

CHAPTER 3. HYDROLOGIC ANALYSIS

Presented in this chapter is information useful for hydrologic analyses, and two analysis methods – the rational method and the HEC-1/HEC-HMS computer programs. The information in this chapter is intended to facilitate and simplify hydrologic analyses using these methods. There are other valid hydrologic analysis methods available that can also be used, if appropriate.

3.1 STORM FREQUENCY AND DURATION CRITERIA

Storm water facilities are sized and designed to handle peak runoff from a design storm. Design storms are described by a storm frequency and duration. Design storm frequency is the long-term average number of years in which a given storm event is equaled or exceeded, and is a measure of the intensity of the storm. Typical city or county design storm frequencies range from 2 years to 100 years. Design storm duration is the length of time that rainfall occurs in a given storm event. Typical design storm durations range from several minutes to 10 days or longer. The combination of design storm frequency and duration determines the design storm's total precipitation.

Design storm frequency and duration criteria for a given location are generally established by the agencies that have responsibility for flood control at that location. City governments normally establish these criteria for areas within the city boundaries. For areas outside of cities, county governments often establish the duration/frequency criteria. Summarized below are the design storm frequency/duration and other relevant criteria established by Solano County and the cities within the County.

The criteria listed below are only summaries, current as of March 1999. For design of drainage facilities, the relevant standards should be consulted to obtain the complete current description of criteria. No design storm frequency/duration criteria are established by this manual.

Dixon

The City of Dixon is revising its design storm criteria. The criteria are defined in the *Dixon Storm Drain Report*, dated March 1999, and include:

- For the design of all pipeline conveyance facilities, the hydraulic grade line (HGL) shall be maintained a minimum of one-half foot below the flow line of all drain inlets during a 10-year, 24-hour storm event.
- Storm drainage systems for new development shall be designed to convey the 100-year storm. All flow greater than the capacity of the pipe system shall be conveyed in the street section while maintaining a water surface at least 1 foot below the finished floor elevations of nearby buildings.
- A 100-year, 4-day storm shall be used for sizing major detention storage areas.

Vacaville

The City of Vacaville drainage design standards are specified in the *City of Vacaville Standard Specifications*, adopted September 11, 1990 and include:

- For determining runoff quantities, the rational method shall be used. The time of concentration shall be determined using the Solano County Drainage Design Manual and the rainfall intensities from Figure 4-01 of the *City of Vacaville Standard Specifications* (a duration intensity chart).
- A 10-year storm shall be used for design of piped systems with the HGL to remain at least 1.5 feet below top of curb.
- For discharges to creeks, a 100-year water level in the creek shall be assumed for calculating the HGL in the drainage system.
- For detention basins, the 10-year and 100-year runoff from the site shall not be increased over the predevelopment flow rates. In the Alamo Creek watershed upstream of Peabody Road, the 10- and 100-year peak flows shall be reduced to 90 percent of the predevelopment peak flows.
- If accepted by the City Engineer/Director of Public Works, permanent open ditches shall be sized for a 100-year storm with at least 6 inches of freeboard (2 feet of freeboard for temporary ditches).

Fairfield

The Fairfield drainage design standards are established in the document *City of Fairfield, Solano County, Standard Specifications & Details* and listed below:

- For design areas of less than 640 acres, a 15-year frequency shall be used and the analysis method shall be the rational method.
- For areas between 640 and 3,200 acres, a return frequency of 25-years shall be used and either the rational method or unit hydrograph method may be used. For use of the unit hydrograph method, the reader is referred to the *Solano County Hydrology and Drainage Design Procedure Manual*.
- For areas greater than 3,200, acres the 100-year, 24-hour design storm and the unit hydrograph method shall be used.
- Pipes shall be sized to convey the appropriate storm without surcharging. If surcharging is permitted by the City Engineer, the HGL must remain 1.5 feet below the top of curb.
- Floodwaters shall be contained within public rights of way and release points shall prevent floodwaters from exceeding 0.5 feet above the top of curb.
- For detention basins, a 100-year, 24-hour storm and the unit hydrograph method shall be used. The peak discharge from the basin may not exceed 90 percent of the predevelopment peak or the capacity of the downstream system.

- If permitted, open channels shall be designed to carry the 100-year flood with 1.0 foot of freeboard.
- Bench drains and diversions ditches shall be designed to convey the 100-year storm runoff.

Suisun City

The Suisun City drainage design standards are contained in the *City of Suisun City Design Standards, Standard Specifications, and Details*, dated 1996. These criteria are area- and performance-based and include:

- For design areas of less than 640 acres, a 15-year frequency shall be used and the analysis method shall be the rational method.
- For areas between 640 and 3,200 acres a return frequency of 25-years shall be used and either the rational or unit hydrograph method may be used. For use of the unit hydrograph method, the reader is referred to the *Solano County Hydrology and Drainage Design Procedure Manual*.
- For areas greater than 3,200 acres, a return frequency storm of 100-years and the unit hydrograph method shall be used.
- Pipes shall be sized to convey the appropriate storm without surcharging.
- Floodwaters shall be contained within public rights of way and release points shall prevent floodwaters from exceeding 0.5 feet above the top of curb.
- For detention basins a 100-year, 24-hour design storm and the unit hydrograph method shall be used. The peak discharge from a detention basin shall not exceed 95 percent of the predevelopment peak or the capacity of the downstream system.
- If permitted, open channels shall be designed to carry the 100-year flood with 1.0 foot of freeboard.

Rio Vista

Rio Vista's drainage design criteria are performance-based, presented in *Design Standards and Standard Plans*, dated 1995, and include:

- Improvements to be designed for the 10-year storm shall generally include local drainage facilities for residential, commercial, office, and industrial developments. This shall almost always include all closed conduits and minor channel sections.
- Generally, improvements requiring a 100-year design capacity include open channels and detention basins.
- The actual storm frequency used for any facility shall be specified at the discretion of the City Engineer.
- One foot of freeboard shall be maintained below the top of curb for the 10-year storm.

- Drainage from areas shown as future development in the City's General Plan shall be provided for using the City's design standards. For all other areas, runoff shall be calculated using the *County of Solano Hydrology and Drainage Design Procedure Manual*.

Vallejo

The Vallejo drainage design standards are defined in the *Vallejo Sanitation and Flood Control District Guide to Existing Policies and Engineering Design Standards*, dated August 1988. The District's criteria are area- and performance-based, and include the following:

- Storm drain conveyance facilities draining areas of less than 200 acres shall be sized using the rational method. For drainage areas greater than 200 acres, facilities shall be sized using any commonly accepted unit hydrograph method (the *County of Solano Hydrology and Drainage Design Procedure Manual* method is referenced).
- The protection level shall be a function of drainage area, with areas less than 640 acres requiring a 15-year level of protection and duration equal to the time of concentration. For areas greater than 640 acres, a 100-year level of protection shall be achieved with the duration equal to the time of concentration. For detention basins, the duration shall be 24 hours. However, the district may require a higher level of protection at its discretion. For example, for sizing spillways the design storm shall be the 24-hour probable maximum flood.
- The energy grade line in gravity storm sewers shall be at least 2 feet below all manhole covers, gratings, and inlets when operating at design flow.
- Intensity-duration-frequency curves, storm distributions, and runoff coefficients for use in Vallejo are provided in figures and tables in the Design Standards.
- Design tide elevation shall be 3.5 feet, and the *Solano County Hydrology and Drainage Design Manual* is referenced.

Benicia

The City of Benicia drainage design standards are defined in the *City of Benicia Public Works Department Engineering Design Standards and Standard Plans* dated December 1992. Benicia's criteria are area- and performance-based, including:

- Storm runoff shall be calculated in accordance with the *County of Solano Hydrology and Drainage Design Procedure* (area-based criteria in the County's manual).
- Drainage design shall include a minimum of 1.0 foot of freeboard.

Solano County

For drainage facilities located in or affecting roadways, the design criteria are established in Solano County's *Road Improvement Standards and Land Development and Subdivision Requirements*, adopted August 27, 1996 and modified August 5, 1997. These criteria include:

- Open channels are appropriate in rural areas, and shall be sized for:
 - 100-year storm with no freeboard for drainage areas greater than 3,200 acres
 - 100-year storm with no freeboard for drainage areas from 640 to 3,200 acres if urbanization exceeds 75 percent
 - 25-year storm with 0.5 ft freeboard for drainage areas from 640 to 3,200 acres if urbanization is under 75 percent
 - 10-year with 1.0 ft freeboard for drainage areas smaller than 640 acres
- Culverts shall be sized for a 10-year storm without head on the inlet under free outfall conditions, and a 100-year storm with a head not higher than the outside edge of the graded road shoulder.
- Pipe drainage systems shall be sized for a 10-year storm without head, and a 100-year storm using the head in the appurtenant structures.
- Bridges shall be designed to convey a 50-year storm flow with 2 feet of freeboard and a 100-year storm flow with no freeboard.

3.2 ANALYSIS METHOD SELECTION

Two of the most widely used runoff analysis methods are the rational method and the computer program HEC-1 (HEC stands for Hydrologic Engineering Center, and “1” indicates the Flood Hydrograph Package). HEC-HMS (HMS stands for Hydrologic Modeling System) is a revision of HEC-1 released in March 1998 by the Hydrologic Engineering Center. HEC-HMS is a program for use with Microsoft Windows that is nearly equivalent to HEC-1. In this hydrology manual, use of HEC-1 and HEC-HMS are considered equivalent. The criteria for selection of these analysis methods are presented in Table 3-1.

Table 3-1. Runoff Analysis Method Selection Criteria

Selection Criteria	Analysis Method
Analysis area is less than 200 acres	Rational Method, HEC-1, or HEC-HMS
Analysis area is equal to or greater than 200 acres	HEC-1 or HEC-HMS
Drainage facilities include a detention basin or reservoir	HEC-1 or HEC-HMS

3.3 RATIONAL METHOD

The rational method equation for design discharge is:

$$Q = C * I * A \quad (\text{Equation 3-1})$$

where

- Q = design discharge in cfs
C = runoff coefficient
I = rainfall intensity in in/hr
A = drainage area in acres

The rational method has received extensive use and application because of its simplicity. The rational equation is based on the premise that for a given basin, the peak runoff rate is directly proportional to rainfall intensity. Implicit in this relationship are several assumptions. It is presumed, for example, that the rate of runoff is maximum when the entire basin is contributing. Thus, maximum runoff is achieved when the rainfall duration is equal to or greater than the time of concentration, *i.e.* the time required for runoff from the most remote point in the drainage area to reach the design point.

The rational method also assumes that the frequency of peak discharge is the same as the frequency of the design storm. The method further assumes that all streams within the drainage area have similar runoff characteristics, and that rainfall is uniformly distributed over the area throughout the time of concentration. Determination of the runoff coefficient and the time of concentration are difficult because these parameters depend on several factors. Furthermore, the rational equation has not been verified for large drainage areas.

Because of the foregoing assumptions and limitations, the rational method is recommended for application to small drainage areas only. As listed in Table 3-1, it is recommended that the rational method be used only when the drainage area is less than 200 acres.

Runoff Coefficient

The runoff coefficient C can be estimated by land use type using the values presented in Table 3-2. For unlisted or non-typical land uses, it may be desirable to determine C as a composite coefficient based on the areas of different land uses within the watershed. Values of C for various surface types are also listed in Table 3-2. For watersheds with more than one land use type, area weighted average C values should be developed.

The coefficients tabulated in Table 3-2 apply to storms with a return period of ten years. For return periods greater than ten years, the coefficient should be adjusted according to the relationships shown in Figure 3-1. For return periods less than 10 years, the 10-year values should be used.

Time of Concentration

The time of concentration, t_c , is the time required for surface runoff from the most remote part of the drainage area to reach the design point. This time (t_c) is the sum of an overland flow time, t_o , gutter flow time t_g (time of flow within gutter or other well-defined channel such as a road side ditch), and pipe flow time t_p . In some situations, some of these terms may not be included, and other terms may be used more than once. For example in rural areas, t_g may be used twice for a roadside ditch and a creek channel, and there may be no drainage pipe systems, so t_p would be omitted.

