

Chapter 5- Answer Key

5.1 Calculate the TC & R coefficients for each subbasin in the given watershed. Assume that the equations listed in Table 5-10 are applicable and that $S = S_0$.

- In Excel create a spreadsheet that utilizes the equations found in table 5-10 to solve for the values of C and $TC+R$.

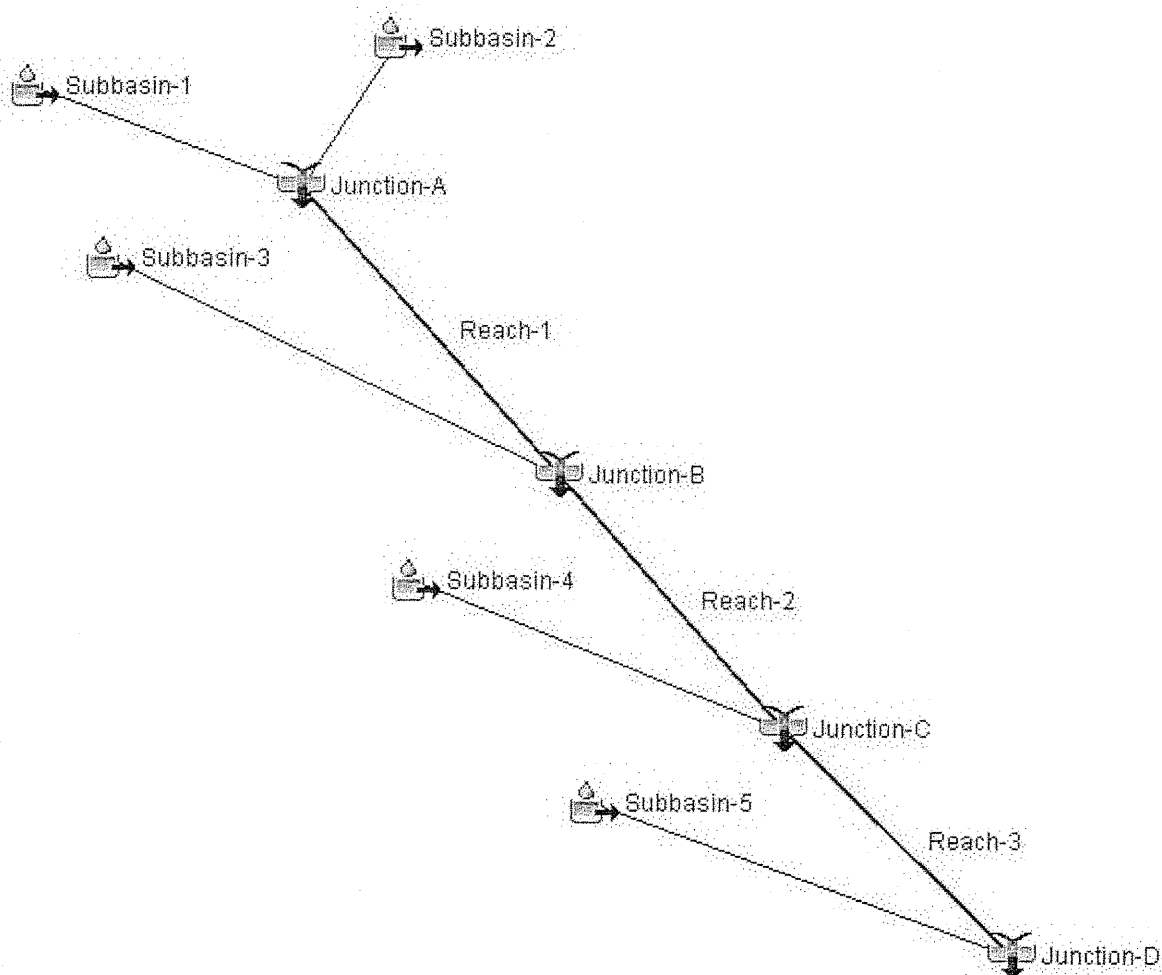
Subbasin Number	$C =$ [%]- . [%]- . (hr)	$TC+R =$ () . (hr)
1	6.18	2.62
2	6.48	3.28
3	2.81	1.78
4	2.81	1.70
5	2.68	1.86

- Linear interpolation must be used to solve for C'' , which is required to solve for TC & R .

