaluated separately.

Sample Problem 8.05d Design of a Steep Gradient Channel with Riprap Lining.

Determine the mean riprap size and flow depth for a steep gradient channel:

Given:

Q = 30 cfs
s = 0.15 ft/ft
b = 3.0 ft
Z = 3

Find:

Flow depth (d_n) and mean riprap size d_{50c}

Solution:

(1) Enter Figure 8.05j,
for b = 2.0 given Q = 30 cfs and s = 0.15 ft/ft,

d_n = 0.92 ft
d_{50c} = 1.1 ft

Enter Figure 8.05k,
for b = 4.0 given Q = 30 ft^3/sec and S = 0.15 ft/ft,

d_n = 0.70 ft
d_{50c} = 0.9 ft

(2) Interpolating for a 3.0 ft bottom width gives,

d_n = 0.81 ft
d_{50c} = 1.0 ft

Survey of the Stream Channel

To apply Manning's equation to a natural stream, a field survey is necessary to determine the relevant channel characteristics. The field survey should identify the following:

- Control points along the channel to define channel reaches to be evaluated. These include confluences with tributaries, points of significant change in grade or cross section, bridges, or culverts that restrict the flow.
- The profile of the channel bottom along the centerline of the stream.
- Selected cross sections, at right angles to the channel centerline in each reach, to determine average channel cross section. The survey should also include elevation of the flood plain and valley abutments if out-of-bank flow is anticipated. An accurate topographic map may provide additional stream valley sections and profile points to supplement the field survey.
- Descriptions of relevant physical characteristics of the channel between control points, such as channel bed and bank materials, vegetation, obstructions, meander and other factors that determine the roughness coefficient *n*.

Determining an *n* Factor for a Natural Channel

An *n* value for each channel reach can be determined by following the procedure outlined in *Appendix 8.04*.

Permissible Velocity in Natural Channels

Natural channels seldom have uniform vegetative lining, especially those with continuous stream flow. Typical natural channels have beds of exposed soil, gravel deposits, rock outcroppings and sand bars, and banks ranging from exposed soil to dense native vegetation.

The permissible velocity in natural channels should be determined for the most erodible soil condition along the evaluation reach. Table 8.05d gives permissible velocities for existing channels in specified soil materials.

Evaluation Procedure

After the channel has been divided into reaches, the following procedure may be used to determine stability. The procedure should be applied to each evaluation reach, beginning at the lowest section and progressing upstream.

Step 1. Determine the peak runoff rate for a 10-year storm after site development, based on the **entire** contributing drainage area at the downstream end of each reach.

Step 2. Determine average cross-sectional area, hydraulic radius, slope and permissible velocity in the channel reach.

Step 3. Determine roughness coefficient, *n,* for the reach.

Step 4. Calculate bankfull velocity, V, and capacity, Q, using Manning's equation and the continuity equation.

Step 5. Compare actual bankfull channel capacity, Q, with the peak rate of runoff from step 1, and compare velocity, V, with the permissible velocity from step 2.

a. Calculated channel velocities for the 10-year peak must be equal to or less than the allowable velocity, or channel stabilization will be necessary (*Practice Standards and Specifications: 6.72, Vegetative Streambank Stabilization; 6.73, Structural Streambank Stabilization*).

b. If the capacity of the channel exceeds the peak runoff rate from the 10-year storm, compute the velocity, V, for the depth at which the 10-year storm discharge will flow for stability comparison.

c. If capacity of the channel is less than the peak runoff rate from the 10-year storm, a deeper flow depth must be determined (considering the quantity of out-of-bank flow) to provide the necessary capacity. The channel velocity at this stage must be calculated and compared to the allowable velocity to determine if the reach will require stabilization.

Design Tables for Grass-lined Channel

Tables 8.05i through 8.05o may be used to facilitate the design of grass-lined channels with parabolic cross-sections. These design tables are based on a retardance of “D” (vegetation newly cut) to determine V_1 for stability considerations. The top width, depth, and velocity, V_2, are based on a retardance of “C” (vegetation at normal cutting height for proper maintenance). Channel capacity is determined by these considerations.

Table 8.05c provides retardance classifications for selected vegetal covers. Table 8.05a gives maximum allowable velocities for grass-lined channels for various grasses, soil conditions, and slopes. The velocities in Table 8.05a guide the selection of V_1 in the Design Tables and should not be exceeded. It is good practice to use a value for V_1 that is significantly less than the maximum allowable when choosing a design cross section. The maximum allowable design velocity should only be used when soils will readily support vegetation, special care will be taken in establishing and maintaining grass linings, and a wider, shallower channel cannot be constructed due to site limitations. Riprap-lined and paved channels should be considered when design velocities approach maximum allowable for vegetation.

Sample Problem 8.05e illustrates the design of grass-lined channels with parabolic cross-sections.

Sample Problem 8.05e Design of grass-lined channel with a parabolic cross-section using Design Table 8.05i through 8.05o.

Determine the top width and depth for a vegetated channel.

Given:

Q: 40 cfs
Grade: 4%
Soil: easily erodible
Grass: bermudagrass

Site will allow a top width of 25 ft.

Find:

Channel top width and depth that will be stable and fit site conditions.

Solution:

From Table 8.05a use maximum permissible velocity = 5.0 ft/sec
From Design Table 8.05n use retardance “D” and “C”; grade 4.0%
Top width = 20.8 ft
Depth = 0.83 ft
V_2 = 3.42

NOTE: A design velocity V_1 of 4.0 ft/sec was used as it was less than maximum allowable and gave a top width that would fit site limitations. Wide, shallow vegetated channels are less subject to erosion, are less costly to maintain, and blend more readily into the natural landscape.

Design Tables for Grass-lined Diversions

Tables 8.05p through 8.05y may be used to facilitate the design of grass-lined diversions with parabolic cross-sections. These tables are based on a retardance of “D” (vegetation newly cut) to determine V_1 for stability considerations. To determine channel capacity, choose a retardance of “C” when proper maintenance is expected; otherwise, design channel capacity based on retardance “B”. Table 8.05c provides retardance classifications for selected vegetal covers. Table 8.05a gives maximum allowable velocities for grass-lined channels. The permissible velocities guide the selection of V_1 and should not be exceeded. It is good practice to use a value for V_1 that is significantly less than the maximum allowable when choosing a design cross-section. When velocities approach the maximum allowable, flatter grades should be evaluated or a more erosion resistant liner such as riprap should be considered.

Sample Problem 8.05f
Design of grass-lined diversions with a parabolic cross-section using Design Tables 8.05p through 8.05y.

Determine the top width and depth for a vegetated diversion.

Given:

Q: 30 cfs
Grade: 1%
Soil: easily erodible
Grass: Tall fescue
Maintenance: low, will be cut only twice a year. Site will allow a top width of 18 ft.

Find:

Diversion top width and depth that will be stable and fit site conditions.

Solution:

From Table 8.05a use maximum permissible velocity = 4.5 ft/sec
From Table 8.05c use Design Tables for capacity based on retardance “B”
From Table 8.05r use retardance “D” and “B”; grade 1%
Top width = 15 ft
Depth = 2.4 ft
V_2 = 1.8 ft/sec
NOTE: V_1 < 4.5 ft/sec; Top width < 18 ft, design OK.
Since V_1 for 2.0 & 2.5 provides a wider top than acceptable,
try V_1 = 3.0 ft/sec.

NOTE: In this case any other cross-section shown opposite Q=30 would have been stable. It is good practice, however, to select a cross-section that will give a velocity, V_1, well below the maximum allowable whenever site conditions permit. Wide, shallow cross-sections are more stable and require less maintenance. It is also prudent to evaluate flatter design grades in order to best fit diversions to the site and keep velocities well below maximum allowable.

Table 8.05i
Parabolic Waterway Design (Retardance “D” and “C”, Grade 0.25%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	9.6	2.36	1.63																								
30	11.4	2.31	1.68																								
35	13.2	2.27	1.73																								
40	15.0	2.25	1.76	10.4	2.67	2.13																					
45	16.8	2.23	1.78	11.6	2.62	2.19																					
50	18.6	2.21	1.80	12.8	2.59	2.24																					
55	20.4	2.20	1.82	14.0	2.56	2.28																					
60	22.2	2.19	1.83	15.2	2.53	2.31																					
65	24.0	2.18	1.84	16.5	2.54	2.30																					
70	25.8	2.18	1.85	17.7	2.52	2.33	12.6	3.05	2.70																		
75	27.6	2.17	1.86	18.9	2.51	2.35	13.4	3.00	2.76																		
80	29.4	2.17	1.87	20.1	2.50	2.37	14.3	3.01	2.76																		
90	33.1	2.17	1.86	22.6	2.49	2.38	16.0	2.97	2.81																		
100	36.7	2.17	1.87	25.1	2.49	2.38	17.7	2.95	2.85																		
110	40.3	2.16	1.88	27.5	2.47	2.41	19.4	2.93	2.88																		
120	43.9	2.16	1.89	30.0	2.47	2.41	21.1	2.91	2.91	15.2	3.58	3.28															
130	47.6	2.16	1.88	32.5	2.48	2.41	22.8	2.89	2.93	16.4	3.55	3.32															
140	51.2	2.16	1.88	34.9	2.46	2.43	24.6	2.91	2.91	17.6	3.53	3.35															
150	54.8	2.16	1.89	37.4	2.47	2.42	26.3	2.90	2.93	18.8	3.51	3.39															
160	58.4	2.16	1.89	39.9	2.47	2.42	28.0	2.89	2.95	20.0	3.49	3.41															
170	62.0	2.16	1.89	42.3	2.46	2.43	29.7	2.88	2.96	21.2	3.47	3.44	16.7	4.03	3.75												
180	65.6	2.16	1.90	44.8	2.47	2.43	31.4	2.87	2.97	22.4	3.46	3.46	17.6	4.00	3.81												
190	69.2	2.16	1.90	47.2	2.46	2.44	33.1	2.87	2.98	23.6	3.45	3.48	18.5	3.97	3.85												
200	72.8	2.16	1.90	49.7	2.46	2.44	34.9	2.88	2.97	24.8	3.44	3.49	19.4	3.94	3.90												
220	80.0	2.16	1.90	54.6	2.46	2.44	38.3	2.87	2.99	27.2	3.42	3.53	21.3	3.92	3.92												
240	87.3	2.16	1.90	59.5	2.46	2.45	41.7	2.86	3.00	29.6	3.40	3.55	23.1	3.88	3.99												
260	94.5	2.16	1.90	64.5	2.46	2.44	45.2	2.86	3.00	32.1	3.41	3.54	25.0	3.87	4.01	19.5	4.57	4.34									
280	101.7	2.16	1.90	69.4	2.46	2.45	48.6	2.85	3.01	34.5	3.40	3.56	26.9	3.86	4.02	21.0	4.57	4.34									
300	108.9	2.16	1.90	74.3	2.46	2.45	52.1	2.86	3.00	36.9	3.39	3.58	28.7	3.83	4.07	22.4	4.53	4.40									

Table 8.05j
Parabolic Waterway Design (Retardance “D” and “C”, Grade 0.5%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	8.6	1.63	1.58																								
20	11.3	1.58	1.66																								
25	14.1	1.57	1.67	9.0	1.91	2.14																					
30	16.9	1.56	1.68	10.7	1.87	2.21	8.2	2.18	2.48																		
35	19.6	1.55	1.71	12.4	1.85	2.26	9.4	2.10	2.62																		
40	22.4	1.55	1.71	14.1	1.83	2.30	10.7	2.08	2.66																		
45	25.1	1.54	1.73	15.8	1.82	2.33	11.9	2.03	2.76																		
50	27.9	1.54	1.73	17.5	1.80	2.35	13.2	2.02	2.78	9.6	2.42	3.19															
55	30.7	1.54	1.72	19.2	1.80	2.37	14.5	2.02	2.79	10.5	2.39	3.25															
60	33.4	1.54	1.74	20.9	1.79	2.38	15.8	2.01	2.80	11.4	2.37	3.30															
65	36.1	1.53	1.75	22.7	1.80	2.36	17.0	1.99	2.86	12.3	2.35	3.34															
70	38.9	1.54	1.74	24.4	1.80	2.37	18.3	1.99	2.86	13.2	2.33	3.38															
75	41.6	1.54	1.75	26.1	1.79	2.38	19.6	1.99	2.86	14.1	2.32	3.41	11.2	2.71	3.66												
80	44.3	1.53	1.75	27.8	1.79	2.39	20.9	1.99	2.86	15.0	2.31	3.43	11.8	2.65	3.80												
90	49.8	1.53	1.75	31.2	1.78	2.41	23.5	1.99	2.87	16.9	2.31	3.42	13.3	2.65	3.78												
100	55.3	1.53	1.75	34.6	1.78	2.42	26.0	1.97	2.90	18.7	2.29	3.47	14.7	2.63	3.85	11.9	3.02	4.13									
110	60.8	1.54	1.75	38.1	1.78	2.41	28.6	1.97	2.90	20.5	2.28	3.50	16.1	2.60	3.90	13.0	2.98	4.22									
120	66.3	1.54	1.75	41.5	1.78	2.42	31.2	1.98	2.90	22.4	2.29	3.49	17.5	2.58	3.94	14.1	2.94	4.30									
130	71.7	1.53	1.76	44.9	1.78	2.42	33.7	1.97	2.92	24.2	2.28	3.51	18.9	2.57	3.98	15.2	2.91	4.36									
140	77.2	1.54	1.76	48.3	1.78	2.43	36.3	1.97	2.92	26.0	2.27	3.54	20.4	2.58	3.95	16.4	2.93	4.34									
150	82.6	1.54	1.76	51.7	1.78	2.43	38.9	1.97	2.91	27.9	2.28	3.52	21.8	2.57	3.98	17.5	2.90	4.39	14.0	3.34	4.77						
160	88.0	1.53	1.76	55.1	1.78	2.44	41.4	1.97	2.93	29.7	2.27	3.54	23.2	2.56	4.01	18.6	2.88	4.44	14.9	3.33	4.80						
170	93.4	1.53	1.77	58.5	1.78	2.44	44.0	1.97	2.92	31.5	2.26	3.55	24.6	2.55	4.03	19.8	2.89	4.41	15.7	3.27	4.92						
180	98.8	1.53	1.77	61.9	1.78	2.44	46.5	1.96	2.94	33.3	2.26	3.57	26.1	2.56	4.01	20.9	2.88	4.45	16.6	3.26	4.94						
190	104.2	1.54	1.77	65.3	1.78	2.44	49.1	1.97	2.93	35.2	2.27	3.55	27.5	2.56	4.03	22.0	2.86	4.49	17.5	3.26	4.96						
200	109.6	1.54	1.77	68.7	1.78	2.44	51.6	1.96	2.94	37.0	2.26	3.56	28.9	2.55	4.04	23.1	2.85	4.52	18.4	3.25	4.98	15.3	3.72	5.23			
220	120.5	1.54	1.77	75.5	1.78	2.44	56.8	1.97	2.93	40.7	2.26	3.56	31.8	2.55	4.04	25.4	2.85	4.53	20.2	3.24	5.01	16.7	3.66	5.36			
240	131.3	1.54	1.77	82.3	1.78	2.45	61.9	1.97	2.94	44.3	2.26	3.58	34.6	2.54	4.07	27.7	2.85	4.53	22.0	3.23	5.04	18.2	3.65	5.38			
260	142.1	1.54	1.77	89.1	1.78	2.45	67.0	1.97	2.94	48.0	2.26	3.58	37.5	2.55	4.06	30.0	2.85	4.54	23.8	3.22	5.06	19.7	3.64	5.39			
280	152.9	1.54	1.78	95.9	1.78	2.45	72.1	1.97	2.95	51.6	2.25	3.59	40.3	2.54	4.08	32.2	2.83	4.58	25.6	3.21	5.08	21.1	3.61	5.48	17.5	4.14	5.75
300	163.7	1.54	1.78	102.6	1.78	2.46	77.2	1.97	2.95	55.3	2.26	3.59	43.2	2.54	4.08	34.5	2.83	4.58	27.3	3.18	5.15	22.6	3.60	5.49	18.7	4.12	5.80

Table 8.05k
Parabolic Waterway Design (Retardance "D" and "C", Grade 1.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	13.4	1.13	1.47	8.4	1.30	2.03																					
20	17.8	1.12	1.49	11.1	1.27	2.10	7.6	1.52	2.55																		
25	22.2	1.11	1.50	13.9	1.27	2.09	9.4	1.49	2.64	7.6	1.62	2.99															
30	26.6	1.11	1.50	16.6	1.26	2.13	11.2	1.46	2.71	9.1	1.61	3.03															
35	30.9	1.11	1.52	19.3	1.25	2.15	13.0	1.45	2.75	10.5	1.57	3.14	8.0	1.80	3.59												
40	35.3	1.11	1.52	22.1	1.26	2.13	14.8	1.44	2.79	12.0	1.57	3.14	9.1	1.78	3.65												
45	39.7	1.11	1.52	24.8	1.25	2.15	16.7	1.45	2.76	13.4	1.55	3.21	10.2	1.76	3.70												
50	44.0	1.11	1.52	27.5	1.25	2.16	18.5	1.44	2.79	14.9	1.55	3.21	11.3	1.75	3.74	8.7	2.02	4.20									
55	48.3	1.11	1.53	30.2	1.25	2.16	20.3	1.43	2.80	16.3	1.54	3.26	12.4	1.75	3.76	9.5	1.99	4.30									
60	52.7	1.11	1.52	32.9	1.25	2.17	22.1	1.43	2.82	17.8	1.54	3.25	13.5	1.74	3.79	10.4	2.01	4.26									
65	57.0	1.11	1.53	35.6	1.25	2.17	23.9	1.43	2.83	19.2	1.53	3.29	14.6	1.73	3.81	11.2	1.98	4.33	9.3	2.22	4.66						
70	61.3	1.11	1.53	38.3	1.25	2.17	25.7	1.43	2.84	20.7	1.53	3.27	15.6	1.71	3.90	12.0	1.96	4.40	10.0	2.21	4.69						
75	65.6	1.11	1.53	41.0	1.25	2.18	27.5	1.42	2.85	22.1	1.53	3.31	16.7	1.71	3.90	12.8	1.95	4.46	10.7	2.21	4.71						
80	69.8	1.11	1.54	43.7	1.25	2.18	29.3	1.42	2.85	23.6	1.53	3.29	17.8	1.71	3.91	13.7	1.96	4.42	11.3	2.16	4.85						
90	78.5	1.11	1.54	49.1	1.25	2.18	32.9	1.42	2.87	26.5	1.53	3.31	20.0	1.70	3.93	15.3	1.93	4.52	12.7	2.16	4.87	10.6	2.42	5.20			
100	87.1	1.11	1.54	54.5	1.25	2.18	36.6	1.43	2.85	29.4	1.52	3.32	22.2	1.70	3.94	17.0	1.93	4.52	14.1	2.15	4.89	11.7	2.39	5.31			
110	95.6	1.11	1.54	59.9	1.25	2.18	40.2	1.42	2.86	32.3	1.52	3.33	24.4	1.70	3.94	18.7	1.93	4.52	15.4	2.12	5.00	12.9	2.40	5.28	11.1	2.59	5.67
120	104.2	1.11	1.54	65.2	1.25	2.19	43.8	1.42	2.87	35.2	1.52	3.33	26.6	1.70	3.95	20.3	1.92	4.59	16.8	2.12	5.00	14.0	2.37	5.36	12.1	2.59	5.69
130	112.7	1.11	1.55	70.6	1.25	2.19	47.4	1.42	2.87	38.1	1.52	3.34	28.8	1.70	3.95	22.0	1.92	4.58	18.2	2.13	5.00	15.1	2.35	5.44	13.0	2.55	5.83
140	121.2	1.11	1.55	76.0	1.25	2.19	51.0	1.42	2.87	41.0	1.52	3.34	30.9	1.69	3.99	23.7	1.92	4.57	19.6	2.13	5.00	16.2	2.34	5.50	14.0	2.55	5.83
150	129.7	1.11	1.55	81.3	1.25	2.19	54.6	1.42	2.87	43.9	1.52	3.34	33.1	1.69	3.99	25.3	1.91	4.62	20.9	2.11	5.07	17.4	2.35	5.46	15.0	2.55	5.84
160	138.1	1.11	1.55	86.6	1.25	2.20	58.2	1.42	2.88	46.8	1.52	3.34	35.3	1.69	3.99	27.0	1.91	4.61	22.3	2.11	5.06	18.5	2.33	5.51	15.9	2.52	5.95
170	146.6	1.11	1.55	91.9	1.25	2.20	61.7	1.42	2.89	49.7	1.52	3.34	37.5	1.69	3.99	28.7	1.92	4.60	23.7	2.11	5.05	19.6	2.32	5.56	16.9	2.52	5.94
180	155.0	1.11	1.55	97.2	1.25	2.20	65.3	1.42	2.89	52.5	1.52	3.36	39.6	1.69	4.01	30.3	1.91	4.63	25.0	2.10	5.10	20.7	2.31	5.60	17.9	2.52	5.93
190	163.4	1.11	1.55	102.5	1.25	2.20	68.9	1.42	2.89	55.4	1.52	3.36	41.8	1.69	4.01	32.0	1.91	4.62	26.4	2.10	5.09	21.9	2.32	5.56	18.8	2.50	6.02
200	171.7	1.11	1.56	107.8	1.25	2.20	72.4	1.42	2.90	58.3	1.52	3.35	44.0	1.69	4.00	33.6	1.91	4.65	27.8	2.11	5.08	23.0	2.32	5.59	19.8	2.50	6.01
220	188.7	1.11	1.56	118.4	1.25	2.21	79.6	1.42	2.89	64.0	1.52	3.37	48.4	1.70	4.00	37.0	1.91	4.63	30.5	2.10	5.12	25.3	2.32	5.59	21.7	2.48	6.08
240	205.5	1.11	1.56	129.0	1.25	2.21	86.7	1.42	2.90	69.8	1.52	3.37	52.7	1.69	4.01	40.3	1.91	4.65	33.3	2.10	5.11	27.5	2.30	5.65	23.6	2.47	6.13
260	222.4	1.11	1.56	139.6	1.25	2.21	93.9	1.42	2.90	75.5	1.52	3.38	57.1	1.69	4.01	43.6	1.91	4.66	36.0	2.10	5.14	29.8	2.30	5.64	25.6	2.48	6.11
280	239.1	1.11	1.56	150.2	1.25	2.22	101.0	1.42	2.91	81.3	1.52	3.37	61.4	1.69	4.02	46.9	1.90	4.68	38.8	2.10	5.12	32.1	2.31	5.63	27.5	2.47	6.15
300	255.9	1.11	1.56	160.8	1.25	2.22	108.1	1.42	2.91	87.0	1.52	3.38	65.7	1.69	4.03	50.3	1.91	4.66	41.5	2.10	5.14	34.3	2.30	5.68	29.5	2.48	6.12

Table 8.05I
Parabolic Waterway Design (Retardance "D" and "C", Grade 2.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.8	0.81	1.32	12.8	0.91	1.90	9.3	1.00	2.37	6.7	1.15	2.85															
20	27.6	0.80	1.33	17.1	0.91	1.89	12.3	0.99	2.43	8.8	1.12	3.00	6.5	1.29	3.51	5.4	1.41	3.84									
25	34.5	0.81	1.33	21.3	0.91	1.91	15.4	0.99	2.43	11.0	1.11	3.01	8.0	1.25	3.69	6.7	1.38	3.96									
30	41.3	0.81	1.34	25.5	0.91	1.92	18.4	0.98	2.46	13.2	1.11	3.02	9.6	1.24	3.71	7.9	1.33	4.20	6.6	1.49	4.48						
35	48.0	0.80	1.35	29.7	0.91	1.93	21.5	0.99	2.44	15.3	1.10	3.08	11.1	1.22	3.82	9.2	1.33	4.23	7.6	1.45	4.68						
40	54.8	0.80	1.34	33.9	0.91	1.93	24.5	0.98	2.46	17.5	1.10	3.07	12.7	1.22	3.81	10.5	1.32	4.26	8.7	1.45	4.67	7.2	1.65	4.96			
45	61.5	0.80	1.35	38.1	0.91	1.93	27.5	0.98	2.47	19.6	1.10	3.11	14.3	1.23	3.80	11.8	1.32	4.27	9.7	1.43	4.80	8.0	1.61	5.16			
50	68.2	0.80	1.35	42.3	0.91	1.93	30.5	0.98	2.48	21.8	1.10	3.09	15.8	1.22	3.86	13.1	1.32	4.28	10.8	1.43	4.78	8.8	1.57	5.33	7.5	1.74	5.64
55	74.9	0.81	1.35	46.4	0.91	1.94	33.5	0.98	2.48	23.9	1.09	3.12	17.4	1.22	3.84	14.4	1.32	4.29	11.8	1.42	4.87	9.7	1.58	5.30	8.2	1.72	5.75
60	81.5	0.81	1.36	50.6	0.91	1.93	36.5	0.98	2.49	26.1	1.10	3.10	18.9	1.21	3.89	15.6	1.30	4.38	12.9	1.42	4.84	10.6	1.59	5.28	9.0	1.74	5.65
65	88.1	0.81	1.36	54.7	0.91	1.94	39.5	0.98	2.49	28.2	1.10	3.12	20.5	1.22	3.87	16.9	1.30	4.38	13.9	1.41	4.92	11.4	1.56	5.40	9.7	1.73	5.74
70	94.7	0.81	1.36	58.8	0.91	1.94	42.5	0.98	2.49	30.3	1.09	3.14	22.0	1.21	3.90	18.2	1.31	4.37	15.0	1.42	4.89	12.3	1.57	5.37	10.4	1.71	5.82
75	101.2	0.81	1.36	62.9	0.91	1.94	45.5	0.99	2.49	32.4	1.09	3.15	23.6	1.22	3.88	19.5	1.31	4.37	16.0	1.41	4.95	13.1	1.55	5.46	11.1	1.70	5.89
80	107.8	0.81	1.36	67.0	0.91	1.95	48.4	0.98	2.50	34.6	1.10	3.13	25.1	1.21	3.91	20.7	1.30	4.42	17.1	1.41	4.91	14.0	1.56	5.43	11.8	1.69	5.95
90	121.0	0.81	1.37	75.2	0.91	1.95	54.4	0.98	2.50	38.8	1.09	3.15	28.2	1.21	3.92	23.3	1.30	4.41	19.2	1.41	4.94	15.7	1.55	5.48	13.3	1.69	5.92
100	134.2	0.81	1.37	83.4	0.91	1.96	60.4	0.99	2.50	43.1	1.10	3.15	31.3	1.21	3.93	25.9	1.30	4.40	21.3	1.41	4.96	17.4	1.55	5.52	14.7	1.68	6.02
110	147.3	0.81	1.37	91.6	0.91	1.96	66.3	0.98	2.51	47.4	1.10	3.15	34.4	1.21	3.93	28.4	1.30	4.44	23.4	1.40	4.98	19.1	1.54	5.55	16.2	1.68	5.99
120	160.3	0.81	1.38	99.8	0.91	1.96	72.2	0.98	2.51	51.6	1.10	3.16	37.5	1.21	3.93	31.0	1.30	4.42	25.5	1.40	4.99	20.8	1.54	5.58	17.6	1.67	6.06
130	173.3	0.81	1.38	107.9	0.91	1.96	78.1	0.98	2.51	55.8	1.09	3.17	40.6	1.21	3.93	33.5	1.30	4.45	27.6	1.40	5.00	22.5	1.53	5.60	19.1	1.68	6.03
140	186.3	0.81	1.38	116.0	0.91	1.97	84.0	0.99	2.52	60.1	1.10	3.16	43.6	1.21	3.96	36.0	1.29	4.47	29.7	1.40	5.00	24.2	1.53	5.62	20.5	1.67	6.08
150	199.2	0.81	1.38	124.1	0.91	1.97	89.9	0.99	2.52	64.3	1.10	3.16	46.7	1.21	3.96	38.6	1.30	4.45	31.8	1.40	5.00	25.9	1.53	5.63	21.9	1.66	6.13
160	212.0	0.81	1.38	132.1	0.91	1.97	95.7	0.99	2.52	68.5	1.10	3.17	49.8	1.21	3.95	41.1	1.30	4.47	33.8	1.40	5.05	27.6	1.53	5.64	23.4	1.67	6.09
170	224.8	0.81	1.39	140.2	0.91	1.97	101.6	0.99	2.52	72.7	1.10	3.17	52.8	1.21	3.97	43.6	1.30	4.48	35.9	1.40	5.05	29.3	1.53	5.65	24.8	1.66	6.13
180	237.5	0.81	1.39	148.2	0.91	1.98	107.4	0.99	2.53	76.8	1.10	3.18	55.9	1.21	3.96	46.2	1.30	4.46	38.0	1.40	5.04	31.0	1.53	5.65	26.3	1.67	6.10
190	250.2	0.81	1.39	156.1	0.91	1.98	113.2	0.99	2.53	81.0	1.10	3.18	58.9	1.21	3.97	48.7	1.30	4.47	40.1	1.40	5.04	32.7	1.53	5.65	27.7	1.67	6.13
200	262.8	0.81	1.39	164.1	0.91	1.98	119.0	0.99	2.53	85.2	1.10	3.18	61.9	1.21	3.98	51.2	1.30	4.48	42.2	1.40	5.03	34.4	1.53	5.66	29.1	1.66	6.16
220	288.5	0.81	1.40	180.2	0.91	1.99	130.7	0.99	2.54	93.6	1.10	3.18	68.1	1.21	3.97	56.3	1.30	4.48	46.3	1.40	5.06	37.8	1.53	5.67	32.0	1.66	6.16
240	314.1	0.81	1.40	196.2	0.91	1.99	142.4	0.99	2.54	102.0	1.10	3.19	74.2	1.21	3.98	61.3	1.30	4.50	50.5	1.40	5.06	41.2	1.53	5.68	34.9	1.66	6.16
260	339.5	0.81	1.40	212.2	0.91	1.99	154.0	0.99	2.54	110.3	1.10	3.20	80.3	1.21	3.98	66.4	1.30	4.49	54.7	1.40	5.05	44.6	1.53	5.68	37.8	1.66	6.16
280	364.9	0.81	1.40	228.2	0.92	1.99	165.6	0.99	2.55	118.7	1.10	3.19	86.3	1.21	4.00	71.4	1.30	4.50	58.8	1.40	5.07	48.0	1.53	5.68	40.6	1.66	6.20
300	390.2	0.81	1.40	244.1	0.92	2.00	177.2	0.99	2.55	127.0	1.10	3.20	92.4	1.21	4.00	76.4	1.30	4.51	63.0	1.40	5.06	51.4	1.53	5.68	43.5	1.66	6.19

Table 8.05m
Parabolic Waterway Design (Retardance “D” and “C”, Grade 3.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	23.6	0.69	1.35	16.3	0.76	1.80	11.4	0.83	2.33	8.8	0.90	2.77	6.5	1.01	3.37	5.0	1.16	3.78									
20	31.4	0.69	1.36	21.7	0.76	1.81	15.2	0.83	2.34	11.7	0.90	2.81	8.6	0.99	3.48	6.6	1.13	3.94	5.9	1.19	4.17						
25	39.2	0.69	1.36	27.0	0.75	1.83	19.0	0.83	2.33	14.6	0.90	2.83	10.8	0.99	3.44	8.1	1.09	4.18	7.3	1.16	4.33	6.0	1.27	4.80			
30	46.9	0.69	1.37	32.4	0.75	1.82	22.7	0.83	2.36	17.4	0.88	2.89	12.9	0.98	3.49	9.7	1.08	4.22	8.7	1.15	4.44	7.1	1.24	5.03	5.8	1.41	5.37
35	54.6	0.69	1.37	37.7	0.75	1.83	26.4	0.83	2.38	20.3	0.89	2.88	15.0	0.98	3.53	11.3	1.08	4.25	10.1	1.13	4.51	8.3	1.24	5.02	6.7	1.38	5.55
40	62.2	0.69	1.37	43.0	0.75	1.83	30.2	0.83	2.37	23.2	0.89	2.88	17.1	0.98	3.55	12.9	1.08	4.26	11.5	1.13	4.57	9.4	1.22	5.17	7.6	1.36	5.70
45	69.9	0.70	1.37	48.3	0.75	1.83	33.9	0.83	2.37	26.0	0.88	2.90	19.2	0.97	3.57	14.5	1.08	4.27	12.9	1.12	4.61	10.6	1.22	5.14	8.5	1.34	5.81
50	77.4	0.69	1.38	53.5	0.75	1.84	37.6	0.83	2.38	28.9	0.89	2.89	21.3	0.97	3.58	16.0	1.06	4.36	14.3	1.12	4.63	11.7	1.21	5.24	9.4	1.33	5.90
55	85.0	0.70	1.38	58.7	0.75	1.85	41.2	0.83	2.40	31.7	0.89	2.91	23.4	0.97	3.58	17.6	1.06	4.35	15.7	1.11	4.66	12.9	1.21	5.20	10.4	1.35	5.80
60	92.5	0.70	1.38	64.0	0.75	1.84	44.9	0.83	2.40	34.5	0.88	2.92	25.5	0.97	3.59	19.2	1.07	4.35	17.1	1.11	4.67	14.0	1.20	5.28	11.3	1.34	5.87
65	99.9	0.69	1.39	69.1	0.75	1.85	48.6	0.83	2.39	37.3	0.88	2.93	27.6	0.97	3.59	20.8	1.07	4.34	18.5	1.11	4.69	15.2	1.21	5.24	12.2	1.33	5.93
70	107.3	0.69	1.39	74.3	0.75	1.86	52.2	0.83	2.40	40.1	0.88	2.93	29.7	0.98	3.59	22.3	1.06	4.39	19.9	1.11	4.69	16.3	1.20	5.30	13.1	1.32	5.98
75	114.7	0.70	1.39	79.4	0.75	1.86	55.8	0.83	2.41	42.9	0.88	2.94	31.8	0.98	3.59	23.9	1.06	4.38	21.3	1.11	4.70	17.5	1.21	5.26	14.0	1.32	6.02
80	122.1	0.70	1.40	84.5	0.75	1.87	59.4	0.83	2.42	45.7	0.88	2.94	33.9	0.98	3.58	25.5	1.07	4.36	22.7	1.11	4.70	18.6	1.20	5.31	15.0	1.33	5.94
90	137.0	0.70	1.40	94.9	0.75	1.87	66.7	0.83	2.42	51.4	0.89	2.93	38.0	0.97	3.61	28.6	1.06	4.40	25.5	1.11	4.72	20.9	1.20	5.33	16.8	1.32	6.01
100	151.8	0.70	1.40	105.2	0.75	1.87	74.0	0.83	2.42	57.0	0.89	2.94	42.2	0.98	3.61	31.7	1.06	4.42	28.3	1.11	4.73	23.2	1.20	5.34	18.6	1.31	6.08
110	166.6	0.70	1.41	115.5	0.75	1.87	81.3	0.83	2.42	62.6	0.89	2.95	46.4	0.98	3.61	34.9	1.06	4.40	31.0	1.10	4.78	25.5	1.20	5.34	20.5	1.32	6.04
120	181.3	0.70	1.41	125.7	0.75	1.88	88.5	0.83	2.43	68.2	0.89	2.95	50.5	0.98	3.62	38.0	1.06	4.42	33.8	1.11	4.78	27.7	1.19	5.40	22.3	1.32	6.08
130	195.9	0.70	1.41	135.9	0.76	1.88	95.7	0.83	2.43	73.7	0.89	2.96	54.6	0.98	3.63	41.1	1.06	4.43	36.6	1.11	4.77	30.0	1.19	5.40	24.2	1.32	6.04
140	210.5	0.70	1.41	146.1	0.76	1.88	102.8	0.83	2.44	79.3	0.89	2.96	58.8	0.98	3.62	44.2	1.06	4.44	39.4	1.11	4.77	32.3	1.20	5.39	26.0	1.32	6.08
150	225.0	0.70	1.42	156.2	0.76	1.89	110.0	0.83	2.44	84.8	0.89	2.96	62.9	0.98	3.63	47.3	1.06	4.44	42.1	1.11	4.80	34.6	1.20	5.38	27.8	1.31	6.11
160	239.4	0.70	1.42	166.2	0.76	1.89	117.1	0.83	2.45	90.3	0.89	2.97	67.0	0.98	3.63	50.4	1.06	4.45	44.9	1.11	4.79	36.8	1.19	5.42	29.6	1.31	6.13
170	253.7	0.70	1.42	176.2	0.76	1.90	124.2	0.83	2.45	95.8	0.89	2.97	71.1	0.98	3.64	53.5	1.06	4.45	47.7	1.11	4.78	39.1	1.20	5.41	31.5	1.32	6.09
180	268.0	0.70	1.43	186.2	0.76	1.90	131.2	0.83	2.46	101.3	0.89	2.97	75.2	0.98	3.64	56.6	1.06	4.45	50.4	1.11	4.80	41.3	1.19	5.44	33.3	1.32	6.11
190	282.2	0.70	1.43	196.1	0.76	1.90	138.3	0.83	2.46	106.7	0.89	2.98	79.2	0.98	3.65	59.7	1.07	4.45	53.1	1.11	4.81	43.6	1.20	5.42	35.1	1.32	6.12
200	296.3	0.70	1.43	206.0	0.76	1.90	145.3	0.83	2.46	112.2	0.89	2.98	83.3	0.98	3.65	62.7	1.06	4.47	55.9	1.11	4.80	45.8	1.19	5.45	36.9	1.32	6.14
220	325.1	0.70	1.44	226.1	0.76	1.91	159.5	0.83	2.47	123.2	0.89	2.98	91.5	0.98	3.65	68.9	1.06	4.47	61.4	1.11	4.81	50.4	1.20	5.43	40.6	1.32	6.12
240	353.8	0.70	1.44	246.2	0.76	1.91	173.7	0.83	2.47	134.2	0.89	2.99	99.7	0.98	3.65	75.1	1.07	4.47	66.9	1.11	4.81	54.9	1.20	5.44	44.2	1.32	6.15
260	382.4	0.70	1.44	266.1	0.76	1.92	187.8	0.83	2.48	145.1	0.89	2.99	107.8	0.98	3.67	81.3	1.07	4.47	72.4	1.11	4.82	59.4	1.20	5.45	47.8	1.31	6.17
280	410.8	0.70	1.45	286.0	0.76	1.92	201.9	0.83	2.48	156.0	0.89	3.00	116.0	0.98	3.66	87.4	1.07	4.48	77.9	1.11	4.82	63.9	1.20	5.46	51.5	1.32	6.15
300	439.0	0.70	1.45	305.8	0.76	1.92	215.9	0.83	2.49	166.9	0.89	3.00	124.1	0.98	3.67	93.6	1.07	4.47	83.3	1.11	4.83	68.4	1.20	5.46	55.1	1.32	6.17

Table 8.05n
Parabolic Waterway Design (Retardance “D” and “C”, Grade 4.0%)