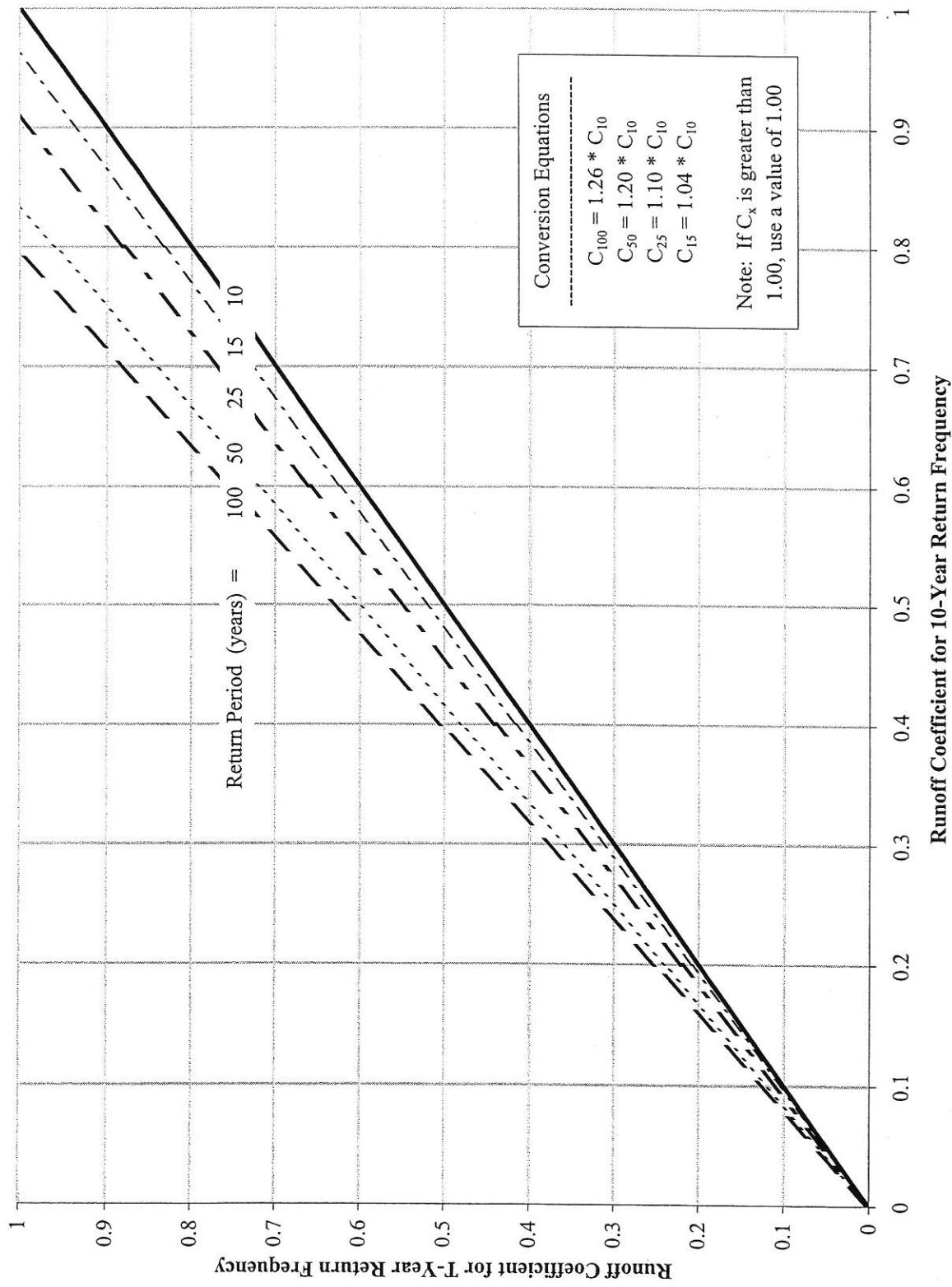
Table 3-2. Runoff Coefficient for 10-Year Return Frequency^(a)

Land Use	C ^(b)
Residential	
Apartments/condominiums	0.50 to 0.70
Single family (6 - 8 units per acre)	0.50 to 0.60
Single family (4 - 6 units per acre)	0.40 to 0.50
Single family (2 - 4 units per acre)	0.30 to 0.40
Single family (1 - 2 units per acre)	0.25 to 0.35
Commercial	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved urban areas	0.10 to 0.30
Agricultural/Open Space	
Cultivated	0.20 to 0.50
Pasture	0.15 to 0.45
Oak Timber & Brush	0.10 to 0.40
Surface Types	
Asphaltic and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns	0.15 to 0.35

^(a) For other return periods, adjust C coefficient based on Figure 3-1.

^(b) For areas with slopes of 1 percent or less, use values in the low end of the given range; for areas with slopes greater than 1 percent and up to 5 percent, use values in the middle of the given range; for areas with slopes greater than 5 percent, use values in the high end of the given range.

Figure 3-1. Runoff Coefficient Correction for Design Frequency



The overland flow time depends on several basin characteristics including slope, distance traveled by surface flow, surface storage and cover, land use, antecedent runoff, and soil infiltration capacity. Overland flow time (t_o) can be determined from Figure 3-2, which relates travel time to the distance of overland travel, ground slope, and the runoff coefficient, or calculated using the following equation:

$$t_o = \sqrt{\frac{D}{80 * S^{1/2}}} * (18.5 - 16.5 * C) \quad (\text{Equation 3 - 2})$$

where

- t_o = overland flow time in minutes
- D = overland flow distance in feet
- S = slope in percent
- C = runoff coefficient from Table 3-2

Gutter flow and pipe flow velocities (in pipes and channels) are determined from the Manning formula:

$$V = \frac{1.486}{n} * R^{2/3} * S^{1/2} \quad (\text{Equation 3-3})$$

where

- V = flow velocity in pipe or channel, in feet per second
- n = Manning roughness coefficient from Table 3-3
- R = hydraulic radius, A_c/P , in feet
- A_c = flow cross-sectional area, in square feet
- P = wetted perimeter, in feet
- S = channel or pipe longitudinal slope in feet/foot

Recommended values of the Manning coefficient n are tabulated in Table 3-3 for various pipes and open channels. The n values are summarized primarily from the following references, which should be consulted if more detailed information is required.

Chow, V. T. (1959). *Open Channel Hydraulics*, McGraw-Hill Book Company, New York, NY.

U.S. Geological Survey (Harry H. Barnes, Jr.) (1967). *Roughness Characteristics of Natural Channels, Water Supply Paper No. 1849*, United States Government Printing Office.

Metcalf & Eddy Inc. (George Tchobanoglous) (1981). *Wastewater Engineering: Collection and Pumping of Wastewater*, McGraw-Hill Book Company, New York, NY.

Water Environment Federation/American Society of Civil Engineers (1992). *Design and Construction of Urban Stormwater Management Systems*, American Society of Civil Engineers and Water Environment Federation.

Figure 3-2. Travel Time for Overland Flow

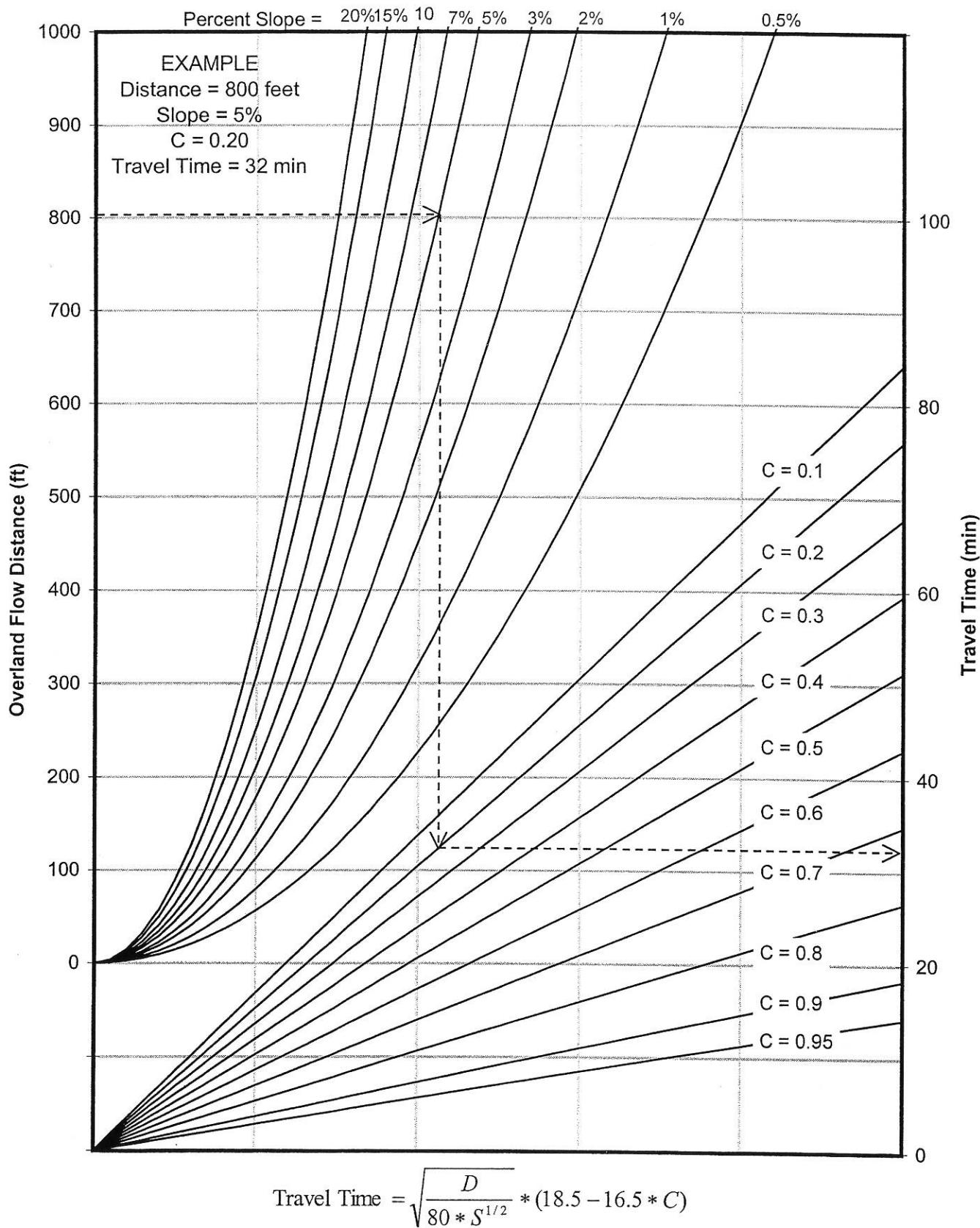


Table 3-3. Manning Roughness Coefficients (n values) for Pipes and Channels

Conveyance Material	Manning n
Closed Conduits	
Concrete	
1. Precast or cast-in-place	0.013 - 0.015
2. Steel troweled or smooth-form finish	0.014 - 0.016
3. Wood float or broomed finish; including pneumatically applied mortar	0.014 - 0.017
Corrugated metal pipe	
1. Plain	0.022 - 0.026
2. Paved invert	0.018 - 0.022
3. Spun asphalt lined	0.011 - 0.015
Plastic (HDPE, PVC)	0.008 - 0.015
Vitrified clay	0.011 - 0.015
Steel, coated	0.010 - 0.017
Brick	0.013 - 0.017
Open Channels	
Excavated or Dredged	
1. Earth, straight and uniform	0.020 - 0.030
2. Earth, winding and fairly uniform	0.025 - 0.040
3. Rock, smooth and uniform	0.025 - 0.033
4. Rock, jagged and irregular	0.035 - 0.045
5. With short grass, few weeds	0.022 - 0.033
6. Unmaintained, abundant vegetation as tall as flow depth	0.050 - 0.140
Lined	
1. Asphalt	0.013 - 0.017
2. Brick	0.011 - 0.018
3. Concrete	0.011 - 0.020
4. Riprap or rubble	0.020 - 0.035
5. Sack concrete riprap: Grouted rock riprap	0.028 - 0.032
6. With short grass, few weeds	0.022 - 0.033
7. Unmainted, abundant vegetation as tall as flow depth	0.050 - 0.140
Natural Stream Channels	
1. Clean, straight bank, full stage no rifts or deep pools	0.025 - 0.033
2. Same as (1), but some weeds and stones	0.030 - 0.040
3. Clean, winding, some pools and shoals	0.033 - 0.045
4. Same as (3), lower stages, more ineffective slope and sections	0.040 - 0.055
5. Same as (3), some weeds and stones	0.035 - 0.050
6. Same as (5), stony sections	0.045 - 0.060
7. Sluggish river reaches, rather weedy or with very deep pools	0.050 - 0.080
8. Very weedy reaches, trees or underbrush	0.075 - 0.150

Gutter/pipe flow times are calculated by dividing gutter/pipe length by the water velocity calculated with these equations:

$$t_g = L/V/60 \quad (\text{Equation 3-4})$$

$$t_p = L/V/60 \quad (\text{Equation 3-5})$$

where

t_g = gutter travel time in minutes

t_p = pipe travel time in minutes

L = length of gutter or pipe in feet

V = water velocity in feet/second

For pipe flow, it may be assumed that the pipe is flowing full, which means that $R = \text{pipe diameter divided by } 4$. For gutters, it may be assumed that the gutter is flowing with the water level at the top of curb. For ditches/channels, it may be assumed that the ditch/channel is flowing with the water level at the top of bank.

Rainfall Intensity

In using the rational equation, it is necessary that a rainfall intensity be determined to match the time of concentration. To calculate the rainfall intensity, a design return period is selected from the criteria specified by the appropriate governmental agency, the mean annual precipitation (MAP) is determined from Figure 2-2, and the storm duration is set equal to the time of concentration (t_c). The rainfall depth is read/interpolated from Tables 3-4A or 3-4B. Alternatively, a formula for the rainfall depth as a function of MAP, return frequency, duration, and other statistical variables is presented on Page 10 of the report *Design Rainfall for Solano County* (see Appendix A).

