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RUNOFF CONDITIONS FOR CONVERTING STORM RAINFALL TO RUNOFF WITH SCS CURVE NUMBERS

by

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INTRODUCTION

In August 1972, the 92nd Congress of the United States authorized the National Dam Safety Program by legislating Public Law 92-367, or the National Dam Inspection Act. This Act authorized the Secretary of the Army, acting through the Chief of Engineers, to initiate an inventory program for all dams satisfying certain size criteria, and a safety inspection of all non-federal dams in the United States that are classified as having a high or significant hazard potential because of the existing dam conditions. The Corps of Engineers (1980) lists 920 federal and non-federal dams in Illinois meeting or exceeding the size criteria as set forth in the Act. About 96 percent of these dams are earth dams, for which the dominant causes of failure are overtopping and piping and, to a lesser extent, unsatisfactory construction and maintenance and foundation problems.

The Corps of Engineers and the Division of Water Resources of the Illinois Department of Transportation, acting on behalf of the Corps of Engineers, have been preparing inspection reports for high-hazard-category dams, or having them prepared by consultants and engineering companies. The inspection report contains the project description; engineering data for construction, operation, and maintenance; results of visual inspection; and hydraulic and hydrologic evaluations of the spillway and outlet works for different inflow flood hydrographs. An integral part of the hydraulic and hydrologic evaluations is an investigation of the adequacy of a spill-way to handle floods of various frequencies without endangering the struc-ture or causing dam failure because of overtopping. These evaluations require information on storms of various frequencies, their depth-area-duration relationships, and the soil moisture condition at the beginning of a design storm, as well as suitable unit hydrographs for converting the design storms into flood hydrographs. The derivation and regionalization of unit-hydrograph parameters for Illinois are given elsewhere (Singh, 1981). This study deals with the development of antecedent'moisture conditions that will convert a 100-year storm rainfall to surface runoff (which can be used in conjunction with the unit hydrograph to derive a 1 00-year flood hydrograph).

Objectives of This Study

The determination of suitable antecedent moisture indexes and conditions for converting a 100-year storm rainfall to runoff for various drainage basins in Illinois is an important part of the hydrologic evaluation of existing dams and of the design of new dams. This conversion is generally achieved with the Soil Conservation Service curve numbers, CN, which are defined for 3 antecedent moisture conditions, AMC I, II, and III. These conditions are classified as follows.

	5-day total antecedent rainfall, inches	
AMC	Dormant season	Growing season
I	<0.5	<1.4
II	0.5-1.1	1.4-2.1
III	>1.1	>2.1

The AMC considerably affects the runoff as well as the flood peak; for example, with CN values of 55, 74, and 88 for AMC I, II, and III, the runoff from a 4.3-inch storm equals 0.65, 1.83, and 3.00 inches, respectively. This study was undertaken to define the suitable moisture condition for converting a 100-year storm to a 100-year runoff, and to estimate how many days total antecedent rainfall was suitable for defining the AMC for various drainage basins in Illinois.

Highlights of This Study

Basin Curve Numbers. In order to provide areal, geographical, meteorological, and hydrological variation, 38 basins were selected (table 1) for developing AMC information. The curve numbers for these basins were estimated with the methodology recommended by the Soil Conservation Service (SCS). The locations of the 38 study basins are shown in figure 1.

Regionalized AMC Values. The 100-year storms for the 38 study basins were developed with the available data (Huff, 1980). The 100-year flood peaks were determined with the new flood frequency method (Singh and Nakashima, 1981) as well as from the USGS publication (Curtis, 1977). The flood peaks were determined with the 100-year storms and relevant unit hydrographs (Singh, 1981), with the runoff factor assumed to be equal to unity. The runoff factor was computed as the ratio of the 100-year flood (determined by one of the methods mentioned above) to that of the 100-year design storm. This was compared with runoff factors derived for AMC I, II, and III. The comparison yields the suitable AMC for use in hydrologic studies. These AMCs helped in defining three regions: the first with AMC II, the second with an average of AMC II and AMC III, and the third with AMC III.

Observed Floods, Storms, and AMCs. Various antecedent precipitation indexes were developed for about 8 top floods at each of the 38 study basins. Consideration of antecedent precipitation for the top 3 or 4 floods for these basins indicated that the use of 5-day antecedent precipi-

Table 1. The 38 Study Basins

No.	USGS No.	Stream and gaging station	A	L	S
1	03336500	Bluegrass Creek at Potomac	35.00	12.77	6.92
2	03343400	Embarras River at Camargo	186.00	27.27	2.96
3	03344500	Range Creek near Casey	7.61	4.58	15.73
4	03346000	N. Fork Embarras River near Oblong	319.00	51.21	4.33
5	03380475	Horse Creek near Keenes	97.20	26.38	4.07
6	03380500	Skillet Fork at Wayne City	464.00	59.52	1.90
7	03385000	Hayes Creek at Glendale	19.10	12.01	21.44
8	05420000	Plum River below Carroll Creek near Savanna	230.00	31.38	6.55
9	05440500	Killbuck Creek near Monroe Center	117.00	26.80	6.34
10	05445500	Rock Creek near Morrison	158.00	38.68	3.91
11	05447000	Green River at Amboy	201.00	23.63	3.85
12	05466000	Edwards River near Orion	155.00	22.91	5.07
13	05495500	Bear Creek near Marcelline	349.00	36.18	3.70
14	05502020	Hadley Creek near Barry	40.90	11.69	19.75
15	05512500	Bay Creek at Pittsfield	39.40	12.20	11.25
16	05525500	Sugar Creek at Milford	446.00	32.02	4.86
17	05531500	Salt Creek at Western Springs	114.00	36.38	2.85
18	05536255	Butterfield Creek at Flossmoor	23.50	13.86	6.34
19	055 39000	Hickory Creek at Joliet	107.00	23.13	7.55
20	055 39900	W. Branch DuPage River near W. Chicago	28.50	14.06	6.58
21	05557000	West Bureau Creek at Wyanet	86.70	22.54	9.03
22	05557500	East Bureau Creek near Bureau	99.00	23.50	12.72
23	05559000	Gimlet Creek at Sparland	5.66	4.81	53.86
24	05563000	Kickapoo Creek near Kickapoo	119.00	22.18	10.93
25	05567000	Panther Creek near El Paso	93.90	13.59	4.22
26	05571000	Sangamon River at Mahomet	362.00	56.41	3.59
27	05574500	Flat Branch near Taylorville	276.00	47.49	2.01
28	05577500	Spring Creek at Springfield	107.00	29.37	5.39
29	05580000	Kickapoo Creek at Waynesville	227.00	36.08	6.23
30	05584400	Drowning Fork at Bushnell	26.30	12.57	5.76
31	05586000	N. Fork Mauvaise Terre Creek near Jacksonville	29.10	13.16	9.03
32	05588000	Indian Creek at Wanda	36.70	20.89	7.92
33	05589500	Canteen Creek at Caseyville	22.60	10.93	11.09
34	05591500	Asa Creek near Sullivan	8.05	4.20	5.23
35	05592300	Wolf Creek near Beecher City	47.90	16.56	6.60
36	05597500	Crab Orchard Creek near Marion	31.70	11.56	8.08
37	05599000	Beaucoup Creek near Matthews	292.00	51.44	2.64
38	05600000	Big Creek near Wetaug	32.20	17.92	11.30

A = drainage area in square miles
L = main-channel length in miles
S = main-channel slope in feet per mile

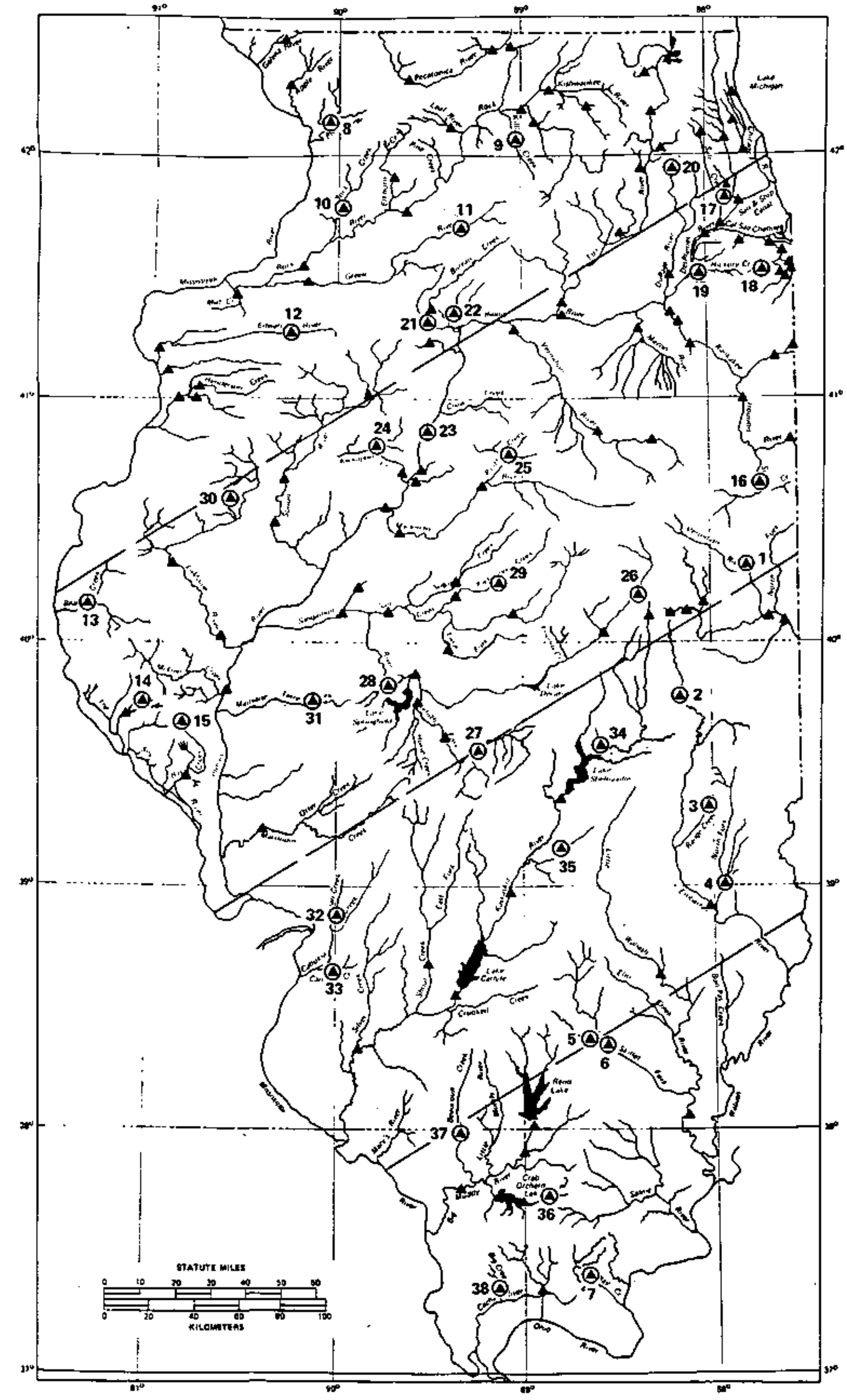

Figure 1. Locations of the 38 study basins

tation for determining AMC needs modification, at least for the Illinois basins. Three regions were defined with 5-10 day, about 10 day, and 10-15 day antecedent precipitation for defining the antecedent soil moisture condition. The probabilities of high floods occurring in winter (December 16 to March 31) were also regionalized for the state of Illinois.

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Tai-Wei Soong, a graduate research assistant, carried out computation of curve numbers and processed other data for this report. Ismael Pagan-Trinidad, a graduate student at the University of Illinois, handled rainfall data and computed various antecedent precipitation indexes. Masahiro Nakashima, a graduate research assistant, provided 100-year flood estimates with the new flood frequency methodology. Linda Jo Riggin prepared the illustrations and Pamela Lovett typed the manuscript.

DERIVATION OF BASIN CURVE NUMBERS

The soils and vegetative covers of a basin are classified separately. A combination of a soil (hydrologic soil group) and a cover (land use and treatment) is referred to as a soil-cover complex. The runoff curve number, CN, assigned to such a complex serves as a parameter indicative of the runoff potential under given antecedent soil moisture conditions. The number is determined for the growing season when the soil is not frozen. The higher the CN, the higher is the runoff potential. Soils are classified on the basis of parent materials from which they have been formed, surface soil color, degree of development, and natural soil drainage. The cover is any material covering the soil and providing protection from the impact of rainfall.

Soil Groups

Soil properties (such as infiltration, transmission, etc.) influence the rainfall-runoff relationship. They have to be considered, directly or indirectly, in any method of runoff estimation. Four soil groups are defined, A through D, in the order of increasing runoff potential. The runoff is affected by the infiltration — the rate at which water enters the soil at the surface. The infiltration depends on the surface conditions and transmission or the rate at which the water moves in the soil, and the rate is controlled by the carrying capacity of different soil horizons.

Group A (Low Runoff Potential). This group includes soils having high infiltration rates even when thoroughly wetted. The soils consist of deep and well-drained to excessively well-drained sands or gravels, and have a high rate of water transmission.

Group B. This group contains soils having moderate infiltration rates when thoroughly wetted. They consist chiefly of soils that are moderately deep to deep and moderately well-drained to well-drained, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C. This group comprises soils having slow infiltration rates when thoroughly wetted, chiefly those with a layer that impedes the downward movement of water. These soils have a moderately-fine texture and a slow rate of water transmission.

Group D (High Runoff Potential). This includes soils having very slow infiltration rates when thoroughly wetted. They consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Cover

The SCS method of runoff estimation considers the effect of basin surface condition in terms of the type of land use and treatment.

Land use generally refers to the type of cover. With agricultural use, the cover may be vegetation, litter, or pasture; with nonagricultural use, it may be water surfaces such as lakes and swamps, and impervious surfaces such as roads and roofs.

Land treatment applies mainly to agricultural land use, and includes mechanical practices such as contouring and terracing, and management practices such as grazing control and rotation of crops.

Surface cover provides protection from the impact of rainfall. Detailed information about the cover and land treatment is usually not available. The effectiveness of the cover varies from season to season. Average values of cover and land treatment for the basin are generally used.

Curve Numbers

The group classifications of more than 4000 soils in the United States are given in the National Engineering Handbook (SCS, 1972) and elsewhere (SCS, 1980). The original classifications were based on the rainfall-runoff data from small watersheds or infiltrometer tests, but most of them are based on the judgments of soil scientists and other field staff who use physical properties of the soils in making their decisions.

Runoff curve numbers are given in tables 2 and 3 for a combination of land use and treatment or practice for the four soil groups under AMC II or average antecedent soil moisture condition. In this study, row crop land use is considered, with a hydrologic condition intermediate between poor and good, and with straight row or contoured practice depending on whether the basin has moderate or steep slopes. Area not under agricultural use is distributed among open spaces, woods, and urban lands. The approximate distribution is estimated from 7-1/2' or 15' quadrangle maps. Usually the area not under agriculture and not in towns is considered to be 80 percent open space and 20 percent woods.

Antecedent Moisture Condition, AMC

The magnitude of storm runoff volume from a given storm rainfall is greatly affected by soil characteristics, vegetation, and antecedent soil moisture condition. The antecedent soil moisture condition at the

Table 2. Runoff Curve Numbers for Hydrologic Soil-Cover Complexes

(Antecedent moisture condition II, and $I_a = 0.2S$)

Cover: Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group: A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		----	74	84	90	92

1/ Close-drilled or broadcast
2/ Including right-of-way

(Table 9.1 in National Engineering Handbook, Section 4, SCS, USDA)

Table 3. Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Land Use
(Antecedent moisture condition II, and $I_a = 0.2S$)

Land Use Description		Hydrologic soil group			
		A	B	C	D
Cultivated land[1]: without conservation treatment		72	81	88	91
: with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
good condition		39	61	74	80
Meadow: good condition		-30	58	71	78
Woods or forest land: thin stand, poor cover, no mulch		45	66	77	83
: good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential[3]					
Average lot size	Average % impervious[4]				
1/8 acres or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972.

[2]Good cover is protected from grazing and litter and brush cover soil.

[3]Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.
The remaining impervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

In some warmer climates of the country a curve number of 95 may be used,
(from Technical Release-55, Engineering Division, SCS, USDA)

beginning of a storm depends on the rainfall sequence for some days prior to the storm. Thus, it can vary widely from one storm to another. The Soil Conservation Service defines antecedent moisture condition, AMC, in three classes — I, II, and III — based on the cumulative 5-day total rainfall before the storm under consideration, for both the dormant and growing seasons.

AMC class	5-day total antecedent rainfall, inches Dormant season	Growing season
I	<0.5	<1.4
II	0.5-1.1	1.4-2.1
III	>1.1	>2.1

The potential maximum retention and abstraction, S, in inches, is the sum of initial abstraction, I_a, and the potential maximum retention (the rain not converted to runoff), S', or

$$S = I_a + S'$$

By taking $I_a = 0.2S$, the direct runoff, Q, in inches, from a storm rainfall, P, in inches, is obtained (SCS, 197 2) from

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

in which S and CN are related according to the expression

$$S = \frac{1000}{CN} - 10$$

The curve numbers for conditions I and III, corresponding to numbers for condition II, are given in table 4.