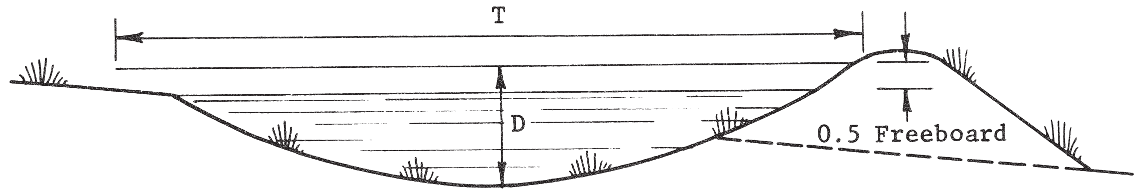
Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	27.9	0.62	1.29	19.9	0.66	1.68	13.9	0.73	2.20	10.3	0.79	2.73	7.9	0.85	3.28	6.3	0.92	3.78	4.9	1.06	4.21						
20	37.1	0.62	1.29	26.5	0.66	1.69	18.5	0.72	2.21	13.7	0.78	2.76	10.5	0.84	3.33	8.4	0.92	3.81	6.4	1.01	4.52	5.5	1.09	4.88			
25	46.2	0.62	1.30	33.0	0.66	1.70	23.0	0.72	2.24	17.1	0.78	2.77	13.1	0.84	3.35	10.5	0.92	3.82	8.0	1.01	4.55	6.8	1.06	5.09	5.7	1.20	5.34
30	55.3	0.62	1.30	39.5	0.66	1.70	27.6	0.72	2.23	20.4	0.77	2.82	15.7	0.84	3.36	12.5	0.91	3.92	9.5	0.99	4.71	8.2	1.07	5.03	6.7	1.15	5.71
35	64.3	0.62	1.31	46.0	0.66	1.71	32.1	0.72	2.25	23.8	0.78	2.81	18.3	0.84	3.37	14.6	0.91	3.90	11.1	0.99	4.70	9.5	1.06	5.15	7.8	1.15	5.77
40	73.3	0.62	1.31	52.4	0.66	1.71	36.6	0.72	2.25	27.1	0.77	2.83	20.8	0.83	3.42	16.6	0.90	3.96	12.7	1.00	4.68	10.8	1.04	5.24	8.9	1.14	5.81
45	82.2	0.62	1.32	58.8	0.66	1.72	41.1	0.72	2.26	30.4	0.77	2.85	23.4	0.84	3.41	18.7	0.91	3.94	14.2	0.98	4.77	12.2	1.05	5.17	10.0	1.14	5.83
50	91.1	0.62	1.32	65.2	0.66	1.72	45.6	0.72	2.26	33.7	0.77	2.86	26.0	0.84	3.40	20.7	0.90	3.97	15.8	0.99	4.74	13.5	1.05	5.24	11.1	1.14	5.85
55	99.9	0.62	1.32	71.5	0.66	1.73	50.1	0.72	2.26	37.0	0.77	2.86	28.5	0.84	3.43	22.8	0.91	3.95	17.3	0.98	4.80	14.8	1.04	5.28	12.2	1.14	5.87
60	108.7	0.62	1.32	77.8	0.66	1.73	54.5	0.72	2.26	40.3	0.77	2.87	31.0	0.83	3.45	24.8	0.90	3.97	18.9	0.99	4.77	16.1	1.04	5.32	13.3	1.14	5.88
65	117.4	0.62	1.33	84.1	0.66	1.73	58.9	0.72	2.27	43.6	0.77	2.87	33.6	0.84	3.43	26.8	0.90	3.99	20.4	0.98	4.81	17.5	1.05	5.26	14.3	1.12	6.00
70	126.1	0.62	1.33	90.3	0.66	1.74	63.3	0.72	2.27	46.9	0.77	2.86	36.1	0.84	3.44	28.8	0.90	4.01	21.9	0.98	4.85	18.8	1.04	5.29	15.4	1.12	6.00
75	134.7	0.62	1.33	96.5	0.66	1.74	67.7	0.72	2.28	50.1	0.77	2.88	38.6	0.84	3.45	30.9	0.91	3.98	23.5	0.98	4.82	20.1	1.04	5.31	16.5	1.13	5.99
80	143.3	0.62	1.34	102.7	0.66	1.74	72.1	0.72	2.28	53.3	0.77	2.89	41.1	0.84	3.46	32.9	0.91	3.99	25.0	0.98	4.84	21.4	1.04	5.33	17.6	1.13	5.98
90	160.8	0.62	1.34	115.2	0.66	1.75	80.9	0.72	2.28	59.9	0.77	2.89	46.2	0.84	3.46	36.9	0.90	4.01	28.1	0.98	4.85	24.0	1.04	5.38	19.7	1.12	6.07
100	178.2	0.62	1.34	127.7	0.66	1.75	89.7	0.72	2.29	66.4	0.77	2.90	51.2	0.84	3.47	41.0	0.91	4.00	31.2	0.98	4.85	26.7	1.04	5.35	21.9	1.12	6.05
110	195.4	0.62	1.35	140.1	0.66	1.76	98.5	0.72	2.29	72.9	0.77	2.90	56.2	0.84	3.48	45.0	0.90	4.02	34.3	0.98	4.85	29.3	1.04	5.37	24.1	1.12	6.03
120	212.6	0.62	1.35	152.5	0.66	1.76	107.2	0.72	2.30	79.4	0.77	2.90	61.2	0.84	3.49	49.0	0.90	4.03	37.3	0.98	4.88	31.9	1.04	5.40	26.2	1.12	6.09
130	229.6	0.62	1.35	164.8	0.66	1.76	115.9	0.72	2.30	85.9	0.77	2.91	66.2	0.84	3.49	53.0	0.90	4.03	40.4	0.98	4.87	34.6	1.04	5.36	28.4	1.12	6.07
140	246.6	0.62	1.36	177.0	0.66	1.77	124.5	0.72	2.30	92.3	0.77	2.91	71.2	0.84	3.49	57.0	0.90	4.04	43.4	0.98	4.90	37.2	1.04	5.38	30.5	1.12	6.10
150	263.5	0.62	1.36	189.1	0.66	1.77	133.2	0.73	2.30	98.7	0.77	2.92	76.2	0.84	3.49	61.0	0.91	4.04	46.5	0.98	4.88	39.8	1.04	5.39	32.7	1.12	6.08
160	280.3	0.62	1.36	201.2	0.66	1.78	141.7	0.73	2.31	105.1	0.77	2.92	81.1	0.84	3.50	65.0	0.91	4.04	49.5	0.98	4.90	42.4	1.04	5.40	34.8	1.12	6.11
170	296.9	0.62	1.37	213.3	0.67	1.78	150.3	0.73	2.31	111.5	0.78	2.92	86.0	0.84	3.51	68.9	0.91	4.05	52.5	0.98	4.91	45.0	1.04	5.40	36.9	1.12	6.13
180	313.5	0.62	1.37	225.3	0.67	1.78	158.8	0.73	2.32	117.8	0.78	2.93	90.9	0.84	3.52	72.9	0.91	4.05	55.6	0.98	4.90	47.6	1.04	5.40	39.1	1.12	6.11
190	330.0	0.62	1.37	237.2	0.67	1.79	167.3	0.73	2.32	124.2	0.78	2.93	95.8	0.84	3.52	76.8	0.91	4.06	58.6	0.98	4.90	50.2	1.04	5.40	41.2	1.12	6.12
200	346.4	0.62	1.37	249.1	0.67	1.79	175.7	0.73	2.32	130.5	0.78	2.93	100.7	0.84	3.52	80.7	0.91	4.07	61.6	0.98	4.91	52.7	1.04	5.43	43.3	1.12	6.14
220	380.0	0.62	1.38	273.3	0.67	1.79	192.9	0.73	2.33	143.3	0.78	2.93	110.6	0.84	3.53	88.7	0.91	4.07	67.6	0.98	4.93	57.9	1.04	5.44	47.6	1.12	6.14
240	413.3	0.62	1.38	297.4	0.67	1.80	209.9	0.73	2.33	156.0	0.78	2.94	120.4	0.84	3.53	96.6	0.91	4.07	73.7	0.98	4.93	63.1	1.04	5.44	51.9	1.12	6.14
260	446.5	0.62	1.39	321.4	0.67	1.80	227.0	0.73	2.33	168.7	0.78	2.94	130.2	0.84	3.54	104.5	0.91	4.08	79.7	0.98	4.94	68.3	1.04	5.44	56.2	1.12	6.13
280	479.5	0.62	1.39	345.3	0.67	1.80	243.9	0.73	2.34	181.3	0.78	2.95	140.0	0.84	3.54	112.3	0.91	4.09	85.8	0.99	4.93	73.5	1.04	5.44	60.4	1.12	6.15
300	512.3	0.62	1.39	369.0	0.67	1.81	260.8	0.73	2.34	193.9	0.78	2.95	149.8	0.84	3.55	120.2	0.91	4.09	91.8	0.99	4.94	78.6	1.04	5.46	64.7	1.12	6.14

Table 8.05o
Parabolic Waterway Design (Retardance "D" and "C", Grade 5.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	29.3	0.57	1.33	21.1	0.60	1.74	15.0	0.66	2.23	12.2	0.70	2.58	9.0	0.75	3.25	7.2	0.83	3.70	5.8	0.93	4.09	4.6	0.99	4.81			
20	39.0	0.57	1.33	28.1	0.61	1.74	19.9	0.66	2.26	16.2	0.70	2.62	12.0	0.75	3.26	9.5	0.81	3.84	7.6	0.89	4.35	6.1	0.97	4.95	5.3	1.06	5.21
25	48.6	0.57	1.34	35.1	0.61	1.73	24.8	0.66	2.28	20.3	0.70	2.59	15.0	0.75	3.27	11.9	0.81	3.82	9.5	0.89	4.37	7.6	0.96	5.03	6.5	1.02	5.56
30	58.1	0.57	1.34	42.0	0.61	1.74	29.7	0.66	2.28	24.3	0.70	2.61	18.0	0.76	3.26	14.2	0.80	3.89	11.3	0.87	4.49	9.1	0.96	5.08	7.8	1.01	5.59
35	67.6	0.57	1.35	48.8	0.61	1.75	34.6	0.66	2.28	28.2	0.70	2.64	20.9	0.75	3.30	16.6	0.81	3.86	13.2	0.88	4.47	10.5	0.94	5.26	9.1	1.01	5.60
40	77.0	0.57	1.35	55.7	0.61	1.75	39.5	0.66	2.28	32.2	0.70	2.64	23.9	0.75	3.29	18.9	0.80	3.90	15.1	0.88	4.46	12.0	0.94	5.26	10.3	0.99	5.77
45	86.4	0.57	1.35	62.5	0.61	1.75	44.3	0.66	2.29	36.1	0.70	2.65	26.8	0.75	3.31	21.3	0.81	3.87	16.9	0.87	4.52	13.5	0.94	5.25	11.6	1.00	5.75
50	95.7	0.57	1.36	69.2	0.61	1.76	49.1	0.66	2.30	40.1	0.70	2.64	29.7	0.75	3.32	23.6	0.81	3.89	18.8	0.88	4.50	15.0	0.94	5.25	12.9	1.00	5.73
55	105.0	0.57	1.36	75.9	0.61	1.77	53.9	0.66	2.30	44.0	0.70	2.65	32.6	0.75	3.33	25.9	0.81	3.90	20.6	0.87	4.54	16.5	0.94	5.24	14.1	0.99	5.84
60	114.2	0.57	1.36	82.6	0.61	1.77	58.7	0.66	2.30	47.9	0.70	2.66	35.5	0.75	3.34	28.2	0.81	3.92	22.4	0.87	4.57	17.9	0.93	5.32	15.4	0.99	5.81
65	123.4	0.57	1.36	89.3	0.61	1.77	63.4	0.66	2.31	51.8	0.70	2.66	38.4	0.75	3.34	30.5	0.81	3.92	24.3	0.87	4.54	19.4	0.94	5.30	16.7	1.00	5.78
70	132.4	0.57	1.37	95.9	0.61	1.77	68.2	0.66	2.31	55.6	0.70	2.67	41.3	0.75	3.34	32.8	0.81	3.93	26.1	0.87	4.56	20.8	0.93	5.36	17.9	0.99	5.85
75	141.5	0.57	1.37	102.4	0.61	1.78	72.9	0.66	2.31	59.4	0.70	2.68	44.1	0.75	3.36	35.1	0.81	3.93	27.9	0.87	4.58	22.3	0.93	5.34	19.2	1.00	5.82
80	150.5	0.57	1.37	109.0	0.61	1.78	77.5	0.66	2.32	63.3	0.70	2.68	47.0	0.75	3.36	37.4	0.81	3.92	29.7	0.87	4.60	23.8	0.94	5.32	20.4	0.99	5.88
90	168.8	0.57	1.38	122.3	0.61	1.79	87.0	0.66	2.33	71.0	0.70	2.69	52.8	0.75	3.36	42.0	0.81	3.93	33.4	0.87	4.59	26.7	0.94	5.35	22.9	0.99	5.91
100	187.0	0.57	1.38	135.5	0.61	1.79	96.5	0.66	2.33	78.7	0.70	2.70	58.5	0.75	3.37	46.5	0.81	3.96	37.0	0.87	4.62	29.6	0.93	5.38	25.5	0.99	5.86
110	205.1	0.57	1.38	148.7	0.61	1.79	105.9	0.66	2.33	86.4	0.70	2.70	64.3	0.75	3.37	51.1	0.81	3.96	40.7	0.87	4.61	32.5	0.93	5.39	28.0	0.99	5.88
120	223.1	0.57	1.39	161.8	0.61	1.80	115.3	0.66	2.33	94.1	0.70	2.70	70.0	0.75	3.38	55.7	0.81	3.96	44.3	0.87	4.62	35.4	0.93	5.41	30.5	0.99	5.89
130	240.9	0.57	1.39	174.8	0.61	1.80	124.6	0.66	2.34	101.7	0.70	2.71	75.7	0.76	3.38	60.2	0.81	3.97	47.9	0.87	4.64	38.3	0.93	5.41	33.0	0.99	5.90
140	258.7	0.57	1.40	187.7	0.61	1.81	133.9	0.66	2.34	109.3	0.70	2.71	81.3	0.75	3.39	64.7	0.81	3.98	51.5	0.87	4.64	41.2	0.93	5.42	35.5	0.99	5.91
150	276.4	0.58	1.40	200.6	0.61	1.81	143.1	0.66	2.35	116.8	0.70	2.72	87.0	0.76	3.39	69.3	0.81	3.97	55.1	0.87	4.65	44.1	0.93	5.42	37.9	0.99	5.96
160	293.9	0.58	1.40	213.4	0.61	1.81	152.3	0.66	2.35	124.3	0.70	2.72	92.6	0.76	3.40	73.7	0.81	3.99	58.7	0.87	4.65	47.0	0.94	5.42	40.4	0.99	5.95
170	311.4	0.58	1.40	226.1	0.61	1.82	161.5	0.66	2.35	131.8	0.70	2.73	98.2	0.76	3.41	78.2	0.81	3.99	62.3	0.87	4.65	49.9	0.94	5.41	42.9	0.99	5.95
180	328.7	0.58	1.41	238.8	0.61	1.82	170.6	0.66	2.36	139.2	0.70	2.73	103.8	0.76	3.41	82.7	0.81	3.99	65.9	0.87	4.65	52.7	0.93	5.44	45.4	0.99	5.94
190	346.0	0.58	1.41	251.4	0.61	1.83	179.7	0.67	2.36	146.6	0.70	2.74	109.4	0.76	3.41	87.1	0.81	4.00	69.4	0.87	4.67	55.6	0.94	5.43	47.8	0.99	5.97
200	363.1	0.58	1.42	263.9	0.61	1.83	188.7	0.67	2.37	154.0	0.70	2.74	114.9	0.76	3.42	91.6	0.81	4.00	73.0	0.87	4.66	58.4	0.94	5.45	50.3	0.99	5.96
220	398.3	0.58	1.42	289.6	0.62	1.83	207.1	0.67	2.37	169.0	0.70	2.75	126.1	0.76	3.43	100.6	0.81	4.00	80.1	0.87	4.68	64.2	0.94	5.45	55.2	0.99	5.99
240	433.2	0.58	1.42	315.0	0.62	1.84	225.4	0.67	2.37	184.0	0.70	2.75	137.4	0.76	3.43	109.5	081	4.01	87.3	0.87	4.68	69.9	0.94	5.46	60.2	0.99	5.98
260	467.9	0.58	1.43	340.4	0.62	1.84	243.7	0.67	2.38	198.9	0.70	2.76	148.5	0.76	3.44	118.5	0.81	4.01	94.4	0.87	4.69	75.6	0.94	5.47	65.1	0.99	5.99
280	502.5	0.58	1.43	365.6	0.62	1.84	261.8	0.67	2.38	213.7	0.70	2.76	159.7	0.76	3.44	127.4	0.81	4.02	101.5	0.87	4.70	81.4	0.94	5.46	70.0	0.99	6.01
300	536.7	0.58	1.43	390.7	0.62	1.85	279.9	0.67	2.38	228.5	0.71	2.77	170.7	0.76	3.45	136.2	0.81	4.03	108.6	0.87	4.70	87.0	0.94	5.48	74.9	0.99	6.01

Table 8.05p
Parabolic Diversion Design (Retardance “D” and “B”, Grade 0.25%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	12	3.8	1.0																								
30	14	3.6	1.1																								
35	17	3.5	1.1																								
40	19	3.5	1.2	13	4.1	1.4																					
45	21	3.4	1.2	14	4.0	1.4																					
50	23	3.4	1.2	16	3.9	1.5																					
55	26	3.4	1.2	17	3.9	1.5																					
60	28	3.4	1.2	19	3.9	1.5																					
65	30	3.4	1.2	20	3.8	1.6																					
70	32	3.4	1.2	22	3.8	1.6	15	4.5	1.8																		
75	34	3.4	1.2	23	3.8	1.6	16	4.4	1.9																		
80	37	3.4	1.2	25	3.8	1.6	17	4.4	1.9																		
90	41	3.4	1.2	28	3.8	1.6	19	4.3	1.9																		
100	46	3.4	1.2	31	3.7	1.6	21	4.3	2.0																		
110	50	3.4	1.2	34	3.7	1.6	23	4.2	2.0																		
120	55	3.4	1.3	37	3.7	1.6	26	4.2	2.0	18	5.0	2.3															
130	59	3.4	1.3	40	3.7	1.6	28	4.2	2.0	19	4.9	2.4															
140	64	3.3	1.3	43	3.7	1.7	30	4.2	2.0	21	4.9	2.4															
150	68	3.3	1.3	46	3.7	1.7	32	4.2	2.0	22	4.8	2.5															
160	73	3.3	1.3	49	3.7	1.7	34	4.2	2.0	24	4.8	2.5															
170	77	3.3	1.3	52	3.7	1.7	36	4.2	2.1	25	4.8	2.5	20	5.5	2.8												
180	82	3.3	1.3	55	3.7	1.7	38	4.2	2.1	26	4.7	2.6	21	5.4	2.8												
190	86	3.3	1.3	58	3.7	1.7	40	4.2	2.1	28	4.7	2.6	22	5.4	2.8												
200	91	3.3	1.3	61	3.7	1.7	42	4.2	2.1	29	4.7	2.6	23	5.3	2.9												
220				67	3.7	1.7	46	4.2	2.1	32	4.7	2.6	25	5.3	2.9												
240				73	3.7	1.7	50	4.1	2.1	35	4.7	2.6	27	5.2	3.0												
260				79	3.7	1.7	54	4.1	2.1	38	4.7	2.6	29	5.2	3.0	22	6.0	3.3									
280				85	3.7	1.7	59	4.1	2.1	40	4.6	2.6	31	5.1	3.1	24	5.9	3.4									
300				91	3.7	1.7	63	4.1	2.1	43	4.6	2.7	33	5.1	3.1	26	5.9	3.4									



T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05q
Parabolic Diversion Design (Retardance “D” and “B”, Grade 0.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	12	2.8	1.0																								
20	15	2.7	1.0																								
25	18	2.7	1.1	12	3.1	1.4																					
30	22	2.6	1.1	14	3.0	1.4	10	3.4	1.6																		
35	25	2.6	1.1	16	3.0	1.5	12	3.3	1.7																		
40	29	2.6	1.1	18	2.9	1.5	13	3.2	1.8																		
45	33	2.6	1.1	20	2.9	1.5	15	3.2	1.8																		
50	36	2.6	1.1	22	2.9	1.5	17	3.1	1.9	12	3.7	2.1															
55	40	2.6	1.1	24	2.9	1.6	18	3.1	1.9	13	3.6	2.2															
60	43	2.6	1.1	27	2.9	1.6	20	3.1	1.9	14	3.6	2.2															
65	47	2.6	1.1	29	2.9	1.6	21	3.1	1.9	15	3.5	2.3															
70	50	2.6	1.1	31	2.9	1.6	23	3.1	1.9	16	3.5	2.3															
75	54	2.6	1.1	33	2.9	1.6	25	3.1	1.9	17	3.5	2.3	14	4.0	2.5												
80	58	2.6	1.1	35	2.9	1.6	26	3.1	1.9	18	3.5	2.4	15	3.9	2.6												
90	65	2.6	1.1	40	2.9	1.6	29	3.1	2.0	21	3.5	2.4	16	3.9	2.6												
100	72	2.6	1.1	44	2.8	1.6	32	3.1	2.0	23	3.4	2.4	18	3.8	2.7	14	4.3	3.0									
110	79	2.6	1.1	48	2.8	1.6	36	3.1	2.0	25	3.4	2.4	20	3.8	2.8	16	4.2	3.1									
120	86	2.6	1.1	52	2.8	1.6	39	3.1	2.0	27	3.4	2.5	21	3.7	2.8	17	4.1	3.1									
130	93	2.6	1.1	57	2.8	1.6	42	3.1	2.0	30	3.4	2.5	23	3.7	2.8	18	4.1	3.2									
140				61	2.8	1.6	45	3.1	2.0	32	3.4	2.5	25	3.7	2.8	19	4.1	3.2									
150				65	2.8	1.6	48	3.1	2.0	34	3.4	2.5	26	3.7	2.9	21	4.1	3.2	17	4.6	3.5						
160				70	2.8	1.6	52	3.0	2.0	36	3.4	2.5	28	3.7	2.9	22	4.0	3.3	18	4.5	3.6						
170				74	2.8	1.6	55	3.0	2.0	39	3.4	2.5	30	3.7	2.9	24	4.0	3.3	19	4.5	3.6						
180				78	2.8	1.6	58	3.0	2.0	41	3.4	2.5	31	3.7	2.9	25	4.0	3.3	20	4.5	3.7						
190				83	2.8	1.6	61	3.0	2.0	43	3.4	2.5	33	3.7	2.9	26	4.0	3.3	21	4.5	3.7						
200				87	2.8	1.6	64	3.0	2.0	45	3.4	2.5	35	3.7	2.9	27	4.0	3.3	22	4.4	3.8	18	5.0	4.0			
220				95	2.8	1.6	71	3.0	2.0	50	3.4	2.5	38	3.7	2.9	30	4.0	3.4	24	4.4	3.8	19	4.9	4.1			
240							77	3.0	2.0	54	3.4	2.5	42	3.7	2.9	33	4.0	3.4	26	4.4	3.8	21	4.9	4.1			
260							83	3.0	2.0	59	3.4	2.5	45	3.7	3.0	36	4.0	3.4	28	4.3	3.9	23	4.8	4.2			
280							90	3.0	2.0	63	3.4	2.5	48	3.7	3.0	38	4.0	3.4	30	4.3	3.9	24	4.8	4.2	20	5.4	4.5
300							96	3.0	2.0	68	3.4	2.5	52	3.6	3.0	41	4.0	3.4	32	4.3	3.9	26	4.8	4.3	21	5.3	4.6

T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05r
Parabolic Diversion Design (Retardance “D” and “B”, Grade 1.0%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	18	2.1	0.9	11	2.3	1.2																					
20	24	2.0	0.9	15	2.2	1.3	10	2.5	1.7																		
25	30	2.0	0.9	19	2.2	1.3	12	2.5	1.7	10	2.7	1.9															
30	36	2.0	0.9	22	2.2	1.4	15	2.4	1.8	12	2.6	2.0															
35	42	2.0	0.9	26	2.2	1.4	17	2.4	1.8	14	2.6	2.1	10	2.9	2.4												
40	48	2.0	1.0	29	2.2	1.4	19	2.4	1.8	15	2.5	2.1	12	2.8	2.5												
45	54	2.0	1.0	33	2.2	1.4	22	2.4	1.8	17	2.5	2.1	13	2.8	2.5												
50	59	2.0	1.0	37	2.2	1.4	24	2.4	1.9	19	2.5	2.2	14	2.8	2.5	11	3.1	2.9									
55	65	2.0	1.0	40	2.2	1.4	26	2.4	1.9	21	2.5	2.2	16	2.8	2.6	12	3.1	2.9									
60	71	2.0	1.0	44	2.2	1.4	29	2.4	1.9	23	2.5	2.2	17	2.7	2.6	13	3.0	3.0									
65	77	2.0	1.0	47	2.2	1.4	31	2.4	1.9	25	2.5	2.2	18	2.7	2.6	14	3.0	3.0	11	3.4	3.2						
70	83	2.0	1.0	51	2.2	1.4	33	2.4	1.9	26	2.5	2.2	20	2.7	2.6	15	3.0	3.0	12	3.3	3.3						
75	88	2.0	1.0	54	2.2	1.4	36	2.4	1.9	28	2.5	2.2	21	2.7	2.7	16	3.0	3.1	13	3.3	3.4						
80	94	2.0	1.0	58	2.2	1.4	38	2.4	1.9	30	2.5	2.2	23	2.7	2.7	17	3.0	3.1	14	3.2	3.4						
90				65	2.2	1.4	43	2.4	1.9	34	2.5	2.2	25	2.7	2.7	19	3.0	3.1	16	3.2	3.5	13	3.5	3.8			
100				72	2.2	1.4	47	2.4	1.9	38	2.5	2.2	28	2.7	2.7	21	3.0	3.1	17	3.2	3.6	14	3.4	3.9			
110				79	2.2	1.4	52	2.4	1.9	41	2.5	2.3	31	2.7	2.7	23	2.9	3.2	19	3.2	3.6	16	3.4	3.9	13	3.7	4.1
120				86	2.2	1.4	57	2.4	1.9	45	2.5	2.3	34	2.7	2.7	25	2.9	3.2	21	3.2	3.6	17	3.4	4.0	15	3.7	4.2
130				94	2.2	1.4	61	2.4	1.9	49	2.5	2.3	36	2.7	2.7	27	2.9	3.2	22	3.1	3.6	18	3.4	4.0	16	3.6	4.3
140							66	2.4	1.9	52	2.5	2.3	39	2.7	2.7	29	2.9	3.2	23	3.1	3.6	20	3.4	4.1	17	3.6	4.3
150							71	2.4	1.9	56	2.5	2.3	42	2.7	2.7	31	2.9	3.2	26	3.1	3.7	21	3.4	4.1	18	3.6	4.4
160							75	2.4	1.9	60	2.5	2.3	45	2.7	2.7	33	2.9	3.2	27	3.1	3.7	22	3.4	4.1	19	3.6	4.4
170							80	2.4	1.9	63	2.5	2.3	47	2.7	2.7	35	2.9	3.3	29	3.1	3.7	24	3.4	4.1	20	3.6	4.5
180							84	2.4	1.9	67	2.5	2.3	50	2.7	2.7	38	2.9	3.3	31	3.1	3.7	25	3.3	4.1	21	3.5	4.5
190							89	2.4	1.9	71	2.5	2.3	53	2.7	2.7	40	2.9	3.3	32	3.1	3.7	26	3.3	4.2	22	3.5	4.5
200							94	2.4	1.9	74	2.5	2.3	55	2.7	2.7	42	2.9	3.3	34	3.1	3.7	28	3.3	4.2	24	3.5	4.6
220										82	2.5	2.3	61	2.7	2.7	46	2.9	3.3	37	3.1	3.7	30	3.3	4.2	26	3.5	4.6
240										89	2.5	2.3	66	2.7	2.8	50	2.9	3.3	41	3.1	3.7	33	3.3	4.2	28	3.5	4.6
260										96	2.5	2.3	72	2.7	2.8	54	2.9	3.3	44	3.1	3.8	36	3.3	4.2	30	3.5	4.7
280													77	2.7	2.8	58	2.9	3.3	47	3.1	3.8	38	3.3	4.2	33	3.5	4.7
300													83	2.7	2.8	62	2.9	3.3	50	3.1	3.8	41	3.3	4.2	35	3.5	4.7

T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05s
Parabolic Diversion Design (Retardance “D” and “B”, Grade 1.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24	1.8	0.9	15	1.9	1.2	10	2.2	1.5																		
20	32	1.8	0.9	20	1.9	1.2	14	2.1	1.6																		
25	39	1.8	0.9	25	1.9	1.2	17	2.1	1.6	11	2.3	2.1															
30	47	1.8	0.9	31	1.9	1.2	20	2.1	1.6	13	2.3	2.2	11	2.4	2.4												
35	55	1.8	0.9	36	1.9	1.2	23	2.1	1.7	16	2.2	2.2	13	2.4	2.5	10	2.6	2.7									
40	63	1.8	0.9	41	1.9	1.2	27	2.1	1.7	18	2.2	2.2	14	2.3	2.6	12	2.5	2.8									
45	70	1.8	0.9	46	1.9	1.2	30	2.1	1.7	20	2.2	2.2	16	2.3	2.6	13	2.5	2.8	10	2.8	3.2						
50	78	1.8	0.9	51	1.9	1.2	33	2.1	1.7	22	2.2	2.2	18	2.3	2.6	15	2.5	2.9	11	2.8	3.3						
55	86	1.8	0.9	55	1.9	1.2	36	2.1	1.7	24	2.2	2.3	20	2.3	2.6	16	2.5	2.9	12	2.7	3.4	10	3.0	3.5			
60	93	1.8	0.9	60	1.9	1.2	40	2.0	1.7	26	2.2	2.3	21	2.3	2.6	17	2.5	2.9	13	2.7	3.4	11	3.0	3.6			
65				65	1.9	1.2	43	2.0	1.7	29	2.2	2.3	23	2.3	2.6	19	2.5	3.0	14	2.7	3.4	12	2.9	3.7			
70				70	1.9	1.2	46	2.0	1.7	31	2.2	2.3	25	2.3	2.6	20	2.5	3.0	15	2.7	3.4	13	2.9	3.8	11	3.1	4.0
75				75	1.9	1.2	49	2.0	1.7	33	2.2	2.3	26	2.3	2.7	22	2.5	3.0	16	2.7	3.5	14	2.9	3.8	12	3.1	4.0
80				80	1.9	1.2	52	2.0	1.7	35	2.2	2.3	28	2.3	2.7	23	2.5	3.0	18	2.7	3.5	15	2.9	3.8	13	3.1	4.2
90				90	1.9	1.2	59	2.0	1.7	39	2.2	2.3	32	2.3	2.7	26	2.5	3.0	20	2.7	3.5	16	2.8	3.9	14	3.0	4.2
100							65	2.0	1.7	44	2.2	2.3	35	2.3	2.7	29	2.4	3.0	22	2.7	3.5	18	2.8	4.0	15	3.0	4.3
110							72	2.0	1.7	48	2.2	2.3	39	2.3	2.7	31	2.4	3.0	24	2.7	3.5	20	2.8	4.0	17	3.0	4.4
120							78	2.0	1.7	52	2.2	2.3	42	2.3	2.7	34	2.4	3.0	26	2.6	3.6	22	2.8	4.0	18	3.0	4.4
130							85	2.0	1.7	57	2.2	2.3	45	2.3	2.7	37	2.4	3.0	28	2.6	3.6	23	2.8	4.0	19	3.0	4.4
140							91	2.0	1.7	61	2.2	2.3	49	2.3	2.7	40	2.4	3.1	30	2.6	3.6	25	2.8	4.0	21	3.0	4.5
150							97	2.0	1.7	65	2.2	2.3	52	2.3	2.7	43	2.4	3.1	32	2.6	3.6	27	2.8	4.0	22	2.9	4.5
160										69	2.2	2.3	56	2.3	2.7	45	2.4	3.1	34	2.6	3.6	29	2.8	4.1	24	2.9	4.5
170										74	2.2	2.3	59	2.3	2.7	48	2.4	3.1	37	2.6	3.6	30	2.8	4.1	25	2.9	4.5
180										78	2.2	2.3	63	2.3	2.7	51	2.4	3.1	39	2.6	3.6	32	2.8	4.1	27	2.9	4.6
190										82	2.2	2.3	66	2.3	2.7	54	2.4	3.1	41	2.6	3.7	34	2.8	4.1	28	2.9	4.6
200										86	2.2	2.3	69	2.3	2.7	56	2.4	3.1	43	2.6	3.7	36	2.8	4.1	30	2.9	4.6
220										95	2.2	2.3	76	2.3	2.7	62	2.4	3.1	47	2.6	3.7	39	2.8	4.1	33	2.9	4.6
240													83	2.3	2.7	68	2.4	3.1	51	2.6	3.7	43	2.8	4.1	35	2.9	4.6
260													90	2.3	2.7	73	2.4	3.1	55	2.6	3.7	46	2.8	4.1	38	2.9	4.6
280													97	2.3	2.7	79	2.4	3.1	60	2.6	3.7	50	2.8	4.1	41	2.9	4.6
300																84	2.4	3.1	64	2.6	3.7	53	2.8	4.1	44	2.9	4.7

T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05t
Parabolic Diversion Design (Retardance “D” and “B”, Grade 2.0%)

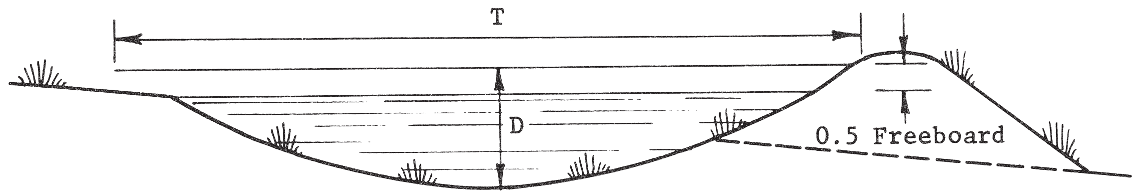
Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	30	1.6	0.8	18	1.8	1.2	13	1.9	1.4	9	2.1	1.8															
20	39	1.6	0.8	24	1.8	1.2	17	1.9	1.5	12	2.0	1.9															
25	49	1.6	0.8	30	1.7	1.2	21	1.9	1.5	15	2.0	2.0	11	2.2	2.4												
30	59	1.6	0.8	35	1.7	1.2	25	1.9	1.5	18	2.0	2.0	13	2.1	2.5	10	2.3	2.8									
35	68	1.6	0.8	41	1.7	1.2	29	1.9	1.5	21	2.0	2.0	15	2.1	2.5	12	2.2	2.9	10	2.4	3.0						
40	78	1.6	0.8	47	1.7	1.2	34	1.9	1.5	23	2.0	2.0	17	2.1	2.5	14	2.2	2.9	11	2.4	3.2						
45	88	1.6	0.8	53	1.7	1.2	38	1.9	1.5	26	2.0	2.0	19	2.1	2.5	15	2.2	2.9	13	2.4	3.2	10	2.6	3.5			
50	97	1.6	0.8	59	1.7	1.2	42	1.9	1.6	29	2.0	2.0	21	2.1	2.6	17	2.2	2.9	14	2.4	3.2	11	2.5	3.6			
55				64	1.7	1.2	46	1.8	1.6	32	2.0	2.0	23	2.1	2.6	19	2.2	2.9	15	2.4	3.3	12	2.5	3.7	10	2.7	4.0
60				70	1.7	1.2	50	1.8	1.6	35	2.0	2.0	25	2.1	2.6	20	2.2	3.0	17	2.4	3.3	13	2.5	3.7	11	2.7	4.0
65				76	1.7	1.2	54	1.8	1.6	38	2.0	2.0	27	2.1	2.6	22	2.2	3.0	18	2.3	3.4	15	2.5	3.7	12	2.7	4.1
70				81	1.7	1.2	58	1.8	1.6	41	2.0	2.1	29	2.1	2.6	24	2.2	3.0	19	2.3	3.4	16	2.5	3.8	13	2.7	4.1
75				87	1.7	1.2	62	1.8	1.6	43	2.0	2.1	31	2.1	2.6	25	2.2	3.0	21	2.3	3.4	17	2.5	3.8	14	2.7	4.1
80				93	1.7	1.2	68	1.8	1.6	46	2.0	2.1	33	2.1	2.6	27	2.2	3.0	22	2.3	3.4	18	2.5	3.8	15	2.6	4.2
90							74	1.8	1.6	52	2.0	2.1	37	2.1	2.6	30	2.2	3.0	25	2.3	3.4	20	2.5	3.8	17	2.6	4.2
100							83	1.8	1.6	58	2.0	2.1	41	2.1	2.6	34	2.2	3.0	27	2.3	3.4	22	2.5	3.9	18	2.6	4.3
110							91	1.8	1.6	63	2.0	2.1	45	2.1	2.6	37	2.2	3.0	30	2.3	3.4	24	2.5	3.9	20	2.6	4.3
120							99	1.8	1.6	69	2.0	2.1	49	2.1	2.6	40	2.2	3.0	33	2.3	3.4	26	2.4	3.9	22	2.6	4.3
130										75	2.0	2.1	53	2.1	2.6	44	2.2	3.0	35	2.3	3.4	29	2.4	3.9	24	2.6	4.3
140										80	2.0	2.1	57	2.1	2.6	47	2.2	3.0	38	2.3	3.5	31	2.4	3.9	26	2.6	4.4
150										86	2.0	2.1	61	2.1	2.7	50	2.2	3.0	41	2.3	3.5	33	2.4	3.9	27	2.6	4.4
160										91	2.0	2.1	65	2.1	2.7	53	2.2	3.0	43	2.3	3.5	35	2.4	3.9	29	2.6	4.4
170										97	2.0	2.1	69	2.1	2.7	57	2.2	3.1	46	2.3	3.5	37	2.4	4.0	31	2.6	4.4
180													73	2.1	2.7	60	2.2	3.1	49	2.3	3.5	39	2.4	4.0	33	2.6	4.4
190													77	2.1	2.7	63	2.2	3.1	51	2.3	3.5	41	2.4	4.0	34	2.6	4.5
200													81	2.1	2.7	66	2.2	3.1	54	2.3	3.5	44	2.4	4.0	36	2.6	4.5
220													89	2.1	2.7	73	2.2	3.1	59	2.3	3.5	48	2.4	4.0	40	2.6	4.5
240													97	2.1	2.7	79	2.2	3.1	65	2.3	3.5	52	2.4	4.0	43	2.6	4.5
260																86	2.2	3.1	70	2.3	3.5	56	2.4	4.0	47	2.6	4.5
280																92	2.2	3.1	75	2.3	3.5	61	2.4	4.0	50	2.6	4.5
300																99	2.2	3.1	81	2.3	3.5	65	2.4	4.0	54	2.6	4.5

T = Top width, Retardance “B”
D = Depth, Retardance “B”
V_2 = Velocity, Retardance “B”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05u
Parabolic Diversion Design (Retardance "D" and "B", Grade 0.25%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	11	2.9	1.6																								
30	13	2.8	1.7																								
35	15	2.8	1.7																								
40	17	2.8	1.8	11	3.2	2.1																					
45	19	2.7	1.8	13	3.1	2.2																					
50	21	2.7	1.8	14	3.1	2.2																					
55	23	2.7	1.8	15	3.1	2.3																					
60	25	2.7	1.8	17	3.0	2.3																					
65	27	2.7	1.8	18	3.0	2.3																					
70	29	2.7	1.9	19	3.0	2.3	14	3.6	2.7																		
75	31	2.7	1.9	21	3.0	2.3	15	3.5	2.8																		
80	33	2.7	1.9	22	3.0	2.4	16	3.5	2.8																		
90	37	2.7	1.9	25	3.0	2.4	17	3.5	2.8																		
100	41	2.7	1.9	28	3.0	2.4	19	3.5	2.9																		
110	45	2.7	1.9	30	3.0	2.4	21	3.4	2.9																		
120	49	2.7	1.9	33	3.0	2.4	23	3.4	2.9	16	4.1	3.3															
130	53	2.7	1.9	36	3.0	2.4	25	3.4	2.9	18	4.1	3.3															
140	57	2.7	1.9	38	3.0	2.4	27	3.4	2.9	19	4.0	3.4															
150	61	2.7	1.9	41	3.0	2.4	29	3.4	2.9	20	4.0	3.4															
160	65	2.7	1.9	44	3.0	2.4	30	3.4	3.0	21	4.0	3.4															
170	69	2.7	1.9	46	3.0	2.4	32	3.4	3.0	23	4.0	3.4	18	4.5	3.8												
180	73	2.7	1.9	49	3.0	2.4	34	3.4	3.0	24	4.0	3.5	19	4.5	3.8												
190	77	2.7	1.9	52	3.0	2.4	36	3.4	3.0	25	4.0	3.5	20	4.5	3.9												
200	81	2.7	1.9	55	3.0	2.4	38	3.4	3.0	27	3.9	3.5	21	4.4	3.9												
220	89	2.7	1.9	60	3.0	2.4	42	3.4	3.0	29	3.9	3.5	23	4.4	3.9												
240	97	2.7	1.9	65	3.0	2.5	45	3.4	3.0	32	3.9	3.6	25	4.4	4.0												
260				71	3.0	2.5	49	3.4	3.0	34	3.9	3.6	27	4.4	4.0	21	5.1	4.3									
280				76	3.0	2.5	53	3.4	3.0	37	3.9	3.6	29	4.4	4.0	22	5.1	4.3									
300				82	3.0	2.5	57	3.4	3.0	40	3.9	3.6	31	4.3	4.1	24	5.0	4.4									



