APPENDIX B. RATIONAL METHOD EXAMPLE

GIVEN

A watershed in the San Francisco Bay drainage region with mixed land uses is shown in Figure B-1. The land uses were determined by a site visit. Subshed boundaries were delineated and acreage of each land use within each subshed determined (see Figure B-1). All ground slopes were surveyed during the site visit, as shown on Figure B-1. Pipe sizes, lengths, and slopes were also surveyed, as shown on Figure B-2. The watershed is located in the San Francisco Bay drainage region and has a mean annual precipitation of 30 inches.

REQUIRED

Determine peak flows for a 10-year storm event at each analysis point.

SOLUTION

The total watershed area is 76.7 acres (less than 200 acres), thus the rational method is an appropriate analysis method (see Table 3-1). A rational method analysis is presented in Table B-1 and described below.

ANALYSIS POINT 1—(Tributary area is subshed A)

Row 2—

Column 1: Analysis Point = 1.

Subshed Data

Column 2: Subshed Name = A.

Column 3: Land Use = Agricultural. The land use can be determined from a site visit, aerial photograph, or land use map.

Column 4: Area = 11.5 acres. Area can be planimetered or scaled from the map.

Column 5: Runoff Coefficient = 0.20. C value is from Table 3-2.

Column 6: C*A = 2.30. This is the product of Columns 4 and 5 for each land use in the subshed (only 1 land use for Subshed A).

Cumulative Watershed Values

Column 7: Cumulative C*A = 2.30. Since this is an uppermost subshed, this cumulative value is simply equal to Column 6.

Column 8: Cumulative Area = 11.5 acres. Since this is an uppermost subshed, this cumulative value is simply equal to Column 5.

Column 9: Cumulative Runoff. Coefficient C = 0.20. This value is Column 7 divided by Column 8.

Overland Flow Data

Column 10: Length = 800 feet. This is the length of the path which generates the longest overland flow time. For this subshed, it is clear that the correct path starts in the northeast corner and flows west to the north end of the creek channel. This is necessarily the longest flow path because it has the longest overland flow length, the flattest slope, and the lowest C value (agricultural land versus street/gutter). It may be necessary to check several paths to ensure the path with the longest flow time is found.

Column 11: Slope = 5%. In this example, slopes were measured during a site visit, and are shown on Figure B-1. However, slope can also be scaled from a topographic map at a scale sufficient to obtain representative slopes.

Column 12: Overland flow path C value = 0.20. The C value along the overland flow path should be used.

Column 13: Overland flow time (t_o) = 32.1 minutes. This time can be read from Figure 3-2 or calculated with Equation 3-2.

Gutter/Channel Data

Column 14: Length = 230 feet. This is the length from the north end of the channel to the pipe inlet.

Column 15: Slope = 0.01. This is the slope of the gutter or channel flow line.

Column 16: Manning's "n" = 0.030. This value can be obtained from Table 3-3. For this example, this channel is an earth bottom channel with rubble sides.

Column 17: Hydraulic Radius = 1.05. This is the bank full hydraulic radius of the channel or gutter. The hydraulic radius is calculated as the area of flow divided by the wetted perimeter. For this channel the hydraulic radius is 8.0 ft^2/7.6 ft = 1.05 ft (see Figure B-1).

Column 18: Flow Velocity = 5.1 ft/sec. Flow velocity is calculated using Manning's equation, which is $V = (1.49 * S^{1/2} * R_h^{2/3})/n$.

Column 19: Gutter Travel Time (t_g)= 0.7 minutes. This value is calculated by dividing the channel length by the flow velocity and converting from seconds to minutes (dividing by 60).

Pipe Data

Column 20: Length = 150 feet. This value can be measured during a site visit or measured from a map or design drawings of the storm water collection system.

Column 21: Pipe Diameter = 18 inches, which is 1.5 feet.

Column 22: Slope = 0.02 feet/foot. This value is available from design drawings or site survey.

Column 23: Manning's "n" = 0.024. This example pipe is corrugated metal with an n value of 0.024.