Subbasin Number	C'' (hr)	$TC =$ '() . (hr)	$R =$ + - (hr)
1	2.004	0.31	2.32
2	2.034	0.40	2.88
3	1.396	0.39	1.39
4	1.396	0.32	1.39

5	1.320	0.47	1.39
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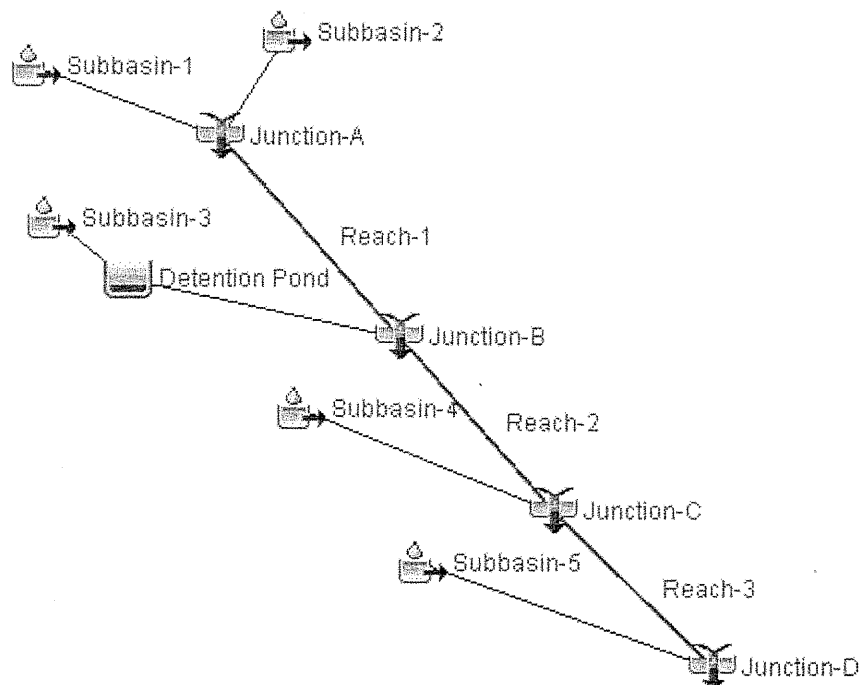
- 5.2 Create the Basin Model of the watershed in HEC-HMS using the data provided. Set up input data for the watershed using Clark's UH method (TC & R). Use Muskingum routing methods and assume that $K = 0.60$ hr and $x = 0.4$ in reaches 1, 2, and 3. Assume two subreaches in each reach and assume baseflow is zero.



5.3 Using the data shown in Table 5–9, create two Meteorologic Models in HEC-HMS using the 24-hr hypothetical design storms for the 100-yr frequency and the 10-yr frequency events. Place the peak center at 50% for both storms and use 15-min maximum intensity duration.

5.4 Create a new Basin Model for HEC-HMS Problem 5.2 to reflect a detention pond near Junction 2. Assume that the pond can be modeled in such a way that only the runoff from subbasin 3 should be routed through it. The storage–discharge relation is given as follows:

S (ac-ft)	0	200	375	508	860	1123	1500	2120
Q (cfs)	0	146	222	352	480	600	710	1733



- 5.5 The watershed is predicted to grow in the next 20 years and approach 100% development over most of the watershed. If this occurs, certain parameters will change, as shown in the following table. Compute the new TC & R coefficients and change the Basin Model of Problem 5.3 to reflect these fully developed conditions. Assume that the Muskingum values used in Problem 5.2 will still be correct.

	Development	Conveyance	Impervious	SCS Curve
Subbasin	(%)	(%)	(%)	Number
1	50	100	38	83
2	75	100	30	81
3	100	100	80	94
4	100	100	85	94
5	100	100	85	94

- See Solution 5.1 for set-up.

Subbasin	$C =$		$TC+R =$	
Number	$\cdot I\%$	$I - \cdot$	$I\%$	$I - \cdot$
	(hr)		()	
1	3.52		1.49	
2	2.68		1.35	
3	2.20		1.40	

4	2.20	1.34
5	2.20	1.53

5.5 cont'

- Linear interpolation must be used to solve for C'', which is required to solve for TC & R.