T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05v
Parabolic Diversion Design (Retardance "D" and "C", Grade 0.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10	2.1	1.6																								
20	13	2.1	1.7																								
25	16	2.1	1.7	10	2.4	2.1																					
30	20	2.1	1.7	12	2.4	2.2	9	2.7	2.5																		
35	23	2.1	1.7	14	2.4	2.3	11	2.6	2.6																		
40	26	2.1	1.7	16	2.3	2.3	12	2.6	2.7																		
45	29	2.0	1.7	18	2.3	2.3	13	2.5	2.8																		
50	32	2.0	1.7	20	2.3	2.4	15	2.5	2.8	11	2.9	3.2															
55	35	2.0	1.7	22	2.3	2.4	16	2.5	2.8	12	2.9	3.3															
60	39	2.0	1.7	24	2.3	2.4	18	2.5	2.8	13	2.9	3.3															
65	42	2.0	1.8	26	2.3	2.4	19	2.5	2.9	14	2.9	3.3															
70	45	2.0	1.8	28	2.3	2.4	21	2.5	2.9	15	2.8	3.4															
75	48	2.0	1.8	30	2.3	2.4	22	2.5	2.9	16	2.8	3.4	12	3.2	3.7												
80	51	2.0	1.8	32	2.3	2.4	23	2.5	2.9	17	2.8	3.4	13	3.2	3.8												
90	57	2.0	1.8	35	2.3	2.4	26	2.5	2.9	19	2.8	3.4	15	3.2	3.8												
100	64	2.0	1.8	39	2.3	2.4	29	2.5	2.9	21	2.8	3.5	16	3.1	3.9	13	3.5	4.1									
110	70	2.0	1.8	43	2.3	2.4	32	2.5	2.9	23	2.8	3.5	18	3.1	3.9	14	3.5	4.2									
120	76	2.0	1.8	47	2.3	2.4	35	2.5	2.9	25	2.8	3.5	19	3.1	3.9	15	3.4	4.3									
130	83	2.0	1.8	51	2.3	2.4	38	2.5	2.9	27	2.8	3.5	21	3.1	4.0	17	3.4	4.4									
140	89	2.0	1.8	55	2.3	2.4	41	2.5	2.9	29	2.8	3.5	22	3.1	4.0	18	3.4	4.3									
150	95	2.0	1.8	59	2.3	2.4	44	2.5	2.9	31	2.8	3.5	24	3.1	4.0	19	3.4	4.4	15	3.8	4.8						
160				62	2.3	2.4	46	2.5	2.9	33	2.8	3.5	25	3.1	4.0	20	3.4	4.4	16	3.8	4.8						
170				66	2.3	2.4	49	2.5	2.9	35	2.8	3.6	27	3.1	4.0	22	3.4	4.4	17	3.8	4.9						
180				70	2.3	2.4	52	2.5	2.9	37	2.8	3.6	29	3.1	4.0	23	3.4	4.5	18	3.8	4.9						
190				74	2.3	2.4	55	2.5	2.9	39	2.8	3.6	30	3.1	4.0	24	3.4	4.5	19	3.8	5.0						
200				78	2.3	2.4	58	2.5	2.9	41	2.8	3.6	32	3.1	4.0	25	3.4	4.5	20	3.8	5.0	16	4.2	5.2			
220				86	2.3	2.4	64	2.5	2.9	45	2.8	3.6	35	3.1	4.0	28	3.4	4.5	22	3.7	5.0	18	4.2	5.3			
240				93	2.3	2.4	69	2.5	2.9	49	2.8	3.6	38	3.0	4.1	30	3.4	4.5	24	3.7	5.0	20	4.2	5.4			
260							75	2.5	2.9	53	2.8	3.6	41	3.0	4.1	33	3.4	4.5	26	3.7	5.0	21	4.1	5.4			
280							81	2.5	3.0	57	2.8	3.6	44	3.0	4.1	35	3.3	4.6	28	3.7	5.0	23	4.1	5.5	19	4.6	5.8
300							87	2.5	3.0	61	2.8	3.6	47	3.0	4.1	38	3.3	4.6	30	3.6	5.0	24	4.1	5.5	20	4.6	5.8

T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Table 8.05w
Parabolic Diversion Design (Retardance “D” and “C”, Grade 1.0%)

Q	V_1	=	2.0	V_1	=	2.5	V_1	=	3.0	V_1	=	3.5	V_1	=	4.0	V_1	=	4.5	V_1	=	5.0	V_1	=	5.5	V_1	=	6.0
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	16	1.6	1.5	10	1.8	2.0																					
20	22	1.6	1.5	13	1.8	2.1																					
25	27	1.6	1.5	17	1.8	2.1	11	2.0	2.6																		
30	32	1.6	1.5	20	1.8	2.1	13	2.0	2.7	11	2.1	3.0															
35	37	1.6	1.5	23	1.8	2.2	15	2.0	2.8	12	2.1	3.1															
40	43	1.6	1.5	26	1.8	2.2	17	1.9	2.8	14	2.1	3.1	10	2.3	3.7												
45	48	1.6	1.5	29	1.8	2.2	19	1.9	2.8	16	2.1	3.2	12	2.3	3.7												
50	53	1.6	1.5	33	1.8	2.2	22	1.9	2.8	17	2.1	3.2	13	2.3	3.7	10	2.5	4.2									
55	58	1.6	1.5	36	1.8	2.2	24	1.9	2.8	19	2.0	3.3	14	2.3	3.8	11	2.5	4.3									
60	64	1.6	1.5	39	1.8	2.2	26	1.9	2.8	21	2.0	3.3	15	2.2	3.8	12	2.5	4.3									
65	69	1.6	1.5	42	1.8	2.2	28	1.9	2.8	22	2.0	3.3	17	2.2	3.8	13	2.5	4.3	10	2.7	4.7						
70	74	1.6	1.5	45	1.8	2.2	30	1.9	2.8	24	2.0	3.3	18	2.2	3.9	14	2.5	4.4	11	2.7	4.7						
75	79	1.6	1.5	49	1.8	2.2	32	1.9	2.9	26	2.0	3.3	19	2.2	3.9	15	2.5	4.5	12	2.7	4.7						
80	84	1.6	1.5	52	1.8	2.2	34	1.9	2.9	27	2.0	3.3	20	2.2	3.9	16	2.5	4.5	13	2.7	4.9						
90	95	1.6	1.5	58	1.8	2.2	38	1.9	2.9	31	2.0	3.3	23	2.2	3.9	17	2.4	4.5	14	2.7	4.9	12	2.9	5.2			
100				65	1.8	2.2	43	1.9	2.9	34	2.0	3.3	25	2.2	3.9	19	2.4	4.5	16	2.7	4.9	13	2.9	5.3			
110				71	1.8	2.2	47	1.9	2.9	37	2.0	3.3	28	2.2	3.9	21	2.4	4.5	17	2.6	5.0	14	2.9	5.3	12	3.1	5.7
120				77	1.8	2.2	51	1.9	2.9	41	2.0	3.3	30	2.2	4.0	23	2.4	4.5	19	2.6	5.0	16	2.9	5.4	13	3.1	5.7
130				84	1.8	2.2	55	1.9	2.9	44	2.0	3.3	33	2.2	4.0	25	2.4	4.5	20	2.6	5.0	17	2.9	5.4	14	3.1	5.8
140				90	1.8	2.2	59	1.9	2.9	47	2.0	3.3	35	2.2	4.0	27	2.4	4.5	22	2.6	5.0	18	2.8	5.5	15	3.1	5.8
150				96	1.8	2.2	64	1.9	2.9	51	2.0	3.3	38	2.2	4.0	29	2.4	4.5	23	2.6	5.0	19	2.8	5.5	17	3.1	5.8
160							68	1.9	2.9	54	2.0	3.3	40	2.2	4.0	30	2.4	4.5	25	2.6	5.0	20	2.8	5.5	18	3.0	6.0
170							72	1.9	2.9	57	2.0	3.3	43	2.2	4.0	32	2.4	4.5	26	2.5	5.0	22	2.8	5.5	19	3.0	6.0
180							76	1.9	2.9	61	2.0	3.4	45	2.2	4.0	34	2.4	4.5	28	2.6	5.0	23	2.8	5.5	20	3.0	6.0
190							80	1.9	2.9	64	2.0	3.4	48	2.2	4.0	36	2.4	4.5	29	2.6	5.0	24	2.8	5.5	21	3.0	6.0
200							84	1.9	2.9	67	2.0	3.4	50	2.2	4.0	38	2.4	4.5	31	2.6	5.0	25	2.8	5.5	22	3.0	6.0
220							93	1.9	2.9	74	2.0	3.4	55	2.2	4.0	42	2.4	4.5	34	2.6	5.0	28	2.8	5.5	24	3.0	6.0
240										81	2.0	3.4	60	2.2	4.0	45	2.4	4.5	37	2.6	5.0	30	2.8	5.5	26	3.0	6.0
260										87	2.0	3.4	65	2.2	4.0	49	2.4	4.5	40	2.6	5.0	33	2.8	5.5	28	3.0	6.0
280										94	2.0	3.4	70	2.2	4.0	53	2.4	4.5	43	2.6	5.0	36	2.8	5.5	30	3.0	6.0
300													75	2.2	4.0	57	2.4	4.5	46	2.5	5.0	38	2.8	5.5	32	3.0	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05x
Parabolic Diversion Design (Retardance “D” and “C”, Grade 1.5%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	21	1.4	1.4	14	1.6	1.9																					
20	28	1.4	1.4	18	1.5	1.9	12	1.7	2.5																		
25	35	1.4	1.4	23	1.5	1.9	15	1.7	2.6	10	1.9	3.2															
30	42	1.4	1.4	27	1.5	1.9	18	1.7	2.6	12	1.8	3.2	10	2.0	3.6												
35	49	1.4	1.4	32	1.5	2.0	21	1.6	2.6	14	1.8	3.3	11	1.9	3.7	10	2.1	4.1									
40	56	1.4	1.4	36	1.5	2.0	24	1.6	2.6	16	1.8	3.3	13	1.9	3.7	11	2.1	4.2									
45	63	1.4	1.4	41	1.5	2.0	27	1.6	2.6	18	1.8	3.4	15	1.9	3.8	12	2.0	4.3									
50	70	1.4	1.4	45	1.5	2.0	30	1.6	2.7	20	1.8	3.4	16	1.9	3.9	13	2.0	4.3	10	2.3	4.8						
55	76	1.4	1.5	50	1.5	2.0	33	1.6	2.7	22	1.8	3.4	18	1.9	3.9	14	2.0	4.3	11	2.3	4.9						
60	83	1.4	1.5	54	1.5	2.0	35	1.6	2.7	24	1.8	3.4	19	1.9	3.9	16	2.0	4.4	12	2.3	4.9	10	2.4	5.2			
65	90	1.4	1.5	58	1.5	2.0	38	1.6	2.7	26	1.8	3.4	21	1.9	3.9	17	2.0	4.4	13	2.2	5.0	11	2.4	5.3			
70	97	1.4	1.5	63	1.5	2.0	41	1.6	2.7	28	1.8	3.4	22	1.9	3.9	18	2.0	4.4	14	2.2	5.0	12	2.4	5.4	10	2.6	5.6
75				67	1.5	2.0	44	1.6	2.7	30	1.8	3.4	24	1.9	3.9	19	2.0	4.4	15	2.2	5.0	12	2.4	5.4	11	2.6	5.6
80				72	1.5	2.0	47	1.6	2.7	32	1.8	3.4	26	1.9	3.9	21	2.0	4.4	16	2.2	5.0	13	2.4	5.4	12	2.5	5.8
90				80	1.5	2.0	53	1.6	2.7	36	1.8	3.5	29	1.9	3.9	23	2.0	4.4	18	2.2	5.0	15	2.4	5.4	13	2.5	5.9
100				89	1.5	2.0	59	1.6	2.7	39	1.8	3.5	32	1.9	3.9	26	2.0	4.5	20	2.2	5.0	17	2.4	5.4	14	2.5	6.0
110				98	1.5	2.0	64	1.6	2.7	43	1.8	3.5	35	1.9	3.9	28	2.0	4.5	22	2.2	5.0	18	2.3	5.5	15	2.5	6.0
120							70	1.6	2.7	47	1.8	3.5	38	1.9	4.0	31	2.0	4.5	24	2.2	5.0	20	2.3	5.5	17	2.5	6.0
130							76	1.6	2.7	51	1.8	3.5	41	1.9	4.0	33	2.0	4.5	26	2.2	5.0	21	2.3	5.5	18	2.5	6.0
140							82	1.6	2.7	55	1.8	3.5	44	1.9	4.0	36	2.0	4.5	27	2.2	5.0	23	2.3	5.5	19	2.5	6.0
150							87	1.6	2.7	59	1.8	3.5	47	1.9	4.0	39	2.0	4.5	29	2.2	5.0	25	2.3	5.5	21	2.5	6.0
160							93	1.6	2.7	63	1.8	3.5	51	1.9	4.0	41	2.0	4.5	31	2.2	5.0	26	2.3	5.5	22	2.5	6.0
170							99	1.6	2.7	67	1.8	3.5	54	1.9	4.0	44	2.0	4.5	33	2.2	5.0	28	2.3	5.5	23	2.5	6.0
180										70	1.8	3.5	57	1.9	4.0	46	2.0	4.5	35	2.2	5.0	29	2.3	5.5	25	2.5	6.0
190										74	1.8	3.5	60	1.9	4.0	49	2.0	4.5	37	2.2	5.0	31	2.3	5.5	26	2.5	6.0
200										78	1.8	3.5	63	1.9	4.0	51	2.0	4.5	39	2.2	5.0	33	2.3	5.5	27	2.5	6.0
220										86	1.8	3.5	69	1.9	4.0	56	2.0	4.5	43	2.2	5.0	36	2.3	5.5	30	2.5	6.0
240										93	1.8	3.5	75	1.9	4.0	61	2.0	4.5	47	2.2	5.0	39	2.3	5.5	33	2.5	6.0
260													82	1.9	4.0	66	2.0	4.5	51	2.2	5.0	42	2.3	5.5	35	2.5	6.0
280													88	1.9	4.0	71	2.0	4.5	54	2.2	5.0	46	2.3	5.5	38	2.5	6.0
300													94	1.9	4.0	76	2.0	4.5	58	2.2	5.0	49	2.3	5.5	41	2.5	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

Table 8.05y
Parabolic Diversion Design (Retardance “D” and “C”, Grade 2.0%)

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	27	1.3	1.3	16	1.4	1.9	11	1.5	2.4																		
20	35	1.3	1.3	21	1.4	1.9	15	1.5	2.4	11	1.6	3.0															
25	44	1.3	1.3	27	1.4	1.9	19	1.5	2.4	13	1.6	3.0	10	1.8	3.7												
30	53	1.3	1.3	32	1.4	1.9	23	1.5	2.5	16	1.6	3.0	11	1.7	3.7	10	1.8	4.2									
35	61	1.3	1.3	37	1.4	1.9	26	1.5	2.5	19	1.6	3.1	13	1.7	3.8	11	1.8	4.2									
40	70	1.3	1.3	42	1.4	1.9	30	1.5	2.5	21	1.6	3.1	15	1.7	3.8	12	1.8	4.3	10	2.0	4.7						
45	78	1.3	1.4	48	1.4	1.9	34	1.5	2.5	24	1.6	3.1	17	1.7	3.8	14	1.8	4.3	11	1.9	4.8						
50	87	1.3	1.4	53	1.4	1.9	38	1.5	2.5	26	1.6	3.1	19	1.7	3.8	15	1.8	4.3	13	1.9	4.8	10	2.1	5.3			
55	95	1.3	1.4	58	1.4	1.9	41	1.5	2.5	29	1.6	3.1	21	1.7	3.8	17	1.8	4.3	14	1.9	4.9	11	2.1	5.3			
60				63	1.4	1.9	45	1.5	2.5	32	1.6	3.1	23	1.7	3.9	18	1.8	4.4	15	1.9	4.9	12	2.1	5.3	10	2.2	5.7
65				68	1.4	1.9	49	1.5	2.5	34	1.6	3.1	24	1.7	3.9	20	1.8	4.4	16	1.9	4.9	13	2.1	5.4	11	2.2	5.7
70				73	1.4	1.9	52	1.5	2.5	37	1.6	3.1	26	1.7	3.9	22	1.8	4.4	18	1.9	4.9	14	2.1	5.4	12	2.2	5.8
75				78	1.4	1.9	56	1.5	2.5	39	1.6	3.1	28	1.7	3.9	23	1.8	4.4	19	1.9	4.9	15	2.1	5.4	13	2.2	5.9
80				83	1.4	2.0	60	1.5	2.5	42	1.6	3.1	30	1.7	3.9	24	1.8	4.4	20	1.9	4.9	16	2.1	5.4	14	2.2	5.9
90				94	1.4	2.0	67	1.5	2.5	47	1.6	3.2	34	1.7	3.9	28	1.8	4.4	22	1.9	4.9	18	2.1	5.5	15	2.2	5.9
100							74	1.5	2.5	52	1.6	3.2	37	1.7	3.9	31	1.8	4.4	25	1.9	5.0	20	2.1	5.5	17	2.2	6.0
110							81	1.5	2.5	57	1.6	3.2	41	1.7	3.9	34	1.8	4.4	27	1.9	5.0	22	2.0	5.5	19	2.2	6.0
120							89	1.5	2.5	62	1.6	3.2	45	1.7	3.9	37	1.8	4.4	30	1.9	5.0	24	2.0	5.5	20	2.2	6.0
130							96	1.5	2.5	67	1.6	3.2	48	1.7	3.9	40	1.8	4.5	32	1.9	5.0	26	2.0	5.5	22	2.2	6.0
140										73	1.6	3.2	52	1.7	4.0	42	1.8	4.5	35	1.9	5.0	28	2.0	5.5	23	2.2	6.0
150										78	1.6	3.2	56	1.7	4.0	46	1.8	4.5	37	1.9	5.0	30	2.0	5.5	25	2.2	6.0
160										83	1.6	3.2	59	1.7	4.0	48	1.8	4.5	39	1.9	5.0	32	2.0	5.5	27	2.2	6.0
170										88	1.6	3.2	63	1.7	4.0	51	1.8	4.5	42	1.9	5.0	34	2.0	5.5	28	2.2	6.0
180										93	1.6	3.2	67	1.7	4.0	54	1.8	4.5	44	1.9	5.0	36	2.0	5.5	30	2.2	6.0
190										98	1.6	3.2	70	1.7	4.0	57	1.8	4.5	47	1.9	5.0	38	2.0	5.5	32	2.2	6.0
200													74	1.7	4.0	60	1.8	4.5	49	1.9	5.0	40	2.0	5.5	33	2.2	6.0
220													81	1.7	4.0	66	1.8	4.5	54	1.9	5.0	44	2.0	5.5	37	2.2	6.0
240													88	1.7	4.0	72	1.8	4.5	59	1.9	5.0	48	2.0	5.5	40	2.2	6.0
260													96	1.7	4.0	78	1.8	4.5	64	1.9	5.0	51	2.0	5.5	43	2.2	6.0
280																84	1.8	4.5	69	1.9	5.0	55	2.0	5.5	46	2.2	6.0
300																90	1.8	4.5	73	1.9	5.0	59	2.0	5.5	50	2.2	6.0

T = Top width, Retardance “C”
D = Depth, Retardance “C”
V_2 = Velocity, Retardance “C”
V_1 = Velocity, Retardance “D”

(Settlement to be added to top of ridge.)

8.06 DESIGN OF RIPRAP OUTLET PROTECTION

Riprap (large stones of various sizes) is often used to prevent erosion at the ends of culverts and other pipe conduits. It converts high-velocity, concentrated pipe flow into low-velocity, open channel flow. Stone should be sized and the apron shaped to protect receiving channels from erosion caused by maximum pipe exit velocities. Riprap outlet structures should meet all requirements in *Practice Standards and Specifications: 6.41, Outlet Stabilization Structure*.

Several methods are available for designing riprap outlet structures. The method presented in this section is adapted from procedures used by the USDA Soil Conservation Service. Outlet protection is provided by a level apron of sufficient length and flare to reduce flow velocities to nonerosive levels.

Design Procedure for Riprap Outlet Protection

The following procedure uses two sets of design curves: Figure 8.06a is used for minimum tailwater conditions, and Figure 8.06b for maximum tailwater conditions.

Step 1. Determine the tailwater depth from channel characteristics below the pipe outlet for the design capacity of the pipe. If the tailwater depth is less than half the outlet pipe diameter, it is classified minimum tailwater condition. If it is greater than half the pipe diameter, it is classified maximum condition. Pipes that outlet onto wide flat areas with no defined channel are assumed to have a minimum tailwater condition unless reliable flood stage elevations show otherwise.

Step 2. Based on the tailwater conditions determined in step 1, enter Figure 8.06a or Figure 8.06b, and determine d_{50} riprap size and minimum apron length (L_a). The d_{50} size is the median stone size in a well-graded riprap apron.

Step 3. Determine apron width at the pipe outlet, the apron shape, and the apron width at the outlet end from the same figure used in Step 2.

Step 4. Determine the maximum stone diameter:

$$d_{max} = 1.5 \times d_{50}$$

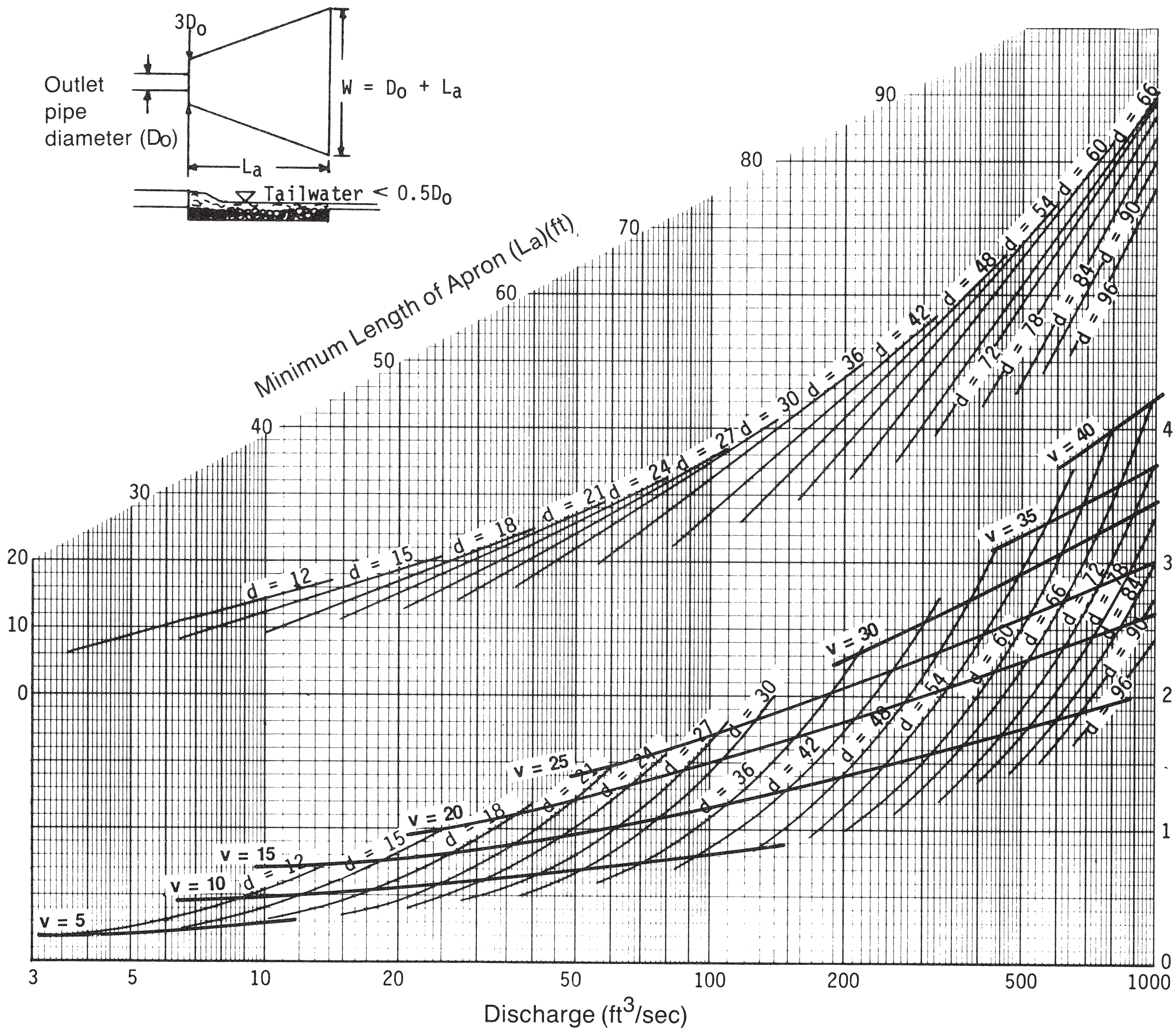
Step 5. Determine the apron thickness:

$$\text{Apron thickness} = 1.5 \times d_{max}$$

Step 6. Fit the riprap apron to the site by making it level for the minimum length, L_a, from Figure 8.06a or Figure 8.06b. Extend the apron farther downstream and along channel banks until stability is assured. Keep the apron as straight as possible and align it with the flow of the receiving stream. Make any necessary alignment bends near the pipe outlet so that the entrance into the receiving stream is straight.

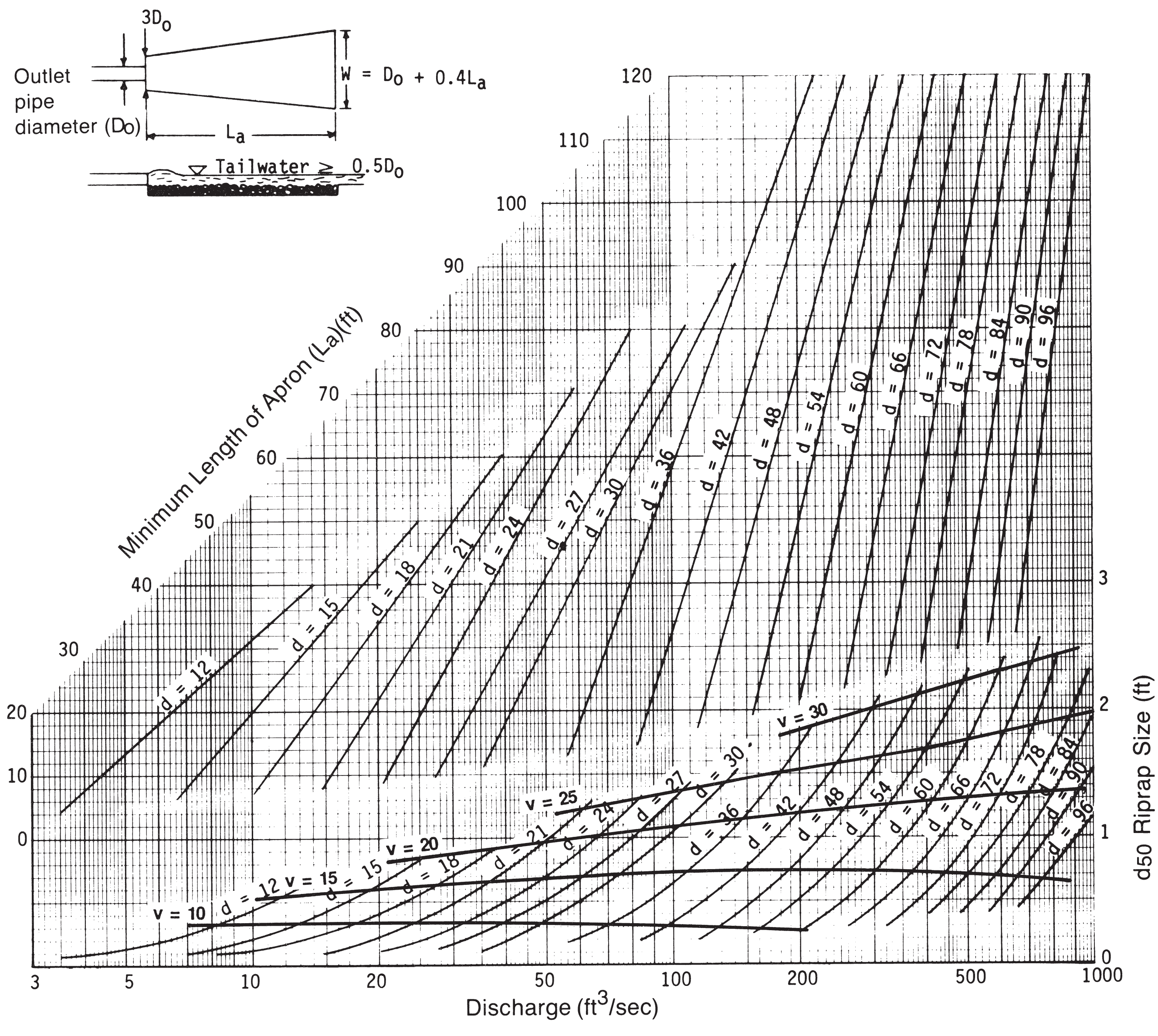
Some locations may require lining of the entire channel cross section to assure stability.

It may be necessary to increase the size of riprap where protection of the channel side slopes is necessary (*Appendix 8.05*). Where overfalls exist at pipe outlets or flows are excessive, a plunge pool should be considered, see page 8.06.8.



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).



Curves may not be extrapolated.

Figure 8.06b Design of outlet protection from a round pipe flowing full, maximum tailwater condition ($T_w \geq 0.5$ diameter).

NEW YORK DOT DISSIPATOR METHOD FOR USE IN DEFINED CHANNELS

(Source: "Bank and channel lining procedures", New York Department of Transportation, Division of Design and Construction, 1971.)

NOTE: To use the following chart you must know:

(1) Q full capacity
(2) Q_{10}
(3) V full
(4) V_{10}

where Q = discharge in cfs and V = Velocity in FPS.

ESTIMATION OF STONE SIZE AND DIMENSIONS FOR CULVERT APRONS

Step 1) Compute flow velocity V_o at culvert or paved channel outlet.

Step 2) For pipe culverts D_o is diameter.
For pipe arch, arch and box culverts, and paved channel outlets, $D_o = A_o$ where A. = cross-sectional area of flow at outlet.

For multiple culverts, use $D_o = 1.25 \times D_o$ of single culvert.

Step 3) For apron grades of 10% or steeper, use recommendations For next higher zone. (Zones 1 through 6).

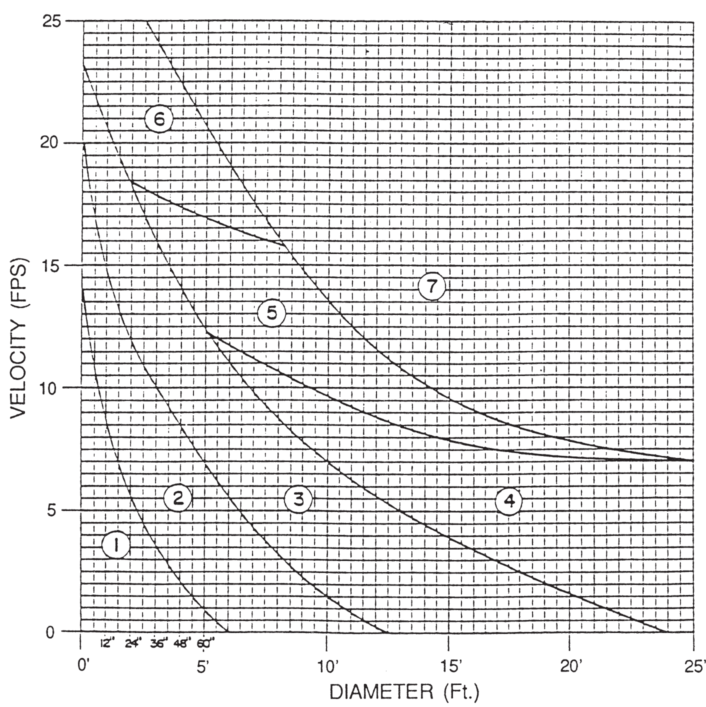


Figure 8.06c

ZONE	APRON MATERIAL		LENGTH OF APRON	
			TO PROTECT CULVERT L1	TO PREVENT SCOUR HOLE USE L2 ALWAYS L2
1	STONE FILLING (FINE)	CL. A	3 X D_0	4 x D_o
2	STONE FILLING (LIGHT)	CL. B	3 X D_0	6 x D_o
3	STONE FILLING (MEDIUM)	CL. 1	4 X D_0	8 x D_o
4	STONE FILLING (HEAVY)	CL. 1	4 X D_0	8 x D_o
5	STONE FILLING (HEAVY)	CL. 2	5 X D_0	10 x D_o
6	STONE FILLING (HEAVY)	CL. 2	6 X D_0	10 x D_o
7	SPECIAL STUDY REQUIRED (ENERGY DISSIPATORS, STILLING BASIN OR LARGER SIZE STONE).			

Figure 8.06d

Width = 3 times pipe dia. (min.)

DETERMINATION OF STONE SIZES FOR DUMPED STONE CHANNEL LININGS AND REVETMENTS

Step 1. Use figure 8.06.b.3 to determine maximum stone size (e.g. for 12 Fps = 20" or 550 lbs.

Step 2. Use figure 8.06.b.4 to determine acceptable size range for stone (for 12 FPS it is 125-500 lbs. for 75% of stone, and the maximum and minimum range in weight should be 25-500 lbs.).

NOTE: In determining channel velocities for stone linings and revetment, use the following coefficients of roughness:

	Diameter (inches)	Manning's "n"	Min. thickness of lining	(inches)
Fine	3	0.031	9	12
Light	6	0.035	12	18
Medium	13	0.040	18	24
Heavy	23	0.044	30	36
			(Channels)	(Dissapators)

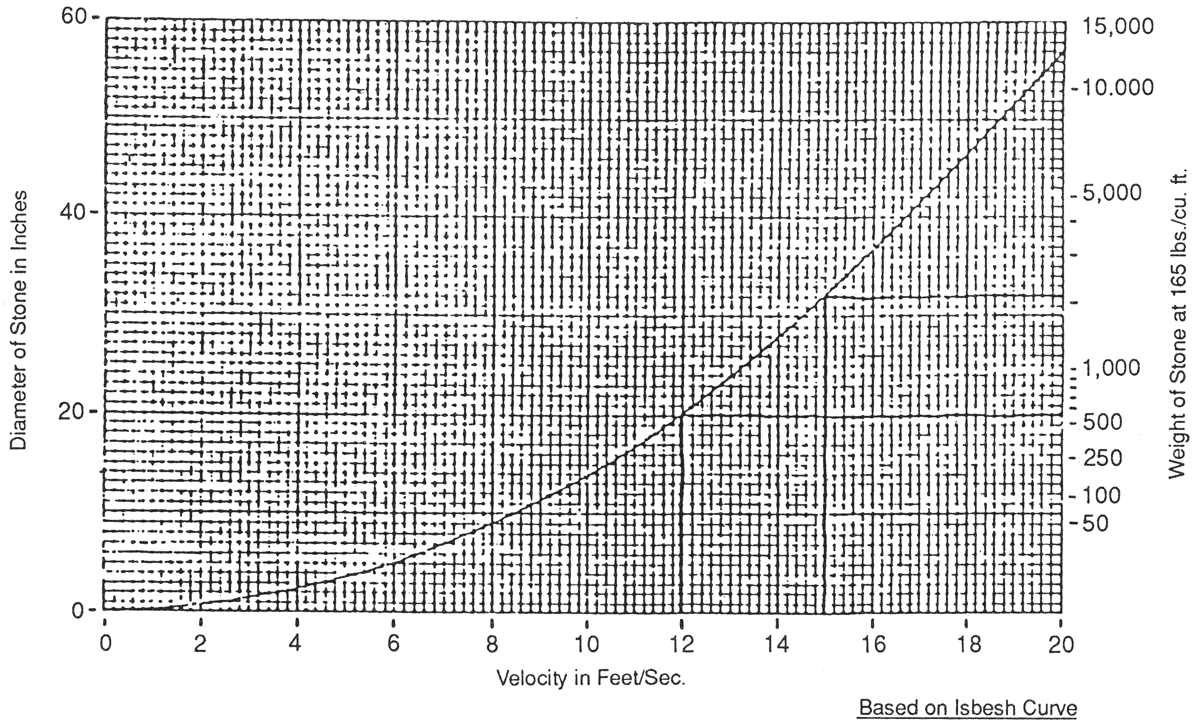


Figure 8.06e Maximum Stone Size for Riprap

Maximum weight of stone required	Minimum and maximum range in weight of stones	Weight range of 75% of stones
(lbs.)	(lbs.)	(lbs.)
150	25 - 150	50 - 150
200	25 - 200	50 - 200
250	25 - 250	50 - 250
400	25 - 400	100 - 400
600	25 - 600	150 - 600
800	25 - 800	200 - 800
1,000	50 - 1000	250 - 1000
1,300	50 - 1,300	325 - 1,300
1,600	50 - 1,600	400 - 1,600
2,000	75 - 2,000	600 - 2,000
2,700	100 - 2,700	800 - 2,700

Figure 8.06f Gradation of Riprap

Source: "Bank and channel lining procedures, " New York Department of Transportation, Division of Design and Construction, 1971.

PLUNGE POOL OUTLET DESIGN

Existing methods for sizing a plunge pool below a pipe outlet have been developed by the Federal Highway Administration (FHWA) and the United States Department of Agriculture (USDA). The FHWA published HEC 14, Hydraulic Design of Dissipaters for culverts and channels in 1983. It can be downloaded from the FHWA Hydraulic Engineering web site. Many of the design procedures in HEC 14 may also be performed using HY8 Energy, a design software that may also be downloaded for free from the FHWA. HY8 Energy will also calculate the anticipated dimensions of a scour hole below an unprotected pipe.

The USDA has developed design criteria for plunge pool outlet protection based on the relative position of the pipe outlet to the downstream tailwater elevation. USDA Design Note 6 is for cantilevered pipe, when the outlet is above the tailwater surface. This situation is most common at the barrel pipe outlet of ponds or sediment basins. Culverts in streams should not be cantilevered, as this poses a barrier to the movement of aquatic life. In fact, culverts in streams are now frequently embedded below grade. Plunge pools in this situation must be designed for the submerged outlet condition. A design methodology developed by the USDA is also presented below.

USDA Design Note 6

Note: An Excel spreadsheet is available for Design Note 6.

The energy in flow exiting from a spillway usually requires dissipation before being released to the outlet channel. For flow exiting from a conduit, when an open plunge pool is acceptable, an excavated riprap lined hole at the downstream end of the conduit can be an economical energy dissipater. However, the size of plunge pool, location relative to the conduit outlet, and size of riprap must be properly designed for the plunge pool to operate successfully.

The plunge pool dimensions were developed using a discharge parameter. The parameter is based on the design discharge, Q, pipe diameter, D, and combined with the acceleration of gravity, g, resulting in a dimensionless parameter of

$$\frac{Q}{\sqrt{gD^5}}$$

The depth of erosion created by the discharging jet can be controlled by the bed material size. The bed material is represented by its mean grain size, d_{50}, the size of which 50 percent by weight is finer in diameter. The d_{50} bed material size must be checked to assure that it is adequate to control shallow beach type erosion at the top of the plunge pool. The d_{50} size is adequate and beach erosion will not occur if:

$$\frac{Q}{\sqrt{gD^5}} < \left[1.0 + 25 \frac{d_{50}}{D} \right]$$

If the bed material is not large enough, protection will need to be added. In case of riprap, a larger particle gradation will be required.

Nomenclature

a_1 = Thickness of riprap, ft

a_2 = Thickness of riprap and filter material, ft

A_1 = Plan rectangular area of the plunge pool at the invert elevation of the outlet channel, ft^2

A_2 = Plan rectangular area at the bottom of the plunge pool at a distance Z below the invert elevation of the outlet channel, ft^2.

d_{50} = Size of rock in riprap of which 50 percent by weight is finer, ft

D = Cantilever outlet pipe diameter, ft

e = Base of natural logarithms

F_d = Densimetric Froude number

g = Acceleration of gravity, ft/sec^2

L_e = Minimum horizontal distance from the center of the pool to the water surface contour at the upstream or downstream end of an elliptical-shape plunge pool, ft

L_r = Adjusted horizontal distance from the center of the pool to the water surface contour at the upstream or downstream end of the rectangular-shape plunge pool, ft

L_{r2} = One-half the length of the bottom of a rectangular-shape plunge pool, ft

Q = Design discharge, cfs

S = Sine of the angle whose tangent is the slope of the pipe

V_{ao} = Volume of the plunge pool between the invert elevation of the outlet channel and the exposed riprap surface, cu. yds.

V_{a1} = Volume of the plunge pool between the invert elevation of the outlet channel and a surface at a thickness, a_1, below the exposed riprap surface, cu. yds.

V_{a2} = Volume of the plunge pool between the invert elevation of the outlet channel and a surface at a thickness, a_2, below the exposed riprap surface, cu. yds.

