CHAPTER 2
THE RATIONAL METHOD

Background

There are many methods abroad for estimating flood peak discharges where no measurements of flow are available. In stormwater collection systems, individual drainage areas are quite small, and of all methods available the Rational Method remains the method of choice.

The following are the steps to be taken in determining the peak discharge for a particular point of interest:

1. Delineate the watershed contributory to the point of interest, and determine the drainage area in acres. (The terms "watershed" and "drainage area" are synonymous.)
2. Determine the time of concentration for the watershed.
3. Determine the rainfall intensity for the designated return period at the time of concentration.
4. Determine the composite runoff coefficient.
5. Apply the Rational Equation to obtain the peak.

Elements of the Model

The Rational Equation is given as:

$$Q = CIA \qquad (2\text{-}1)$$

in which:

- Q = the estimated design discharge (cfs).
- C = the composite runoff coefficient (dimensionless) for the watershed.
- I = rainfall intensity (in/hr) for the designated return period and time of concentration.
- A = watershed area (ac.)

Observe the units carefully. The left and right sides of the equation are essentially equal because one acre-inch per hour is very nearly one cubic foot per second.

The limit of application of the Rational Method is much in debate. Various writers will recommend as an upper limit of applicability anywhere from zero to two square miles of watershed area. Dr. Rooney Malcolm has had acceptable results up to two square miles when compared to statistical analysis of gaged floods.

Following the steps given above:

1. Delineate the watershed: Normally this is done on a topographic map. Determine the area of the watershed by using a digitizer, a planimeter, an overlaid grid or other suitable device. Remember to put the watershed in acres. Question the applicability of the Rational Method if the watershed exceeds 1300 acres.

2. Determine the Time of Concentration: The time of concentration is interpreted as the longest time of flow from points on the watershed ridge to the outlet of the watershed.

There are several recognized ways to estimate time of concentration. One way is to use the Kirpich Equation, which is widely recognized (Bureau of Reclamation, 1974, p. 71):

$$t_c = \left[\frac{L^3 / H}{128} \right]^{0.385} \quad (2\text{-}2)$$

in which:
t_c = Time of concentration (min).

L = Hydraulic length of the watershed (ft). Hydraulic length is the length of the longest flow path from the most remote point on the watershed ridge to the outlet.

H = The height (ft) of the most remote point on the watershed ridge above the watershed outlet. It is the elevation difference, or fall, along the hydraulic length.

Another efficient method is by the use of the nomograph shown on Exhibit 2-1, which is based on the Kirpich formula. Correction factors are given for the type of surface for the overland flow.

For times of concentration less than 5 minutes, use 5 minutes.

3. Determine Rainfall Intensity: Rainfall intensity is determined from the statistical distribution of rainfall at the design location. The National Weather Service publishes such data for the nation. A typical form of presentation is the Intensity-Duration-Frequency Chart, an example of which is given for Greensboro, NC, in Exhibits 2-2, 2-3, and 2-4.

To use such a chart for finding rainfall intensity, duration is set equal to time of concentration, and intensity is read at the designated return period.

Alternatively, one may use an equation that represents the same relationship. For Guilford County, a satisfactory set of equations is of the form:

$$I = g/(h + T) \quad (2\text{-}3)$$

in which

I = Rainfall intensity (in/hr)
T = Time of duration (min)

and the values of g and h for various return periods are as follows (for Guilford County only):

Return Period (yrs.)	g	h
2	124	18
5	160	21
10	186	22
25	221	23
50	249	24
100	277	24

This equation applies only when the time of duration is in the range of 5 to 120 minutes. For times of concentration less than 5 minutes, use 5 minutes.

4. Determine the Composite Runoff Coefficient: The runoff coefficient must be estimated based on experience. The table in Exhibit 2-5 is typical and reasonable. It compares favorably with tables in several references (Chow, 1964, for example).

