CHAPTER

11

Time of Concentration Calculation

The time of concentration is the time required for runoff from the most hydrologically remote point in the subarea to reach the subarea outlet. The Modified Rational Method requires a time of concentration calculation for each subarea.

In the past, Public Works used kinematic wave theory to calculate the time of concentration (Section 7.3). To simplify these calculations, Public Works developed a regression equation based on hundreds of studies using kinematic wave theory. The regression equation replaces the original kinematic wave calculations.

Time of concentration calculations can either be done by hand (Section 11.1) or using the T_C calculator program (Section 11.2). Watershed Modeling System (WMS) and XP-SWMM software also incorporate these calculations.

11.1 TIME OF CONCENTRATION – HAND CALCULATIONS

The following provides a step-by-step approach for using the regression equation to calculate the time of concentration. The steps show the calculations for the example in Chapter 7 shown in Figure 7.3.3.

1. **Determine subarea boundaries and then calculate flow path length and flow path slope**

   L = 1,150 feet
   S = (150*0.02+1,000*0.005) / 1,150 = 0.007 ft/ft

2. **Assume an initial value for T_C**

   Assume T_C = 12 minutes

3. Use Equation 5.1.2 to calculate intensity at time t, I_t

$$I_t = I_{1440} * \left(\frac{1440}{t}\right)^{0.47} \Rightarrow I_{12} = \frac{5\,\text{in}}{24\,\text{hr}} * \left(\frac{1440}{12}\right)^{0.47}$$
$$= 1.98 \text{ in/hr}$$

4. Determine the developed soil runoff coefficient using the soil curve data and Equation 6.3.2.

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$
$$= (0.9 * 0.42) + (1.0 - 0.42) * 0.58 = 0.71$$

5. Use Equation 7.3.5 to determine a new T_C value

$$T_C = \frac{0.31 * L^{0.483}}{(C_d * I_t)^{0.519} * S^{0.135}}$$

$$= \frac{0.31 * 1150^{0.483}}{(0.71 * 1.98)^{0.519} * 0.007^{0.135}} = 15.27 \text{ minutes}$$

6. Compare initial assumption with new T_C value

15.27 minutes > 12.0 minutes

7. If the value is not within 0.5 minutes of the assumed, use the new T_C value and begin at Step 3 to complete another iteration

Use T_C = 15 minutes for the next assumption

8. Iterate until initial and final T_C values are with 0.5 minutes

The new values using T_C = 15 minutes are:

I_t = 1.78 in/hr
C_u = 0.54
C_d = 0.69
T_C = 16.37 minutes

The difference between 15 and 16.37 is greater than 0.5 minutes

Use T_C = 17 minutes and recalculate

I_t = 1.68 in/hr
C_u = 0.53
C_d = 0.69
T_C = 16.87 minutes

The difference between 17 and 16.87 is less than 0.5 minutes, use T_C = 17 minutes for subarea.

The acceptable T_C range is from 5 to 30 minutes. If a T_C of less than 5 minutes is calculated, use 5 minutes. If a T_C greater than 30 minutes is calculated for the 50-year 24-hour design storm, the subarea must be divided into two subareas.

11.2 TIME OF CONCENTRATION - T_C CALCULATOR

Public Works developed a time of concentration calculator to automate time of concentration calculations. In addition to carrying out the T_C calculation process, the T_C Calculator completes the full modified rational runoff calculation process yielding peak runoff rates and volumes. Routing is not a feature in the calculator.

The T_C Calculator spreadsheet, "TC_calc_vol.xls", has been included on the CD with the Hydrology Manual.

1. The inputs to the calculator are the same as for the hand calculation method and are summarized in Table 11.2.1:

Table 11.2.1
T_C Calculator Inputs

Subarea size	7 acres
Soil type	068
Land use	42% impervious
Flow path length	1150 feet
Flow path slope	0.007
Rainfall depth	5 inches

2. If burned flow rates are desired, the appropriate fire factor should be determined from Table 6.3.3. In this case, no burned flow rate was necessary. A fire factor of 0 was used.

3. Figure 11.2.1 shows the interface for the T_C calculator with the data for Subarea 1A entered. For calculating the runoff from a single subarea, fill out the boxes in the upper left hand corner of the calculator under “Subarea Parameters Manual Input.” Depressing the “Calculate T_C” button in the lower right will display the results shown in the figure.

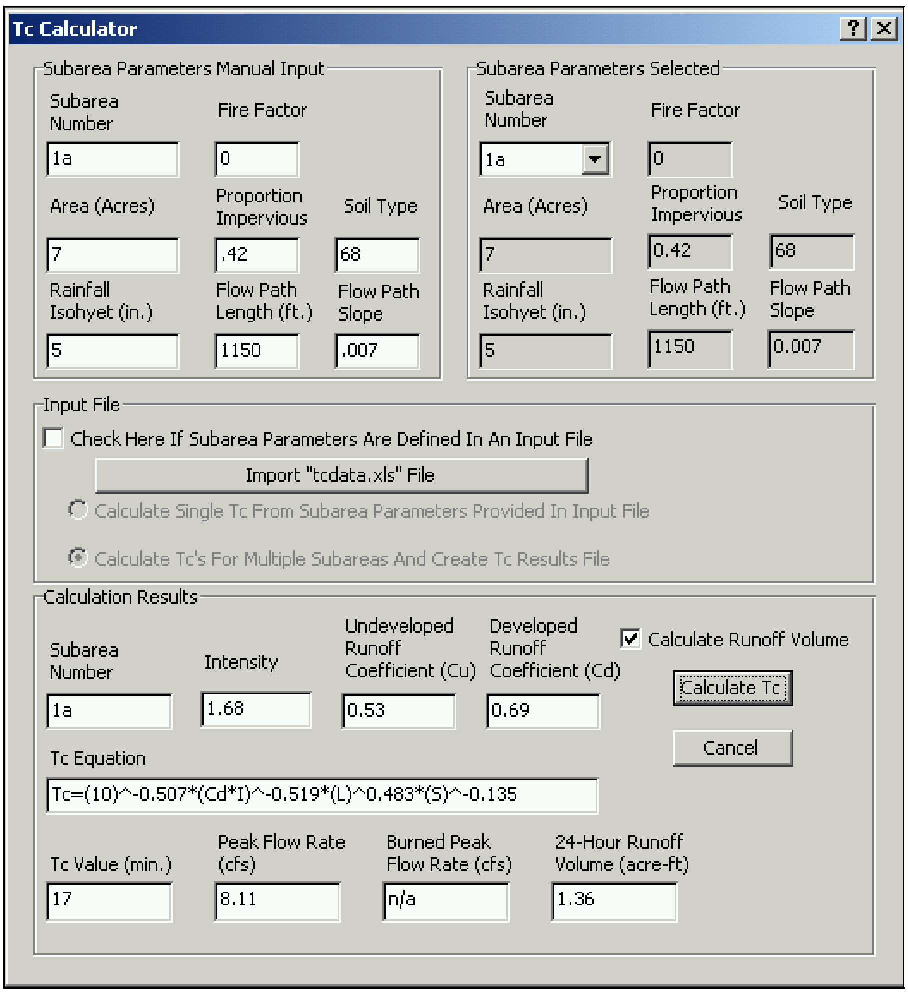

Figure 11.2.1
T_C Calculator Interface with Subarea 1A Results

The calculated T_C value, intensity, runoff coefficients, and peak flow rate are all the same as the values reached by hand calculation. Round off error and the uncertainties of reading table values cause the minor differences. The 24-hour runoff volume is also calculated if the "Calculate Runoff Volume" box is checked. By checking this box, the number of calculations increases and may take more time to display the results.