V_h = Horizontal component of the jet impingement velocity, V_P, ft/sec

V_o = Velocity in the pipe corresponding to the design discharge, Q, ft/sec

V_p = Velocity where the jet plunges into the water surface, ft/sec

V_v = Vertical component of the jet impingement velocity, V_P, ft/sec

W_e = One-half the minimum width at the center of the elliptical-shape plunge pool at the water surface elevation, ft

W_r = One-half the adjusted width at the center of the rectangular-shape plunge pool at the water surface elevation, ft

W_{r2} = One-half the width of the bottom of a rectangular plunge pool, ft

X_m = Horizontal distance from the pipe exit to the center of the plunge pool, ft

X_p = Horizontal distance from the pipe exit to the center of the jet plunging into the water surface, ft

z_ℓ = Side slope ratio of the upstream or downstream slope of the rectangular-shape plunge pool

z_w = Side slope ratio of the side slopes of the rectangular-shape plunge pool

z_d = Water depth above the invert elevation of the outlet channel, ft

z_m = Maximum computed depth of the plunge pool, ft

z_p = Vertical distance from the tailwater surface to the cantilever pipe invert, ft

ρ = Water density

ρ_s = Bed material or riprap particle density

α = Jet impingement angle where the jet plunges Into the water surface

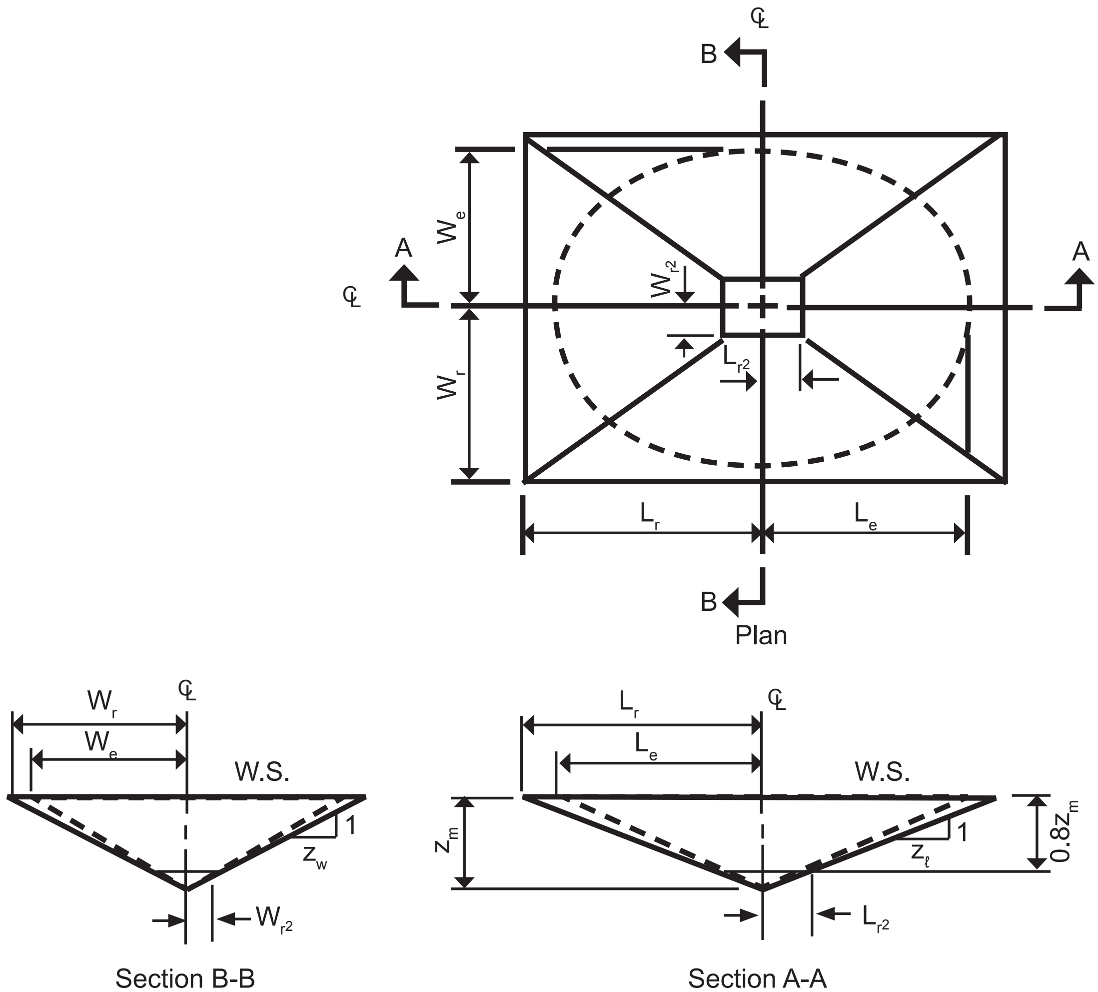


Figure 8.06g Plunge pool

Procedure

The step procedure given below is in a form that can easily be programmed on either programmable calculators or computers.

1. Compute: $\dfrac{Q}{\sqrt{gD^5}}$

2. Compute: $V_o = \dfrac{4Q}{\pi D^2}$

3. Compute: $V_h = V_o \cos(\sin^{-1} s)$

$$V_v = \sqrt{(V_o s)^2 + 2g\left[z_p + \frac{D}{2}\cos(\sin^{-1} s)\right]}$$

$$\tan\alpha = \frac{V_v}{V_h}$$

$$V_p = \sqrt{V_h^{\ 2} + V_v^{\ 2}}$$

$$X_p = \frac{V_h}{g} (V_v - V_o s)$$

4. Compute: $F_d = \dfrac{V_p}{\sqrt{g\, d_{50} (\rho_s - \rho) / \rho}}$

5. Compute: $\dfrac{z_p}{D}$ if < 1, go to step 6a; if > 1, go to step 6b

6a. Compute: $z_m = 7.5\, D\, [1 - e^{-0.6 (F_d - 2)}]$; go to step 7

6b. Compute: $z_m = 10.5\, D\, [1 - e^{-0.35 (F_d - 2)}]$

7. Compute: $1.0 + 25 \dfrac{d_{50}}{D}$

8. Compute: If $\dfrac{Q}{\sqrt{gD^5}} < 1.0 + 25 \dfrac{d_{50}}{D}$, then go to step 9; otherwise, make design adjustments to increase d_{50} and return to step 4

9. Compute: $X_m = \left[X_p + \dfrac{z_m}{\tan \alpha} \right] 1.15 e^{-0.15 [Q/(gD^5)^{1/2}]}$

10. Compute: $L_e = z_m \left[\dfrac{3}{2} + \dfrac{1}{3} \dfrac{Q}{\sqrt{gD^5}} \right]$

$$W_e = z_m \left[1.5 + 0.15 \frac{Q}{\sqrt{gD^5}} \right]$$

11. Compute: Determine A_2, plan rectangular area of the plunge pool bottom at $0.8 z_m$ below the water surface

$L_{r2} = 0.2\, L_e$

$W_{r2} = 0.2\, W_e$

$A_2 = 4\, L_{r2}\, W_{r2}$

12. Compute: Check the side slopes of the plunge pool and adjust, if necessary to acceptable grades, z_ℓ and z_w. The final length and width of the plunge pool at the water surface are $2L_r$ and $2W_r$, respectively.

$L_r = 0.8\, z_m z_\ell + L_{r2}$

$W_r = 0.8\, z_m z_w + W_{r2}$

13. Compute: If $L_r < X_m$, increase side slope, z_ℓ, so that $L_r > X_m$

14. Compute: Determine A_1, plan rectangular area of the plunge pool at the invert elevation of the outlet channel

$A_1 = 4\, (L_r - z_\ell z_d)\, (W_r - z_w z_d)$

15. Compute: Plunge Pool Volume:

The volume between a horizontal plane at the invert elevation of the outlet channel and the exposed riprap surface is V_{ao}

$$V_{ao} = \frac{1}{81} [A_1 + A_2 + \sqrt{A_1 A_2}] [0.8z_m - z_d], \text{ cu. yds.}$$

The volume between a horizontal plane at the inverted elevation of the outlet channel and a surface at a thickness, a_1, below the exposed riprap surface is V_{a1}

$$V_{a1} = \frac{1}{81} [A_{1(a_1)} + A_{2(a_1)} + \sqrt{A_{1(a_1)} A_{2(a_1)}}] [0.8z_m - z_d + a_1], \text{ cu. yds.}$$

where: $A_{1(a_1)} = 4 [L_r - z_\ell z_d + a_1 \sqrt{1 + z_\ell^2}] [W_r - z_w z_d + a_1 \sqrt{1 + z_w^2}]$

and, $A_{2(a_1)} = 4 [L_{r^2} + a_1(\sqrt{1 + z_\ell^2} - z_\ell)] [W_{r^2} + a_1(\sqrt{1 + z_w^2} - z_w)]$

The volume riprap at thickness, a_1, below a horizontal plane at the invert elevation of the outlet channel, exclusive of the volume of the riprap filter cap is $V_{a1} - V_{ao}$, cu. yds.

The volume between a horizontal plane at the inverted elevation of the outlet channel and a surface at a thickness, a_2, below the exposed riprap surface is V_{a2} .

$$V_{a2} = \frac{1}{81} [A_{1(a_2)} + A_{2(a_2)} + \sqrt{A_{1(a_2)} A_{2(a_2)}}] [0.8z_m - z_d + a_2], \text{ cu. yds.}$$

where: $A_{1(a_2)} = 4 [L_r - z_\ell z_d + a_2 \sqrt{1 + z_\ell^2}] [W_r - z_w z_d + a_2 \sqrt{1 + z_w^2}]$

and, $A_{2(a_2)} = 4 [L_{r^2} + a_2(\sqrt{1 + z_\ell^2} - z_\ell)] [W_{r^2} + a_2(\sqrt{1 + z_w^2} - z_w)]$

The volume of filter material of thickness, $a_2 - a_1$, below a horizontal plane at the invert of the riprap filter cap, is equal to $V_{a2} - V_{a1}$, cu. yds.

Plunge Pool Design at Submerged Pipe Spillway Outlets

Note: An Excel spreadsheet is available for this method

Procedure

1. Determine Design Flow, Q, Pipe Diameter, D_o, and downstream Tailwater Elevation, TW. This procedure is valid for a ratio of $0.7 \leq TW / D_o \leq 2$. The dimensions determined by this procedure are shown on Figure 8.06h, and as defined as follows:

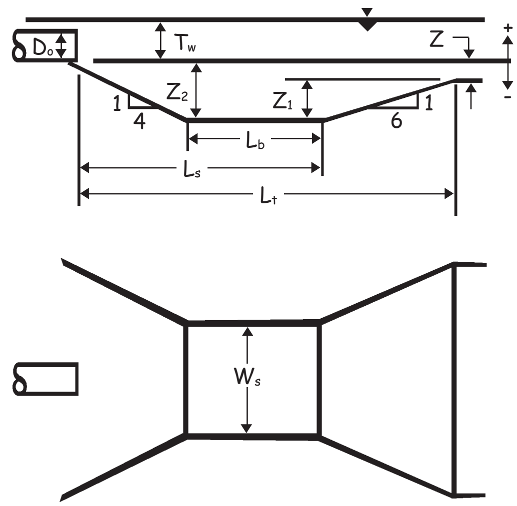


Figure 8.06h

A_o = Cross-sectional area of pipe

D_o = Pipe diameter

D_{50} = Diameter of average size of riprap

g = Acceleration due to gravity [9.81 m/s^2 (32.17 ft/s^2)]

L_b = bottom length of plunge pool

L_s = Length from outlet to downstream end of bottom of plunge pool

L_t = [$L_s - 6(Z_1)$], length from outlet to downstream end of plunge pool

Q = discharge

S = slope of pipe outlet

TW = tailwater elevation relative to outlet invert, measured adjacent to outlet, positive up

V_o = Q/ A_o = mean pipe velocity

W_s = bottom width of plunge pool

W_t = top width of plunge pool for Z_1 depth plunge pool

W_{TW} = top width of plunge pool at tailwater elevation

x = distance downstream of pipe exit

y = distance normal to pipe centerline

Z = distance from outlet invert to natural bed elevation, negative down

Z_1 = ($Z_2 - Z_1$), depth of plunge pool; distance from natural channel bed elevation to bottom of plunge pool, negative down

Z_2 = distance from outlet invert to bottom of plunge pool, negative down

Z_p = height of pipe invert above (+) or below (–) the tailwater surface

2. Select a median stone size, $D_{50.}$

3. Determine the plunge pool depth to pipe diameter ratio.

$$\frac{Z_2}{D_o} = -3.75 \left\{ \log \frac{Q^2}{gD_o^5} - \log \left[4.35 \frac{D_{50}}{D_o} \right]^{1.18} \right\}$$

4. Determine the plunge pool width, W_s to pipe diameter ratio.

$$\frac{W_s}{D_o} = 3.0 - \frac{Z_2}{D_o}$$

Side slope of the plunge pool should be 2H:1V or flatter.

5. Determine the plunge pool length to pipe diameter ratio.

$$\frac{L_s}{D_o} = 10 - 1.5 \frac{Z_2}{D_o}$$

6. Calculate values for Z_2, W_s and L_s by multiplying the ratios by D_o

$$\left\{ \left(\frac{Z_2}{D_o}\right) \left(\frac{W_s}{D_o}\right) \left(\frac{L_s}{D_o}\right) \right\} D_o = Z_2, W_s, L_s$$

7. Determine Z_1.

$Z_1 = Z_2 - Z$

8. Determine L_t and L_b .

$L_t = L_s - 6Z_1$ (Z_1 is negative down)

$L_b = L_s + 4Z_2$ (Z_2 is negative down)

9. Determine the plunge pool top width, W_t, and the water surface top width of tailwater, W_{TW}.

$W_t = W_s - 4Z_2$ (Z_2 is negative down)

$W_{TW} = W_s + 4(TW - Z_2)$ (Z_2 is negative down)

This method is valid for:

$$\frac{Q^2}{gD_o^5} > 0.5$$

$$\frac{Z_1}{D_o} \leq -0.25$$

References

Rice, C.E. and Kadauy, K.C. 1994. Plunge Pool Design at Submerged Pipe Spillway Outlets. Transactions of the ASCE. Vol. 37(4):1167-1173.

USDA. SCS. 1986 Design Note No.6. Riprap Lined Plunge Pool for Cantilevered Outlet.

USDOT, FHWA. 1983 Hydraulic Engineering Circular No.14. Hydraulic Design of Energy Dissipaters for Culverts and Channels.

8.07

SEDIMENT BASIN DESIGN

The design of temporary sediment basins for construction sites should meet all minimum requirements contained in *Practice Standards and Specifications: 6.61, Sediment Basin*.

The following outline provides guidance in designing sediment basins to meet those requirements.

Size, Location, and Efficiency

Structures intended for more than 3 years of use should be designed as permanent structures. **Procedures outlined in this section do not apply to permanent structures.** All high hazard potential dams and structures taller than 25 feet and that also have a maximum storage capacity of 50 acre-feet or more are subject to the N.C. Dam Safety Law of 1967.

Basic requirements for design of a sediment basin are the following:

- drainage area less than 100 acres;
- design structure life less than 3 years;
- minimum design storm, 10-yr peak runoff with minimum 1 ft freeboard;
- In High Quality Water (HQW) Zones, minimum design storm, 25-yr peak runoff with minimum 1 foot freeboard. The sediment basin shall settle the 40-micron particle with a minimum efficiency of at least 70% during the 2-yr peak runoff event. See appendices beginning on pg. 8.07.13.
- hazard classification: sudden failure should not cause loss of life or serious property damage.

Basin location—Locate the basin so that a maximum amount of runoff from disturbed areas can be brought into the structure. It should be accessible for periodic cleanout and should not interfere with construction activities. When possible delay clearing the sediment impoundment area until the dam is in place. Keep the remaining temporary pool area undisturbed.

Basin volume—Minimum volume of the basin should be 1,800 ft^3/acre for the disturbed area draining into the basin. Volume is measured below the principal spillway crest. Where possible the entire drainage basin is used for this computation, rather than the disturbed area alone, to help ensure adequate trapping efficiency.

Trapping efficiency—For additional information see Appendices pg. 8.07.13-8.07.42) Maximize the trapping efficiency of the basin by:

- diverting runoff from undisturbed areas away from the basin;
- limiting drainage area to increase the ratio of basin surface area to peak inflow rate. This ratio should be 435 ft^2/cfs or greater to achieve more than 75% efficiency on most soils. Subdivide area with additional traps and barriers to limit inflow rate and improve efficiency;
- maximizing the length-to-width ratio of the basin. Length to width should be 2:1 to 6:1;
- locating sediment inflow points as far as possible from the principal spillway inlet;
- controlling flow at inlet points to maintain nonerosive velocities.

Basin cleanout—Plan to remove sediment when approximately one half of the basin volume has been filled. **The minimum volume requirement (1,800 ft^3/acre) must always be met.**

Spillway System Design

The spillway system, consisting of a principal spillway and an emergency spillway, should carry the peak runoff from a 10-year storm with a minimum 1 foot freeboard above the design water surface in the emergency spillway. Base runoff computations on the most severe soil cover conditions expected during the effective life of the structure (*Appendix 8.03*).

PRINCIPAL SPILLWAY
The principal spillway consists of a vertical pipe riser fastened to a horizontal pipe barrel with watertight connectors. The horizontal conduit must extend beyond the toe of the dam and must be stabilized, usually by riprap.

Minimum capacity—2-year peak runoff, computed for water surface at the emergency spillway elevation.

Crest elevation of the riser may be set no lower than the elevation of the sediment detention pool as a minimum.

Barrel conduit and riser—The minimum barrel conduit size allowable is 15 inches for corrugated pipe and 12 inches for smooth-walled pipe. Limit the maximum barrel diameter to 30 inches. The riser should have a cross-sectional area at least 1.5 times that of the barrel. Rod and lug type connector bands with gaskets are recommended for corrugated pipe to provide positive watertight connections.

Basin dewatering should be from the water surface, using a floating surface intake or by operating a flash board riser.

The minimum dewatering time is 48 hours, and not more than 1 foot of stage draw-down per day.

Trash guard—Install a trash guard on top of the riser. A fabricated cone of steel rods, spaced 2 inches apart, fastened to the top of the riser is recommended.

Protection against piping—Secure at least one watertight antiseep collar with a minimum projecting of 1.5 feet around 12-inch or larger conduits. Locate the collar just downstream from the centerline of the dam. A properly designed drainage diaphragm installed around the barrel may be substituted for an antiseep collar.

Protection against flotation—Anchor the riser with a mass with a buoyant weight greater than 1.1 times the weight of water displaced by the riser.

Stabilize the outlet below the barrel against erosion (*Appendix 8.06*).

EMERGENCY SPILLWAY

Construct the entire flow area of the emergency spillway in undisturbed soil. Cross section should be trapezoidal, with side slopes 3:1 or flatter. Select vegetated lining to meet flow requirements and site conditions (Figure 8.07a)

Capacity—Design the emergency spillway for runoff from the 10-year storm less any reduction due to flow in the principal spillway.

Inlet protection—Ensure that the approach section has a slope toward the impoundment area of not less than 2% and is flared at its entrance, gradually reducing to the design width of the control section.

The control section should be level and straight and at least 20 ft long. Determine the width and depth for the required capacity and site conditions. Wide, shallow spillways are preferred because they reduce outlet velocities.

The outlet section should be straight, aligned and sloped to assure supercritical flow with exit velocities not exceeding values acceptable for site conditions.

Outlet velocity—Ensure that the velocity of flow from the basin is nonerosive for existing site conditions. It may be necessary to stabilize the downstream areas or the receiving channels.

EMBANKMENT DESIGN

There should be a cutoff trench in stable soil material under the dam at the centerline, extending up the abutments to the elevation of the emergency spillway. The trench should be at least 2 feet deep with 1:1 side slopes, and sufficiently wide to allow compaction by machine.

Top width—Fill height 10 feet: minimum top width 8 feet
Fill height 10-15 feet: minimum top width 10 feet

Allowment for settlement—10% of fill height.

Side slope—2.5:1 or flatter

Freeboard—minimum 1 foot between the settled top of the dam and the design water level in the emergency spillway.

Embankment material should be a stable mineral soil, free of roots, woody vegetation, rocks or other objectionable materials, with adequate moisture for compaction. Place fill in 8-inch layers through the length of dam and compact by routing construction hauling equipment over it. Equipment must traverse the entire surface of each layer by at least one wheel width.

EROSION CONTROL

Construct the structure to minimize the area disturbed. Divert surface water away from disturbed areas. Complete the embankment before clearing the impoundment area. Stabilize the emergency spillway, embankment, and all other disturbed areas above the crest elevation of the principal spillway immediately after construction (*Practices 6.10-6.15, Surface Stabilization*).

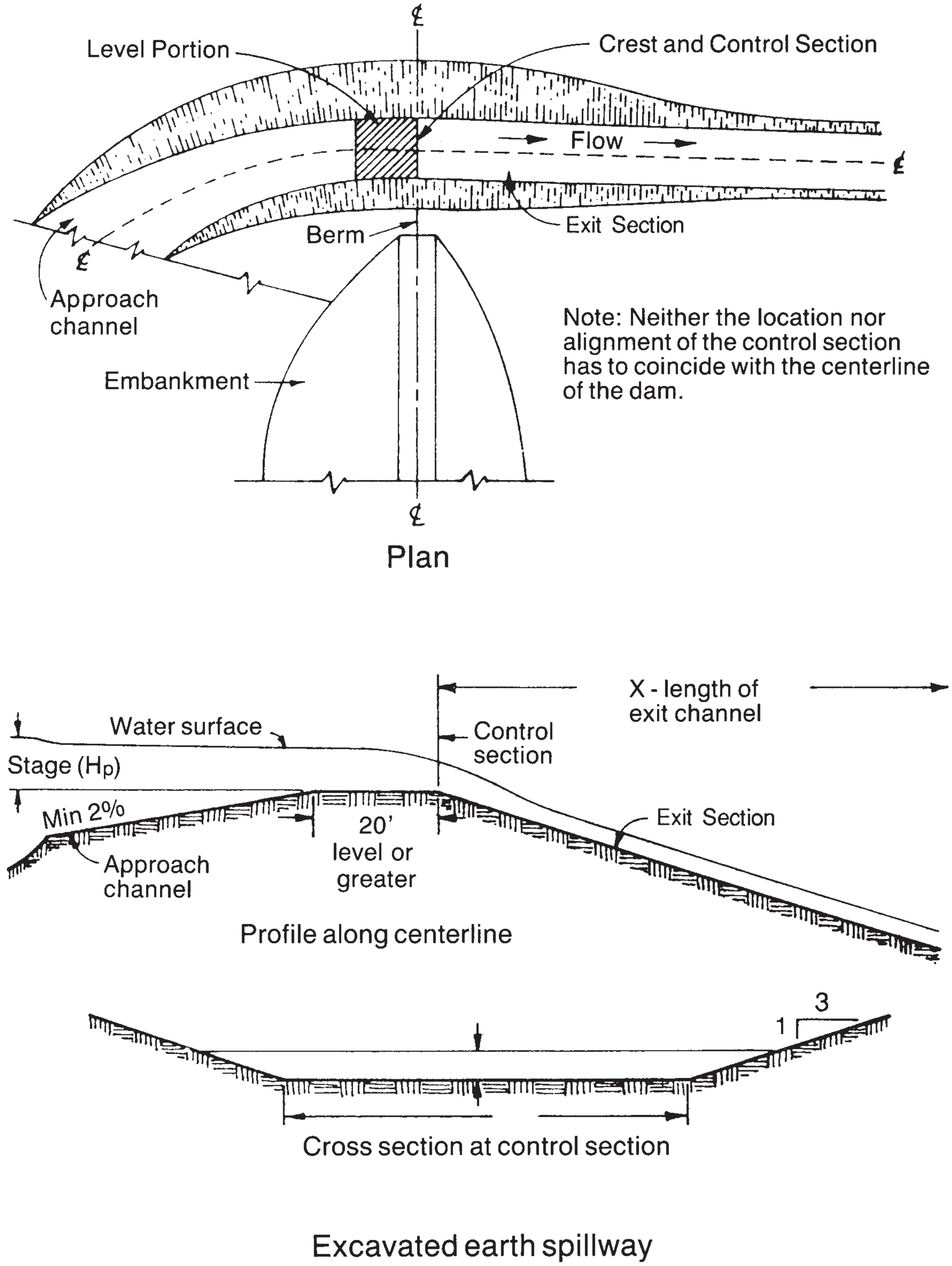


Figure 8.07a Design of excavated earthen spillway.

Safety—Avoid steep side slopes. Fence basins properly and mark them with warning signs if trespassing is likely. Follow all State and local safety requirements.

Design Procedure

Step 1. Determine peak flow, Q_{10}, for the basin drainage area (*Appendix 8.03*).

Step 2. Determine any site limitations for the sediment pool elevation, emergency spillway or top of the dam.

Step 3. Determine basin volumes:

- Compute minimum volume required (1800 ft^3/acre disturbed).
- Specify sediment cleanout level to be marked on riser (one-half the design volume referenced to the top of the riser) and sediment storage area to be cleared after the dam is built.

Step 4. Determine area and shape of basin:

- Check length/width ratio (should be 2:1 to 6:1).
- Compute the basin surface area at principal spillway elevation.
- Check the ratio of basin surface area to peak inflow rate (should be greater than or equal to 435 ft^2/cfs). Employ diversions with additional traps and basins to reduce area drained.

Determine barrel capacity required for site conditions (minimum capacity for Q_p is the 2-year peak runoff, Q_2.

Step 5. Determine the principal spillway discharge capacity.

- The combined capacities of the principal and emergency spillways must be at least the 10-year peak flow for the entire watershed of the basin.
- The principal spillway is analyzed for three possible limiting flow types: Weir flow, Orifice flow, and Pipe flow. The principal spillway discharge capacity is the smallest of these three flow rates. Discharges through a skimmer should be disregarded during this computation. Weir, orifice and pipe flow may be determined by the following equations:

1. Weir Flow: $Q = CLH^{1.5}$

where:
Q = discharge in cubic feet per second (cfs)
C = weir coefficient, use 3.1 for corrugated metal pipe risers.
L = circumference of the riser in feet
H = head above riser crest in feet

2. Orifice Flow: $Q = CA\,(2gH)^{0.5}$

where:
Q = discharge in cubic feet per second (cfs)
C = orifice coefficient, use C = 0.6 for corrugated metal pipe risers.
A = cross-sectional area of the riser pipe in square feet
g = acceleration due to gravity, 32.2 ft/sec^2
H = head above riser crest in feet

3. Pipe Flow: $Q = a \left[\frac{2gh}{1 + K_m + K_p L}\right]^{0.5}$

where:

Q = discharge in cubic feet per second (cfs)
a = cross-sectional area of the barrel in square feet
g = acceleration due to gravity, 32.2 ft/sec^2
h = head above the centerline of the outlet end of the barrel
K_m = coefficient of minor losses, can be assumed to be 1.0 for most principal spillway systems
L = barrel length in feet
K_p = pipe friction coefficient:

$$= \frac{5087n^2}{di^{4/3}}$$

(See Table 8.07c for K_p values for common size of pipe.)

n = Manning's coefficient of roughness, use n = 0.025 for corrugated metal pipe
n = 0.015 for reinforced concrete pipe
di = inside diameter of the barrel in inches

Select riser and barrel dimensions so that the riser has a cross-sectional area at least 1.5 times that of the barrel. Spillway hydraulics are improved by maximizing weir flow and minimizing orifice flow. See Table 8.07b for recommended riser/barrel proportions.

Table 8.07a K_p Values for Common Sizes of Pipe

Pipe Diameter (inches)	Flow Area (square feet)	Manning's Coefficient	
		0.015	0.025
6	0.196	0.1050	0.2916
8	0.349	0.0715	0.1987
10	0.545	0.0531	0.1476
12	.0785	0.0417	0.1157
14	1.069	0.0339	0.0942
15	1.23	0.0309	0.0859
16	1.40	0.0284	0.0789
18	1.77	0.0243	0.0674
21	2.41	0.0198	0.0549
24	3.14	0.0165	0.0459
27	3.98	0.0141	0.0393
30	4.91	0.0123	0.0341
36	7.07	0.0096	0.0267
42	9.62	0.0078	0.0218
48	12.57	0.0066	0.0182
54	15.90	0.0056	0.0156
60	19.64	0.0049	0.0135

RISER

Select trail riser and barrel dimensions. Use the weir, orifice and pipe flow equations to determine if the 2-year peak discharge is passed without activating the emergency spillway. Determine riser size from Table 8.07b. Check the head and stage requirements. If the design stage is too high, choose larger dimensions and recalculate. As a minimum, set the elevation of the riser at the same elevation as the top of the sediment pool. A riser height 2 to 5 times the barrel diameter is recommended. Select the type of trash guard.

Select a dewatering device. If a skimmer is used, refer to the manufacturers dewatering data, or Table 6.64.a.

Step 6. Design antiseep collar.
Ensure that antiseep collars are no closer than 2 ft from a pipe joint. Collar must project at least 1.5 ft from the pipe. Indicate watertight connections.

Step 7. Design antiflotation block.
Determine the weight of water displaced by the empty riser, and design a block with buoyant weight 1.1 times the weight of water displaced.

Step 8. Design outlet.
Determine discharge velocity from the barrel. Design outlet protection to assure stable conditions. Riprap placement is usually necessary (*Appendix 8.06*).

Step 9. Design emergency spillway.

- Determine the required capacity for the emergency spillway as

$$Q_e = Q_{10} - Q_p \ (Q_p \geq Q_2)$$

- From Table 8.07e or Table 8.07f, select the width and depth of the outlet, depending on soil conditions. In general, the wider bottom widths and lower slopes are preferred to minimize exit velocities at supercritical flow.

- An acceptable alternative is the use of the weir equation

$$Q = CLH^{1.5}$$

  Where this option is used, the maximum value of C should be 2.8. L is the bottom width of the spillway at the crest, and H is the depth of flow above the spillway crest in feet. Note: Manning's channel equation should not be used to size the spillway crest. However, it should be used to design the outlet channel below the spillway crest.

- The total of the emergency and principle spillway capacities must equal or exceed the required 10-year peak discharge.

- Set the elevation of the crest of the emergency spillway a minimum of 1 foot above the crest of the riser.

Step 10. Spillway approach section.
Adjust the spillway alignment so that the control section and outlet section are straight. The entrance width should be 1.5 times the width of the control section with a smooth transition to the width of the control section. Approach channel should slope toward the reservoir no less than 2%.

Table 8.07b Design chart for riser outlet

Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (d) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes-3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%

Find: Bottom width and Stage in Spillway

Procedure: Enter table from left at 90 c.f.s. Note that Spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. State in Spillway will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = 0.40. Maximum velocity 5.50 ft. per sec.

Table 8.07d
Design Table for Vegetated Spillways Excavated in Very Erodible Soils
(side slopes-3 horizontal:1 vertical)

Discharge Q CFS	Slope Range		Bottom Width Feet	Stage Feet
	Minimum Percent	Maximum Percent		
10	3.5	4.7	8	.68
15	3.4	4.4	12	.69
	3.4	5.9	16	.60
20	3.3	3.3	12	.80
	3.3	4.1	16	.70
	3.5	5.3	20	.62
25	3.3	3.3	16	.79
	3.3	4.0	20	.70
	3.5	4.9	24	.64
30	3.3	3.3	20	.78
	3.3	4.0	24	.71
	3.4	4.7	28	.65
	3.4	5.5	32	.61
35	3.2	3.2	24	.77
	3.3	3.9	28	.71
	3.5	4.6	32	.66
	3.5	5.2	36	.62
40	3.3	3.3	28	.76
	3.4	3.8	32	.71
	3.4	4.4	36	.67
	3.4	5.0	40	.64
45	3.3	3.3	32	.76
	3.4	3.8	36	.71
	3.4	4.3	40	.67
	3.4	4.8	44	.64
50	3.3	3.3	36	.75
	3.3	3.8	40	.71
	3.3	4.3	44	.68
60	3.2	3.2	44	.75
	3.2	3.7	48	.72
70	3.3	3.3	52	.75
80	3.1	3.1	56	.78

Example of Use

Given: Discharge, Q = 38 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Spillway.

Procedure: Enter table from left at 40 c.f.s. Note that Spillway slope (4.0%) falls within slope ranges corresponding to bottom widths of 36 and 40 ft. Use wider bottom width, 40 ft., to minimize velocity. Stage in Spillway will be 0.64 ft.

Note: Computations based on: Roughness coefficient, n = 0.40. Maximum velocity = 3.50 ft. per sec.

Step 11. Spillway control section

- Locate the control section in the spillway near where it intersects the extension of the centerline of the dam.
- Keep a level area to extend at least 20 ft upstream from the outlet end of the control section, to ensure a straight alignment.
- Side slopes should be 3:1.

Step 12. Design spillway exit section.

- Spillway exit should align with the control section and have the same bottom width and side slopes.
- Slope should be sufficient to maintain supercritical flow, but make sure it does not create erosive velocities for site conditions. (Stay within slope ranges in appropriate design tables.)
- Extend the exit channel to a point where the water may be released without damage.

Step 13. Size the embankment.

- Set the design elevation of the top of the dam a minimum of 1 ft above the water surface for the design flow in the emergency spillway.
- Constructed height should be 10% greater than the design to allow for settlement.
- Base top width on the design height.
- Set side slopes 2.5:1 or flatter.
- Determine depth of cutoff trench from site borings. It should extend to a stable, tight soil layer (a minimum of 2 ft deep).
- Select borrow site–the emergency spillway cut will provide a significant amount of fill.

Step 14. Erosion control

- Locate and design diversions to protect embankment and spillway (*Practice Standards and Specifications: 6.20, Temporary Diversions*).
- Select surface protection measures to control erosion (*Practice Standards and Specifications: 6.10, Temporary Seeding; 6.14, Mulching; and 6.15, Riprap*).
- Select groundcover for emergency spillway to provide protection for design flow velocity and site conditions. Riprap stone over geotextile fabric may be required in erodible soils or when the spillway is not in undisturbed soils.

Step 15. Safety.

- Construct a fence and install warning signs as needed.

EFFICIENCY-BASED SEDIMENT BASINS

DEFINITION

Efficiency-based sediment basins are sediment basins that are designed to settle particles of a given size at a specified minimum settling efficiency during the passage of a specified design storm.

PURPOSE

To capture fine sediment particles with a high degree of confidence at sites in sensitive areas.

CONDITION WHERE PRACTICE APPLIES

Efficiency-based basins are to be used for sediment basins on sites located in areas designated as High Quality Waters.

PLANNING CONSIDERATIONS

Basin site selection

Locate sediment basins in drainage swales near periphery of the site and at other points in the disturbed area where it is important to remove fine sediment particles from stormwater runoff. It is especially important to consider:

- Topography: The ideal shape of a sediment basin is broad and shallow, with length about three times width.
- Drainage area: The drainage area of the sediment basin is the <u>maximum</u> area that will contribute flow to the basin during any phase of land disturbance.
- Offsite water: The drainage area of any watercourse that contributes off-site flow to the sediment basin must be included in the drainage area of the sediment basin.
- Diversion channels: Construct diversion channels where needed to ensure that all stormwater intended for treatment in the sediment basin is conveyed to the basin in all phases of land disturbance.

Basin description

The sediment basin will consist of a dike or dam fitted with a riser-barrel principal spillway and an emergency spillway, a sediment storage volume, a stormwater treatment volume, and an inlet zone.

Preparation of source data

Analytical verification of expected basin performance will depend on three sets of information:

- The inflow hydrograph is based upon data collected on local rainfall statistics, soil conditions and watershed size and topography.
- The stage-storage function is based on the size and shape of the sediment and water storage area behind the dam.
- The stage-discharge function is based on the hydraulics of the principal spillway.

DESIGN CRITERIA

Design objective

The sediment basin shall be designed to settle the 40 micron particle with minimum settling efficiency of 70 percent during the two-year storm event.

Basin configuration

In the design and configuration, the following elements of the basin should be considered:

- Inlet and outlet zone: Arrange the basin inlet and outlet to interrupt the flow path by baffles or by directing the inlet flow so that flow will not tend to flow in a narrow band directly from inlet to outlet.
- Sediment-storage zone/cleanout schedule: Consider carefully the size of the sediment-storage volume in relation to the cleanout schedule. A small sediment-storage zone will lead to a smaller pond, but it will require more frequent cleanout.
- Riser/barrel: Design, fabrication, installation and maintenance of this feature are critical in determining settling behavior of the basin.
- Drain hole(s): These holes provide slow drawdown of the water level after a storm so that fine particles are captured before water release. They should be checked after a rainfall event to remove any blockage.
- **Emergency spillway: Provide an emergency spillway to pass safely that flow that exceeds the design storm for sediment control.**
- Dam: The dam or dike should be carefully designed and constructed for safe and effective performance.

HYDROLOGIC DATA

In the procedures that follow, locally specific hydrologic data are necessary. Refer to the table for the values that apply at the location of interest.

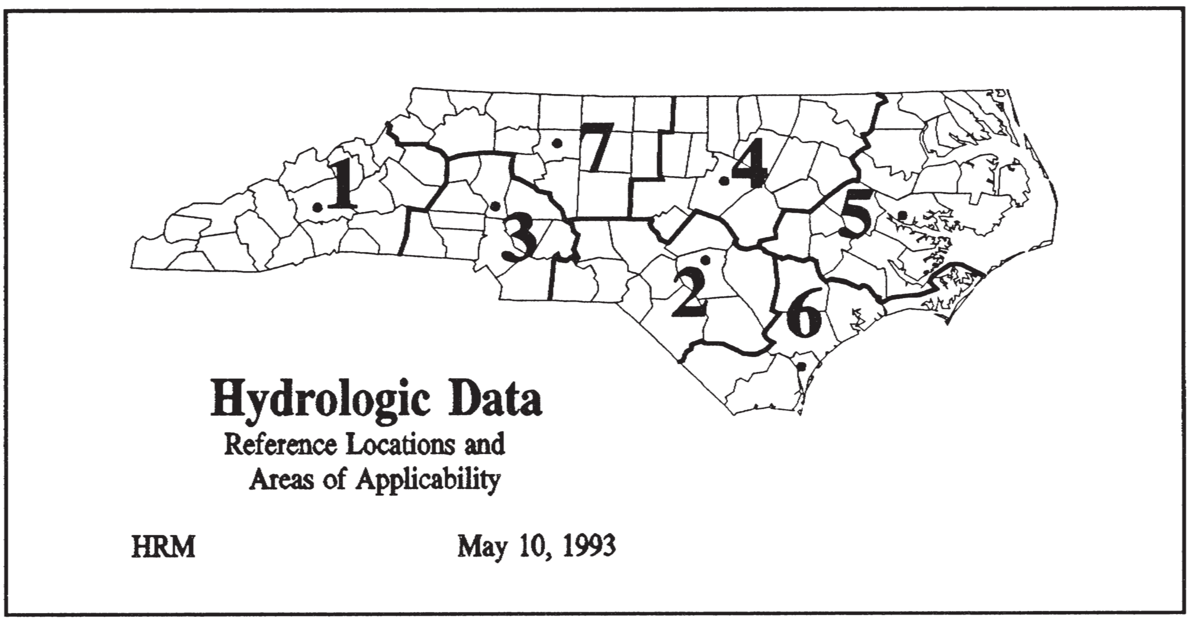
For use in the Rational Equation, the applicable value of rainfall intensity, *I*, can be found by the expression

$$I = \frac{g}{h + T_c}$$

in which I = Applicable rainfall intensity (in/hr)

T_c = Time of concentration at the point of interest (min)

g and h are locally specific constants obtained from the table below.



Hydrologic Reference Data

Region	Office	2-yr intensity values g	h	2-yr, 6-hr precip (in)	2-yr, 24 hr precip (in)
1	Asheville	145	23	2.8	3.80
2	Fayetteville	149	20	2.9	3.80
3	Mooresville	130	19	2.6	3.50
4	Raleigh	132	18	2.7	3.60
5	Washington	153	21	3.0	4.00
6	Wilmington	171	24	3.3	4.50
7	Winston-Salem	126	19	2.6	3.50

ALTERNATIVE PROCEDURES

Three alternative procedures are given for designing sediment basins. Method 1 applies to basins on relatively small and uncomplicated sites for which a conservative approximation is appropriate. Method 2 is for small and intermediate sites for which rectangular approximations of basin geometry are reasonable. Method 3 is the most precise in representing site conditions, basin geometry and settling behavior.

Method 1 can be applied to sediment traps fitted with stone spillways. Stone spillways are not suitable for basins designed by Methods 2 and 3.