Column 24: Hydraulic Radius (R_h) = 0.375 feet. For a pipe flowing full, the R_h is the pipe diameter divided by 4. For this example, the pipe is an 18-inch pipe and thus has an R_h value of 0.375 feet.

Column 25: Flow Velocity = 4.6 feet/second. Flow velocity is calculated using Manning's equation, which is $V = (1.49 * S^{1/2} * R_h^{2/3})/n$.

Column 26: Pipe Travel Time (t_p) = 0.5 minutes. This value is calculated by dividing the pipe length by the flow velocity and converting from seconds to minutes.

Subshed Rational Method

Column 27: Time of Concentration = 33.4 minutes. This value is the sum of t_o, t_g, and t_p.

Column 28: Rainfall Depth = 1.06 inches. This value can be read/interpolated using Table 3-4, read/interpolated using Table 1 of the report *Design Rainfall for Solano County* (see Appendix A) or calculated using Equation 1 from the report *Design Rainfall for Solano County.*

Column 29: Rainfall Intensity = 1.90 in/hr. This value is calculated by dividing Column 27 by Column 27 (converted to hours).

Column 30: Flow = 4.4 cfs. This peak flow is calculated with the rational method, Flow = C*I*A, with C in Column 5, I in Column 29 and A in Column 4.

Cumulative Watershed Rational Method

Column 31: Time of Concentration = 33.4 minutes. Because this is an uppermost subshed, t_c is simply equal to Column 27.

Column 32: Rainfall Depth = 1.06 inches. This value is based on the time of concentration for the watershed (Column 31).

Column 33: Rainfall Intensity =1.90 in/hr. This value is calculated by dividing Column 32 by Column 31 (converted to hours).

Column 34: Flow = 4.4 cfs. This is the peak flow from the subshed and is calculated with the rational method equation, Flow = C*I*A, with C in Column 9, I in Column 33 and A in Column 8.

ANALYSIS POINT 2—(Tributary area = Subsheds A-B)

Row 4

This row is used to determine the time of flow from Analysis Point 1 to Analysis Point 2.

Column 1: Analysis Point = 2.

Columns 20 -26: Pipe data are entered and the pipe flow time is calculated to be 2.6 minutes

Column 27: Time of Concentration = 36.0 minutes. This value is the sum of the upstream time of concentration (Cell R2C31) and the pipe flow time (Cell R4C26) and is the time of concentration from the northeast corner of the watershed to Analysis Point 2.

Rows 6-8

Subshed Data

Column 2: Subshed Name = B.

Column 3: Land Uses = Park, single family residential (SFR), and neighborhood commercial. Enter each land use on a separate line.

Column 4: Area = 6.8 acres of park, 4.7 acres of SFR, and 2.9 acres of neighborhood commercial. Total the areas of each land use in this column in a separate row. In this case, the total area is 14.4 acres.

Column 5: Runoff Coefficient = 0.18 for park because the slope is between 2 and 10 percent, the C for the SFR is 0.45 because the slope is between 2 and 10 percent, and C for the neighborhood commercial is 0.60 because the slope is 2 percent (see Table 3-2).

Column 6: This is the product of Columns 4 and 5 and is calculated for each land use in the subshed. Total this column for each land use in the subshed (5.08 for this subshed).

Cumulative Watershed Values

Column 7: Cumulative C*A = 7.38. This is the sum of this column (Column 7) for the previous row (Cell C7R2, 2.30) and the total C*A for this watershed (Cell C6R9, 5.08).

Column 8: Cumulative Area = 25.9 acres. This is the sum of this column (Column 8) for the previous analysis point (Cell C8R2, 11.5 acres) and the total area for this watershed (Cell C4R9, 14.4 acres).

Column 9: Cumulative Runoff Coefficient C = 0.28. This value is Column 7 divided by Column 8.

Overland Flow Data

Column 10: Length. This is the length of the path which generates the longest overland flow time. For this subshed, it is not clear where this path will be, because there are several paths with different land uses, lengths, and C values. For the park area the path from the east to the channel has a flatter slope (5%) but shorter flow distance (300 feet) and the path from the west has a longer distance (510 feet), but a steeper slope (7%). Using Equation 3-2, the overland flow time from the east is 20.1 minutes and the overland flow time from the west is 24.1 minutes. Thus the correct path is the one from the west. Similarly, the appropriate path is determined for each land use.

