FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 1 OF 6

DETAIL CAVE CREEK WATERSHED COMPUTED _____ DATE _____

CHECKED BY _____ DATE _____

METHOD COMPARISON: APPLICATION TO LARGE, NATURAL WATERSHEDS

SCENARIO: THIS EXAMPLE COMPARES THE METHODS OUTLINED IN THE HYDROLOGIC DESIGN MANUAL WITH THE COMMONLY USED TECHNIQUES, i.e., THE SCS METHODS, FOR APPLICATION TO LARGE, NATURAL WATERSHEDS. THEN, THE RESULTS ARE COMPARED WITH DISCHARGE FREQUENCY ANALYSIS.

WATERSHED DISCRIPTION:

LOCATION: UPPER CAVE CREEK WATERSHED

DRAINAGE AREA: 126 Mi^2

INDIVIDUAL BASINS: 80.28 Mi^2; 34.86 Mi^2; 6.38 Mi^2; 4.81 Mi^2 & .59 Mi^2

THE CAVE CREEK WATERSHED IS CHARACTERIZED BY GENERALLY STEEP SLOPING AREAS WITH RATHER DENSE VEGETATIVE COVER AND IRREGUAR CHANNELS.

STUDY DISTRIPTION:

THIS STUDY WILL COMPARE THE GENERATED PEAK DISCHARGE VALUES OF 10-YEAR, 50-YEARS AND 100-YEAR FREQUENCIES AMOUNG THE THREE METHODS DESCRIBED EARLIER. THE GENERATED BASIN HYDROGRAPHS ARE ADDED AND WHEN NECESSARY, ROUTED THROUGH THE CAVE CREEK WASH. THE FINAL PEAK DISCHARGE VALUE IS COMPUTED AT THE EXTREME SOUTH WEST LOCATION OF THE WATERSHED WHERE A COMPARISON OF VALUES IS MADE (SEE ENCLOSED MAP).

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 2 OF 6

DETAIL _____ COMPUTED _____ DATE _____

_____ CHECKED BY _____ DATE _____

HYDROLOGIC INPUT CRITERIA					
METHOD OF COMPUTATION	RAINFALL CRITERIA	METHOD OF LOSS COMPUTATION	HYDROGRAPH GENERATION	ROUTING METHOD	COMPUTER PROGRAM
HYDROLOGIC DESIGN MANUAL	100-YEAR, 6-HOUR PATTERN DISTRIBUTION	INITIAL & UNIFORM LOSS METHOD	CORPS OF ENG. S-GRAPHS	MUSKINGUM	HEC-1
SCS METHODS	100-YEAR, 24-HOUR SCS TYPE II	CURVE NUMBERS	SCS UNIT-GRAPH	MUSKINGUM	TR-20

1. HYROLOGIC DESIGN MANUAL

A - CALCULATION OF RAINFALL DEPTHS:

BASIN SIZE	RED. FACTOR	10-YEAR RAIN FALL	50-YEAR RAIN FALL	100-YEAR RAIN FALL
80.28	.815	.815(2.5) = 2.04	.815 (3.3) = 2.60	.815 (3.65) = 2.97
34.86	.88	.88 (2.5) = 2.20	.88 (3.2) = 2.82	.88 (3.60) = 3.12
6.38	.96	.96 (2.5) = 2.40	.96 (3.2) = 3.07	.96 (3.60) = 3.46
4.81	.97	.97 (2.5) = 2.43	.97 (3.2) = 3.10	.97 (3.60) = 3.49
.59	1.0	1.0 (2.5) = 2.50	1.0 (3.2) = 3.20	1.0 (3.60) = 3.60

B - SELECTION OF LOSS PARAMETERS:

AREA (Mi^2)	80.28	34.86	6.38	4.81	0.59
INITIAL LOSS	0.73	0.75	0.75	0.75	0.75
UNIFORM LOSS	0.12	0.18	0.16	0.20	0.20

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 3 OF 6

DETAIL _____ COMPUTED _____ DATE _____

CHECKED BY _____ DATE _____

C- CALCULATION OF BASIN LAGS:

(*) AREA = 80.28 mi^2, L = 116160 ft, Lca = 79200 ft, $\bar{n}$ = .05

$$SLOPE = \frac{4400-2100}{116160/5280} = 105 \text{ ft/mi}; \quad BASIN\ FACTOR = \frac{(116160 \times 79200)/5280^2}{(105)^{1/2}} = 32.3$$

$$\Rightarrow LAG = 20\,(.05)(32.3)^{.38} = 3.70 \text{ HOURS}$$

(*) AREA = 34.86 mi^2, L = 49280 ft, Lca = 29920 ft, $\bar{n}$ = .05

$$SLOPE = \frac{3460-2040}{49280/5280} = 152 \text{ ft/mi}; \quad BASIN\ FACTOR = \frac{(49280 \times 29920)/5280^2}{(152)^{1/2}} = 4.29$$

$$\Rightarrow LAG = 20\,(.05)(4.29)^{.38} = 1.74 \text{ HOURS}$$

(*) AREA = 6.38 mi^2, L = 33440 ft, Lca = 18000 ft, $\bar{n}$ = 0.05

$$SLOPE = \frac{2500-1900}{33440/5280} = 94.7 \text{ ft/mi}; \quad BASIN\ FACTOR = \frac{(33440 \times 18000)/5280^2}{(94.7)^{1/2}} = 2.22$$

$$\Rightarrow LAG = 20\,(.05)(0.29)^{.38} = 1.35 \text{ HOURS}$$

(*) AREA = 4.81 mi^2, L = 44000 ft, Lca = 24640 ft, $\bar{n}$ = .045

$$SLOPE = \frac{3100-2100}{44000/5280} = 120 \text{ ft/mi}; \quad BASIN\ FACTOR = \frac{(44000 \times 24640)/5280^2}{(120)^{1/2}} = 3.55$$

$$\Rightarrow LAG = 20\,(.045)(3.55)^{.38} = 1.46 \text{ HOURS}$$

(*) AREA = .59 mi^2, L = 15000 ft, Lca = 5000 ft, $\bar{n}$ = .045

$$SLOPE = \frac{2120-1881}{15000/5280} = 83 \text{ ft/mi}; \quad BASIN\ FACTOR = \frac{(15000 \times 5000)/5280^2}{(83)^{1/2}} = .29$$

$$\Rightarrow LAG = 20\,(.045)(.29)^{.38} = .56 \text{ HOURS}.$$

2. SCS METHODS

SINCE A COMPLETE DOCUMENTATION OF THE 1977 STUDY OF THE CAVE CREEK WATERSHED WAS NOT AVAILABLE, ONLY THE PARAMETER DESCRIPTION AND THE RESULTS BY THE TR-20 PROGRAM ARE INCLUDED. THIS INFORMATION INCLUDES SELECTION OF CURVE NUMBERS FOR LOSS COMPUTATIONS, LENGTH OF ROUTING REACHES, AND THE RESULTING DISCHARGE VALUES.