Basin Curve Number

A soil association is composed of several soils developed from similar parent material and having similar surface soil cover. The information on

Table 4. Curve Numbers, CN, for AMC I, II, and III

CN for condition II	CN for conditions I	CN for conditions III	S values* (inches)	CN for condition II	CN for conditions I	CN for conditions III	S values* (inches)
100	100	100	0.0	60	40	78	6.67
99	97	100	.101	59	39	77	6.95
98	94	99	.204	58	38	76	7.24
97	91	99	.309	57	37	75	7.54
96	89	99	.417	56	.36	75	7.86
95	87	98	.526	55	35	74	8.18
94	85	98	.638	54	34	73	8.52
93	83	98	.753	53	33	72	8.87
92	81	97	.870	52	32	71	9.23
91	80	97	.989	51	31	70	9.61
90	78	96	1.11	50	31	70	10.0
89	76	96	1.24	49	30	69	10.4
88	75	95	1.36	48	29	68	10.8
87	73	95	1.49	47	28	67	11.3
86	72	94	1.63	46	27	66	11.7
85	70	94	1.76	45	26	65	12.2
84	68	93	1.90	44	25	64	12.7
83	67	93	2.05	43	25	63	13.2
82	66	92	2.20	42	24	62	13.8
81	64	92	2.34	41	23	61	14.4
80	63	91	2.50	40	22	60	15.0
79	62	91	2.66	39	21	59	15.6
78	60	90	2.82	38	21	58	16.3
77	59	89	2.99	37	20	57	17.0
76	58	89	3.16	36	19	56	17.8
75	57	88	3.33	35	18	55	18.6
74	55	88	3.51	34	18	54	19.4
73	54	87	3.70	33	17	53	20.3
72	53	86	3.89	32	16	52	21.2
71	52	86	4.08	31	16	51	22.2
70	51	85	4.28	30	15	50	23.3
69	50	84	4.49				
68	48	84	4.70	25	12	43	30.0
67	47	83	4.92	20	9	37	40.0
66	46	82	5.15	15	6	30	56.7
65	45	82	5.38	10	4	22	90.0
64	44	81	5.62	5	2	13	190.0
63	43	80	5.87	0	0	0	infinity
62	42	79	6.13				
61	41	78	6.39				

*Potential maximum retention and abstraction in inches corresponds to AMC II.

(Table 10.1 in Natural Engineering Handbook, Section 4, SCS, USDA) soil associations can be obtained from the work of Fehrenbacher et al. (1967). In this study, equal weights are assigned to the soils in an association and these weights are multiplied by the curve number for each soil (depending on the soil group it belongs to) to obtain an average weighted curve number for the soil association. The information on soil groups is obtained from the updated hydrologic soil groups for Illinois (SCS, 1980). A basin often consists of several soil associations. Precise measurement of their respective areas, such as by planimetering, is not necessary for hydrologic purposes. Grid computations are satisfactory in determining percent areal coverage of various soil associations. The curve number for each association is weighted by the relative area covered by that association, and the curve number for the entire basin is obtained by summing the weighted curve numbers of different soil associations in the basin.

The derivation of a basin curve number is illustrated here for the Sangamon River at Mahomet, USGS No. 05571000. The major basin factors are: drainage area, 362 square miles; main-channel length, 56.51 miles; and main-channel slope, 3.59 feet/mile. County soil maps indicate that the basin contains five different soil associations: B, J, K, M, and W. More than 75 percent of soils in types B, J, K, and W, and less than 25 percent of soils in type M, are suitable for agricultural purposes (University of Illinois, 1977). The information on the soil associations; soil series within each association; proportions to total area, AA/A (from grid computation); hydrologic soil group corresponding to a soil series; and the proportion defined as potential farm land is given in table 5.

The calculations for the basin curve numbers are shown in table 6. The multiplication terms under the soil series are ordered as AA/A or area

Table 5. Pertinent Data for Computing CN for the Sangamon River at Mahomet

Soil association	Soil series	AA/A*	Hydrologic soil group	Farmland* factor
	Sidell		B	
	Catlin	15/182	B	3/4
	Flanagan		B	
	Drummer		B/D	
	Elliott		C	
J	Ashkum	42/182	B/D	3/4
	Andres		B	
	Swygert		C	
K	Bryce	20/182	D	3/4
	Clarence		D	
	Rowe		D	
	Birkbeck		B	
M	Ward	7/182	D	1/4
	Russell		B	
	Littleton		B	
	Proctor		B	
W	Plano	98/182	B	3/4
	Camden	'	B	
	Hurst		D	
	Ginat		D	

* AA/A and farmland factor apply to the soil association

Table 6. Runoff Curve Number for the Sangamon River Basin above Mahomet (AMC II Condition)

Item	Hydrologic soil group	CN	Soil associations B	J	K	M	W	Sum	CN Sum
Row crops (straight rows)	B	79.5	$\left[\frac{15}{182}\times\frac{3.5}{4}\times\frac{3}{4}\right.$ +	$\frac{42}{182}\times\frac{1.5}{3}\times\frac{3}{4}$ +		$\frac{7}{182}\times\frac{2}{3}\times\frac{1}{4}$ +	$\left.\frac{98}{182}\times\frac{4}{6}\times\frac{3}{4}\right]$	0.416	33.07
	C	86.5	[	$\frac{42}{182}\times\frac{1}{3}\times\frac{3}{4}$ +	$\frac{20}{182}\times\frac{1}{4}\times\frac{3}{4}$		]	0.078	6.75
	D	90	$\left[\frac{15}{182}\times\frac{0.5}{4}\times\frac{3}{4}\right.$ +	$\frac{42}{182}\times\frac{0.5}{3}\times\frac{3}{4}$ +	$\frac{20}{182}\times\frac{3}{4}\times\frac{3}{4}$ +	$\frac{7}{182}\times\frac{1}{3}\times\frac{1}{4}$ +	$\left.\frac{98}{182}\times\frac{2}{6}\times\frac{3}{4}\right]$	0.236	21.24
Open space	B	69	$\left[\frac{15}{182}\times\frac{3.5}{4}\times\frac{1}{4}\right.$ +	$\frac{42}{182}\times\frac{1.5}{3}\times\frac{1}{4}$ +		$\frac{7}{182}\times\frac{2}{3}\times\frac{3}{4}$ +	$\left.\frac{98}{182}\times\frac{4}{6}\times\frac{1}{4}\right]\frac{4}{5}$	0.125	8.63
	C	79	[	$\frac{42}{182}\times\frac{1}{3}\times\frac{1}{4}$ +	$\frac{20}{182}\times\frac{1}{4}\times\frac{1}{4}$		$]\frac{4}{5}$	0.021	1.66
	D	84	$\left[\frac{15}{182}\times\frac{0.5}{4}\times\frac{1}{4}\right.$ +	$\frac{42}{182}\times\frac{0.5}{3}\times\frac{1}{4}$ +	$\frac{20}{182}\times\frac{3}{4}\times\frac{1}{4}$ +	$\frac{7}{182}\times\frac{1}{3}\times\frac{3}{4}$ +	$\left.\frac{98}{182}\times\frac{2}{6}\times\frac{1}{4}\right]\frac{4}{5}$	0.070	5.88
Woods	B	60	[	same as open space B			$]\frac{1}{5}$	0.031	1.86
	C	73	[	same as open space C			$]\frac{1}{5}$	0.005	0.36
	D	79	[	same as open space D			$]\frac{1}{5}$	0.018	1.42
								1.000	80.87

Notes: 4/5 of the remaining area, within parentheses, is allocated to open space
1/5 of the remaining area, within parentheses, is allocated to woods

proportion x proportion of soils in a hydrologic soil group x farmland factor. The nonagricultural area is allocated 80 percent to open space and 20 percent to woods. The composite curve number for the AMC II condition is calculated as 80.87 or 81. The corresponding curve numbers for AMC I and AMC III are 64 and 92, respectively.

The runoff curve numbers for the 38 study basins were calculated in a similar manner. These basins and their curve numbers for AMC I, II, and III are given in table 7.

Table 7. Runoff Curve Numbers for the Study Basins

Basin no.	CN I	CN II	CN III	Basin no.	CN I	CN II	CN III
01	66	82	92	20	60	78	90
02	62	79	91	21	53	72	86
03	67	83	93	22	57	75	88
04	64	81	92	23	58	76	89
05	66	82	92	24	53	72	86
06	68	84	93	25	60	78	90
07	55	74	88	26	64	81	92
08	51	70	85	27	62	79	91
09	62	79	91	28	62	79	91
10	51	70	85	29	57	75	88
11	59	77	89	30	60	78	90
12	60	78	90	31	59	77	89
13	58	76	89	32	57	75	88
14	51	70	85	33	62	79	91
15	51	70	85	34	62	79	91
16	66	82	92	35	68	84	93
17	57	75	88	36	58	76	89
18	70	85	94	37	70	85	94
19	64	81	92	38	63	80	91

AMC FROM 100-YEAR FLOODS AND STORMS

The runoff from a storm rainfall over a drainage basin can be estimated for any of the three antecedent moisture conditions: AMC I, II, or III. A 100-year storm rainfall can be converted to a 100-year flood hydrograph with a suitable antecedent moisture condition. If the linearity of basin response is assumed, then the ratio of a 100-year flood peak (with small or relatively negligible baseflow) to the product of the 100-year storm rainfall (from intense, short duration precipitation) and the unit hydrograph peak corresponds to the runoff factor or the ratio of direct surface runoff to rainfall. For a given storm rainfall, the runoff factors can be obtained with the 3 AMCs if the basin curve numbers associated with these AMCs are known. A suitable AMC for converting a 100-year storm rainfall to a 100-year flood can be estimated by interpolating the runoff factor derived from flood and unit hydrograph peak and rainfall between those for the 3 AMCs.

Runoff Factors with SCS Curve Numbers

The runoff is obtained with the following expression:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

in which Q and P are the runoff and precipitation, in inches, and S equals the potential maximum retention, in inches. The value of S depends on the soil-cover complex, and it is related to the curve number, CN, by

$$S = \frac{1000}{CN} - 10$$

For a drainage basin, the CN increases with increases in AMC, as shown in table 4. The runoff factor, RF, equals Q/P:

$$RF = \frac{(P - 0.2S)^2}{P(P + 0.8S)}$$

If the duration of rainfall exceeds 24 hours, P equals rainfall in the first 24 hours. The previous 5-day rainfall and hence the AMC can be updated for the rainfall on the second day in calculating RF for that day, and so on.

100-Year Storms in Illinois

Huff (1980) presented regional estimates of storm rainfall for various durations, recurrence intervals, and areal coverage. He divided the state of Illinois into 4 regions, as shown in figure 2. The 100-year rainfall for storm durations of 0.25 to 48 hours and point rainfall to average rainfall over 300 square miles is given in table 8. The storm rainfall over a basin can be interpolated for the desired storm duration and basin areal coverage. Rainfall over a basin covering two regions can be taken as the average of the estimates for each of the two regions.

The time distribution of storm rainfall is important in developing flood hydrographs. One the basis of an extensive investigation of heavy rainfalls observed over various parts of Illinois, the rainfall distributions were grouped according to the heaviest rainfall occurring in the first, second, third or fourth quartile of a storm. The percent distribution of analyzed storms in these four groups was 33, 33, 23, and 11, respectively. The storms are classified as first-, second-, third-, and fourth-quartile storms. The first-quartile storms are also known as advanced type and the fourth-quartile storms as delayed type storms.

In deriving unit hydrographs for Illinois streams, Singh (1981) considered the critical duration, t_r, of a unit hydrograph as the

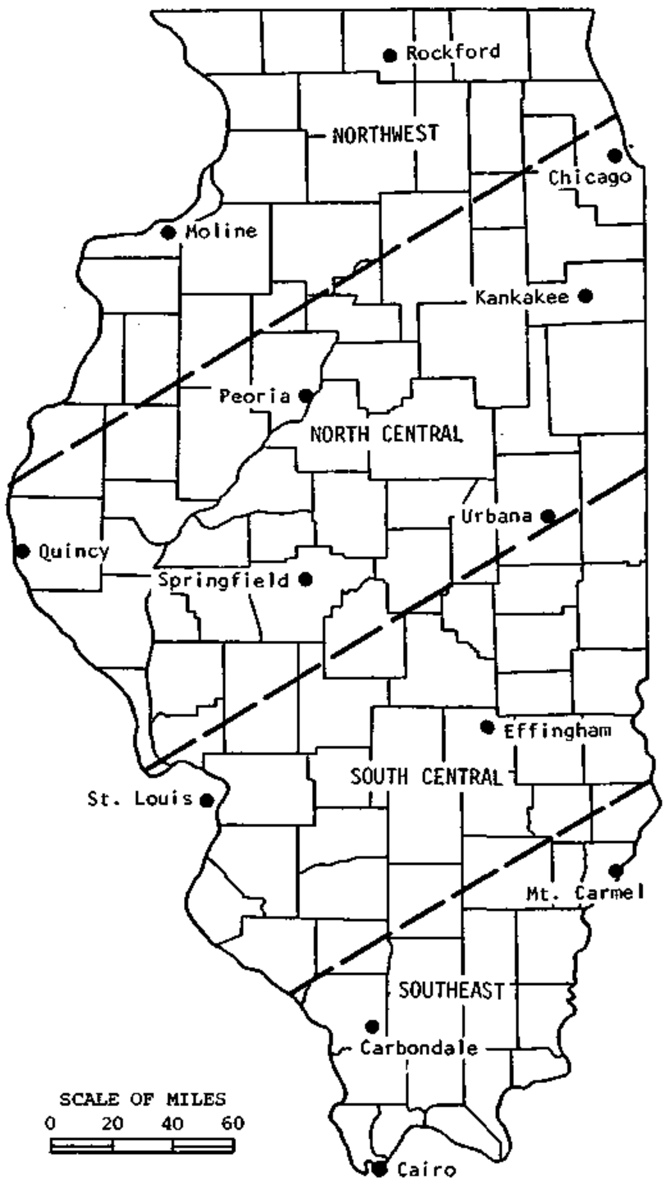

Figure 2. Regional divisions for design storms (Huff, 1980)

Table 8. 100-Year Rainfall Frequencies in Illinois (Huff, 1980)

Storm duration (hours)	Point rainfall (in.)	Average rainfall (in.) for given area (mi^2) 10	31	50	100	200	300
				Northwest Section			
0.25	1.8	1.6	1.3	1.2	0.9	0.8	0.7
0.5	2.6	2.4	2.2	2.0	1.8	1.6	1.5
1	3.6	3.3	3.1	2.9	2.7	2.4	2.3
2	4.4	4.3	4.0	3.8	3.6	3.3	3.2
3	4.9	4.7	4.5	4.3	4.1	3.9	3.7
6	5.8	5.7	5.5	5.3	5.1	5.0	4.9
12	6.9	6.8	6.6	6.5	6.3	6.2	6.0
24	8.3	8.2	8.0	7.9	7.8	7.6	7.6
48	9.2	9.1	9.0	8.9	8.7	8.6	8.5
				North Central Section			
0.25	1.6	1.4	1.2	0.9	0.8	0.6	0.4
0.5	2.3	2.1	1.8	1.6	1.4	1.3	1.2
1	3.1	2.9	2.7	2.5	2.3	2.1	2.0
2	3.7	3.5	3.4	3.2	3.0	2.7	2.6
3	4.2	4.1	4.0	3.8	3.6	3.4	3.3
6	5.1	5.0	4.7	4.6	4.4	4.2	4.1
12	5.9	5.8	5.7	5.5	5.4	5.3	5.2
24	7.2	7.1	7.0	6.8	6.7	6.6	6.5
48	8.0	7.8	7.7	7.5	7.3	7.2	7.1
				South Central Section			
0.25	1.8	1.6	1.3	1.1	1.0	0.9	0.8
0.5	2.7	2.4	2.1	1.9	1.7	1.5	1.4
1	3.6	3.3	3.1	2.9	2.6	2.4	2.3
2	4.5	4.3	4.2	3.9	3.6	3.3	3.2
3	4.9	4.8	4.7	4.4	4.2	3.9	3.8
6	5.9	5.8	5.6	5.4	5.2	5.0	4.8
12	7.0	6.9	6.8	6.6	6.4	6.3	6.0
24	8.4	8.3	8.1	8.0	7.9	7.7	7.5
48	9.2	9.0	8.9	8.7	8.5	8.4	8.2
				Southeast Section			
0.25	2.0	1.7	1.4	1.2	1.0	0.9	0.8
0.5	3.0	2.7	2.4	2.1	1.9	1.7	1.6
1	4.0	3.7	3.5	3.2	2.9	2.7	2.6
2	4.7	4.5	4.3	4.0	3.8	3.5	3.4
3	5.2	5.0	4.9	4.7	4.5	4.2	4.1
6	6.3	6.1	5.9	5.7	5.6	5.4	5.3
12	7.4	7.3	7.1	6.9	6.8	6.6	6.5
24	8.8	8.6	8.5	8.4	8.3	8.1	8.0
48	9.6	9.3	9.2	9.0	8.9	8.8	8.7

duration over which the effective rainfall may be considered similar for various storms producing high floods, in the range of 10- to 100-year floods. The hydrographs for storm durations of 2 or more times the t_r can be developed considering rainfall increments in t_r time increments. The hydrographs for longer duration were developed for the following three conditions (figure 3).

1) Rainfall is uniform over the storm duration. This may be satisfactory for the duration equal to t_r because of the manner in which unit hydrographs were developed, but not for durations of mt_r where m = 2, 3, 4, or 5.
2) For the rainfall type A, the relatively large rainfall increments lie to the left of the t -rainfall and the small increments to the right of it. Type A storms will generally follow the time distribution of rainfall intermediate between the second- and third-quartile storms.
3) For the rainfall type B, one increment lies to the left of the t_r-rainfall and other increments lie to the right of it. Type B storms will generally follow the time distribution of rainfall intermediate between the first- and second-quartile storms.