The rainfall intensity is calculated by dividing the rainfall depth by the duration of the design storm (in hours).

Analysis Procedure

The procedure for use of the rational method is as follows:

1. Delineate area tributary to the analysis point and determine the area in acres.
2. Obtain runoff coefficient C for appropriate land use within subshed from Table 3-2. If various land uses exist within the subshed, compute an area-weighted average C value.
3. Determine the average MAP over the tributary area from Figure 2-2.
4. Delineate the flow path to the analysis point with the longest time of concentration. It may be necessary to check several potential flow paths. Measure the overland flow length, gutter/channel flow length, and pipe flow length.

Table 3-4A. Solano County Design Rainfall for San Francisco Bay Drainage Region

2-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.13	0.18	0.21	0.28	0.38	0.51	0.61	0.82	1.11	1.49	1.95	2.04	2.30	2.48	2.67	2.98	3.31	3.87	4.65	5.13	7.54	13.61
15	0.14	0.19	0.22	0.30	0.41	0.55	0.65	0.88	1.18	1.59	2.07	2.19	2.47	2.67	2.87	3.21	3.57	4.16	4.97	5.50	8.11	14.58
16	0.15	0.20	0.24	0.32	0.43	0.59	0.70	0.94	1.26	1.70	2.20	2.34	2.64	2.86	3.07	3.44	3.82	4.45	5.29	5.87	8.68	15.55
17	0.16	0.21	0.25	0.34	0.46	0.62	0.74	1.00	1.34	1.81	2.32	2.49	2.81	3.05	3.27	3.67	4.07	4.74	5.61	6.24	9.25	16.53
18	0.17	0.23	0.27	0.36	0.49	0.66	0.78	1.06	1.42	1.91	2.45	2.64	2.97	3.24	3.47	3.91	4.33	5.03	5.93	6.61	9.82	17.50
19	0.18	0.24	0.28	0.38	0.52	0.70	0.83	1.11	1.50	2.02	2.57	2.79	3.14	3.43	3.67	4.14	4.58	5.33	6.25	6.98	10.39	18.47
20	0.19	0.25	0.30	0.40	0.54	0.73	0.87	1.17	1.58	2.13	2.70	2.94	3.31	3.62	3.87	4.37	4.83	5.62	6.57	7.35	10.96	19.44
22	0.21	0.28	0.33	0.44	0.60	0.81	0.96	1.29	1.74	2.34	2.94	3.24	3.65	4.00	4.27	4.83	5.34	6.20	7.21	8.09	12.10	21.39
24	0.22	0.30	0.36	0.48	0.65	0.88	1.05	1.41	1.90	2.55	3.19	3.54	3.99	4.38	4.67	5.30	5.84	6.79	7.85	8.84	13.24	23.33
26	0.24	0.33	0.39	0.52	0.71	0.95	1.13	1.52	2.05	2.76	3.44	3.84	4.33	4.76	5.07	5.76	6.35	7.37	8.49	9.58	14.38	25.27
28	0.26	0.35	0.42	0.57	0.76	1.02	1.22	1.64	2.21	2.98	3.69	4.14	4.67	5.13	5.47	6.22	6.85	7.96	9.13	10.32	15.52	27.22
30	0.28	0.38	0.45	0.61	0.82	1.10	1.31	1.76	2.37	3.19	3.94	4.44	5.01	5.51	5.87	6.69	7.36	8.54	9.78	11.06	16.66	29.16
32	0.30	0.40	0.48	0.65	0.87	1.17	1.39	1.88	2.53	3.40	4.19	4.74	5.34	5.89	6.28	7.15	7.86	9.13	10.42	11.80	17.80	31.11
34	0.32	0.43	0.51	0.69	0.92	1.24	1.48	1.99	2.68	3.61	4.44	5.04	5.68	6.27	6.68	7.61	8.37	9.71	11.06	12.54	18.94	33.05
36	0.34	0.45	0.54	0.73	0.98	1.32	1.57	2.11	2.84	3.83	4.69	5.34	6.02	6.65	7.08	8.08	8.88	10.30	11.70	13.28	20.08	35.00
38	0.36	0.48	0.57	0.77	1.03	1.39	1.66	2.23	3.00	4.04	4.94	5.64	6.36	7.03	7.48	8.54	9.38	10.88	12.34	14.02	21.22	36.94
40	0.37	0.50	0.60	0.81	1.09	1.46	1.74	2.35	3.16	4.25	5.19	5.94	6.70	7.41	7.88	8.90	9.89	11.47	12.98	14.76	22.36	38.88
45	0.42	0.57	0.67	0.91	1.22	1.65	1.96	2.64	3.55	4.78	5.82	6.69	7.55	8.36	8.88	10.16	11.15	12.93	14.58	16.62	25.21	43.75

5-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.18	0.25	0.29	0.40	0.53	0.72	0.85	1.15	1.55	2.08	2.81	2.93	3.27	3.54	3.81	4.22	4.62	5.33	6.39	7.06	10.25	17.80
15	0.20	0.26	0.32	0.42	0.57	0.77	0.92	1.23	1.66	2.23	2.99	3.15	3.51	3.81	4.10	4.55	4.97	5.74	6.83	7.57	11.02	19.07
16	0.21	0.28	0.34	0.45	0.61	0.82	0.98	1.31	1.77	2.38	3.17	3.36	3.75	4.08	4.38	4.88	5.32	6.14	7.27	8.08	11.80	20.34
17	0.22	0.30	0.36	0.48	0.65	0.87	1.04	1.40	1.88	2.53	3.35	3.58	3.99	4.35	4.67	5.20	5.67	6.54	7.71	8.59	12.57	21.62
18	0.24	0.32	0.38	0.51	0.69	0.92	1.10	1.48	1.99	2.68	3.53	3.80	4.23	4.62	4.95	5.53	6.02	6.95	8.15	9.10	13.35	22.89
19	0.25	0.34	0.40	0.54	0.72	0.97	1.16	1.56	2.10	2.83	3.71	4.01	4.47	4.89	5.24	5.86	6.38	7.35	8.59	9.60	14.12	24.16
20	0.26	0.35	0.42	0.57	0.76	1.03	1.22	1.64	2.21	2.98	3.89	4.23	4.71	5.17	5.53	6.19	6.73	7.75	9.03	10.11	14.90	25.43
22	0.29	0.39	0.46	0.62	0.84	1.13	1.34	1.81	2.43	3.28	4.25	4.66	5.19	5.71	6.10	6.84	7.43	8.56	9.92	11.13	16.45	27.97
24	0.31	0.42	0.50	0.68	0.91	1.23	1.46	1.97	2.65	3.57	4.61	5.09	5.68	6.25	6.67	7.50	8.14	9.37	10.80	12.15	18.00	30.52
26	0.34	0.46	0.55	0.74	0.99	1.33	1.59	2.14	2.88	3.87	4.97	5.52	6.16	6.79	7.24	8.16	8.84	10.18	11.68	13.17	19.55	33.06
28	0.37	0.49	0.59	0.79	1.07	1.44	1.71	2.30	3.10	4.17	5.33	5.95	6.64	7.33	7.81	8.81	9.54	10.98	12.56	14.19	21.10	35.60
30	0.39	0.53	0.63	0.85	1.14	1.54	1.83	2.46	3.32	4.47	5.69	6.39	7.12	7.87	8.39	9.47	10.25	11.79	13.44	15.21	22.65	38.14
32	0.42	0.56	0.67	0.91	1.22	1.64	1.95	2.63	3.54	4.77	6.05	6.82	7.60	8.41	8.96	10.13	10.95	12.60	14.32	16.23	24.20	40.69
34	0.45	0.60	0.71	0.96	1.29	1.74	2.07	2.79	3.76	5.06	6.41	7.25	8.08	8.95	9.53	10.78	11.66	13.40	15.20	17.25	25.75	43.23
36	0.47	0.64	0.76	1.02	1.37	1.85	2.20	2.96	3.98	5.36	6.78	7.68	8.57	9.50	10.10	11.44	12.36	14.21	16.09	18.27	27.30	45.77
38	0.50	0.67	0.80	1.07	1.45	1.95	2.32	3.12	4.20	5.66	7.14	8.11	9.05	10.04	10.68	12.10	13.06	15.02	16.97	19.29	28.85	48.32
40	0.52	0.71	0.84	1.13	1.52	2.05	2.44	3.29	4.42	5.96	7.50	8.55	9.53	10.58	11.25	12.75	13.77	15.82	17.85	20.31	30.40	50.86
45	0.59	0.79	0.95	1.27	1.71	2.31	2.75	3.70	4.98	6.70	8.40	9.62	10.73	11.93	12.68	14.39	15.53	17.84	20.05	22.85	34.27	57.22

10-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.22	0.30	0.35	0.47	0.64	0.86	1.02	1.37	1.85	2.49	3.40	3.54	3.93	4.11	4.42	4.89	5.44	6.23	7.45	8.25	11.85	20.22
15	0.23	0.32	0.38	0.51	0.68	0.92	1.09	1.47	1.98	2.67	3.62	3.80	4.22	4.43	4.76	5.27	5.85	6.70	7.97	8.85	12.74	21.67
16	0.25	0.34	0.40	0.54	0.73	0.98	1.17	1.57	2.11	2.85	3.83	4.06	4.50	4.74	5.09	5.65	6.27	7.17	8.48	9.45	13.64	23.11
17	0.27	0.36	0.43	0.57	0.77	1.04	1.24	1.67	2.25	3.02	4.05	4.32	4.79	5.05	5.42	6.03	6.68	7.64	9.00	10.04	14.53	24.56
18	0.30	0.38	0.45	0.61	0.82	1.10	1.31	1.77	2.38	3.20	4.27	4.58	5.08	5.37	5.75	6.41	7.10	8.11	9.51	10.64	15.43	26.00
19	0.30	0.40	0.48	0.64	0.86	1.16	1.38	1.86	2.51	3.38	4.49	4.84	5.37	5.68	6.08	6.79	7.51	8.59	10.02	11.23	16.33	27.45
20	0.31	0.42	0.50	0.68	0.91	1.22	1.46	1.96	2.64	3.56	4.70	5.10	5.66	6.00	6.42	7.17	7.93	9.06	10.54	11.83	17.22	28.89
22	0.34	0.46	0.55	0.74	1.00	1.35	1.60	2.16	2.91	3.91	5.14	5.62	6.24	6.63	7.08	7.93	8.75	10.00	11.57	13.02	19.01	31.78
24	0.38	0.51	0.60	0.81	1.09	1.47	1.75	2.35</														

Table 3-4A. Solano County Design Rainfall for San Francisco Bay Drainage Region

25-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.26	0.35	0.42	0.57	0.77	1.03	1.23	1.65	2.22	2.99	4.13	4.30	4.74	5.07	5.45	6.00	6.43	7.33	8.76	9.68	13.69	22.98
15	0.28	0.38	0.45	0.61	0.82	1.10	1.31	1.77	2.38	3.21	4.40	4.61	5.09	5.45	5.86	6.47	6.92	7.88	9.36	10.38	14.72	24.63
16	0.30	0.41	0.48	0.65	0.87	1.18	1.40	1.89	2.54	3.42	4.66	4.93	5.44	5.84	6.27	6.93	7.41	8.44	9.96	11.08	15.76	26.27
17	0.32	0.43	0.51	0.69	0.93	1.25	1.49	2.00	2.70	3.63	4.93	5.25	5.79	6.23	6.68	7.40	7.90	8.99	10.57	11.78	16.79	27.91
18	0.34	0.46	0.54	0.73	0.98	1.32	1.58	2.12	2.86	3.85	5.19	5.56	6.14	6.61	7.09	7.87	8.39	9.55	11.17	12.48	17.83	29.55
19	0.36	0.48	0.57	0.77	1.04	1.40	1.66	2.24	3.02	4.06	5.46	5.88	6.49	7.00	7.50	8.33	8.88	10.10	11.78	13.18	18.86	31.19
20	0.38	0.51	0.60	0.81	1.09	1.47	1.75	2.36	3.17	4.27	5.72	6.20	6.84	7.39	7.90	8.80	9.37	10.65	12.38	13.87	19.90	32.84
22	0.41	0.56	0.66	0.89	1.20	1.62	1.93	2.59	3.49	4.70	6.25	6.83	7.54	8.16	8.72	9.74	10.35	11.76	13.59	15.27	21.97	36.12
24	0.45	0.61	0.72	0.97	1.31	1.77	2.10	2.83	3.81	5.13	6.78	7.46	8.24	8.94	9.54	10.67	11.33	12.87	14.79	16.67	24.04	39.40
26	0.49	0.66	0.78	1.06	1.42	1.91	2.28	3.06	4.13	5.56	7.31	8.10	8.94	9.71	10.36	11.60	12.31	13.98	16.00	18.07	26.11	42.69
28	0.53	0.71	0.84	1.14	1.53	2.06	2.45	3.30	4.44	5.98	7.84	8.73	9.64	10.48	11.18	12.54	13.29	15.09	17.21	19.47	28.18	45.97
30	0.56	0.76	0.90	1.22	1.64	2.21	2.63	3.54	4.76	6.41	8.37	9.36	10.34	11.26	12.00	13.47	14.27	16.20	18.42	20.86	30.25	49.25
32	0.60	0.81	0.96	1.30	1.75	2.35	2.80	3.77	5.08	6.84	8.90	10.00	11.03	12.03	12.81	14.40	15.26	17.30	19.63	22.26	32.32	52.54
34	0.64	0.86	1.02	1.38	1.86	2.50	2.98	4.01	5.40	7.27	9.43	10.63	11.73	12.81	13.63	15.34	16.24	18.41	20.83	23.66	34.39	55.82
36	0.68	0.91	1.09	1.46	1.97	2.65	3.15	4.24	5.71	7.69	9.96	11.26	12.43	13.58	14.45	16.27	17.22	19.52	22.04	25.06	36.46	59.10
38	0.71	0.96	1.15	1.54	2.08	2.80	3.33	4.48	6.03	8.12	10.49	11.90	13.13	14.36	15.27	17.20	18.20	20.63	23.25	26.46	38.53	62.39
40	0.75	1.01	1.21	1.62	2.19	2.94	3.50	4.72	6.35	8.55	11.02	12.53	13.83	15.13	16.09	18.14	19.18	21.74	24.46	27.86	40.60	65.67
45	0.85	1.14	1.36	1.83	2.46	3.31	3.94	5.30	7.14	9.62	12.35	14.11	15.58	17.07	18.13	20.47	21.63	24.51	27.47	31.35	45.77	73.88