4. To calculate multiple subareas simultaneously, the T_C calculator can also accept Excel spreadsheets as input files containing a number of subareas. This file must be in the format specified in the "datasamp" sheet of the T_C calculator and in Figure 11.2.2

	A	B	C	D	E	F	G	H	I	J
1	Project	Subarea	Area	%imp	Frequency	Soil Type	Length	Slope	Isohyet	Fire Factor
2	Example	1a	7	0.42	standard	68	1150	0.007	5	0
3	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.52	0
4	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	4.38	0
5	Herondo Drainage	6a	11	0.92	standard	10	1600	0.017	4.24	0
6	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.1	0
7	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	3.96	0

Figure 11.2.2
T_C Calculator Input File Format

Name the Excel spreadsheet "tcdata.xls". To use an input file with the program, first check the box on the input dialog that says, "Check Here If Subarea Parameters Are Defined In An Input File". Then select the button labeled, "Calculate T_C's for Multiple Subareas and Create a T_C Results File."

Import the data by clicking "Import 'tcdata.xls' File" button. Once the data is imported, the box in the upper right corner of the calculator window displays data for individual subareas. You can select a subarea of interest by scrolling through the pull down box called "Subarea Number" at the right.

5. After pressing the "Calculate Tc" button, you will be prompted to name the results file. The results can then be viewed using Excel or individually using the pull down box. The results file shown in Figure 11.2.3 contains all the input and output information.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Project	Subarea	Area (acres)	%imp	Frequency	Soil Type	Length (ft)	Slope (ft/ft)	Isohyet (in.)	Tc-calculated (min.)	Intensity (in./hr)	Cu	Cd	Flow rate (cfs)
2	Example	1a	7	0.42	standard	68	1150	0.007	5	17	1.68	0.53	0.69	8.11
3	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.52	25	1.27	0.23	0.85	32.39
4	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	4.38	23	1.28	0.23	0.85	20.67
5	Herondo Drainage	6a	11	0.92	standard	10	1600	0.017	4.24	17	1.42	0.27	0.85	13.28
6	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.1	27	1.11	0.18	0.84	27.97
7	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	3.96	25	1.11	0.18	0.84	17.72

Figure 11.2.3
T_C Calculator Results File for Multiple Subareas

Peak Flow Rate and Volume Calculations

Runoff volumes are calculated by calculating runoff rates for multiple time steps. Section 7.3.2 explains the calculations needed to define a hydrograph. The volume of flow equals the total area under the hydrograph.

Calculating flow volume by hand is impractical for all but the simplest cases. The T_C Calculator program has an option that allows the user to calculate the total runoff volume. After indicating this intention by checking the box marked “Calculate Runoff Volume,” the user can produce the 4th day runoff volume by pressing the “Calculate Tc” button and naming the output file as before.

Substituting the rainfall depths for the first through third days into the calculator produces daily runoff volumes for the other days of the design storm. Rainfall depths for these days are a specified percentage of the fourth day as Table 11.2.2 indicates.

Day of Storm	Percentage
1st day	10%
2nd day	40%
3rd day	35%

Table 11.2.2
Percentage of Fourth Day Depth

The T_C calculator also produces a hydrograph plot when calculating runoff volumes. The hydrographs are accessed by pressing cancel in the calculator. This takes you to the workbook that contains the sheets that store the data behind the calculator interface. One of these sheets is labeled “hydrograph chart”. The hydrograph shown is from the last subarea selected for analysis. Figure 11.2.4 shows the runoff hydrograph for the previous example.

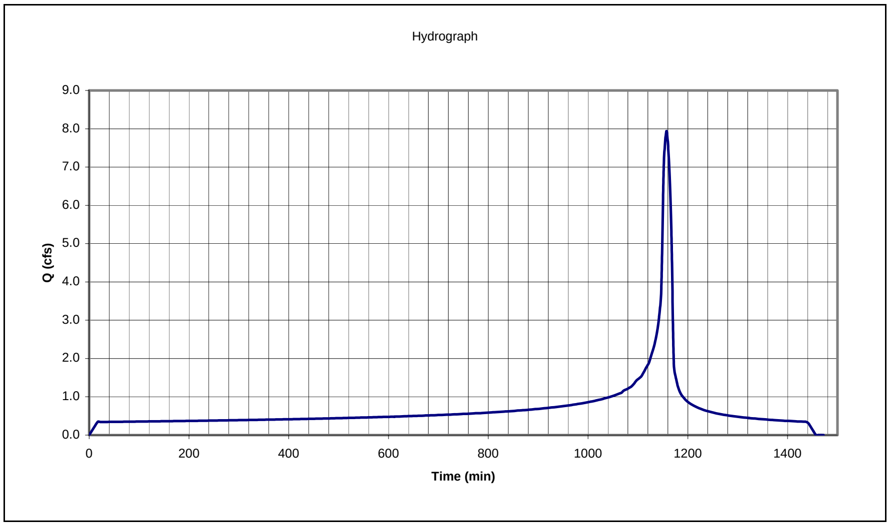

Figure 11.2.4
Runoff Hydrograph From the T_C Calculator

Storage Volume Requirements

Regional Basins

Regional Basins must be able to handle the 4-day design storm runoff volume. This may be accomplished by passing the first 3 days of storm flow through the basin, if the flow rate increase does not exceed pre-development flow rate levels. The regional basins must be able to store the post-development 4-day runoff volume, excluding the outflow during the storm. The basins must also meet other requirements determined by Land Development Division and Building and Safety Division.

∆Q Basins – Antelope Valley

∆Q Basins must store the change between pre- and post-development flow volumes, from all 4 days, for a 25-year event for percolation.

CHAPTER

12

Rational & Modified Rational Modeling

12.1 WATERSHED MODEL CREATION

The County of Los Angeles uses two related methods, the Rational and Modified Rational Method to calculate runoff rates. This section describes the necessary steps for creating a watershed model using both methods.

The first step in creating a model is to delineate the watershed using the methods described in Section 10.2. For countywide uniformity, subarea sizes should be approximately 40 acres. Smaller subarea sizes are acceptable.

Once the watershed and subareas are delineated, subareas and outlets must be numbered. The County of Los Angeles uses a subarea numbering system for hydrologic modeling that indicates the spatial relationships without the need for a diagram. A number and letter are assigned to each subarea and collection point.

Figure 12.1.1 shows an example of watershed numbering. Subarea IDs are indicated with a box and outlets are indicated with a leader. Numbers are assigned starting along the “mainline”. This is typically the longest stream channel in a watershed.

The upper most subarea on the mainline is assigned the label 1A. The watershed outlet of Subarea 1A is labeled 2A. The next watershed downstream from 1A is labeled 3A. In the example, Subarea 3A shares its outlet with another subarea, so instead of assigning the ID 4A to this outlet, 4A is assigned to the connecting subarea. The outlet downstream of 3A and 4A is labeled 5A. The numbering continues sequentially downstream.

When a confluence point with another stream or tributary is reached, numbering continues at the upstream end of the second stream or tributary. In the example, the A-line subarea upstream of the confluence is numbered

8A. The most upstream subarea in the confluencing stream is numbered 9B. The B-line is numbered the same way as the A-line. When the B-line reaches the confluence with the A-line, the confluence ID requires two suffix letters. One represents the mainline and the other represents the lateral. In this case, the confluence is labeled 16AB. This ends the B-line numbering. Continue the numbering in sequence using the suffix A. This numbering system can be extended to accommodate any number of confluencing laterals.