The 100-year storm rainfall, P_{100}, for durations of t_r to 5 t_r for the 38 study basins is given in table 9.

100-Year Floods

The estimates of 100-year floods, Q_{100}, have been developed by Curtis (1977) for streams in Illinois. Three estimates are given at a station: from individual station frequency curves, from regression

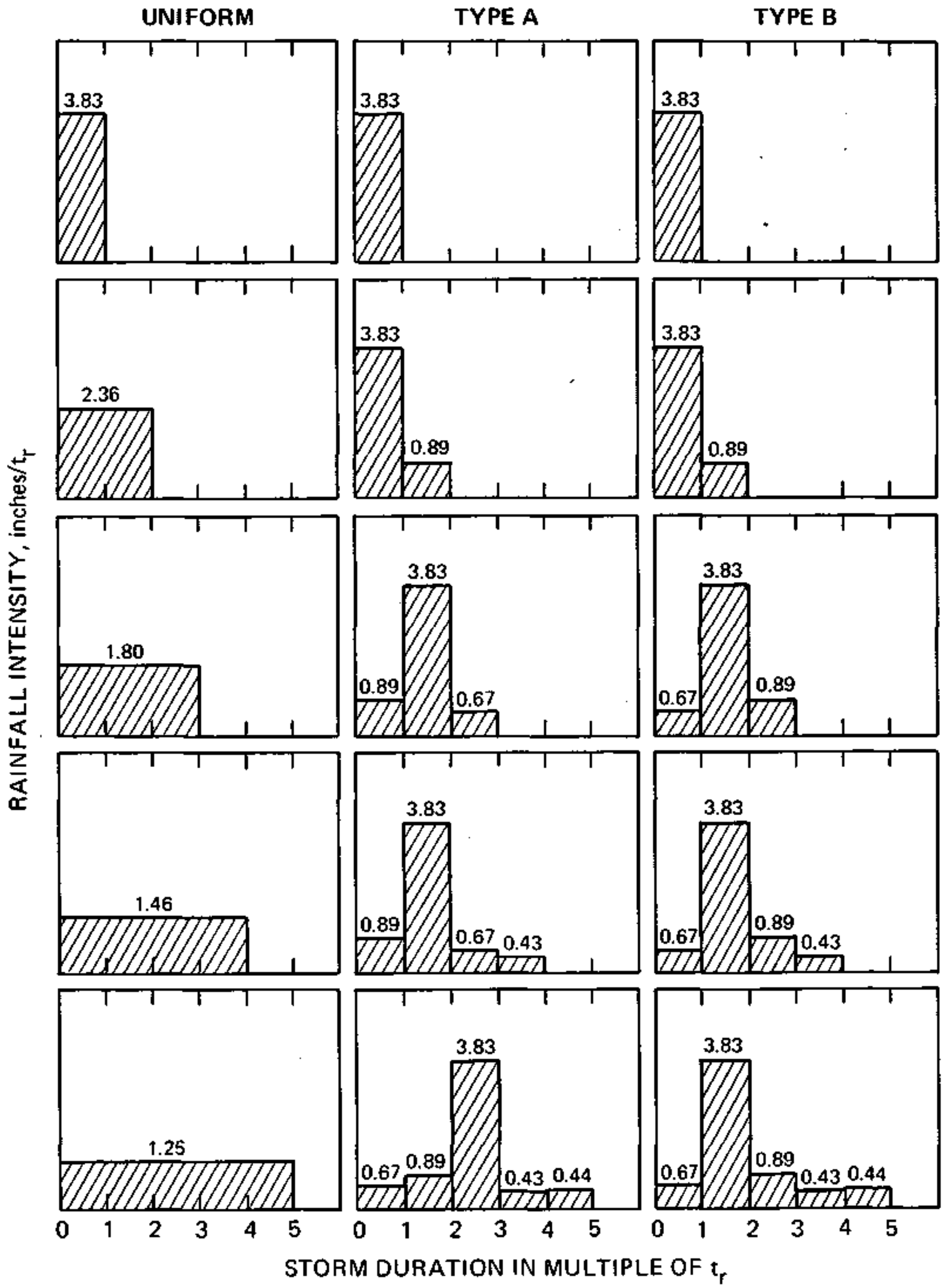

Figure 3. Three types of rainfall distributions

Table 9. P_{100}, Q_{100}, and Runoff Factors for the 38 Study Basins

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	type A	type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	II	III	Est. AMC
01	03336500	5290.	6234	3.0	3.92	9408	9408	9408	0.58	0.69	0.26	0.54	0.77	II-III
		5760		6.0	4.68	10234	10785	10785			0.32	0.60	0.81	
		(5721)		9.0	5.15	9858	11423	11505			0.36	0.62	0.81	
		(6488)		12.0	5.63	9187	11501	11582			0.39	0.65	0.83	
				15.0	5.95	8175	11862	11582			0.40	0.66	0.84	
02	03343400	8910	8282	5.0	4.66	13980	13980	13980	0.64	0.59	0.26	0.54	0.78	II-III
		8330		10.0	5.89	17022	17387	17387			0.34	0.61	0.82	
		(8433)		15.0	6.67	18647	19313	19384			0.38	0.64	0.84	
		(7005)		20.0	7.25	19600	20411	20511			0.41	0.66	0.85	
				25.0	7.74	20008	21532	20867			0.43	0.68	0.86	
03	03344500	3610	5817	1.0	3.38	4056	4056	4056	0.89	1.43	0.23	0.52	0.77	III
		4030		2.0	4.36	4569	4756	4756			0.31	0.60	0.82	
		(4965)		3.0	4.82	4516	5263	5169			0.35	0.62	0.83	
		(4509)		4.0	5.15	4236	5365	5270			0.37	0.64	0.84	
				5.0	5.47	4005	5490	5288			0.39	0.66	0.85	
04	03346000	36400	31902	5.0	4.45	31150	31150	31150	1.17	1.02	0.28	0.56	0.80	III
		40400		10.0	5.54	36322	37187	37187			0.35	0.63	0.83	
		(35865)		15.0	6.30	38863	41724	41581			0.39	0.66	0.85	
		(21188)		20.0	6.95	40135	43555	43540			0.43	0.68	0.86	
				25.0	7.49	40105	46133	44132			0.45	0.70	0.87	
05	03380475	11400	11388	5.0	5.24	14148	14148	14148	0.80	0.80	0.36	0.63	0.83	III
		11900		10.0	6.40	16699	17042	17042			0.43	0.68	0.85	
		(11191)		15.0	7.17	17374	18476	18639			0.46	0.71	0.87	
		(17873)		20.0	7.80	17451	19296	19459			0.49	0.73	0.88	
				25.0	8.32	16939	19971	19648			0.51	0.74	0.88	

Table 9. Continued

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	type A	type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	II	III	Est. AMC
06	03380500	31700	37723	10.0	6.00	33000	33000	33000	0.96	1.14	0.44	0.70	0.86	III
		32900		20.0	7.39	35148	37027	37027			0.50	0.75	0.89	
		(36642)		30.0	8.07	37752	40475	39837			0.53	0.76	0.90	
		(36719)		40.0	8.36	36901	40822	40774			0.54	0.77	0.90	
07	03385000	6810	6878	3.0	5.00	7500	7500	7500	0.91	0.92	0.20	0.47	0.73	III
		7020		6.0	6.10	7412	8079	8079			0.26	0.54	0.77	
		(6884)		9.0	6.70	6774	8776	8603			0.29	0.57	0.79	
		(7743)												
08	05420000	13500	13454	3.0	3.83	29108	29108	29108	0.46	0.46	0.08	0.32	0.60	II-III
		13100		6.0	4.96	36051	36125	36125			0.15	0.40	0.67	
		(12856)		9.0	5.54	38409	40312	40027			0.18	0.44	0.70	
		(14651)		12.0	6.12	39635	42490	42206			0.21	0.47	0.72	
				15.0	6.49	39434	44816	43252			0.23	0.49	0.73	
09	05440500	10400	7647	3.0	4.03	16926	16926	16926	0.61	0.45	0.22	0.49	0.76	II
		11100		6.0	5.09	20387	20570	20570			0.29	0.57	0.80	
		(10329)		9.0	5.68	21820	22763	22643			0.33	0.60	0.82	
		(7748)		12.0	6.27	23052	24059	24261			0.36	0.63	0.83	
				15.0	6.65	22951	25237	24583		0.38		0.64	0.83	
10	05445500	5790	5687	3.0	3.83	17235	17235	17235	0.33	0.33	0.08	.0.32	0.60	II
		5250		6.0	4.97	21056	21765	21765			0.15	0.40	0.67	
		(5418)		9.0	5.54	22675	23794	23912			0.18	0.44	0.70	
		(5741)		12.0	6.12	24240	25431	25549			0.21	0.47	0.72	
				15.0	6.51	24630	26946	25863			0.23	0.49	0.73	

Table 9. Continued

		Q_{100}, cfs		t_r	P_{100}	Q_{100}cfs with RF=100 &			RF		RF(with P_{100} and CN)			Est.
No.	USGS No.	USGS	SWS	(hr)	(in)	uniform	type A	type B	USGS	SWS	I	II	III	AMC
11	054470000	8100	7063	3.0	3.90	21060	21060	21060	0.38	0.33	0.17	0.44	0.70	II
		7950		6.0	5.00	26221	26204	26204			0.25	0.52	0.75	
		(8515)		9.0	5.60	27982	29214	29039			0.28	0.56	0.78	
		(6425)		12.0	6.20	29416	30897	31007			0.32	0.59	0.80	
				15.0	6.55	29339	32636	31769			0.33	0.61	0.80	
12	05466000	8780	7004	3.0	3.48	25404	25404	25404	0.34	0.27	0.15	0.43	0.70	I-II
		8500		6.0	4.29	28777	30358	30358			0.21	0.49	0.74	
		(8858)		9.0	4.81	30384	33068	33236			0.25	0.53	0.77	
		(6629)		12.0	5.33	30401	34316	34485			0.28	0.56	0.79	
				15.0	5.65	29077	35836	34485			0.30	0.58	0.80	
13	05495500	28900	26575	4.0	3.53	34594	34594	34594	0.83	0.77	0.13	0.39	0.67	III
		30200		8.0	4.42	39525	40412	40412			0.19	0.47	0.73	
		(28223)		12.0	5.15	44547	45482	45415			0.24	0.52	0.76	
		(27472)		16.0	5.58	46991	49194	48661			0.27	0.54	0.77	
				20.0	6.02	46859	51375	50987			0.29	0.56	0.79	
14	05502020	11400	11636	1.5	2.93	18752	18752	18752	0.61	0.62	0.03	0.23	0.52	III
		11110		3.0	3.89	22312	.23621	23621			0.09	0.32	0.61	
		(14125)		4.5	4.27	19902	23817	24517			0.11	0.35	0.63	
		(9586)		6.0	4.65	18398	23914	25178			0.13	0.38	0.66	
				7.5	4.89	16434	24578	25178			0.14	0.40	0.67	
15	05512500	17600	18334	1.5	2.94	13230	13230	13230	1.33	1.39	0.03	0.23	0.52	III
		20100		3.0	3.90	16465	16472	16472			0.09	0.32	0.61	
		(20395)		4.5	4.28	16753	17941	18225			0.11	0.36	0.63	
		(16866)		6.0	4.66	16780	18363	18470			0.13	0.38	0.66	
				7.5	4.90	15377	18423	19388			0.14	0.40	0.67	

Table 9. Continued

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	type A	type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	II	III	Est. AMC
16*	05525500	21800	26112	6.0	4.00	22980	22980	22980	0.95	1.14	0.27	0.55	0.78	III
		22800		12.0	5.09	28125	28600	28600			0.35	0.62	0.82	
		(21855)		18.0	5.74	31118	32056	32015			0.39	0.65	0.84	
		(26406)		24.0	6.40	33738	34480	34516			0.43	0.68	0.85	
				30.0	6.55	33138	35850	35102			0.44	0.69	0.86	
17t	05531500	—	2181	4.0	3.84	8064	8064	8064	0.26	0.27	0.14	0.40	0.67	I-II
		2120		8.0	4.72	9205	9524	9524			0.20	0.47	0.72	
		(2181)		12.0	5.39	10064	10755	10726			0.24	0.51	0.75	
		(2221)		16.0	5.82	10475	11271	11288			0.27	0.54	0.77	
				20.0	6.26	10883	11974	11696			0.29	0.56	0.78	
18t	05536255	—	2927	4.0	4.39	3951	3951	3951	0.54	0.74	0.36	0.64	0.84	II-III
		2120		8.0	5.25	4264	4161	4161			0.42	0.69	0.87	
		(2126)		12.0	5.80	4245	4697	4573			0.46	0.71	0.88	
		(3101)		16.0	6.20	4073	4699	4582			0.48	0.72	0.89	
				20.0	6.61	3922	4982	4582			0.50	0.74	0.89	
19	05539000	9730	14536	6.0	4.39	17560	17560	17560	0.55	0.83	0.27	0.56	0.80	II-III
		10700		12.0	5.39	18328	19281	19281			0.34	0.62	0.83	
		(10122)		18.0	6.04	17085	21131	20875			0.38	0.65	0.85	
		(15548)		24.0	6.70	15943	21345	21090			0.41	0.68	0.86	
				30.0	6.85	14083	22047	21090			0.42	0.68	0.86	
20t	05539900	—	1241	3.0	3.99	3790	3790	3790	0.33	0.33	0.19	0.47	0.73	I-II
		1240		6.0	4.70	4294	4383	4383			0.24	0.52	0.76	
		(1265)		9.0	5.18	4458	4739	4743			0.27	0.55	0.78	
		(1575)		12.0	5.67	4559	4990	5021			0.30	0.58	0.80	
				15.0	6.00	4424	5197	5113			0.32	0.60	0.81	

Table 9. Continued

		Q_{100}, cfs		t_r	P_{100}	Q_{100}cfs with RF=100 &			RF		RF(with P_{100} and CN)			Est.
No.	USGS No.	USGS	SWS	(hr)	(in)	uniform	type A	type B	USGS	SWS	I	II	III	AMC
21	05557000	12300	13632	3.0	4.12	20600	20600	20600	0.60	0.66	0.12	0.37	0.64	III
		13000		6.0	5.13	23927	24973	24973			0.18	0.45	0.70	
		(12576)		9.0	5.73	23941	26436	26896			0.21	0.48	0.72	
		(15363)		12.0	6.33	22786	27205	27666			0.24	0.51	0.75	
				15.0	6.71	20937	27917	27742			0.26	0.53	0.76	
22	05557500	8780	10380	3.0	4.10	27880	27880	27880	0.31	0.37	0.16	0.42	0.69	II
		8340		6.0	5.10	29978	30942	30942			0.23	0.50	0.74	
		(9967)		9.0	5.70	28473	34410	33759			0.26	0.53	0.76	
		(11260)		12.0	6.30	26703	34630	33978			0.30	0.56	0.78	
				15.0	6.67	24265	35987	33978			0.31	0.58	0.79	
23	05559000	2550	2527	1.0	2.98	7152	7152	7152	0.36	0.35	0.09	0.34	0.63	II
		2570		2.0	3.60	5800	7420	7420			0.14	0.40	0.68	
		(2462)		3.0	4.17	4917	7771	7763			0.18	0.45	0.72	
		(2519)		4.0	4.46	4010	7771	7763			0.20	0.47	0.73	
				5.0	4.76	3423	7771	7763			0.22	0.49	0.74	
24	05563000	26900	34720	4.0	3.83	38300	38300	38300	0.70	0.91	0.10	0.35	0.62	III
		30100		8.0	4.72	32748	40021	40021			0.16	0.42	0.68	
		(27759)		12.0	5.39	28479	43045	42619			0.19	0.46	0.71	
		(38334)		16.0	5.82	24556	43112	42685			0.22	0.49	0.73	
				20.0	6.26	21684	43366	42685			0.24	0.51	0.74	
25	05567000	6470	8140	4.0	3.89	12448	12448	12448	0.52	0.65	0.18	0.46	0.72	II-III
		6990		8.0	4.75	13070	13720	13720			0.24	0.53	0.77	
		(8007)		12.0	5.40	14718	15264	15122			0.29	0.57	0.79	
		(9481)		16.0	5.84	14481	15812	15802			0.31	0.59	0.80	
				20.0	6.27	13993	16791	16041			0.33	0.61	0.81	