50-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.30	0.40	0.47	0.64	0.86	1.16	1.38	1.85	2.49	3.36	4.67	4.85	5.34	5.67	6.10	6.71	7.13	8.03	9.59	10.69	14.95	24.87
15	0.32	0.43	0.51	0.68	0.92	1.24	1.47	1.98	2.67	3.60	4.97	5.21	5.73	6.10	6.56	7.23	7.68	8.64	10.25	11.46	16.09	26.65
16	0.34	0.45	0.54	0.73	0.98	1.32	1.57	2.12	2.85	3.84	5.27	5.57	6.12	6.54	7.02	7.75	8.22	9.24	10.91	12.23	17.22	28.42
17	0.36	0.48	0.57	0.77	1.04	1.40	1.67	2.25	3.03	4.08	5.57	5.93	6.52	6.97	7.47	8.27	8.77	9.85	11.57	13.00	18.35	30.20
18	0.38	0.51	0.61	0.82	1.10	1.49	1.77	2.38	3.21	4.32	5.87	6.28	6.91	7.40	7.93	8.80	9.31	10.46	12.23	13.78	19.48	31.98
19	0.40	0.54	0.64	0.87	1.16	1.57	1.87	2.51	3.38	4.56	6.17	6.64	7.30	7.84	8.39	9.32	9.85	11.07	12.89	14.55	20.61	33.75
20	0.42	0.57	0.68	0.91	1.23	1.65	1.96	2.65	3.56	4.79	6.47	7.00	7.70	8.27	8.85	9.84	10.40	11.67	13.56	15.32	21.74	35.53
22	0.46	0.63	0.74	1.00	1.35	1.82	2.16	2.91	3.92	5.27	7.06	7.71	8.48	9.14	9.76	10.88	11.49	12.89	14.88	16.86	24.00	39.08
24	0.51	0.68	0.81	1.09	1.47	1.98	2.36	3.17	4.27	5.75	7.66	8.43	9.27	10.00	10.68	11.93	12.57	14.10	16.20	18.41	26.26	42.64
26	0.55	0.74	0.88	1.18	1.59	2.15	2.55	3.44	4.63	6.23	8.26	9.14	10.06	10.87	11.60	12.97	13.66	15.32	17.52	19.95	28.53	46.19
28	0.59	0.80	0.95	1.27	1.72	2.31	2.75	3.70	4.99	6.71	8.86	9.86	10.84	11.74	12.51	14.01	14.75	16.53	18.84	21.49	30.79	49.74
30	0.63	0.85	1.01	1.37	1.84	2.48	2.95	3.97	5.34	7.19	9.46	10.57	11.63	12.60	13.43	15.06	15.84	17.74	20.17	23.04	33.05	53.29
32	0.68	0.91	1.08	1.46	1.96	2.64	3.14	4.23	5.70	7.67	10.06	11.29	12.42	13.47	14.35	16.10	16.93	18.96	21.49	24.58	35.31	56.85
34	0.72	0.97	1.15	1.55	2.08	2.81	3.34	4.50	6.05	8.15	10.66	12.00	13.20	14.34	15.26	17.14	18.01	20.17	22.81	26.13	37.57	60.40
36	0.76	1.02	1.22	1.64	2.21	2.97	3.54	4.76	6.41	8.63	11.26	12.72	13.99	15.20	16.18	18.19	19.10	21.39	24.13	27.67	39.83	63.95
38	0.80	1.08	1.29	1.73	2.33	3.14	3.73	5.03	6.77	9.11	11.86	13.43	14.78	16.07	17.09	19.23	20.19	22.60	25.46	29.21	42.10	67.51
40	0.84	1.14	1.35	1.82	2.45	3.30	3.93	5.29	7.12	9.59	12.45	14.15	15.56	16.94	18.01	20.28	21.28	23.82	26.78	30.76	44.36	71.06
45	0.95	1.28	1.52	2.05	2.76	3.71	4.42	5.95	8.01	10.79	13.95	15.93	17.53	19.10	20.30	22.89	24.00	26.85	30.08	34.62	50.01	79.94

100-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.36	0.48	0.57	0.77	1.04	1.40	1.66	2.24	3.02	4.06	5.71	5.93	6.48	6.83	7.35	8.07	8.47	9.41	11.23	12.58	17.01	28.30
15	0.38	0.52	0.61	0.83	1.11	1.50	1.78	2.40	3.23	4.35	6.08	6.37	6.96	7.36	7.90	8.70	9.12	10.12	12.00	13.49	18.30	30.33
16	0.41	0.55	0.65	0.88	1.19	1.60	1.90	2.56	3.45	4.64	6.44	6.80	7.44	7.88	8.46	9.32	9.76	10.84	12.78	14.40	19.59	32.35
17	0.43	0.58	0.70	0.94	1.26	1.70	2.02	2.72	3.66	4.93	6.81	7.24	7.91	8.40	9.01	9.95	10.41	11.55	13.51	15.31	20.87	34.37
18	0.46	0.62	0.74	0.99	1.33	1.80	2.14	2.88	3.88	5.22	7.18	7.68	8.39	8.92	9.56	10.58	11.05	12.26	14.33	16.22	22.16	36.39
19	0.49	0.65	0.78	1.05	1.41	1.90	2.26	3.04	4.09	5.51	7.54	8.12	8.87	9.45	10.11	11.21	11.70	12.97	15.10	17.13	23.45	38.41
20	0.51	0.69	0.82	1.10	1.48	2.00	2.38	3.20	4.31	5.80	7.91	8.55	9.35	9.97	10.67	11.84	12.35	13.68	15.88	18.04	24.73	40.44
22	0.56	0.76	0.90	1.21	1.63	2.20	2.61	3.52	4.74	6.38	8.64	9.43	1									

Table 3-4A. Solano County Design Rainfall for San Francisco Bay Drainage Region

500-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.40	0.53	0.63	0.85	1.15	1.55	1.84	2.48	3.34	4.50	6.30	6.54	7.19	7.55	8.12	8.91	9.27	10.34	12.33	13.87	18.79	30.46
15	0.42	0.57	0.68	0.92	1.23	1.66	1.97	2.66	3.58	4.82	6.71	7.03	7.72	8.13	8.73	9.60	9.98	11.12	13.18	14.87	20.21	32.63
16	0.45	0.61	0.73	0.98	1.31	1.77	2.11	2.84	3.82	5.14	7.51	7.91	8.25	8.71	9.34	10.29	10.69	11.90	14.03	15.87	21.64	34.81
17	0.48	0.65	0.77	1.04	1.40	1.88	2.24	3.01	4.06	5.46	7.52	7.99	8.78	9.28	9.95	10.99	11.39	12.68	14.88	16.87	23.06	36.99
18	0.51	0.69	0.82	1.10	1.48	1.99	2.37	3.19	4.30	5.78	7.92	8.47	9.31	9.86	10.56	11.68	12.10	13.47	15.73	17.87	24.48	39.16
19	0.54	0.72	0.86	1.16	1.56	2.10	2.50	3.37	4.53	6.11	8.33	8.95	9.85	10.44	11.17	12.37	12.81	14.25	16.58	18.88	25.90	41.34
20	0.57	0.76	0.91	1.22	1.64	2.21	2.63	3.55	4.77	6.43	8.73	9.44	10.38	11.01	11.78	13.06	13.52	15.03	17.43	19.88	27.32	43.51
22	0.62	0.84	1.00	1.34	1.81	2.43	2.90	3.90	5.25	7.07	9.54	10.40	11.44	12.17	13.00	14.45	14.93	16.59	19.13	21.88	30.16	47.86
24	0.68	0.91	1.09	1.46	1.97	2.65	3.16	4.25	5.73	7.71	10.35	11.36	12.50	13.32	14.22	15.84	16.35	18.16	20.83	23.88	33.00	52.22
26	0.74	0.99	1.18	1.59	2.14	2.88	3.42	4.61	6.21	8.35	11.16	12.33	13.56	14.48	15.44	17.22	17.76	19.72	22.53	25.89	35.85	56.57
28	0.79	1.07	1.27	1.71	2.30	3.10	3.69	4.96	6.68	9.00	11.96	13.29	14.62	15.63	16.66	18.61	19.17	21.29	24.23	27.89	38.69	60.92
30	0.85	1.14	1.36	1.83	2.47	3.32	3.95	5.32	7.16	9.64	12.77	14.25	15.68	16.78	17.88	19.99	20.59	22.85	25.93	29.89	41.53	65.27
32	0.91	1.22	1.45	1.95	2.63	3.54	4.21	5.67	7.64	10.28	13.58	15.22	16.74	17.94	19.10	21.38	22.00	24.41	27.63	31.90	44.37	69.62
34	0.96	1.30	1.54	2.08	2.79	3.76	4.48	6.03	8.11	10.93	14.39	16.18	17.80	19.09	20.32	22.76	23.42	25.98	29.33	33.90	47.22	73.97
36	1.02	1.37	1.63	2.20	2.96	3.98	4.74	6.38	8.59	11.57	15.20	17.15	18.66	20.25	21.54	24.15	24.83	27.54	31.03	35.90	50.06	78.32
38	1.08	1.45	1.72	2.32	3.12	4.20	5.00	6.74	9.07	12.21	16.01	18.11	19.92	21.40	22.76	25.54	26.25	29.10	32.73	37.90	52.90	82.68
40	1.13	1.52	1.81	2.44	3.29	4.42	5.27	7.09	9.55	12.85	16.82	19.07	20.98	22.56	23.98	26.92	27.66	30.67	34.43	39.91	55.74	87.03
45	1.27	1.71	2.04	2.75	3.70	4.98	5.92	7.98	10.74	14.46	18.84	21.48	23.63	25.44	27.03	30.39	31.20	34.58	38.68	44.92	62.85	97.90