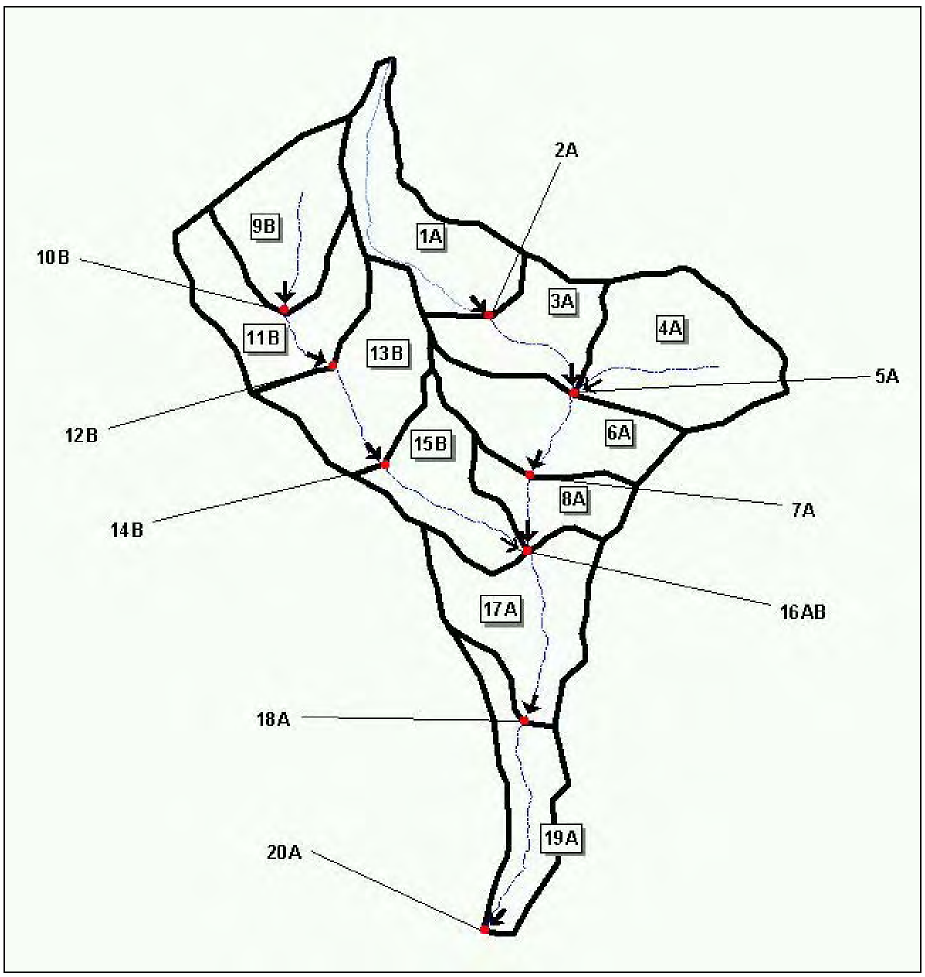

Figure 12.1.1
Watershed Numbering Example

Diversions are numbered as reverse confluences and begin at a collection point numbered with two suffix letters. The first letter represents the line where the diversion occurs. The second represents the letter for the diversion line. The diversion can be collected further downstream at a confluence or be allowed to divert water out of the watershed being studied. Figure 12.1.2 shows the same example of watershed numbering except with a diversion just upstream of the watershed outlet.

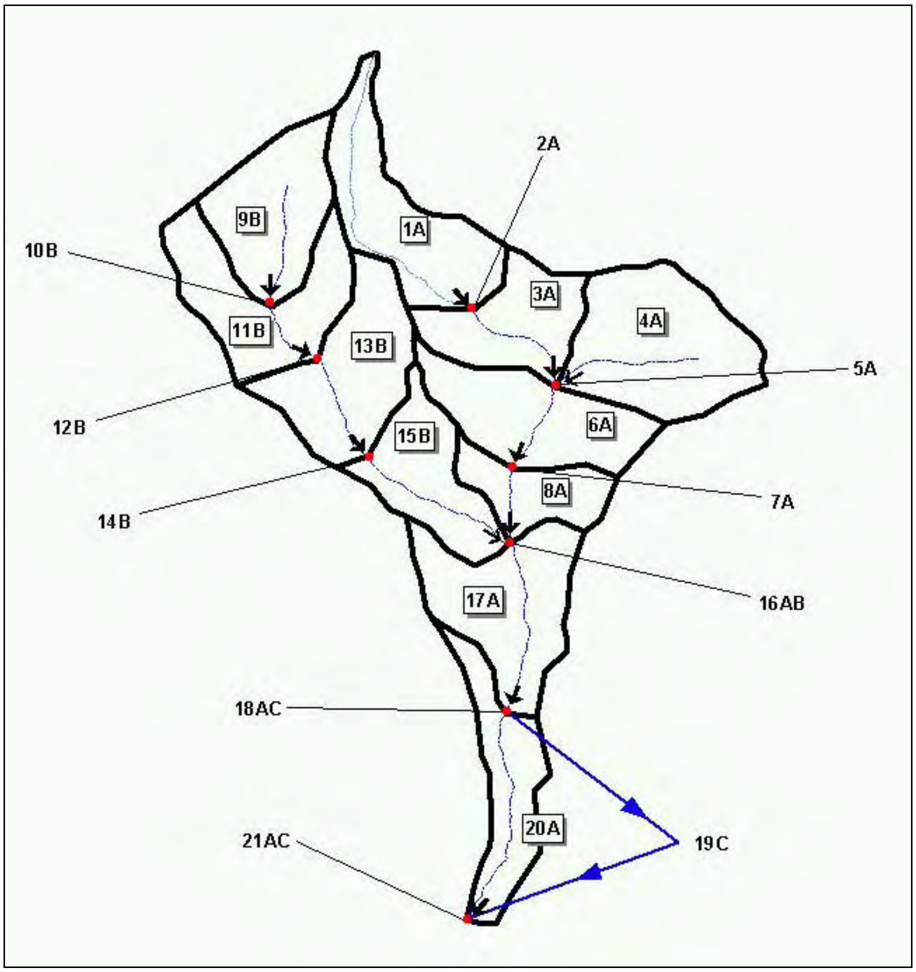

Figure 12.1.2
Watershed Numbering Example With a Diversion

After labeling the subareas and collection points, subarea characteristics must be determined. Table 12.1.1 contains a description of each of these characteristics and the procedure for calculating them. These steps are illustrated in examples in the following two sections. Also, see Section 10.5.

Table 12.1.1
Required Parameters for Rational and Modified Rational Modeling

Parameter	Units	Symbol	Procedure	Related Section
Basin Area	Acres	A	Measure the drainage area from a scaled topographic map.	-
Conveyance Length	Feet	L	Measure the length of the conveyances between subarea collection points.	-
Conveyance Slope	Feet/Feet	S	Slope is the change in elevation between collection points divided by the conveyance length. If mountain or valley slopes exceed 0.1 see Figure 7.3.8.	-
Soil Type	-	-	Use the maps in Appendix B or the GIS shapefile to determine the predominate soil type.	Section 6.3
Percent Impervious	%	IMP	Assign each subarea a percent impervious based on land use. When more than one land use exists, assign an area-weighted imperviousness average.	Section 6.3
Rainfall Depth	Inches	-	Use the isohyetal method to determine the average rainfall depth for a subarea.	Section 5.4
Time of Concentration	Minutes	T_C	Use Regression Method Equation.	Sections 7.3, 11.1, 11.2

12.2 RATIONAL METHOD

The Los Angeles County Hydrology Method allows use of the rational method for runoff calculation in small watersheds. The Rational Method is the basis of the Modified Rational Method and allows calculation of the peak runoff rate for a single subarea.

Since the rational method generates only peak flow rates and not hydrographs, the only way to combine the flows from two subareas is to add the peak flow rates together. This method of combination neglects the effects of channel routing, peak flow attenuation, and variable times of concentration. These factors reduce the peak flow rate in larger watersheds.

The peak-to-peak method is overly conservative in watersheds larger than a few subareas.

Subarea 1A, a typical rural watershed from the example in Section 5.4, will be used to illustrate the rational method. Figure 12.1.1 shows the entire watershed. Figure 12.2.1 shows an enlarged view of Subarea 1A.