These procedures provide for the configuration of the outlet devices and sediment settling and storage zones of the basins. **The designer must also insure that the basin is capable of passing the 25-year storm without overtopping the dam or dike.**

METHOD 1

Select basin location

Determine values of input data

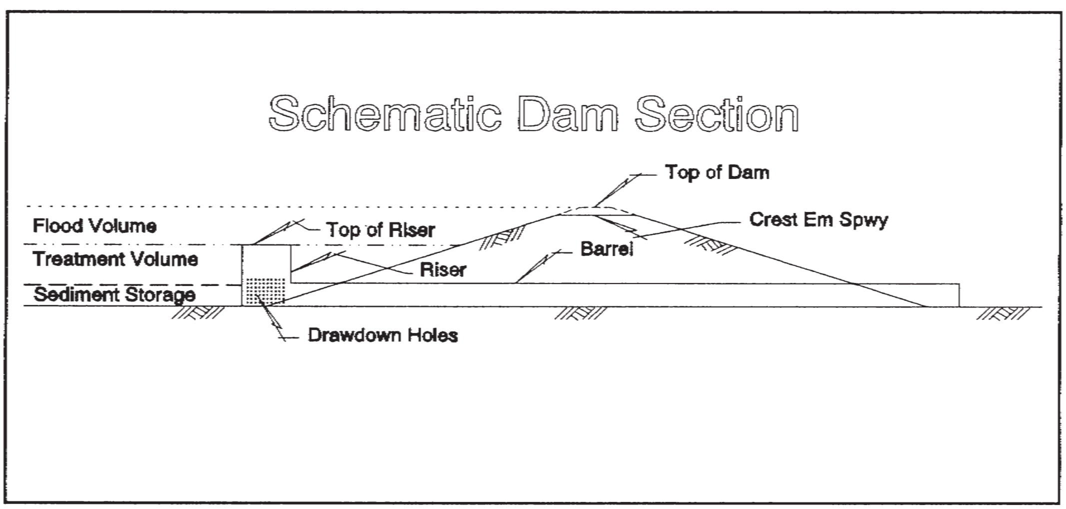
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  SCS Curve Number
  Area available for basin (sq ft)

- Storm data

  2-yr, 24-hr rainfall depth (in)

Review the schematic of the riser/barrel and dike



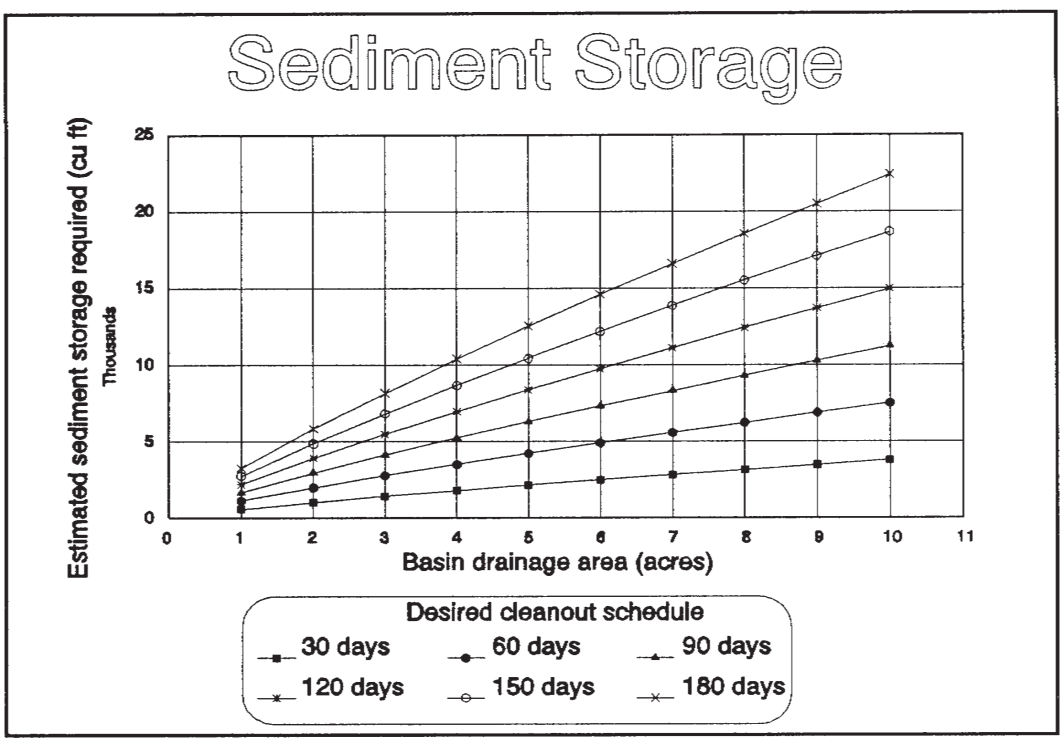
Compute estimated volume of sediment to be stored before cleanout

- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)
- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Estimate volume of stormwater to be treated by the procedure or the graph

- Determine runoff depth of 2-yr, 24-hr storm.

$$S = \frac{1000}{CN} - 10$$

in which S = Ultimate soil storage capacity (in)
CN = SCS CN for basin drainage area

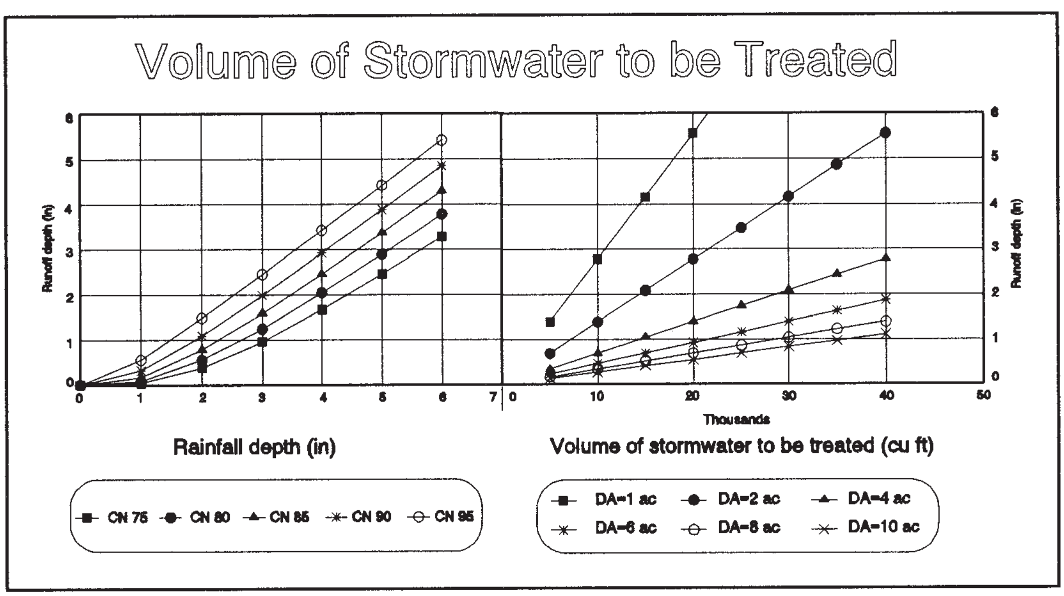
$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which Q^* = Estimated runoff depth (in)
P = 2-yr, 24-hr rainfall depth (in)
S = Ultimate soil storage capacity (in)

- Compute volume of stormwater to be treated.

$$V_s = 3630 Q^* A$$

in which V_s = Volume of stormwater to be treated (cu ft)
Q^* = Estimated runoff depth (in)
A = Basin drainage area (ac)



- Decide on the dimensions of the basin.

- Set the width and length such that the length is three times the width.

- Determine the basin surface area (width times length).

- Determine the depth of sediment storage by dividing the sediment storage volume by the basin surface area. Check to insure that this is a safe and workable depth. It will be full of water during rainy periods.

- Determine the depth of treatment volume by dividing the treatment volume by the basin surface area.

- The total height of the riser is the sum of the depths of sediment storage and treatment volume.

Select the sizes of the riser/barrel and emergency spillways to safely convey the maximum peak rate of runoff from the 25-year storm.

- Refer to *Appendix 8.07*.

Set the number and diameter of drawdown holes to drain the pond after a storm.

Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07)*

METHOD 2

Note: This procedure assumes that the basin bottom is essentially flat and that the sides are nearly vertical. The basin surface area is the area of the bottom of the basin.

Select basin location

Determine values of input data

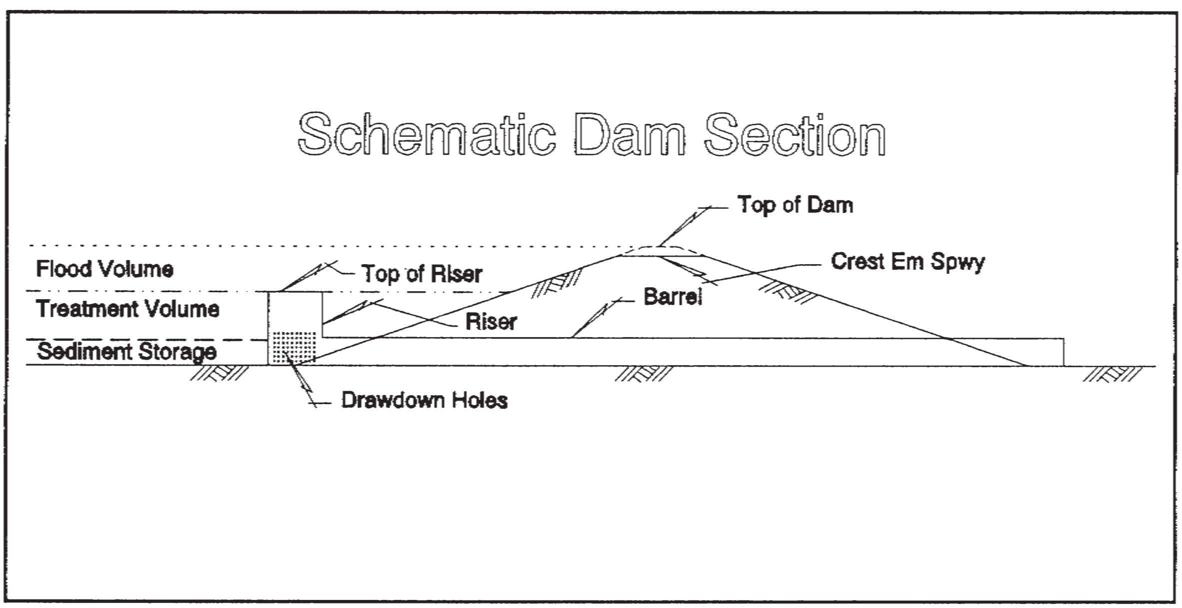
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  Time of concentration (min)
  Rational runoff coefficient
  SCS Curve Number
  Area available for basin (sq ft)

- Storm data

  2-yr, 6-hr rainfall depth (in)
  2-yr rainfall intensity for the time of concentration

Review the schematic of the riser/barrel and dike



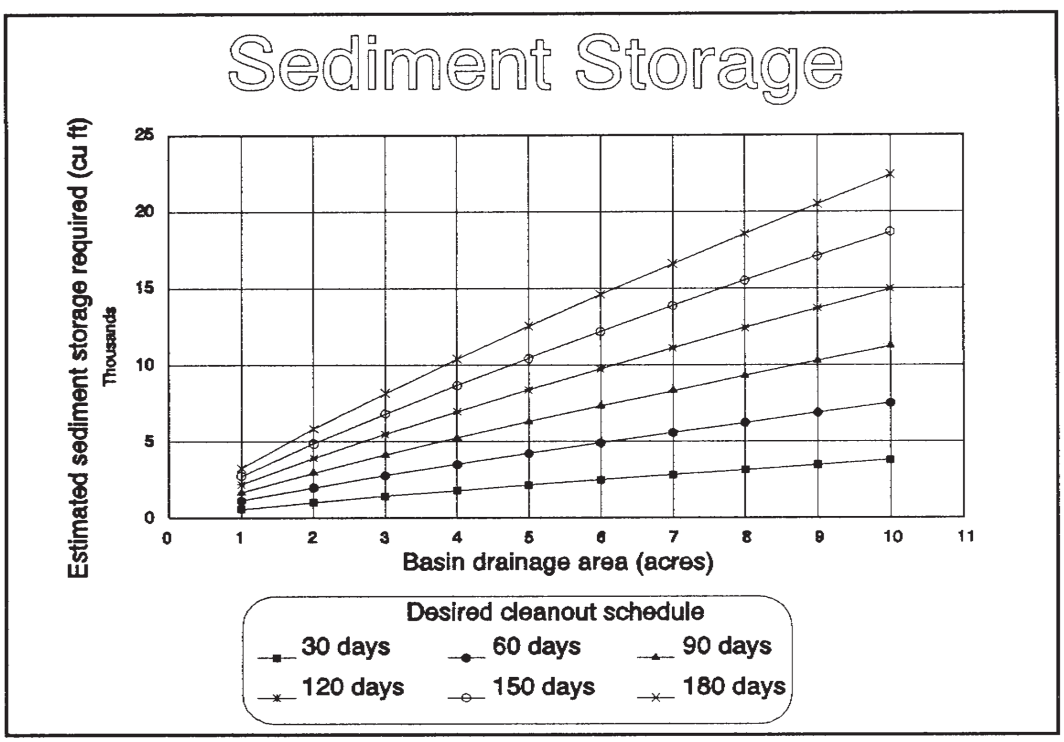
Compute estimated volume of sediment to be stored before cleanout

- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)
- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Formulate inflow hydrograph

Note: The inflow hydrograph should be formulated for the worst combination of cover conditions and contributory drainage area during the period of disturbance.

- Estimate the peak flow, Q_p, by Rational method (*Appendix 8.03*).
- Estimate the time to peak, T_p:

  Determine the depth of runoff in the 2-yr, 6-hr storm using the SCS method.

$$S = \frac{1000}{CN} - 10$$

in which	S	=	Ultimate soil storage capacity (in)
	CN	=	SCS CN for basin drainage area

$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which	Q*	=	Estimated runoff depth (in)
	P	=	2-yr, 6-hr rainfall depth (in)
	S	=	Ultimate soil storage capacity (in)

Determine the time to peak.

$$T_p = \frac{43.5 Q^* A}{Q_p}$$

in which	Q*	=	Estimated runoff depth (in)
	A	=	Drainage area (ac)
	Q_p	=	Estimated peak flow by Rational equation (cfs)
	T_p	=	Time to peak (min)

- Discharges at various times of interest can be computed for the estimated inflow hydrograph by the step function given below. (*Note: It is not necessary to compute points on the hydrograph unless the designer wishes to verify the design by flood routing*).

  For times of interest between 0 and 1.25 T_p:

$$Q = \frac{Q_p}{2}\left[1 - \cos\left(\frac{\pi t}{T_p}\right)\right]$$

  For times of interest longer than 1.25 T_p:

$$Q = 4.34\, Q_p \exp\left[-1.30 \left(\frac{t}{T_p}\right)\right]$$

in which
Q_p = Peak flow (cfs)
T_p = Time to peak (min)
t = Time of interest for which the flow is sought (min)
Q = Flow at time of interest (cfs)

In these expressions, the argument of the cosine is in units of radians (the calculator should be in "radians mode"). The exponential function, *exp*, is frequently written as e^x, where x is the argument, as in *exp(x)*.

Set basin configuration

- Select basis surface area, length and width.
- Estimate allowable maximum outflow.

$$Q_o = \frac{A_s}{458}$$

in which
A_s = Surface area of the basin (sq ft)
Q_o = Allowable maximum outflow (cfs)

- Estimate required stormwater storage.

$$S = 60(Q_p - Q_o)T_p$$

in which
Q_p = Estimated peak inflow (cfs)
T_p = Estimated time to peak (min)
Q_o = Allowable maximum outflow (cfs)
S = Estimated stormwater storage required (cu ft)

- Determine maximum pond volume

  The maximum pond volume is the sum of the sediment storage, V_c, and the stormwater storage, S.

- Determine expected maximum stage.

$$Z_{max} = \frac{\textit{Maximum pond volume}}{A_s}$$

in which A_s = Surface area of the basin (sq ft)
Z_{max} = Expected maximum stage (ft)
(Maximum pond volume is expressed in cubic feet)

- Select barrel size.

  The barrel should be selected to deliver the expected maximum outflow, Q_o, when the water surface is at the maximum expected stage, Z_{max}. Selection may be made by using commonly available culvert capacity charts and tables, or it may be sized by application of the orifice equation. (Note that the orifice equation applies when the pipe is *inlet controlled.* If the outlet is submerged by high tailwater, the barrel must be analyzed under *outlet control*.) The orifice equation may be modified for direct application as:

$$Q=0.0437C_D D^2 \sqrt{Z_{max} - \frac{D}{24}}$$

in which C_D = Coefficient of discharge (typically 0.6)
D = Pipe diameter (in)
Z_{max} = Expected maximum stage (ft)
Q = Discharge delivered by pipe (cfs)

Proceed by selecting a pipe diameter, computing the discharge, Q, and comparing it to the expected maximum outflow, Q_o. Select the pipe whose delivered discharge, Q, is at or just below the expected maximum outflow, Q_o.

- Select riser size.

  The cross section of the riser should be at least 1.5 times the cross-sectional area of the barrel.

- Compute stage of top of riser.

  The stage or elevation of the top of the riser should be sufficiently below the maximum expected water level to allow flow to enter the riser freely, but the top of riser should not be set grossly below the maximum expected water level. It is recommended that the location of the top of the riser be computed from the maximum expected water level, Z_{max}, and an application of the weir equation:

$$Z_{riser} = Z_{max} - \left[\frac{Q_o}{0.86D} \right]^{\frac{2}{3}}$$

in which
Q_o = Expected maximum outflow (cfs)
D = Selected pipe diameter (in)
Z_{max} = Maximum expected water level (ft)
Z_{riser} = Recommended top of riser (ft above bottom of pond)

- Specify location, number and size of drawdown holes.
- Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07*)
- **Specify location, stage and length of emergency spillway to safely convey the maximum peak rate of runoff from the 25-year storm.** (*Appendix 8.07*)
- Configure dam or dike. (*Appendix 8.07*)
- Check and verify results.
- Prepare construction details and specifications.

METHOD 3

Note: This procedure allows more design control over the elements of the basin, and it considers more precisely such influences on settling behavior as the topography of the basin, and the shape of the hydrograph. When the trial basin is configured, the design storm must be routed through the facility to verify that settling performance is acceptable. It can be shown that settling performance is acceptable if, when the design hydrograph is routed through the sediment basin, the ratio of surface area to outflow exceeds 458 sq ft/cfs in all time steps.

Select basin location

Determine values of input data

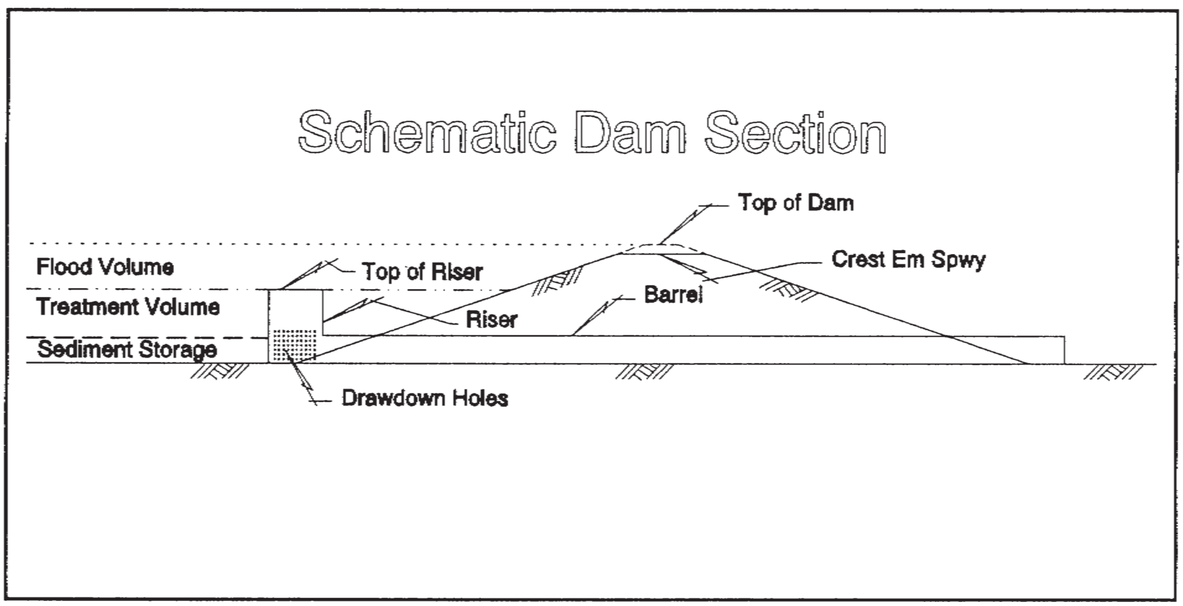
- Site data

  Drainage area (ac)
  Disturbed area (ac)
  Time of concentration (min)
  Rational runoff coefficient
  SCS Curve Number
  Area available for basin (sq ft)
  Topography of the basin (contour map)

- Storm data

  2-yr, 6-hr rainfall depth (in)
  2-yr rainfall intensity for the time of concentration

Review the schematic of the riser/barrel and dike



Compute estimated volume of sediment to be stored before cleanout

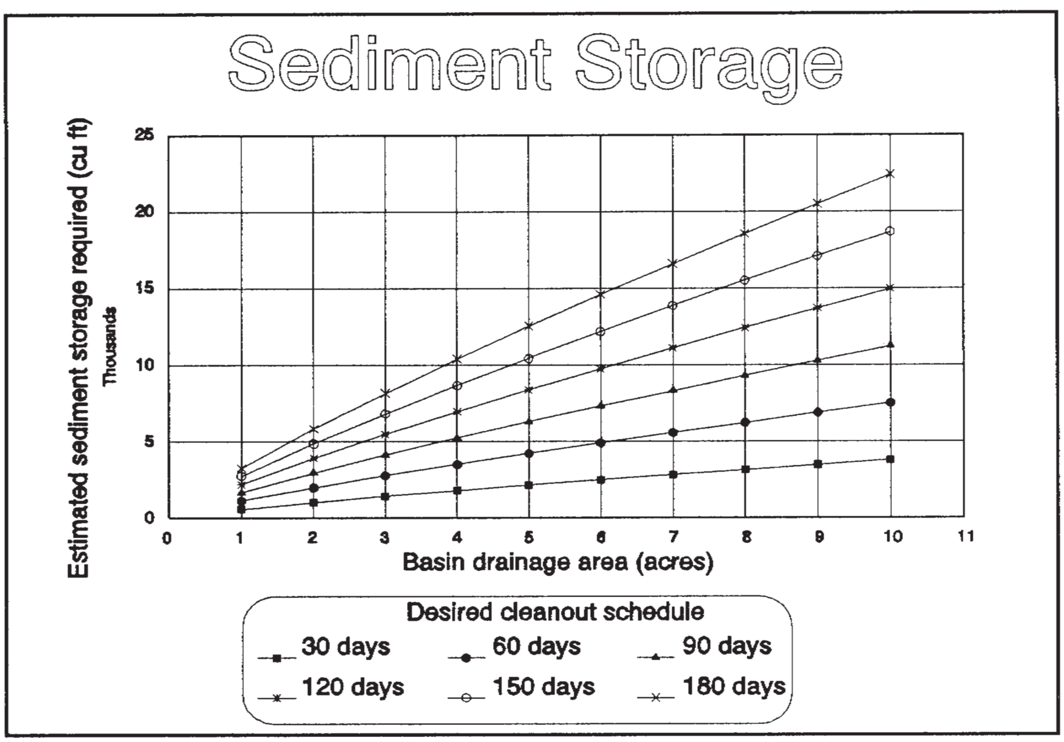
- Set desired cleanout interval (days).

  Note: The actual cleanout interval will depend upon weather and site conditions. This estimate is based on average conditions. (The equation is based on a sediment-discharge study: Malcom (1977), H.R. and Smallwood, C., "Sediment Prediction in the Eastern United States," J. Water Resources, Planning and Management Div., ASCE, v. 103, no. WR2.)

- Estimate the volume of sediment storage, V_c, by the equation, or by the graph:

$$V_c = 18TA^{0.84}$$

in which V_c = Cleanout volume (cu ft)
T = Cleanout interval (days)
A = Disturbed area (ac)



Formulate inflow hydrograph

Note: The inflow hydrograph should be formulated for the worst combination of cover conditions and contributory drainage area during the period of disturbance.

- Estimate the peak flow, Q_p, by Rational method (*Appendix 8.03*).
- Estimate the time to peak, T_p:

Determine the depth of runoff in the 2-yr, 6-hr storm using the SCS method.

$$S = \frac{1000}{CN} - 10$$

in which	S	=	Ultimate soil storage capacity (in)
	CN	=	SCS CN for basin drainage area

$$Q^* = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which	Q*	=	Estimated runoff depth (in)
	P	=	2-yr, 6-hr rainfall depth (in)
	S	=	Ultimate soil storage capacity (in)

Determine the time to peak.

$$T_p = \frac{43.5 Q^* A}{Q_p}$$

in which	Q*	=	Estimated runoff depth (in)
	A	=	Drainage area (ac)
	Q_p	=	Estimated peak flow by Rational equation (cfs)
	T_p	=	Time to peak (min)

- For the routing, discharges at various times of interest can be computed for the estimated inflow hydrograph by the step function given below.

  For times of interest between 0 and 1.25 T_p:

$$Q = \frac{Q_p}{2}\left[1 - \cos\left(\frac{\prod t}{T_p}\right)\right]$$

  For times of interest longer than 1.25 T_p:

$$Q = 4.34\ Q_p\ exp\left[-1.30\ \left(\frac{t}{T_p}\right)\right]$$

in which Q_p = Peak flow (cfs)
T_p = Time to peak (min)
t = Time of interest for which the flow is sought (min)
Q = Flow at time of interest (cfs)

In these expressions, the argument of the cosine is in units of radians (the calculator should be in "radians mode"). The exponential function, *exp*, is frequently written as e^x, where x is the argument, as in *exp(x)*.

Determine the stage-storage relation representing basin topography

The stage-storage relation can be formulated as a graph or as a mathematical expression. The latter is more useful in this application because it includes in a straightforward manner both water volume information and surface area information as they relate to depth in a pond of complex shape. Stage is the depth of water relative to the bottom of the pond. Storage is the volume of storage at a given stage. Storage includes both water and sediment stored above the bottom of the pond.

A stage-storage function may be formulated for a given basin as follows:

- Compute a set of representative storage volumes at various stages by applying the average-end area method of volume computation vertically to the set of known contours that express the basin topography. Arrange them as a list of stages, Z, and associated storages, S. If one plots the logarithms of storage versus the logarithms of stage, the resulting graph is usually a remarkably straight line, even for the apparently complex topography of a natural draw or swale. This observation leads to the power-curve representation described below.
- The expression for the stage-storage function is

$$S = K_s Z^b$$

in which Z = Stage (ft above the pond bottom)
S = Storage (cu ft)
K_s and b are constants to be determined for the basin of interest.

- There are two reasonable ways to determine K_s and b from the stage-storage list. One is to use a linear regression routine applied to the logarithms of the data and back calculate the constants, K_s and b, from the regression results. The regression procedure is preferred because the shape information contained in a number of contours can be used to set the constants. Regression routines are included in many scientific calculators and spreadsheet programs. Consult the appropriate manual for details.

  The other method is to obtain an approximation of the constants algebraically by using stage and storage values from two of the contours. It is usually best to select one point near the maximum expected water-surface elevation and the other at about mid-depth. The precision of the result can be tested and improved by trial and error.

  Select two points on the stage-storage function as described above. Let the lower be point number one and the upper be point number two.

  Estimate the exponent:

$$b = \frac{\ln\left[\frac{S_2}{S_1}\right]}{\ln\left[\frac{Z_2}{Z_1}\right]}$$

  Estimate the coefficient:

$$K_s = \frac{S_2}{Z_2^b}$$

in which Z = Stage of the specified point (ft above pond bottom)
S = Storage of the specified point (cu ft)
K_s and b are constants determined for the basin of interest.

- Test the validity of the function by substitution of known values of storage to estimate the associated stages. If the estimated stages agree acceptably with the actual stages (say with 0.1 ft or so), the expression is valid. For that check, the expression can be reformulated as

$$Z = \left[\frac{S}{K_s}\right]^{\frac{1}{b}}$$

  in which the variables are the same as above.

- The stage-storage function can be reformulated to yield a stage-area function for use in determining pond surface area when the water surface is at any stage in the range used to determine the function. The relationship between pond surface area and discharge determines significantly the extent to which particles are settled.

  The stage-area function is

$$A_s = bK_sZ^{(b-1)}$$

in which Z = Stage of the specified point (ft above pond bottom)
S = Pond surface area (sq ft)
K_s and b are constants determined for the basin of interest.

Select the trial barrel

In order to reduce the number of riser/barrel selections, a trial barrel size can be obtained by using an approximate relationship that suggests an expected maximum water level in the pond during routing. This expression is based on the minimum surface-area-to-discharge-ratio, the estimated effect on the hydrograph of temporary storage of stormwater, and the effect of the topography of the pond on settling behavior.

- Determine three coefficients:

$$C_1 = K_s$$

$$C_2 = \frac{60bK_sT_p}{458}$$

$$C_3 = 60\ Q_pT_p + K_sZ_{sed}^b$$

in which K_g = Stage-storage coefficient
b = Stage-storage exponent
Q_p = Peak inflow (cfs)
T_p = Time to peak (min)
Z_{sed} = Stage of top of sediment storage (ft)

- Using the coefficients, compute the expected maximum stage, Z, by trial and error:

$$C_1Z^b + C_2Z^{b-1} = C_3$$

- The expected peak outflow can be estimated from

$$Q_0 = Q_p - \frac{K_s(Z^b - Z^b_{sed})}{60T_p}$$

in which the variables are the same as above.

- Select the diameter of the barrel to deliver the expected maximum outflow, Q_o, when the water level is at the computed expected maximum, Z. Selection may be made by using commonly available culvert capacity charts and tables, or it may be sized by application of the orifice equation. (Note that the orifice equation applies when the pipe is *inlet controlled.* If the outlet is submerged by high tailwater, the barrel must be analyzed under *outlet control*.) The orifice equation may be modified for direct application as:

$$Q=0.0437C_D D^2 \sqrt{Z_{max} - \frac{D}{24}}$$

in which C_D = Coefficient of discharge (typically 0.6)
D = Pipe diameter (in)
Z_{max} = Expected maximum stage (ft)
Q = Discharge delivered by pipe (cfs)

Select the trial riser

The cross section of the riser should be at least 1.5 times the cross-sectional area of the barrel.

- Compute stage of top of riser.

The stage or elevation of the top of the riser should be sufficiently below the maximum expected water level to allow flow to enter the riser freely, but the top of the riser should not be set grossly below the maximum expected water level. It is recommended that the location of the top of the riser be computed from the maximum expected water level, Z_{max}, and an application of the weir equation:

$$Z_{riser} = Z_{max} - \left[\frac{Q_o}{0.86D}\right]^{\frac{2}{3}}$$

in which Q_o = Expected maximum outflow (cfs)
D = Selected pipe diameter (in)
Z_{max} = Maximum expected water level (ft)
Z_{riser} = Recommended top of riser (ft above bottom of pond)

Verify the design by flood routing and settling analysis

The system can be analyzed by one of several commonly available routing procedures. Analysis of settling behavior can be done by computing water-surface area at each time step in the routing and verifying in all time steps that surface area divided by basin outflow exceeds 458 sq ft/cfs. The following should be considered in the routing:

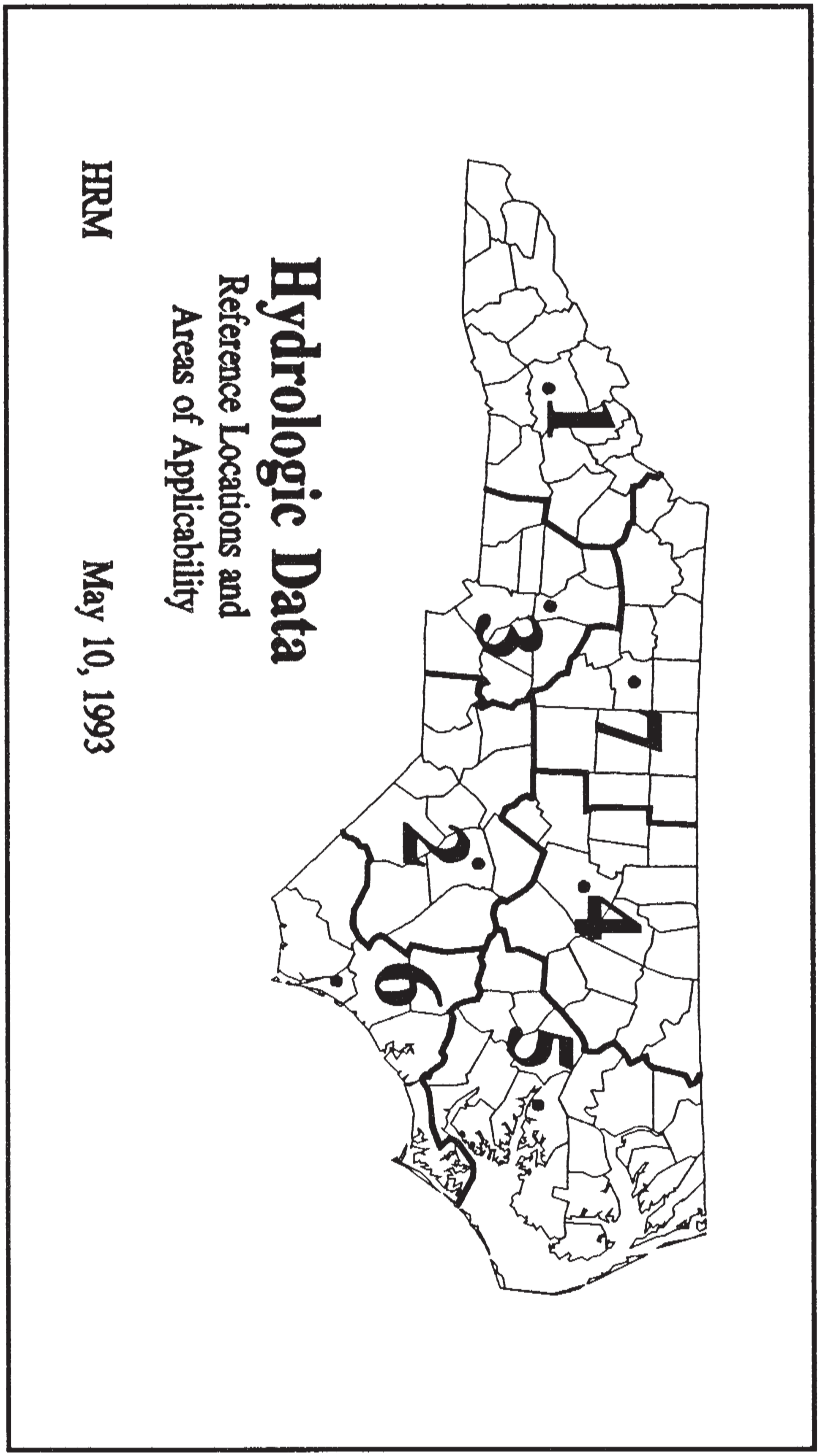
- Points on the inflow hydrograph can be computed using the inflow hydrograph equations described above.
- Base stage-storage data on the stage-storage function.
- Develop stage-discharge data for the riser/barrel selected.
- The initial conditions (at time = 0) should reflect that the sediment storage is full. Set initial water level at the top of the sediment storage, and set initial value of water storage equal to the volume of sediment stored.
- The value of water-surface area can be computed at any time step from the stage-area function using the current stage.
- Other hydrograph formulation procedures, such as SCS TR-55, can be incorporated into the above methodology as follows. If a hydrograph is based on the 2-yr, 24-hr storm, ignore the insignificant low flow early and late in the storm. Retain the portion of the hydrograph from the time of significant rise of the rising limb through the falling limb. Let T_p be as measured from the time of significant rise of the rising limb to the time of peak. Then use Q_p and T_p in the above computations.

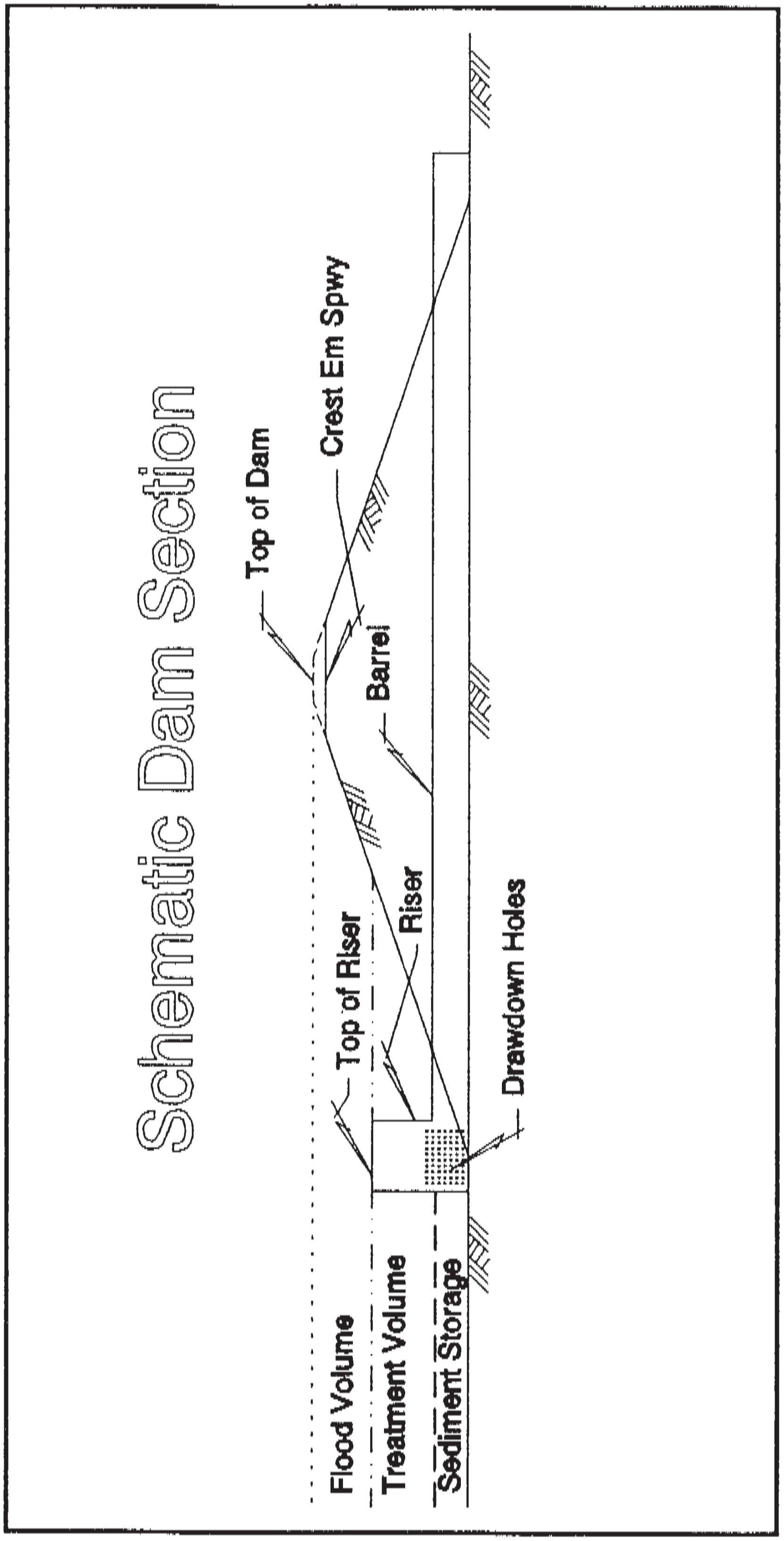
Specify location, number and size of drawdown holes

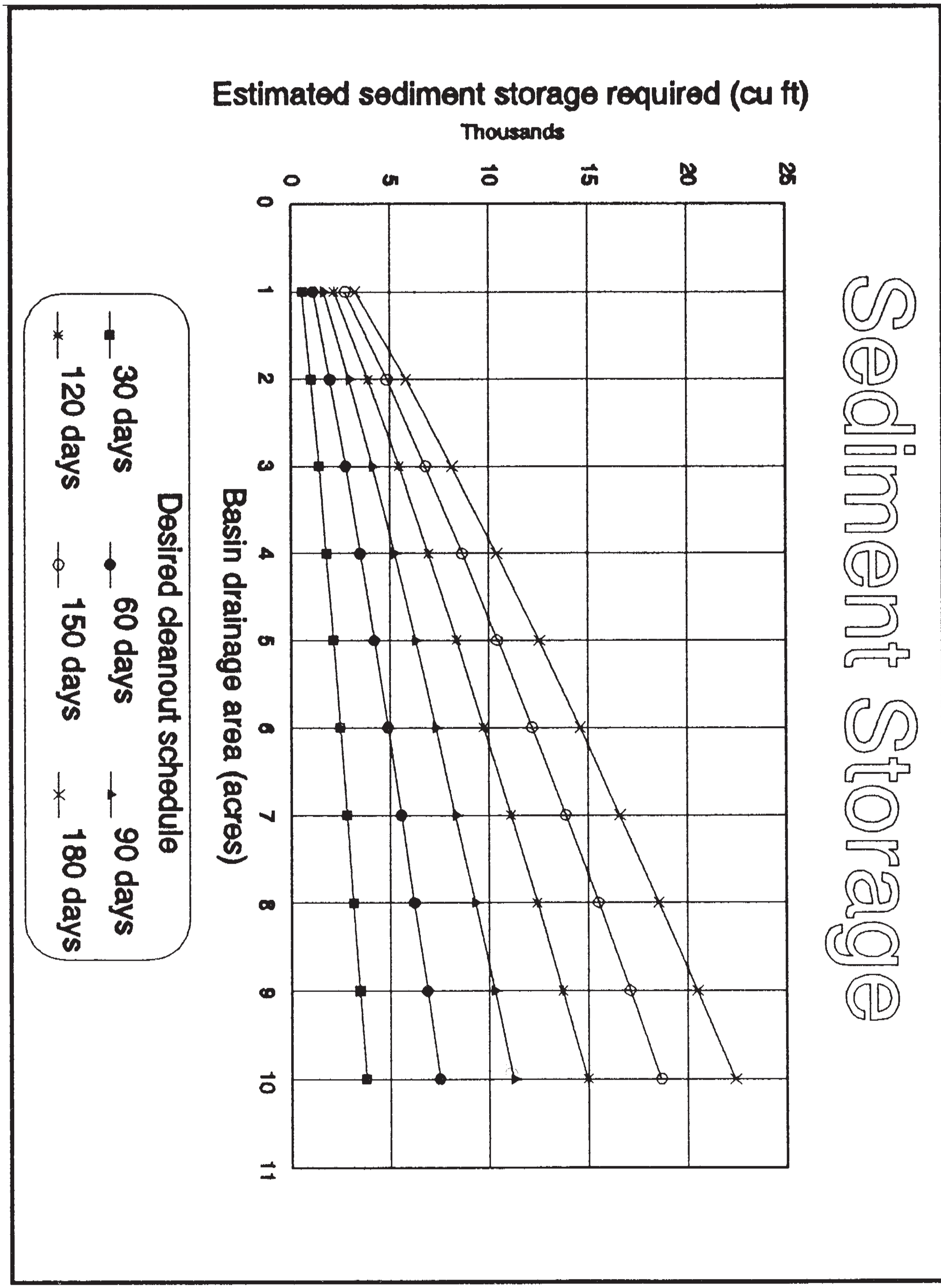
Specify drawdown holes in the lower half of the riser as required. (*Appendix 8.07*)

Complete detailed design

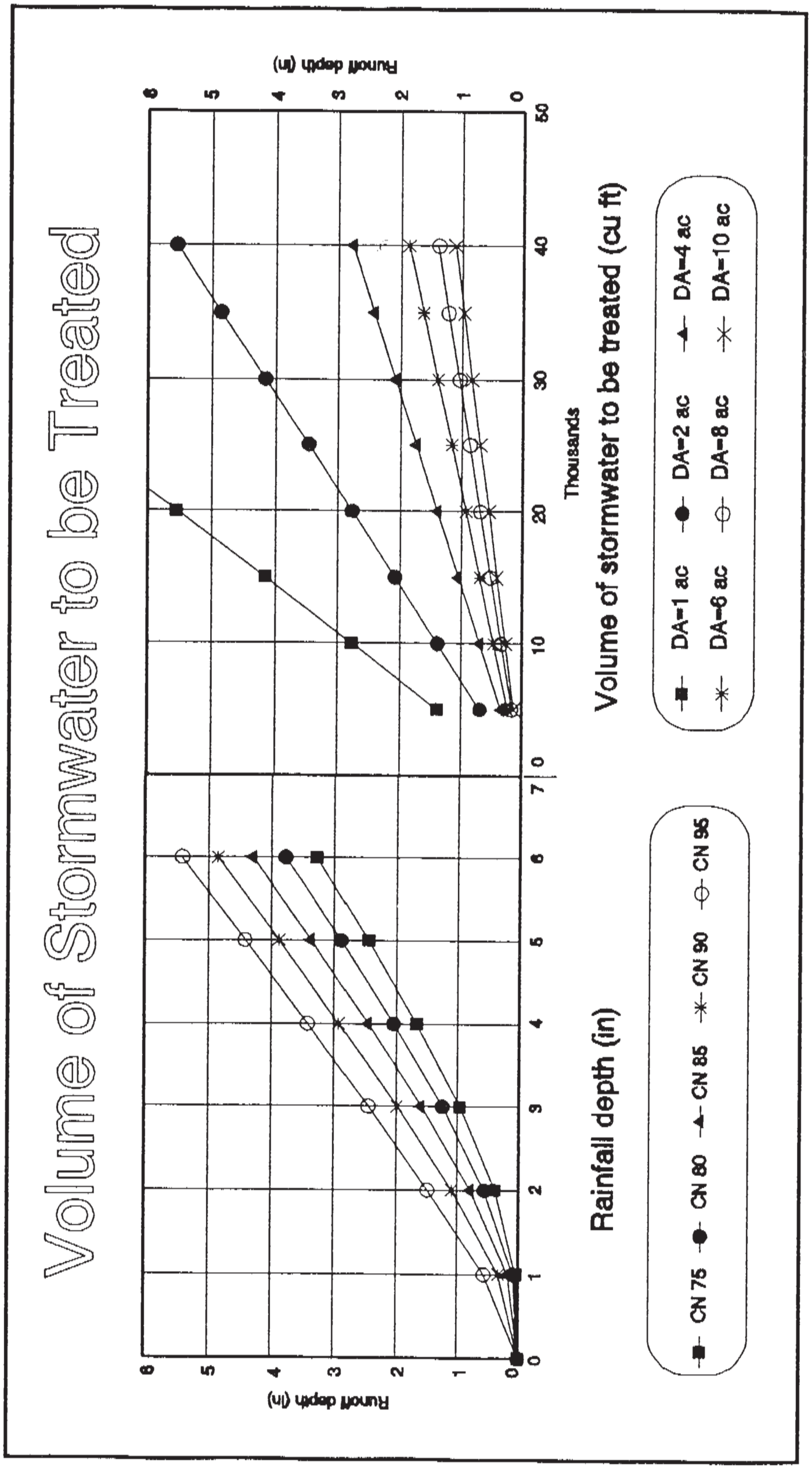
- **Specify location, stage and length of emergency spillway to safely convey the maximum peak rate of runoff from the 25-year storm.** (*Appendix 8.07*)
- Configure dam or dike. (*Appendix 8.07*)
- Check and verify results.
- Prepare construction details and specifications.


