Rational Formula Calculations
Contra Costa County Flood Control District
Hydrology Class Presentation

Formula: $Q = C_f i A$

Where Q = Peak Flow-rate in Cubic-Feet/Second (cfs)
             C = Runoff Coefficient
             f = Adjusting factor for 25, 50 and 100-year storms[1]
             i = Rainfall intensity in inches/hour
             A = Watershed area in acres

1. Adjusting Factors (f) for 25, 50 and 100-year storms (Modified Rational Formula):

   Q_{10} = 1.00
   Q_{25} = 1.10
   Q_{50} = 1.20
   Q_{100} = 1.25

   Note: The product Cf obviously must be less than 1.0

Assumptions:

1. The rainfall intensity is uniformly distributed over the entire watershed.
2. The runoff rate resulting from any rainfall intensity is a maximum when this rainfall intensity lasts as long or longer than t_c.
3. The maximum runoff resulting from a rainfall intensity is a simple fraction of such rainfall intensity.
4. The frequency of peak runoff is the same as that of the rainfall intensity for a given t_c.
5. The runoff coefficient is the same for various storm frequencies and durations.

It should be clear that the above assumptions might hold for a small paved area!

Time of Concentration:

Kirpich Equation:

$$t_c = 0.0078 \, L^{1.155}/H^{0.385}$$

Where: t_c = Time of concentration in minutes
L = Length of main watercourse in feet
H = Fall between ridge and outlet in feet

Composite Approach:
Kerby Equation: Overland flow (See Nomograph)

$$tc^{2.14} = 2Ln/3S^{1/2}$$

Where: tc = Time of concentration in minutes
L = Length in feet
n = Surface retardant factor
S = Slope in feet/feet

Roof to Gutter Time: See attached Table
Gutter Flow: Drawing B-120

Pipe Velocity:
Manning's Formula or
Estimation

To Calculate the intensity in inches/hour, 1. use the time of concentration as the duration, 2. determine the depth of rain for the duration based on the mean seasonal precipitation from the frequency-depth-duration curve and isohyet map and 3. Convert to intensity by multiplying the depth times 60-minutes/hour and dividing by the time of concentration in minutes.

Runoff Coefficients:

Use Attached Handout (Proposed CCCFCD Standard).

CCCFCD STANDARD - RUNOFF COEFFICIENTS

Rational Formula

Land Use	Runoff Coefficient	Average Impervious Area (%)	Time of Concentration- Roof to Gutter (min)
Residential:			
R - 6	.50 - .70	76	3 - 5
R - 10	.45 - .60	53	5 - 7
R - 20	.40 - .50	35	6 - 8
R - 40	.35 - .45	25	8 - 10
Apartment	.60 - .80		3 - 10
Commercial	.70 - .95		3 - 8
Industrial	.60 - .90		3 - 10
Open	.20 - .40		
Street:			
Asphalt	.75 - .95		
Concrete	.80 - .95		
Drives and Walks	.80 - .95		
Roofs	.75 - .95		

Legend

$$R - 6 = 6,000 \text{ ft}^2 \text{ Lot}$$
$$R - 10 = 10,000 \text{ ft}^2 \text{ Lot}$$
$$R - 20 = 20,000 \text{ ft}^2 \text{ Lot}$$
$$R - 40 = 40,000 \text{ ft}^2 \text{ Lot}$$

Note: For Contra Costa County Land Uses use the highest runoff coefficient in the range. This more closely approximates the peak flows calculated by the Unit Hydrograph method developed for Contra Costa County and calibrated with local rainfall and runoff data.

INTENSITY (INCHES/HOUR)

The mean seasonal rainfall Isohyetal map (Drawing B-166) and rainfall depth-duration-frequency curves (Drawings B-158-162) for the 5, 10, 25, 50 and 100 year recurrence intervals were developed for this county in 1974. The map and curves can be used together to estimate rainfall amount (depth) or intensity for any location in Contra Costa County.

To obtain the intensity (i) for the Rational Formula, use the calculated time of concentration (tc) as the duration, fine the mean seasonal precipitation of your location, obtain the depth of rainfall for that duration, and convert the depth to intensity in inches per hour.

For example: Find the intensity for a 25-year, 30-minute time of concentration in downtown Walnut Creek. From the Isohyetal map, the mean seasonal precipitation is 20-inches; from Drawing B-160, the rainfall depth for a 30-minute storm event is 0.7 inches.

Then the rainfall intensity is:

$$\frac{0.7 \text{inches} \times 60 \text{min/hour}}{30 \text{min}} = 1.4 \text{ inches/hour}$$

Then back to the Modified Rational Formula, Q=CfiA.

Figure 1

HYDRO Program N-Values
(For Areas < 100 Acres)

N-Value

Watershed Area (Acres)

Comm-Lt Ind

R-6

R-10

R-20

R-40