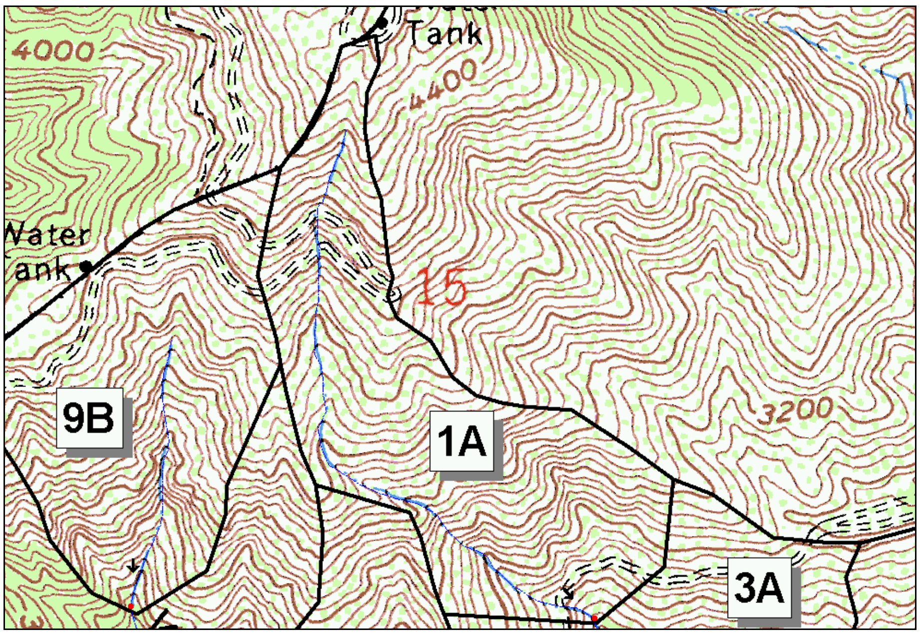

Figure 12.2.1
Subarea 1A

1. Section 5.4 contains the following data for Subarea 1A.

   Subarea size: 67.7 acres
   Rainfall Depth (50-year, 24-hour): 12.0 inches

2. Appendix B contains maps with hydrologic data. Figure 12.2.2 shows the Mount Baldy Quad, 1-H1-31, with soil types delineated. Subarea 1A contains soil types 081 and 088. However, the majority of the area is soil type 081. The characteristics of soil type 081 are used in the runoff calculation.

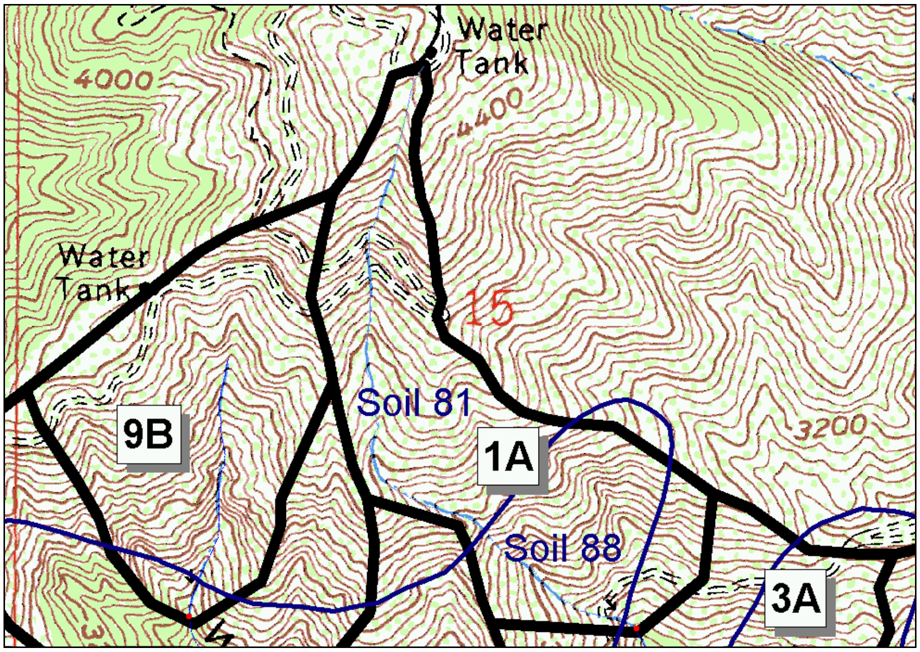

Figure 12.2.2

Appendix B Hydrologic Data Map – Mt. Baldy Quad with Subarea 1A and Soil Types Delineated

3. Appendix D contains information on imperviousness values based on land use. Subarea 1A is mountainous and undeveloped. Undeveloped rural areas are given an imperviousness of 1% in the Los Angeles County Method. For developed areas, the area-weighted imperviousness value is needed for each subarea. Section 6.3 illustrates area-weighted imperviousness calculations.

4. A time of concentration flow path is drawn from the most hydraulically remote location to the subarea outlet. The length and slope of this path needs to be determined. For Subarea 1A, the upper end of the T_C path is at an elevation of 4,612 feet and the collection point elevation is 2,739 feet. The flow path length measured using a planimeter is 4,109 feet.

   The slope is:

$$\text{Slope} = (4{,}612 \text{ ft} - 2{,}739 \text{ ft}) / 4{,}109 \text{ ft} = 0.456$$

5. Find the time of concentration by iteration:

- Convert the 24-hour rainfall depth into intensity, I_{1440}.

  I_{1440} = 12.0 in / 24 hrs = 0.5 in/hr

- Assume an initial T_C value of 12 minutes.

- Use the rainfall intensity-duration-frequency relationship, Equation 5.1.2, to determine the ratio of the 12-minute intensity to the 24-hour intensity.

$$\left(\frac{I_{12}}{I_{1440}}\right) = \left(\frac{1440}{12}\right)^{0.47} = 9.49$$

- Calculate the 12-minute intensity in in/hr;

$$I_{12\,min} = I_{1440} * \left(\frac{I_{12}}{I_{1440}}\right)$$

$$I_{12\,min} = 0.5 * 9.49 = 4.75 \text{ in/hr}$$

- Figure 12.2.3 is the soil runoff coefficient curve for soil type 081 from Appendix C. Using the intensity, I_{12min}, determine the undeveloped runoff coefficient: C_u = 0.89.

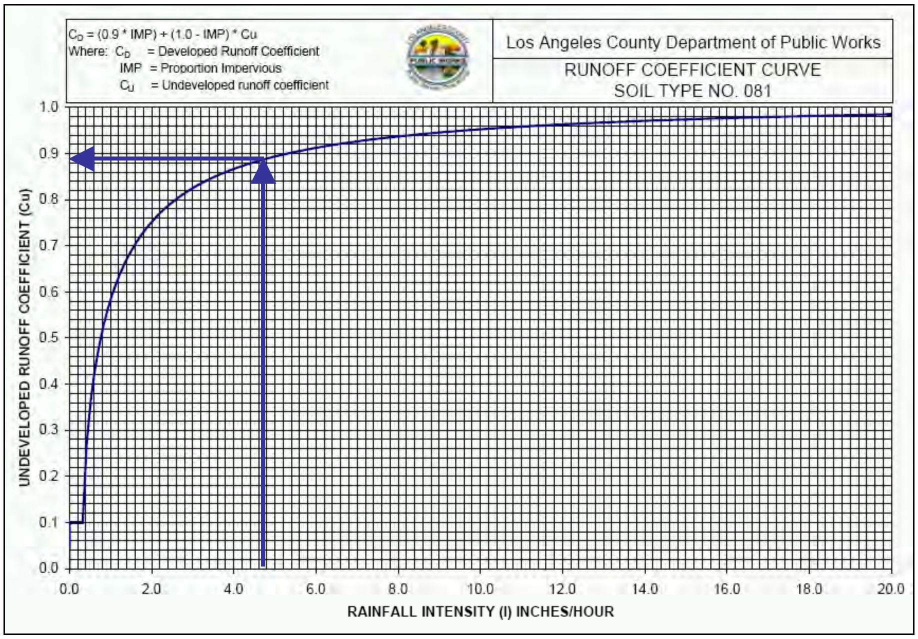

Figure 12.2.3
Soil Type No. 081, Runoff Coefficient Curve from Appendix C

- Calculate the developed runoff coefficient using Equation 6.3.2;

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$
$$C_d = (0.9 * 0.01) + (1.0 - 0.01) * 0.89 = 0.89$$

- Calculate the value for rainfall excess;

Excess rainfall = C_d* I_{12min}
= 0.89 * 4.75 = 4.23 in/hr

- Calculate the time of concentration using Equation 7.3.5;

$$T_C = \frac{0.31 * L^{0.483}}{(C_d * I_t)^{0.519} * S^{0.135}}$$
$$= 0.31 * 4.23^{-0.519} * 4{,}109^{0.483} * 0.456^{-0.135} = 9.1 \text{ minutes}$$

- Since the resulting T_C, 9.1 minutes, is not within half a minute of the assumed T_C, 12.0 minutes, assume another T_C and repeat the calculations. Use the calculated T_C as the guess for the next iteration.

