CHAPTER 5. STORM SEWERS

5.1 Design Criteria

5.1.1 Design Frequency

Storm sewer sizing shall be based on the just full capacity for a 2-year frequency rainfall. After initial sizing, a hydraulic grade line (HGL) check shall be made for a 5-year frequency rainfall. If the check shows water flowing out of the system, then the system needs to be revised to contain the rainfall.

Final design shall indicate water surface elevations for the design storm. In addition, 100-year water surface elevations for all storm sewers shall be shown on the storm sewer profile.

5.1.2 Depth

The minimum cover for storm sewers in or within the right-of-way of streets with curb and gutter shall be the deeper of (a) 1 foot (clearance) from the bottom of the curb or underdrain to the top of the conduit; or (b) 2 feet below the bottom of the roadway base. A minimum cover of 2 feet of unfinished ground surface, or as recommended by manufacturer or as required for structural adequacy, is recommended at all other locations.

5.1.3 Velocity

A minimum velocity of 2.5 feet per second (fps) is recommended to insure self cleaning. The maximum allowable velocity shall be 12 fps unless special materials are included for protection against scouring.

5.1.4 Time of Concentration

The minimum inlet time of concentration for storm sewers shall be 10 minutes.

5.1.5 Design Discharge Method

The Rational Method or the Soil Conservation Service method may be used for drainage areas less than 200 acres to determine peak discharge. For areas between 200 and 640 acres, the Graphical Peak Discharge method of calculations shall be used as presented in Soil Conservation Service, Technical Release No. 55. For areas greater than 640 acres, the hydrograph method of calculation shall be used as presented in Soil Conservation Service, Technical Release No. 20.

5.1.6 Hydraulic Design

The hydraulic design of storm sewers shall be based on the Manning Equation: $V = (1.49\ r^{2/3}\ S^{1/2})/(n)$.

5.1.7 Roughness Coefficients

Table 5-1 lists the Manning roughness coefficients (n) to be used for different conduit materials.

Table 5-1

Manning Roughness Coefficients

Closed Conduit Material	Manning "n"
Concrete, vitrified clay, bituminous lined corrugated metal, or smooth polyethylene	.013
Concrete (monolithic)	
Smooth forms	.013
Rough forms	.017
Corrugated metal pipe or corrugated polyethylene pipe (1/2 inch x 2 3/4 inch corrugations)	
Plain	.024
Paved invert	.022

5.1.8 Manhole Spacing

Manholes should be located at junctions of conduits, at changes in conduit direction, at changes in slope, and at changes in pipe size. Maximum manhole spacing should be 300 feet for storm sewers with diameters up to and including 36 inches and 500 feet for storm sewers larger than 36 inches.

5.1.9 Conduit Size

The minimum conduit size shall be 12 inches in diameter. In no case will storm sewers being used as private property detention basins which use conduit size less than 12 inches in diameter be allowed without permission from the City Engineer.

5.1.10 Hydraulics at Structures

The inverts of curb inlets, manholes, and other structures shall be rounded and sloped to minimize turbulence and collection of debris.

5.1.11 Location of Sewers

Location of sewers in street right-of-way shall be as approved by the City Engineer.

5.2 General Design Procedures

The following general design procedures provide a uniform approach to storm sewer design. The procedure as outlined is for a storm sewer system serving an urban area with curbed streets. With minor modifications, it can apply as well to streets with side ditch swales.

The general procedures for street and inlet design, and a generalized approach to inlet spacing are discussed in the preceding chapter of the manual (Chapter 4). Street and inlet design is a basic part of the storm sewer drainage system. Maximum use should be made of the street gutter capacity to transport storm water runoff to inlets, and thereby reduce the size of the storm sewers.

The following basic data is required:

1. Map of drainage area for which the storm sewer system is to serve (Subdivision plan supplemented by United States Geological Survey [USGS] maps or City of Newark topographic maps for off-site area, if required).

2. Typical street cross sections and profiles.

3. Pavement Drainage Computations (use form T5-1 (page 5-7) provided).

4. Soil maps and data.

5. Outfall Elevation (from field measurement).

6. Rainfall intensity-duration-frequency curves or tabulation (Exhibit I-1 page 1-2).

Step 1. Determine proposed curb inlet locations based on gutter capacity (Article 4.3).

Calculate the initial storm sewer pipe size starting at the most upstream inlet location and working downstream as follows.

Step 2. Calculate the initial storm, 2-year frequency, total runoff (Q) to the storm sewer inlet.