Subbasin	C''	TC = '() .	R = + -
Number	(hr)	(hr)	(hr)
1	1.70	0.26	1.23
2	1.32	0.26	1.10
3	0.94	0.26	1.14
4	0.94	0.21	1.12
5	0.94	0.34	1.20

5.6 Run the HEC-HMS model with $\Delta t = 15$ min to reflect the existing conditions, the effect of the pond with existing conditions, fully developed conditions, and the effect of the pond with fully developed conditions for both the 100-yr and the 10-yr design storms. Compare the peak flows at Junction 3 for the various run combinations.

	10-year storm event				100-year storm event			
	Existing	Det.Pond	Dev.	Dev + Det.Pond	Existing	Det.Pond	Dev.	Dev + Det.Pond
Peak Outflow (cfs)	6320.0	3921.7	8467.5	5705.5	11978.4	7703.0	15171.8	10412.1
Total Outflow (ac-ft)	3119.2	2753.0	3455.9	3055.3	6508.4	5619.8	6888.2	5986.6
Time	13:30 (1 Jan)	14:00 (1 Jan)	13:30 (1 Jan)	13:30 (1 Jan)	13:30 (1 Jan)	13:45 (1 Jan)	13:30 (1 Jan)	13:30 (1 Jan)

- For both 10 yr and 100 yr storm events and all the different scenarios, the addition of a detention pond detains the water and delays the time to peak.
- The highest peak outflow is observed, as expected, in the developed watershed scenario. The addition of a detention pond decreases the peak outflow significantly in both the 100 yr and 10 yr storms.

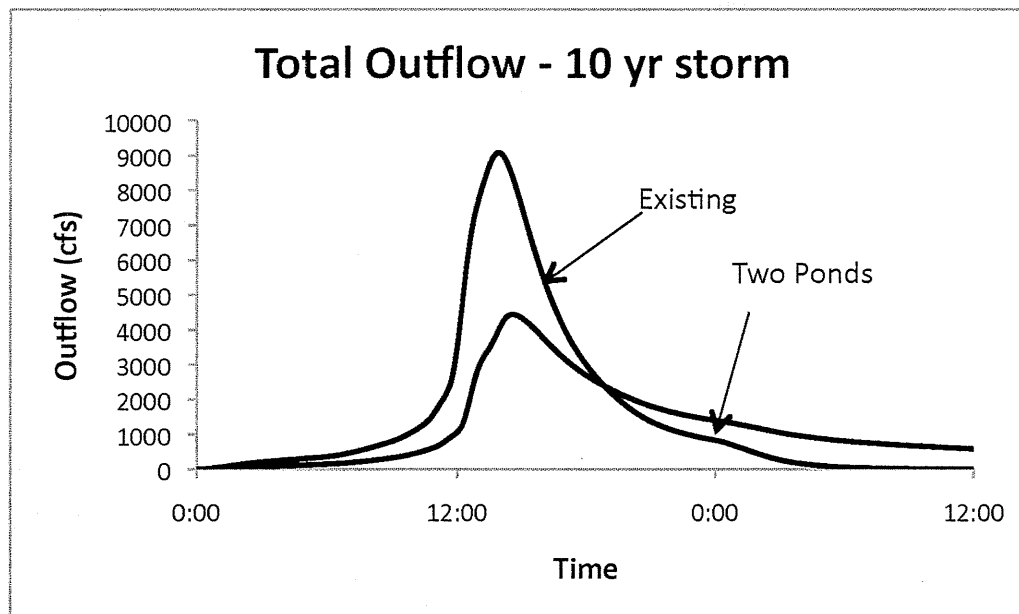
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- 5.7 Set up a diversion at Junction 2 of the existing condition basin so that Reach 1 and Sub-basin 3 flow into it. Use the inflow-diversion relationship from Table 5–16, and compare the peak outflows at Junction 3 of the new basin model for the 10-yr and 100-yr storm events.

	10-yr storm event		100-yr storm event	
	Existing	Exist.+Diversion	Existing	Exist.+Diversion
Peak Outflow (cfs)	6320.0	3522.7	11978.4	7353.8
Total Outflow (ac-ft)	3119.2	1598.3	6508.4	3527.6
Time	13:30 (1 Jan)	13:15 (1 Jan)	13:30 (1 Jan)	13:30 (1 Jan)