Hydrologic Data
Reference Locations and
Areas of Applicability
HRM
May 10, 1993
1
2
3
4
5
6
7


Schematic Dam Section
Top of Dam
Crest Em Spwy
Barrel
Riser
Top of Riser
Drawdown Holes
Flood Volume
Treatment Volume
Sediment Storage



Sediment Storage
Estimated sediment storage required (cu ft)
Thousands
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
9
10
11
Basin drainage area (acres)
Desired cleanout schedule
30 days
60 days
90 days
120 days
150 days
180 days



Volume of Stormwater to be Treated
Runoff depth (in)
Rainfall depth (in)
0 1 2 3 4 5 6 7
0 1 2 3 4 5 6
-■- CN 75 -●- CN 80 -▲- CN 85 -✳- CN 90 -○- CN 95
Runoff depth (in)
Volume of stormwater to be treated (cu ft)
Thousands
0 10 20 30 40 50
0 1 2 3 4 5 6
-■- DA=1 ac -●- DA=2 ac -▲- DA=4 ac
-✳- DA=6 ac -○- DA=8 ac -✕- DA=10 ac

8.08

THE SEDIMENTATION CONTROL LAW

The following pages contain the complete text of the North Carolina Sedimentation Pollution Control Act of 1973. The Act creates the North Carolina Sedimentation Control Commission and authorizes this commission to adopt and enforce rules and regulations for control of erosion and sedimentation from land-disturbing activities. The Act also establishes mandatory standards for land-disturbing activities, specifies the authority of the Secretary of the Department of Environment, Health, and Natural Resources, and encourages the development of educational activities and local erosion control programs. Finally, the Act establishes civil and criminal penalties with injunctive relief for violation of the State Program.

8

Sedimentation Pollution Control Act of 1973

(As Amended through 2005)

North Carolina General Statutes Chapter 113A Article 4

§ 113A-50. Short title.

This Article shall be known as and may be cited as the "Sedimentation Pollution Control Act of 1973." (1973, c. 392, s. 1.)

§ 113A-51. Preamble.

The sedimentation of streams, lakes and other waters of this State constitutes a major pollution problem. Sedimentation occurs from the erosion or depositing of soil and other materials into the waters, principally from construction sites and road maintenance. The continued development of this State will result in an intensification of pollution through sedimentation unless timely and appropriate action is taken. Control of erosion and sedimentation is deemed vital to the public interest and necessary to the public health and welfare, and expenditures of funds for erosion and sedimentation control programs shall be deemed for a public purpose. It is the purpose of this Article to provide for the creation, administration, and enforcement of a program and for the adoption of minimal mandatory standards which will permit development of this State to continue with the least detrimental effects from pollution by sedimentation. In recognition of the desirability of early coordination of sedimentation control planning, it is the intention of the General Assembly that preconstruction conferences be held among the affected parties, subject to the availability of staff.(1973, c. 392, s. 2; 1975, c. 647, s. 3.)

§ 113A-52. Definitions.

As used in this Article, unless the context otherwise requires:

(1) Repealed by Session Laws 1973, c. 1417, s. 1.

(1a) "Affiliate" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "affiliate" as a person that directly, or indirectly through one or more intermediaries, controls, is controlled by, or is under common control of another person.

(2) "Commission" means the North Carolina Sedimentation Control Commission.

(3) "Department" means the North Carolina Department of Environment and Natural Resources.

(4) "District" means any Soil and Water Conservation District created pursuant to Chapter 139, North Carolina General Statutes.

(5) "Erosion" means the wearing away of land surface by the action of wind, water, gravity, or any combination thereof.

(6) "Land-disturbing activity" means any use of the land by any person in residential, industrial,

educational, institutional or commercial development, highway and road construction and maintenance that results in a change in the natural cover or topography and that may cause or contribute to sedimentation.

(7) "Local government" means any county, incorporated village, town, or city, or any combination of counties, incorporated villages, towns, and cities, acting through a joint program pursuant to the provisions of this Article.

(7a) "Parent" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "parent" as an affiliate that directly, or indirectly through one or more intermediaries, controls another person.

(8) "Person" means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, interstate body, or other legal entity.

(9) "Secretary" means the Secretary of Environment and Natural Resources.

(10) "Sediment" means solid particulate matter, both mineral and organic, that has been or is being transported by water, air, gravity, or ice from its site of origin.

(10a) Subsidiary" has the same meaning as in 17 Code of Federal Regulations § 240.12(b)-2 (1 June 1993 Edition), which defines "subsidiary" as an affiliate that is directly, or indirectly through one or more intermediaries, controlled by another person.

(10b) "Tract" means all contiguous land and bodies of water being disturbed or to be disturbed as a unit, regardless of ownership.

(11) "Working days" means days exclusive of Saturday and Sunday during which weather conditions or soil conditions permit land-disturbing activity to be undertaken.(1973, c. 392, s. 3; c. 1417, s. 1; 1975, c. 647, s. 1; 1977, c. 771, s. 4; 1989, c. 179, s. 1; c. 727, s. 218(60); 1989 (Reg. Sess., 1990), c. 1004, s. 19(b); 1991, c. 275, s. 1; 1993 (Reg. Sess., 1994), c. 776, s. 1; 1997-443, s. 11A.119(a).)

§ 113A-52.01. Applicability of this Article.

This Article shall not apply to the following land-disturbing activities:

(1) Activities, including the breeding and grazing of livestock, undertaken on agricultural land for the production of plants and animals useful to man, including, but not limited to:

a. Forages and sod crops, grains and feed crops, tobacco, cotton, and peanuts.

b. Dairy animals and dairy products.

c. Poultry and poultry products.

d. Livestock, including beef cattle, llamas, sheep, swine, horses, ponies, mules, and goats.

e. Bees and apiary products.

f. Fur producing animals.

(2) Activities undertaken on forestland for the production and harvesting of timber and timber products and conducted in accordance with best management practices set out in Forest Practice Guidelines Related to Water Quality, as adopted by the Department.

(3) Activities for which a permit is required under the Mining Act of 1971, Article 7 of Chapter 74 of the General Statutes.

(4) For the duration of an emergency, activities essential to protect human life.(1993 (Reg. Sess., 1994), c. 776, s. 2; 1997-84, s. 1.)

§ 113A-52.1. Forest Practice Guidelines.

(a) The Department shall adopt Forest Practice Guidelines Related to Water Quality (best management practices). The adoption of Forest Practices Guidelines Related to Water Quality under this section is subject to the provisions of Chapter 150B of the General Statutes.

(b) If land-disturbing activity undertaken on forestland for the production and harvesting of timber and timber products is not conducted in accordance with Forest Practice Guidelines Related to Water Quality, the provisions of this Article shall apply to such activity and any related land-disturbing activity on the tract.

(c) The Secretary shall establish a Technical Advisory Committee to assist in the development and periodic review of Forest Practice Guidelines Related to Water Quality. The Technical Advisory Committee shall consist of one member from the forest products industry, one member who is a consulting forester, one member who is a private landowner knowledgeable in forestry, one member from the United States Forest Service, one member from the academic community who is knowledgeable in forestry, one member who is knowledgeable in erosion and sedimentation control, one member who is knowledgeable in wildlife management, one member who is knowledgeable in marine fisheries management, one member who is knowledgeable in water quality, and one member from the conservation community. (1989, c. 179, s. 2.)

§ 113A-53. Repealed by Session Laws 1973, c. 1262, s. 41.

§ 113A-54. Powers and duties of the Commission.

(a) The Commission shall, in cooperation with the Secretary of Transportation and other appropriate State and federal agencies, develop, promulgate, publicize, and administer a comprehensive State erosion and sedimentation control program.

(b) The Commission shall develop and adopt and shall revise as necessary from time to time, rules and regulations for the control of erosion and sedimentation resulting from land- disturbing activities. The Commission shall adopt or revise its rules and regulations in accordance with Chapter 150B of the General Statutes.

(c) The rules and regulations adopted pursuant to G.S. 113A-54(b) for carrying out the erosion and sedimentation control program shall:

(1) Be based upon relevant physical and developmental information concerning the watershed and drainage basins of the State, including, but not limited to, data relating to land use, soils, hydrology, geology, grading, ground cover, size of land area being disturbed, proximate water bodies and their characteristics, transportation, and public facilities and services;

(2) Include such survey of lands and waters as may be deemed appropriate by the Commission or required by any applicable laws to identify those areas, including multijurisdictional and watershed areas, with critical erosion and sedimentation problems; and

(3) Contain conservation standards for various types of soils and land uses, which standards shall include criteria and alternative techniques and methods for the control of erosion and sedimentation resulting from land-disturbing activities.

(d) In implementing the erosion and sedimentation control program, the Commission shall:

(1) Assist and encourage local governments in developing erosion and sedimentation control programs and, as a part of this assistance, the Commission shall develop a model local erosion and sedimentation control ordinance. The Commission shall approve, approve as modified, or disapprove local programs submitted to it pursuant to G.S. 113A-60.

(2) Assist and encourage other State agencies in developing erosion and sedimentation control programs to be administered in their jurisdictions. The Commission shall approve, approve as modified, or disapprove programs submitted pursuant to G.S. 113A-56 and from time to time shall review these programs for compliance with rules adopted by the Commission and for adequate enforcement.

(3) Develop recommended methods of control of sedimentation and prepare and make available for distribution publications and other materials dealing with sedimentation control techniques appropriate for use by persons engaged in land-disturbing activities, general educational materials on erosion and sedimentation control, and instructional materials for persons involved in the enforcement of this Article and erosion and sedimentation control rules, ordinances, regulations, and plans.

(4) Require submission of erosion and sedimentation control plans by those responsible for initiating land-disturbing activities for approval prior to commencement of the activities.

(e) To assist it in developing the erosion and sedimentation control program required by this Article, the Commission is authorized to appoint an advisory committee consisting of technical experts in the fields of water resources, soil science, engineering, and landscape architecture.

(f) Repealed by Session Laws 1987, c. 827, s. 10, effective August 13, 1987. (1973, c. 392, s. 5; c. 1331, s. 3; c. 1417, s. 6; 1975, 2nd Sess., c. 983, s. 74; 1977, c. 464, s. 35; 1979, c. 922, s. 2; 1983 (Reg. Sess., 1984), c. 1014, ss. 1, 2; 1987, c. 827, s. 10; 1987 (Reg. Sess., 1988), c. 1000, s. 3; 1989, c. 676, s. 1; 1993 (Reg. Sess., 1994), c. 776, s. 3; 2002-165, ss. 2.2, 2.3.)

§ 113A-54.1. Approval of erosion control plans.

(a) A draft erosion and sedimentation control plan must contain the applicant's address and, if the applicant is not a resident of North Carolina, designate a North Carolina agent for the purpose of receiving notice from the Commission or the Secretary of compliance or noncompliance with the plan, this Article, or any rules adopted pursuant to this Article. If the applicant is not the owner of the land to be disturbed, the draft erosion and sedimentation control plan must include the owner's written consent for the applicant to submit a draft erosion and sedimentation control plan and to conduct the anticipated land-disturbing activity. The Commission shall approve, approve with modifications, or disapprove a draft erosion and sedimentation control plan for those land-disturbing activities for which prior plan approval is required within 30 days of receipt. The Commission shall condition approval of a draft erosion and sedimentation control plan upon the applicant's compliance with federal and State water quality laws, regulations, and rules. Failure to approve, approve with modifications, or disapprove a completed draft erosion and sedimentation control plan within 30 days of receipt shall be deemed approval of the plan. If the Commission disapproves a draft erosion and sedimentation control plan or a revised erosion and sedimentation control plan, it must state in writing the specific reasons that the plan was disapproved. Failure to approve, approve with modifications, or disapprove a revised erosion and sedimentation control plan within 15 days of receipt shall be deemed approval of the plan. The Commission may establish an expiration date for erosion and sedimentation control plans approved under this Article.

(b) If, following commencement of a land-disturbing activity pursuant to an approved erosion and sedimentation control plan, the Commission determines that the plan is inadequate to meet the requirements of this Article, the Commission may require any revision of the plan that is necessary to comply with this

Article. Failure to approve, approve with modifications, or disapprove a revised erosion and sedimentation control plan within 15 days of receipt shall be deemed approval of the plan.

(c) The Commission shall disapprove an erosion and sedimentation control plan if implementation of the plan would result in a violation of rules adopted by the Environmental Management Commission to protect riparian buffers along surface waters. The Director of the Division of Land Resources may disapprove an erosion and sedimentation control plan upon finding that an applicant or a parent, subsidiary, or other affiliate of the applicant:

(1) Is conducting or has conducted land-disturbing activity without an approved plan, or has received notice of violation of a plan previously approved by the Commission or a local government pursuant to this Article and has not complied with the notice within the time specified in the notice;

(2) Has failed to pay a civil penalty assessed pursuant to this Article or a local ordinance adopted pursuant to this Article by the time the payment is due;

(3) Has been convicted of a misdemeanor pursuant to G.S. 113A-64(b) or any criminal provision of a local ordinance adopted pursuant to this Article; or

(4) Has failed to substantially comply with State rules or local ordinances and regulations adopted pursuant to this Article.

(d) In the event that an erosion and sedimentation control plan is disapproved by the Director pursuant to subsection (c) of this section, the Director shall state in writing the specific reasons that the plan was disapproved. The applicant may appeal the Director's disapproval of the plan to the Commission. For purposes of this subsection and subsection (c) of this section, an applicant's record may be considered for only the two years prior to the application date. (1989, c. 676, s. 2; 1993 (Reg. Sess., 1994), c. 776, s. 4; 1998-221, s. 1.11(a); 1999-379, s. 1; 2005-386, s. 7.1.)

§ 113A-54.2. Approval Fees.

(a) The Commission may establish a fee schedule for the review and approval of erosion and sedimentation control plans under this Article. In establishing the fee schedule, the Commission shall consider the administrative and personnel costs incurred by the Department for reviewing the plans and for related compliance activities. An application fee may not exceed fifty dollars ($50.00) per acre of disturbed land shown on an erosion and sedimentation control plan or of land actually disturbed during the life of the project.

(b) The Sedimentation Account is established as a nonreverting account within the Department. Fees collected under this section shall be credited to the Account and shall be applied to the costs of administering this Article.

(c) Repealed by Session Laws 1991 (Reg. Sess., 1992), c. 1039, s. 3, effective July 24, 1992.

(d) This section may not limit the existing authority of local programs approved pursuant to this Article to assess fees for the approval of erosion and sedimentation control plans. (1989 (Reg. Sess., 1990), c. 906, s. 1; 1991 (Reg. Sess., 1992), c. 1039, s. 3; 1993 (Reg. Sess., 1994), c. 776, s. 5; 1999-379, s. 5; 2002-165, s. 2.4.)

§ 113A-55. Authority of the Secretary.

The sedimentation control program developed by the Commission shall be administered by the Secretary under the direction of the Commission. To this end the Secretary shall employ the necessary clerical, technical, and administrative personnel, and assign tasks to the various divisions of the Department for the purpose of implementing this Article. The Secretary may bring enforcement actions pursuant to G.S.

113A-64 and G.S. 113A-65. The Secretary shall make final agency decisions in contested cases that arise from civil penalty assessments pursuant to G.S. 113A-64. (1973, c. 392, s. 6; c. 1417, s. 3; 1993 (Reg. Sess., 1994), c. 776, s. 6.)

§ 113A-56. Jurisdiction of the Commission.

(a) The Commission shall have jurisdiction, to the exclusion of local governments, to adopt rules concerning land-disturbing activities that are:

(1) Conducted by the State;

(2) Conducted by the United States;

(3) Conducted by persons having the power of eminent domain;

(4) Conducted by local governments; or

(5) Funded in whole or in part by the State or the United States.

(b) The Commission may delegate the jurisdiction conferred by G.S. 113A- 56(a), in whole or in part, to any other State agency that has submitted an erosion and sedimentation control program to be administered by it, if the program has been approved by the Commission as being in conformity with the general State program.

(c) The Commission shall have concurrent jurisdiction with local governments over all other land-disturbing activities. (1973, c. 392, s. 7; c. 1417, s. 4; 1987, c. 827, s. 130; 1987 (Reg. Sess., 1988), c. 1000, s. 4; 2002-165, s. 2.5.)

§ 113A-57. Mandatory standards for land-disturbing activity.

No land-disturbing activity subject to this Article shall be undertaken except in accordance with the following mandatory requirements:

(1) No land-disturbing activity during periods of construction or improvement to land shall be permitted in proximity to a lake or natural watercourse unless a buffer zone is provided along the margin of the watercourse of sufficient width to confine visible siltation within the twenty-five percent (25%) of the buffer zone nearest the land-disturbing activity. Waters that have been classified as trout waters by the Environmental Management Commission shall have an undisturbed buffer zone 25 feet wide or of sufficient width to confine visible siltation within the twenty-five percent (25%) of the buffer zone nearest the land-disturbing activity, whichever is greater. Provided, however, that the Sedimentation Control Commission may approve plans which include land-disturbing activity along trout waters when the duration of said disturbance would be temporary and the extent of said disturbance would be minimal. This subdivision shall not apply to a land-isturbing activity in connection with the construction of facilities to be located on, over, or under a lake or natural watercourse.

(2) The angle for graded slopes and fills shall be no greater than the angle that can be retained by vegetative cover or other adequate erosion-control devices or structures. In any event, slopes left exposed will, within 21 calendar days of completion of any phase of grading, be planted or otherwise provided with temporary or permanent ground cover, devices, or structures sufficient to restrain erosion.

(3) Whenever land-disturbing activity that will disturb more than one acre is undertaken on a tract, the person conducting the land-disturbing activity shall install erosion and sedimentation control devices and practices that are sufficient to retain the sediment generated by the land-disturbing activity within the boundaries of the tract during construction upon and development of the tract, and shall plant or otherwise provide a permanent ground cover sufficient to restrain erosion after completion of construction or development within a time

period to be specified by rule of the Commission.

(4) No person shall initiate any land-disturbing activity that will disturb more than one acre on a tract unless, 30 or more days prior to initiating the activity, an erosion and sedimentation control plan for the activity is filed with the agency having jurisdiction and approved by the agency. An erosion and sedimentation control plan may be filed less than 30 days prior to initiation of a land-disturbing activity if the plan is submitted under an approved express permit program, and the land-disturbing activity may be initiated and conducted in accordance with the plan once the plan has been approved. The agency having jurisdiction shall forward to the Director of the Division of Water Quality a copy of each erosion and sedimentation control plan for a land-disturbing activity that involves the utilization of ditches for the purpose of de-watering or lowering the water table of the tract. (1973, c. 392, s. 8; c. 1417, s. 5; 1975, c. 647, s. 2; 1979, c. 564; 1983 (Reg. Sess., 1984), c. 1014, s. 3; 1987, c. 827, s. 131; 1989, c. 676, s. 3; 1991, c. 275, s. 2; 1998-99, s. 1; 1999-379, s. 2; 2002-165, s. 2.6; 2005-386, s. 7.2; 2005-443, s. 2.)

§ 113A-58. Enforcement authority of the Commission.

In implementing the provisions of this Article the Commission is authorized and directed to:

(1) Inspect or cause to be inspected the sites of land-disturbing activities to determine whether applicable laws, regulations or erosion and sedimentation control plans are being complied with;

(2) Make requests, or delegate to the Secretary authority to make requests, of the Attorney General or solicitors for prosecutions of violations of this Article. (1973, c. 392, s. 9; 2002-165, s. 2.7.)

§ 113A-59. Educational activities.

The Commission in conjunction with the soil and water conservation districts, the North Carolina Agricultural Extension Service, and other appropriate State and federal agencies shall conduct educational programs in erosion and sedimentation control, such programs to be directed towards State and local governmental officials, persons engaged in land-disturbing activities, and interested citizen groups. (1973, c. 392, s.10.)

§ 113A-60. Local erosion and sedimentation control programs.

(a) A local government may submit to the Commission for its approval an erosion and sedimentation control program for its jurisdiction, and to this end local governments are authorized to adopt ordinances and regulations necessary to establish and enforce erosion and sedimentation control programs. Local governments are authorized to create or designate agencies or subdivisions of local government to administer and enforce the programs. An ordinance adopted by a local government shall at least meet and may exceed the minimum requirements of this Article and the rules adopted pursuant to this Article. Two or more units of local government are authorized to establish a joint program and to enter into any agreements that are necessary for the proper administration and enforcement of the program. The resolutions establishing any joint program must be duly recorded in the minutes of the governing body of each unit of local government participating in the program, and a certified copy of each resolution must be filed with the Commission.

(b) The Commission shall review each program submitted and within 90 days of receipt thereof shall notify the local government submitting the program that it has been approved, approved with modifications, or disapproved. The Commission shall only approve a program upon determining that its standards equal or exceed those of this Article and rules adopted pursuant to this Article.

(c) If the Commission determines that any local government is failing to administer or enforce an approved erosion and sedimentation control program, it shall notify the local government in writing and shall specify the deficiencies of administration and enforcement. If the local government has not taken corrective action within 30 days of receipt of notification from the Commission, the Commission shall assume administration and enforcement of the program until such time as the local government indicates its willingness and ability to resume administration and enforcement of the program. (1973, c. 392, s. 11; 1993 (Reg. Sess., 1994), c. 776, s. 7; 2202-165, s. 2.8.)

§ 113A-61. Local approval of erosion and sedimentation control plans.

(a) For those land-disturbing activities for which prior approval of an erosion and sedimentation control plan is required, the Commission may require that a local government that administers an erosion and sedimentation control program approved under G.S. 113A-60 require the applicant to submit a copy of the erosionand sedimentation control plan to the appropriate soil and water conservation district or districts at the same time the applicant submits the erosion and sedimentation control plan to the local government for approval. The soil and water conservation district or districts shall review the plan and submit any comments and recommendations to the local government within 20 days after the soil and water conservation district received the erosion and sedimentation control plan or within any shorter period of time as may be agreed upon by the soil and water conservation district and the local government. Failure of a soil and water conservation district to submit comments and recommendations within 20 days or within agreed upon shorter period of time shall not delay final action on the proposed plan by the local government.

(b) Local governments shall review each erosion and sedimentation control plan submitted to them and within 30 days of receipt thereof shall notify the person submitting the plan that it has been approved, approved with modifications, or disapproved. A local government shall only approve a plan upon determining that it complies with all applicable State and local regulations for erosion and sedimentation control.

(b1) A local government shall condition approval of a draft erosion and sedimentation control plan upon the applicant's compliance with federal and State water quality laws, regulations, and rules. A local government shall disapprove an erosion and sedimentation control plan if implementation of the plan would result in a violation of rules adopted by the Environmental Management Commission to protect riparian buffers along surface waters. A local government may disapprove an erosion and sedimentation control plan upon finding that an applicant or aparent, subsidiary, or other affiliate of the applicant:

(1) Is conducting or has conducted land-disturbing activity without an approved plan, or has received notice of violation of a plan previously approved by the Commission or a local government pursuant to this Article and has not complied with the notice within the time specified in the notice.

(2) Has failed to pay a civil penalty assessed pursuant to this Article or a local ordinance adopted pursuant to this Article by the time the payment is due.

(3) Has been convicted of a misdemeanor pursuant to G.S. 113A-64(b) or any criminal provision of a local ordinance adopted pursuant to this Article.

(4) Has failed to substantially comply with State rules or local ordinances and regulations adopted pursuant to this Article.

(b2) In the event that an erosion and sedimentation control plan is disapproved by a local government pursuant to subsection (b1) of this section, the local government shall so notify the Director of the Division of Land Resources within 10 days of such disapproval. The local government shall advise the applicant and the Director in writing as to the specific reasons that the plan was disapproved. Notwithstanding the provisions of subsection (c) of this section, the applicant may appeal the local government's disapproval of the plan directly to the Commission. For purposes of this subsection and subsection (b1) of this section, an applicant's record may be considered for only the two years prior to the application date.

(c) The disapproval or modification of any proposed erosion and sedimentation control plan by a local government shall entitle the person submitting the plan to a public hearing if such person submits written demand for a hearing within 15 days after receipt of written notice of the disapproval or modification. The hearings shall be conducted pursuant to procedures adopted by the local government. If the local government upholds the disapproval or modification of a proposed erosion and sedimentation control plan following the public hearing, the person submitting the erosion and sedimentation control plan shall be entitled to appeal the local government's action disapproving or modifying the plan to the Commission. The Commission, by regulation, shall direct the Secretary to appoint such employees of the Department as may be necessary to hear appeals from the disapproval or modification of erosion and sedimentation control plans by local governments. In addition to providing for the appeal of local government decisions disapproving or modifying erosion and sedimentation control plans to designated employees of the Department, the Commission shall designate an erosion and sedimentation control plan review committee consisting of three members of the Commission. The person submitting the erosion and sedimentation control plan may appeal the decisionof an employee of the Department who has heard an appeal of a local government action disapproving or modifying an erosion and sedimentation control plan to the erosion and sedimentation control plan review committee of the Commission. Judicial review of the final action of the erosion and sedimentation control plan review committee of the Commission may be had in the superior court of the county in which the local government is situated.

(d) Repealed by Session Laws 1989, c. 676, s. 4, effective October 1, 1989. (1973, c. 392, s. 12; 1979, c. 922, s. 1; 1989, c. 676, s. 4; 1993 (Reg. Sess., 1994), c. 776, ss. 8, 9; 1998-221, s. 1.11(b); 1999-379, s. 3; 2002-165, s. 2.9.)

§ 113A-61.1. Inspection of land-disturbing activity; notice of violation.

(a) The Commission, a local government that administers an erosion and sedimentation controlprogram approved under G.S. 113A-60, or other approving authority shall provide for inspection of land-disturbing activities to ensure compliance with this Article and to determine whether the measures required in an erosion and sedimentation control plan are effective in controlling erosion and sedimentation resulting from the land-disturbing activity. Notice of this right of inspection shall be included in the certificate of approval of each erosion and sedimentation control plan.

(b) No person shall willfully resist, delay, or obstruct an authorized representative of the Commission, an authorized representative of a local government, or an employee or an agent of the Department while the representative, employee, or agent is inspecting or attempting to inspect a land-disturbing activity under this section.

(c) If the Secretary, a local government that administers an erosion and sedimentation control program approved under G.S. 113A-60, or other approving authority determines that the person engaged in the land-disturbing activity has failed to comply with this Article, the Secretary, local government, or other approving authority shall immediately serve a notice of violation upon that person. The notice may be served by any means authorized under G.S. 1A- 1, Rule 4. A notice of violation shall specify a date by which the person must comply with this Article and inform the person of the actions that need to be taken to comply with this Article. Any person who fails to comply within the time specified is subject to additional civil and criminal penalties for a continuing violation as provided in G.S. 113A-64. (1989, c. 676, s. 5; 1993 (Reg. Sess., 1994), c. 776, s. 10; 1999-379, s. 6; 2002-165, s. 2.10.)

§ 113A-62. Cooperation with the United States.

The Commission is authorized to cooperate and enter into agreements with any agency of the United

States government in connection with plans for erosion and sedimentation control with respect to land-disturbing activities on lands that are under the jurisdiction of such agency. (1973, c. 392, s. 13; 2002-165, s. 2.11.)

§ 113A-63. Financial and other assistance.

The Commission and local governments are authorized to receive from federal, State, and other public and private sources financial, technical, and other assistance for use in accomplishing the purposes of this Article.(1973, c. 392, s. 14.)

§ 113A-64. Penalties.

(a) Civil Penalties. --

(1) Any person who violates any of the provisions of this Article or any ordinance, rule, or order adopted or issued pursuant to this Article by the Commission or by a local government, or who initiates or continues a land-disturbing activity for which an erosion and sedimentation control plan is required except in accordance with the terms, conditions, and provisions of an approved plan, is subject to a civil penalty. The maximum civil penalty for a violation is five thousand dollars ($5,000). A civil penalty may be assessed from the date of the violation. Each day of a continuing violation shall constitute a separate violation.

(2) The Secretary or a local government that administers an erosion and sedimentation control-program approved under G.S. 113A-60 shall determine the amount of the civil penalty and shall notify the person who is assessed the civil penalty of the amount of the penalty and the reason for assessing the penalty. The notice of assessment shall be served by any means authorized under G.S. 1A-1, Rule 4, and shall direct the violator to either pay the assessment or contest the assessment within 30 days by filing a petition for a contested case under Article 3 of Chapter 150B of the General Statutes. If a violator does not pay a civil penalty assessed by the Secretary within 30 days after it is due, the Department shall request the Attorney General to institute a civil action to recover the amount of the assessment. If a violator does not pay a civil penalty assessed by a local government within 30 days after it is due, the local government may institute a civil action to recover the amount of the assessment. The civil action may be brought in the superior court of any county where the violation occurred or the violator's residence or principal place of business is located. A civil action must be filed within three years of the date the assessment was due. An assessment that is not contested is due when the violator is served with a notice of assessment. An assessment that is contested is due at the conclusion of the administrative and judicial review of the assessment.

(3) In determining the amount of the penalty, the Secretary shall consider the degree and extent of harm caused by the violation, the cost of rectifying the damage, the amount of money the violator saved by noncompliance, whether the violation was committed willfully and the prior record of the violator in complying or failing to comply with this Article.

(4) Repealed by Session Laws 1993 (Reg. Sess., 1994), c. 776, s. 11, effective October 1, 1994.

(5) The clear proceeds of civil penalties collected by the Department or other State agency under this subsection shall be remitted to the Civil Penalty and Forfeiture Fund in accordance with G.S. 115C-457.2. Civil penalties collected by a local government under this subsection shall be credited to the general fund of the local government as nontax revenue.

(b) Criminal Penalties. -- Any person who knowingly or willfully violates any provision of this Article or any ordinance, rule, regulation, or order duly adopted or issued by the Commission or a local government, or who knowingly or willfully initiates or continues a land- disturbing activity for which an erosion and sedimentation control plan is required, except in accordance with the terms, conditions, and provisions of an approved plan, shall be guilty of a Class 2 misdemeanor that may include a fine not to exceed five thousand dollars ($5,000). (1973, c. 392, s. 15; 1977, c. 852; 1987, c. 246, s. 3; 1987 (Reg. Sess., 1988), c. 1000, s. 5; 1989, c. 676, s. 6; 1991, c. 412, s. 2; c. 725, s. 5; 1993, c. 539, s. 873; 1994, Ex. Sess., c. 24, s. 14(c); 1993 (Reg. Sess., 1994), c. 776, s. 11; 1998-215, s. 52; 1999-379, s. 4; 2002-165, s. 2.12.)

§ 113A-64.1. Restoration of areas affected by failure to comply.

The Secretary or a local government that administers a local erosion and sedimentation control program approved under G.S. 113A-60 may require a person who engaged in a land-disturbing activity and failed to retain sediment generated by the activity, as required by G.S. 113A-57(3), to restore the waters and land affected by the failure so as to minimize the detrimental effects of the resulting pollution by sedimentation. This authority is in addition to any other civil or criminal penalty or injunctive relief authorized under this Article. (1993 (Reg. Sess., 1994), c. 776, s. 12; 2002-165, s. 2.13.)

§ 113A-65. Injunctive relief.

(a) Violation of State Program. -- Whenever the Secretary has reasonable cause to believe that any person is violating or is threatening to violate the requirements of this Article he may, either before or after the institution of any other action or proceeding authorized by this Article, institute a civil action for injunctive relief to restrain the violation or threatened violation. The action shall be brought in the superior court of the county in which the violation or threatened violation is occurring or about to occur, and shall be in the name of the State upon the relation of the Secretary.

(b) Violation of Local Program. -- Whenever the governing body of a local government having jurisdiction has reasonable cause to believe that any person is violating or is threatening to violate any ordinance, rule, regulation, or order adopted or issued by the local government pursuant to this Article, or any term, condition or provision of an erosion and sedimentation control plan over which it has jurisdiction, may, either before or after the institution of any other action or proceeding authorized by this Article, institute a civil action in the name of the local government for injunctive relief to restrain the violation or threatened violation. The action shall be brought in the superior court of the county in which the violation is occurring or is threatened.

(c) Abatement, etc., of Violation. -- Upon determination by a court that an alleged violation is occurring or is threatened, the court shall enter any order or judgment that is necessary to abate the violation, to ensure that restoration is performed, or to prevent the threatened violation. The institution of an action for injunctive relief under subsections (a) or (b) of this section shall not relieve any party to the proceeding from any civil or criminal penalty prescribed for violations of this Article. (1973, c. 392, s. 16; 1993 (Reg. Sess., 1994), c. 776, s. 13; 2002-165, s. 2.14.)

§ 113A-65.1. Stop-work orders.

(a) The Secretary may issue a stop-work order if he finds that a land-disturbing activity is being conducted in violation of this Article or of any rule adopted or order issued pursuant to this Article, that the violation is knowing and willful, and that either:

(1) Off-site sedimentation has eliminated or severely degraded a use in a lake or natural watercourse or that such degradation is imminent.

(2) Off-site sedimentation has caused severe damage to adjacent land or that such damage is

imminent.

(3) The land-disturbing activity is being conducted without an approved plan.

(b) The stop-work order shall be in writing and shall state what work is to be stopped and what measures are required to abate the violation. The order shall include a statement of the findings made by the Secretary pursuant to subsection (a) of this section, and shall list the conditions under which work that has been stopped by the order may be resumed. The delivery of equipment and materials which does not contribute to the violation may continue while the stop- work order is in effect. A copy of this section shall be attached to the order.

(c) The stop-work order shall be served by the sheriff of the county in which the land- disturbing activity is being conducted or by some other person duly authorized by law to serve process as provided by G.S. 1A-1, Rule 4, and shall be served on the person at the site of the land-disturbing activity who is in operational control of the land-disturbing activity. The sheriff or other person duly authorized by law to serve process shall post a copy of the stop- work order in a conspicuous place at the site of the land-disturbing activity. The Department shall also deliver a copy of the stop-work order to any person that the Department has reason to believe may be responsible for the violation.

(d) The directives of a stop-work order become effective upon service of the order. Thereafter, any person notified of the stop-work order who violates any of the directives set out in the order may be assessed a civil penalty as provided in G.S. 113A-64(a). A stop-work order issued pursuant to this section may be issued for a period not to exceed five days.

(e) The Secretary shall designate an employee of the Department to monitor compliance with the stop-work order. The name of the employee so designated shall be included in the stop- work order. The employee so designated, or the Secretary, shall rescind the stop-work order if all the violations for which the stop-work order are issued are corrected, no other violations have occurred, and all measures necessary to abate the violations have been taken. The Secretary shall rescind a stop-work order that is issued in error.

(f) The issuance of a stop-work order shall be a final agency decision subject to judicial review in the same manner as an order in a contested case pursuant to Article 4 of Chapter 150B of the General Statutes. The petition for judicial review shall be filed in the superior court of the county in which the land-disturbing activity is being conducted.

(g) As used in this section, days are computed as provided in G.S. 1A-1, Rule 6. Except as otherwise provided, the Secretary may delegate any power or duty under this section to the Director of the Division of Land Resources of the Department or to any person who has supervisory authority over the Director. The Director may delegate any power or duty so delegated only to a person who is designated as acting Director.

(h) The Attorney General shall file a cause of action to abate the violations which resulted in the issuance of a stop-work order within two business days of the service of the stop-work order. The cause of action shall include a motion for an ex parte temporary restraining order to abate the violation and to effect necessary remedial measures. The resident superior court judge, or any judge assigned to hear the motion for the temporary restraining order, shall hear and determine the motion within two days of the filing of the complaint. The clerk of superior court shall accept complaints filed pursuant to this section without the payment of filing fees. Filing fees shall be paid to the clerk of superior court within 30 days of the filing of the complaint. (1991, c. 412, s. 1; 1998-99, s. 2; 2005-386, s. 7.3.)

§ 113A-66. Civil relief.

(a) Any person injured by a violation of this Article or any ordinance, rule, or order duly adopted by the Secretary or a local government, or by the initiation or continuation of a land- disturbing activity for which an erosion and sedimentation control plan is required other than in accordance with the terms, conditions, and provisions of an approved plan, may bring a civil action against the person alleged to be in violation (including the State and any local government). The action may seek any of the following:

(1) Injunctive relief.

(2) An order enforcing the law, rule, ordinance, order, or erosion and sedimentation control plan violated.

(3) Damages caused by the violation.