3. DISCHARGE-FREQUENCY ANALYSIS:

30 YEARS OF DATA ON ANNUAL DISCHARGE WAS AVAILABLE FOR THE PERIOD OF 1958-1987. THIS INFORMATION WAS USED TO ESTIMATE THE 100-YEAR DISCHARGE BY THE WEIBULL POSITIONING METHOD (NEXT PAGE SHOWS THE INDIVIDUAL AND THE RANKED VALUES. THEN DATA WAS ARRANGED BASED ON WEIBULL POSITION AND PLOTTED ON FREQUENCY PAPER FOR AN ESTIMATION OF A DESIRED FREQUENCY.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 5 OF 6

DETAIL _____ COMPUTED _____ DATE _____

CHECKED BY _____ DATE _____

DATE OF FLOW	DISCHARGE (CFS)	RANK	WEIBULL POSITION (*)	WATER YEAR
12-19-67	12400	1	31	68
10-29-59	8570	2	15.5	60
3-2-78	7500	3	10.3	78
12-18-78	6900	4	7.75	79
12-22-65	6000	5	6.2	66
9-12-58	5680	6	5.2	58
9-17-72	3950	7	4.4	72
10-19-72	3950	8	3.9	73
8-5-59	3590	9	3.4	59
8-2-64	3120	10	3.1	64
9-5-70	2700	11	2.8	70
9-6-67	1800	12	2.6	67
8-6-63	1510	13	2.4	63
3-3-83	1420	14	2.2	83
8-5-74	1390	15	2.1	74
7-22-86	1350	16	1.9	86
2-9-76	1260	17	1.8	76
10-2-81	1200	18	1.7	82
12-27-84	910	19	1.6	85
11-2-74	856	20	1.55	75
9-17-61	696	21	1.5	61
7-16-65	610	22	1.4	65
2-4-71	364	23	1.3	71
12-16-61	280	24	1.29	62
8-9-84	140	25	1.24	84
1969	0	26	1.2	69
1977	0	27	1.1	77
1981	0	28	1.1	81
1987	0	29	1.07	87
1980	0	30	1.03	80

(*) WEIBULL POSITION $T = \frac{n+1}{m}$, WHERE m = RANK OF DATA, n IS TOTAL NUMBER OF DATA POINTS.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 6 OF 6

DETAIL _____ COMPUTED _____ DATE _____

_____ CHECKED BY _____ DATE _____

COMPARISON OF DISCHARGE VALUES:

COMPARISON OF 100-YEAR DISCHARGE AS A FUNCTION OF AREA		
DRAINAGE AREA (mi^2)	DISCHARGE BY HDM* (CFS)	DISCHARGE BY SCS (CFS)
.59	986	780
4.81	3361	3989
6.38	4443	4871
34.86	16759	18864
80.28	19971	23604
126.92	29790	36841

* HYDROLOGIC DESIGN MANUAL

COMPARISON OF DISCHARGE VALUES WITH FLOW FREQUENCY			
	10-YR DISCHARGE (CFS)	50-YR DISCHARGE (CFS)	100-YR DISCHARGE (CFS)
HYDROLOGIC DESIGN MANUAL	18455	26081	29790
SCS METHODS	20610	32975	36841
FLOW FREQUENCY	9000	22000	28000