1,000-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.43	0.57	0.68	0.92	1.24	1.67	1.99	2.68	3.60	4.85	6.89	7.15	7.77	8.13	8.75	9.59	9.94	10.91	13.01	14.66	19.77	31.93
15	0.46	0.62	0.73	0.99	1.33	1.79	2.13	2.87	3.86	5.20	7.33	7.67	8.34	8.75	9.41	10.33	10.70	11.74	13.91	15.72	21.27	34.21
16	0.49	0.66	0.78	1.05	1.42	1.91	2.27	3.06	4.12	5.54	7.77	8.20	8.91	9.38	10.06	11.08	11.46	12.56	14.81	16.78	22.76	36.49
17	0.52	0.70	0.83	1.12	1.51	2.03	2.41	3.25	4.37	5.89	8.21	8.73	9.48	10.00	10.72	11.82	12.22	13.39	15.70	17.83	24.26	38.77
18	0.55	0.74	0.88	1.18	1.59	2.15	2.55	3.44	4.63	6.24	8.66	9.25	10.05	10.62	11.38	12.57	12.97	14.22	16.60	18.89	25.75	41.05
19	0.58	0.78	0.93	1.25	1.68	2.27	2.70	3.63	4.89	6.58	9.10	9.78	10.63	11.24	12.03	13.32	13.73	15.04	17.50	19.95	27.25	43.33
20	0.61	0.82	0.98	1.32	1.77	2.39	2.84	3.82	5.15	6.93	9.54	10.31	11.20	11.86	12.69	14.06	14.49	15.87	18.39	21.01	28.75	45.61
22	0.67	0.90	1.08	1.45	1.95	2.62	3.12	4.20	5.66	7.62	10.42	11.36	12.34	13.10	14.00	15.55	16.01	17.52	20.19	23.13	31.74	50.17
24	0.73	0.99	1.17	1.58	2.13	2.86	3.41	4.59	6.17	8.31	11.31	12.41	13.49	14.35	15.32	17.04	17.52	19.17	21.98	25.24	34.73	54.73
26	0.79	1.07	1.27	1.71	2.30	3.10	3.69	4.97	6.69	9.01	12.19	13.47	14.63	15.59	16.63	18.54	19.04	20.82	23.78	27.36	37.72	59.29
28	0.85	1.15	1.37	1.84	2.48	3.34	3.97	5.35	7.20	9.70	13.07	14.52	15.78	16.83	17.95	20.03	20.55	22.47	25.57	29.48	40.71	63.85
30	0.92	1.23	1.47	1.97	2.66	3.58	4.26	5.73	7.72	10.39	13.96	15.57	16.92	18.08	19.26	21.52	22.07	24.12	27.37	31.59	43.70	68.41
32	0.98	1.31	1.56	2.11	2.83	3.82	4.54	6.12	8.23	11.09	14.84	16.62	18.07	19.32	20.57	23.01	23.59	25.77	29.16	33.71	46.69	72.98
34	1.04	1.40	1.66	2.24	3.01	4.05	4.83	6.50	8.75	11.78	15.72	17.68	19.21	20.56	21.89	24.50	25.10	27.42	30.95	35.83	49.68	77.54
36	1.10	1.48	1.76	2.37	3.19	4.29	5.11	6.88	9.26	12.47	16.61	18.73	20.36	21.81	23.20	25.99	26.62	29.07	32.75	37.95	52.67	82.10
38	1.16	1.56	1.86	2.50	3.37	4.53	5.39	7.26	9.78	13.16	17.49	19.78	21.50	23.05	24.52	27.49	28.14	30.72	34.54	40.06	55.66	86.66
40	1.22	1.64	1.95	2.63	3.54	4.77	5.68	7.64	10.29	13.86	18.37	20.84	22.65	24.29	25.83	28.98	29.65	32.37	36.34	42.18	58.65	91.22
45	1.37	1.85	2.20	2.96	3.99	5.37	6.39	8.60	11.58	15.59	20.58	23.47	25.51	27.40	29.12	32.71	33.44	36.50	40.82	47.47	66.13	102.62

10,000-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.52	0.71	0.84	1.13	1.52	2.05	2.44	3.28	4.42	5.95	8.54	8.85	9.55	9.93	10.68	11.69	11.95	13.31	15.85	17.47	23.07	36.68
15	0.56	0.76	0.90	1.21	1.63	2.19	2.61	3.52	4.73	6.37	9.08	9.50	10.26	10.69	11.48	12.60	12.86	14.31	16.94	18.74	24.81	39.30
16	0.60	0.81	0.96	1.29	1.74	2.34	2.79	3.75	5.05	6.80	9.63	10.16	10.96	11.45	12.29	13.50	13.78	15.32	18.03	20.00	26.55	41.92
17	0.64	0.86	1.02	1.37	1.85	2.49	2.96	3.99	5.37	7.22	10.18	10.81	11.67	12.21	13.09	14.41	14.69	16.32	19.13	21.26	28.30	44.54
18	0.67	0.91	1.08	1.45	1.96	2.63	3.13	4.22	5.68	7.65	10.73	11.46	12.37	12.96	13.89	15.32	15.60	17.33	20.22	22.52	30.04	47.16
19	0.71	0.96	1.14	1.53	2.06	2.78	3.31	4.45	6.00	8.07	11.27	12.11	13.08	13.72	14.69	16.23	16.51	18.34	21.31	23.78	31.79	49.78
20	0.75	1.01	1.20	1.61	2.17	2.93	3.48	4.69	6.31	8.50	11.82	12.76	13.78	14.48	15.49	17.14	17.42	19.34	22.41	25.05	33.53</	

Table 3-4B. Solano County Design Rainfall for Sacramento River Drainage Region

2-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.13	0.18	0.21	0.29	0.39	0.52	0.62	0.84	1.13	1.52	1.99	2.08	2.29	2.49	2.74	3.07	3.37	3.92	4.68	5.20	7.55	13.71
15	0.14	0.19	0.23	0.31	0.42	0.56	0.67	0.90	1.21	1.63	2.12	2.23	2.46	2.68	2.94	3.31	3.62	4.22	5.00	5.58	8.12	14.69
16	0.15	0.21	0.25	0.33	0.44	0.60	0.71	0.96	1.29	1.74	2.25	2.39	2.63	2.87	3.15	3.55	3.88	4.52	5.33	5.95	8.69	15.67
17	0.16	0.22	0.26	0.35	0.47	0.64	0.76	1.02	1.37	1.85	2.38	2.54	2.80	3.06	3.35	3.78	4.14	4.81	5.65	6.33	9.26	16.65
18	0.17	0.23	0.28	0.37	0.50	0.67	0.80	1.08	1.45	1.96	2.50	2.69	2.97	3.25	3.56	4.02	4.39	5.11	5.97	6.70	9.83	17.63
19	0.18	0.24	0.29	0.39	0.53	0.71	0.85	1.14	1.53	2.07	2.63	2.85	3.14	3.44	3.76	4.26	4.65	5.41	6.29	7.08	10.40	18.61
20	0.19	0.26	0.31	0.41	0.56	0.75	0.89	1.20	1.62	2.17	2.76	3.00	3.31	3.63	3.97	4.50	4.91	5.70	6.62	7.46	10.97	19.58
22	0.21	0.28	0.34	0.45	0.61	0.82	0.98	1.32	1.78	2.39	3.01	3.31	3.65	4.01	4.38	4.98	5.42	6.30	7.26	8.21	12.11	21.54
24	0.23	0.31	0.37	0.50	0.67	0.90	1.07	1.44	1.94	2.61	3.27	3.61	3.98	4.40	4.79	5.46	5.93	6.89	7.91	8.96	13.25	23.50
26	0.25	0.34	0.40	0.54	0.72	0.97	1.16	1.56	2.10	2.83	3.53	3.92	4.32	4.78	5.20	5.93	6.45	7.48	8.55	9.71	14.40	25.46
28	0.27	0.36	0.43	0.58	0.78	1.05	1.25	1.68	2.26	3.04	3.78	4.22	4.66	5.16	5.61	6.41	6.96	8.08	9.20	10.46	15.54	27.42
30	0.29	0.39	0.46	0.62	0.83	1.12	1.34	1.80	2.42	3.26	4.04	4.53	5.00	5.54	6.02	6.89	7.47	8.67	9.84	11.21	16.68	29.38
32	0.31	0.41	0.49	0.66	0.89	1.20	1.43	1.92	2.58	3.48	4.29	4.84	5.34	5.92	6.43	7.37	7.99	9.26	10.49	11.96	17.82	31.34
34	0.33	0.44	0.52	0.70	0.95	1.27	1.51	2.04	2.75	3.70	4.55	5.14	5.67	6.30	6.84	7.84	8.50	9.86	11.13	12.72	18.96	33.29
36	0.34	0.46	0.55	0.74	1.00	1.35	1.60	2.16	2.91	3.91	4.80	5.45	6.01	6.68	7.26	8.32	9.01	10.45	11.78	13.47	20.10	35.25
38	0.36	0.49	0.58	0.78	1.06	1.42	1.69	2.28	3.07	4.13	5.06	5.76	6.35	7.06	7.67	8.80	9.52	11.05	12.43	14.22	21.24	37.21
40	0.38	0.52	0.61	0.83	1.11	1.50	1.78	2.40	3.23	4.35	5.32	6.06	6.69	7.44	8.08	9.27	10.04	11.64	13.07	14.97	22.39	39.17
45	0.38	0.58	0.69	0.93	1.25	1.68	2.00	2.70	3.63	4.89	5.95	6.83	7.53	8.39	9.10	10.47	11.32	13.12	14.68	16.85	25.24	44.07

5-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.18	0.24	0.29	0.39	0.52	0.70	0.84	1.12	1.51	2.04	2.75	2.90	3.24	3.50	3.79	4.22	4.61	5.32	6.40	7.07	10.18	17.54
15	0.19	0.26	0.31	0.42	0.56	0.75	0.90	1.21	1.62	2.18	2.93	3.11	3.48	3.77	4.07	4.55	4.97	5.72	6.84	7.58	10.95	18.79
16	0.21	0.28	0.33	0.44	0.60	0.80	0.95	1.29	1.73	2.33	3.11	3.32	3.72	4.04	4.36	4.88	5.32	6.13	7.28	8.09	11.72	20.05
17	0.22	0.29	0.35	0.47	0.63	0.85	1.01	1.37	1.84	2.48	3.28	3.54	3.96	4.31	4.64	5.21	5.67	6.53	7.72	8.60	12.49	21.30
18	0.23	0.31	0.37	0.50	0.67	0.90	1.07	1.45	1.95	2.62	3.46	3.75	4.20	4.57	4.92	5.54	6.02	6.93	8.16	9.11	13.26	22.55
19	0.24	0.33	0.39	0.53	0.71	0.95	1.13	1.53	2.06	2.77	3.64	3.97	4.43	4.84	5.21	5.87	6.37	7.34	8.60	9.62	14.03	23.81
20	0.26	0.35	0.41	0.55	0.75	1.00	1.19	1.61	2.16	2.91	3.82	4.18	4.67	5.11	5.49	6.20	6.72	7.74	9.05	10.13	14.80	25.06
22	0.28	0.38	0.45	0.61	0.82	1.10	1.31	1.77	2.38	3.20	4.17	4.61	5.15	5.65	6.06	6.85	7.43	8.54	9.93	11.16	16.34	27.57
24	0.31	0.41	0.49	0.66	0.89	1.20	1.43	1.93	2.60	3.50	4.52	5.03	5.63	6.18	6.63	7.51	8.13	9.35	10.81	12.18	17.88	30.07
26	0.33	0.45	0.53	0.72	0.97	1.30	1.55	2.09	2.81	3.79	4.88	5.46	6.11	6.72	7.20	8.17	8.84	10.15	11.69	13.20	19.42	32.58
28	0.36	0.48	0.58	0.77	1.04	1.40	1.67	2.25	3.03	4.08	5.23	5.89	6.58	7.25	7.77	8.82	9.54	10.96	12.58	14.22	20.96	35.08
30	0.38	0.52	0.62	0.83	1.12	1.50	1.79	2.41	3.25	4.37	5.58	6.31	7.06	7.79	8.34	9.48	10.24	11.76	13.46	15.24	22.50	37.59
32	0.41	0.55	0.66	0.89	1.19	1.60	1.91	2.57	3.46	4.66	5.94	6.74	7.54	8.32	8.91	10.14	10.95	12.57	14.34	16.26	24.03	40.09
34	0.44	0.59	0.70	0.94	1.27	1.70	2.03	2.73	3.68	4.95	6.29	7.17	8.02	8.86	9.47	10.79	11.65	13.37	15.22	17.28	25.57	42.60
36	0.46	0.62	0.74	1.00	1.34	1.81	2.15	2.89	3.89	5.24	6.64	7.59	8.49	9.39	10.04	11.45	12.35	14.18	16.10	18.30	27.11	45.11
38	0.49	0.66	0.78	1.05	1.42	1.91	2.27	3.05	4.11	5.54	7.00	8.02	8.97	9.93	10.61	12.11	13.06	14.98	16.99	19.33	28.65	47.61
40	0.51	0.69	0.82	1.11	1.49	2.01	2.39	3.21	4.33	5.83	7.35	8.45	9.45	10.46	11.18	12.77	13.76	15.79	17.87	20.35	30.19	50.12
45	0.58	0.78	0.92	1.25	1.68	2.26	2.69	3.62	4.87	6.55	8.23	9.51	10.64	11.80	12.60	14.41	15.52	17.80	20.08	22.90	34.04	56.38

10-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.21	0.28	0.34	0.45	0.61	0.82	0.97	1.31	1.77	2.38	3.27	3.45	3.85	4.05	4.45	4.94	5.37	6.15	7.43	8.19	11.73	19.72
15	0.22	0.30	0.36	0.48	0.65	0.88	1.04	1.41	1.89	2.55	3.48	3.71	4.13	4.36	4.78	5.33	5.78	6.61	7.94	8.78	12.62	21.12
16	0.24	0.32	0.38	0.52	0.70	0.94	1.11	1.50	2.02	2.72	3.69	3.96	4.42	4.67	5.12	5.71	6.19	7.08	8.45	9.37	13.51	22.53
17	0.25	0.34	0.41	0.55	0.74	0.99	1.18	1.59	2.14	2.89	3.90	4.22	4.70	4.98	5.45	6.09	6.60	7.54	8.96	9.96	14.39	23.94
18	0.27	0.36	0.43	0.58	0.78	1.05	1.25	1.69	2.27	3.06	4.11	4.47	4.98	5.28	5.79	6.48	7.01	8.01	9.48	10.56	15.28	25.35
19	0.28	0.38	0.46	0.61	0.83	1.11	1.32	1.78	2.40	3.23	4.32	4.72	5.27	5.59	6.12	6.86	7.42	8.47	9.99	11.15	16.17	26.76
20	0.30	0.40	0.48	0.65	0.87	1.17	1.39	1.87	2.52	3.40	4.53	4.98	5.55	5.90	6.46	7.25	7.83	8.94	10.50	11.74	17.06	28.17
22	0.33	0.44	0.53	0.71	0.96	1.29	1.53	2.06	2.78	3.74	4.95	5.49	6.12	6.52	7.12	8.02	8.65	9.87	11.53	12.92	18.83	30.98
24	0.36	0.48	0.58	0.77	1.04	1.40	1.67	2.25														