Table 9. Continued

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	Q_{100} cfs with RF=100 & type A	Q_{100} cfs with RF=100 & type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	RF(with P_{100} and CN) II	RF(with P_{100} and CN) III	Est. AMC
26	05571000	15500	16369	8.0	4.31	24136	24136	24136	0.64	0.68	0.27	0.55	0.79	II-III
		16300		16.0	5.56	28771	29646	29646			0.35	0.63	0.83	
		(15506)		24.0	6.42	30864	33416	33326			0.40	0.66	0.85	
		(17954)		32.0	6.63	29751	33914	33837			0.41	0.67	0.86	
				40.0	6.84	28541	34339	33952			0.42	0.68	0.86	
27	05574500	15100	16294	7.0	5.06	17457	17457	17457	0.86	0.93	0.29	0.56	0.80	III
		16900		14.0	6.31	19504	20676	20676			0.37	0.63	0.83	
		(16633)		21.0	7.16	22010	23087	22930			0.41	0.66	0.85	
		(13468)		28.0	7.65	22802	24449	23910			0.43	0.68	0.86	
				35.0	7.86	22317	24595	24155			0.44	0.68	0.86	
28	05577500	8870	10037	4.0	3.86	13896	13896	13896	0.64	0.72	0.21	0.48	0.75	III
		8840		8.0	4.73	16358	16545	16545			0.27	0.54	0.79	
		(9681)		12.0	5.40	17347	18280	18368			0.31	0.58	0.81	
		(10125)		16.0	5.83	17072	19042	19177			0.34	0.60	0.82	
				20.0	6.27	16753	19722	19421			0.36	0.63	0.83	
29*	05580000	14400	17328	5.0	3.92	28330	28330	28330	0.51	0.61	0.15	0.41	0.68	III
		14600		10.0	4.92	33288	33566	33566			0.21	0.48	0.73	
		(14155)		15.0	5.61	35453	38012	37754			0.26	0.53	0.76	
		(18869)		20.0	6.15	33520	39173	39164			0.29	0.55	0.77	
				25.0	6.60	34523	41348	39636			0.31	0.57	0.78	
30*	05584400	2600	2562	1.5	3.05	6509	6509	6509	0.40	0.39	0.11	0.38	0.67	II
		2360		3.0	4.00	7814	8060	8060			0.19	0.47	0.73	
		(2608)		4.5	4.35	7955	8764	8680			0.22	0.50	0.75	
		(2697)		6.0	4.70	8365	9039	8955			0.24	0.52	0.76	
				7.5	4.95	8254	9513	9039			0.24	0.53	0.76	

Table 9. Continued

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	Q_{100} cfs with RF=100 & type A	Q_{100} cfs with RF=100 & type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	RF(with P_{100} and CN) II	RF(with P_{100} and CN) III	Est. AMC
31	05586000	5760	4673	2.0	3.37	5729	5729	5729	1.01	0.82	0.13	0.40	0.66	III
		5780		4.0	4.21	6935	7068	7068			0.19	0.47	0.72	
		(6218)		6.0	4.70	7207	7607	7708			0.23	0.51	0.74	
		(4426)		8.0	5.02	6874	7858	7959			0.25	0.53	0.76	
				10.0	5.35	6692	8022	8074			0.27	0.55	0.77	
32*	05588000	9350	10292	2.0	4.08	10378	10378	10378	0.90	0.99	0.16	0.42	0.69	III
		9740		4.0	4.88	11837	12224	12224			0.21	0.48	0.73	
		(9661)		6.0	5.50	12531	13397	13455			0.25	0.52	0.75	
		(12097)		8.0	5.91	12370	13871	13928			0.27	0.54	0.77	
				10.0	6.31	12050	14232	14103			0.29	0.56	0.78	
33	05589500	8270	7510	2.0	4.21	11577	11577	11577	0.71	0.65	0.23	0.51	0.76	III
		8710		4.0	5.02	12487	12460	12460			0.29	0.56	0.80	
		(8389)		6.0	5.63	11393	13870	13586			0.33	0.59	0.82	
		(9736)		8.0	5.86	9809	13893	13610			0.34	0.61	0.82	
				10.0	6.09	8673	14126	13609			0.35	0.62	0.82	
34	05591500	1670	2028	2.0	4.36	2180	2180	2180	0.77	0.93	0.24	0.52	0.77	III
		1740		4.0	5.15	2261	2329	2329			0.30	0.57	0.80	
		(2502)		6.0	5.80	2253	2597	2572			0.34	0.60	0.82	
		(1161)		8.0	6.17	2146	2612	2585			0.36	0.62	0.83	
				10.0	6.55	2074	2734	2585			0.38	0.64	0.84	
35	05592300	10400	10152	3.0	4.43	11518	11518	11518	0.90	0.88	0.33	0.62	0.82	III
		12200		6.0	5.41	13242	12913	12913			0.40	0.67	0.85	
		(11560)		9.0	6.01	13386	14412	14136			0.44	0.70	0.86	
		(11115)		12.0	6.62	13212	14621	14543			0.47	0.72	0.87	
				15.0	6.97	12413	15565	14588			0.49	0.73	0.88	

Table 9. Concluded

No.	USGS No.	Q_{100}, cfs USGS	Q_{100}, cfs SWS	t_r (hr)	P_{100} (in)	Q_{100} cfs with RF=100 & uniform	type A	type B	RF USGS	RF SWS	RF(with P_{100} and CN) I	II	III	Est. AMC
36*	05597500	4710	4989	3.0	4.85	6872	6872	6872	0.69	0.73	0.22	0.50	0.75	III
		4530		6.0	5.88	8128	8104	8104			0.29	0.56	0.79	
		(4712)		9.0	6.46	8204	8766	8711			0.32	0.59	0.80	
		(4833)		12.0	7.05	8095	9043	9137			0.35	0.61	0.82	
				15.0	7.41	7798	9467	9267			0.36	0.62	0.82	
37	05599000	22700	23480	9.0	5.90	22420	22420	22420	1.01	1.05	0.46	0.71	0.88	III
		24500		18.0	7.25	25546	26779	26779			0.53	0.76	0.90	
		(23259)		27.0	8.09	27174	29264	29324			0.56	0.78	0.91	
		(30456)		36.0	8.35	26118	29668	29769			0.57	0.78	0.91	
				45.0	8.62	24784	29903	29955			0.58	0.79	0.92	
38	05600000	4590	5216	3.0	4.85	7760	7760	7760	0.59	0.67	0.29	0.57	0.79	II-III
		4270		6.0	5.87	8877	9081	9081			0.35	0.62	0.82	
		(4921)		9.0	6.45	9287	9964	9907			0.39	0.65	0.84	
		(6206)		12.0	7.03	9314	10331	10274			0.41	0.67	0.85	
				15.0	7.39	8822	10733	10311			0.43	0.68	0.86	

Notes

1) * Fitted unit hydrograph parameters used; for the rest, derived unit hydrograph parameters used (Singh, 1981).

2) 4 values of Q_{100} under USGS are: from weighted or best estimated frequency curve, from individual station frequency curve, with log-Pearson type III and sample skew, and with log-Pearson type III and weighted skew, respectively. The last two values are in parentheses and are for the flood record as given in table 11.

3) t Not natural flow streams; Q_{100} from individual station frequency curve used in computing RF for USGS.

4) RF (with P_{100} and CN) is obtained from equation $(P-0.2S)^2/[P(P+0.8S)]$.

5) Q_{100} sws corresponds to the estimate from the methodology developed by Singh and Nakashima (1981). It includes detection and modification of any outliers/inliers at 0.3 significance level.

equations, and from the weighted or best estimated frequency curves. The log-Pearson type III distribution was used for developing station curves with the regional skew values as recommended by the U.S. Water Resources Council (1977). Only the Q_{100} values corresponding to the weighted or best estimated frequency curve as well as the station frequency curve are given in table 9 for the 38 study basins.

The values of sample skew, g , and weighted skew, g , for the number of years of record, n, at each of the 35 natural flow streams, as given by Curtis (1977), are shown in table 10. The absolute difference in the two skew values $|g_s - g_w|$ lies in the following range:

$\|g_s - g_w\|$ range	>1.0	>0.8	>0.6	>0.4	>0.2	>0.1
No. of basins	3	5	10	16	26	29

The 100-year flood, Q_{100}, IS derived from

$$\log Q_{100} - \text{mean} + \text{standard deviation} \times k$$

in which the frequency factor k is obtained for the 100-year recurrence interval and the weighted skew value. Some large differences in Q_{100} estimates with station frequency and weighted frequency curves can be explained by similar differences in g_s and g_w.

Singh and Nakashima (1981) have developed a new methodology for flood frequency analysis, with objective detection and modification of outliers/ inliers at various levels of significance. An outlier is defined as a flood that is much higher/lower at the high/low end of the flood spectrum than indicated by the rest of the data. An inlier is a flood that is much lower/higher at the high/low end than indicated. In an earlier study, Singh (1980) indicated that 1) better tests were needed for identifying high or low outliers/inliers, 2) modification of outliers/inliers changed both the standard deviation and skew, and 3) regionalization of both

Table 10. Sample and Weighted Skews (from Curtis, 1977)

Basin no.	n yrs	g_s	g_w	$g_s - g_w$	Basin no.	n yrs	g_s	g_w	$g_s - g_w$
1	26	0.0250	-0.3940	0.4190	20*				
2	15	-1.1750	-0.4000	-0.7750	21	39	0.0810	-0.3100	0.3910
3	25	-0.7880	-0.4000	-0.3880	22	38	-0.5180	-0.4210	-0.0970
4	35	-1.3790	-0.5310	-0.8480	23	28	-0.5660	-0.4070	-0.1590
5	16	0.9860	-0.4000	1.3860	24	31	0.1280	-0.3580	0.4860
6	58	-0.3860	-0.3940	0.0080	25	26	0.2740	-0.4000	0.6740
7	26	-0.1250	-0.3470	0.2220	26	28	-0.0950	-0.3880	0.2930
8	35	-0.1230	-0.3630	0.2400	27	26	-0.9210	-0.4070	-0.5140
9	36	-0.9450	-0.4800	-0.4650	28	28	-0.3280	-0.3970	0.0690
10	32	0.0090	-0.3670	0.3760	29	28	0.2710	-0.3730	0.6440
11	36	-1.3310	-0.5240	-0.8070	30	15	-0.2320	-0.4000	0.1680
12	35	-1.0970	-0.4930	-0.6040	31	26	-1.0270	-0.4080	-0.6190
13	32	-0.4370	-0.4030	-0.0340	32	35	0.1200	-0.3310	0.4510
14	19	-0.5500	-0.4000	-0.1500	33	37	-0.0860	-0.3500	0.2640
15	36	-0.7990	-0.4580	-0.3410	34	25	-1.4690	-0.4000	-1.0690
16	27	-0.0770	-0.3910	0.3140	35	17	-0,7030	-0.4000	-0.3030
17*					36	24	-0.2810	-0.3500	0.0690
18*					37	30	0.1280	-0.3180	0.4460
19	34	0.6843	-0.3277	1.0120	38	34	-0.2710	-0.3420	0.0710

Notes: * Not natural flow rural streams

g_s = sample skew; g_w = weighted skew; n is the number of years of record used in the report by Curtis (1977) parameters may be needed instead of the skew alone. The Q_{100} estimates for the window 5 or 0.3 significance level, developed with the new methodology, are given under the SWS heading in table 9. The estimates of Q_{100} with the log-Pearson type III distribution, without any detection or modification of outliers/inliers, are also given for both g_s and g_w. These estimates differ from the USGS estimates (Curtis, 1977), largely because of different lengths of record used.

Up to three lowest and three highest observed floods at each of the 38 gaging stations are given in table 11. Any outliers/inliers detected and modified in the 5th window are shown in bold type. The number of outlier/inlier candidates for detection are given by [n/10] in which n is the number of years of record. The sample skew, g_s, of the observed flood series is also included in the table. The difference in g_s values in table 10 and 11 is due mostly to different lengths of record.

Q_{100} with RF = 1.0 and Runoff Factors

The 100-year flood hydrographs were developed for each study basin for storm durations equal to 1, 2, 3, 4, and 5 times the unit-hydrograph duration, t_r, for uniform, type A, and type B rainfall, assuming a runoff factor of 1.0. Time distribution of storm rainfall will not be uniform for 2 to 5 times t_r duration. The Q_{100} estimates are given in table 9 only to show the relative difference in the flood peaks from the three assumed time distributions. For a storm rainfall of t_r duration, the runoff factor, both for the USGS and SWS estimate of Q_{100}, is obtained by dividing the relevant estimate by the Q_{100} with runoff factor equal to unity. Actually, the runoff factor will be somewhat lower if there is baseflow accretion to the stream at the time of peak flow, or somewhat higher if there is net outflow from the channel into the banks.

Table 11. Sample g and Any Modification of Outliers/Inliers in Window 5

No.	USGS No.	n	Sample skew g	Item	Lowest floods L_1	L_2	L_3	Highest floods H_1	H_2	H_3
01	03336500	30	-0.086	Obsd*	562	578	754	5160	4520	4380
				Modt		**649**	**761**			**4003**
02	03343400	19	-0.841	Obsd	697			6240		
				Mod	**1028**					
03	03344500	29	-0.551	Obsd	56	262		3500	2790	
				Mod	**135**	**213**		**3917**	**2878**	
04	03346000	39	-1.421	Obsd	228	1110	1880	26100	25000	21900
				Mod	**521**		**1866**		**22947**	**20128**
05	03380475	19	0.729	Obsd	1550	2200		17100	5890	
				Mod		**2017**		**9694**	**7633**	
06	03380500	51	-0.394	Obsd	858	1450	2110	51000	22800	20000
				Mod				**37862**	**26139**	**23188**
07	03385000	30	-0.089	Obsd	815	970	1010	6400	5130	4570
				Mod	**800**					
08	0542000	37	-0.070	Obsd	1120	1300	1330	11600	10700	8470
				Mod	**929**	**1189**				
09	05440500	40	-1.011	Obsd	267	298	612	6100	6100	5570
				Mod	**221**			**6680**		
10	05445500	32	-0.210	Obsd	765	857	1100	5770	4780	4180
				Mod		**957**		**5072**	**4317**	**3929**
11	05447000	40	-1.147	Obsd	480	502	593	6120	5750	5010
				Mod		**598**	**832**			
12	05466000	39	-1.268	Obsd	612	613	725	8910	5760	5420
				Mod		**931**	**1227**	**6690**		
13	05495500	36	-0.475	Obsd	2000	2230	2870	21200	20500	18800
				Mod		**2271**		**22821**		
14	05502020	24	-1.241	Obsd	583	1740		9000	8000	
				Mod		1611				
15	05512500	40	-0.822	Obsd	530	1000	1040	12600	12200	12200
				Mod			**1139**	**15097**	**12973**	

Table 11. Continued

No.	USGS No.	n	Sample skew g	Item	Lowest floods L_1	L_2	L_3	Highest floods H_1	H_2	H_3
16	05525500	31	0.039	Obsd	1720	1890	2240	22900	16700	14900
				Mod		**2048**	**2401**			
17	05531500	34	-0.319	Obsd	506	585	624	1930	1920	1790
				Mod				**1952**	**1902**	**1769**
18	05536255	32	0.541	Obsd	187	251	297	2550	1960	1630
				Mod	**190**		**285**			**1578**
19	05539000	35	0.734	Obsd	850	1180	1220	15200	10200	8130
				Mod	**905**			**13250**	**8748**	**7092**
20	05539900	19	0.114	Obsd	158			1510		
				Mod				**1019**		
21	05557000	43	0.082	Obsd	496	519	852	20100	10800	6620
						683		**13224**	**9784**	**7566**
22	05557500	43	-0.101	Obsd	415	665	845	13000	6200	6030
				Mod		**632**	**746**	**11197**	**7260**	**6313**
23	05559000	30	-0.345	Obsd	189	216	385	1940	1860	1780
				Mod		**247**	**342**	**1998**		**1667**
24	05563000	35	0.304	Obsd	1300	2420	2680	27500	26000	18400
				Mod	**1374**	**2076**	**2366**		**25050**	
25	05567000	30	-0.062	Obsd	369	525	626	10900	5800	3840
							627	**6929**	**5392**	**4404**
26	05571000	31	-0.073	Obsd	1020	1340	1580	14600	11100	9100
				Mod						**9354**
27	05574500	30	-0.803	Obsd	457	660	1770	13000	11300	9400
				Mod		**821**	**1357**		**11067**	
28	05577500	32	-0.325	Obsd	217	225	639	6750	5780	5290
				Mod		**306**	**487**	**7548**	**5799**	
29	05580000	31	0.251	Obsd	1300	1330	1500	15100	12800	8420
					1160				**12349**	**8673**
30	05584400	19	-0.343	Obsd	167			1680		
				Mod	**154**			**1794**		
31	05586000	30	-0.891	Obsd	75	94	108	4700	3320	2870
						130	**196**	**4133**	**3188**	**2725**

Table 11. Concluded

No.	USGS No.	n	Sample skew g	Item	Lowest floods L_1	L_2	L_3	Highest floods H_1	H_2	H_3
32	05588000	39	0.075	Obsd	409	482	482	9340	7750	6320
				Mod			**546**			
33	05589500	41	-0.049	Obsd	327	438	502	10200	10000	5100
				Mod		**461**	**569**	**6894**	**5522**	**4854**
34	05591500	29	-1.437	Obsd	6	58		1460	1120	
				Mod	**18**	**53**				
35	05592300	21	-0.475	Obsd	803	997		7480	6760	
				Mod				**8080**		
36	05597500	28	-0.339	Obsd	450	458		3500	3380	
				Mod		**517**		**3883**		
37	05599000	34	0.114	Obsd	1120	1320	1360	18800	18100	13800
				Mod	**982**	**1266**		**22188**		
38	05600000	37	0.664	Obsd	1000	1240	1280	7200	4350	3800
				Mod	**1195**	**1337**	**1428**	**5019**	**4177**	**3786**

However, the runoff factor derived without consideration of baseflow gives a reasonable estimate of the actual runoff factor.

For 3 basins out of the 38, the derived runoff factors exceed unity for both the USGS and SWS estimates. Some reasons for getting such values (theoretically, the runoff factor cannot exceed unity) are given below.

1) A sizeable baseflow accretion at the time of flood peak will lower the runoff factor: for example Q_{100} with RF = 1.0 is 5000 cfs and Q_{100} (USGS or SWS) is 5400 cfs; runoff factor without considering baseflow = 5400/5000 or 1.08. Assume baseflow is 1000 cfs; then runoff factor considering baseflow = (5400-1000)/5000 or 0.88.