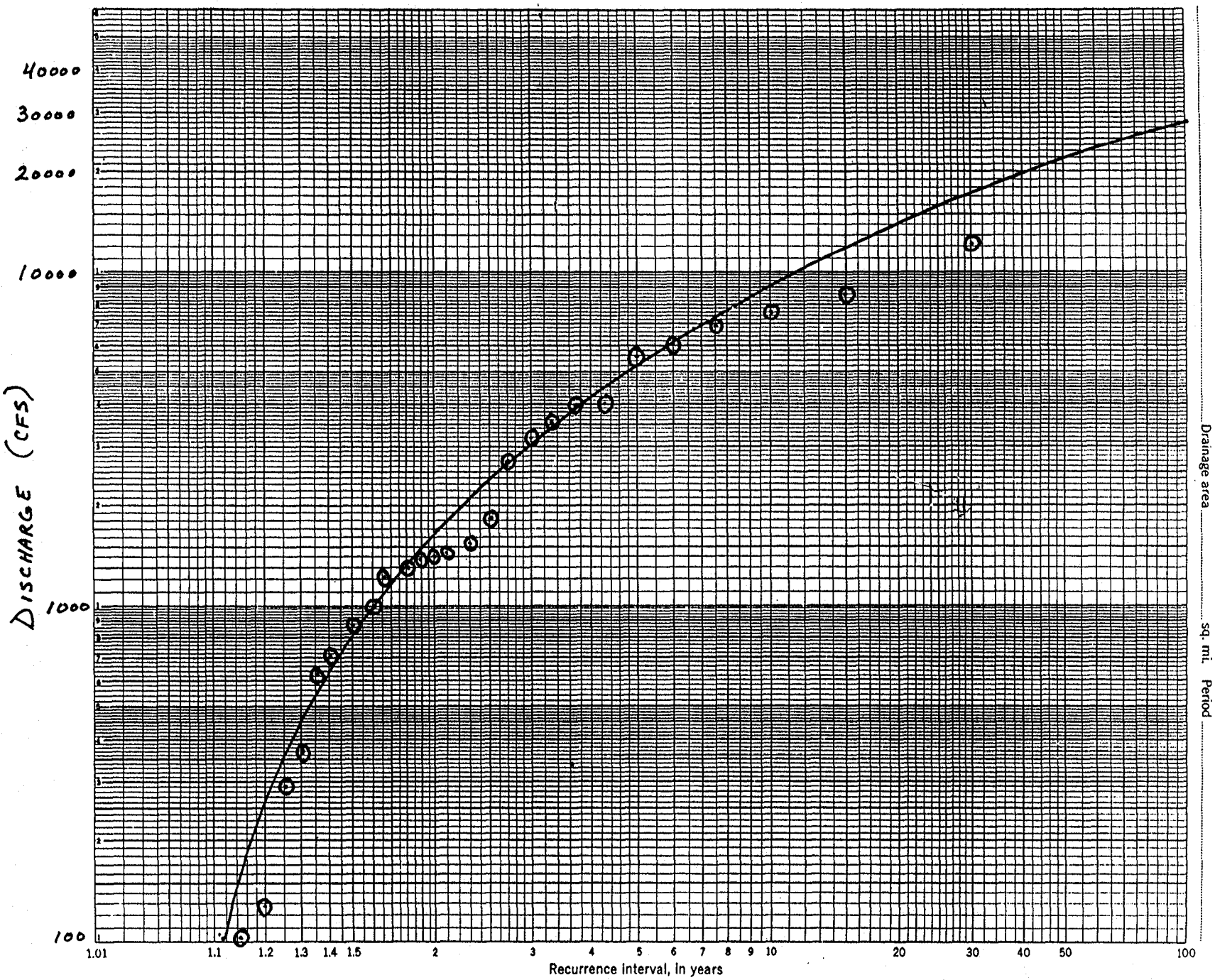
9–179b
Extreme log data plot
April 1955

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File

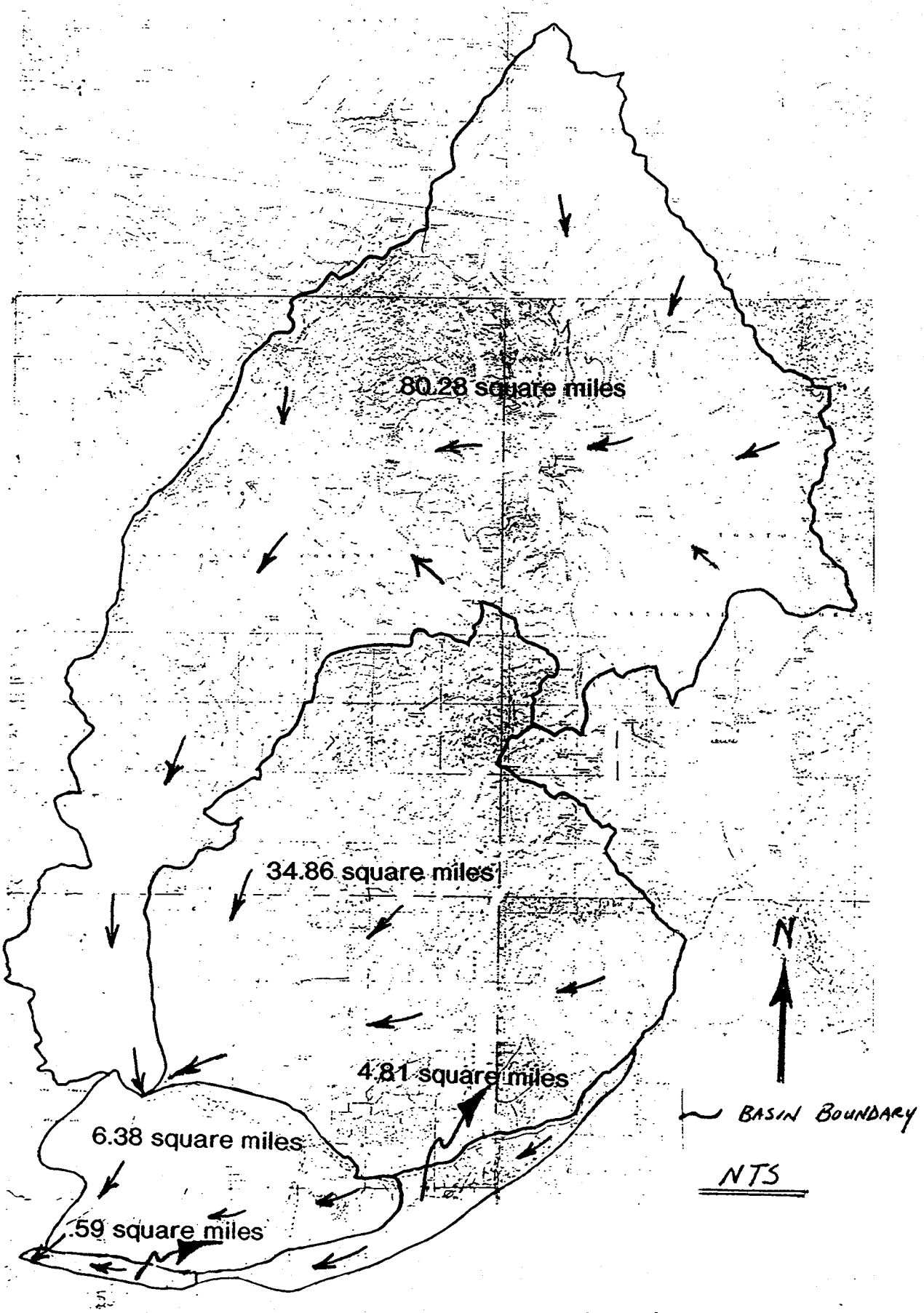
Magnitude and frequency of CAVE CREEK WASH NEAR CAVE CREEK on USGS GAGE # 09512300

Drainage area ____ sq. mi. Period ____



Sheet No. ____ of ____ Sheets. Prepared by ____ Date ____ Checked by ____ Date

GPO 863751



Schematic watershed for cave creek wash.

STANDARD CONTROL INSTRUCTIONS

```
6 RUNOFF    1       1           6          80.2800    82.0000    4.45000 0 0 0 0 1
6 REACH     3       28      6   5        6200.0000      .8800    0.00000 0 0 0 0 1
6 RUNOFF    1       28          6          34.8600    83.5000    2.21000 0 0 0 0 1
6 ADDHYD    4       28      5   6   7                                  0 0 0 0 0 1
6 REACH     3       29      7       5    14100.0000      .8800    0.00000 0 0 0 0 1
6 RUNOFF    1       29              6        6.3800    80.0000    1.10000 0 0 0 0 1
6 ADDHYD    4       29      5   6   7                                  0 0 0 0 0 1
6 RUNOFF    1       30              6        4.8100    79.0000     .90000 0 0 0 0 1
6 REACH     3       31      6       1    15000.0000      .8800    0.00000 0 0 0 0 1
6 RUNOFF    1       31              6         .5900    79.0000     .35000 0 0 0 0 1
6 ADDHYD    4       31      6   1   5                                  0 0 0 0 0 1
6 ADDHYD    4       32      7   5   6                                  0 0 0 0 0 1
  ENDATA

END OF LISTING
```

TR-20 DATA INPUT FOR:
CAVE CREEK WATERSHED

SUMMARY TABLE 1

ALT	STORM	ID	DA SQ-MI.	RAIN TBLE	AMC	DELTA-T HRS.	TZERO HRS.	PRECIP IN.	PRECIP DURATION	PEAK-Q CFS	PEAK-TIME	PEAK-ELEV	RUNOFF IN.	CSM
1	1	1	80.28	1	2	.20	0.00	3.29	24.00	13212.43	14.69	0.00	1.61	164.58
1	1	28	80.28	1	2	.20	0.00	3.29	24.00	13187.85	14.90	0.00	1.61	164.27
1	1	28	34.86	1	2	.20	0.00	3.33	24.00	10746.21	13.27	0.00	1.75	308.27
1	1	28	115.14	1	2	.20	0.00	3.33	24.00	19643.48	13.90	0.00	1.65	170.61
1	1	29	115.14	1	2	.20	0.00	3.33	24.00	19577.37	14.22	0.00	1.65	170.03
1	1	29	6.38	1	2	.20	0.00	3.10	24.00	2377.49	12.57	0.00	1.32	372.65
1	1	29	121.52	1	2	.20	0.00	3.10	24.00	20129.47	14.18	0.00	1.63	165.65
1	1	30	4.81	1	2	.20	0.00	3.10	24.00	1928.89	12.43	0.00	1.26	401.02
1	1	31	4.81	1	2	.20	0.00	3.10	24.00	1828.84	12.77	0.00	1.26	380.22
1	1	31	.59	1	2	.20	0.00	3.10	24.00	376.51	12.06	0.00	1.27	638.16
1	1	31	5.40	1	2	.20	0.00	3.10	24.00	1914.15	12.75	0.00	1.26	354.47
1	1	32	126.92	1	2	.20	0.00	3.10	24.00	20610.58	14.13	0.00	1.62	162.39
1	2	1	80.28	1	2	.20	0.00	4.42	24.00	21480.38	14.66	0.00	2.56	267.57
1	2	28	80.28	1	2	.20	0.00	4.42	24.00	21414.28	14.85	0.00	2.56	266.74
1	2	28	34.86	1	2	.20	0.00	4.41	24.00	16668.87	13.25	0.00	2.68	478.17
1	2	28	115.14	1	2	.20	0.00	4.41	24.00	31428.40	13.88	0.00	2.60	272.96
1	2	29	115.14	1	2	.20	0.00	4.41	24.00	31301.63	14.20	0.00	2.60	271.86
1	2	29	6.38	1	2	.20	0.00	4.20	24.00	4065.01	12.54	0.00	2.20	637.15
1	2	29	121.52	1	2	.20	0.00	4.20	24.00	32182.89	14.15	0.00	2.58	264.84
1	2	30	4.81	1	2	.20	0.00	4.20	24.00	3347.66	12.41	0.00	2.12	695.98
1	2	31	4.81	1	2	.20	0.00	4.20	24.00	3172.77	12.74	0.00	2.12	659.62
1	2	31	.59	1	2	.20	0.00	4.20	24.00	649.57	12.05	0.00	2.13	1100.97
1	2	31	5.40	1	2	.20	0.00	4.20	24.00	3315.77	12.72	0.00	2.13	614.03
1	2	32	126.92	1	2	.20	0.00	4.20	24.00	32975.39	14.10	0.00	2.56	259.81
1	3	1	80.28	1	2	.20	0.00	4.70	24.00	23603.94	14.65	0.00	2.81	294.02
1	3	28	80.28	1	2	.20	0.00	4.70	24.00	23527.20	14.84	0.00	2.81	293.06
1	3	28	34.86	1	2	.20	0.00	4.80	24.00	18864.46	13.24	0.00	3.03	541.15
1	3	28	115.14	1	2	.20	0.00	4.80	24.00	35000.54	13.86	0.00	2.87	303.98
1	3	29	115.14	1	2	.20	0.00	4.80	24.00	34854.32	14.18	0.00	2.88	302.71
1	3	29	6.38	1	2	.20	0.00	4.70	24.00	4871.41	12.53	0.00	2.63	763.54
1	3	29	121.52	1	2	.20	0.00	4.70	24.00	35906.32	14.12	0.00	2.86	295.48
1	3	30	4.81	1	2	.20	0.00	4.70	24.00	4028.78	12.40	0.00	2.54	837.58
1	3	31	4.81	1	2	.20	0.00	4.70	24.00	3818.32	12.73	0.00	2.54	793.83
1	3	31	.59	1	2	.20	0.00	4.70	24.00	780.38	12.04	0.00	2.55	1322.68
1	3	31	5.40	1	2	.20	0.00	4.70	24.00	3988.80	12.71	0.00	2.54	738.67
1	3	32	126.92	1	2	.20	0.00	4.70	24.00	36860.94	14.07	0.00	2.85	290.43