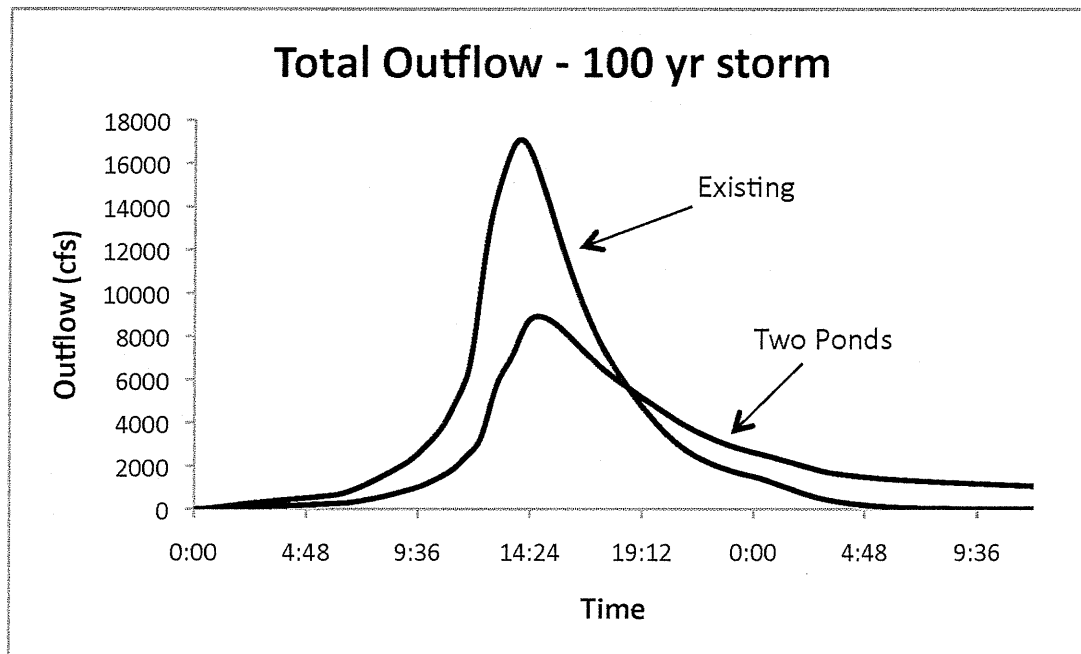
- The diversion at Junction 2 produces a significant impact on the peak outflow at Junction 3. Approximately the outflow for the 10-yr storm event is reduced by 44% and for the 100-yr storm event by 38%.

- 5.8** Use the Existing Basin conditions from Problem 5.2, and add a detention pond in the two largest sub-basins, using the storage-discharge relationship from Problem 5-4 for each. Run the 10-yr and 100-yr storm events, and compare the hydrograph and peak outflow at the outlet to that of the existing basin model. Discuss the differences.

	10-yr storm event		100-yr storm event	
	Existing	Two Ponds	Existing	Two Ponds
Peak Outflow (cfs)	9070.7	4435.3	17096.0	8926.5
Total Outflow (ac-ft)	4670.1	3706.7	9561.1	7607.8
Time	14:00 (1 Jan)	14:30 (1 Jan)	14:00 (1 Jan)	14:45 (1 Jan)



5.8 cont'



- The addition of the detention ponds decreases the peak outflow at the outlet of the basin significantly. The peak outflow decreases greater than 8,000 cfs for the 100-yr storm event and nearly 5,000 cfs for the 10-yr storm event.
- The addition of the detention ponds also causes the peak outflow to occur approximately an hour later for each storm event.

- 5.9 Use the Existing Basin conditions to make a new model, setting the loss method to Green and Ampt for each sub-basin. Enter the Green and Ampt parameters shown in the following table (values come from Table 2.7) and run the 10-yr and 100-yr storm event. Compare the resulting hydrographs and peak flows at Junction 1 and Junction 4.

Subbasin	Initial Content	Saturated Content	Suction (in)	Conductivity (in/hr)
1	.232	.464	8.22	.039
2	.232	.464	8.22	.039
3	.232	.464	8.22	.039
4	.232	.464	8.22	.039
5	.232	.464	8.22	.039

Junction 1	10-yr storm event		100-yr storm event	
	Existing	Green & Ampt	Existing	Green & Ampt
Peak Outflow (cfs)	2322.7	2758.8	4676.5	5016.5
Total Outflow (ac-ft)	1213.9	1156.8	2671.2	2637.8
Time	13:00 (1 Jan)	12:45 (1 Jan)	13:00 (1 Jan)	12:45 (1 Jan)

5.9 cont'

Junction 4	10-yr storm event		100-yr storm event	
	Existing	Green & Ampt	Existing	Green & Ampt
Peak Outflow (cfs)	9058.3	9191.6	16994.4	17041.6
Total Outflow (ac-ft)	4670.1	3799.9	9561.0	8664.5
Time	13:45 (1 Jan)	13:45 (1 Jan)	13:45 (1 Jan)	13:45 (1 Jan)

- Using the Green and Ampt method as opposed to the SCS Curve Number method does not produce a major change. For all scenarios, while the total outflow decreases with the Green and Ampt method, the peak outflow increases slightly.
- When comparing the resulting hydrographs, the Green and Ampt is slightly skinnier than the SCS hydrographs.