- Table 12.2.1 contains data for each iteration of the T_C calculations

Iteration Number	I_{1440} (in/hr)	Initial T_C (min)	$I_t/I1440$	I_t (in/hr)	C_u	C_d	C_d*I (in/hr)	Calculated T_C (min)	Difference (min)
1	0.5	12.00	9.49	4.75	0.89	0.89	4.23	9.1	2.9
2	0.5	9.1	10.8	5.4	0.90	0.90	4.86	8.4	.7
3	0.5	8.4	11.2	5.6	0.90	0.90	5.0	8.3	.1
Final	0.5	8.0	11.5	5.75	0.90	0.90	5.18		

Table 12.2.1
Iterative T_C Calculations for Subarea 1A

- When the T_C is within half a minute of the assumed T_C, round to the nearest minute to get the final T_C and calculate the I_t, C_u and C_d.

- The subarea peak flow rate in cfs is calculated using the rational method. Multiply the rainfall excess (in/hr) by the area of the catchment (acres) to get peak flow.

$$Q_{peak} = (C_d*I_t)*Area$$
$$= (0.90*5.75\ in/hr)*(67.7\ ac) = 350.3\ cfs$$

Using the rational method for multiple subareas requires adding peak flow rates. For example, Subarea 3A has a peak flow rate of 146.9 cfs. The total flow rate at outlet 4A is 497.2 cfs using the rational method.

12.3 MODIFIED RATIONAL METHOD

The Modified Rational Method is an extension of the rational method used to create runoff hydrographs from a watershed of any size over a specific time period. The Rational method is limited to considering storms with a duration equal to the time of concentration and provides only a peak flow. The Modified Rational Method can consider single event storms with changing intensities and longer durations. The Modified Rational Method was developed as a means to produce hydrographs for storage design based on the rational method.

In the Modified Rational Method, the rational method is applied to each subarea's hyetograph to produce a hydrograph for each subarea in the watershed. The hydrograph for Subarea 1A of the Palmer Canyon watershed will be generated to show how calculations are performed. Computational implementations of the modified rational method use 1-minute timesteps to define the hyetograph. For illustration, only a few timesteps around the peak runoff at 1152 minutes will be used to define the hydrograph. The following information is needed:

Area:	67.7 acres
T_C:	8 minutes
Soil type:	088
Percent Impervious:	1%
4th day rainfall:	12.0 inches

The steps for hydrograph generation from Section 7.3 are as follows:

1. Determine the rainfall intensity for a time period equal to the T_C.
2. Determine the undeveloped soil runoff coefficient for the time period using the intensity.
3. Adjust the soil runoff coefficient using Equation 6.3.2 to determine C_d.
4. Use the rational equation, Equation 7.2.1, to determine the runoff for the time period.
5. Repeat steps 1 through 4 for each time period.

Illustration of hydrograph calculations will use time steps ending at 1128, 1153, and 1178 minutes. Figure 12.3.1 shows the three time periods used from the portion of the hyetograph near the peak rainfall intensity. Start with the time step ending at 1128. The 8 minute T_C calculated in Table 12.2.1 is used to define the time increment.

The first time interval of interest becomes minutes 1120 to 1128. The slope of the subarea hyetograph in Figure 12.3.1 changes during this period. The average intensity is used for the calculation. To calculate the average intensity, determine the total rainfall during this time and divide by the T_C in hours. The total rainfall from 1120 to 1128 is 0.203 inches in 8 minutes. This is equivalent to an intensity of 1.52 in/hr.

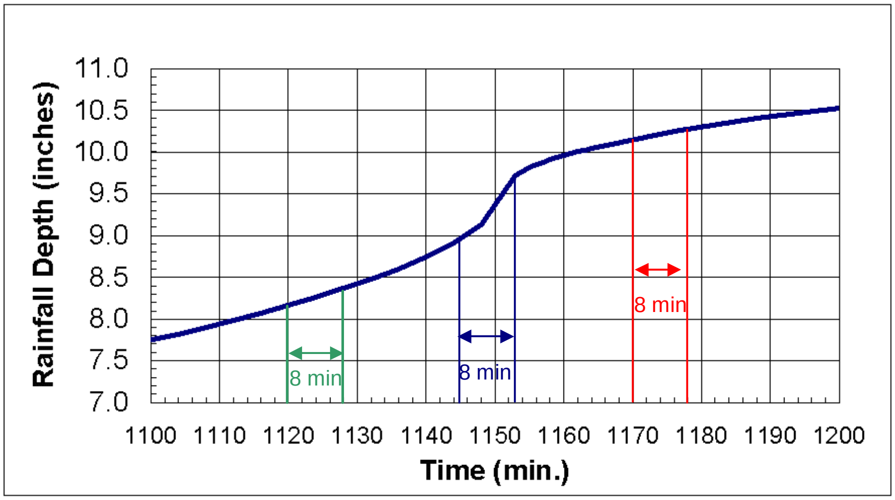

Figure 12.3.1
Subarea 1A Hyetograph With Calculation Points and T_C's Indicated

Figure 12.3.2 provides the C_u values for the three time steps of interest. From Figure 12.3.2, the undeveloped runoff coefficient for this intensity is 0.69.

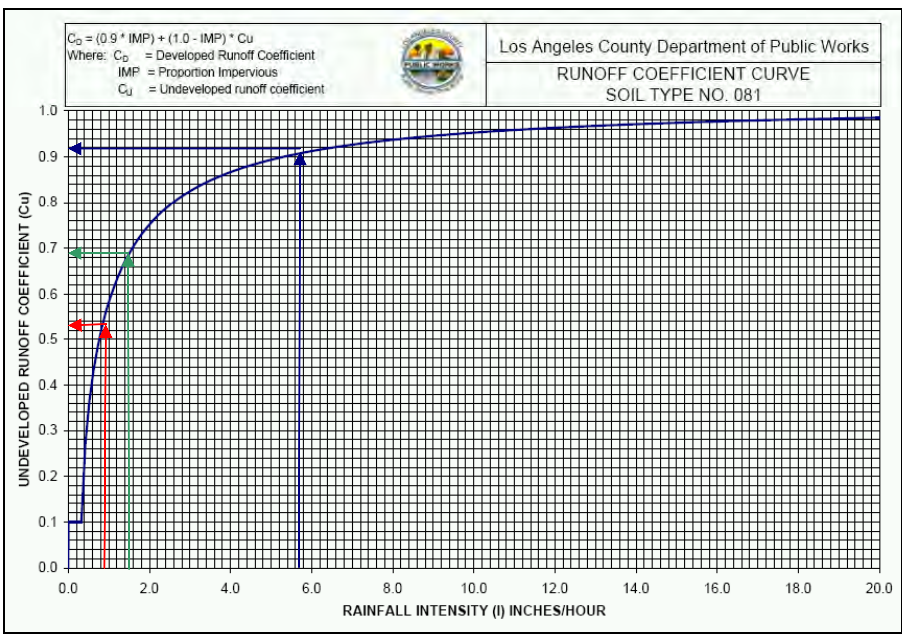

Figure 12.3.2
Soil Type 081 with Runoff Coefficients for 3 Time Steps Indicated.