TR-20 OUTPUT FOR CAVE CREEK WATERSHED

```
****************************************
*                                      *
*  OD HYDROGRAPH PACKAGE  (HEC-1)      *
*                                      *
*          FEBRUARY 1981               *
*                                      *
*         REVISED 05 DEC 88            *
*                                      *
*                                      *
*                                      *
*  RUN DATE  01/10/1990  TIME  16:01:06 *
*                                      *
*                                      *
*                                      *
****************************************
```

```
*                                      *
*   U.S. ARMY CORPS OF ENGINEERS       *
*  THE HYDROLOGIC ENGINEERING CENTER   *
*         609 SECOND STREET            *
*       DAVIS, CALIFORNIA 95616        *
*          (916) 551-1748              *
*                                      *
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X       XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID    TEST OF COMPARISON: HYDROLOGY MANUAL METHODS VERSUS MOSTLY USED METHODS
  2           ID    APPLICATION TO LARGE WATERSHEDS
  3           ID    UPPER CAVE CREEK WATERSHED
  4           ID    ORIGINAL ANAYLSIS IN 1977, THIS ANAYSIS BY DDK, DEC. 1989.
  5           IT      20                      120
  6           IO

  7           KK
  8           KM   UPPER CAVE CREEK BASIN
  9           PB    2.97
 10           IN      15
 11           PC   0.000   0.021   0.035   0.051   0.071   0.087   0.105   0.125   0.143   0.160
 12           PC   0.179   0.201   0.232   0.281   0.364   0.500   0.658   0.773   0.841   0.888
 13           PC   0.927   0.958   0.965   0.976   1.000
 14           BA   80.29
 15           LU     .73     .12
 16           UI    695.   1410.   2571.   4072.   6090.   8011.  10016.  10120.  11202.  11202.
 17           UI  11202.   8727.   7811.   7156.   5831.   5454.   5325.   3846.   3638.   3451.
 18           UI   2677.   2543.   2430.   2327.   2232.   2119.   1470.   1416.   1366.   1299.
 19           UI    718.    695.    674.    654.    687.    687.    383.    372.    362.    353.
 20           UI    344.    335.    327.    320.    284.    169.    166.    162.    159.    1552
 21           UI    152.    149.     93.      0.      0.

 22           KK      1
 23           KM   ROUTE TO ANDORA HILLS CONFLUENCE
 24           RM      1     .25     .20

 25           KK
 26           KM   MIDDLE BASIN
 27           PB   3.168
 28           IN      15
 29           PC   0.000   0.018   0.027   0.040   0.058   0.074   0.089   0.106   0.122   0.137
 30           PC   0.155   0.174   0.201   0.249   0.331   0.485   0.665   0.786   0.856   0.901
 31           PC   0.937   0.967   0.978   0.988   1.000
 32           BA   34.86
 33           LU     .75     .18
 34           UI   1028.   3486.   7373.   9720.  10463.   8065.   6085.   4896.   3441.   2683.
 35           UI   2683.   2263.   2104.   1353.   1215.    656.    614.    440.    337.    319.
 36           UI    349.    160.    152.    145.    139.      1.      0.

 37           KK
 38           KM   ADD HYDROGRAPHS
 39           HC      2

 40           KK
 41           KM   ROUTE TO LOWER WATERSHED
 42           RM      2     .70     .25
```

```
43      KK
44      KM   LOWER BASIN
45      PB   3.456
46      IN     15
47      PC   0.000   0.010   0.016   0.025   0.039   0.051   0.062   0.073   0.085   0.097
48      PC   0.110   0.125   0.146   0.191   0.277   0.461   0.682   0.817   0.885   0.926
49      PC   0.957   0.980   0.985   0.988   1.000
50      BA    6.38
51      LU     .75     .20
52      UI    304.   1136.   2119.   2422.   1771.   1248.    896.    630.    512.    399.
53      UI    399.    297.    151.    137.     80.     74.     73.     36.     34.     32.
54      UI      0.      0.

55      KK
56      KM   ADD HYDROGRAPH
57      HC      2

58      KK
59      KM   BASIN ALONG CAREFREE HIGHWAY
60      PB    3.49
61      IN     15
62      PC   0.000   0.009   0.014   0.023   0.036   0.046   0.057   0.067   0.078   0.089
63      PC   0.101   0.116   0.137   0.181   0.268   0.457   0.687   0.825   0.890   0.930
64      PC   0.961   0.982   0.987   0.989   1.000
65      BA    4.81
66      LU     .75     .16
67      UI    204.    745.   1431.   1724.   1406.    986.    734.    518.    386.    386.
68      UI    355.    222.    174.    105.     87.     56.     53.     50.     26.     24.
69      UI     23.      2.      .0

70      KK
71      KM   ROUTE
72      RM      2     .58     .25

73      KK
74      KM   SMALL LOWER BASIN
75      PB    3.60
76      IN     15
77      PC   0.000   0.005   0.009   0.014   0.022   0.030   0.038   0.047   0.054   0.062