(4) Repealed by Session Laws 2202-165, s. 2.15, effective October 23, 2002. If the amount of actual damages as found by the court or jury in suits brought under this subsection is five thousand dollars ($5,000) or less, the plaintiff shall be awarded costs of litigation including reasonable attorneys fees and expert witness fees.

(b) Civil actions under this section shall be brought in the superior court of the county in which the alleged violations occurred.

(c) The court, in issuing any final order in any action brought pursuant to this section may award costs of litigation (including reasonable attorney and expert-witness fees) to any party, whenever it determines that such an award is appropriate. The court may, if a temporary restraining order or preliminary injunction is sought, require, the filing of a bond or equivalent security, the amount of such bond or security to be determined by the court.

(d) Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek injunctive or other relief. (1973, c. 392, s. 17; 1987 (Reg. Sess., 1988), c. 1000, s. 6; 2002-165, s. 2.15.)

SEDIMENTATION CONTROL COMMISSION

§ 143B-298. Sedimentation Control Commission - creation; powers and duties.

There is hereby created the Sedimentation Control Commission of the Department of Environment, Health, and Natural Resources with the power and duty to develop and administer a sedimentation control program as herein provided. The Sedimentation Control Commission has the following powers and duties:

(1) In cooperation with the Secretary of the Department of Transportation and Highway Safety and other appropriate State and federal agencies, develop, promulgate, publicize, and administer a comprehensive State erosion and sedimentation control program.

(2) Develop and adopt on or before July 1, 1974, rules and regulations for the control of erosion and sedimentation pursuant to G.S. 113A-54.

(3) Conduct public hearings pursuant to G.S. 113A-54.

(4) Assist local governments in developing erosion and sedimentation control programs pursuant to G.S. 113A-60.

(5) Assist and encourage other State agencies in developing erosion and sedimentation control programs pursuant to G.S. 113A-56.

(6) Develop recommended methods of control of sedimentation and prepare and make available for distribution publications and other materials dealing with sedimentation control techniquespursuant to G.S. 113A-54. (1973, c. 1262, s. 39; 1977, c. 771, s. 4; 1989, c. 727, s. 218(137).)

§ 143B-299. Sedimentation Control Commission - members;selection; compensation; meetings.

(a) Creation; Membership. -- There is hereby created in the Department of Environment, Health, and Natural Resources the North Carolina Sedimentation Control Commission, which is charged with the duty of developing and administering the sedimentation control program provided for in this Article. The Commission shall consist of the following members:

(1) A person to be nominated jointly by the boards of the North Carolina League of Municipalities and the North Carolina Association of County Commissioners;

(2) A person to be nominated by the Board of the North Carolina Home Builders Association;

(3) A person to be nominated by the Carolinas Branch, Associated General Contractors of America;

(4) The president, vice-president, or general counsel of a North Carolina public utility company;

(5) The Director of the North Carolina Water Resources Research Institute;

(6) A member of the State Mining Commission who shall be a representative of nongovernmental conservation interests, as required by G.S. 74-38(b);

(7) A member of the State Soil and Water Conservation Commission;

(8) A member of the Environmental Management Commission;

(9) A soil scientist from the faculty of North Carolina State University;

(10) Two persons who shall be representatives of nongovernmental conservation interests; and

(11) A professional engineer registered under the provisions of Chapter 89C of the General Statutes nominated by the Professional Engineers of North Carolina, Inc.

(b) Appointment. -- The Commission members shall be appointed by the Governor. All Commission members, except the person filling position number five, as specified above, shall serve staggered terms of office of three years and until their successors are appointed and duly qualified. The person filling position number five shall serve as a member of the Commission, subject to removal by the Governor as hereinafter specified in this section, so long as he continues as Director of the Water Resources Research Institute. The terms of office of members filling positions two, four, seven, and eight shall expire on 30 June of years evenly divisible by three. The terms of office of members filling positions one, three, and ten shall expire on 30 June of years that follow by one year those years that are evenly divisible by three. The terms of office of members filling positions six, nine, and eleven shall expire on 30 June of years that precede by one year those years that are evenly divisible by three. Except for the person filling position number five, no member of the Commission shall serve more than two complete consecutive three-year terms. Any member appointed by the Governor to fill a vacancy occurring in any of the appointments shall be appointed for the remainder of the term of the member causing the vacancy. The Governor may at any time remove any member of the Commission for inefficiency, neglect of duty, malfeasance, misfeasance, nonfeasance or, in the case of members filling positions five, six, seven, eight, nine, and eleven as specified above, because they no longer possess the required qualifications for membership. In each instance appointments to fill vacancies in the membership of the Commission shall be a person or persons with similar experience and qualifications in the same field required of the member being replaced. The office of the North Carolina Sedimentation Control Commission is declared to be an office that may be held concurrently with any other elective or appointive office, under the authority of Article VI, Sec. 9, of the North Carolina Constitution.

(b1) Chairman. -- The Governor shall designate a member of the Commission to serve as chairman.

(c) Compensation. -- The members of the Commission shall receive the usual and customary per diem allowed for the other members of boards and commissions of the State and as fixed in the Biennial Appropriation Act, and, in addition, the members of the Commission shall receive subsistence and travel expenses according to the prevailing State practice and as allowed and fixed by statute for such purposes, which said travel expenses shall also be allowed while going to or from any place of meeting or when on official business for the Commission. The per diem payments made to each member of the Commission shall include necessary time spent in traveling to and from their places of residence within the State to any place of meeting or while traveling on official business for the Commission.

(d) Meetings of Commission. -- The Commission shall meet at the call of the chairman and shallhold special meetings at the call of a majority of the members. (1973, c. 1262, s. 40; 1977, c. 771, s. 4; 1981, c. 248, ss. 1, 2; 1989, c. 727, s. 218(138); 1989 (Reg. Sess., 1990), c. 1004, s. 19(b); 1991, c. 551, s. 1.)

§ 113A-67. Annual Report.

The Department shall report to the Environmental Review Commission on the implementation of this Article on or before 1 October of each year. The Department shall include in the report an analysis of how the implementation of the Sedimentation Pollution Control Act of 1973 is affecting activities that contribute to the sedimentation of streams, rivers, lakes, and other waters of the State. The report shall also include a review of the effectiveness of local erosion and sedimentation control programs. (2004-195, s. 2.1.)

BUILDING PERMITS

In 1988, the General Assembly amended G.S. 153A-357 and 160A-417 regarding building permits. The amendments were as follows:

> G.S. 153-357(b): "No permit shall be issued pursuant to subsection (a) for any land-disturbing activity, as defined in G.S. 113A-52(6), for any activity covered by G.S. 113A-57, unless an erosion control plan has been approved by the Sedimentation Pollution Control Commission pursuant to G.S. 113A-54(d)(4) or by a local government pursuant to G.S. 113A-61 for the site of the activity or a tract of land including the site of the activity."
>
> G.S. 160A-417(b): "No permit shall be issued pursuant to subsection (a) for any land-disturbing activity, as defined in G.S. 113A-52(6), for any activity covered by G.S. 113A-57, unless an erosion control plan has been approved by the Sedimentation Pollution Control Commission pursuant to G.S. 113A-61 for the site of the activity or a tract of land including the site of the activity."

8

CHAPTER 4 - SEDIMENTATION CONTROL

This Chapter 4 of Title 15A of the North Carolina Administrative Code (T15A.04); SEDIMENTATION CONTROL; has been transferred and recodified from Chapter 16 of Title 15 of the North Carolina Administrative Code (T15.16), effective November 1, 1989. The recodification was pursuant to G.S. 143B-279.1.

SUBCHAPTER 4A - SEDIMENTATION CONTROL COMMISSION ORGANIZATION

15A NCAC 04A .0101 OFFICES OF THE SEDIMENTATION CONTROL COMMISSION

Persons may write or visit the North Carolina Sedimentation Control Commission offices at the Archdale Building, 512 N. Salisbury Street, P.O. Box 27687, Raleigh, North Carolina 27611. Persons may write or visit regional offices of the Commission's staff in the Land Quality Section of the Division of Land Resources at the following locations:

(1) Interchange Building
59 Woodfin Place
P.O. Box 370
Asheville, N.C. 28801

(2) 585 Waughtown Street
Winston-Salem, N.C. 27107

(3) 919 North Main Street
P.O. Box 950
Mooresville, N.C. 28115

(4) 3800 Barrett Drive
P.O. Box 27687
Raleigh, N.C. 27611

(5) Wachovia Building
Suite 714
Fayetteville, N.C. 28301

(6) 1424 Carolina Avenue
P.O. Box 2188
Washington, N.C. 27889

(7) 127 Cardinal Dr., Ext.
Wilmington, N.C. 28405-3845

History Note: Authority G.S. 143B-298;
Eff. February 1, 1976;
Amended Eff. October 1, 1995; February 1, 1992; May 1, 1990; December 1, 1988.

15A NCAC 04A .0102 PURPOSES
15A NCAC 04A .0103 STRUCTURE
15A NCAC 04A .0104 DELEGATION

History Note: Authority G.S. 113A-54(b)(d)(3); 113A-56(a)(b); 113A-58(1); 113A-61(d); 143B-298;
Eff. February 1, 1976;
Amended Eff. August 1, 1985; November 1, 1984; June 5, 1981; January 31, 1979;
Repealed Eff. August 1, 1988.

15A NCAC 04A .0105 DEFINITIONS

As used in this Chapter, the following terms shall have these meanings:

(1) "Accelerated Erosion" means any increase over the rate of natural erosion, as a result of land-disturbing activities.

(2) "Adequate Erosion Control Measure, Structure, or Device" means one which controls the soil material within the land area under responsible control of the person conducting the land-disturbing activity.

(3) "Borrow" means fill material which is required for on-site construction and is obtained from other locations.
(4) "Buffer Zone" means the strip of land adjacent to a lake or natural watercourse.
(5) "Ground Cover" means any natural vegetative growth or other material which renders the soil surface stable against accelerated erosion.
(6) "Lake or Natural Watercourse" means any stream, river, brook, swamp, sound, bay, creek, run, branch, canal, waterway, estuary, and any reservoir, lake or pond, natural or impounded in which sediment may be moved or carried in suspension, and which could be damaged by accumulation of sediment.
(7) "Natural Erosion" means erosion as defined in G.S. 113A-52(5) under natural environmental conditions undisturbed by man.
(8) "Person Who Violates", as used in G.S. 113A-64, means:
  (a) the developer or other person who has or holds himself out as having financial or operational control over the land-disturbing activity; or
  (b) the landowner or person in possession or control of the land when he has directly or indirectly allowed the land-disturbing activity or has benefitted from it or he has failed to comply with any provision of the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, the North Carolina Administrative Code, Title 15A, Chapter 4, or any order or local ordinance adopted pursuant to the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, as imposes a duty upon him.
(9) "Person Conducting Land Disturbing Activity" means any person who may be held responsible for a violation unless expressly provided otherwise by the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66, the North Carolina Administrative Code, Title 15A Chapter 4, or any order or local ordinance adopted pursuant to the Sedimentation Pollution Control Act of 1973, G.S. 113A-50 to -66.
(10) "Phase of Grading" means one of two types of grading, rough or fine.
(11) "Plan" means an erosion control plan.
(12) "Sedimentation" means the process by which sediment resulting from accelerated erosion has been or is being transported off the site of the land-disturbing activity or into a lake or natural watercourse.
(13) "Storm Water Runoff" means the direct runoff of water resulting from precipitation in any form.
(14) "Being Conducted" means a land-disturbing activity has been initiated and permanent stabilization of the site has not been completed.
(15) "Uncovered" means the removal of ground cover from, on, or above the soil surface.
(16) "Undertaken" means the initiating of any activity, or phase of activity, which results or will result in a change in the ground cover or topography of a tract of land.
(17) "Waste" means surplus materials resulting from on-site construction and disposed of at other locations.
(18) "Energy Dissipator" means a structure or a shaped channel section with mechanical armoring placed at the outlet of pipes or conduits to receive and break down the energy from high velocity flow.
(19) "Storm Drainage Facilities" means the system of inlets, conduits, channels, ditches and appurtenances which serve to collect and convey stormwater through and from a given drainage area.
(20) "Ten Year Storm" means the surface runoff resulting from a rainfall of an intensity expected to be equaled or exceeded, on the average, once in 10 years, and of a duration which will produce the maximum peak rate of runoff, for the watershed of interest under average antecedent wetness conditions.
(21) "Velocity" means the average velocity of flow through the cross section of the main channel at the peak flow of the storm of interest. The cross section of the main channel shall be that area defined by the geometry of the channel plus the area of flow below the flood height defined by vertical lines at the main channel banks. Overload flows are not to be included for the purpose of computing velocity of flow.
(22) "Discharge Point" means that point at which runoff leaves a tract of land.

(23) "Completion of Construction or Development" means that no further land-disturbing activity is required on a phase of a project except that which is necessary for establishing a permanent ground cover.
(24) "High Quality Waters" means those classified as such in 15A NCAC 2B .0101(e)(5) - General Procedures, which is incorporated herein by reference to include further amendments.
(25) "High Quality Water (HQW) Zones" means areas in the Coastal Counties that are within 575 feet of High Quality Waters and for the remainder of the state areas that are within one mile of and drain to HQW's.
(26) "Director" means the Director of the Division of Land Resources of the Department of Environment, Health, and Natural Resources.
(27) "Coastal counties" means the following counties: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Gates, Hertford, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell and Washington.
(28) "Twenty-five Year Storm" means the surface runoff resulting from a rainfall of an intensity expected to be equaled or exceeded, on the average, once in 25 years, and of a duration which will produce the maximum peak rate of runoff, from the watershed of interest under average antecedent wetness conditions.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Filed as a Temporary Amendment Eff. November 1, 1990 for a period of 180 days to expire on April 29, 1991;
Statutory Authority G.S. 113A-52; 113A-54;
Eff. November 1, 1984;
Amended Eff. May 1, 1990;
ARRC Objection Lodged November 14, 1990;
ARRC Objection Removed December 20, 1990;
Amended Eff. October 1, 1995; April 1, 1992; January 1, 1991.

SUBCHAPTER 4B - EROSION AND SEDIMENT CONTROL

15A NCAC 04B .0101 AUTHORITY

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0102 PURPOSE
15A NCAC 04B .0103 SCOPE

History Note: *Authority G.S. 113A-54(a)(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0104 DEFINITIONS

History Note: *Authority G.S. 113A-52; 113A-54;*
Eff. February 1, 1976;
Amended Eff. March 14, 1980; January 31, 1979; July 1, 1978;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0105 PROTECTION OF PROPERTY
Persons conducting land-disturbing activity shall take all reasonable measures to protect all public and private property from damage caused by such activities.

History Note: *Authority G.S. 113A-54(b); 113A-54(d)(2);*
Eff. February 1, 1976;
Amended Eff. August 1, 1988; November 1, 1984.

15A NCAC 04B .0106 BASIC CONTROL OBJECTIVES
(a) An erosion and sedimentation control plan may be disapproved pursuant to 15A NCAC 4B .0118 if the plan fails to address the following control objectives:

(1) Identify Critical Areas: Identify site areas subject to severe erosion, and off-site areas especially vulnerable to damage from erosion and sedimentation.
(2) Limit Exposed Areas. Limit the size of the area exposed at any one time.
(3) Limit Time of Exposure. Limit exposure to the shortest feasible time.
(4) Control Surface Water. Control surface water run-off originating upgrade of exposed areas in order to reduce erosion and sediment loss during exposure.
(5) Control Sedimentation. All land-disturbing activity is to be planned and conducted so as to prevent off-site sedimentation damage.
(6) Manage Storm Water Runoff. When the increased velocity of storm water runoff resulting from a land-disturbing activity causes accelerated erosion of the receiving watercourse, plans shall include measures to control the velocity to the point of discharge.

(b) When deemed necessary by the approving authority a preconstruction conference may be required.

History Note: *Authority G.S. 113A-54(d)(4); 113A-54.1;*
Eff. February 1, 1976;
Amended Eff. July 1, 2000; February 1, 1992; May 1, 1990; November 1, 1984; March 14, 1980.

15A NCAC 04B .0107 MANDATORY STANDARDS FOR LAND-DISTURBING ACTIVITY

(a) No land-disturbing activity subject to these Rules shall be undertaken except in accordance with the G.S. 113A-57.
(b) Pursuant to G.S. 113A-57(3), provisions for a ground cover sufficient to restrain erosion must be accomplished within 15 working days or 90 calendar days following completion of construction or development, whichever period is shorter, except as provided in 15A NCAC 4B .0124(e).
(c) Pursuant to G.S. 113A-57(4) and 113A-54(d)(4), an erosion and sedimentation control plan must be both filed and approved by the agency having jurisdiction.

History Note: *Authority G.S. 113A-54(d)(4); 113A-57; 113A-57(3)(4);*
Eff. February 1, 1976;
Amended Eff. July 1, 2000; May 1, 1990; August 1, 1988; November 1, 1984; March 14, 1980.

15A NCAC 04B .0108 DESIGN AND PERFORMANCE STANDARD

Erosion and sedimentation control measures, structures, and devices shall be so planned, designed, and constructed to provide protection from the run off of that 10 year storm which produces the maximum peak rate of run off as calculated according to procedures in the United States Department of Agriculture Soil Conservation Service's "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; July 1, 1978.

15A NCAC 04B .0109 STORM WATER OUTLET PROTECTION

(a) Persons shall conduct land disturbing activity so that the post construction velocity of the ten year storm run off in the receiving watercourse to the discharge point does not exceed the greater of:

(1) the velocity established by the table in Paragraph (d) of this Rule; or
(2) the velocity of the ten year storm run off in the receiving watercourse prior to development.

If conditions (1) or (2) of this Paragraph cannot be met, then the receiving watercourse to and including the discharge point shall be designed and constructed to withstand the expected velocity anywhere the velocity exceeds the "prior to development" velocity by ten percent.
(b) Acceptable Management Measures. The commission recognizes that management of storm water run off to control downstream erosion constitutes a developing technology and consequently invites the use of innovative techniques shown to produce successful results. Alternatives include:

(1) Compensate for increased run off from areas rendered impervious by designing measures to promote infiltration.
(2) Avoid increases in storm water discharge velocities by using vegetated or roughened swales and waterways in place of closed drains and paved sections.
(3) Provide energy dissipators at storm drainage outlets to reduce flow velocities to the discharge points.
(4) Protect watercourses subject to accelerated erosion by improving cross sections and/or providing erosion-resistant lining.

(c) Exceptions. This Rule shall not apply when storm water discharge velocities will not create an erosion problem in the receiving watercourse.

(d) The following table sets maximum permissible velocity for storm water discharges:

Material	Maximum Permissible Velocities For	
	F.P.S.	M.P.S.
Fine Sand (noncolloidal)	2.5	.8
Sandy Loam (noncolloidal)	2.5	.8
Silt Loam (noncolloidal)	3.0	.9
Ordinary Firm Loam	3.5	1.1
Fine Gravel	5.0	1.5
Stiff Clay (very colloidal)	5.0	1.5
Graded, Loam to Cobbles (noncolloidal)	5.0	1.5
Graded, Silt to Cobbles (colloidal)	5.5	1.7
Alluvial Silts (noncolloidal)	3.5	1.1
Alluvial Silts (colloidal)	5.0	1.5
Coarse Gravel (noncolloidal)	6.0	1.8
Cobbles and Shingles	5.5	1.7
Shales and Hard Pans	6.0	1.8

Source: Adapted from recommendations by Special Committee on Irrigation Research, American Society of Civil Engineers, 1926, for channels with straight alignment. For sinuous channels multiply allowable velocity by 0.95 for slightly sinuous, by 0.9 for moderately sinuous channels, and by 0.8 for highly sinuous channels.

History Note: *Authority G.S. 113A-54(b)(c);*
Eff. February 1, 1976;
Amended Eff. February 1, 1992; May 1, 1990; November 1, 1984; July 1, 1978.

15A NCAC 04B .0110 BORROW AND WASTE AREAS

If the same person conducts the land disturbing activity and any related borrow or waste activity, the related borrow or waste activity shall constitute part of the land disturbing activity unless the borrow or waste activity is regulated under the Mining Act of 1971, or is a landfill regulated by the Division of Solid Waste Management. If the land disturbing activity and any related borrow or waste activity are not conducted by the same person, they shall be considered separate land-disturbing activities.

History Note: *Authority G.S. 74-67; 113A-54(b); 130A-166.21;*
Eff. February 1, 1976;
Amended Eff. May 1, 1990; November 1, 1984.

15A NCAC 04B .0111 ACCESS AND HAUL ROADS

Temporary access and haul roads, other than public roads, constructed or used in connection with any land-disturbing activity shall be considered a part of such activity.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976.

15A NCAC 04B .0112 OPERATIONS IN LAKES OR NATURAL WATERCOURSES

Land disturbing activity in connection with construction in, on, over, or under a lake or natural watercourse shall minimize the extent and duration of disruption of the stream channel. Where relocation of a stream forms an essential part of the proposed activity, the relocation shall minimize unnecessary changes in the stream flow characteristics.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0113 RESPONSIBILITY FOR MAINTENANCE
During the development of a site, the person conducting the land-disturbing activity shall install and maintain all temporary and permanent erosion and sedimentation control measures as required by the approved plan or any provision of the Act, these Rules, or any order or local ordinance adopted pursuant to the Act. After site development, the land owner or person in possession or control of the land shall install and/or maintain all necessary permanent erosion and sediment control measures, except those measures installed within a road or street right of way or easement accepted for maintenance by a governmental agency.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; July 1, 1978.

15A NCAC 04B .0114 GUIDELINES FOR EROSION AND SEDIMENT CONTROL PRACTICES

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0115 ADDITIONAL MEASURES
Whenever the commission or a local government determines that significant erosion and sedimentation continues despite the installation of protective practices, the person conducting the land disturbing activity will be required to and shall take additional protective action.

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0116 EXISTING UNCOVERED AREAS
(a) All uncovered areas which:
(1) existed on the effective date of these Rules;
(2) resulted from land disturbing activity;
(3) exceed one acre;
(4) are experiencing continued accelerated erosion; and
(5) are causing off-site damage from sedimentation,

shall be provided with ground cover or other protective measures, structures, or devices sufficient to restrain accelerated erosion and control off-site sedimentation.
(b) The commission or local government shall serve a notice to comply with the provisions of G.S. 113A-50 et. seq. or any ordinance, rule or order adopted or issued pursuant to G.S. 113A-50 et. seq. by the Commission or by a local government upon the landowner or other person in possession or control of the land by any means authorized under G.S. 1A-1, Rule 4. The notice shall state the measures needed and the time allowed for compliance. The commission or local government issuing the notice shall consider the economic feasibility, technological expertise and quantity of work required, and shall establish reasonable time limits for compliance.
(c) State agency erosion and sedimentation control programs submitted to the commission for delegation of authority to administer such programs shall contain provisions for the treatment of existing exposed areas. Such provisions shall consider the economic feasibility, existing technology, and quantity of work required.

(d) This Rule shall not require ground cover on cleared land forming the future basin of a planned reservoir.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; February 1, 1992; May 1, 1990; November 1, 1984.

15A NCAC 04B .0117 STATEMENT OF FINANCIAL RESPONSIBILITY AND OWNERSHIP

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. May 1, 1990.

15A NCAC 04B .0118 APPROVAL OF PLANS

(a) Persons conducting land-disturbing activity on a tract which covers one or more acres shall file three copies of the erosion and sedimentation control plan with the local government having jurisdiction or with the Commission if no local government has jurisdiction, at least 30 days prior to beginning such activity and shall keep another copy of the plan on file at the job site. After approving a plan, if the Commission or local government determines, either upon review of such plan or on inspection of the job site, that a significant risk of accelerated erosion or off-site sedimentation exists, the Commission or local government shall require a revised plan. Pending the preparation of the revised plan, work shall cease or shall continue under conditions outlined by the appropriate authority.

(b) Commission Approval:

(1) The Commission shall review plans for all land-disturbing activity over which the Commission has exclusive jurisdiction by statute and all other land-disturbing activity if no local government has jurisdiction.

(2) The Commission shall complete its review of any completed plan within 30 days of receipt and shall notify the person submitting the plan in writing that it has been:

(A) approved,
(B) approved with modification,
(C) approved with performance reservations, or
(D) disapproved.

(3) The Commission's disapproval, modification, or performance reservations of any proposed plan, shall entitle the person submitting the plan to an administrative hearing in accordance with the provisions of G.S. 150B-23. (This Section does not modify any other rights to a contested case hearing which may arise under G.S. 150B-23).

(4) Subparagraph (b)(3) of this Rule shall not apply to the approval or modification of plans reviewed by the Commission pursuant to G.S. 113A-61(c).

(5) Any plan submitted for a land-disturbing activity for which an environmental document is required by the North Carolina Environmental Policy Act shall be deemed incomplete until a complete environmental document is available for review. The Commission shall promptly notify the person submitting the plan that the 30 day time limit for review of the plan pursuant to Subparagraph (b)(2) of this Rule shall not begin until a complete environmental document is available for review.

(c) Erosion and sedimentation control plans may also be disapproved unless they include an authorized statement of financial responsibility and ownership. This statement shall be signed by the person financially responsible for the land-disturbing activity or his attorney in fact. The statement shall include the mailing and street addresses of the principal place of business of the person financially responsible and of the owner of the land or their registered agents.

(d) Local Government Approval:

(1) Local Governments administering erosion and sedimentation control programs shall develop and publish procedures for approval of plans. Such procedures shall respect applicable laws, ordinances, and rules, and shall contain procedures for appeal consistent with the local government's organization and operations.

(2) The secretary shall appoint such employee(s) of the Department as he deems necessary to consider appeals from the local government's final disapproval or modification of a plan. Within 30 days following receipt of notification of the appeal, such departmental employee shall complete the review and shall notify the local government and the person appealing the local government's decision that the plan should be approved, approved with modifications, approved with performance reservations, or disapproved.

(3) If either the local government or the person submitting the plan disagrees with the decision reached by an employee of the Department then he may appeal the decision to the Commission by filing notice within 15 days with the Director of the Division of Land Resources. The director shall make the proposed erosion control plan and the records relating to the local government's and departmental employees' review, available to an appeals review committee consisting of three members of the Commission appointed by the chairman. Within 10 days following receipt of the notification of appeal, the appeals review committee shall notify the local government and the person submitting the plan of a place and time for consideration of the appeal, and shall afford both parties an opportunity to present written or oral arguments. The appeals review committee shall notify both parties of its decision concerning the approval, disapproval, or modification of the proposed plan within 30 days following such hearing.

(e) The applicant's right under G.S. 113A-54.1(d) to appeal the Director's disapproval of an erosion control plan under G.S. 113A-54.1(c) gives rise to a right to a contested case under G.S. 150B, Article 3. An applicant desiring to appeal the Director's disapproval of an erosion control plan shall file with the Office of Administrative Hearings a contested case petition under G.S. 150B, Article 3. The general time limitation for filing a petition, and the commencement of the time limitation, shall be as set out in G.S. 150B-23(f). Contested cases shall be conducted under the procedures of G.S. 150B, Article 3 and applicable rules of the Office of Administrative Hearings. The Commission shall make the final decision on any contested case under G.S. 150B-36.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Statutory Authority G.S. 113A-2; 113A-54; 113A-54.1; 113A-60(a); 113A-61(b); 113A-61(c); 150B, Article 3; 150B-23;
Eff. February 1, 1976;
Amended Eff. June 1, 1995; February 1, 1992; May 1, 1990; August 1, 1988.

15A NCAC 04B .0119 COMPLIANCE WITH PLAN REQUIREMENT

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0120 INSPECTIONS AND INVESTIGATIONS

(a) The Commission, Department of Environment, Health, and Natural Resources or local government may require written statements, or the filing of reports under oath, concerning land disturbing activity.

(b) Inspection of sites shall be carried out by the staff of Department of Environment, Health, and Natural Resources or other qualified persons authorized by the Commission or Department of Environment, Health, and Natural Resources as necessary to carry out its duties under the Act.

(c) No person shall refuse entry or access to any representative of the Commission or any representative of a local government who requests entry for purposes of inspection.

History Note: *Authority G.S. 113A-54(b); 113A-58; 113A-61.1;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; May 1, 1990; November 1, 1984.

15A NCAC 04B .0121 PENALTIES

History Note: *Authority G.S. 113A-54; 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04B .0122 SEVERABILITY CLAUSE

If any of these provisions are held invalid or unenforceable, all of the other provisions shall nevertheless continue in full force and effect.

History Note: *Authority G.S. 113A-54;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04B .0123 EFFECTIVE DATE

History Note: *Authority G.S. 113A-54(b);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; November 15, 1976;
Repealed Eff. August 1, 1988.

15A NCAC 04B .0124 DESIGN STANDARDS IN SENSITIVE WATERSHEDS

(a) Uncovered areas in HQW zones shall be limited at any time to a maximum total area within the boundaries of the tract of 20 acres. Only the portion of the land-disturbing activity within a HQW zone shall be governed by this Rule. Larger areas may be uncovered within the boundaries of the tract with the written approval of the Director.
(b) Erosion and sedimentation control measures, structures, and devices within HQW zones shall be so planned, designed and constructed to provide protection from the runoff of the 25 year storm which produces the maximum peak rate of runoff as calculated according to procedures in the United States Department of Agricultural Soil Conservation Service's "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.
(c) Sediment basins within HQW zones shall be designed and constructed such that the basin will have a settling efficiency of at least 70 percent for the 40 micron (0.04mm) size soil particle transported into the basin by the runoff of that two-year storm which produces the maximum peak rate of runoff as calculated according to procedures in the United States Department of Agriculture Soil Conservation Services "National Engineering Field Manual for Conservation Practices" or according to procedures adopted by any other agency of this state or the United States or any generally recognized organization or association.
(d) Newly constructed open channels in HQW zones shall be designed and constructed with side slopes no steeper than two horizontal to one vertical if a vegetative cover is used for stabilization unless soil conditions permit a steeper slope or where the slopes are stabilized by using mechanical devices, structural devices or other acceptable ditch liners. In any event, the angle for side slopes shall be sufficient to restrain accelerated erosion.
(e) Pursuant to G.S. 113A-57(3) provisions for a ground cover sufficient to restrain erosion must be provided for any portion of a land-disturbing activity in a HQW zone within 15 working days or 60 calendar days following completion of construction or development, whichever period is shorter.

History Note: *Authority G.S. 113A-54(b); 113A-54(c)(1);*
Eff. May 1, 1990.

15A NCAC 04B .0125 BUFFER ZONE REQUIREMENTS

(a) Unless otherwise provided, the width of a buffer zone is measured from the edge of the water to the nearest edge of the disturbed area, with the 25 percent of the strip nearer the land-disturbing activity containing natural or artificial means of confining visible siltation.

(b) The 25 foot minimum width for an undisturbed buffer zone adjacent to designated trout waters shall be measured horizontally from the top of the bank.

(c) Where a temporary and minimal disturbance is permitted as an exception by G.S. 113A-57(1), land-disturbing activities in the buffer zone adjacent to designated trout waters shall be limited to a maximum of ten percent of the total length of the buffer zone within the tract to be distributed such that there is not more than 100 linear feet of disturbance in each 1000 linear feet of buffer zone. Larger areas may be disturbed with the written approval of the Director.

(d) No land-disturbing activity shall be undertaken within a buffer zone adjacent to designated trout waters that will cause adverse temperature fluctuations, as set forth in 15A NCAC 2B .0211 "Fresh Surface Water Classification and Standards", in these waters.

History Note: *Authority G.S. 113A-54(b); 113A-54(c)(1); 113A-57(1);*
Eff. May 1, 1990;
Amended Eff. February 1, 1992.

15A NCAC 04B .0126 PLAN REVIEW FEE

(a) A nonrefundable plan review processing fee, in the amount stated in Paragraph (e) of this Rule, shall be paid when an erosion and sedimentation control plan is filed in accordance with 15A NCAC 04B .0118.

(b) Each plan shall be deemed incomplete until the plan review processing fee is paid.

(c) The plan review processing fee shall be based on the number of acres, or any part of an acre, of disturbed land shown on the plan.

(d) No plan review processing fee shall be charged for review of a revised plan unless the revised plan contains an increase in the number of acres to be disturbed. If the revised plan contains an increase in the number of acres to be disturbed, the plan review processing fee to be charged shall be the amount stated in Paragraph (e) of the Rule for each additional acre (or any part thereof) disturbed.

(e) The nonrefundable plan review processing fee shall be fifty dollars ($50.00) for each acre or part of any acre of disturbed land.

(f) Payment of the plan review processing fee may be by check or money order made payable to the "N.C. Department of Environment and Natural Resources". The payment shall refer to the erosion and sedimentation control plan.

History Note: *Authority G.S. 113A-54; 113A-54.2;*
Filed as a Temporary Rule Eff. November 1, 1990, for a period of 180 days to expire on April 29, 1991; AARC Objection Lodged November 14, 1990;
AARC Objection Removed December 20, 1990;
Eff. January 1, 1991;
Amended Eff. August 1, 2002; July 1, 2000.

15A NCAC 04B .0127 PLAN APPROVAL CERTIFICATE

(a) Approval of a sedimentation and erosion control plan will be contained in a document called "Certificate of Plan Approval" to be issued by the Commission.

(b) The Certificate of Plan Approval must be posted at the primary entrance of the job site before construction begins.

(c) No person may initiate a land-disturbing activity until notifying the agency that issued the Plan Approval of the date that the land-disturbing activity will begin.

History Note: *Filed as a Temporary Rule Eff. November 1, 1990, for a period of 180 days to expire on April 29, 1991;*
Authority G.S. 113A-54(b);

ARRC Objection Lodged November 14, 1990;
ARRC Objection Removed December 20, 1990;
Eff. January 1, 1991;
Amended Eff. July 1, 2000.

15A NCAC 04B .0128 RAILROAD COMPANIES

(a) The Commission recognizes that under the Federal Railroad Safety Act of 1970 (FRSA), 45 U.S.C. 421 et seq., as interpreted by federal administrative rules and court decisions, existing railroad roadbeds comprise a zone of federal preeminence within which federal law takes precedence over the Act [the SPCA].
(b) While the specific definition of this zone of federal preeminence is a question of federal law and regulation, in general the zone of federal preeminence extends outward from the center of the railroad roadbed to and including drainage ditches and spoil banks on either side of the roadbed.
(c) In the event of a derailment, washout, or other emergency condition which requires immediate action to protect public safety, the zone of federal preeminence temporarily expands, for the duration of the emergency condition, to encompass areas adjacent to the roadbed within which emergency repairs are undertaken pursuant to the FRSA and Federal Railroad Administration rules.
(d) The Act and rules do not apply to activities conducted within the zone of federal preeminence. The Act and rules apply to all other activities conducted by railroad companies. Railroad companies shall take all reasonable measures that are consistent with the requirements of federal law to control sedimentation originating in the zone of federal preeminence.
(e) A railroad company's failure to comply with a requirement of the Act or rules in order to avoid creating a safety hazard or to avoid noncompliance with a federal safety requirement is not a knowing or willful violation of the Act or rules.
(f) The Commission will provide advice and technical assistance to railroad companies in the development and implementation of voluntary best management practices to reduce environmental impacts that may otherwise result from activities conducted within the zone of federal preeminence.

History Note: Authority G.S. 113A-52(6); 113A-54(b); 113A-54(c); 113A-54(d)(4); 113A-57(1);
Eff. August 1, 1995.

15A NCAC 04B .0129 EROSION CONTROL PLAN EXPIRATION DATE

An erosion control plan shall expire three years following the date of approval, if no land-disturbing activity has been undertaken.

History Note: Authority G.S. 113A-54.1(a);
Eff. October 1, 1995.

15A NCAC 04B .0130 EMERGENCIES

Any person who conducts an emergency repair essential to protect human life, that constitutes a land-disturbing activity within the meaning of G.S. 113A-52(6) and these Rules:

(1) shall notify the Commission of such repair as soon as reasonably possible, but in no event later than five working days after the emergency ends; and
(2) shall take all reasonable measures to protect all public and private property from damage caused by such repair as soon as reasonably possible, but in no event later than 15 working days after the emergency ends.

History Note: Authority G.S. 113A-52.01(4); 113A-54(b);
Eff. October 1, 1995.

SUBCHAPTER 4C - SEDIMENTATION CONTROL CIVIL PENALTIES

15A NCAC 04C .0101 PURPOSE AND SCOPE

History Note: *Authority G.S. 113A-54(b); 113A-64(a);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; October 5, 1980;
Repealed Eff. August 1, 1988.

15A NCAC 04C .0102 DEFINITIONS

History Note: *Authority G.S. 143B-10;*
Eff. February 1, 1976;
Amended Eff. January 31, 1979; September 3, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04C .0103 WHO MAY ASSESS
The director may assess civil penalties against any person responsible for a violation.

History Note: *Authority G.S. 113A-55; 113A-64; 143B-10;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984.

15A NCAC 04C .0104 WHEN ASSESSABLE

History Note: *Authority G.S. 113A-64;*
Eff. February 1, 1976;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04C .0105 AMOUNT OF ASSESSMENT

History Note: *Authority G.S. 113A-64;*
Eff. February 1, 1976;
Repealed Eff. November 1, 1984.

15A NCAC 04C .0106 CRITERIA
In determining the amount of the civil penalty assessment, the director shall consider the following criteria:

(1) severity of the violation,
(2) degree and extent of the harm,
(3) type of violation,
(4) duration,
(5) cause,
(6) extent of any off-site damage which may have resulted,
(7) effectiveness of action taken by violator,
(8) adherence to plan submitted by violator,

(9) effectiveness of plan submitted by violator,
(10) cost of rectifying any damage,
(11) the violator's previous record in complying with rules of the commission,
(12) estimated cost of installing and/or maintaining corrective sediment control measures, and
(13) staff investigative costs.

History Note: *Authority G.S. 113A-54(b); 113A-55; 113A-64(a);*
Eff. February 1, 1976;
Amended Eff. November 1, 1984; April 1, 1978.

15A NCAC 04C .0107 PROCEDURES: NOTICES

(a) The notice of violation shall describe the violation with reasonable particularity, request that all illegal activity cease, and inform the violator that a civil penalty may be assessed pursuant to G.S. 113A-64. If particular actions need to be taken to comply with the Sedimentation Pollution Control Act, the notice shall specify the actions to be taken, shall specify a time period for compliance, and shall state that upon failure to comply within the allotted time the person shall become subject to the assessment of a civil penalty for each day of the continuing violation beginning with the date of the violation.
(b) The stop work order provided in G.S. 113A-65.1 shall serve as the notice of violation for purposes of the assessment of a civil penalty pursuant to G.S. 113A-64(a)(1). Copies of the stop work order shall be served upon persons the Department has reason to believe may be responsible for the violation by any means authorized under G.S. 1A-1, Rule 4.

History Note: *Filed as a Temporary Amendment Eff. January 14, 1992 for a period of 180 days to expire on July 11, 1992;*
Authority G.S. 113A-54; 113A-61.1; 113A-64; 113A-65.1; 143B-10;
Eff. February 1, 1976;
Amended Eff. August 1, 2000; October 1, 1995; April 1, 1992; May 1, 1990; November 1, 1984;
Temporary Amendment Eff. August 1, 2000;
Amended Eff. April 1, 2001.

15A NCAC 04C .0108 REQUESTS FOR ADMINISTRATIVE HEARING

After receipt of notification of any assessment, the assessed person must select one of the following options within 30 days:

(1) tender payment; or
(2) file a petition for an administrative hearing in accordance with G.S. 150B-23.

History Note: *Authority G.S. 113A-64; 143B-10; 150B-23;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; October 1, 1988; October 5, 1980; April 1, 1978.

15A NCAC 04C .0109 TENDER OF PAYMENT

The director shall accept and acknowledge all tenders of payment on behalf of the secretary.

History Note: *Authority G.S. 113A-55; 143B-10;*
Eff. February 1, 1976;
Amended Eff. October 5, 1980; April 1, 1978.

15A NCAC 04C .0110 ADMINISTRATIVE HEARING

Administrative hearings shall be conducted in accordance with the procedures outlined in G.S. 150B-22 et seq. and the contested case procedures in 15A NCAC 1B .0200.

History Note: *Authority G.S. 113A-55; 150B-22 et seq.;*
Eff. February 1, 1976;
Amended Eff. October 1, 1995; August 1, 1988; November 1, 1984; October 5, 1980.

15A NCAC 04C .0111 FURTHER REMEDIES

No provision of this Subchapter shall be construed to restrict or impair the right of the secretary, the director, or the Sedimentation Control Commission to pursue any other remedy provided by law for violations of the Sedimentation Pollution Control Act.

History Note: *Authority G.S. 113A-54; 113A-60; 113A-64 through 113A-66;*
Eff. February 1, 1976.

SUBCHAPTER 4D - LOCAL ORDINANCES

15A NCAC 04D .0101 SUBMISSION AND APPROVAL OF PROPOSED LOCAL ORDINANCES

History Note: Authority G.S. 113A-54; 113A-60;
Eff. February 1, 1976;
Repealed Eff. August 1, 1988.