5.10 Rain gage data is given in Table P5-15A for three rain gages within the watershed.

Weight the gage data over the five subareas according to the weighting values given in Table P5-15B (see Example 1-3 in Chapter 1). Set up the meteorological model for subareas 1 through 5 in the watershed to reference this storm's rainfall data. For example, subbasin 2 receives 1/3 of gage 100R rainfall and 2/3 of gage 200R rainfall. Enter the actual rain gage data and weights into HEC-HMS.

Table P5-15A. Cumulative Rainfall Data

Time (hr)	Gage Numbers		
	100R	200R	300R
0	0.0	0.0	0.0
1	0.60	0.50	0.30
2	1.03	1.10	0.93
3	1.06	1.10	0.95
4	1.29	1.20	1.05
5	1.94	1.40	1.13
6	4.18	2.50	1.38
7	4.32	2.90	1.88
8	4.38	3.00	1.96
9	4.54	3.10	2.25

10	4.70	3.20	2.36
11	4.76	3.40	2.58
12	4.84	3.50	2.65
13	4.88	3.50	2.69
14	4.90	3.50	2.71

Table P5–13B. Precipitation Gage Weights

Subbasin	Gage Numbers		
	100R	200R	300R
1	1.00	0.00	0.00
2	0.33	0.67	0.00
3	0.00	0.61	0.39
4	0.00	0.00	1.00
5	0.00	0.00	1.00

5.11 Run the given storm through the watershed using the Existing Basin conditions. Find the peak flows for this storm at Junction 2 and at the outlet.

	Junction 2	Outlet
Peak Outflow (cfs)	2195.2	3088.3
Total Outflow (ac-ft)	1045.1	1840.8
Time	7:00 (1 Jan)	8:00 (1 Jan)

5.12 For the Muskingum coefficients given in Problem 5.2, determine the dimensions of a wide rectangular channel needed to carry the 100-yr flow under existing development conditions. Use a Manning's n value of 0.04, and assume a channel $L = 10,000$ ft and $S = 0.001$. (Hint: Use Muskingum's K equation and Manning's equation)

