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HYDROLOGIC RUNOFF MODELS FOR THE ARID SOUTHWEST UNITED STATES

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Abstract

Recently, hydrologic study criteria manuals (or hydrology manuals) were prepared for the arid southwest regions of Clark County (Las Vegas vicinity, Nevada), Maricopa County (Phoenix vicinity, Arizona), and Kern County, California. Other hydrology manuals pertaining to the arid southwest have been prepared by San Bernardino County, San Diego County, and Riverside County, California. These hydrology manuals are required for use in developing the flood flow quantities that are used in the planning and design of flood control systems, master plans of drainage, dams, flood plains, among other topics. The hydrology manuals contain hydrologic methods, modeling approaches, and data requirements, for use in the arid southwest region of the United States. In this paper, these hydrology manuals are compared as to modeling approaches, and modeling components are examined for similarities.

Unit Hydrograph Method Techniques

Table 1. Rational Method Maximum Area Limitations

Country		Catchment Area Limits (Acres)
San Bernardino		640
Maricopa		160
Clark		20
Riverside		500
San Diego		320[1]
San Diego	(mean)	(328)

1 Modified rational methods may be used up to 15 square miles.

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Table 2. Unit-Hydrograph Method Area Limits

County	Area (Square Miles)	Method
San Bernardino	Greater than 1	S-graph
Maricopa	Less than about 5	Clark[1] Unit-Hydrograph
Maricopa	Greater than about 5	S-graph
Clark	Greater than 20 acres	SCS
Riverside	Greater than 500 acres	S-graph
San Diego	Greater than 320 acres	SCS
(mean)	(Greater than 936 acres)	

1 Modified rational methods may be used up to 15 square miles.

Table 3. Catchment Lag Formulae

Agency	Lag Formulae
San Bernardino[1]	$Lag = K_1 (LL_c/S^{0.5})^{m_1}$
Maricopa[2]	$Lag = K_2 (LL_c/S^{0.5})^{m_2}$
Clark[3]	$Lag = K_3 (LL_c/S^{0.5})^{m_3}$
Riverside	$Lag = K_4 (LL_c/S^{0.5})^{m_4}$
San Diego	$Lag = K_5 (LL_c/S^{0.5})^{m_5}$
COE (1988)	$Lag = K_6 (LL_c/S^{0.5})^{m_6}$

1 A calibrated lag estimator used is $Lag = 0.8\ T_c$.
2 For smaller catchments, T_c is utilized.
3 T_c is assumed related to lag for smaller catchments.

Table 4. Lag Formula Parameters

i	Agency	K_i[2]	m_i
1	San Bernardino	$24\bar{n}$	0.38
2	Maricopa[1]	$20\bar{n}$; or $26\bar{n}$	0.38; or 0.33
3	Clark	$20\bar{n}$	0.33
4	Riverside	$24\bar{n}$	0.38
5	San Diego	$24\bar{n}$	0.38
6	COE (1988)	$24\bar{n}$	0.38
	(mean)	$(23.14\bar{n})$	(0.366)

1 (K_2, m_2) equals $(20\bar{n}, 0.38)$ or $(26\bar{n}, 0.33)$.
2 $\bar{n}$ is similar for all manuals and COE (1988).

Table 5. Design Storm Areal Limits

County	Design Storm Maximum Area (Square Miles)
San Bernardino	150
Maricopa	100
Clark	200
Riverside	300[1]
San Diego	100[1]
(mean)	(170)

1 Limits from county depth-area reduction curves.

Table 6. Design Storm Areal Limits

County	Usage
San Bernardino	NOAA Atlas II, modified (as approved by Agency) by local rain gauge analysis[1].
Maricopa	NOAA Atlas II.
Clark	NOAA Atlas II, modified by adjustment factors[2].
Riverside	NOAA Atlas II.
San Diego	NOAA Rainfall Statistics.

1 The State of California Department of Water Resources (or "DWR") provides regional rain gauge analysis, with frequent updates.