Step 3. Estimate the slope of the storm sewer to the next manhole and using Exhibit V-1 (page 5-6) with flow, pipe roughness, and pipe slope determine the standard size storm sewer pipe diameter required. For this size, read flowing full capacity and the corresponding pipe velocity.

Step 4. Check that flowing full discharge is greater than total runoff discharge and that the pipe velocity meets the design criteria velocity.

Step 5. Calculate the flow travel time between the two manholes. Travel time equals pipe length/pipe velocity (L/V). For each successive downstream manhole, the time of concentration used should be the greater of the preceding manhole's time of concentration plus the flow travel time between the two manholes or the time of concentration of the intermediate area between the two manholes.

Step 6. Calculate the manhole bottom elevation which equals manhole elevation minus pipe length times pipe slope and check depth meets the design criteria.

Step 7. Go back to Step 2 and repeat Steps 2 through 6 for each length of storm sewer throughout the system until initial sizing of all the storm sewer pipes has been completed.

Calculate the hydraulic gradient for the 5-year frequency rainfall starting at the storm sewer system outlet and working upstream as follows:

Step 8. The control elevation (hydraulic gradient elevation) at the system outlet can be taken as the conduit crown for a freely discharging sewer or as the pool elevation for a submerged outlet.

Step 9. Determine the 5-year rainfall intensity at the outlet. This intensity will be used throughout the storm sewer system so long as the system is under pressure. If the system is not under pressure then the intensity would change at that manhole and would be used so long as the system is under pressure.

Step 10. Calculate the 5-year frequency total runoff at the storm sewer outlet.

Step 11. Using Exhibit V-1 (page 5-6) with flow, pipe size, and pipe roughness determine the friction slope to the next inlet.

Step 12. Calculate head loss to next inlet which equals friction slope times pipe length.

Step 13. Determine the hydraulic gradient elevation at the next inlet which equals hydraulic gradient elevation of inlet plus head loss. This hydraulic gradient elevation must be lower than the inlet gutter elevation. If it is not, the pipe must be resized. Go to Step 2 and begin calculations again. For the next pipe upstream, the HGL is assumed to be the greater of the crown of the conduit at the downstream end of that conduit or the calculated hydraulic gradient elevation. Ordinarily, the hydraulic gradient will be above the top of the pipe causing the system to operate under pressure. If, however, any run in the system does not flow full (pipe slope steeper than friction slope), the hydraulic gradient slope will follow the friction slope until it reaches normal depth of flow in the steep run. From that point, it will coincide with normal depth of flow until it reaches a run flatter than the friction slope for the run.