$$n = 0.04$$

$$K = 0.6 h^3 = 2160$$

$$K = 0.04$$

$$L = 10,000$$

$$S = 0.001$$

- K is the travel time through the reach

$$K = L / V = 10,000 / 4.63$$

$$\text{Manning's Equation: } V = 1.49 R^{2/3} S^{1/2}$$

$$V = 1.49 (0.04)^{2/3} (0.001)^{1/2} = 4.36$$

- Solving for $y \rightarrow R = 3.93$

$$R = \frac{h}{2}$$

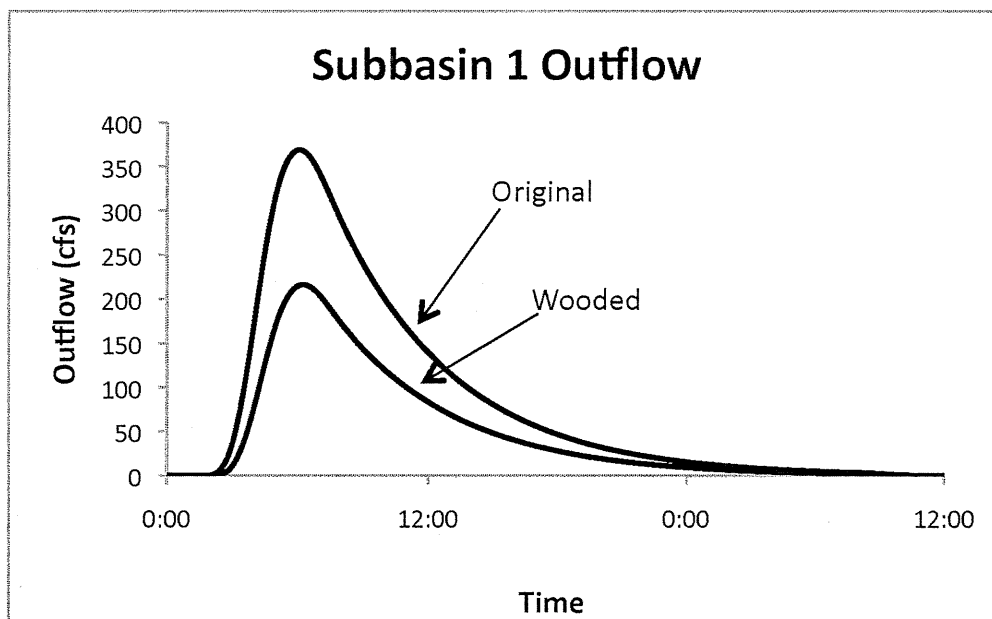
$$\text{For } Q = 17,081.1$$

$$h = \frac{Q}{V} = \frac{17,081.1}{4.36} = 3,917.7$$

5.13 Rework Example 5.1, assuming the same type of soil and that the woods in subbasin 1 have grown much denser and provide good cover. Run the revised HEC-HMS and then graph the original and the updated discharge hydrographs from subbasin 1. How does the curve number affect the amount of runoff?

- Based on the information, subbasin 1 is a wooded area with poor cover with an original SCS Curve number of 66. The SCS Curve number must be changed to 55 to account for the change in cover.

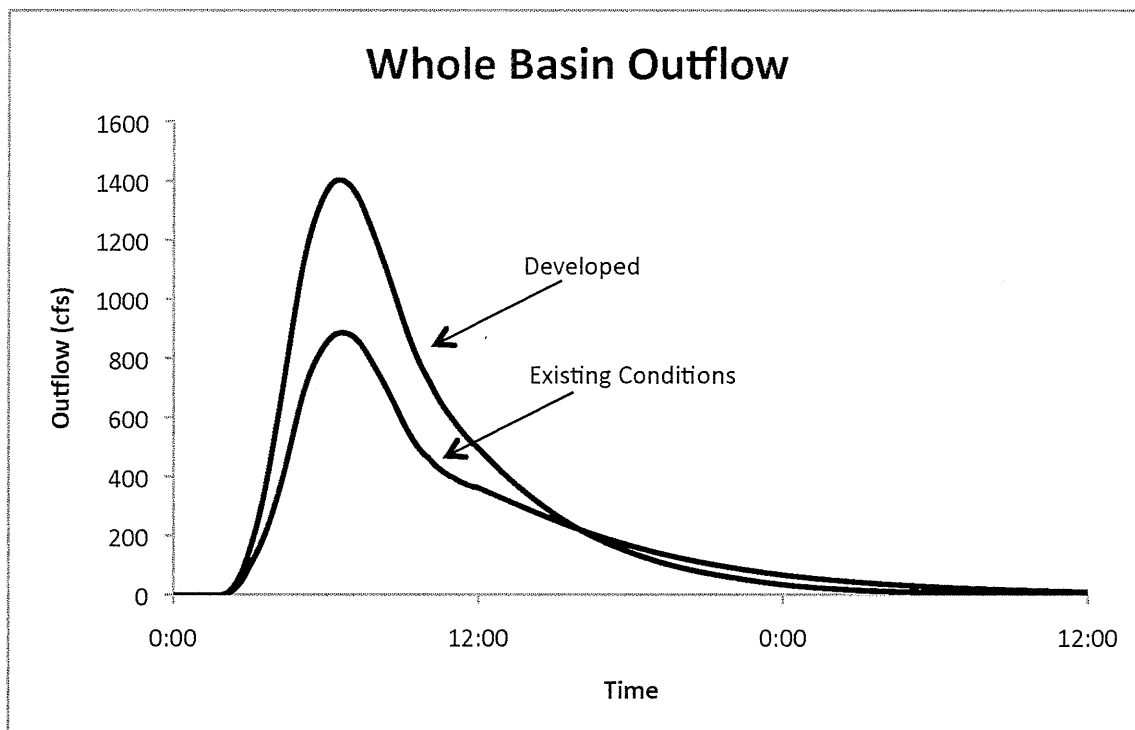
	Original Subbasin 1	Wooded Subbasin 1	Original Watershed Outlet	Wooded Watershed Outlet
Peak Outflow (cfs)	368.7	216.3	884.9	794.7
Total Outflow (ac-ft)	244.1	140.7	637.5	534.4
Time	N/A	N/A	06:30 (19 June)	06:30 (19 June)



- The change in curve number significantly decreases both the total outflow and the peak outflow in the wooded subbasin.