2) Statistically derived Q_{100} may be caused by 2 or 3 times the t_r-duration rainfall. This can increase the flood peak by 20 percent or more. An allowance for this factor will reduce the runoff factor to 80 percent or less of the computed value.

3) The USGS and SWS estimates are obtained from flood frequency analyses. These estimates represent a reasonable estimate of Q_{100} However, a range of flood peaks for different confidence bands is associated with such estimates.

4) Usually, the observed high floods are determined from extended rating curves, and thus have some errors associated with them. The magnitude of error will depend on the accuracy of the rating curve, the suitability of the method used for extending the rating curve, and the stream hydraulic characteristics at the gaging station.

5) The unit hydrographs developed for a satisfactory derivation of 100-year flood hydrographs from the 100-year storm hyetographs, are also subject to some errors, since they are developed from 4 to 6 rainfall runoff events.

Estimated Basin AMCs

The curve numbers, CN, for AMC I, II, and III for each of the 38 study basins are given in table 7. The runoff from storm rainfall was computed for durations of 1, 2, 3, 4, and 5 times the t_r for each curve number, and it was divided by the associated rainfall to obtain the runoff factor. Runoff factors for each of the 3 AMCs and 5 durations of storm rainfall are given in table 9 for each of the 38 study basins. Comparison of the runoff (from Q_{100} estimates) with runoff factors from the SCS equation allows estimation of a suitable antecedent moisture condition for the basin in transforming a 100-year storm rainfall to a 100-year flood hydrograph. The estimated AMCs are given in table 9 and shown in figure 4. The state is regionalized into three zones: A, B, and C. Zone A has AMC II, zone B has an average of AMC II and AMC III, and zone C has AMC III.

Effect of Updating AMC

Consider a storm rainfall occurring in either one or two rainfall-reporting days as shown in figure 5a. Assume that there was no rainfall on the 5th day prior to the storm rainfall under consideration. Then the 5-day antecedent precipitation, AP5, will be lower for P than for P_2 by the amount P_1; $P = P_1 + P_2$ The same storm rainfall can yield different runoff estimates depending on the change in AP5 because of the storm occurring over 1 or 2 reporting days. This problem may be circumvented by updating the antecedent precipitation as the storm rainfall continues.

The effects of updating AP for a 100-year storm rainfall, P, of 4, 8, 12, 16, and 20 hours duration are shown in table 12, for 6 initial values of AP5 equal to 0.5, 1.0, 1.4, 1.7, 2.0, and > 2.1 inches. For the growing

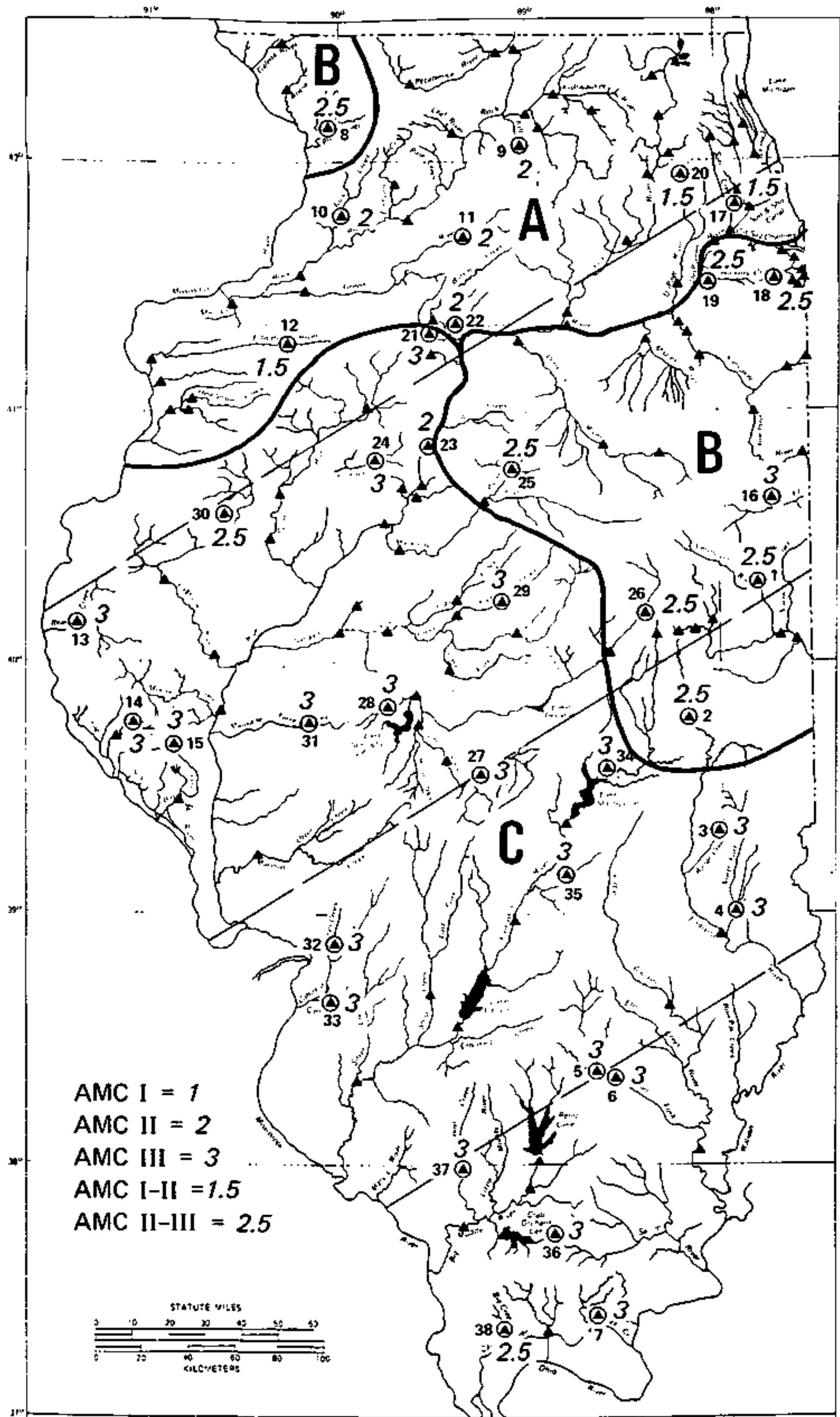

Figure 4. Regionalization of antecedent moisture conditions

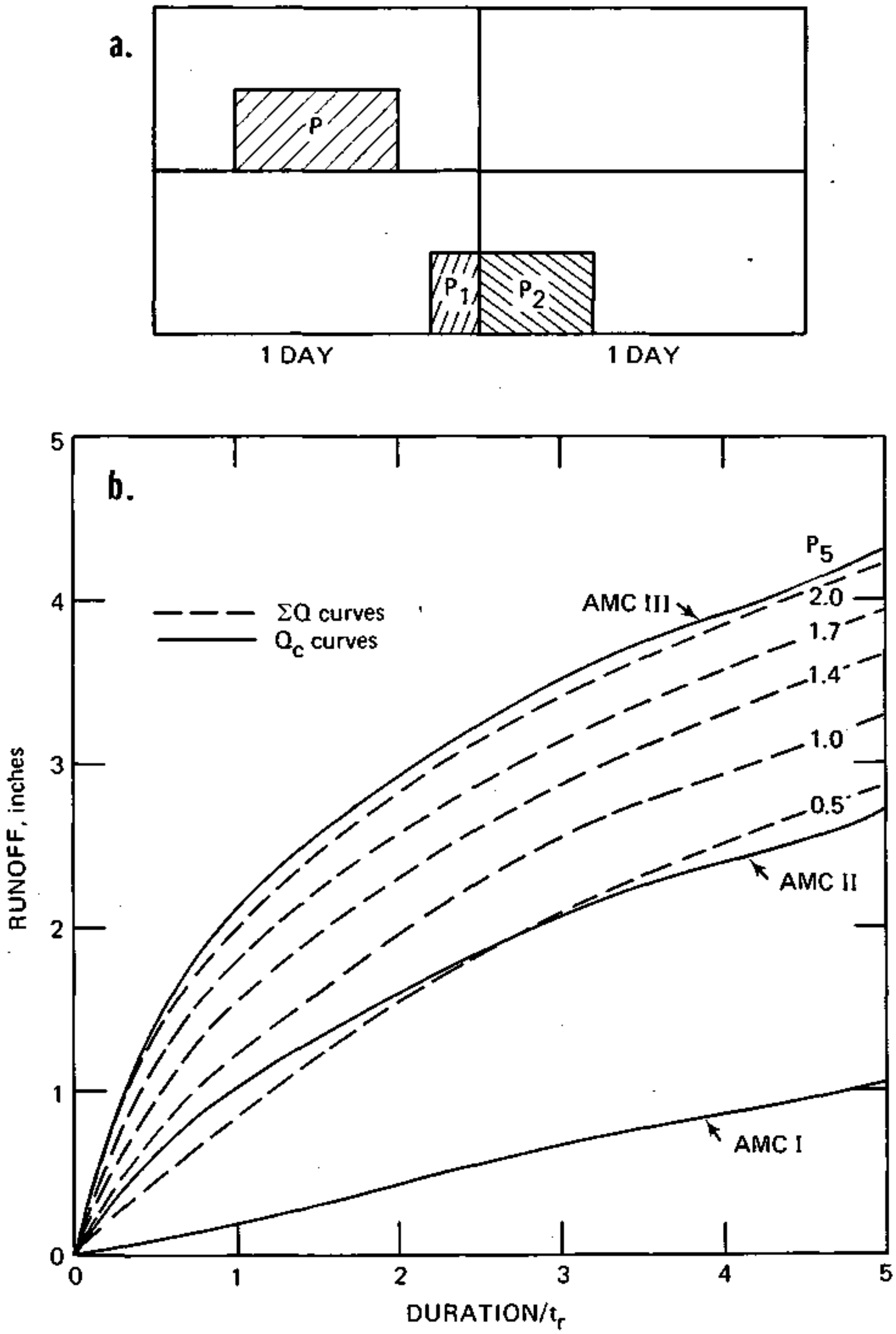

Figure 5. Effects of updating AMC during the storm rainfall

Table 12. Effects of Updating Antecedent Moisture during the Storm

AP	m	P in	Q_c in	$*P_1$ AMC I	$*P_2$ AMC II	$*P_3$ AMC III	Q_1 in	Q_2 in	Q_3 in	Q in
0.5	1	3.83	0.19	0.9	0.7	2.23	0	0	0.86	0.86
	2	4.72	0.44	0.9	0.7	3.12	0	0	1.54	1.54
	3	5.39	0.68	0.9	0.7	3.79	0	0	2.10	2.10
	4	5.82	0.86	0.9	0.7	4.22	0	0	2.48	2.48
	5	6.24	1.05	0.9	0.7	4.64	0	0	2.85	2.85
1.0	1	3.83	0.19	0.4	0.7	2.73	0	0	1.23	1.23
	2	4.72	0.44	0.4	0.7	3.62	0	0	1.96	1.96
	3	5.39	0.68	0.4	0.7	4.29	0	0	2.54	2.54
	4	5.82	0.86	0.4	0.7	4.72	0	0	2.92	2.92
	5	6.24	1.05	0.4	0.7	5.14	0	0	3.30	3.30
1.4	1	3.83	1.04	0	0.7	3.13	0	0	1.55	1.55
	2	4.72	1.61	0	0.7	4.02	0	0	2.30	2.30
	3	5.39	2.08	0	0.7	4.69	0	0	2.89	2.89
	4	5.82	2.40	0	0.7	5.12	0	0	3.28	3.28
	5	6.24	2.73	0	0.7	5.54	0	0	3.67	3.67
1.7	1	3.83	1.04	0	0.4	3.43	0	0	1.80	1.80
	2	4.72	1.61	0	0.4	4.32	0	0	2.57	2.57
	3	5.39	2.08	0	0.4	4.99	0	0	3.16	3.16
	4	5.82	2.40	0	0.4	5.42	0	0	3.56	3.56
	5	6.24	2.73	0	0.4	5.84	0	0	3.94	3.94
2.0	1	3.83	1.04	0	0.1	3.73	0	0	2.05	2.05
	2	4.72	1.61	0	0.1	4.62	0	0	2.83	2.83
	3	5.39	2.08	0	0.1	5.29	0	0	3.44	3.44
	4	5.82	2.40	0	0.1	5.72	0	0	3.83	3.83
	5	6.24	2.73	0	0.1	6.14	0	0	4.22	4.22
≥2.01	1	3.83	2.14	0	0	3.83	0	0	2.14	2.14
	2	4.72	2.92	0	0	4.72	0	0	2.92	2.92
	3	5.39	3.53	0	0	5.39	0	0	3.53	3.53
	4	5.82	3.92	0	0	5.82	0	0	3.92	3.92
	5	6.24	4.31	0	0	6.24	0	0	4.31	4.31

Unit hydrograph duration, t_r is 4.0 hours; Q_c = runoff with constant AMC corresponding to AP5 or the antecedent 5-day precipitation; * = portions of P contributed to each AMC with AMC corresponding to continuous accounting of AP; runoffs Q_1, Q_2, and Q_3 developed from P_1, P_2, and P_3 and relevant AMC; CNs for AMC I, II, and III are 47, 67, and 83, respectively; and m equals storm duration divided by t_r in hours.

season, the AMC changes from I to II when AP5 equals or exceeds 1.4 inches and from II to III when it equals or exceeds 2.1 inches. The runoff computed with the SCS equation or Q_c is shown by the solid curves in figure 5b. For updating the AP5 during the storm, the storm rainfall P is divided into three portions: P_1 (which brings the initial AP5 to 1.4 inches; it is zero if the initial AP5 is > 1.4 inches), P_2 (which brings the AP5 to 2.1 inches; it is zero if the initial AP5 > 2.1 inches), and P3 which equals P - (P_1 + P_2). The sum of runoff corresponding to P_1, P_2, and P_3, i.e., Q_1, Q_2, and Q_3 is denoted by Q. The Q curves are shown by the dashed lines in figure 5b. It is evident that updating the AP5 during the storm tremendously increases the runoff for low values of initial AP5. Historical storm rainfalls, APs, and runoffs are analyzed in the next chapter to investigate the suitability of updating AP.

OBSERVED FLOODS AND ASSOCIATED STORMS AND AMCs

The observed annual flood series for the 38 study basins were used in selecting about 8 top floods in each series. The daily rainfall data, up to 25 days preceding the storm causing the flood, were obtained from *Climatologieal Data, Illinois.* The data were used in computing various antecedent soil moisture indexes. Observed storm precipitation and surface runoff from 15 flood events were analyzed in detail to explore the suitability of a 5-day or some other duration antecedent precipitation (AP) for converting rainfall to runoff with the SCS equation.

Observed High Floods and Antecedent Precipitation, AP

The data for an annual flood series comprised the period of continuous discharge record up to 1976. Each of the annual flood series for the 38 study basins was ranked in a descending order of magnitude and about 8 top floods were selected. These floods are listed in table 13. The date of occurrence of the flood peak is also given in order to decide whether the flood occurred in the winter period, which has been taken as December 16 to March 31. From the number of winter floods at each gaging station, as given in table 13, the regional probability, P_r, of high floods occurring in winter is shown in figure 6 in terms of 3 categories: $P_r<0.25$, $0.25<P_r<0.50$, and $P_r>0.50$. There is a semblance of increase or decrease in P_r going from one region to the other with the exception of the northern Illinois area comprising the basins of Rock River, Bureau Creek, and Plum River.