78      PC   0.075   0.088   0.107   0.127   0.205   0.366   0.823   0.900   0.920   0.939
79      PC   0.952   0.965   0.977   0.988   1.000
80      BA    0.59
81      LU     .75     .20
82      UI    212.    484.    239.    114.     52.     22.     13.     13.      6.      0.

83      KK
84      KM   ADD HYDROGRAPH
85      HC      3
86      ZZ
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT		19971.	7.00	12977.	4138.	2504.	80.29		
+	ROUTED TO	1	19712.	7.33	12959.	4138.	2504.	80.29		
+	HYDROGRAPH AT		16759.	5.33	7284.	1884.	1140.	34.86		
+	2 COMBINED AT		27089.	6.00	19609.	6022.	3644.	115.15		
+	ROUTED TO		26753.	7.00	19426.	6022.	3644.	115.15		
+	HYDROGRAPH AT		4443.	5.00	1568.	397.	240.	6.38		
+	2 COMBINED AT		27886.	6.67	20586.	6419.	3884.	121.53		
+	HYDROGRAPH AT		3361.	5.00	1255.	318.	193.	4.81		
+	ROUTED TO		3125.	5.67	1250.	318.	193.	4.81		
+	HYDROGRAPH AT		986.	4.33	152.	38.	23.	.59		
+	3 COMBINED AT		29790.	6.33	21845.	6775.	4099.	126.93		

*** NORMAL END OF HEC-1 ***

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 2 OF 6

DETAIL _____ COMPUTED _____ DATE _____

_____ CHECKED BY _____ DATE _____

HYDROLOGIC DESIGN CRITERIA					
METHOD OF ANALYSIS	RAINFALL CRITERIA	METHOD OF LOSS CALCULATIONS	HYDROGRAPH GENERATION	ROUTING METHOD	COMPUTER PROGRAM
HYDROLOGIC DESIGN MANUAL	100-YR, 6-HR PATTERN DISTRIBUTION, SCS TYPE II	GREEN-AMPT LOSS METHOD	CORPS OF ENG. S-GRAPH	MUSKINGUM	HEC-1
SCS METHODS	SCS TYPE II DISTRIBUTION	CURVE NUMBERS	SCS UNIT-GRAPH		TR-20

1. HYDROLOGIC DESIGN MANUAL

A - RAINFALL INPUT: BOTH THE 6-HOUR PATTERN DISTRIBUTION AND THE 24-HOUR SCS TYPE II WERE USED IN THIS CASE. THE FACT THAT THE WATERSHED SIZE WAS LARGER THAN 100 MI^2, REQUIRED AN EXAMINATION OF BOTH DISTRIBUTIONS SO THAT THE PEAK PRODUCING EVENT COULD BE DETERMINED.

(*) FOR THE SCS TYPE II RAINFALL DEPTH OF 5.00" WITH AN AEREAL REDUCTION COEFFICIENT OF 0.84 (HYDRO 40) WAS USED.

(*) FOR THE 6-HOUR PATTERN DISTRIBUTION, RAINFALL DEPTH OF 3.60" WITH AN AEREAL REDUCTION ~~COEFFICIENT OF 0.78 AND PATTERN # 4.2~~ (MCUHP2) WAS USED.

SOIL LOSS COMPUTATIONS

B - SELECTION OF LOSS PARAMETERS: SINCE GREEN-AMPT LOSS METHOD WAS TO APPLIED, ALL OF THE ASSOCIATED PARAMETERS HAD TO BE ESTIMATED. BOTH THE GENERAL SOIL MAPS FROM SCS FOR YAVAPIE COUNTY AND MARICOPA COUNTY WERE USED. THERE IS NO DETAILED SOIL INFORMATION FOR THIS AREA.

LOG AVERAGE METHOD NOT USED IN THIS CASE

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT HYDROLOGIC DESIGN MANUAL PAGE 3 OF 6

DETAIL _____ COMPUTED _____ DATE _____

_____ CHECKED BY _____ DATE _____

LOSS COMPUTATIONS (CONTINUED)

FROM MARICOPA COUNTY MAPS:

SOIL # 13 : CELLAR - LEHMAN - ROCK OUTCROP ASSOCIATION

25% CELLAR : GRAVELLY - SANDY - LOAM ⇒ XKSAT = .40

20% LEHMAN : COBBLEY - LOAM ⇒ XKSAT = .25

30% ROCK OUTCROP ⇒ IMP = 15%

$$\Rightarrow XKSAT = \frac{25}{45}(.40) + \frac{20}{45}(.25) = .33$$

SOIL # 14 : BRAKERVILLE - CABEZON - ROCK OUTCROP ASSOCIATION

25% BRAKERVILLE : COBBLEY - SANDY - LOAM ⇒ XKSAT = .40

20% CABEZON : COBBLEY - LOAM ⇒ XKSAT = .25

ROCK OUTCROP ⇒ UNKOWN

SOIL # 11 : CONTINENTAL - PINALENO - CAVE ASSOCIATION

30% CONTINENTAL : GRAVELLY - SANDY - LOAM ⇒ XKSAT = .40

25% PINALENO : VERY GRAVELLY - SANDY - LOAM ⇒ XKSAT = .40

25% CAVE : GRAVELLY - SANDY - LOAM ⇒ XKSAT = .40

⇒ XKSAT = .40

SOIL # 7 : EBON - PINAMT - TREMANT ASSOCIATION

35% EBON : GRAVELLY LOAM ⇒ XKSAT = .25

25% PINAMT : VERY GRAVELLY LOAM ⇒ XKSAT = .25

20% TREMANT : VERY GRAVELLY LOAM ⇒ XKSAT = .25

⇒ XKSAT = .25

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT *HYDROLOGIC DESIGN MANUAL* PAGE 4 OF 6

DETAIL _____ COMPUTED _____ DATE _____

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FROM YAVAPIE COUNTY MAPS:

SOIL #2 (SHALLOW SANDY LOAM) ⇒ XKSAT = .40

SOIL #5 (SHALLOW TO MODERATELY DEEP CLAY SOILS) ⇒ XKSAT = .01

CALCULATION OF LOSS PARAMETERS:

AREA SIZE: 80.28 Mi^2

$$\frac{44.86}{80.28}(\text{SOIL \#13}) + \frac{25.74}{80.28}(\text{SOIL \#14}) + \frac{4.30}{80.28}(\text{SOIL \#5}) + \frac{2.20}{80.28}(\text{SOIL \#2}) + \frac{3.18}{80.28}(\text{SOIL \#11})$$

$$\Rightarrow XKSAT = \frac{44.86}{80.28}(.33) + \frac{25.74}{80.28}(.33) + \frac{4.30}{80.28}(.01) + \frac{2.20}{80.28}(.40) + \frac{3.18}{80.28}(.40)$$

$\Rightarrow$ XKSAT = .317, PSIF = 3.873, θ = .35, % IMP = 15% ASSUMED

AREA SIZE: 34.86 Mi^2

$$\frac{23.83}{34.86}(\text{SOIL \#11}) + \frac{11.03}{34.86}(\text{SOIL \#13}) = \left(\frac{23.83}{34.86}\right)(.40) + \left(\frac{11.03}{34.86}\right)(.33)$$

$\Rightarrow$ XKSAT = .377, PSIF = 4.177, θ = .35, % IMP = 10% ASSUMED

AREA SIZE: 6.83 Mi^2

$$\frac{2.52}{6.38}(\text{SOIL \#7}) + \frac{4.31}{6.38}(\text{SOIL \#13}) = \frac{2.52}{6.38}(.25) + \frac{4.31}{6.38}(.40)$$

$\Rightarrow$ XKSAT = .340, PSIF = 4.0, θ = .35

AREA SIZE: 4.81 Mi^2