Since this area has an imperviousness of 1%, the developed runoff coefficient as calculated using Equation 6.3.2 is also 0.69. The runoff for this time step is:

$$Q = C_d * I_t * A$$
$$= 0.69*1.52*67.7 = 71.0 \text{ cfs}$$

Table 12.3.1 shows the values used for the calculations at the end of each of the three time periods.

Table 12.3.1
Table of Runoff Calculations

Time (minutes) From	Time (minutes) To	Rainfall (in)	Intensity, I (in/hr)	Undeveloped Runoff Coefficient, C_u Fig. 7.3.3	Developed Runoff Coefficient, C_d Eq. 6.3.2	Area (acres)	Q = C_d *I*A (cfs)
1120	1128	0.20	1.52	0.69	0.69	67.7	71.0
1145	1153	0.76	5.71	0.90	0.90	67.7	348.0
1170	1178	0.12	0.89	0.53	0.53	67.7	23.52

Figure 12.3.3 shows the hydrograph made by connecting these points and assuming no flow at the start or end of the day. The shape would be further defined by calculating runoff at additional time increments.

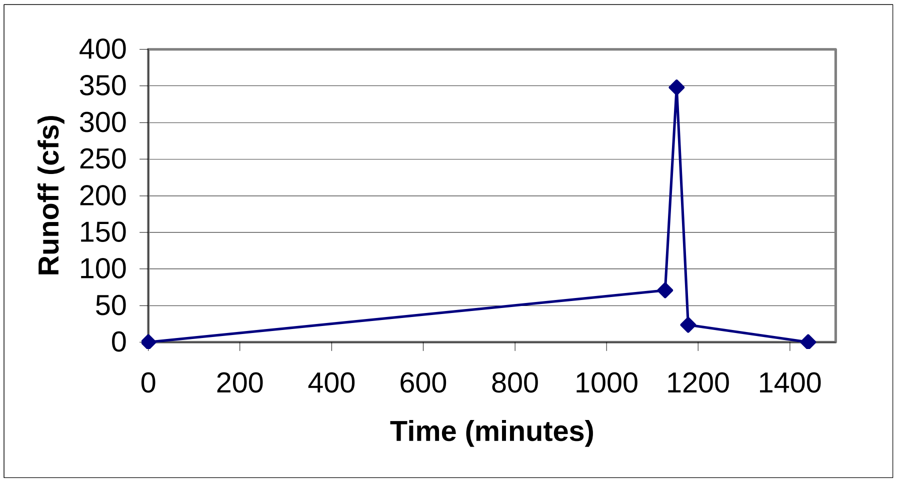

Figure 12.3.3
Hand Calculations Hydrograph for Subarea 1A

Figure 12.3.4 shows the hydrograph defined using 1-minute time shifts throughout the 24-hour time period.

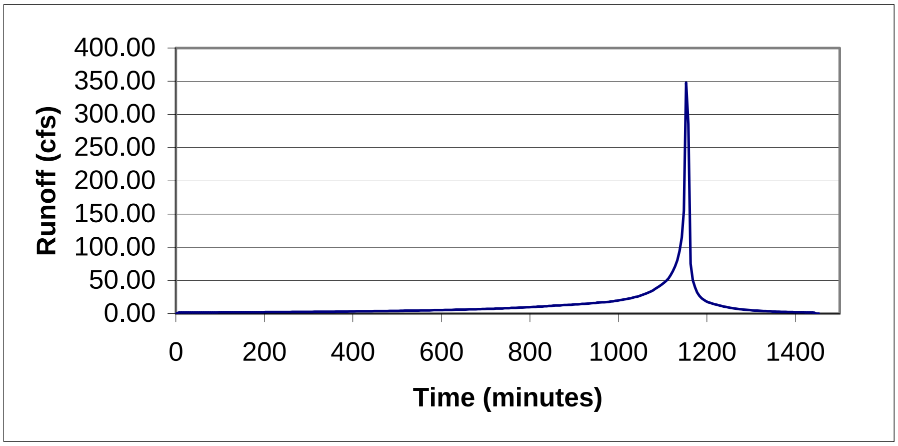

Figure 12.3.4
Subarea 1A Hydrograph, Using 1-minute Time Shifts

The hydrographs produced from successive subareas or laterals are routed and combined to produce hydrographs for successively larger watersheds. Section 7.3 describes the hydrologic routing process. The hydrographs are subjected to routing time lags and attenuation. The flow values for each time increment from all the hydrographs are added together. This hydrograph superposition allows large watersheds to be modeled using the modified rational method.

Table 12.3.2 compares the peak outflow from the Palmer Canyon watershed created by combining hydrographs peak-to-peak and hydrograph superpositioning for each time period. As shown, combining peak-to-peak always results in higher peak flow rates than hydrograph superposition after routing and channel storage.

Method		Rational	Modified Rational
Flow Combination		Peak-to-Peak	Hydrograph Superposition
Subarea Id	Area (acres)	Total Q (cfs)	Total Q (cfs)
1A	67.7	350.3	350.3
3A	47.7	497.2	475.0
4A	82.9	821.6	799.4
6A	62.5	1,060.8	1,004.5
8A	31.5	1,177.7	1,092.3
9B	57.7	264.5	264.5
11B	60.8	498.2	490.0
13B	65.6	749.3	716.3
15B	48.9	924.0	836.6
16AB	233.0	2,101.7	1,928.4
17A	69.3	2,311.5	2,088.2
19A	46.0	2,448.4	2,173.2
Total	640.6	2,448.4	2,173.2

Table 12.3.2
Comparison of Peak Watershed Outflow using Peak-to-Peak Combination and Hydrograph Superposition

Figure 12.3.5 is the modified rational method hydrograph for the entire Palmer Canyon watershed.

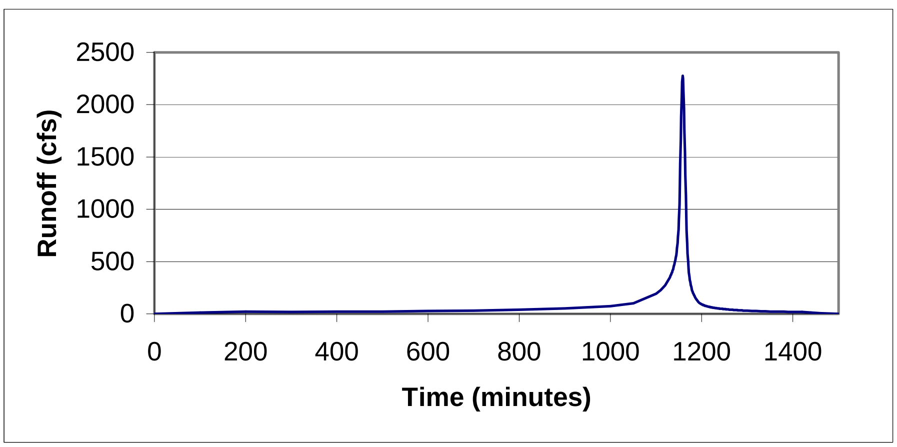

Figure 12.3.5
Modified Rational Method Hydrograph at Outlet of Palmer Canyon Watershed

Hand calculations for hydrographs, hydrograph routing, and superposition require a lot of time and careful organization. The calculations are ideally suited for computer programming and have been included in several software packages. Use of this software is encouraged to reduce the time required to reach a solution. Chapter 15 contains a list of software for Modified Rational Hydrology Studies within the County of Los Angeles.

Figure 12.3.6 is a view of the Palmer Canyon watershed used in the previous example.

Figure 12.3.6
Palmer Canyon Watershed
November 2003

CHAPTER

13

Classification of Hydrologic Models

13.1 EVENT VERSUS CONTINUOUS MODELS

Hydrologic models are divided into two categories: event or continuous models. Models that calculate runoff from a single storm lasting up to several days are called event models. The Los Angeles County Modified Rational Method model is an *event* model. Models that account for changes in the watershed over a long period of time and through several storm events are called *continuous* models. The Stanford Model and its descendant Hydrologic Simulation Program – Fortran (HSPF) are examples of continuous models. It is important to understand the differences between these types of models.