The probability of a high flood occurring in winter varies from one region to another. This variability can be attributed to:

Table 13. Antecedent Precipitation Indexes for High Floods at 38 Gaging Stations

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
1	03336500	5160	05.16.68	.398	.868	.868	.239	.404	.404	.285	.523	.523	.338	.675	.675
		4520	04.20.64	.032	.032	.922	.014	.014	.125	.019	.019	.249	.025	.025	.485
		4380	05.28.56	.580	.762	1.020	.268	.304	.347	.351	.415	.496	.454	.563	.710
		3700	02.10.59W	.040	.460	.840	.034	.187	.251	.036	.254	.373	.038	.343	.559
		3540	07.09.51	1.002	1.721	2.834	.446	.591	.739	.593	.847	1.146	.776	1.209	1.795
		2460	12.22.49W	.762	1.460	1.625	.505	.643	.671	.582	.826	.878	.668	1.086	1.180
		2210	12.07.66	1.203	3.595	3.911	.909	1.433	1.483	1.003	1.896	1.991	1.101	2.581	2.757
		2080	07.14.62	1.161	1.786	6.002	.847	.970	1.609	.946	1.164	2.403	1.051	1.425	3.745
2	03343400	6230	06.23.74	.680	1.646	2.356	.512	.809	.884	.566	1.013	1.177	.622	1.284	1.631
		5200	05.09.61	.892	1.162	3.913	.643	.696	1.012	.721	.815	1.489	.804	.966	2.351
		4400	12.09.66	.022	.022	.022	.018	.018	.018	.019	.019	.019	.021	.021	.021
		3940	04.23.73	1.388	1.478	1.926	.833	.853	.917	.990	1.024	1.151	1.174	1.230	1.472
		3530	02.02.68W	.995	.995	1.014	.609	.609	.611	.722	.722	.726	.850	.850	.859
		3500	02.17.76W	.009	.009	.585	.008	.008	.100	.008	.008	.184	.009	.009	.331
		3380	01.30.69W	.250	.411	.924	.144	.178	.238	.173	.232	.359	.208	.307	.566
		3220	04.21.64	.139	.238	1.478	.118	.155	.302	.125	.178	.488	.132	.205	.836
3	03344500	3500	08.11.61	.081	1.537	3.378	.036	.514	.725	.048	.752	1.203	.062	1.083	2.011
		2790	06.23.60	.998	1.397	2.533	.703	.797	.984	.794	.949	1.302	.892	1.143	1.786
		2650	02.20.51W	.610	.640	1.800	.352	.362	.512	.427	.441	.748	.512	.533	1.140
		2440	12.19.57W	1.220	1.220	2.100	1.037	1.037	1.169	1.098	1.098	1.355	1.159	1.159	1.642
		2360	06.28.57	.200	.400	4.130	.089	.135	.580	.118	.196	1.130	.155	.281	2.178
		2120	04.03.56	.000	.250	.450	.000	.058	.075	.000	.097	.138	.000	.158	.250
		1970	05.30.74	.512	.796	4.941	.386	.464	.938	.426	.547	1.557	.467	.655	2.732
		1020	04.24.70	4.230	4.511	4.889	2.208	2.263	2.326	2.769	2.867	2.986	3.439	3.607	3.822
4	03346000	27100	01.04.50W	.468	1.255	2.877	.391	.605	.818	.417	.754	1.189	.442	.963	1.817
		25000	06.29.57	.354	.581	3.190	.213	.266	.540	.253	.342	.944	.300	.444	1.719
		21900	12.22.67W	.643	1.319	2.445	.377	.550	.713	.453	.730	1.049	.541	.978	1.585
		20800	05.09.61	1.720	1.879	3.151	1.394	1.431	1.598	1.500	1.562	1.901	1.609	1.709	2.376
		13000	12.20.57W	.034	.535	.981	.027	.127	.189	.029	.205	.329	.032	.333	.571
		12800	01.30.69W	.540	.923	1.532	.269	.353	.451	.342	.485	.670	.432	.668	1.009
		10900	03.05.63W	.258	.368	.479	.152	.182	.198	.183	.230	.262	.218	.291	.352
		10200	03.22.62W	.064	.474	1.105	.053	.157	.251	.057	.225	.408	.060	.326	.671
5	03380475	17100	05.08.61	3.017	3.228	4.443	2.485	2.547	2.688	2.660	2.753	3.052	2.837	2.979	3.589
		5840	03.12.75W	.978	.978	1.059	.590	.590	.597	.700	.700	.717	.828	.828	.866
		5420	03.11.73W	.790	1.122	1.122	.536	.648	.648	.611	.775	.775	.696	.931	.931
		5260	04.14.72	.671	1.174	1.377	.519	.647	.671	.567	.773	.823	.618	.942	1.045
		4850	12.22.67W	.526	2.362	3.085	.301	.799	.903	.366	1.150	1.354	.440	1.651	2.040
		4460	01.29.69W	.833	1.524	2.031	.429	.574	.658	.539	.790	.947	.673	1.093	1.381
		4270	11.25.73	.499	.789	.789	.315	.396	.396	.370	.497	.497	.431	.625	.625
		4100	03.09.64W	1.290	1.290	1.315	.721	.721	.725	.884	.884	.892	1.072	1.072	1.087

Table 13. Continued

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
6	03380500	51000	05.09.61	3.671	2.986	3.829	2.176	2.263	2.357	2.337	2.473	2.675	2.502	2.711	3.130
		22800	12.23.67W	.524	2.728	3.128	.316	.897	.951	.377	1.299	1.408	.446	1.884	2.096
		20000	01.05.50W	.277	.881	2.256	.225	.393	.567	.242	.505	.865	.259	.662	1.378
		18500	12.20.57W	.070	.462	.885	.057	.135	.200	.062	.199	.324	.066	.301	.534
		18000	01.31.69W	.697	1.148	1.918	.363	.464	.590	.454	.624	.861	.564	.844	1.278
		17000	05.12.43	1.389	1.389	2.016	.911	.911	.975	1.055	1.055	1.199	1.214	1.214	1.520
		17000	03.10.64W	1.191	1.204	1.227	.645	.650	.654	.800	.807	.814	.981	.990	1.003
		16500	05.23.57	2.981	3.676	4.567	1.721	1.913	2.044	2.081	2.383	2.639	2.498	2.961	3.447
7	03385000	6400	05.27.73	.710	.710	.770	.413	.413	.418	.499	.499	.512	.598	.598	.626
		4570	06.23.69	.150	3.380	3.380	.078	.762	.762	.098	1.277	1.277	.122	2.097	2.097
		4390	07.22.58	5.880	5.920	9.420	3.562	3.573	3.983	4.228	4.245	5.115	4.996	5.023	6.798
		4120	01.21.59W	1.220	1.330	1.370	.541	.583	.590	.720	.779	.791	.944	1.025	1.048
		3830	05.22.57	1.660	3.990	4.940	.990	1.646	1.805	1.185	2.208	2.506	1.407	2.967	3.507
		3640	04.25.75	.760	.900	.970	.337	.370	.377	.449	.503	.519	.588	.676	.710
		3600	05.10.70	.000	.870	2.240	.000	.233	.365	.000	.370	.670	.000	.574	1.226
		3540	04.15.72	.110	1.260	1.340	.071	.384	.396	.083	.578	.600	.095	.858	.902
8	05420000	11600	01.06.46W	.073	.596	1.022	.032	.136	.207	.043	.226	.359	.057	.370	.612
		10700	02.28.48W	.204	.204	.211	.130	.130	.130	.152	.152	.154	.177	.177	.180
		8470	06.02.43	.670	.970	3.040	.416	.498	.745	.492	.622	1.141	.576	.776	1.831
		7840	05.20.74	3.983	5.565	6.806	2.364	2.821	2.990	2.833	3.537	3.877	3.371	4.435	5.095
		7780	07.09.51	.720	.747	1.447	.330	.337	.420	.434	.445	.620	.563	.580	.936
		7460	12.30.72W	.058	.058	.058	.027	.027	.027	.035	.035	.035	.045	.045	.045
		6000	02.20.71W	.019	.019	.640	.014	.014	.078	.016	.016	.158	.017	.017	.321
9	05440500	6100	07.09.51	.680	.680	1.770	.302	.302	.408	.402	.402	.641	.526	.526	1.046
		6100	10.10.54	.950	2.330	2.510	.508	.980	1.010	.632	1.317	1.374	.779	1.757	1.860
		4750	01.05.46W	.270	1.030	1.180	.124	.275	.300	.163	.430	.477	.211	.668	.753
		4390	03.19.48W	.210	.210	.210	.110	.110	.110	.138	.138	.138	.171	.171	.171
		4040	02.09.66W	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
		4030	07.19.52	.360	1.080	1.150	.266	.408	.415	.295	.546	.561	.326	.757	.791
		3720	02.19.71W	.265	.265	.761	.225	.225	.279	.238	.238	.355	.251	.252	.497
		3610	02.23.59W	.000	.110	1.210	.000	.025	.176	.000	.042	.346	.000	.069	.657
10	05445500	5770	01.06.46W	.150	.970	1.300	.078	.251	.306	.098	.395	.499	.122	.621	.809
		4780	02.28.48W	.280	.280	.380	.176	.176	.187	.207	.207	.230	.242	.242	.291
		4180	12.27.42W	.300	.480	.510	.157	.219	.221	.197	.287	.293	.244	.372	.386
		3540	02.20.51W	.609	.786	1.015	.394	.448	.480	.457	.538	.603	.528	.649	.772
		3060	03.15.44W	.410	1.560	1.560	.300	.553	.553	.335	.765	.765	.371	1.082	1.082
		2900	02.20.53W	.076	.554	1.092	.049	.159	.208	.057	.241	.355	.066	.366	.619
		2740	02.20.55W	.000	.023	.169	.000	.005	.019	.000	.009	.040	.000	.015	.084
		2480	02.24.49W	.181	.290	.901	.117	.140	.238	.136	.176	.362	.157	.224	.567

Table 13. Continued

NO	USGS NQ	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
11	05447000	6120	10.10.54	1.551	2.264	2.778	.709	.923	1.001	.933	1.258	1.410	1.210	1.697	1.980
		3960	01.05.46W	.230	1.125	1.360	.103	.282	.321	.137	.451	.525	.179	.716	.850
		3030	03.19.48W	.064	.064	.112	.034	.034	.040	.043	.043	.055	.052	.052	.077
		2890	04.25.50	.156	.177	1.652	.075	.083	.250	.097	.108	.468	.124	.139	.881
		2820	03.15.44W	.413	1.399	1.415	.299	.516	.518	.335	.703	.708	.373	.983	.992
		2770	02.19.51W	.585	.797	1.231	.356	.424	.486	.422	.522	.645	.497	.645	.879
		2680	03.16.43W	.269	.420	.460	.119	.154	.158	.159	.217	.226	.208	.303	.323
12	05466000	8910	02.19.51W	.952	1.257	1.682	.610	.696	.756	.711	.843	.963	.824	1.026	1.256
		5760	06.23.74	1.864	2.091	4.372	1.393	1.452	1.697	1.538	1.632	2.168	1.695	1.842	2.968
		5420	04.24.50	.140	.142	1.022	.072	.073	.175	.091	.092	.309	.113	.114	.560
		5000	07.06.53	.918	1.338	1.338	.576	.693	.693	.678	.861	.861	.792	1.072	1.072
		4590	04.21.73	.636	.990	2.977	.329	.401	.726	.414	.540	1.154	.516	.730	1.851
		4560	01.05.46W	.354	.841	1.193	.161	.274	.333	.212	.400	.510	.276	.581	.781
		4420	04.06.47	.052	.052	1.842	.037	.037	.324	.041	.041	.587	.046	.046	1.049
		4250	06.11.67	3.436	3.909	4.161	2.128	2.221	2.258	2.517	2.682	2.755	2.952	3.235	3.373
13	05495500	21200	07.22.51	.240	.785	1.255	.181	.355	.426	.199	.458	.595	.219	.596	.854
		20500	05.14.70	1.565	1.580	3.260	.894	.898	1.083	1.082	1.089	1.491	1.305	1.314	2.151
		18800	05.20.74	3.116	3.342	4.078	2.114	2.178	2.297	2.407	2.506	2.732	2.738	2.890	3.304
		17200	09.14.61	2.722	3.640	3.640	2.311	2.504	2.504	2.448	2.781	2.781	2.585	3.145	3.145
		16800	04.11.44	.715	.715	1.193	.445	.445	.505	.526	.526	.649	.615	.615	.863
		15700	07.01.60	1.091	4.680	5.019	.912	1.901	1.937	.971	2.520	2.599	1.031	3.409	3.577
		15300	04.21.73	.735	.772	1.981	.348	.361	.536	.451	.470	.815	.579	.605	1.262
		15000	07.08.69	.938	4.468	5.654	.595	1.696	1.834	.695	2.346	2.639	.809	3.242	3.840
14	05502020	8000	04.29.56	.310	.310	.310	.190	.190	.190	.226	.226	.226	.266	.266	.266
		6960	05.08.61	1.720	1.720	2.770	1.174	1.174	1.301	1.342	1.342	1.609	1.524	1.524	2.063
		5560	06.03.62	.570	1.140	1.140	.253	.400	.400	.337	.573	.573	.441	.812	.812
		5280	03.04.63W	.140	.800	.800	.119	.275	.275	.126	.385	.385	.133	.551	.551
		5240	04.20.64	.470	.470	2.290	.375	.375	.575	.406	.406	.841	.437	.437	1.344
		5140	09.16.65	.050	.050	.930	.031	.031	.178	.036	.036	.313	.043	.043	.543
		5070	05.17.66	.700	1.880	1.880	.432	.748	.748	.506	1.002	1.002	.595	1.364	1.364
		5000	05.17.57	1.200	2.850	2.850	.940	1.469	1.469	1.022	1.811	1.811	1.109	2.261	2.261
15	05512500	12600	09.16.65	.820	1.020	1.560	.697	.744	.821	.738	.816	.969	.779	.906	1.198
		12200	05.17.66	.380	1.470	1.470	.275	.614	.614	.308	.815	.815	.343	1.091	1.091
		12200	04.21.73	1.400	1.400	2.700	.721	.721	.934	.906	.906	1.308	1.130	1.130	1.864
		11300	05.14.70	2.300	2.400	6.000	1.589	1.612	1.973	1.791	1.830	2.640	2.026	2.089	3.830
		10900	07.28.67	2.730	7.270	7.270	1.610	2.755	2.755	1.928	3.782	3.782	2.299	5.232	5.232
		8100	04.20.64	.590	.590	1.490	.476	.476	.555	.513	.513	.698	.551	.551	.968

Table 13. Continued

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
16	05525500	22900	02.21.51W	.755	1.294	1.855	.484	.670	.730	.563	.832	.964	.653	1.037	1.314
		16700	07.13.57	.001	.908	3.636	.000	.247	.511	.001	.391	.990	.001	.602	1.907
		14900	12.22.49W	.558	1.396	1.402	.396	.588	.589	.447	.769	.770	.501	1.026	1.030
		14400	06.14.52	.461	.798	1.077	.254	.326	.352	.313	.436	.497	.382	.588	.720
		10600	02.02.68W	1.198	1.198	1.275	.722	.722	.730	.859	.859	.877	1.017	1.017	1.055
		9650	06.13.58	4.102	4.102	5.038	2.665	2.665	2.816	3.097	3.097	3.384	3.574	3.574	4.101
		9000	02.10.59W	.033	.438	.758	.028	.175	.229	.029	.239	.340	.031	.325	.507
		8800	07.06.53	1.824	2.826	2.992	1.023	1.259	1.286	1.253	1.644	1.696	1.519	2.152	2.247
17	05531500	1920	03.20.48W	.901	.911	1.026	.537	.539	.554	.643	.648	.677	.764	.771	.831
		1790	08.28.72	1.018	1.159	2.028	.690	.737	.837	.791	.860	1.071	.900	.999	1.435
		1710	10.11.54	1.117	3.947	4.098	.536	1.487	1.510	.692	2.087	2.131	.884	2.888	2.971
		1600	04.19.75	.061	.076	.139	.040	.044	.049	.047	.052	.065	.054	,063	.092
		1460	05.12.66	.309	.309	2.195	.177	.177	.420	.215	.215	.713	.259	.259	1.244
		1460	03.05.76W	2.352	2.352	3.621	1.507	1.507	1.672	1.758	1.758	2.095	2.038	2.038	2.703
		1430	09.14.61	.310	2.432	2.763	.263	.846	.896	.279	1.191	1.287	.294	1.697	1.878
		1360	04.25.50	.172	.191	1.131	.092	.100	.208	.114	.125	.356	.141	.155	.630
18	05536255	2550	07.13.57	.100	.110	4.150	.052	.055	.463	.066	.070	.984	.081	.088	2.048
		1960	08.17.68	.750	1.150	2.150	.638	.783	.950	.675	.883	1.196	.713	1.003	1.572
		1630	06.07.74	.400	.600	1.130	.324	.378	.425	.348	.434	.544	.373	.506	.752
		1480	10.10.54	1.070	1.460	1.460	.554	.667	.667	.698	.871	.871	.869	1.130	1.130
		970	03.19.48W	.850	.900	1.070	.525	.539	.557	.622	.643	.684	.730	.763	.847
		935	09.23.61	.980	3.100	4.730	.708	1.181	1.445	.794	1.595	2.096	.884	2.204	3.122
		888	12.25.65W	.080	.080	.800	.042	.042	.123	.052	.052	.228	.065	.065	.427
		820	12.30.72W	.000	.000	.080	.000	.000	.008	.000	.000	.018	.000	.000	.039
19	05539000	15200	07.13.57	.124	.138	2.928	.065	.069	.351	.081	.087	.719	.101	.110	1.464
		10200	04.05.47	.123	.802	2.029	.081	.222	.409	.094	.338	.699	.108	.520	1.195
		8130	10.11.54	1.131	1.479	1.521	.590	.684	.691	.741	.889	.902	.921	1.149	1.172
		5070	05.17.74	.947	2.319	2.451	.634	1.001	1.017	.727	1.308	1.341	.830	1.733	1.800
		4680	05.12.66	.704	.704	2.442	.417	.417	.637	.501	.501	.954	.596	.596	1.497
		4560	09.24.61	.744	4.067	5.263	.567	1.297	1.492	.623	1.867	2.236	.682	2.741	3.416
		4370	03.19.48W	.470	.530	.737	.289	.305	.333	.343	.368	.425	.403	.443	.553
		4080	04.22.73	.814	1.376	2.249	.474	.599	.725	.568	.779	1.029	.680	1.029	1.503
20	05539900	1510	06.10.67	.833	.833	1.092	.534	.534	.569	.624	.624	.695	.723	.723	.861
		715	08.26.72	1.282	1.514	2.414	.869	.945	1.041	.995	1.108	1.317	1.133	1.296	1.737
		656	05.12.66	.343	.343	1.949	.212	.212	.434	.251	.251	.695	.295	.295	1.153
		557	03.05.76W	1.723	1.723	3.047	1.198	1.198	1.381	1.358	1.358	1.725	1.533	1.533	2.241
		537	04.19.75	.075	.076	.677	.049	.049	.101	.057	.057	.181	.065	.066	.345
		522	01.27.74W	.457	1.638	1.702	.232	.653	.659	.294	.899	.912	.369	1.221	1.251
		521	06.02.70	.783	2.063	2.072	.515	.879	.880	.596	1.162	1.164	.685	1.544	1.549