   Usually, the drainage area of interest will consist of several different categories of composition, and these must be combined to obtain a composite runoff coefficient. The accepted procedure is simply to weight the individual coefficients according to the area taken by each category:

$$C = \frac{\Sigma (C_i A_i)}{\Sigma A_i} \qquad (2\text{-}4)$$

in which:

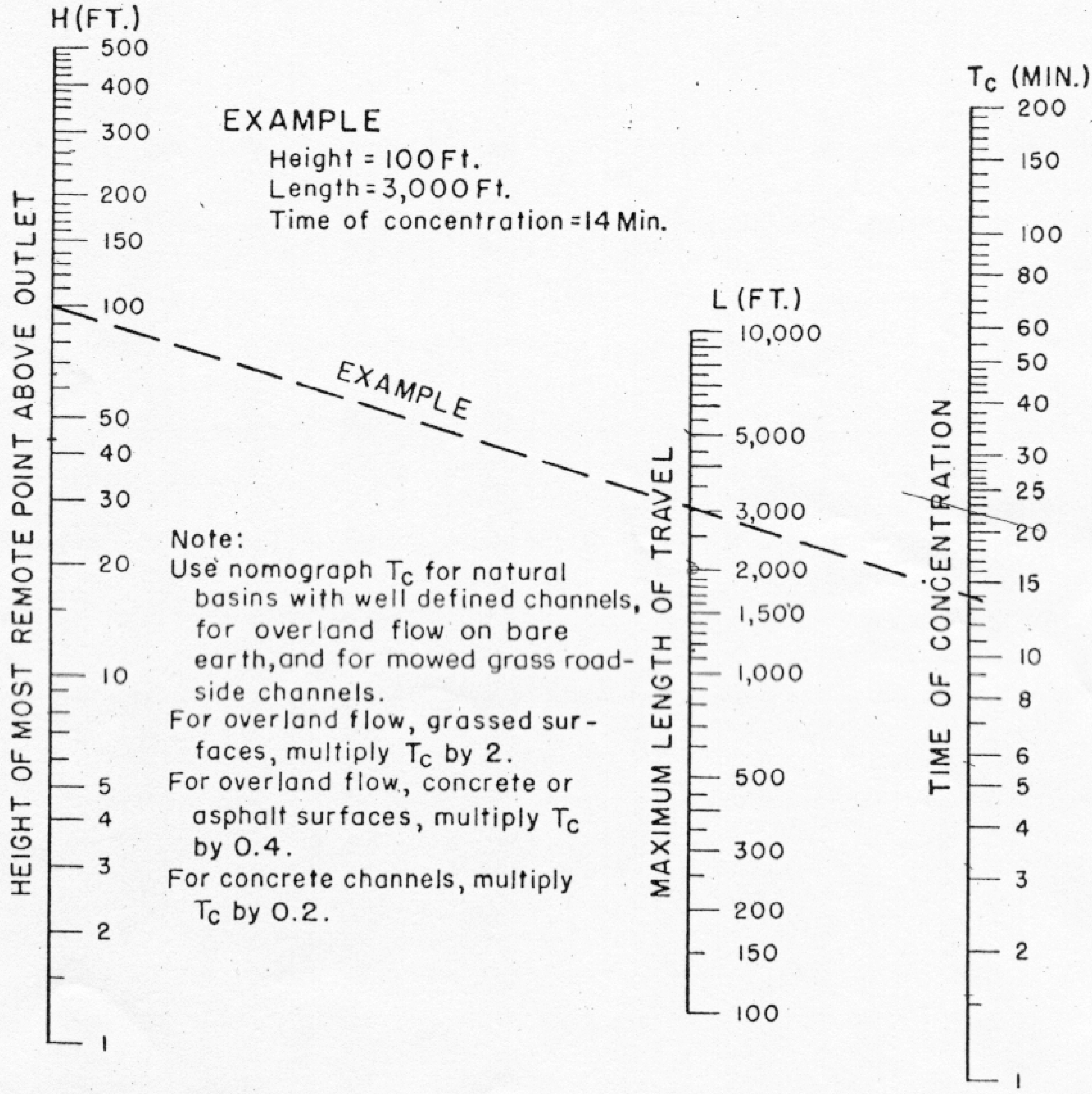
C = the composite runoff coefficient (dimensionless).

A_i = the area taken by an individual category of composition.

C_i = the runoff coefficient for the individual area.

The units of the areas are immaterial as long as they are the same in numerator and denominator.

5. Apply the Rational Equation: Substitute the values for C, I and A into Equation 2-1, taking care that the values are expressed in the correct units.