Hydrologists and engineers typically use event models to calculate runoff from a design storm event. This event may last from several hours to several days with nearly continuous rain. Event models lack mechanisms to account for changes over time in watershed conditions such as soil moisture. Event models must therefore use assumed watershed conditions. These assumptions work well for specific design criteria, but do not provide adequate results for longer periods. Watershed conditions may change between storms and through dry periods due to infiltration, evaporation, and transpiration. Watersheds also change over longer periods due to fire, construction, and changes in land uses. Event models have the advantage of being relatively simple to create and run.

Continuous models attempt to represent the effect of soil moisture and processes such as evaporation, transpiration, and flow through the subsurface on the runoff process. Continuous models account for changes in watershed characteristics at each time period and are suited to modeling runoff over long periods. Continuous model inputs require several months or years of historic data that contain most expected watershed conditions. The increased data requirements over event based models make the continuous models more complex to develop and calibrate. The spatial and temporal variation of parameter values for soil infiltration rates, soil moisture capacity, evaporation rates, and rainfall are required. Table 13.1.1 contains examples of event and continuous models. The table also lists some of the parameters required by the models.

Table 13.1.1
Comparison of Event and Continuous Models

Model Type	Rainfall Input	Data Requirements	Examples
Event	Design Storm	Soil runoff characteristics, land use data, relevant rainfall duration.	HEC-HMS, SWMM, Modified Rational
Continuous	Historic Data or Design Storms	Land use, detailed soil and vegetation information, seasonal data, time series data including rainfall, runoff, evaporation, temperature, etc..	Stanford Model, HSPF, SWMM

13.2 LUMPED AND DISTRIBUTED PARAMETER MODELS

The Los Angeles County Modified Rational Method is classified as a lumped parameter model because parameters influencing runoff are lumped together and assumed uniform for each subarea. The model uses a combination of physical and analytical relationships to model runoff response to a rainfall design storm. Subareas are defined with reference to the drainage pattern of the watershed. Properties of a subarea such as rainfall, imperviousness, and soil properties are lumped for the entire subarea. Lumped parameter models usually require less data that is easier to obtain or estimate.

The alternative to a lumped parameter model is a distributed model. Instead of breaking up the watershed using drainage boundaries, a distributed model represents the properties of a watershed using small grid cells. These regularly spaced cells are assigned unique properties, reducing the simplification that occurs when parameters are lumped at the subarea level. Distributed modeling is compatible with watershed data inputs such as radar rainfall and soil moisture accounting. Distributed models generally require more data that may not be readily available.

CHAPTER

14

Divisions With Hydrologic and Hydraulic Responsibilities

In addition to the Water Resources Division, several divisions within the Los Angeles County Department of Public Works have responsibilities associated with hydrology and hydraulics. The divisions that provide these services are listed below along with key responsibilities that relate to hydrology and hydraulics.

14.1 BUILDING AND SAFETY DIVISION

The primary function of Building & Safety is the enforcement of Los Angeles County Building, Plumbing, Mechanical, and Electrical Codes, as well as other local and State requirements relevant to the construction and occupancy of public and private structures. The Division provides this enforcement through plan checking and inspection of new commercial and residential construction. The County's unincorporated area and 21 contracted cities are served by 25 branch or city inspection offices and a central administrative office. The Drainage and Grading Section provides the following services related to hydrology and hydraulics:

Hydrology Review Includes:

- Reviewing hydrologic studies for single lot residential and commercial projects based on Public Works' standards. The review identifies flood hazards due to inundation, overflow, or debris, and verifies that the appropriate levels of protection exist against these hazards.

- Verifying single lot residential and commercial project compliance with the Department's National Pollution Discharge Elimination System (NPDES) permit, including the enforcement of Standard Urban Stormwater Mitigation Plan (SUSMP) compliance.

- Verifying that post-development flow rates in watercourses adjacent to the development are no greater than pre-development flow rates.

<u>Hydraulics Review Includes:</u>

- Reviewing proposed drainage facilities and storm drains for capacity, appropriate levels of protection, and negative impacts on existing drainage systems.

- Checking pre- and post-development flows, velocities, and flow areas at the upstream and downstream of proposed single lot residential and commercial projects to verify that no negative impacts, including diversions, are created.

- Enforcing compliance with the National Flood Insurance Program (NFIP), including FEMA and County floodplain and floodway regulations.

- Reviewing hydraulic models of floodway and flood plain encroachments to determine development requirements and effects to upstream and downstream properties.

<u>Grading Review Includes:</u>

- Verifying that grading plans for single lot residential and commercial projects do not affect off-site areas negatively in terms of hydrology or debris production.

- Verifying compliance with the Department's NPDES permit by reviewing grading plans and inspecting the installation of required BMP's.

14.2 CONSTRUCTION DIVISION

The Construction Division is responsible for the administration and inspection of Public Works construction contracts; inspection of subdivision improvements; issuance and inspection of permits for road, drainage, and sewer projects; and utility coordination. In addition, the division awards and administers contracts to clean approximately 70,000 catch basins during the late summer months prior to each rainy season. Cleaning the basins improves storm water quality by minimizing the amount of debris that would otherwise flow through the storm drains and into the ocean. Construction Division's Permits and Subdivisions Section hydrology related responsibilities include:

- Confirming hydrology of tributary area and check the drainage area map of a proposed site with the existing sub-area map.

- Checking hydrology calculations using Public Works' standards. Check Design Hydrology peak flow rate and T_C calculations using the Public Works' T_C calculator.

- Submitting requests to Water Resources Division to perform hydrologic studies for the areas of interest, when no hydrologic study is available.

- Verifying that the allowable discharge flow rate, $Q_{Allowable}$ (cfs/acre), for the existing subarea has been obtained from Design Division.

- Comparing design hydrology with the system design hydraulics and requiring that any connections are designed based on the smaller value.

- Reviewing permit applications and construction projects for impacts of water releases into flood control facilities and coordinating with Water Resources Division on operational activities of Public Works' facilities.

14.3 DESIGN DIVISION

Design Division is responsible for preparing contract drawings, cost estimates, and specifications for Public Works' new construction, repair, retrofit, and rehabilitation projects. Projects include streets and highways, bridges, storm drains, water and sewer lines, debris control facilities, pumping plants, and facilities appurtenant to dams. The division also lends technical design support to other agencies and the public, and it publishes its *Standard Plan Manual* and *Standard Specifications Book* for construction contractors. The Design Division's Hydraulic Analysis Unit has the following duties:

- Providing the allowable discharge flow rate, $Q_{Allowable}$ (cfs/acre), which is the maximum discharge allowed for new connections to a drainage facility. The $Q_{Allowable}$ is based on the design hydrology study and any hydraulic capacity limitations of the subject drain or the downstream connecting system(s).

- Providing hydrologic data/information from facility design hydrologic studies including: the design storm frequency, scale-down factors, sub-area acreage, peak flow rates (including specific catch basin design subarea acreage and flow rates), and design reach peak flow rates throughout the system.

- Providing hydrology maps that graphically outline the limits of all subareas within the facility drainage area. Each subarea is individually identified with a corresponding number from the design hydrology study, as well as the acreage and peak flow rate.

- Providing hydraulic analysis calculations for drainage facilities. These include the hydraulic calculation sheets or Water Surface Pressure Gradient (WSPG) output data with the design flow rate, velocity, and hydraulic grade line (H.G.L.) or water surface elevation (W.S.E.) at various locations throughout the system. A WSPG hydraulic calculation for a proposed connection to a drainage facility must be based on the facility design H.G.L. or W.S. E. at the point of connection.

- Providing conceptual review on the preliminary hydraulic design of projects involving connections to, or modifications/realignment of, a drainage facility. The conceptual review determines the hydraulic, hydrologic, and/or structural feasibility of the proposal prior to proceeding with the design.