5.14 Rework Example 5–1 as described in Problem 5.13 and also assume that subbasin 2 has been developed into 1/4-ac residences. Let the values for $TC = 1.14$ and $R = 3.5$. Plot the final hydrograph for the whole basin versus the original one in Example 5.1. Discuss the differences.

	Existing	Developed
Peak Outflow (cfs)	884.9	1402.9
Total Outflow (ac-ft)	637.5	869.1
Time	06:30 (19 June)	06:30 (19 June)



- In the existing conditions scenario, the peak outflow is almost half of the peak outflow in the developed watershed scenario. Furthermore, the total outflow in the existing conditions is less than the total outflow in the developed watershed. Of course the duration of the flow in the existing conditions is longer than the one in the developed

conditions, but the level of the flow at the additional period is very low.

5.15 Alter the rainfall in Example 5–1 by using the following hourly cumulative measurements:

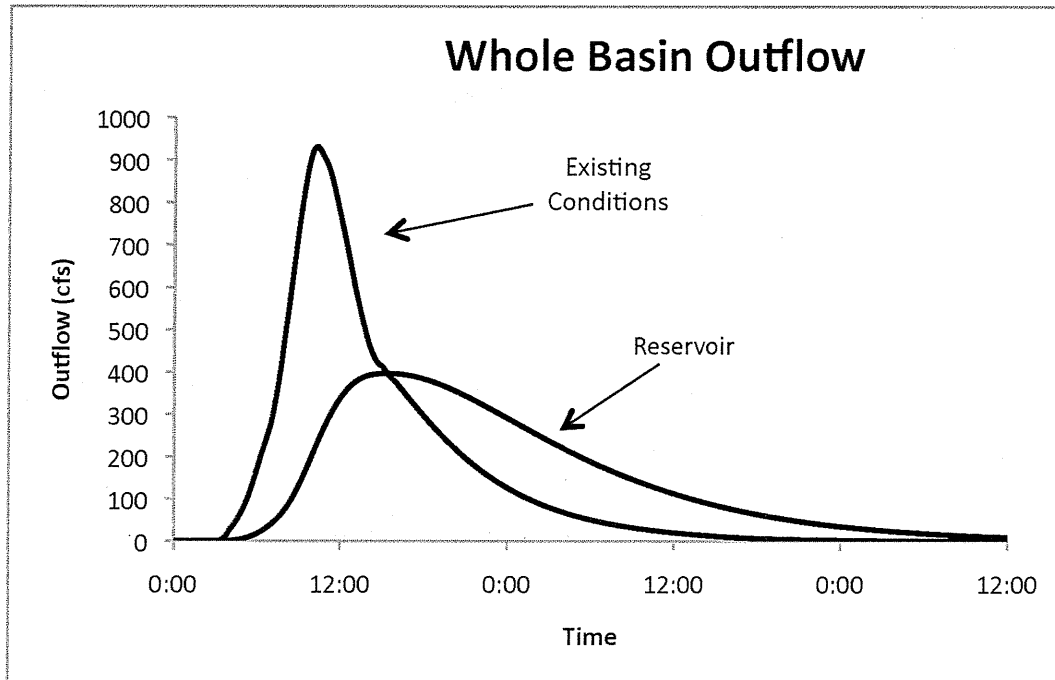
Time (hr)	0	1	2	3	4	5	6	7	8	9	10
Rainfall (in.)	0	0.47	0.74	1.34	2.64	2.87	3.08	3.95	5.16	5.44	5.44

Assume that there is a detention pond at point *B* of the basin that is used for flood control.

Assume a storage–discharge relationship $S = k \times Q$, where k is equivalent to 0.75 ac-ft/cfs.

Prepare a graph of the outflow from the basin, with and without detention, and compare results.

	Existing	Detention Pond
Peak Outflow (cfs)	930.9	396.1
Total Outflow (ac-ft)	712.5	714.4
Time	10:15 (19 June)	15:15 (19 June)



5.15 cont'

- The addition of the reservoir decreases the peak outflow by more than one half. As we can see from the graph, the duration of the flow in the reservoir scenarios is significantly increased, but the level of the flow for the most part of that additional time is low.