$$\frac{.91}{4.81}(\text{SOIL \#13}) + \frac{3.90}{4.81}(\text{SOIL \#7}) = \frac{.91}{4.81}(.33) + \frac{3.9}{4.81}(.25)$$

$\Rightarrow$ XKSAT = .263, PSIF = 3.569, θ = .35, % IMP = 3%

AREA SIZE: 0.59 Mi^2

$$\frac{.59}{.59}(\text{SOIL \#7}) = 1.0(.25) \Rightarrow XKSAT = .25,\ PSIF = 3.5\quad \theta = .35$$

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT _____ PAGE ___ OF ___

DETAIL _____ COMPUTED _____ DATE _____

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C- CALCULATION OF BASIN LAGS

(*) AREA = 80.28 MI^2, L = 116160 FT, L_{ca} = 79200 FT

$$\text{SLOPE} = \frac{4400-2100}{116160/5280} = 105 \text{ ft/mi} \Rightarrow \text{BASIN FACTOR} = \frac{116160 \times 79200/(5280)^2}{(105)^{1/2}} = 32.3$$

SELECT $\bar{n}$ BY COMPARISON WITH HYDROLOGICALLY SIMILAR WATERSHEDS

NO.	NAME	A	L	L_{ca}	S	LAG	$\bar{n}$
11	LIVEOAK CR.	81.4	15.1	7.3	290	2.5	.05
23	NEW RIVER	85.7	23.2	13.8	145	3.7	.045

SELECT $\bar{n}$ BY COMPARISON WITH LAG RELATIONS

NO.	NAME	$\bar{n}$
#13	MURRIETA CR.	.05

$\Rightarrow$ SELECT $\bar{n}_{100\text{-YR}} = .045$ $\bar{n}_{50\text{-YR}} =$ $\bar{n}_{10\text{-YR}} =$

100-YR FREQUENCY LAG = $24(.045)(32.3)^{.38}$ = 4.05 HOURS

50-YR FREQUENCY LAG = $24(\quad)(32.3)^{.38}$ = HOURS

10-YR FREQUENCY LAG = $24(\quad)(32.3)^{.38}$ = HOURS

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT _____ PAGE ___ OF ___

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(*) AREA = 34.86 MI^2, L = 49280 FT, Lca = 29920 FT

SLOPE = $\frac{3460 - 2040}{49280/5280}$ = 152 ft/mi, BASIN FACTOR = $\frac{49280 \times 29920 / 5280^2}{(152)^{1/2}}$ = 4.29

SELECT $\bar{n}$ BY COMPARISON WITH HYDROLOGICALLY SIMILAR WATERSHEDS

NO.	NAME	A	L	Lca	S	LAG	$\bar{n}$
2	SAN GABRIEL	40.4	9.3	4.3	450	1.6	.05
15	PACOIMA WASH	27.8	15	8	315	2.4	.05

SELECT $\bar{n}$ BY COMPARISON WITH LAG RELATIONS

NO.	NAME	$\bar{n}$
#12	TUJUNGA CREEK	.05

⇒ SELECT $\bar{n}_{100\text{-}YR}$ = .05 $\bar{n}_{50\text{-}YR}$ = $\bar{n}_{10\text{-}YR}$ =

100-YR FREQUENCY LAG = 24(.05)(4.29)$^{.38}$ = 2.09 HRS

50-YR FREQUENCY LAG = 24 (.)(4.29)$^{.38}$ = HRS

10-YR FREQUENCY LAG = 24 ( )(4.29)$^{.38}$ = HRS

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

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DETAIL _____ COMPUTED _____ DATE _____

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⊛ AREA SIZE 6.38 Mi^2, $L = 33440$ ft, $L_{ca} = 18000$ ft,

$$\text{SLOPE} = \frac{2500 - 1900}{33440/5280} = 94.7 \text{ ft/mi}, \quad \text{BASIN FACTOR} = \frac{33440 \times 18000/5280^2}{(94.7)^{1/2}} = 2.22$$

SELECT $\bar{n}$ BY COMPARISON WITH HYDROLOGICALLY SIMILAR WATERSHEDS

NO.	NAME	A	L	L_{ca}	S	LAG	$\bar{n}$
5	EATON WASH	9.5	7.3	4.4	600	1.3	.05

SELECT $\bar{n}$ BY COMPARISON WITH LAG RELATIONS

NO.	NAME	$\bar{n}$
# 4	SAN DIMAS CREEK	.05

→ SELECT $\bar{n}_{100\text{-YR}} = .05$ $\bar{n}_{50\text{-YR}} =$ $\bar{n}_{10\text{-YR}} =$

100-YR FREQUENCY LAG $= 24(.05)(2.22)^{.38} = 1.62$ HRS

50-YR FREQUENCY LAG $= 24(\quad)(2.22)^{.38} =$ HRS

10-YR FREQUENCY LAG $= 24(\quad)(2.22)^{.38} =$ HRS

6000-018 5-80

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

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(7) AREA SIZE 4.81 mi^2, $L = 44000$ ft, $L_{ca} = 26640$ ft

$$\text{SLOPE} = \frac{3100-2100}{44000/5280} = 120 \text{ ft/mi}, \quad \text{BASIN FACTOR} = \frac{44000 \times 26640/5280^2}{(120)^{1/2}} = 3.55$$

SELECT $\bar{n}$ BY COMPARISON WITH HYDROLOGICALLY SIMILAR WATERSHEDS

NO.	NAME	A	L	L_{ca}	S	LAG	$\bar{n}$
11	LIVE OAK CR.	2.3	2.9	1.5	700	.8	.07

SELECT $\bar{n}$ BY COMPARISON WITH LAG RELATIONS

NO.	NAME	$\bar{n}$
2	SAN GABRIEL RIVER	.05
4	SAN DIMAS	.05

SELECT $\bar{n}_{100\text{-YR}} = .05$ $\bar{n}_{50\text{-YR}} =$ $\bar{n}_{10\text{-YR}} =$

100-YR FREQUENCY LAG $= 24(.05)(3.55)^{.38} = 1.75$ HRS

50-YR FREQUENCY LAG $= 24(\quad)(3.55)^{.38} =$ HRS

10-YR FREQUENCY LAG $= 24(\quad)(3.55)^{.38} =$ HRS

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PROJECT _____ PAGE ___ OF ___

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(*) AREA SIZE 0.59 Mi^2, $L = 15000$ ft, $L_{ca} = 5000$ ft

$$\text{SLOPE} = \frac{2120 - 1880}{15000/5280} = 83 \text{ ft/mi}; \quad \text{BASIN FACTOR} = \frac{15000 \times 5000/5280^2}{(83)^{1/2}} = .29$$

NO. SELECT $\bar{n}$ BY COMPARISON WITH HYDROLOGICALLY SIMILAR WATERSHEDS

NO.	NAME	A	L	L_{ca}	S	LAG	$\bar{n}$
11	LIVE OAK CR.	2.3	2.9	1.5	700	.8	.07

SELECT $\bar{n}$ BY COMPARISON WITH LAG RELATIONSHIPS

NO.	NAME	$\bar{n}$
11	LIVE OAK CR.	.07

$\Rightarrow$ SELECT $\bar{n}_{100\text{-}YR} = .07$ $\quad \bar{n}_{50\text{-}YR} =$ $\quad \bar{n}_{10\text{-}YR} =$

100-YR FREQUENCY $LAG = 24(.07)(.29)^{.38} = 1.05$

50-YR FREQUENCY $LAG = 24(\quad)(.29)^{.38} =$

10-YR FREQUENCY $LAG = 24(\quad)(.29)^{.38} =$

SELECTION OF HYDROGRAPH TIME STEP