Table 3-4B. Solano County Design Rainfall for Sacramento River Drainage Region

25-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.25	0.33	0.39	0.53	0.71	0.96	1.14	1.54	2.07	2.79	3.91	4.14	4.60	4.96	5.25	5.80	6.31	7.10	8.63	9.50	13.52	22.16
15	0.26	0.35	0.42	0.57	0.76	1.03	1.23	1.65	2.22	2.99	4.16	4.45	4.94	5.34	5.65	6.25	6.79	7.63	9.23	10.18	14.54	23.74
16	0.28	0.38	0.45	0.61	0.82	1.10	1.31	1.76	2.37	3.19	4.42	4.75	5.28	5.72	6.04	6.70	7.27	8.17	9.82	10.87	15.57	25.32
17	0.30	0.40	0.48	0.64	0.87	1.17	1.39	1.87	2.52	3.39	4.67	5.06	5.62	6.09	6.43	7.15	7.75	8.71	10.42	11.56	16.59	26.91
18	0.32	0.43	0.51	0.68	0.92	1.24	1.47	1.98	2.66	3.59	4.92	5.36	5.96	6.47	6.83	7.60	8.23	9.25	11.01	12.24	17.61	28.49
19	0.33	0.45	0.53	0.72	0.97	1.30	1.55	2.09	2.81	3.79	5.17	5.67	6.30	6.85	7.22	8.05	8.71	9.78	11.61	12.93	18.63	30.07
20	0.35	0.47	0.56	0.76	1.02	1.37	1.63	2.20	2.96	3.99	5.42	5.97	6.64	7.23	7.62	8.50	9.19	10.32	12.20	13.61	19.66	31.66
22	0.39	0.52	0.62	0.83	1.12	1.51	1.80	2.42	3.26	4.39	5.92	6.58	7.31	7.99	8.41	9.40	10.16	11.39	13.39	14.99	21.70	34.82
24	0.42	0.57	0.67	0.91	1.22	1.65	1.96	2.64	3.55	4.78	6.42	7.19	7.99	8.75	9.20	10.31	11.12	12.47	14.58	16.36	23.74	37.99
26	0.46	0.61	0.73	0.98	1.33	1.78	2.12	2.86	3.85	5.18	6.93	7.80	8.67	9.50	9.98	11.21	12.08	13.54	15.77	17.73	25.79	41.15
28	0.49	0.66	0.79	1.06	1.43	1.92	2.29	3.08	4.15	5.58	7.43	8.41	9.35	10.26	10.77	12.11	13.04	14.61	16.96	19.10	27.83	44.32
30	0.53	0.71	0.84	1.14	1.53	2.06	2.45	3.30	4.44	5.98	7.93	9.02	10.03	11.02	11.56	13.01	14.01	15.69	18.15	20.47	29.88	47.48
32	0.56	0.76	0.90	1.21	1.63	2.20	2.61	3.52	4.74	6.38	8.43	9.63	10.71	11.78	12.35	13.91	14.97	16.76	19.34	21.84	31.92	50.65
34	0.60	0.80	0.96	1.29	1.73	2.33	2.78	3.74	5.03	6.78	8.93	10.24	11.38	12.54	13.14	14.82	15.93	17.84	20.53	23.22	33.97	53.82
36	0.63	0.85	1.01	1.36	1.84	2.47	2.94	3.96	5.33	7.18	9.44	10.85	12.06	13.29	13.93	15.72	16.89	18.91	21.72	24.59	36.01	56.98
38	0.67	0.90	1.07	1.44	1.94	2.61	3.10	4.18	5.63	7.57	9.94	11.46	12.74	14.05	14.72	16.62	17.85	19.98	22.91	25.96	38.06	60.15
40	0.70	0.95	1.12	1.51	2.04	2.74	3.27	4.40	5.92	7.97	10.44	12.07	13.42	14.81	15.50	17.52	18.82	21.06	24.10	27.33	40.10	63.31
45	0.79	1.06	1.27	1.70	2.29	3.09	3.68	4.95	6.66	8.97	11.69	13.60	15.11	16.70	17.48	19.78	21.22	23.74	27.08	30.76	45.22	71.23

50-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.27	0.37	0.44	0.59	0.79	1.06	1.26	1.70	2.29	3.09	4.38	4.64	5.14	5.53	5.82	6.40	6.90	7.75	9.47	10.41	14.75	23.81
15	0.29	0.39	0.47	0.63	0.85	1.14	1.35	1.82	2.46	3.31	4.66	4.98	5.52	5.96	6.26	6.90	7.43	8.34	10.12	11.16	15.87	25.51
16	0.31	0.42	0.50	0.67	0.90	1.21	1.44	1.95	2.62	3.53	4.94	5.33	5.90	6.38	6.69	7.40	7.96	8.93	10.77	11.91	16.98	27.21
17	0.33	0.44	0.53	0.71	0.96	1.29	1.54	2.07	2.78	3.75	5.22	5.67	6.28	6.80	7.13	7.90	8.48	9.51	11.42	12.66	18.10	28.92
18	0.35	0.47	0.56	0.75	1.01	1.37	1.63	2.19	2.95	3.97	5.50	6.01	6.66	7.23	7.57	8.39	9.01	10.10	12.08	13.41	19.21	30.62
19	0.37	0.50	0.59	0.80	1.07	1.44	1.72	2.31	3.11	4.19	5.78	6.35	7.04	7.65	8.01	8.89	9.54	10.68	12.73	14.16	20.33	32.32
20	0.39	0.52	0.62	0.84	1.13	1.52	1.81	2.43	3.27	4.41	6.07	6.69	7.41	8.07	8.44	9.39	10.06	11.27	13.38	14.91	21.44	34.02
22	0.43	0.57	0.68	0.92	1.24	1.67	1.99	2.67	3.60	4.85	6.63	7.38	8.17	8.92	9.32	10.39	11.12	12.44	14.69	16.42	23.68	37.42
24	0.47	0.63	0.75	1.00	1.35	1.82	2.17	2.92	3.93	5.29	7.19	8.06	8.93	9.76	10.19	11.38	12.17	13.62	15.99	17.92	25.91	40.82
26	0.50	0.68	0.81	1.09	1.47	1.97	2.35	3.16	4.26	5.73	7.75	8.74	9.69	10.61	11.07	12.38	13.22	14.79	17.30	19.42	28.14	44.22
28	0.54	0.73	0.87	1.17	1.58	2.12	2.53	3.40	4.58	6.17	8.31	9.43	10.45	11.46	11.94	13.37	14.27	15.96	18.60	20.93	30.37	47.63
30	0.58	0.78	0.93	1.26	1.69	2.28	2.71	3.65	4.91	6.61	8.87	10.11	11.20	12.30	12.81	14.37	15.33	17.13	19.91	22.43	32.60	51.03
32	0.62	0.84	1.00	1.34	1.80	2.43	2.89	3.89	5.24	7.05	9.44	10.79	11.96	13.15	13.69	15.37	16.38	18.31	21.21	23.93	34.83	54.43
34	0.66	0.89	1.06	1.42	1.92	2.58	3.07	4.13	5.57	7.49	10.00	11.48	12.72	13.99	14.56	16.36	17.43	19.48	22.52	25.43	37.06	57.83
36	0.70	0.94	1.12	1.51	2.03	2.73	3.25	4.38	5.89	7.93	10.56	12.16	13.48	14.84	15.44	17.36	18.49	20.65	23.82	26.94	39.29	61.23
38	0.74	0.99	1.18	1.59	2.14	2.88	3.43	4.62	6.22	8.38	11.12	12.85	14.24	15.69	16.31	18.35	19.54	21.82	25.13	28.44	41.52	64.63
40	0.78	1.05	1.24	1.67	2.25	3.03	3.61	4.86	6.55	8.82	11.68	13.53	14.99	16.53	17.18	19.35	20.59	23.00	26.43	29.94	43.76	68.04
45	0.87	1.18	1.40	1.88	2.54	3.41	4.06	5.46	7.36	9.90	13.40	15.52	17.11	18.83	19.33	21.61	22.87	25.21	29.24	33.04	47.15	72.74

100-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.30	0.40	0.48	0.64	0.86	1.16	1.38	1.86	2.50	3.37	4.83	5.13	5.67	6.10	6.37	5.89	7.50	8.37	10.26	11.27	15.91	25.35
15	0.32	0.43	0.51	0.69	0.92	1.24	1.48	1.99	2.68	3.61	5.14	5.51	6.08	6.56	6.85	6.35	8.08	9.00	10.96	12.08	17.12	27.16
16	0.34	0.46	0.54	0.73	0.99	1.33	1.58	2.13	2.86	3.85	5.45	5.88	6.50	7.03	7.32	6.81	8.65	9.64	11.67	12.89	18.32	28.97
17	0.36	0.49	0.58	0.78	1.05	1.41	1.68	2.26	3.04	4.09	5.76	6.26	6.92	7.49	7.80	7.27	9.22	10.27	12.38	13.71	19.52	30.78
18	0.38	0.51	0.61	0.82	1.11	1.49	1.78	2.39	3.22	4.33	6.07	6.64	7.34	7.96	8.28	7.73	9.79	10.90	13.08	14.52	20.73	32.59
19	0.40	0.54	0.65	0.87	1.17	1.57	1.87	2.52	3.40	4.58	6.38	7.02	7.75	8.43	8.76	8.19	10.36	11.53	13.79	15.33	21.93	34.40
20	0.42	0.57	0.68	0.91	1.23	1.66	1.97	2.66	3.58	4.82	6.69	7.39	8.17	8.89	9.24	8.65	10.94	12.17	14.50	16.15	23.13	36.21
22	0.47	0.63	0.75	1.01	1.35	1.82	2.17	2.92	3.93	5.30	7.31	8.15	9.01	9.82								

Table 3-4B. Solano County Design Rainfall for Sacramento River Drainage Region

500-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.35	0.48	0.57	0.76	1.03	1.38	1.64	2.21	2.98	4.01	5.84	6.21	6.82	7.33	7.55	8.31	8.87	9.73	12.02	13.19	18.48	28.72
15	0.38	0.51	0.61	0.82	1.10	1.48	1.76	2.37	3.19	4.30	6.21	6.67	7.32	7.89	8.12	8.96	9.54	10.47	12.85	14.14	19.88	30.77
16	0.40	0.54	0.65	0.87	1.17	1.58	1.88	2.53	3.41	4.59	6.59	7.12	7.83	8.45	8.68	9.60	10.22	11.21	13.68	15.09	21.27	32.82
17	0.43	0.58	0.69	0.93	1.25	1.68	2.00	2.69	3.62	4.87	6.96	7.58	8.33	9.01	9.25	10.25	10.89	11.94	14.51	16.04	22.67	34.87
18	0.45	0.61	0.73	0.98	1.32	1.78	2.11	2.85	3.83	5.16	7.34	8.04	8.83	9.57	9.82	10.89	11.57	12.68	15.34	17.00	24.07	36.92
19	0.48	0.65	0.77	1.03	1.39	1.88	2.23	3.01	4.05	5.45	7.71	8.49	9.33	10.13	10.38	11.54	12.25	13.41	16.17	17.95	25.47	38.97
20	0.50	0.68	0.81	1.09	1.47	1.97	2.35	3.16	4.26	5.73	8.09	8.95	9.84	10.69	10.95	12.19	12.92	14.15	17.00	18.90	26.86	41.02
22	0.56	0.75	0.89	1.20	1.61	2.17	2.58	3.48	4.68	6.31	8.84	9.87	10.84	11.81	12.08	13.48	14.28	15.62	18.66	20.81	29.66	45.13
24	0.61	0.82	0.97	1.31	1.76	2.37	2.82	3.80	5.11	6.88	9.58	10.78	11.85	12.93	13.22	14.77	15.63	17.10	20.31	22.71	32.45	49.23
26	0.66	0.88	1.05	1.42	1.91	2.57	3.05	4.11	5.54	7.45	10.33	11.69	12.85	14.05	14.35	16.06	16.98	18.57	21.97	24.62	35.25	53.33
28	0.71	0.95	1.13	1.52	2.05	2.76	3.29	4.43	5.96	8.03	11.08	12.61	13.86	15.17	15.48	17.36	18.33	20.04	23.63	26.52	38.04	57.43
30	0.76	1.02	1.21	1.63	2.20	2.96	3.52	4.74	6.39	8.60	11.83	13.52	14.86	16.29	16.62	18.65	19.69	21.51	25.29	28.43	40.84	61.54
32	0.81	1.09	1.29	1.74	2.35	3.16	3.76	5.06	6.81	9.17	12.58	14.44	15.87	17.41	17.75	19.94	21.04	22.99	26.95	30.33	43.63	65.64
34	0.86	1.16	1.38	1.85	2.49	3.36	3.99	5.38	7.24	9.75	13.33	15.35	16.87	18.53	18.88	21.24	22.39	24.46	28.60	32.23	46.43	69.74
36	0.91	1.22	1.46	1.96	2.64	3.55	4.23	5.69	7.67	10.32	14.08	16.27	17.88	19.65	20.02	22.53	23.74	25.93	30.26	34.14	49.22	73.84
38	0.96	1.29	1.54	2.07	2.79	3.75	4.46	6.01	8.09	10.89	14.83	17.18	18.88	20.77	21.15	23.82	25.09	27.40	31.92	36.04	52.02	77.95
40	1.01	1.36	1.62	2.18	2.93	3.95	4.70	6.33	8.52	11.47	15.58	18.10	19.89	21.89	22.29	25.11	26.45	28.87	33.58	37.95	54.81	82.05
45	1.14	1.53	1.82	2.45	3.30	4.44	5.29	7.12	9.58	12.90	17.45	20.38	22.40	24.69	25.12	28.35	29.83	32.56	37.72	42.71	61.80	92.30