Based on study by P. Z. Kirpich,
Civil Engineering, Vol. 10, No. 6, June 1940, p. 362

EXHIBIT 2-1

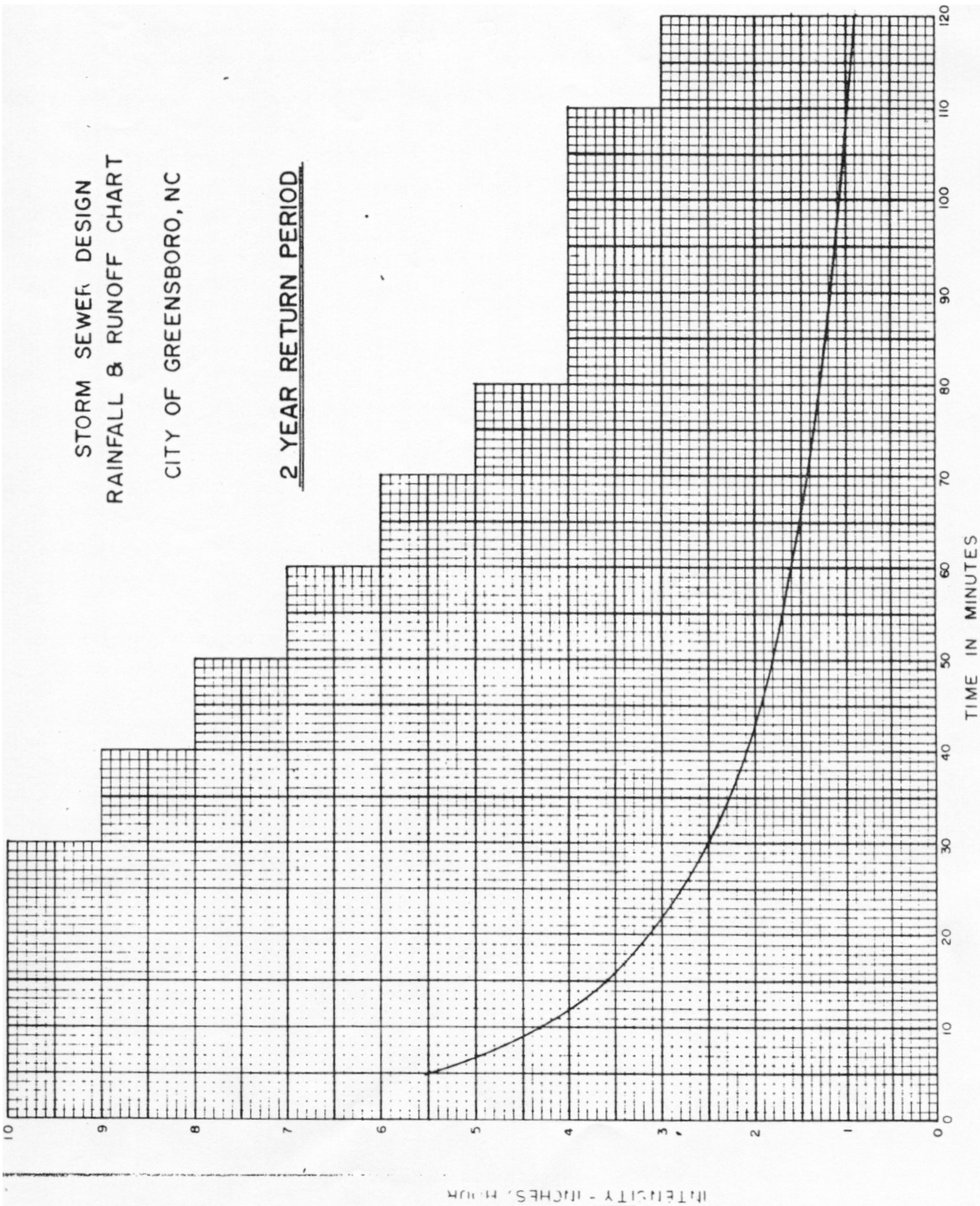

STORM SEWER DESIGN
RAINFALL & RUNOFF CHART
CITY OF GREENSBORO, NC
2 YEAR RETURN PERIOD
TIME IN MINUTES
0 10 20 30 40 50 60 70 80 90 100 110 120
0 1 2 3 4 5 6 7 8 9 10