2 Adjustment factors provide for an increase in rainfall of 1.43 for a 100-year event, and 1.0 for a 2-year event.

Table 7. Ratio of Design Storm Time-to-Peak versus Total Storm Duration

County	Ratio
San Bernardino[1]	0.67
Maricopa	0.67
Clark[2]	0.62
Riverside[3]	0.91
San Diego[4]	0.63
(mean)	(0.70)

1 Peak 6 hours of 24-hour storm pattern.
2 Clark County storm characteristics are identical to COE (1988).
3 6-hour storm pattern considered.
4 Storm pattern is uniform from hours 3.5 to 4.0

Table 8. Rainfall Mass Prior to Rainfall Peak

County	Mass (percent)
San Bernardino[1]	67
Maricopa	(62.7-83.4)[2]
Clark[3]	78[2]
Riverside[4]	95.6
San Diego[5]	60.0
(mean)	(75)

1 Peak 6 hours of 24-hour storm pattern.
2 Rainfall mass decreases as catchment area increases.
3 Characteristics are identical to COE (1988).
4 Riverside County 6-hour storm pattern.
5 Storm is nearly uniform from hours 3.5 to 4.0

Table 9. Comparison of 100-year Rainfalls

	San Bernardino	Maricopa	Clark	Riverside	San Diego
Rainfall Duration	Amboy	Phoenix Metro	McCarran Airport	Desert Hot Springs	Crawford Ranch
5-minute	.52(25)	0.75(20)	0.63(21)	0.47(11)	0.52(11)
30-minute	1.14(54)	2.00(52)	1.79(60)	1.25(28)	1.33(29)
1-hour	1.32(62)	2.50(65)	2.06(70)	1.59(36)	1.67(36)
3-hour	1.62(76)	3.00(78)	2.48(84)	2.36(53)	2.40(52)
6-hour	1.83(86)	3.30(86)	2.77(94)	3.13(70)	3.03(66)
24-hour	2.12(100)	3.84(100)	2.96(100)	4.45(100)	4.61(100)

Table 10. Design Storm Interior Duration Return Frequencies[1] for 100-year Storm Event

Peak Storm Duration	San Bernardino	Maricopa	Clark	Riverside	San Diego
30-minutes	100	19	60+	12	45
1-hour	100	29	100+	30	50
3-hour	100	50	100-	90	80
6-hour	100	100	100	100	100
(mean)[2]	(100)	(36.4)	(96)	(52.2)	(61.5)

1 Based on local rain gauge data.
2 Mean for durations 30-minutes to 3-hour.

Table 11. Loss Rate Methods

Agency	Loss rate, f(t)
San Bernardino[1]	$f(t) = \min\{\phi_1, \overline{Y}\, I(t)\}$
Maricopa[2]	$f(t): \begin{cases} \text{method \#1:} & \min\{K_s(1 + \frac{\psi\theta}{F}), I(t)\} \\ \text{method \#2:} & \begin{cases} I(t), \text{ for } \int_{s=0}^{t} I(s)\,ds \le STRTL \\ \phi_2, \text{ for } \int_{s=0}^{t} I(s)\,ds > STRTL \end{cases} \end{cases}$
Clark, San Diego	SCS Curve-Number Technique[3]
Riverside[4]	$f(t) = \min(\phi_3, kI(t))$
COE[5] (1988)	$f(t) = \phi_4$

Notes:

1 (i) ϕ_1 = phi index; function of SCS Curve Number

(ii) $\overline{Y}$ = (1-yield); yield computed from SCS Curve Number based on 24-hour storm rainfall depth (or total storm).

(iii) I(t) = rainfall intensity, at time t>0.

2 (i) Either method may be used.

(ii) Green-Ampt model. K_s = hydraulic conductivity.

ψ = wetted soil capillary suction;

θ = soil moisture deficit;

F = depth of infiltrated rainfall since storm time t = 0.

(iii) STRTL = initial infiltration + surface retention

3 See Hromadka et al (1987), or McCuen (1983).

4 Phi-Index, ϕ_3, is used for 3- and 6-hour storm patterns; k is a low-loss constant, usually 0.8 to 0.9.

5 Reconstituted phi-index, ϕ_4, is 0.40 in/hr for dry catchment.

Table 12. Example Problem Loss Rate Comparisons

Agency	Constant loss or phi-index (in/hr)	Total runoff (inches)
San Bernardino	0.45	2.28 (2.25)[1]
Maricopa[2]	0.25	2.28
Clark[3], San Diego[3,5]	- -	1.16
Riverside[4]	0.30	2.33
COE (1988)[6]	0.40	1.99
(mean)[7]	0.36	(1.87)

1 24-hour rainfall value used to estimate yield. Value in parenthesis is runoff volume for 6-hour rainfall.

2 Method 2 used. (Surface retention loss assumed to be 0.18 inches (average non-agricultural value); normal initial loss = 0.3 inches.)

3 Loss rates are per standard SCS methods.

4 Low-loss rate assumed as 0.85.

5 Los-loss rate of 0.05 in/hr neglected.

6 Reconstituted loss rate shown.

7 Mean based on six samples.

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