Table 13. Continued

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
21	05557000	6620	07.08.51	.913	1.143	1.644	.405	.450	.524	.539	.619	.763	.706	.844	1.116
		5910	01.24.38W	.048	.067	.434	.022	.026	.059	.029	.036	.113	.037	.049	.221
		5740	01.05.46W	.227	1.059	1.293	.101	.268	.307	.134	.427	.501	.175	.676	.809
		5060	07.11.62	.000	.992	1.070	.000	.260	.267	.000	.416	.433	.000	.650	.686
		4420	03.19.48W	.101	.101	.426	.062	.062	.101	.073	.073	.156	.086	.086	.253
		4090	02.13.49W	.011	.511	.511	.009	.139	.139	.010	.217	.217	.010	.335	.335
		3980	03.15.44W	.417	1.407	1.455	.301	.516	.524	.338	.704	.719	.377	.986	1.013
		3920	03.12.39W	.000	.294	.520	.000	.111	.148	.000	.156	.226	.000	.216	.343
22	05557500	6200	01.24.38W	.040	.069	.514	.020	.025	.069	.025	.035	.134	.032	.049	.262
		5010	04.25.50	1.503	1.572	3.520	1.184	1.210	1.412	1.284	1.320	1.767	1.389	1.440	2.391
		4830	03.25.54W	.895	.903	1.138	.399	.401	.430	.530	.533	.594	.693	.698	.820
		4740	07.08.51	.624	1.558	2.075	.279	.462	.531	.370	.695	.834	.484	1.043	1.315
		4290	06.12.52	1.173	1.368	2.008	.720	.765	.835	.855	.931	1.081	1.005	1.129	1.444
		4230	03.30.60W	.614	.656	1.336	.272	.281	.354	.363	.377	.537	.475	.500	.836
		3860	02.21.37W	.165	.165	.215	.092	.092	.098	.112	.112	.125	.136	.136	.162
		3780	03.12.39W	.008	.229	.535	.003	.087	.137	.005	.122	.217	.006	.169	.342
23	05559000	1860	07.02.58	.000	.590	1.090	.000	.159	.212	.000	.252	.368	.000	.390	.635
		1780	05.31.70	.230	1.280	1.300	.170	.508	.510	.189	.692	.696	.209	.943	.952
		1510	06.19.64	1.000	1.380	1.560	.458	.588	.607	.603	.791	.834	.781	1.051	1.141
		1470	08.20.52	1.360	1.540	2.440	.670	.712	.860	.859	.929	1.208	1.087	1.200	1.710
		1360	07.17.50	.200	.200	.440	.114	.114	.140	.139	.139	.196	.167	.167	.286
		1220	06.11.55	2.490	3.680	6.100	1.483	1.840	2.081	1.769	2.311	2.853	2.103	2.911	4.079
		1150	07.08.51	.190	1.100	1.750	.084	.264	.361	.112	.430	.618	.147	.692	1.047
		1050	09.17.65	2.290	3.100	3.220	1.668	1.830	1.846	1.860	2.145	2.178	2.067	2.554	2.618
24	05563000	18400	07.22.51	.486	.747	2.223	.215	.267	.446	.287	.378	.754	.376	.533	1.291
		17100	09.23.61	.740	4.020	5.210	.556	1.202	1.391	.615	1.758	2.119	.676	2.640	3.305
		12100	07.02.58	.000	.560	1.090	.000	.170	.224	.000	.258	.379	.000	.384	.641
		10000	03.30.60W	.380	.420	.850	.315	.323	.367	.336	.350	.448	.357	.381	.591
		9340	03.19.48W	.480	.610	.930	.287	.320	.359	.342	.396	.477	.406	.490	.655
		8590	04.24.55	1.354	1.534	2.355	.775	.814	.937	.942	1.009	1.248	1.134	1.245	1.696
		7310	06.14.57	1.030	1.330	2.310	.696	.804	.904	.794	.948	1.172	.905	1.122	1.599
		7300	07.17.50	1.120	1.120	1.360	.940	.940	.964	.999	.999	1.054	1.059	1.059	1.176
25	05567000	10900	07.09.51	.000	.772	2.161	.000	.152	.351	.000	.269	.662	.000	.462	1.211
		3020	09.27.59	.548	.609	.609	.297	.309	.309	.366	.387	.387	.449	.486	.486
		2500	06.13.60	.059	1.633	1.707	.050	.519	.528	.053	.769	.788	.056	1.127	1.165
		2350	04.13.52	.676	1.063	1.516	.481	.589	.655	.542	.711	.841	.607	.865	1.112
		1950	05.28.54	.085	.116	.116	.070	.078	.078	.075	.088	.088	.080	.100	.100
		1650	08.08.58	1.610	2.320	2.320	.836	1.070	1.070	1.052	1.396	1.396	1.309	1.806	1.806
		825	07.20.55	.310	.310	.490	.231	.231	.255	.255	.255	.303	.281	.281	.376

Table 13. Continued

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
26	05571000	14600	05.28.56	.337	.643	.983	.175	.236	.293	.220	.328	.434	.274	.458	.651
		11100	05.16.68	.462	.665	.665	.304	.378	.378	.350	.455	.455	.402	.550	.550
		9100	02.22.51W	.625	1.010	2.047	.406	.530	.648	.471	.656	.908	.544	.813	1.334
		9060	04.21.64	.106	.109	1.487	.047	.048	.209	.062	.064	.405	.082	.084	.782
		8940	06.23.74	.425	.858	3.159	.316	.442	.690	.351	.543	1.084	.387	.678	1.812
		8200	12.23.49W	.636	1.692	1.746	.399	.636	.643	.470	.870	.885	.548	1.207	1.236
		7600	02.11.59W	.072	.508	.776	.062	.221	.265	.065	.292	.375	.069	.386	.538
		6760	04.23.73	.884	.998	1.482	.526	.551	.619	.626	.669	.804	.744	.815	1.076
27	05574500	13000	06.29.57	.064	.102	4.418	.042	.051	.555	.049	.064	1.132	.056	.080	2.263
		9400	01.05.50W	.335	.853	3.391	.272	.414	.735	.292	.516	1.180	.313	.657	1.978
		8620	06.16.70	1.306	1.848	2.948	1.017	1.124	1.295	1.110	1.299	1.627	1.206	1.531	2.140
		7540	06.23.74	.613	2.066	3.501	.470	.941	1.100	.516	1.215	1.557	.563	1.580	2.293
		7350	06.29.51	1.212	1.479	2.285	.885	.959	1.077	.985	1.101	1.331	1.094	1.272	1.708
		5900	05.26.68	.408	.998	3.172	.225	.374	.615	.276	.517	1.039	.337	.718	1.803
		5870	04.22.73	.995	1.000	1.976	.598	.599	.741	.710	.712	.991	.841	.845	1.375
		5750	02.11.39W	.011	1.526	2.128	.007	.324	.421	.008	.556	.742	.010	.932	1.271
28	05577500	6750	03.30.60W	.000	.063	.539	.000	.012	.066	.000	.022	.137	.000	.037	.276
		5100	06.02.65	.021	1.311	1.823	.013	.457	.510	.015	.660	.777	.018	.936	1.187
		4760	05.01.70	.077	1.546	3.790	.055	.441	.812	.062	.673	1.372	.069	1.023	2.294
		4700	06.19.73	1.849	1.918	2.858	1.263	1.289	1.382	1.440	1.477	1.686	1.635	1.686	2.138
		3320	06.10.58	.236	1.577	1.577	.198	.489	.489	.211	.708	.708	.223	1.051	1.051
		3230	02.10.59W	.014	.422	.422	.012	.161	.161	.013	.224	.224	.013	.310	.310
		3040	04.21.64	.584	.908	2.153	.491	.613	.736	.522	.693	.971	.553	.790	1.390
		3030	06.28.51	1.990	2.017	3.678	1.398	1.408	1.642	1.578	1.593	2.055	1.775	1.795	2.683
29	05580000	15100	04.22.73	1.036	1.053	1.962	.609	.613	.742	.726	.733	.990	.867	.879	1.369
		12800	06.22.74	.854	1.447	3.840	.652	.832	1.059	.717	.989	1.507	.784	1.189	2.324
		8420	04.21.64	.467	.758	1.759	.397	.501	.608	.420	.570	.804	.443	.654	1.148
		8300	04.25.50	.188	.188	.561	.099	.099	.150	.124	.124	.226	.153	.153	.352
		7900	02.10.59W	.003	.353	.399	.003	.114	.119	.003	.168	.178	.003	.245	.267
		6500	05.27.56	.482	.535	.787	.272	.283	.325	.332	.351	.430	.402	.434	.577
		6140	05.08.61	1.057	1.193	2.161	.747	.774	.875	.843	.891	1.114	.947	1.028	1.501
		5400	05.16.68	.401	.639	.639	.293	.383	.383	.326	.452	.452	.362	.537	.537
30	05584400	1650	09.24.61	.487	5.210	6.824	.403	1.417	1.675	.431	2.172	2.662	.458	3.363	4.267
		1330	07.05.69	1.231	2.479	3.464	.671	1.002	1.131	.824	1.350	1.614	1.009	1.827	2.346
		1220	09.24.70	.215	3.043	3.346	.100	.836	.878	.131	1.310	1.394	.169	2.014	2.177
		1140	06.23.74	1.730	2.500	4.560	1.327	1.557	1.763	1.454	1.805	2.267	1.588	2.113	3.107
		922	03.17.65W	.058	.120	.927	.037	.051	.146	.044	.066	.268	.050	.088	.498
		754	06.20.64	.432	1.510	1.982	.217	.575	.624	.276	.802	.911	.347	1.106	1.337
		645	06.26.73	.000	2.132	2.578	.000	.631	.683	.000	.966	1.077	.000	1.448	1.674
		598	07.24.67	3.603	3.603	4.071	1.942	1.942	1.990	2.409	2.409	2.515	2.958	2.958	3.186

Table 13. Continued

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
31	05586000	3320	05.01.70	.200	.710	2.980	.153	.317	.659	.168	.412	1.077	.184	.540	1.788
		2870	06.28.51	4.610	4.650	7.300	3.118	3.131	3.495	3.553	3.572	4.304	4.047	4.075	5.491
		1850	03.30..60W	.000	.000	.650	.000	.000	.069	.000	.000	.151	.000	.000	.319
		1770	06.19.73	2.190	2.370	3.720	1.568	1.636	1.776	1.763	1.859	2.169	1.970	2.103	2.762
		1470	04.20.64	.570	.630	1.750	.468	.488	.586	.502	.530	.762	.535	.577	1.097
		1460	02.08.69W	.040	.980	1.460	.031	.217	.291	.034	.362	.506	.037	.600	.866
		1450	06.14.57	2.760	3.450	4.100	1.678	1.913	1.980	1.992	2.336	2.484	2.351	2.843	3.159
		1400	02.10.59W	.820	1.120	1.120	.697	.785	.785	.738	.873	.873	.779	.982	.982
32	05588000	9340	08.15.46	.631	3.383	5.318	.478	1.246	1.566	.525	1.724	2.326	.576	2.409	3.506
		7750	06.15.57	2.176	3.429	4.370	1.611	2.059	2.156	1.789	2.431	2.646	1.977	2.881	3.340
		6320	04.22.44	.092	1.229	4.413	.047	.409	.911	.059	.600	1.559	.074	.865	2.638
		5480	01.03.50W	.160	.820	2.814	.124	.299	.550	.135	.414	.933	.147	.581	1.615
		4840	11.01.46	.000	.371	2.038	.000	.137	.329	.000	.195	.605	.000	.271	1.113
		4320	05.31.74	.057	.389	1.500	.030	.120	.236	.037	.180	.435	.047	.267	.808
		3900	07.09.42	.024	.069	3.029	.014	.024	.439	.017	.034	.862	.020	.048	1.640
		3680	06.10.52	.032	.122	.798	.017	.037	.104	.021	.056	.206	.026	.083	.407
33	05589500	10200	06.15.57	1.222	2.833	4.040	.881	1.418	1.542	.987	1.777	2.053	1.101	2.239	2.827
		10000	08.16.46	3.001	6.749	8.917	2.430	3.265	3.566	2.614	4.024	4.627	2.804	5.128	6.290
		5100	05.08.61	1.858	2.014	2.865	1.459	1.495	1.604	1.587	1.648	1.871	1.720	1.819	2.261
		4640	07.09.42	.466	.474	1.798	.392	.394	.552	.417	.419	.753	.441	.446	1.123
		3650	07.04.56	.478	1.362	3.343	.398	.599	.797	.424	.763	1.207	.451	1.005	1.961
		3630	02.09.66W	.000	.726	.726	.000	.203	.203	.000	.318	.318	.000	.486	.486
		3000	07.07.65	.542	1.908	2.808	.454	.858	.953	.482	1.102	1.311	.512	1.441	1.883
		2970	06.20.51	2.081	3.432	4.267	1.326	1.735	1.870	1.551	2.172	2.427	1.802	2.725	3.194
34	05591500	1460	05.19.74	2.020	2.910	3.360	1.304	1.542	1.608	1.512	1.890	2.020	1.750	2.336	2.581
		1120	10.12.69	1.080	1.610	1.840	.893	1.093	1.113	.954	1.236	1.283	1.016	1.406	1.512
		1110	06.28.57	.000	.550	3.320	.000	.126	.419	.000	.211	.854	.000	.345	1.703
		690	02.09.59W	.020	.410	.490	.017	.156	.169	.018	.217	.242	.019	.300	.345
		625	06.26.60	1.070	2.460	3.600	.719	1.146	1.312	.825	1.470	1.797	.942	1.897	2.518
		562	12.21.67W	.620	1.350	2.160	.441	.603	.709	.494	.768	.984	.554	1.005	1.430
		515	06.19.56	.530	.530	.920	.306	.306	.371	.370	.370	.493	.445	.445	.667
		490	08.06.62	.000	.000	.280	.000	.000	.036	.000	.000	.074	.000	.000	.147
35	05592300	7480	04.19.70	.156	.847	.920	.072	.332	.340	.094	.462	.478	.122	.630	.666
		6760	02.22.75W	.190	.580	.940	.085	.186	.226	.113	.274	.360	.147	.400	.580
		6400	07.21.67	.000	1.870	1.920	.000	.369	.377	.000	.653	.668	.000	1.120	1.148
		6360	12.21.67W	.467	1.813	3.670	.253	.588	.877	.313	.858	1.412	.385	1.250	2.279
		4600	05.31.74	1.142	1.746	2.740	.959	1.107	1.228	1.019	1.262	1.515	1.080	1.467	1.978
		4420	01.26.62W	.200	.496	2.259	.101	.193	.455	.128	.267	.779	.161	.366	1.332
		4420	04.25.65	.000	.738	1.056	.000	.150	.188	.000	.263	.342	.000	.447	.608
		4350	12.08.66	1.017	2.473	2.819	.762	1.056	1.110	.843	1.359	1.463	.928	1.806	1.999

Table 13. Concluded

NO	USGS NO	Q (CFS)	DATE	AP 5	AP 10	AP 15	AP(.85) 5	AP(.85) 10	AP(.85) 15	AP(.90) 5	AP(.90) 10	AP(.90) 15	AP(.95) 5	AP(.95) 10	AP(.95) 15
36	05597500	3380	05.22.57	2.680	3.770	4.140	1.511	1.773	1.826	1.845	2.278	2.382	2.233	2.927	3.127
		3300	03.20.50W	.120	1.390	1.450	.087	.445	.452	.097	.654	.669	.108	.957	.988
		2570	03.09.64W	2.000	2.120	2.120	1.044	1.089	1.089	1.312	1.376	1.376	1.629	1.717	1.717
		2550	07.18.58	2.490	4.390	6.610	1.467	1.896	2.267	1.758	2.477	3.174	2.097	3.277	4.540
		2100	04.27.66	1.490	3.060	6.440	.925	1.434	1.783	1.091	1.845	2.619	1.279	2.375	4.023
		1850	04.13.52	.260	1.470	1.470	.202	.484	.484	.220	.691	.691	.240	1.004	1.004
		1530	04.16.72	.950	1.150	1.150	.686	.762	.762	.769	.876	.876	.857	1.004	1.004
37	05599000	18800	05.09.61	.241	.709	1.185	.112	.215	.274	.146	.321	.443	.189	.478	.723
		18100	08.17.46	.106	1.380	4.269	.076	.427	.884	.086	.635	1.507	.095	.940	2.550
		13800	01.29.49W	2.105	2.982	3.299	.934	1.189	1.228	1.243	1.636	1.718	1.629	2.222	2.386
		13800	01.05.50W	.044	1.044	2.311	.037	.347	.503	.040	.507	.832	.042	.732	1.384
		11600	12.23.67W	.417	2.477	3.060	.251	.832	.917	.300	1.201	1.367	.355	1.729	2.044
		11200	04.05.57	1.149	2.719	3.077	.818	1.156	1.205	.921	1.500	1.599	1.031	1.997	2.188
		10500	12.21.57W	.150	.271	.649	.125	.149	.207	.133	.175	.287	.141	.214	.423
		8340	03.11.64W	1.029	1.082	1.112	.556	.576	.581	.690	.718	.728	.847	.886	.903
38	05600000	7200	03.19.43W	.280	1.540	1.830	.196	.567	.604	.222	.792	.869	.250	1.106	1.258
		4350	04.11.44	1.330	1.330	2.890	1.108	1.108	1.291	1.181	1.181	1.569	1.255	1.255	2.047
		3800	03.06.45W	1.210	5.440	7.780	.782	2.149	2.474	.911	2.945	3.596	1.054	4.015	5.270
		3620	01.04.50W	.030	1.140	2.210	.022	.326	.475	.024	.504	.802	.027"	.765	1.339
		3260	05.25.46	.410	1.410	2.730	.320	.581	.720	.348	.766	1.072	.377	1.031	1.679
		2830	05.13.55	.840	.840	.840	.643	.643	.643	.706	.706	.706	.771	.771	.771
		2790	03.09.64W	2.060	2.290	2.290	1.075	1.162	1.162	1.352	1.474	1.474	1.678	1.847	1.847