AREA SIZE: 80.28 Mi^2 $\quad .10(4.05)60 < \Delta T < .25(4.05)60 \Rightarrow 24 < \Delta T < 61$

AREA SIZE: 34.86 Mi^2 $\quad .10(2.09)60 < \Delta T < .25(2.09)60 \Rightarrow 13 < \Delta T < 31$

AREA SIZE: 6.38 Mi^2 $\quad .10(1.62)60 < \Delta T < .25(1.62)60 \Rightarrow 10 < \Delta T < 24$

AREA SIZE: 4.81 Mi^2 $\quad .10(1.75)60 < \Delta T < .25(1.75)60 \Rightarrow 11 < \Delta T < 26$

AREA SIZE: 0.59 Mi^2 $\quad .10(1.05)60 < \Delta T < .25(1.05)60 \Rightarrow 6 < \Delta T < 16$

$\Rightarrow$ SELECT $\Delta T = 20$ MIN.

G.V. Sabol
18 July 1991

TESTING AND VERIFICATION
CAVE CREEK WATERSHED

Previous Testing and Verification

Testing and verification of the procedures in the Maricopa County Hydrologic Design Manual (Manual) previously were performed by the staff of the Flood Control District of Maricopa County (District). The testing and verification as reported, herein, is to expand on those previous tests. The information on the watershed that was compiled by the District in its testing was used where appropriate in the present testing.

Testing Objectives

The following were the objectives for the present hydrologic testing using this watershed:

1. Use the procedures in the Manual to attempt to reproduce the flood frequency relation for the nearby gaging station.
2. Evaluate the effect of using log-area weighted averaging of Green and Ampt parameters rather than linear-area weighted averaging that was used on the District testing.
3. Investigate the need to adjust K_t when S-graphs are used to estimate floods of return periods that are more frequent than 100-yr.

Watershed

The 127 square mile watershed is in Maricopa with a small portion in Yavapai County and is drained by Cave Creek. The watershed is a combination of hilly Sonoran desert and rugged mountain. The minimum elevation at the watershed outlet is slightly less than 1,900 ft. There is considerable watershed at elevations above 4,000 ft with maximum elevation near 5,100 ft at the northern end of the basin. Vegetation is sparse being mainly cacti and rangeland grasses and forbs. Considerable rock outcrop occurs throughout the watershed although the outcrop is not directly connected to the outlet.

HEC-1 Model

The HEC-1 model that was used in the present tests was developed by the District. The District's HEC-1 model has the file name COMPR2. The 100-yr

peak discharge from that model with input developed by the District is 12,200 cfs. Other input for the present testing was developed, as described herein, and was used with the District's model.

Flood Frequency Analysis

Gaging station records are available for Cave Creek near Cave Creek (09512300) for the period 1958 through 1989. A graphical flood frequency analysis is presented in Appendix A. The results of the flood frequency analysis, using extreme value graph paper are:

Return Period, years	Flood Peak, cfs
2	1,300
5	4,800
10	7,000
25	10,000
50	12,400
100	14,600

Description of Model Input

Rainfall

The rainfall statistics, as shown below, were selected from the isopluvial maps in the Manual:

2-yr, 6-hr	1.60 inch
100-yr, 6-hr	3.60 inch
2-yr, 24-hr	2.20 inch
100-yr, 24-hr	4.80 inch

Those statistics were input to the PREFRE Program and a depth-duration-frequency table was produced (Appendix B).

The rainfall was distributed according to the Maricopa County 6-hr distribution as defined in the Manual.

Rainfall Losses

Soils information for the watershed was compiled by the District and that information was used to calculate the log-area weighted values of the Green and Ampt parameters for each subbasin. The watershed has considerable rock outcrop, and the RTIMP was recalculated based on SCS soils descriptions and estimates of rock outcrop in various soil groups. A 30% RTIMP was assumed for soils containing rock outcrop and the area weighted values of RTIMP for each

subbasin were calculated. A comparison of the Green and Ampt parameters as used in the District's model and the present model are summarized below:

Subbasin	IA	DTHETA	PSIF	XKSAT	RTIMP
			(District values in COMPR2.)		
A	.25	.35	3.87	.32	15
B	.25	.35	4.18	.38	10
C	.25	.35	4.00	.34	0
D	.25	.35	3.57	.26	3
E	.25	.35	3.50	.25	0
			(present model with log-area weighted XKSAT)		
A	.25	.35	4.8	.28	26
B	.25	.35	4.2	.38	10
C	.25	.35	4.7	.30	19
D	.25	.35	4.9	.26	6
E	.25	.35	3.5	.25	0

The values of the Green and Ampt parameters are only slightly different for this watershed. The revised values of RTIMP are somewhat higher than the values used in the District model.

S-Graph and Lag