EXHIBIT 2-2

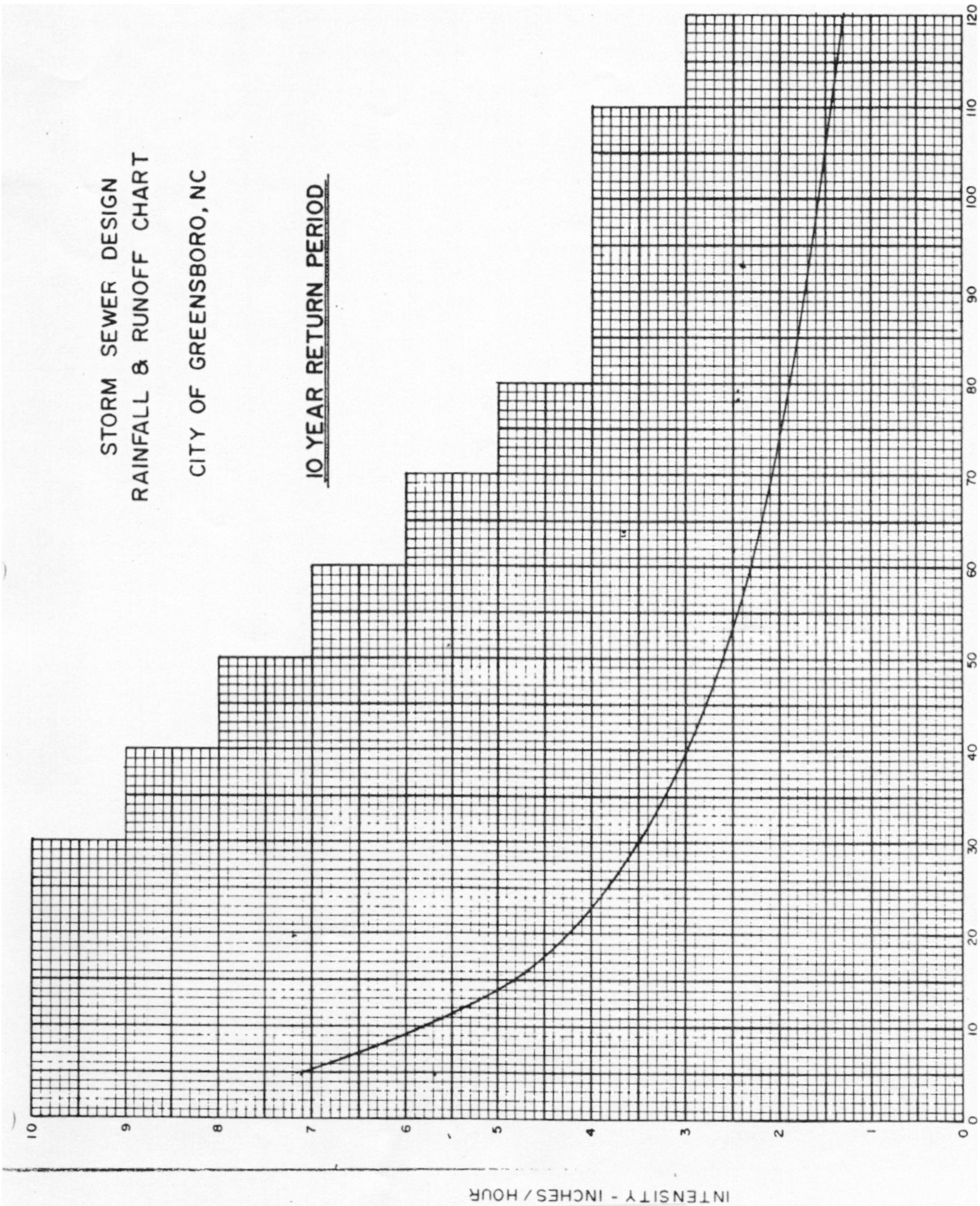

STORM SEWER DESIGN
RAINFALL & RUNOFF CHART
CITY OF GREENSBORO, NC
10 YEAR RETURN PERIOD
INTENSITY - INCHES / HOUR
0 1 2 3 4 5 6 7 8 9 10
0 10 20 30 40 50 60 70 80 90 100 110 120

