CHAPTER 4
PIPE SIZING

Basic Procedure

Pipe sizing is conventionally done independently of inlet location. A suggested set of steps follows:

1. Determine the drainage areas for each point of interest in the drainage system.

2. Proceeding from upstream toward the downstream, select a pipe for design. Determine the inlet time for the most remote inlet upstream of the pipe of interest. This is the time of concentration for that inlet. It is popular to assume that inlet time is 5 minutes, which is the minimum time of duration given in the Intensity-Duration-Frequency charts. The assumption may be verified by computing or estimating the actual time of concentration.

3. If there are pipes upstream of the pipe of interest, compute the flow time in each pipe all the way to the upstream end of the pipe of interest.

4. The time of concentration is the sum of the inlet time of the most remote inlet and the flow times along the longest path (in terms of flow time) to the upstream end of the pipe of interest.

5. The runoff coefficient is composited for all drainage areas contributing flow to the pipe of interest. The runoff coefficient for on-site and off-site flow shall be selected based on the anticipated future development.

6. The rainfall intensity is determined for the design storm at a duration equal to the time of concentration found in step 4.

7. The discharge is computed by the Rational Equation using the composite C of step 5, the I of step 6, and the total drainage area contributing flow to the pipe of interest.

8. The pipe slope is selected based on profile constraints.

9. The pipe diameter is determined from Manning Equation for the pipe to flow just full.

10. The full-flow velocity is computed and used to find the flow time in the pipe for use in the next section downstream.

11. Continue at step 2 with the next pipe to be designed. Always work downstream, being sure that all pipes contributing flow to the pipe of interest have been sized and located in the profile.

12. At the bottom of the system check for a high tailwater situation that may constrain the system to a flow less than that designed for. In such a case, apply the energy equation to estimate water levels and surcharge pressures in the system. This operation is referred to as plotting the hydraulic grade line through the system. If no restriction of flow exists, the hydraulic grade line follows the top of the pipe.

Practical Constraints

Note the following:

1. If pipe sections are designed to flow under surcharge, care should be taken to insure that the hydraulic grade line does not rise above ground level, and special attention should be given to prevention of leakage at joints.

2. In the event that further development is anticipated upstream of the system being designed, consider placing a stubbed-out pipe of sufficient depth and capacity to accept flow from the future development.

3. To reduce clogging problems, the minimum size for storm drainage should be 15 inches. There should be no reduction in pipe size in the downstream direction, even if steeper slopes would seem to permit a smaller pipe.

4. Manholes should be provided at pipe junctions, bends, and in straight sections such that the maximum distance between points of access is 400 feet.

5. At all structures, the invert of the mainline should be dropped to offset minor losses. These may be computed or convenient rules of thumb may be used:

   a. If there is an increase in pipe size at the structure, align the tops of the pipes.

   b. Drop the invert of the mainline through the structure one tenth of a foot for each incoming flow stream, whether from a pipe or from the flow through the inlet top.

6. Pipes should be laid at least as steeply as the slope that will provide flow at a self-scouring velocity at or near design discharge. That velocity is usually taken to be three feet per second. Use 0.5% as the minimum slope in Guilford County (See Exhibit 4-1) regardless of the type of material. Usually ten percent (10%) is the maximum slope for RCP.

7. Minimum cover should be three feet to the top of the pipe if heavy equipment or vehicles will cross.

Application of Manning Equation

The Manning equation can be stated as:

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2} \qquad (4\text{-}1)$$

in which:
Q = Discharge (cfs).

n = Manning roughness coefficient (dimensionless), an experientially determined value which is a function of the nature of the channel lining. (See Exhibit 4-1)

A = Cross-sectional area of flow (square feet), the area through which flow takes place.

R = Hydraulic radius (ft), found by dividing cross-sectional area, A (sq ft), by wetted perimeter, P (ft). Wetted perimeter is the distance along the perimeter of the cross section against which water is flowing. It does not include the free water surface.

s = Longitudinal slope of the water surface (ft fall/ft run). If flow is uniform, it is also the slope of the invert of the channel.

Long pipe segments operating under gravity flow, are frequently sized to flow just full with the Manning equation. Usual source data are the discharge, slope and roughness coefficient. The pipe diameter for full flow is computed, and average cross-sectional velocity is often of interest. Another recurring problem is to find the capacity (discharge) of a pipe at a given slope.

For circular pipes flowing just full, the Manning equation can be reformulated as:

$$D = 16\left[\frac{Q\,n}{\sqrt{s}}\right]^{3/8} \qquad (4\text{-}2)$$

where:

D = Theoretical pipe diameter (in) for just-full flow.

Q = Discharge (cfs).

n = Manning roughness coefficient (dimensionless).

s = Longitudinal slope (ft/ft).

The pipe diameter obtained should be rounded up to the nearest standard pipe size. Standard pipe sizes (diameter in inches) used in drainage systems are 15, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 72. Sizes larger than 72 inches are available, but sometimes require special order.

For circular pipes flowing just full, the average cross-sectional velocity of flow can be found by another reformulation of the Manning equation:

$$V = \frac{\sqrt{s}\,D^{2/3}}{8.9n} \qquad (4\text{-}3)$$

where:

V = Full-flow velocity (ft/sec).

D = Pipe diameter (in).

s = Longitudinal slope (ft/ft).

n = Manning roughness coefficient (dimensionless).

A Tabular Approach

The following is a sample table format which can be used to size the drainage system.

Minimum slopes for pipe selection.

Minimum slope required to maintain stated minimum velocity at full flow.

Material	Concrete	Concrete	Corr Mtl	Corr Mtl
Application	Storm	Sanitary	Storm	Sanitary
Manning n	0.013	0.013	0.024	0.024
Min V (ft/sec)	3	2	3	2
Pipe Diameter (in)	**Minimum Slope**			
15	0.00325	0.00144	0.01107	0.00492
18	0.00255	0.00113	0.00868	0.00386
21 *	0.00207	0.00092	0.00707	0.00314
24	0.00174	0.00077	0.00592	0.00263
27 *	0.00148	0.00066	0.00506	0.00225
30	0.00129	0.00057	0.00439	0.00195
33 *	0.00114	0.00050	0.00387	0.00172
36	0.00101	0.00045	0.00345	0.00153
42	0.00082	0.00037	0.00281	0.00125
48	0.00069	0.00031	0.00235	0.00104
54	0.00059	0.00026	0.00201	0.00089
60	0.00051	0.00023	0.00174	0.00077
66	0.00045	0.00020	0.00154	0.00068
72	0.00040	0.00018	0.00137	0.00061

* Non-standard in some markets.

Abbreviated Table of Values of Manning Roughness Coefficients.

Description of Lining	n
Reinforced concrete pipe	0.013
Corrugated metal pipe	0.024
Concrete, trowelled finish	0.013
Concrete, float finish	0.015
Street gutter or paved channel	0.015
Earth, straight and uniform	0.022
Grass-lined swales	0.030
Unmaintained brushy channel	0.080
Stone-lined channel (4-inch)	0.028
Stone-lined channel (6-in)	0.030
Stone-lined channel (9-in)	0.032
Stone-lined channel (12-in)	0.034
Stone-lined channel (15-in)	0.035
Stone-lined channel (18-in)	0.036

EXHIBIT 4-1