1,000-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.38	0.51	0.60	0.81	1.09	1.47	1.75	2.36	3.17	4.27	6.29	6.69	7.34	7.88	8.09	8.78	9.36	10.24	12.68	13.90	19.43	29.91
15	0.40	0.54	0.65	0.87	1.17	1.58	1.88	2.53	3.40	4.58	6.69	7.18	7.88	8.49	8.69	9.47	10.07	11.01	13.55	14.90	20.90	32.05
16	0.43	0.58	0.69	0.93	1.25	1.68	2.00	2.69	3.63	4.88	7.09	7.67	8.42	9.09	9.30	10.15	10.78	11.79	14.42	15.90	22.37	34.18
17	0.46	0.62	0.73	0.99	1.33	1.79	2.13	2.86	3.85	5.19	7.50	8.17	8.96	9.69	9.91	10.83	11.50	12.56	15.30	16.91	23.84	36.32
18	0.48	0.65	0.78	1.04	1.40	1.89	2.25	3.03	4.08	5.49	7.90	8.66	9.50	10.29	10.52	11.52	12.21	13.34	16.17	17.91	25.31	38.46
19	0.51	0.69	0.82	1.10	1.48	2.00	2.38	3.20	4.31	5.80	8.30	9.15	10.04	10.90	11.12	12.20	12.92	14.11	17.05	18.91	26.78	40.59
20	0.54	0.72	0.86	1.16	1.56	2.10	2.50	3.37	4.53	6.10	8.71	9.65	10.58	11.50	11.73	12.88	13.64	14.89	17.92	19.92	28.25	42.73
22	0.59	0.80	0.95	1.28	1.72	2.31	2.75	3.70	4.99	6.71	9.51	10.63	11.67	12.70	12.95	14.25	15.06	16.44	19.67	21.93	31.19	47.00
24	0.64	0.87	1.03	1.39	1.87	2.52	3.00	4.04	5.44	7.33	10.32	11.62	12.75	13.91	14.16	15.61	16.49	17.98	21.42	23.93	34.13	51.28
26	0.70	0.94	1.12	1.51	2.03	2.73	3.25	4.38	5.89	7.94	11.13	12.60	13.83	15.11	15.38	16.98	17.92	19.53	23.16	25.94	37.07	55.55
28	0.75	1.01	1.21	1.62	2.19	2.94	3.50	4.71	6.35	8.55	11.93	13.59	14.91	16.32	16.59	18.35	19.34	21.08	24.91	27.95	40.01	59.82
30	0.81	1.09	1.29	1.74	2.34	3.15	3.75	5.05	6.80	9.16	12.74	14.57	15.99	17.52	17.80	19.71	20.77	22.63	26.66	29.95	42.94	64.09
32	0.86	1.16	1.38	1.86	2.50	3.36	4.00	5.39	7.25	9.77	13.55	15.56	17.08	18.73	19.02	21.08	22.20	24.18	28.41	31.96	45.88	68.37
34	0.91	1.23	1.46	1.97	2.65	3.57	4.25	5.72	7.71	10.38	14.35	16.54	18.16	19.93	20.23	22.45	23.62	25.73	30.16	33.97	48.82	72.64
36	0.97	1.30	1.55	2.09	2.81	3.78	4.50	6.06	8.16	10.99	15.16	17.53	19.24	21.14	21.45	23.81	25.05	27.28	31.90	35.98	51.76	76.91
38	1.02	1.37	1.64	2.20	2.97	3.99	4.75	6.40	8.61	11.60	15.97	18.51	20.32	22.34	22.66	25.18	26.48	28.83	33.65	37.98	54.70	81.19
40	1.07	1.45	1.72	2.32	3.12	4.20	5.00	6.74	9.07	12.21	16.77	19.50	21.40	23.55	23.88	27.90	30.38	35.40	39.99	57.64	85.46	
45	1.21	1.63	1.94	2.61	3.51	4.73	5.63	7.58	10.20	13.73	18.79	21.96	24.11	26.56	26.91	29.96	31.47	34.25	39.77	45.01	64.99	96.14

10,000-Year Return Period

MAP	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	8 Day	10 day	15 Day	20 Day	30 Day	60 Day	Year
14	0.45	0.61	0.72	0.97	1.31	1.77	2.10	2.83	3.81	5.13	7.69	8.20	8.94	9.60	9.71	10.47	11.39	11.94	14.90	16.32	22.63	33.95
15	0.48	0.65	0.78	1.04	1.41	1.89	2.25	3.03	4.08	5.50	8.19	8.80	9.60	10.33	10.44	11.29	12.26	12.84	15.93	17.50	24.34	36.38
16	0.52	0.70	0.83	1.11	1.50	2.02	2.40	3.24	4.36	5.87	8.68	9.41	10.26	11.06	11.17	12.10	13.12	13.75	16.96	18.67	26.05	38.80
17	0.55	0.74	0.88	1.18	1.59	2.15	2.55	3.44	4.63	6.23	9.17	10.01	10.92	11.80	11.90	12.92	13.99	14.65	17.98	19.85	27.76	41.23
18	0.58	0.78	0.93	1.25	1.69	2.27	2.70	3.64	4.90	6.60	9.67	10.61	11.58	12.53	12.63	13.73	14.86	15.55	19.01	21.03	29.48	43.65
19	0.61	0.83	0.98	1.32	1.78	2.40	2.85	3.84	5.17	6.97	10.16	11.22	12.24	13.27	13.36	14.54	15.73	16.45	20.04	22.21	31.19	46.08
20	0.65	0.87	1.03	1.39	1.88	2.52	3.00	4.05	5.45	7.33	10.65	11.82	12.90	14.00	14.09	15.36	16.60	17.36	21.07	23.39	32.90	48.50
22	0.71	0.96																				

5. Compute average ground slope of drainage area from an appropriate topographic map. Compute the slope of the gutter flow path and the pipe slope.
6. Compute t_o using Figure 3-2 or Equation 3-2. Compute the t_g and t_p using Equations 3-4 and 3-5. Sum t_o , t_g , t_p to get the time of concentration, t_c . Be sure to use the time of concentration for the longest flow path, which may be from an upstream subshed that flows through the current subshed.
7. Using MAP, t_c , and Table 3-4, determine the rainfall depth (linear interpolation between table entries may be required).
8. Compute the rainfall intensity I (inches/hour) by dividing the rainfall depth (inches) by t_c (hours).
9. Compute peak discharge Q using the rational formula, Equation 3-1.

A rational method example is provided in Appendix B.

3.4 HEC-1 & HEC-HMS

For drainage areas greater than 200 acres or if the drainage system includes a detention basin or reservoir, it is recommended that HEC-1 or HEC-HMS be used as the analysis method.

HEC-1 and HEC-HMS are computer programs which, among other capabilities, calculate runoff hydrographs, and route the hydrographs through channels, pipes, detention basins, and reservoirs. Both of these programs were developed by the U.S. Army Corp. of Engineers Hydrologic Engineering Center (HEC). HEC-1 was originally developed (version 1.0) in 1968. Since then it has been revised several times, with the most current version (version 4.0) having been released in 1990. HEC-1 is a disk operating system (DOS) based program, which means that the input is provided to the programs from a text file. HEC-HMS is a new program (released in March 1998) with many of the same capabilities of HEC-1. However, HEC-HMS was programmed to run with Microsoft Windows, which means that the input data is provided to the program through a series of dialog boxes (pop up windows with data entry boxes and tables). The information presented in this section applies to both HEC-1 and HEC-HMS.

This manual is not intended to describe how to use HEC-1 or HEC-HMS. It is assumed that the reader is familiar with either or both of these programs. If this is not the case, the appropriate program manual should be consulted for guidance on use of these programs.

The basic process of hydrologic modeling with HEC-1/HEC-HMS includes:

- Simulation of rainfall from some storm event.
- Simulation of rainfall losses due to interception and infiltration.
- Simulation of the flow of the rain over the ground surface as it concentrates into runoff hydrographs in creeks, channels or pipes.
- Simulation of the routing of the hydrographs through pipes, channels, or creeks.
- Simulation of the routing of hydrographs through detention basins or reservoirs.

It is important to remember that these computer programs only simulate, or model, the processes that are occurring in the real world. Sometimes the programs deviate significantly from the actual process which is supposed to be simulated. Thus, when using these programs (or any model), it is important to verify that the results represent a reasonable simulation of the actual conditions.

Data for implementation of each of these process steps with HEC-1/HEC-HMS is presented and described below. Information is presented below which simplifies the use of the recommended methods. However, use of these recommended methods is not required, and other methods within HEC-1 or HEC-HMS (or other programs) can be used.

In HEC-1 a single line of input data is referred to as a record, with each record beginning with a two character code that identifies the record type (for example, the PH record). Data entry is discussed in this manual by reference to these HEC-1 record types. Additionally, for each reference to a HEC-1 record, the HEC-HMS menu selection leading to the equivalent data entry dialog box is given.

Precipitation

One of the first steps in estimating a runoff hydrograph is to quantify the storm or precipitation which is generating the runoff hydrograph. The frequency-based hypothetical storm method (the PH record in HEC-1) simulates nested/centered storms, and is recommended for use because: (1) it is intended specifically for developing hydrographs and peak flows from "design" storms of any frequency for which data are available and for durations of up to 10 days, (2) the required data are all available in the report *Design Rainfall for Solano County* (see Appendix A), and (3) this method is very simple to use.

In HEC-HMS, the PH data are entered as follows:

1. From the HEC*Project Definition window, select menu item "Edit-Precipitation Model-New". This will open the HMS*New Precipitation Model dialog box.
2. Enter appropriate data, and click the "OK" button. The HMS Precipitation Model-Method Select dialog box will open.
3. Select "Frequency-Based Hypothetical Storm", and click OK.

The data include:

- Storm Frequency (%)—Leave blank.
- Storm Area (mi^2)—Leave blank (assuming storm covers entire watershed area entered in BA record).
- 5-minute through 10-day rainfall depths (inches)—Enter the appropriate rainfall depths to cover the time period of the model.

Shown on Figure 2-2 is an isohyetal map of Solano County. Design rainfall depths are presented in Tables 3-4A and 3-4B for the San Francisco Bay and Sacramento River drainage regions.

Precipitation Losses

Precipitation losses account for how much rain is intercepted by wetting of vegetation, storage in depressions, and infiltration into the ground. The difference between the precipitation rate and the precipitation loss is the quantity of rainfall that becomes runoff.

The Initial/Constant precipitation loss method is recommended for use in HEC-1 or HEC-HMS (The LU data record in HEC-1. For HEC-HMS, from the HMS*Schematic window, double-click on the subbasin element icon, select the “Loss Rate” folder, and select “Initial/Constant” from the “Method” drop down list.). This is the simplest of the precipitation loss methods and the most intuitively understandable. For this method, only three simple values are needed, including:

- Initial loss (inches of rainfall)—Value to account for interception and depression storage. No runoff occurs from pervious areas until this quantity of precipitation has fallen.
- Constant loss rate (inches/hour)—After the cumulative precipitation exceeds the initial loss, precipitation is lost at this constant loss rate to account for infiltration.
- Percent impervious (%)—Represents the fraction of the area that is impervious, such as rooftops, roads, and paved areas. No losses (neither initial nor constant) are subtracted from the precipitation for the percentage of the basin that is impervious.

Presented in Table 3-5 are recommended initial loss rates for various land uses. Although there are small depression storage losses on impervious surfaces, HEC-1 and HEC-HMS automatically assume no losses occur on impervious surfaces, and this simplifying assumption is included in the recommendations in Table 3-5.

Table 3-5. Recommended Initial Losses

Land Use	Recommended Initial Loss, inches
Paved Areas	0.0
Sloped Roofs	0.0
Flat Roofs	0.0
Lawn Grass	0.3
Open Fields with Minimal Vegetation	0.2
Open Fields with Cover Crop	0.3
Wooded Areas	0.4

Presented in Table 3-6 are recommended constant loss rates for each of the NRCS hydrologic soil groups. The appropriate hydrologic soil group for any location or soil type in Solano County can be found in *Soil Survey of Solano County, California* (issued May 1977).