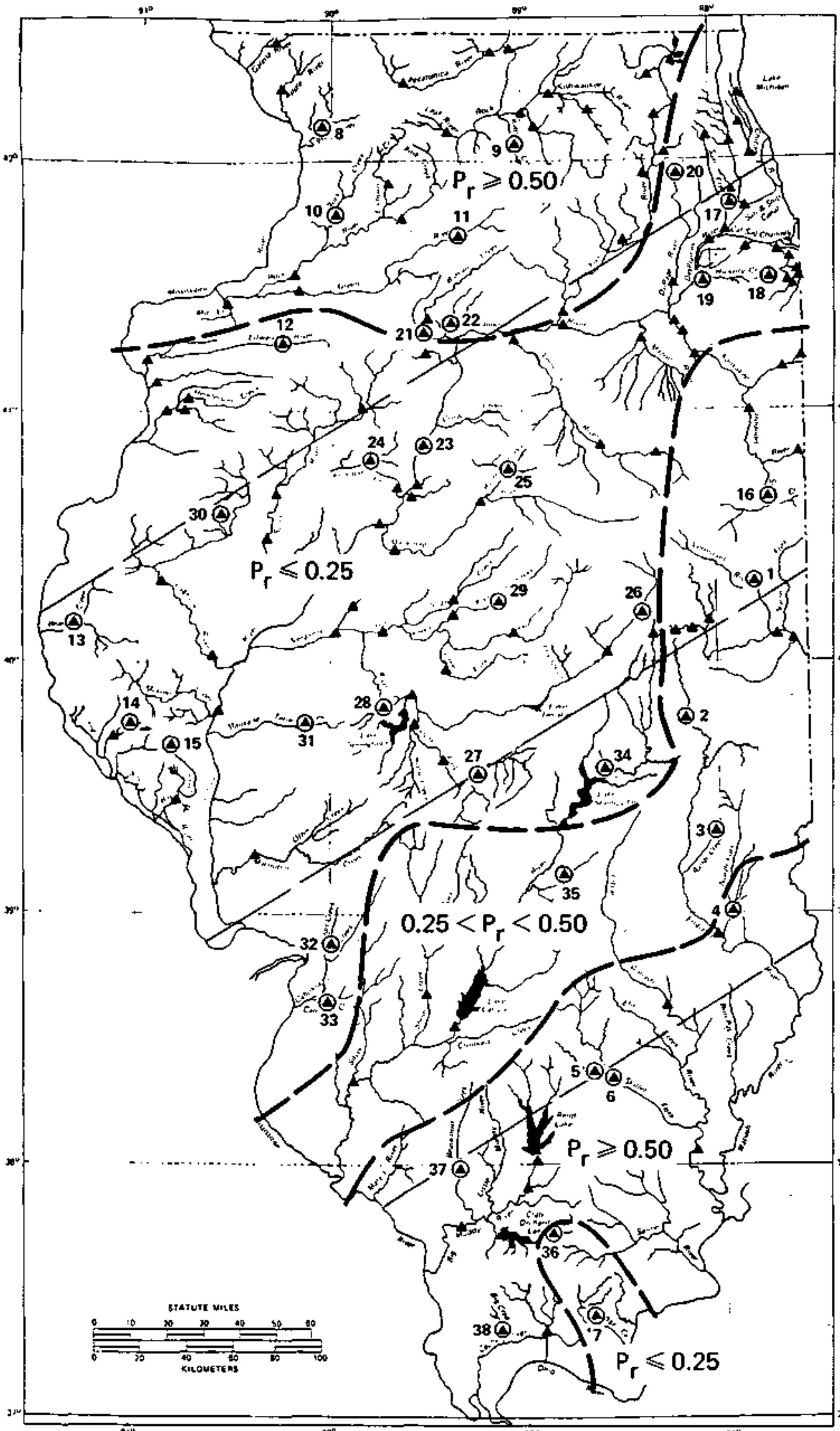

Figure 6. Probability, P_r, of high floods occurring in winter

1) Variations in magnitude, duration, intensity, and areal coverage of storms producing high floods, as well as their month of occurrence from one region to another because of meteorologic and geographic factors

2) Variations in seasonal temperatures from one region to another—the relatively higher temperatures result in reduced antecedent soil moisture if other factors remain unchanged

3) Variations in soil characteristics, soil cover, and management practices

4) Variations in basin factors such as land slopes and stream slopes

The Soil Conservation Service recommends the use of 5-day antecedent precipitation, AP5, but values of AP10, AP15, and AP25 were also calculated. Values of AP5, AP10, and AP15 are given in table 13 for all the 296 storms for the 38 study basins. The Thiessen method (1911) was used to compute daily basin precipitation, and suitable procedures were used for filling in missing data where necessary. A computer algorithm was developed to determine the values of antecedent moisture indexes. Kohler and Linsley (1951) postulate that soil moisture decreases logarithmically with time during periods of no precipitation,

$$It = Io^{k\,t}$$

where I_o is the initial value of antecedent precipitation index, I_t is the reduced value t days later, and k is a recession factor normally ranging between 0.85 and 0.98. Starting t days before the storm producing the flood under consideration, the antecedent moisture index AP(k) is computed from

$$AP(k)t = P_t k^t + P_{t-1} k^{t-1} + \ldots + P_1 k$$

The t was taken as 5, 10, 15, and 25, and k was taken as 0.85, 0.90, and 0.95. Values of AP(k)t for t = 5, 10, and 15 and for k = 0.85, 0.90, and 0.95 are given in table 13. Because the proper values of k for the study basins are not known, the information is presented for use by those who want to derive suitable k values and to interpolate the. antecedent soil moisture index from the data in table 13.

From a consideration of AP5, AP10, and AP15 values in table 13 for 3 or 4 highest observed floods for each of the 38 study basins, the value of t in days which causes the APt to correspond to the AMC given in figure 4, is generalized in figure 7 in terms of 3 categories: 5-10 days, about 10 days, and 10-15 days. The variation in days is attributed to physiography, surficial soil characteristics, temperature and precipitation regimes, and relative probability of floods occurring in winter.

<u>Observed Storm Rainfall, Surface Runoff, and AP</u>

The stage hydrographs for 14 flood events and rating tables for 5 basins were obtained from the U.S. Geological Survey office in Urbana. The basins were selected to present geographic, meteorologic, physiographic, and hydrologic variation. The stage hydrographs were converted to discharge hydrographs and finally to surface runoff hydrographs by subtracting the baseflow (which was approximated by a straight line with an upward trend from the beginning of surface runoff to its end). The area under a surface runoff hydrograph was planimetered and converted to surface runoff, in inches, shown as observed Q in table 14. The basin storm rainfall, P, in inches, causing the surface runoff was calculated with the Thiessen method from hourly and daily rainfall records available for the

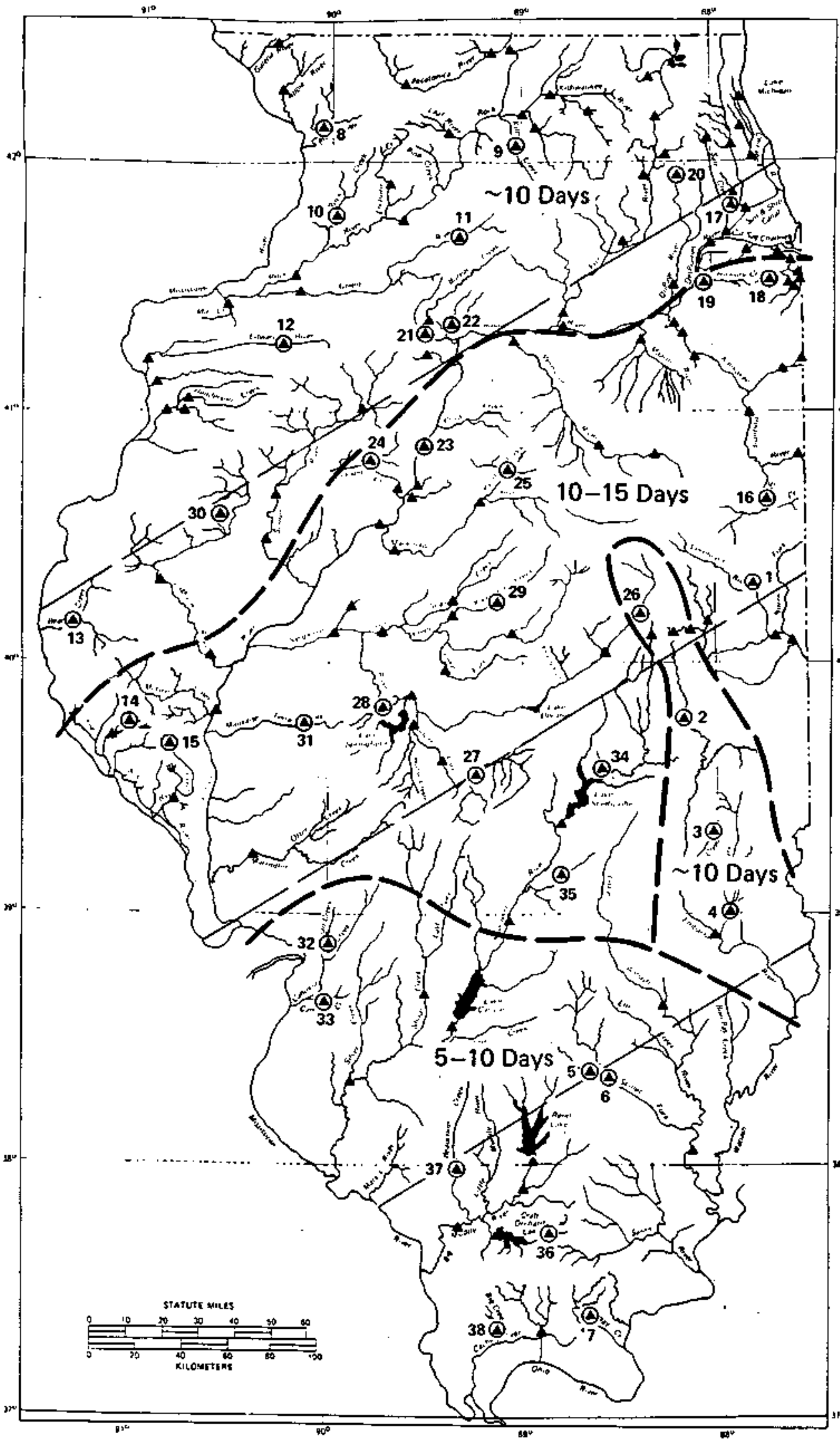

Figure 7. Antecedent precipitation days to simulate AMC in figure 4

Table 14. Observed Storm Rainfall, Surface Runoff, ar AP

Date	Observed P	Observed Q	AP5	Q_c	ΣQ	AP10	Q_c	IQ	API 5	Q_c	ΣQ	*
03385000: Hayes Creek at Glendale (CNs are 55, 74, 88)												
7/22/58	4.16	3.39	5.88	2.88	2.88	5.92	2.88	2.88	9.42	2.88	2.88	G
6/23/69	5.43	3.52	0.15	1.20	2.25	3.38	4.08	4.08	3.38	4.08	4.08	G
4/15/72	6.50	3.02	0.11	1.81	4.15	1.26	5.11	5.11	1.34	5.11	5.11	D
			0.11	1.81	3.20	1.26	1.81	4.30	1.34	1.81	4.37	G
05440500: Killbuck Creek near Monroe Center (CNs are 62, 79, 91)												
7/9/51	5.34	1.84	0.68	1.65	2.95	0.68	1.65	2.95	1.77	3.09	3.99	G
7/19/52	3.71	0.85	0.36	0.72	1.15	1.08	0.72	1.79	1.15	0.72	1.86	G
05563000: Kickapoo Creek near Kickapoot (CNs are 53, 72, 86)												
6/14/57	1.47	0.62	1.03	0.00	0.00	1.33	0.00	0.07	2.31	0.47	0.47	G
7/2/58	3.85	1.21	0.00	0.39	0.66	0.56	0.39	0.93	1.09	0.39	1.53	G
9/23/61	3.70	1.60	0.74	0.34	1.11	4.02	2.28	2.28	5.21	2.28	2.28	G
05567000: Panther Creek near El Paso (CNs are 60, 78, 90)												
7/9/51	4.92	3.43	0.00	1.25	1.83	0.77	1.25	2.54	2.16	3.80	3.80	G
4/13/52	2.41	0.80	0.68	0.73	1.09	1.06	1.45	1.45	1.52	1.45	1.45	D
			0.68	0.15	0.32	1.06	0.15	0.59	1.52	0.73	0.95	G
05599000: Beaucoup Creek near Matthews (CNs are 70, 85, 94)												
8/17/46	8.77	5.30	0.11	5.13	6.17	1.38	5.13	7.33	4.27	8.05	8.05	G
5/9/61	8.69	5.47	0.24	5.06	6.20	0.71	5.06	6.65	1.19	5.06	7.12	G
3/11/64	4.91	2.64	1.03	3.28	4.15	1.08	4.22	4.22	1.11	4.22	4.22	D
			1.03	1.97	3.23	1.08	1.97	3.25	1.11	1.97	3.31	G
12/23/67	4.09	2.31	0.42	1.39	2.78	2.48	3.41	3.41	3.06	3.41	3.41	G

Remarks: *G and D refer to growing and dormant season, respectively.
tRaingage at Edelstein has been used for calculating P.

raingage stations in and around the basin. The values of AP5, AP10, and AP15 in table 14 are the same as in table 13 for these storm events. The runoff computed with the expression

$$Q_c = \frac{(P-0.2S)^2}{(P+0.8S)}$$

in which S = (1000/CN)-10 is given for AP5, AP10, and AP15. Values of CN for the 5 basins are given in table 7. The ΣQ in table 14 refers to the computed runoff if the antecedent moisture condition is updated during the storm as discussed in the previous chapter and exemplified in table 12. A comparison of observed Q, Q_c, and ΣQ for the three AP values indicates the following:

1) For Hayes Creek at Glendale, 03385000 or number 7 in figure 7, the observed Q and Q_c, are close for average t equal to 9 days for computing AP. The observed Q and ΣQ are close for average t equal to 7 days.

2) For Killbuck Creek near Monroe Center, 05440500 or number 9 in figure 7, observed Q and Q_c, are close for average t equal to 11 days. The observed Q and ΣQ are close for t less than 5 days.

3) For Kickapoo Creek near Kickapoo, 05563000 or number 24 in figure 7, observed Q and Q_c. are close for average t equal to 15 days. The observed Q and *IQ* are close for average t equal to 12 days.

4) For Panther Creek near El Paso, 05567000 or number 25 in figure 7, observed Q and Q_c are close for average t equal to 14 days. The observed Q and ΣQ are close for average t equal to 12 days.

5) For Beaucoup Creek near Matthews, 05599000 or number 37 in figure 7, observed Q and Q_c are close for average t equal to

6 days. The observed Q and ΣQ are close for average t less than 5 days.

It is evident that if antecedent precipitation is calculated for the number of days shown in figure 7, the runoff for major storms computed with the SCS equation will be close to the actual runoff. Then there may be no need of updating the antecedent moisture index during the storm, which is usually less than a 24-hour duration for drainage basins less than 500 square miles in Illinois.

SUMMARY AND CONCLUSIONS

Curve numbers, CN, were derived for the 38 study basins. These basins were selected to provide geographical, meteorological, and hydrological variation, and suitable information for regionalization. The comparison of statistically-developed 100-year floods and those from 100-year storms and unit hydrographs with runoff factor equal to unity yielded suitable antecedent moisture conditions, AMC, for each basin. Regionalization of these AMCs indicated AMC II for the Rock River and northeastern Illinois basins, an AMC intermediate between II and III for the Plum Creek and east-central Illinois basins, and AMC III for the rest of the state as delineated in figure 4. Analyses of observed high floods, associated storm rainfall, and antecedent precipitation indicated that 5-day total antecedent rainfall may not provide the AMCs as given in figure 4, but that the period varies from 5 to 15 days. The regionalization of this period in 3 categories (5-10, about 10, and 10-15 days) is shown in figure 7. The analyses of observed high floods for the 38 study basins showed that the probability, P_r, of these floods occurring in winter (December 16 to March 31) varies from one part of the state to the other. This variation is shown in figure 6 in terms of 3 categories : $P_r \leq 0.25$, $0.25 < P_r < 0.50$, and $P_r > 0.50$. The reasons for this variation are explored in the text.

The following conclusions are drawn from this study:

1) The AMC conditions for converting a 100-year storm rainfall to runoff (and to 100-year flood hydrograph with the unit hydrographs) as shown in figure 4 are satisfactory. For areas near the boundary of two adjacent regions, the larger of the two

AMCs may be taken, to be on the safe side. Alternatively, an average of the two may be used.

2) For the t-day total antecedent rainfall in determining AMC for high floods, the value of t may be taken from figure 7 instead of 5 days as recommended by the SCS.

The suggestion is made for further research in relating the t-day period to soil characteristics, land slope, cover, etc., as well as in estimating the probability that storm rainfall, reported over 2 days, has actually occurred in one day or less for small and medium size basins as used in this study.

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