15A NCAC 04D .0102 MODEL ORDINANCE

The commission has adopted a model ordinance. Local governmental units wishing to establish a local erosion and sedimentation control program may obtain a copy of the model ordinance upon writing to:

North Carolina Department of Environment, Health, and Natural Resources
Land Quality Section
P.O. Box 27687
Raleigh, North Carolina 27611

History Note: Authority G.S. 113A-54(d); 113A-60;
Eff. February 1, 1976;
Amended Eff. March 14, 1980; February 23, 1979;
Summary Rule Filed January 26, 1982;
Amended Eff. October 1, 1995; May 1, 1990; August 1, 1988; November 1, 1984.

15A NCAC 04D .0103 REVISIONS TO APPROVED LOCAL ORDINANCES

History Note: Authority G.S. 113A-54(d); 113A-60;
Eff. May 1, 1990;
Amended Eff. January 4, 1993;
Repealed Eff. October 1, 1995.

SUBCHAPTER 4E - RULEMAKING PROCEDURES

SECTION .0100 - GENERAL PROVISIONS

15A NCAC 04E .0101 GENERAL PURPOSE
Rules at 15A NCAC 1B .0100 are adopted by reference and with the rules of this Subchapter shall govern rule-making hearings conducted under the purview of the commission.

History Note: *Authority G.S. 113A-54; 113A-55; 150B;*
Eff. March 14, 1980;
Amended Eff. November 1, 1984.

15A NCAC 04E .0102 DEFINITIONS
As used in this Subchapter:
(1) "Commission" means the North Carolina Sedimentation Control Commission.
(2) "Director" means the Director of the Division of Land Resources of the Department of Environment, Health, and Natural Resources.

History Note: *Authority G.S. 113A-54; 113A-55;*
Eff. March 14, 1980;
Amended Eff. May 1, 1990.

15A NCAC 04E .0103 ADDRESS

History Note: *Authority G.S. 113A-54;*
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0104 COPIES OF RULES: INSPECTION
(a) Anyone desiring to obtain a copy of any or all of the rules of the commission may do so by requesting such from the director at the address of the commission as set forth at Rule .0001 of Subchapter A of this Chapter. The request must specify the rules requested, for example, 15A NCAC 4, Sedimentation Control, or 15A NCAC 4E, Rulemaking Procedures. The director may charge reasonable fees to recover mailing and duplication costs for requests of more than one copy of the same rule(s).
(b) The rules of the commission (15A NCAC 4) and other documents specified in G.S. 150B-11 are available for public inspection at the Office of the Director (P.O. Box 27687, 512 N. Salisbury Street, Raleigh, N.C. 27611) during regular office hours.

History Note: *Authority G.S. 113A-54; 113A-55; 150B-11;*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984.

15A NCAC 04E .0105 DELEGATIONS OF AUTHORITY TO THE DIRECTOR

History Note: *Authority G.S. 113A-54; 113A-55; 150B;*
Eff. March 14, 1980;
Amended Eff. November 1, 1984; June 5, 1981;
Repealed Eff. August 1, 1988.

SECTION .0200 - PETITIONS FOR RULEMAKING

15A NCAC 04E .0201 PETITION FOR RULEMAKING HEARINGS
Any person wishing to submit a petition requesting the adoption, amendment, or repeal of a rule by the commission shall forward the petition to the director at the address of the commission in Rule .0001 of Subchapter A of this Chapter. The first page of the petition should clearly bear the notation: RULEMAKING PETITION RE and then the subject area (for example, RE PLAN REQUIREMENTS, RE PENALTIES, RE INSPECTIONS) or an indication of any other area over which the commission may have rulemaking authority.

History Note: Authority G.S. 113A-54; 150B-16;
Eff. March 14, 1980;
Amended Eff. November 1, 1984.

15A NCAC 04E .0202 CONTENTS OF PETITION

History Note: Authority G.S. 113A-54; 150B-16;
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0203 DISPOSITION OF PETITIONS
(a) The director will determine whether the petition contains sufficient information for the commission to determine whether the public interest will be served by granting the request. The director may request additional information from the petitioner(s), he may contact interested persons or persons likely to be affected by the proposed rule and request comments, and he may use any other appropriate method for obtaining additional information.
(b) The commission will render a decision within 30 days after the petition is submitted. If the decision is to grant the petition, the director, within 30 days of submission, will initiate a rulemaking proceeding. If the decision is to deny the petition, the director will notify the petitioner(s) in writing, stating the reasons therefor.
(c) If the commission is not scheduled to meet within 30 days of submission of a petition the director may either:
(1) accept the petition and initiate a rulemaking proceeding; or
(2) Ask the chairman of the commission to call a special meeting of the commission so that a decision can be made by the commission within the 30 day time period required by 150B-16 and in accordance with the procedures set out in (b) of this Rule.

History Note: Authority G.S. 113A-54; 113A-55; 150B-16;
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984; June 5, 1981.

SECTION .0300 - NOTICE OF RULEMAKING HEARINGS

15A NCAC 04E .0301 TIMING OF NOTICE
History Note: Authority G.S. 113A-54; 150B-12;
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0302 NOTICE MAILING LIST

History Note: Authority G.S. 113A-54; 150B-12(b);
Eff. March 14, 1980;
Amended Eff. November 1, 1984;
Repealed Eff. August 1, 1988.

15A NCAC 04E .0303 ADDITIONAL INFORMATION

History Note: *Authority G.S. 113A-54; 150B-12;*
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

SECTION .0400 - RULEMAKING HEARINGS

15A NCAC 04E .0401 REQUEST TO PARTICIPATE
15A NCAC 04E .0402 CONTENTS OF REQUEST: GENERAL TIME LIMITATIONS

History Note: *Authority G.S. 113A-54; 150B-12(d),(e);*
Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0403 WRITTEN SUBMISSIONS
(a) Any person may file a written submission containing data, comments, or arguments after distribution or publication of a rulemaking notice until the day of the hearing, unless a longer period has been prescribed in the notice or granted upon request. These written comments should be sent to the director at the address of the commission.
(b) The first page of any written submission shall clearly identify the rulemaking proceeding or proposed rule to which the comments are addressed and include a statement of the position of the person making the submission (for example, "In support of adopting proposed Rule .0000," "In opposition to adopting proposed Rule .0000").
(c) Upon receipt of written comments, acknowledgment will be made with an assurance that the comments therein will be considered fully by the commission.

History Note: *Authority G.S. 113A-54; 150B-12(e);*
Eff. March 14, 1980;
Amended Eff. June 5, 1981.

15A NCAC 04E .0404 PRESIDING OFFICER: POWERS AND DUTIES

History Note: *Authority G.S. 113A-54; 150B-12;*

Eff. March 14, 1980;
Repealed Eff. November 1, 1984.

15A NCAC 04E .0405 STATEMENT OF REASONS FOR DECISION
(a) Any interested person desiring a concise statement of the principal reasons for and against the adoption of a rule by the commission and the factors that led to overruling the considerations urged for or against its adoption may submit a request to the director of the address of the commission.
(b) The request must be made in writing and submitted prior to adoption of the rule or within 30 days thereafter.

History Note: *Authority G.S. 113A-54; 150B-12(e);*
Eff. March 14, 1980.

15A NCAC 04E .0406 RECORD OF PROCEEDINGS
A record of all rulemaking proceedings will be maintained by the director for as long as the rule is in effect, and for five years thereafter, following filing with the Office of Administrative Hearings. Record of rulemaking proceedings will be

available for public inspection during the hours of 8:30 AM to 5:30 PM on workdays.

History Note: *Authority G.S. 113A-54; 150B-11(2);*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; November 1, 1984.

SECTION .0500 - DECLARATORY RULINGS

15A NCAC 04E .0501 SUBJECTS OF DECLARATORY RULINGS

Any person aggrieved by a statute administered or rule promulgated by the commission may request a declaratory ruling as to either the manner in which a statute or rule applies to a given factual situation, if at all, or whether a particular agency rule is valid. For purposes of this Section, an aggrieved person means a person substantially affected by a statute administered by the commission or a rule promulgated by the commission.

History Note: *Authority G.S. 113A-54; 150B-17;*
Eff. March 14, 1980.

15A NCAC 04E .0502 SUBMISSION OF REQUEST FOR RULING

All requests for declaratory rulings shall be written and mailed to the director at the address of the commission. The first page of the request should bear the notation: REQUEST FOR DECLARATORY RULING. The request must include the following information:

(1) name and address of petitioner;
(2) statute or rule to which petition relates;
(3) concise statement of the manner in which petitioner is aggrieved by the rule or statute or its potential application to him;
(4) a statement of whether an oral hearing is desired and, if so, the reason therefor.

History Note: *Authority G.S. 113A-54; 150B-17;*
Eff. March 14, 1980.

15A NCAC 04E .0503 DISPOSITION OF REQUESTS

(a) Upon receiving a request, the director is authorized to initiate a declaratory ruling proceeding to receive information concerning the request. A declaratory ruling proceeding may consist of written submissions, an oral hearing, or other procedures as may be appropriate in the circumstances of the particular request. If the proceeding takes the form of an oral hearing the director may direct that the proceeding take place before the commission.
(b) The director will compile the information collected in the proceeding, along with other relevant information, in a recommendation to the commission on whether to issue the ruling and what the ruling should be.
(c) A decision whether to issue the ruling will be made by the commission at the next regularly scheduled meeting of the commission within the 60 day period required by 150B-17 and after the director's recommendation is presented. If no meeting is scheduled within that time period, the director will ask the chairman of the commission to call a special meeting so that the commission can comply with the requirements of G.S. 150B-17.
(d) If the decision of the commission is to issue the ruling, the ruling will be issued by the commission with the 60 day period required by G.S. 150B-17. If necessary, the chairman of the commission will call a special meeting so that the commission can comply with this requirement.
(e) If the decision of the commission is to deny the request, the director will notify the petitioner(s) in writing stating the reasons therefor.
(f) For purposes of this Rule, the commission will ordinarily refuse to issue a declaratory ruling:

(1) unless the rule is unclear on its face;
(2) unless the petitioner shows that the circumstances are so changed since the adoption of the rule that such a ruling would be warranted;
(3) unless the petitioner shows that the agency did not give to the factors specified in the request for a

declaratory ruling a full consideration at the time the rule was issued;

(4) where there has been a similar controlling factual determination in a contested case or where the factual context being raised for a declaratory ruling was specifically considered upon the adoption of the rule or directive being questioned, as evidenced by the rulemaking record; or

(5) where the subject matter of the request is involved in pending litigation in any state or federal court in North Carolina.

History Note: *Authority G.S. 113A-54; 113A-55; 150B-17;*
Eff. March 14, 1980;
Amended Eff. August 1, 1988; June 5, 1981.

15A NCAC 04E .0504 RECORD OF DECISION

A record of all declaratory rulemaking proceedings will be maintained in the director's office for as long as the ruling is in effect and for five years thereafter. This record will contain: the petition, the notice, all written submissions filed in the request, whether filed by the petitioner or any other person, and a record or summary of oral presentations, if any. Records of declaratory rulemaking proceedings will be available for public inspection during the regular office hours of the director.

History Note: *Authority G.S. 113A-54; 150B-11;*
Eff. March 14, 1980.

8.10 GLOSSARY

This glossary includes terms pertinent to sediment control. Some of these terms do not appear in the text, but all are in common usage by planners, engineers, soil scientists and conservationists.

AASHTO classification The official classification of soil materials and soil aggregate mixtures for highway construction used by the American Association of State Highway and Transportation Officials.

Abutment The sloping sides of a valley that support the ends of a dam.

Acid soil A soil with a preponderance of hydrogen ions (and probably of aluminum) in proportion to hydroxyl ions. Specifically, soil with a pH value less than 7.0. For most practical purposes, a soil with a pH value less than 6.6.

Acre-foot The volume of water that will cover 1 acre to a depth of 1 foot.

Alluvial soils Soils developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the original material by soil-forming processes.

Alluvium A general term for all detrital material deposited or in transit by streams, including gravel, sand, silt, clay, and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

Annual storm The highest peak storm discharge that is expected in any given year. This storm has a 2-year frequency of occurrence.

Antecedent moisture conditions (AMC) The degree of wetness of a watershed at the beginning of a storm.

Anti-seep collar A device constructed around a pipe or other conduit placed through a dam, levee, or dike for the purpose of preventing soil movement and piping failures.

Anti-vortex device A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Apron A pad of non-erosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices.

Aquifer An underground porous, water-bearing geological formation. The term is generally restricted to materials capable of yielding an appreciable supply of water.

Barrel A conduit placed through a dam, levee, or dike to control the release of water.

Base flow Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Bearing capacity The maximum load that a material can support before failing.

Bedrock The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium or hard and have a smooth or irregular surface.

Bentonite A highly plastic clay consisting of the minerals montmorillonite and beidellite that swells extensively when wet. Often used to seal soil to reduce seepage losses.

Berm A narrow shelf or flat area that breaks the continuity of a slope.

Borrow area A source of earth fill material used in the construction of embankments or other earth fill structures.

Bunchgrass Grass plant that forms a distinct clump and does not spread by long, horizontal stems.

Buoyant weight The downward force exerted by an object with a specific gravity greater than one, when it is submerged in water.

Capillary action The tendency of drier soil particles to attract moisture from wetter portions of soil.

Catch basin A chamber usually build at the curb line of a street, for the admission of surface water to a storm sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Channel A natural stream or excavated ditch that conveys water.

Channel stabilization Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops or other structures and/or by lining the channel with a suitable liner such as vegetation, riprap, concrete or other similar material.

Channelization Alteration of a stream channel by widening, deepening, straightening, or paving certain areas to improve flow characteristics.

Chute A high-velocity, open channel for conveying water down a steep slope without erosion, usually paved.

Clay (1) Soil fraction consisting of particles less than 0.002 mm in diameter. (2) A soil texture class which is dominated by clay or at least has a larger proportion of clay than either silt or sand.

Cohesion The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Cohesive soil A soil that, when unconfined, has considerable strength when air-dried and significant strength when saturated.

Compost Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Conservation district A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body but with limited authorities. Often called a soil conservation district or a soil and water conservation district.

Contour An imaginary line on the surface of the earth connecting points of the same elevation.

Cut Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below the original ground surface to the excavated surface.

Cut-and-fill Process of earth grading by excavating part of a higher area and using the excavated material for fill to raise the surface of an adjacent lower area.

Cutoff trench A long, narrow excavation (keyway) constructed along the center line of a dam, dike, levee or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Cutting A leaf, stem or branch cut from a plant to establish a new plant.

Dam A barrier to confine or impound water for storage or diversion, to prevent gully erosion, or for retention of soil, sediment, or other debris.

Debris dam A barrier built across a stream channel to retain logs, tree limbs, sand, gravel, silt or other material.

Design highwater The elevation of the water surface at peak flow conditions of the design flood.

Design life The period of time for which a facility is expected to perform its intended function.

Design storm A selected rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Desilting area An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water; located above a stock tank, pond, field, or other area needing protection from sediment accumulation.

Detention Managing stormwater runoff by temporary holding and controlled release.

Detention time The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Dewatering The removal of water temporarily impounded in a holding basin.

Dibble bar A heavy metal tool with a blade and a foot pedal used to open holes for planting seeds, sprigs, cuttings or seedlings.

Dike An embankment to confine or control water, often built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge Usually the rate of water flow; a volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day.

Dispersion, Soil The breaking down of fine soil aggregates into individual particles, resulting in single-grain structure. Ease of dispersion influences the erodibility of soils. Generally speaking, the more easily dispersed the soil, the more erodible it is.

Diversion A channel with a supporting ridge on the lower side constructed at the top, across, or at the bottom of a slope for the purpose of controlling surface runoff.

Diversion dike A barrier built to divert surface runoff.

Divide, Drainage The boundary between watersheds.

Drain A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drainage The removal of excess surface water or groundwater from land by means of ditches or subsurface drains.

Drainage, Soil As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation. Soil drainage conditions are defined as:

- Well drained—Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.
- Moderately well drained—Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.
- Somewhat poorly drained—Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.
- Poorly drained—Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.
- Very poorly drained—Water is removed so slowly that the water table remains at or near the surface for the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drainageway A natural or artificial depression that carries surface water to a larger watercourse or outlet such as a river, lake, or bay.

Drawdown Lowering of the water surface in an open channel or lake or groundwater.

Drop inlet Overall structure in which the water drops through a vertical riser connected to a discharge conduit or storm sewer.

Drop spillway Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop structure A structure for dropping water to a lower level and dissipating its surplus energy without erosion.

Dune A high ridge of sand usually formed by wind deposition and normally found along the coastline.

Dune formation The building of a dune by trapping blowing sand—either naturally by resident vegetation, or artificially by building sand fences and/or planting adapted vegetation such as American beachgrass or sea oats.

Dune, frontal or foredune The dune line nearest the ocean.

Earth dam Dam constructed of compacted suitable soil materials.

Embankment A man-made deposit of soil, rock, or other material often used to form an impoundment.

Emergency spillway Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy dissipator A device used to reduce the energy of flowing water to prevent erosion.

Environment The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erodibility Susceptibility to erosion.

Erosion The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are sued to describe different types of water erosion:

- Accelerated erosion—Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.
- Channel erosion—The erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.
- Gully erosion—The erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.
- Rill erosion—An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See Rill.
- Splash erosion—The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.
- Sheet erosion—The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Estuary Area where fresh water meets salt water, (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as spawning and feeding grounds for large numbers of marine organisms and provide shelter and food for birds and wildlife.

Evapotranspiration The combined loss of water from an area by evaporation from the soil surface and by transpiration of plants.

Excess rainfall The amount of rainfall that runs directly off an area.

Filter blanket A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

Filter fabric A woven or non-woven, water-permeable material generally made of synthetic products such as polypropylene and used in erosion and sediment control applications to trap sediment or prevent the movement of fine soil particles. Often used instead of a filter blanket.

Filter strip Usually long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties.

Flood peak The highest stage or greatest discharge attained by a flood event. Thus, peak stage or peak discharge.

Floodplain The lowland that borders a stream and is subject to flooding when the stream overflows its banks.

Flood stage The stage at which overflow of the natural banks of a stream begins.

Floodway A channel, either natural, excavated, or bounded by dikes and levees, used to carry flood flows.

Flume A constructed channel lined with erosion-resistant materials used to convey water on steep grades without erosion.

Fluvial sediment Those deposits produced by stream or river action.

Foundation drain A pipe or series of pipes which collects groundwater from the foundation or footing of structures to improve stability.

Freeboard A vertical distance between the elevation of the design high-water and the top of a dam, diversion ridge, or other water control device.

Frequency of storm (design storm frequency) The anticipated period in years that will elapse before another storm of equal intensity and/or total volume will recur: a 10-year storm can be expected to occur on the average once every 10 years.

Froude number (F) A calculated number for classifying water flow as critical ($F = 1$), supercritical ($F > 1$) or subcritical ($F < 1$).

Gabion A wire mesh cage, usually rectangular, filled with rock and used to protect channel banks and other sloping areas from erosion.

Gauge Device for measuring precipitation, water level, discharge, velocity, pressure, temperature, etc., e.g., a rain gauge. A measure of the thickness of metal, e.g., diameter of wire or wall thickness of steel pipe.

Gauging station A selected section of a stream channel equipped with a gauge, stage recorder, or other facilities for determining stream stage and discharge.

Gradation The distribution of the various sized particles that constitute a sediment, soil, or other material such as riprap.

Grade (1) The slope of a road, a channel, or natural ground. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grade stabilization structure A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel bottom.

Gradient Change of elevation, velocity, pressure, or other characteristics per unit length; slope.

Grading The cutting and/or filling of the land surface to a desired slope or elevation.

Grass A member of the botanical family *Gramineae*, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Grassed waterway A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to safely conduct surface water from an area.

Ground cover (Horticulture) Low-growing, spreading plants useful for low-maintenance landscape areas.

Habitat The environment in which the life needs of a plant or animal are supplied.

Head The height of water above any plain of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head or velocity head.

Head loss Energy loss due to friction, eddies, changes in velocity, elevation or direction of flow.

Headwater The source of a stream. The water upstream from a structure or point on a stream.

Hulled seed Seed from which some outer protective covering has been removed to speed germination. Scarified seed must also be hulled.

Hydrograph A graph showing for a given point on a stream the discharge, stage (depth), velocity, or other property of water with respect to time.

Hydrologic cycle The circuit of water movement from the atmosphere to the earth and back to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrology The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Impact basin A device used to dissipate the energy of flowing water to reduce erosion. Generally constructed of concrete partially submerged with baffles to dissipate velocities.

Impervious Not allowing infiltration.

Impoundment Generally, an artificial water storage area, as a reservoir, pit, dugout, sump, etc.

Inoculum A culture of microorganisms intentionally introduced into a medium such as seed, soil, or compost.

Invert The inside bottom of a culvert or other conduit.

Keyway A cutoff trench dug beneath the entire length of a dam to cut through soil layers that may cause seepage and possible dam failure.

Lag time The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Laminar flow Flow at relatively slow velocity in which fluid particles slide smoothly along straight lines everywhere parallel to the axis of a channel or pipe.

Land capability The suitability of land for use. Land capability classification involves consideration of: 1) the risks of land damage from erosion and other causes and 2) the difficulties in land use owing to physical land characteristics, including climate.

Land use controls Methods for regulating the uses to which a given land area may be put, including such things as zoning, subdivision regulation, and floodplain regulation.

Legume Any member of the pea or pulse family which includes peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, black locust, and kudzu. Practically all legumes are nitrogen-fixing plants.

Liquid limit The moisture content at which the soil passes from a plastic to a liquid state.

Loam A soil textural classification in which the proportions of sand, silt, and clay are well balanced. Loams have the best properties for cultivation of plants.

Mean depth Average depth; cross-sectional area of a stream or channel divided by its surface or top width.

Mean velocity The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Microclimate The climate specifically associated with a very small area such as a crevice in a rock outcropping.

Mulch A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Natural drainage The flow patterns of stormwater runoff over the land in its pre-development state.

Nitrogen fixation The conversion of atmospheric nitrogen into stable compounds usable by plants. Carried out by bacteria that colonize the roots of most legumes.

Node (Botany) The point on a plant stem where a leaf or leaves arise. Creeping stems (rhizomes and stolons), and in some plants the upright stem, produce roots at the nodes.

Nonpoint source pollution Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Normal depth Depth of flow in an open conduit during uniform flow for the given conditions.

Nutrient(s) A substance necessary for the growth and reproduction of organisms. In water, those substances that promote growth of algae and bacteria; chiefly nitrates and phosphates.

Open drain Natural watercourse or constructed open channel that conveys drainage water.

Outfall The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.

Outlet Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel A waterway constructed or altered primarily to carry water from man-made structures, such as smaller channels, tile lines, and diversions.

Overland flow irrigation A process of land application of wastewater that provides spray distribution onto gently sloping soil of relatively impervious nature, such as clays, for the purpose of attaining aerobic biotreatment of the exposed flow in contact with ground cover vegetation, followed by the collection of runoff waters in intercepting ditches or channels and the return of the wastewater back to the spray system, or its discharge into receiving waters; sometimes called spray runoff.

Peak discharge The maximum instantaneous flow from a given storm condition at a specific location.

Percolation The movement of water through soil.

Percolation rate The rate, usually expressed as inches/hour or inches/day, at which water moves through the soil profile.

Perennial stream A stream that maintains water in its channel throughout the year.

Permeability, Soil The quality of a soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Permeability rate The rate at which water will move through a saturated soil. Permeability rates area classified as follows:

- Very slow—Less than 0.06 inches per hour.
- Slow—0.06 to 0.20 inches per hour.
- Moderately slow—0.20 to 0.63 inches per hour.
- Moderate—0.63 to 2.0 inches per hour.
- Moderately rapid—2.0 to 6.3 inches per hour.
- Rapid—6.3 to 20.0 inches per hour.
- Very rapid—More than 20.0 inches per hour.

Pervious Allowing movement of water.

Pesticides Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodenticides, nematicides, fungicides, and growth regulators.

pH A numerical measure of hydrogen ion activity. The neutral point is pH 7.0. All pH values below 7.0 are acid and all above 7.0 are alkaline.

Phosphorus, Available Inorganic phosphorus that is readily available for plant growth.

Physiographic region (province) Large-scale unit of land defined by its climate, geology, and geomorphic history and therefore uniform in physiography.

Plasticity index The numerical difference between the liquid limit and the plastic limit of soil; the range of moisture content within which the soil remains plastic.

Plastic limit The moisture content at which a soil changes from a semi-solid to a plastic state.

Plunge pool A basin used to dissipate the energy or flowing water usually constructed to a design depth and shape. The pool may be protected from erosion by various lining materials.

Point source Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. (P.L. 92-500, Section 502(14).

Porosity The volume of pore space in soil or rock.

Principal spillway A dam spillway generally constructed of permanent material and designed to regulate the normal water level, provide flood protection and/or reduce the frequency of operation of the emergency spillway.

Rainfall intensity The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Rational method A means of computing storm drainage flow rates, Q, by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.

Reach The smallest subdivision of the drainage system consisting of a uniform length of open channel. Also, a discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

Receiving stream The body of water into which runoff or effluent is discharged.

Recharge Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recharge basin A basin provided to increase infiltration for the purpose of replenishing groundwater supply.

Retention The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Retention structure A natural or artificial basin that functions similar to a detention structure except that it maintains a permanent water supply.

Rhizome A modified plant step that grows horizontally underground. A rhizomatous plant spreads (reproduces) vegetatively and can be transplanted with rhizome fragments.

Rill A small intermittent watercourse with steep sides, usually only a few inches deep.

Riparian Of, on, or pertaining to the banks of a stream, river, or pond.

Riparian rights A principal of common law which requires that any user of waters adjoining or flowing through his lands must so use and protect them that he will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Riser The inlet portions of a drop inlet spillway that extend vertically from the pipe conduit barrel to the water surface.

Runoff That portion of precipitation that flows from a drainage area on the land surface, in open channels or in stormwater conveyance systems.

Sand (1) Soil particles between 0.05 and 2.0 mm in diameter. (2) A soil textural class inclusive of all soils which are at least 70% sand and 15% or less clay.

Saturation In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

Scarified seed Seed which has been subjected to abrasive treatment to encourage germination.

Scour The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the stream bed and outside bank of a curved channel.

Sediment Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site or origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment delivery ratio The fraction of the soil eroded from upland sources that actually reaches a stream channel or storage reservoir.

Sediment discharge The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Sediment pool The reservoir space allotted to the accumulation of sediment during the life of the structure.

Seedbed The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seedling A young plant grown from seed.

Settling basin An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Shoot The above-ground portion of a plant.

Silt (1) Soil fraction consisting of particles between 0.002 and 0.05 mm in diameter. (2) A soil textural class indicating more than 80% silt.

Slope Degree of deviation of a surface from the horizontal; measured as a numerical ration or percent. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), e.g., 2:1. Slope can also be expressed as the rise over the run. For instance, a 2:1 slope is a 50 percent slope.

Soil The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil horizon A horizontal layer of soil that, through processes of soil formation, has developed characteristics distinct from the layers above and below.

Soil profile A vertical section of the soil from the surface through all horizons.

Soil structure The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil texture The physical structure or character of soil determined by the relative proportions of the soil separates (sand, silt and clay) of which it is composed.

Spillway A passage such as a paved apron or channel for surplus water over or around or through a dam or similar structure. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Sprig Section of plant stem material (rhizome, shoot, or stolon) used in vegetative planting.

Stolon Modified plant stem that grows horizontally on the soil surface.

Storm frequency The time interval between major storms of predetermined intensity and volumes of runoff, e.g., a 5-year, 10-year or 20-year storm.

Storm sewer A sewer that carries stormwater, surface drainage, street wash and other wash waters, but excludes sewage and industrial wastes. Also called a storm drain.

Streambanks The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

Stream gauging The quantitative determination of stream flow using gauges, current meters, weirs, or other measuring instruments at selected locations. See Gauging station.

Subcritical flow Flow at relatively low velocity where the wave from a disturbance can move upstream. Froude No. less than 1.

Subsoil The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface drain A pervious backfilled trench usually containing stone and perforated pipe for intercepting groundwater or seepage.

Subwatershed A watershed subdivision of unspecified size that forms a convenient natural unit.

Supercritical flow Flow at relatively high velocity where the wave from a disturbance will always be swept downstream. Froude number is greater than 1.

Surface runoff Precipitation that falls onto the surfaces of roofs, streets, the ground, etc., and is not absorbed or retained by the surface, but collects and runs off.

Suspended solids Solids either floating or suspended in water or sewage and other liquid wastes.

Swale An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Tailwater depth The depth of flow immediately downstream from a discharge structure.

Tile drain Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Tile drainage Land drainage by means of a series of tile lines laid at a specified depth, grade and spacing.

Toe of dam The base or bottom of the sloping faces of a constructed dam at the point of intersection with the natural ground surface--normally a much flatter slope. A dam has an inside toe (the impoundment or upstream side) and an outside toe (the downstream side).

Toe of slope The base or bottom of a slope at the point where the ground surface abruptly changes to a significantly flatter grade.

Topography General term to include characteristics of the ground surface such as plains, hills, mountains, degree of relief, steepness of slopes, and other physiographic features.

Topsoil The dark-colored surface layer of A horizon of a soil. When present it ranges in depth from a fraction of an inch to 2 or 3 ft; equivalent to the plow layer of cultivated soils. Commonly used to refer to the surface soil layer(s), enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Toxicity The characteristic of being poisonous or harmful to plant or animal life; the relative degree or severity of this characteristic.

Trash rack A structural device used to prevent debris from entering a pipe spillway or other hydraulic structure.

Turbidity Cloudiness of a liquid, caused by suspended solids; a measure of the suspended solids in a liquid.

Turf Surface soil supporting a dense growth of grass and associated root mat.

Unified soil classification system A classification system based on the identification of soils according to their particle size, gradations, plasticity index, and liquid limit.

Uniform flow A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Vegetative stabilization Protection of erodible or sediment-producing areas with:

- permanent seeding, producing long-term vegetative cover,
- short-term seeding, producing areas covered with a temporary vegetative cover, or
- sodding, producing areas covered with a turf of perennial sod-forming grass.

Watercourse A definite channel with bed and banks within which concentrated water flows, either continuously or intermittently.

Water quality A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water resources The supply of groundwater and surface water in a given area.

Watershed The region drained by or contributing water to a stream, lake, or other body of water.

Watershed area All land and water within the confines of a drainage divide.

Water table The free surface of the groundwater. That surface subject to atmospheric pressure under the ground, generally rising and falling with the season, or from other conditions such as water withdrawal.

Weir Device for measuring or regulating the flow of water

Weir notch The opening in a weir for the passage of water.

Zoning ordinance An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and intense type of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial, or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

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WHERE TO GO FOR HELP

The Land Quality Section of the North Carolina Department of Environment, Health, and Natural Resources employs some 50 properly qualified engineers, geologists, and technicians to implement laws pertaining to safety of non-federal dams, erosion and sediment control on construction sites, and responsible operation and reclamation of mines in North Carolina.

This section maintains seven regional field offices across the state and a central administrative office in Raleigh, which provides specialized technical and legal support.

The field office personnel are cross-trained to implement the inspection, public education, and enforcement responsibilities and dam safety, erosion control and mine reclamation. For further information or assistance please contact the nearest regional engineer or our Raleigh Headquarters.

1) Janet Boyer, P.E.
Asheville Regional Office
2090 U.S. Highway 70
Swannanoa, NC 28778
(828) 296-4500

2) Steve Cook, CPESC
Fayetteville Regional Office
Systel Building,
225 Green St., Suite 714
Fayetteville, NC 28301-5094
(910) 486-1541

3) Zahid Kahn
Mooresville Regional Office
610 East Center Ave.
Mooresville, NC 28115
(704) 663-1699

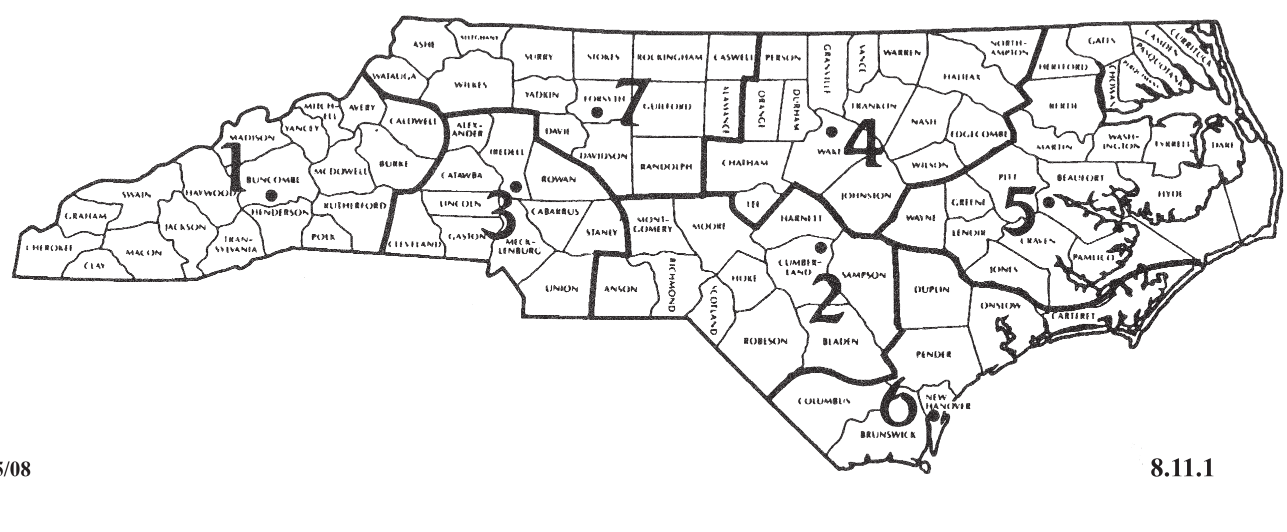
4) John Holley, P.E.
Raleigh Regional Office
3800 Barrett Dr.
Suite 101
Raleigh, NC 27609
(919) 591-4200

5) Pat McClain, P.E.
Washington Regional Office
943 Washington Square Mall
Washington, NC 27889
(252) 946-6481

6) Dan Sams, P.E.
Wlmington Regional Office
127 Cardinal Dr. Ext.
Wilmington, NC 28405-3845
(910) 796-7215

7) Matthew Gant, P.E.
Winston-Salem Regional Office
585 Waughtown St.
Winston-Salem, NC 27107
(336) 771-5000

* Raleigh Central Office
Francis M. Nevils, Jr., P. E.
Land Quality Section
1612 Mail Service Center
Raleigh, NC 27699-1612
(919) 733-4574



LOCAL ORDINANCES

The North Carolina Sediment Control Commission has approved a number of local erosion and sediment control programs for administration by county and municipal governments. For information concerning a specific local ordinance contact the appropriate office listed below.

TOWN OF APEX	Erosion Control Office PO Box 250 Apex, NC 27502	(919) 249-3397
CITY OF ASHEVILLE	City Engineer Office PO Box 7148 Asheville, NC 28802	(828) 259-5617
AVERY COUNTY	Ordinance Administrator PO Box 596 Newland, NC 28657	(828) 733-8204
TOWN OF BEECH MOUNTAIN	Code Enforcement Officer 403 Beech Mtn. Pkwy. Beech Mountain, NC 28604	(828) 387-4236
TOWN OF BOONE	Environmental Planner 1510 Blowing Rock Rd. Boone, NC 28607	(828) 262-4540
BUNCOMBE COUNTY	Erosion Control Officer 46 Valley St. Asheville, NC 28801	(828) 250-4848
CITY OF BURLINGTON	City Engineer 425 S. Lexington Ave. Burlington, NC 27215	(336) 222-5050
CALDWELL COUNTY	County Environmental Engineer 1051 Harper Avenue SW Lenoir, NC 28645	Phone: (828) 757-6860 Fax: (828) 757-6864 billd@caldwellcountync.org
CABARRUS COUNTY	Erosion Control Specialist 65 Church St. Concord, NC 28026-0707	(704) 920-2411
TOWN OF CARY	Erosion Control Supervisor 318 N. Academy St. Cary, NC 27513	(919) 469-4347
CATAWBA COUNTY	Water Resources Engineer PO Box 389 Newton, NC 28658	(828) 465-8161

TOWN OF CHAPEL HILL	Stormwater Management Engineer 209 N. Columbia St. Chapel Hill, NC 27516-3699	(919) 968-2833
CITY OF CHARLOTTE	WQ/Erosion Control Administrator 600 E. Fourth St., 14th Floor Charlotte, NC 28202	(704) 336-3632
CHATHAM COUNTY	Environmental Health Director PO Box 87 Pittsboro, NC 27312	(919) 542-8200
DURHAM CITY/ DURHAM CO.	County Engineer 120 E. Parrish St. Law Building, Suite 100 Durham, NC 27701	(919) 560-0739
GASTON COUNTY	Program Administrator 1303 Cherryville Highway Dallas, NC 28034	(704) 922-2154
GRANDFATHER VILLAGE	Zoning Administrator PO Box 368 Linville, NC 28646	(828) 898-4531
CITY OF GREENSBORO	Sediment and Erosion Control P.O. box 3136 Greensboro, NC 27402-3136	(336) 373-2158
CITY OF GREENVILLE	City Engineer 1500 Beatty St. Greenville, NC 27834	(252) 329-4467
GUILFORD COUNTY	Erosion Control Section Chief P.O. Box 3427 Greensboro, NC 27402	(336) 641-3803
HAYWOOD COUNTY	Erosion Control Specialist 1233 N. Main St., Annex II Waynesville, NC 28786	(828) 452-6706
CITY OF HENDERSON	Director of Engineering P.O. Box 1434 Henderson, NC 27536	(252) 431-6026
HENDERSON COUNTY	Erosion Control Division Chief 240 Second Avenue East Hendersonville, NC 28792	Phone: (828) 694-6523 Fax: (828) 698-6185 nberry@hendersoncountync.org
HIGHLANDS	Planning & Watershed Zoning Adm. P.O. Box 460 Highlands, NC 28741	(828) 526-2118

CITY OF HIGH POINT	Erosion Control Inspector P.O. Box 230 High Point, NC 27261	(336) 883-3199
TOWN OF HOLLY SPRINGS	Director of Engineering PO Box 8 Holly Springs, NC 27540	(919) 557-3926
IREDELL COUNTY	Erosion Control Administrator PO Box 788 Statesville, NC 28687	Phone: (704) 832-2352 Fax: (704) 878-3122 mselquist@co.iredell.nc.us
JACKSON COUNTY	Erosion Control Officer 401 Grindstaff Cove Rd., Suite 110 Sylva, NC 28779	(828) 631-2256
CITY OF JACKSONVILLE	Construction Specialist P.O. Box 128 Jacksonville, NC 28540	(910) 938-5262
TOWN OF KILL DEVIL HILLS	Building Inspector P.O. Box 1719 Kill Devil Hills, NC 27948	(252) 449-5318
TOWN OF KITTY HAWK	Environmental Planner P.O. Box 549 Kitty Hawk, NC 27949	(252) 261-3552
LINCOLN COUNTY	Natural Resources Conservationist 115 West Main Street Lincolnton, NC 28092	Phone: (704) 736-8501 Fax: (704) 736-8504 rmcswain@lincolncounty.org
MACON COUNTY	Erosion Control Officer 1834 Lakeside Dr. Franklin, NC 28734	(828) 349-2560
MECKLENBURG	North Office Manager 18335 Old Statesville Rd., Suite K Cornelius, NC 28031	(704) 336-7783
CITY OF MONROE	Engineer Director PO Box 69 Monroe, NC 28111-0069	(704) 282-4529
TOWN OF NAGS HEAD	Code Compliance Officer PO Box 99 Nags Head, NC 27959	(252) 441-5508
NEW HANOVER	Erosion Contol Engineer 230 Market Place Dr., Suite 160 Wilmington, NC 28403	(910) 798-7139
CITY OF NEWTON	Planning Director PO Box 550 Newton, NC 28658	(828) 465-7400

ORANGE COUNTY	Erosion Control Supervisor Orange Co. Planning Dept. P.O. Box 8181 Hillsborough, NC 27278	(919) 245-2586
PITT COUNTY	Planner II 1717 W. Fifth St. Greenville, NC 27834	(252) 902-3250
CITY OF RALEIGH	Senior Conservation Engineer 222 W. Hargett St. P.O. Box 590 Raleigh, NC 27602	(919) 890-3766
CITY OF ROCKY MOUNT	Assistant City Engineer P.O. Drawer 1180 Rocky Mount, NC 27802-1180	(252) 972-1122
ROWAN COUNTY	Environmental Specialist 402 N. Main St. Salisbury, NC 28144	(704) 638-3078
TOWN OF SOUTHERN PINES	Public Works Director 140 Memorial Park Ct. Southern Pines, NC 28387	(910) 692-1983
SWAIN COUNTY	Director of Inspections PO Box 2321 Bryson City, NC 28713	(828) 488-9134
WAKE COUNTY	Erosion & Sedimentation Control P.O. Box 550 Raleigh, NC 27602	(919) 856-6195
WATAUGA COUNTY	Property Development Coordinator I 842 West King St., #7 Boone, NC 28607	(828) 265-8043
WINSTON-SALEM/FORSYTH CO.	Erosion Control Engineer 100 E. First St., Suite 328 Winston-Salem, NC 27101	(336) 727-2388

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