14.4 ENVIRONMENTAL PROGRAMS DIVISION

The Environmental Programs Division is responsible for five major environmental programs within the County: Hazardous Material Underground Storage Tank (UST) Regulation; Solid and Hazardous Waste Management Planning and Implementation; Stormwater Discharge/Water Quality Monitoring and Control; Industrial Waste Control; and administration of the County's Garbage Disposal Districts. In addition, Environmental Programs provides technical support and advice for County recycling, composting, and hazardous waste programs, reviews road and utilities improvement plans relative to sanitary sewers, reviews building construction plans for the Methane Gas Intrusion Protection System, and provides waste management advice and coordination. Environmental Program's specific hydrologic duties include:

- Reviewing SUSMP plans for non-residential projects within the Industrial Waste Unit's areas of jurisdiction. After the commercial or industrial developer receives approval of the peak mitigated flow, "Q_{pm}", from the County Building and Safety, Land Development, or the local City Building & Safety office, the developer submits the approved "Q_{pm}" report and the required sets of plans to the Industrial Waste Unit. A permit application and fees for plan checking and permit processing are required. See the website http://www.ladpw.org/epd/industrial_waste/index.cfm for more information.

- Checking the storm water treatment devices and post-BMPs for suitability to the "Q_{pm}" and the site's storm water constituents. The approved storm water treatment devices are placed under a SUSMP permit.

- Inspecting storm water treatment devices to ensure that the devices are properly maintained.

14.5 LAND DEVELOPMENT DIVISION

Land Development Division is responsible for plan reviews and approval of all types of Public Works' infrastructure and final maps as part of the land development subdivision process. These subdivisions range in size from two lot parcel maps to 12,000-acre master plan communities including residential, commercial, and industrial development. In addition, this Division reviews and approves proposals to comply with storm water quality requirements of the Regional Water Quality Control Board. Land Development Division's responsibilities regarding hydrology are:

Hydrology Review Includes:

- Reviewing development plans to determine if on-site hydrology meets Public Works' standards.
- Checking SUSMP compliance and requiring use of BMPs during and after construction.
- Checking for required debris control structures for areas upstream of tracts and on-site locations.
- Checking post-development flow rates in adjacent watercourses to ensure that they do not exceed pre-development flow rates.

Hydraulics Review Includes:

- Reviewing proposed on-site drains for capacity, maintenance issues, and adequate downstream capacity. Ensuring that appropriate levels of protection exist.
- Checking pre- and post-development flows, velocities, and flow areas at the upstream and downstream tract boundaries to prevent negative off-site impacts.
- Enforcing floodplain and floodway regulations.
- Reviewing HEC-RAS models of floodway encroachments for compliance with regulations to prevent negative effects to the upstream and downstream areas.

Grading Review Includes:

- Reviewing grading plans to ensure that topographic changes do not affect off-site areas negatively in terms of hydrology or debris production.

14.6 WATERSHED MANAGEMENT DIVISION

Watershed Management Division is responsible for planning and implementing watershed management projects that protect the County's residents from flooding while integrating the elements of natural resources, groundwater, and stormwater conservation, improved stormwater runoff quality, and socio-economic, environmental, and recreational features. Watershed Management's hydrologic responsibilities include:

- Providing Flood Zone determinations for the public and lending institutions.

- Interpreting Flood Insurance Rate Maps (FIRMs) and identifying flood zone designations for properties and construction projects.

- Processing Letters of Map Revision (LOMR) and Conditional Letters of Map Revision (CLOMR).

CHAPTER

15

Computer Programs for Use in Los Angeles County Hydrologic Studies

Computer programs are powerful tools that simplify hydrologic computations. Several hydrologic software packages include the Los Angeles County Modified Rational Method. The software packages listed in Table 15.1 have been reviewed for use in hydrologic studies within the County of Los Angeles. The table provides contact information for purchasing the software and provides a brief description of approved uses for the software.

Table 15.1
Approved Computer Programs

Name	Version	Description	Publisher
Watershed Modeling System (WMS)	7.1 and later	Implements the Modified Rational Method with reservoir routing and optional GIS capability	Environmental Modeling Systems www.ems-i.com 1-801-302-1400
XP-SWMM	9.0 and later	Implements the Modified Rational Method with some enhancements and the ability to model hydraulics and water quality	XP Software www.xpsoftware.com 1-888-554-5022
HEC-HMS	2.2.2 and later	Physically based, single event model can be used for reservoir routing.	Corps of Engineers Hydrologic Engineering Center www.hec.usace.army.mil
LAR04		Implements the Modified Rational Method	Civildesign Corp www.civildesign.com 1-909-885-3806
RETARD		Performs reservoir routing using the Modified Puls method.	Civildesign Corp www.civildesign.com 1-909-885-3806
TC_calc_vol.xls TC_calc_depth.xls		Implements the Modified Rational Method into calculations for single subareas and small watersheds.	LA County Dept. of Public Works www.ladpw.org

15.1 WATERSHED MODELING SYSTEM (WMS)

Watershed Modeling System (WMS) is a hydrologic modeling software that incorporates many standard hydrologic models. A key capability of WMS is the extraction of model input parameters from GIS data such as DEMs, TINs, and shapefiles. The program also allows use of georeferenced images for backgrounds. WMS is modular and pricing is based on the number of modules purchased.

The Los Angeles County Modified Rational Method has been fully implemented in WMS. This implementation maintains the functionality of the prior F0601 code with several useful additions. WMS includes a graphical user interface to the model which facilitates data input and model creation. Reservoir routing, automatic T_C calculation, and automatic burned watershed simulations are recently added features.

15.2 XP-SWMM

The Storm Water Management Model (SWMM) is widely used to model storm drain systems. The United States Environmental Protection Agency (EPA) maintains this model. XP-SWMM is a Windows based interface for the SWMM model developed by XP Software.

XP-SWMM version 9.0 allows for the simulation of runoff, water quality, and hydraulic routing using the Los Angeles County Modified Rational Method. The XP-SWMM software has a graphical interface with the Modified Rational Method. Reservoir routing, automatic T_C calculation, and automatic burned watershed simulations are included features. A scenario manager also allows simultaneous simulation of multiple design storms. Future upgrades of XP-SWMM plan to include GIS capabilities.

15.3 HEC-HMS

HEC-HMS was developed by Hydrologic Engineering Center (HEC), Corps of Engineers. HEC-HMS does not support the Modified Rational Method. However, HEC-HMS was adopted as a replacement for the Mountain Hydrology Method (Q-S Method)[1]. Currently, Public Works uses HEC-HMS to model debris basins and dams.

15.4 LAR04/RETARD

The LAR04 program is a modified version of Public Works' F0601 program. The modifications include changing the program to a Windows console program, adoption of the latest soil and rainfall data files distributed by Public

Works, and user options to select output data for design storms ranging from 2-year to 500-year events. There is also the option to output data in metric units, include volume calculations with hydrographs and, an input option for areas as small as 0.1 acres.

LAR04 is a text-based implementation of the Modified Rational Method similar to F0601. This program uses the Los Angeles County Flood Control District program source code for the F0601 series programs. It also includes an independent program module, which assists the user in preparing an input data file for use by the F0601 program.

The RETARD program reads F0601 hydrographs, up to a 4-day storm series, and performs detention basin calculations using the Modified Puls, or storage indication method. The resulting outflow hydrograph may be inputted into the LAR04/F0601 program.

15.5 T_C CALCULATOR

The T_C Calculator may be used to calculate runoff and runoff volumes for small subareas and for small watersheds. Since it has no routing capabilities, use for watersheds larger than 100 acres is discouraged because routing alters peak flows and changes timing. These changes normally reduce flow rates in a storm drain system.

[1] Los Angeles County Department of Public Works Hydrology Manual, 1982, page C-9

INDEX

K

L

M

N

O

P

Q

R

S

T

U

W

X