Table 3-6. Recommended Constant Loss Rates

NRCS Hydrologic Soil Group	Recommended Constant Loss Rate, ^(a) inches/hour
A	0.35
B	0.20
C	0.10
D	0.02

^(a) Some agricultural practices compact the soil and reduce infiltration rates. In such areas, the loss rate should be reduced appropriately.

Initial and constant loss rates for a watershed of several land uses or soil groups can be calculated with an area-weighted average.

In addition to the loss rates, it is also necessary to enter the impervious percentage on the LU data record. Typical impervious percentages for several land uses are listed in Table 3-7. However, for any specific development project or area, the actual impervious percentage should be used, if it is known or can be determined.

Table 3-7. Impervious Percentage for Common Land Uses

Land Use Type	Impervious Percentage
Highways, Parking Areas	95
Commercial, Industrial, Office	85-95
Apartments, Condominiums	70-80
Single Family Residential (including duplex or split lot housing)	
6 - 10 units/acre	50-60
3 - 6 units/acre	30-50
1 - 3 units/acre	15-30
< 1 unit/acre	5-15
Parks	5-10
Open Space (fields, wooded areas)	1-5

Precipitation Excess Transform Methods

The Snyder Method is recommended for use in HEC-1 and HEC-HMS for transforming the rainfall excess into a runoff hydrograph. (The US record in HEC-1. For HEC-HMS, from the HMS*Schematic window, double-click on the subbasin element icon, select the "Transform" folder, and select "Snyder" from the "Method" drop down list.) This method estimates unit hydrographs based on the physical characteristics of the watershed/channel system. The data requirements for the Snyder method are:

- Snyder's standard lag (hrs)—This value is the time from the centroid of rainfall excess to the peak flow at the point of analysis (see Figure 3-3).
- Snyder's peaking coefficient (cfs)—This value represents the peak flow for the unit hydrograph at the point of analysis. A value of 0.45 should be used.

One optional data set could be used to describe the time-area relationship of the watershed (the UA record in HEC-1, not available in HEC-HMS), but because this relationship is difficult to develop accurately, use of the UA record is not recommended. If this record is not used, HEC-1/HEC-HMS automatically uses a default relationship.

The Snyder Standard Lag is defined as the time from the centroid of the rainfall to the time of peak flow, as shown in Figure 3-3. Snyder's standard lag can be determined using Figure 3-4 or calculated using Equation 3-6. This equation for L_s has been developed so that peak flows from recent large storms in Gibson Canyon Creek match the gaged flows for the creek (see the example in Appendix C).

$$L_s = 0.34 * (0.728 - 0.00546 * P) * (A/(S^{0.5}))^{0.2} \quad (\text{Equation 3-6})$$

where:

- L_s = Snyder's standard lag time, hours
- P = Percent urbanization, or the percentage of the watershed that is commercial, industrial, residential, institutional, and otherwise developed. Percent urbanization is **not** the same as the percent impervious.
- A = Area of watershed, acres
- S = Slope of the main channel, feet/feet

Hydrograph Routing

The Muskingum-Cunge hydrograph routing method is recommended for use (The RD record in HEC-HMS. From the HMS*Schematic window, double-click on a reach element icon, and select "Muskingum Cunge Std" or "Muskingum Cunge 8 Point" from the "Routing Method" drop down list.). This method can be used with the standard channel sections (trapezoidal, square, or circular) or with 8 point channel cross sections (on RC, RX, and RY records). The data required to use this method include:

- Channel length (ft)—Measured from drainage system maps or USGS quadrangle maps.
- Energy grade line slope (ft/ft)—Approximated with the channel or pipe slope.
- Manning's n—Standard values for many pipe materials may be used. For open channels, a site visit is recommended to accurately determine the n value.
- Channel shape—Either trapezoidal, square, or circular (or an 8 point channel cross-section on RC, RX, RY records).
- Channel bottom width (for trapezoidal channels) or diameter (for pipelines).

Figure 3-3. Definition of Snyder's Standard Lag Time

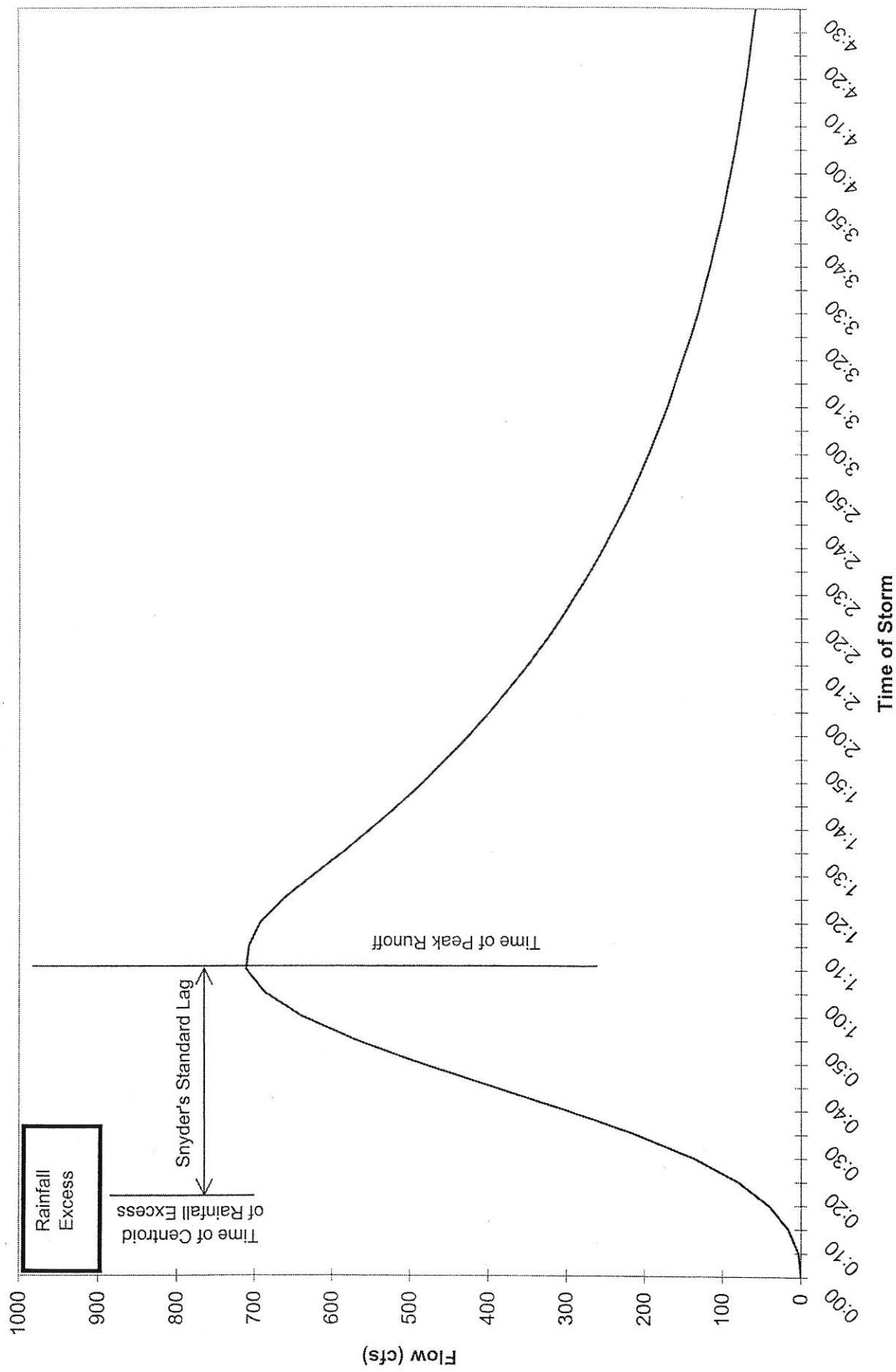
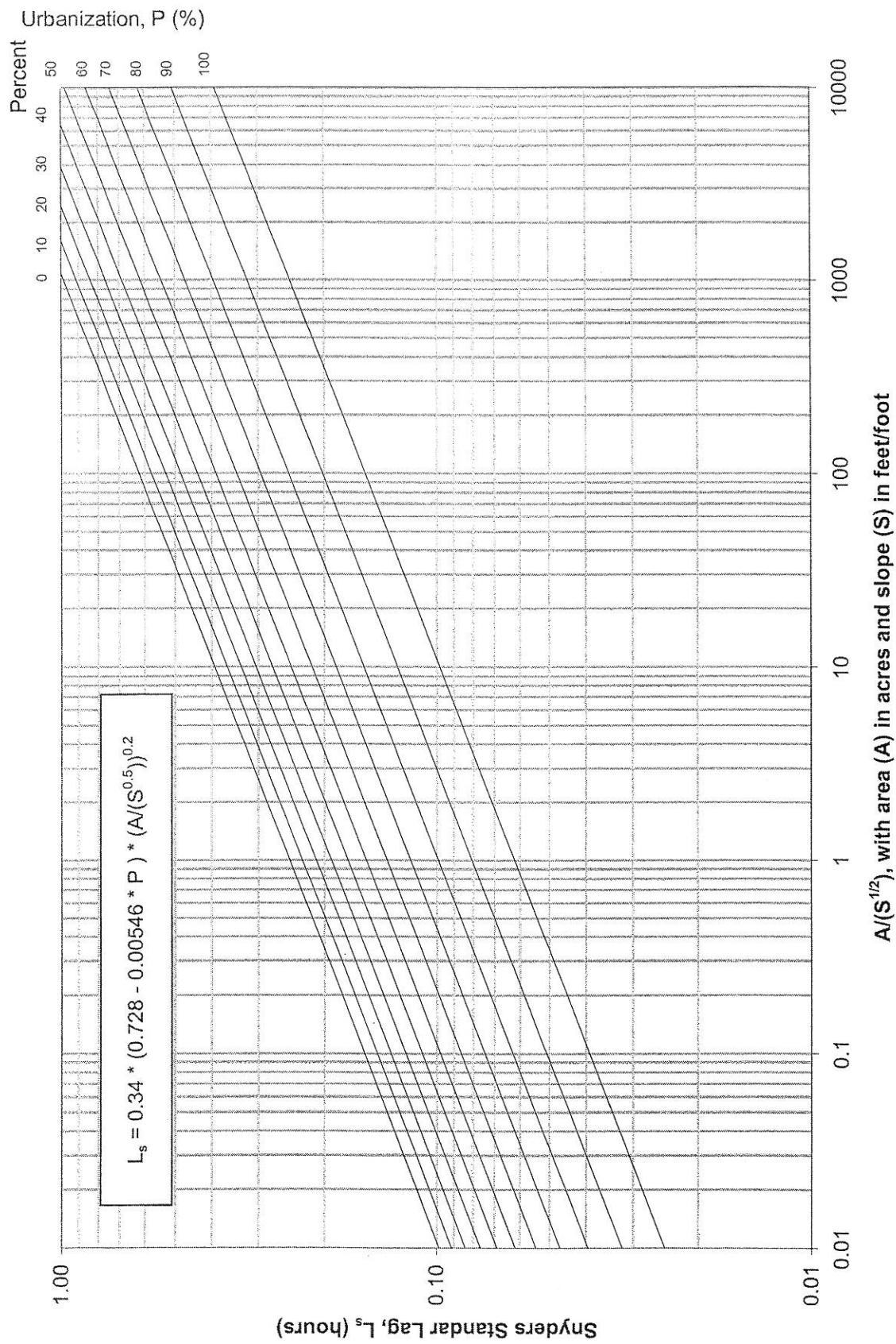


Figure 3-4. Snyder's Standard Lag Time, L_s



- Side slopes (for trapezoidal channels only).
- Routing increments—Number of increments used in the finite difference solution. This value is optional, and if not specified, the HEC program will automatically select an appropriate value.

If used, the RC, RX, and RY data records describe the channel roughness, length, slope, and geometry.

Reservoir Routing

Reservoir routing in HEC-1 is completed using one of two general approaches:

1. Providing the program with the user defined reservoir elevation (on SE records) versus storage volumes (on SV records) or reservoir surface area (on SA records, and the program calculates volumes), and the physical dimensions of the low level release structure and the spillway structure (on SL, SS, ST records). The program then calculates an elevation versus release relationship and tracks the inflow, storage, and release based on the user defined and program calculated relationships.
2. Providing the program with the user defined reservoir elevation (on SE records) versus storage volumes (on SV records) or reservoir surface area (on SA records, and the program calculates volumes), versus release (on SQ records) relationship. The program then tracks the inflow, storage, and release based on the user-defined relationships.

Either of these methods is recommended for use in HEC-1, however, HEC-HMS currently provides only the capability to use the second method. From the HMS*Schematic window, double-click the reservoir element icon. The data for these reservoir routing methods is dependent upon the specific reservoir site, dam/basin size, and release structure. Consequently, simple formulas for calculating the data values can not be provided.

Other HEC-1/HEC-HMS Capabilities

HEC-1/HEC-HMS have many other capabilities, such as simulations of pump stations, flow diversions, optimization capabilities, and more. Although not discussed here, any of these capabilities can and should be used if appropriate.