EXHIBIT 2-3

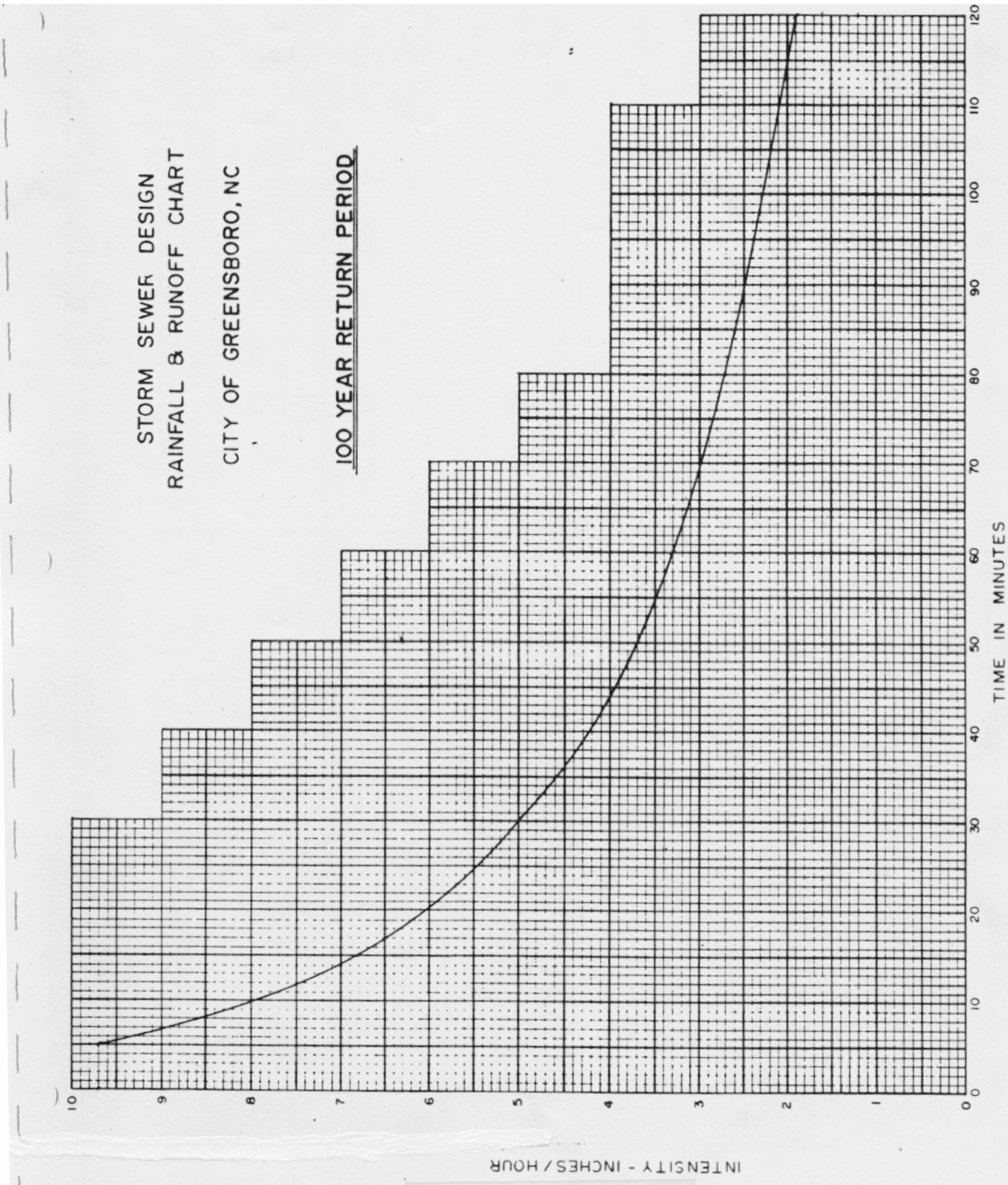

STORM SEWER DESIGN
RAINFALL & RUNOFF CHART
CITY OF GREENSBORO, NC
100 YEAR RETURN PERIOD
TIME IN MINUTES
INTENSITY - INCHES / HOUR
0
10
20
30
40
50
60
70
80
90
100
110
120
1
2
3
4
5
6
7
8
9
10

EXHIBIT 2-4

Table of Rational Runoff Coefficients

Description	C	Source
Roof, inclined	1.00	Malcom
Street, driveway, sidewalk	0.95	Chow, 1964
Parking lot	0.90	Malcom
Roof, flat	0.90	Malcom
Commercial, generalized	0.85	Malcom
Apartments, schools, churches	0.60	WSSC, c.1968
Residences 10 dwellings/acre	0.60	Malcom
Residences: 6 dwellings/acre	0.55	Malcom
Residences, 4 dwellings/acre	0.50	Malcom
Residences, 2 dwellings/acre	0.40	Malcom
Unimproved cleared area	0.35	Malcom
Lawn, dense soil, steep >7%	0.35	Chow, 1964
Playground	0.35	Chow, 1964
Park, cemetery	0.25	Chow, 1964
Lawn, dense soil, avg. 2-7%	0.22	Chow, 1964
Wooded, sparse ground litter	0.20	Malcom
Lawn, dense soil, flat 2%	0.17	Chow, 1964
Lawn, sandy, avg. 2-7%	0.15	Chow, 1964
Lawn, sandy, flat <2%	0.10	Chow, 1964
Wooded, deep ground litter	0.10	Malcom

EXHIBIT 2-5