Column 11: Slope. In this example, slopes were measured during a site visit, and are shown on Figure B-1. The slope is entered for each land use. For the park, the 7 percent slope is entered because it generates the longest t_c.

Column 12: Overland Flow Path C Value. The C value along each overland flow path is entered.

Column 13: Overland Flow Time. For each land use, this time can be read from Figure 3-2 or calculated with the Equation 3-2.

Gutter/Channel Data

Column 14: Length. For the park, this is a short reach of channel because the longest overland flow path was from the west to the east just north of the road.

Column 15: Slope. This is the slope of the gutter or channel flow line.

Column 16: Manning's "n." This value can be obtained from Table 3-3 for each subshed flow path.

Column 17: Hydraulic Radius. This is the bank full hydraulic radius of the channel or gutter.

Column 18: Flow Velocity. Flow velocity is calculated using Manning's equation.

Column 19: Gutter Travel Time. This value is calculated by dividing the channel length by the flow velocity and converting from seconds to minutes (dividing by 60) for each subshed path.

Pipe Data

Columns 20 through 26: Typically, short lengths of pipe from the inlet to the main pipe are ignored. However, including them will result in slightly larger times of concentration and lower peak flows. They can be either ignored or included, and in this example they are ignored.

Subshed Rational Method

Column 27: Time of Concentration = 24.3 minutes. This value is the maximum of the sums of t_o, t_g, and t_p for each of the flow paths.

Column 28: Rainfall Depth = 0.93 inches. This value is based on the time of concentration for the subshed (Cell R9C27, which is the maximum of the 3 cells above) and can be read/interpolated using Table 3-4A, read/interpolated using Table 1A of *Design Rainfall for Solano County* (see Appendix A), or calculated using Equation 1 from *Design Rainfall for Solano County*.

Column 29: Rainfall Intensity = 2.28 in/hr. This value is calculated by dividing Column 28 by Column 27 (converted to hours).

Column 30: Flow = 11.6 cfs. This is the peak flow from the subshed and is calculated with the rational method equation, Flow = C*I*A, with C in Column 5, I in Column 29 and A in Column 4.

Cumulative Watershed Rational Method

Column 31: Time of Concentration = 36.0 minutes. This is the longest flow time for any path reaching analysis point 2. In this case it is the flow path from the northeast corner of the watershed via analysis point 1.

Column 32: Rainfall Depth = 1.10 inches. This value is based on the time of concentration for the watershed.

Column 33: Rainfall Intensity =1.83 in/hr. This value is calculated by dividing Column 32 by Column 31 (converted to hours).

Column 34: Flow = 13.5 cfs. This is the peak flow from the subshed and is calculated with the rational method equation, Flow = C*I*A, with C in Column 9, I in Column 33 and A in Column 8.

ANALYSIS POINT 3—(Tributary area = subshed C)

Because analysis point 3 is also at the upstream end of a drainage pipe, the data are entered into the spreadsheet similarly to analysis point 1.

ANALYSIS POINT 4—(Tributary area = Subsheds A - D)

The data for Subshed 4 are entered into the spreadsheet similarly to Analysis Point 2. The cumulative watershed values, however, are the sums of the values for Analysis Point 2, Analysis Point 3, and Subshed 4. There are two pathways going upstream from this analysis point. The first is from Point 4 to Point 1, which has a t_c of 38.0 minutes. The second is from 4 to 3, which has a t_c of 32.1 minutes. For the cumulative watershed rational method analysis at Point 4, the longest t_c for these two pathways must be used (38.0 minutes).

ANALYSIS POINT 5—(Tributary area = Subshed E)

Because Analysis Point 5 is at the upstream end of a drainage pipe, the data are entered into the spreadsheet similarly to Analysis Point 1.

ANALYSIS POINT 6—(Tributary area = Subsheds A - F)

Analysis Point 6 is evaluated similarly to Analysis Point 4.

At this point the rational method analysis is complete, and the peak flow results are summarized in Table B-2.