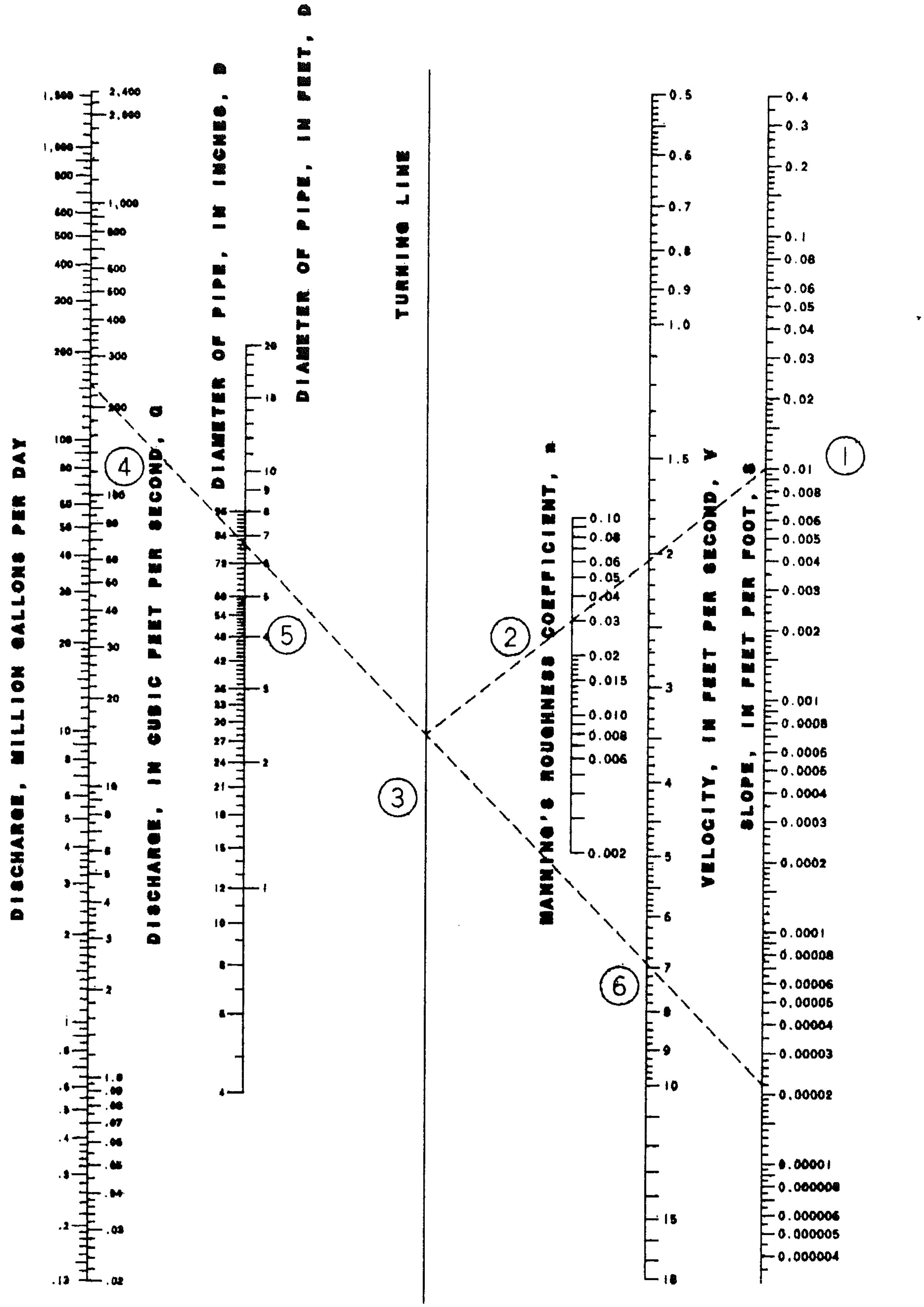
Step 14. Go back to Step 9 and repeat Steps 8 through 11 for each length of storm sewer throughout the system.

Step 15. The hydraulic effects of the 100-year storm on the drainage system are determined for compliance with the physical design criteria presented herein.

Step 16. The final design is drawn on prepared plan and profile sheets.

5.3 Major Storm Considerations

The 5- and 100-year storm runoff is routed through the drainage system to determine if the combined capacity of the street and storm sewer system is sufficient to maintain surface flows within permissible limits. The maximum allowable flow depth of a storm is stated in Article 4.1.2. The capacity of the storm sewer conduit at any given point for the 5- and 100-year storm is assumed to be one-half of the design storm capacity for determining the required capacity of surface channels as stated in Article 4.1.2. If the 5- and 100-year storm runoff exceeds the combined capacity of the street and storm sewer drainage system, revision in the design is required. Where a drainageway is located outside a street right-of-way, easements shall be provided.



NOMOGRAPH FOR SOLUTION OF THE MANNING FORMULA

$$Q = AV = A \frac{1.49}{n} r^{2/3} s^{1/2}$$

STORM SEWER COMPUTATIONS

PROJECT ______________________ DESIGNER ______________________ DATE ____________

DISCHARGE											STORM SEWER SIZE											HYDRAULIC GRADIENT						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
INLET LOCATION (DESIGN POINT)	RUNOFF COEFFICIENT C	DRAINAGE AREA A	CA	ΣCA	INLET OR CONDUIT TRAVEL TIME	TIME OF CONCENTRATION t_c	RAINFALL INTENSITY ___ YEAR FREQUENCY I	RUNOFF IΣCA	OTHER CONTROLLED RUNOFF	TOTAL RUNOFF, Q	PIPE LINE DESIGNATION	PIPE DIAMETER	LENGTH, L	SLOPE	GUTTER AT INLET OR COVER ELEV.	INLET OR MANHOLE BOTTOM	PIPE COVER	MEETS COVER DESIGN CRITERIA	JUST FULL CAPACITY	VELOCITY	MEETS VELOCITY DESIGN CRITERIA	RAINFALL INTENSITY ___ YEAR FREQUENCY I	TOTAL RUNOFF Q	SLOPE	HEAD LOSS	ELEVATION OF HYDRAULIC GRADIENT	CROWN PIPE	PRESSURE FLOW
		ACRES			MIN.	MIN.	IN/HR	CFS	CFS	CFS		IN	FT	FT/FT			FT		CFS	FPS		IN/HR	CFS	FT/FT	FT			