where I = rainfall intensity, in/h

K, b, n, and n_1 = respectively, coefficient, factor, and exponents depending on conditions that affect rainfall intensity

F = frequency of occurrence of rainfall, years

t = duration of storm, min
= time of concentration

Perhaps the most useful of these formulas is the **Steel formula**:

$$I = \frac{K}{t+b} \tag{21.129}$$

Table 21.15 Common Runoff Coefficients

Type of Drainage Area	Runoff Coefficient C
Business:	
Downtown areas	0.70 – 0.95
Neighborhood areas	0.50 – 0.70
Residential:	
Single-family areas	0.30 – 0.50
Multiunits, detached	0.40 – 0.60
Multiunits, attached	0.60 – 0.75
Suburban	0.25 – 0.40
Apartment dwelling areas	0.50 – 0.70
Industrial:	
Light areas	0.50 – 0.80
Heavy areas	0.60 – 0.90
Parks, cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.35
Railroad-yard areas	0.20 – 0.40
Unimproved areas	0.10 – 0.30
Streets:	
Asphaltic	0.70 – 0.95
Concrete	0.80 – 0.95
Brick	0.70 – 0.85
Drives and walks	0.75 – 0.85
Roofs	0.75 – 0.95
Lawns:	
Sandy soil, flat, 2%	0.05 – 0.10
Sandy soil, avg, 2–7%	0.10 – 0.15
Sandy soil, steep, 7%	0.15 – 0.20
Heavy soil, flat, 2%	0.13 – 0.17
Heavy soil, avg, 2–7%	0.18 – 0.22
Heavy soil, steep, 7%	0.25 – 0.35

USED FOR POST CONSTRUCTION PLANT AREA

USED FOR UPSTREAM OF PLANT AREA

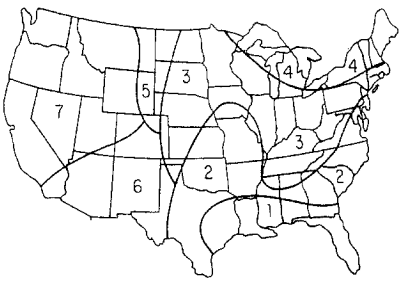

Fig. 21.71 Regions of the United States for use with the Steel formula.

where K and b are dependent on the storm frequency and region of the United States (Fig. 21.71 and Table 21.16).

Equation (21.129) gives the average maximum precipitation rates for durations up to 2 h.

The time of concentration T_c at any point in a drainage system is the sum of the overland flow time; the flow time in streets, gutters, or ditches; and the flow time in conduits. Overland flow time may be determined from any number of formulas developed for the purpose. (See D. R. Maidment, "Handbook of Hydrology," McGraw-Hill, Inc., New York.) The flow time in gutters, streets, ditches, and conduits can be determined from a calculation of the average velocity using the Manning equation [Eq. (21.89)] . The time of concentration is usually expressed in minutes.

After determining the time of concentration, calculate the corresponding rainfall intensity from either Eq. (21.128) or Eq. (21.129), or any equivalent method. Then select the runoff coefficient from Table 21.15 and determine the peak discharge from Eq. (21.127).

Since the rational formula assumes a constant uniform rainfall for the time of concentration over the entire area, the area A must be selected so that this assumption applies with reasonable accuracy. Adhering to this assumption may necessitate subdividing the drainage area.

21.41.2 Method for Determining Runoff for Major Hydraulic Structures

The unit-hydrograph method, pioneered in 1932 by LeRoy K. Sherman, is a convenient, widely accept-