The Phoenix Mountain S-graph was used (as was used in the District model). The K_n was selected for each subbasin based on a comparison with similar watersheds (see worksheets in Appendix C). The only deviation in the selection of K_n between the District model and the present model was for subbasin E; K_n = .07 in the District model and K_n = .05 in the present model. Since subbasin E is so small (.59 sq. mi.) this will have negligible impact on the results of the model. A summary of the subbasin K_n's and Lags are shown below:

Subbasin	K_n	Lag, hours
A	.045	4.05
B	.05	2.09
C	.05	1.62
D	.05	2.00
E*	.05 (.07)	.76 (1.05)

* Values in the District model are shown in parenthesis if they differ from the values used in the present model.

K_n was <u>not</u> adjusted for flood estimates for different return periods.

Results

The model, with input as described, produced the following peak discharges:

Return Period, yrs	Peak Discharge, cfs	
	Hec-1 Model	Flood Frequency
2	3,400	1,300
5	4,400	4,800
10	6,000	7,000
25	9,100	10,000
50	11,800	12,400
100	14,600	14,600

A graph of the flood frequency data and the results from the HEC-1 model are shown in Figure 1. The HEC-1 model of the watershed seems to reproduce the flood frequency relation very well. The model is particularly good for the larger floods. The 2-yr flood peak is overestimated and this is probably because the more frequent floods are caused by partial area rainfalls that do not cover the entire watershed, and because channel transmission losses are not incorporated in the model and these are more significant for the smaller rainfalls.

Satisfactory results were obtained using an S-graph without the need to adjust the K_s for the different return periods. It may be that K_s does not need to be adjusted when used for larger subbasins. This may be because larger watersheds have a greater diversity in watershed roughness conditions resulting in less relative impact when smaller storms occur, or because large watersheds have relatively large discharges even for more frequent events resulting in nearly similar roughness characteristics over a wide range of flood events. K_s may only need to be adjusted for different return period floods when used for small (maybe less than 5 sq. mi. watersheds).

Appendix A

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT ____

DATE ____

PROJECT Flood Frequency Analysis

BY ____

SUBJECT Data Compilation Form

PROJECT NO. ____

Project Model Verification
Station Name Cave Creek near Cave Creek, AZ
Station No. 09512300 Drainage Area 121 sq. mi.
Period of Systematic Record 1958-79, 1981-86, 1988-89

Water Year (1)	Annual Peak Discharge cfs (2)	Date (3)	Flood Type[a] (4)	Comment (5)
58	5,680	12 Sept 58	R	
59	3,590	5 Aug 59	R	
60	8,570	29 Oct 59	R	
61	696	17 Sept 61	R	
62	280	16 Dec 61	R	
63	1,510	6 Aug 63	R	
64	3,120	2 Aug 64	R	
65	610	16 July 65	R	
66	6,000	22 Dec 65	R	
67	1,800	6 Sept 67	R	
68	12,400	19 Dec 67	R	E
69	0	—		zero flow year
70	2,700	5 Sept 70	R	E
71	364	4 Aug 71	R	E
72	3,950	17 July 72	R	E
73	3,950	19 Oct 72	R	E
74	1,390	5 Aug 74	R	E
75	856	2 Nov 74	R	E
76	1,260	9 Feb 76	R	E
77	0	—		zero flow year
78	7,500	2 Mar 78	R	E
79	6,900	18 Dec 78	R	E
broken				
81	0	—		zero flow year
82	1,200	2 Oct 81	R	
83	1,420	3 Mar 83	R	
84	148	9 Aug 84	R	E
85	910	27 Dec 84	R	
86	1,350	22 July 86	R	
broken				
88	170	21 Aug 88	R	
89	0	—		zero flow year

$N = 30$, $\bar{Q} = 2,610$, $s = 3,070$

a – rainfall (R), snowmelt (S), rain on snow (R/S), uncertain (U), other (X) – note in Comments

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT

DATE 8 May 91

PROJECT

BY GVS

SUBJECT Cave Creek near Cave Creek, AZ

PROJECT NO. 5-5

Test of high and low outliers

$\overline{\log Q} = 3.2275 \qquad N = 26$

$S_{\log} = .5233 \qquad K_N = 2.502$

High Outlier:

$$\log Q_H = \overline{\log Q} + K_n S_{\log}$$
$$= 3.2275 + (2.502)(.5233)$$
$$= 4.5367 \qquad (34{,}400 \text{ cfs})$$

No Q's are greater than 34,400 cfs.
Therefore, no high outliers suspected.

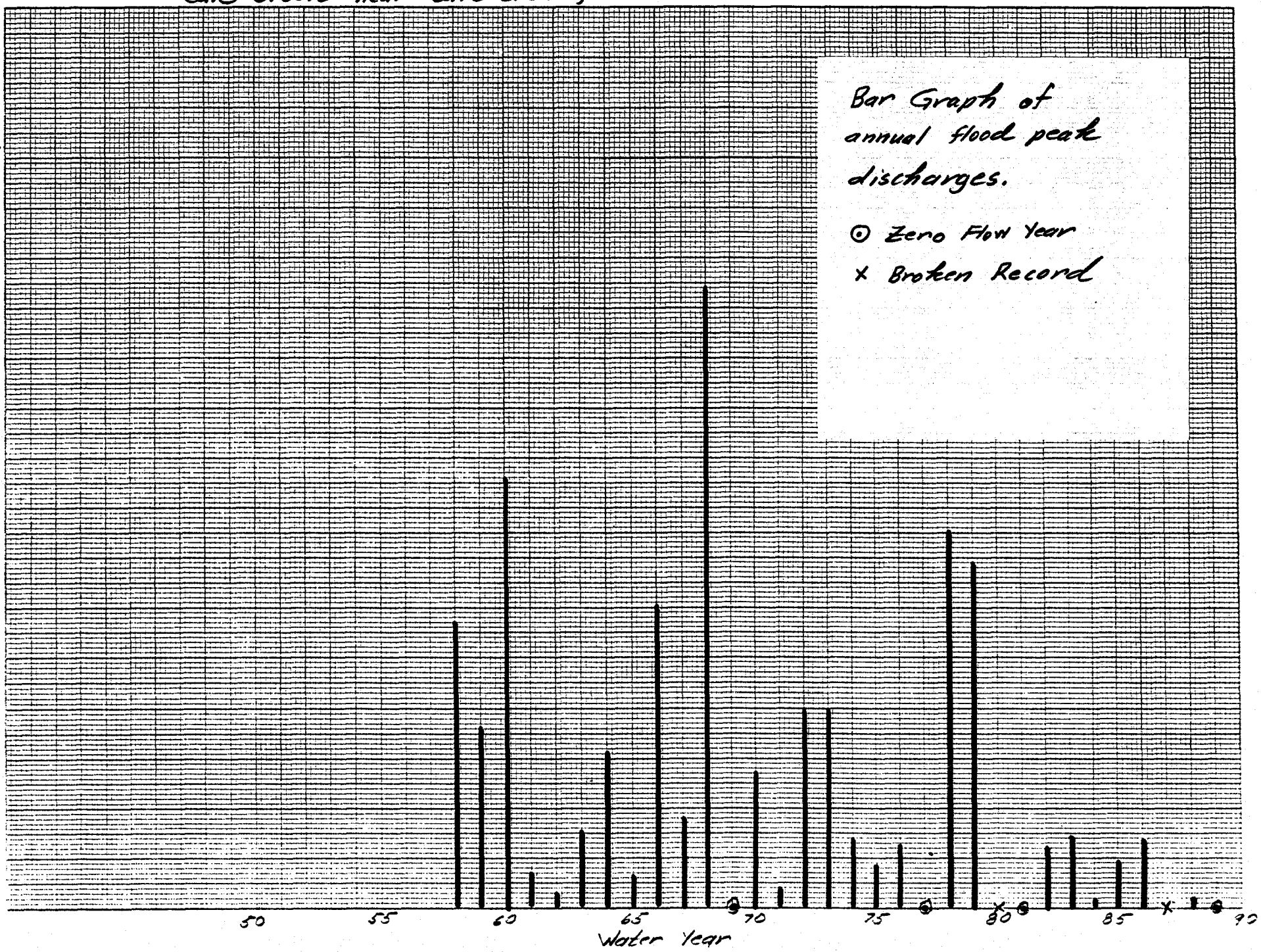
Low Outlier:

$$\log Q_L = \overline{\log Q} - K_n S_{\log}$$
$$= 3.2275 - (2.502)(.5233)$$
$$= 1.9182 \qquad (82 \text{ cfs})$$

No Q's (other than zero flow years) are less than 82 cfs.
Therefore, no low outliers suspected.

amDg 8 May 91

Cave Creek near Cave Creek, AZ



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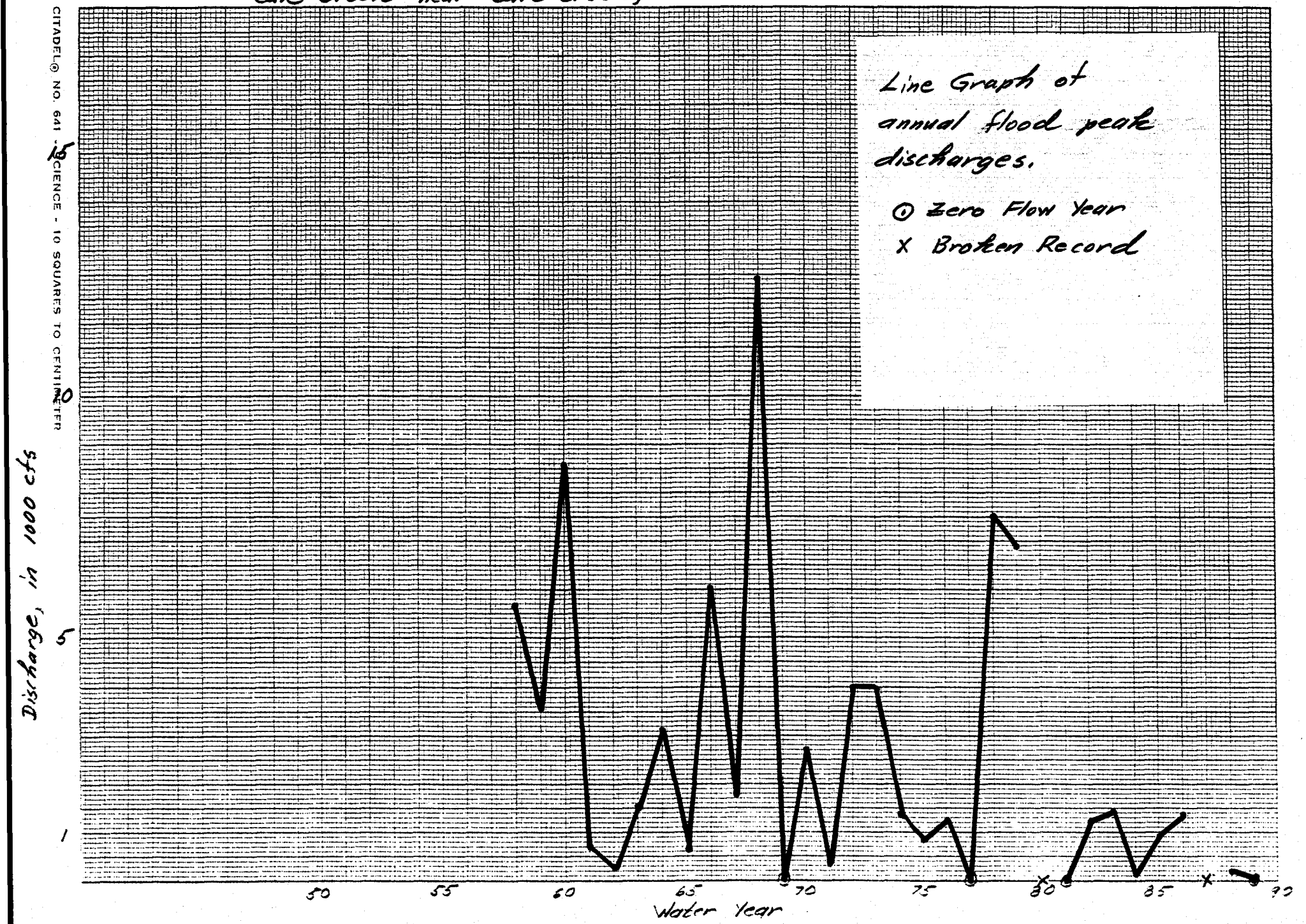
amDg 8 May 91

Cave Creek near Cave Creek, AZ



CITADEL® NO. 641 - SCIENCE - 10 SQUARES TO CENTIMETER

Plotting Position Eq'n:

Cunnane + treatment for zero flow years

$$P_e = \left(\frac{m-.4}{N+.2}\right)\left(\frac{N_t - z}{N_t}\right)$$

$N = 26$
$N_t = 30$
$z = 4$
$m = 1, \ldots, 26$

$$P_e = \left(\frac{m-.4}{26+.2}\right)\left(\frac{30-4}{30}\right) \qquad m = 1, \ldots, 26$$

$$= .0331(m-.4) \qquad m = 1, \ldots, 26$$

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT ____

DATE ____

PROJECT Flood Frequency Analysis

BY ____

SUBJECT Plotting Position Calculation Form

PROJECT NO. ____

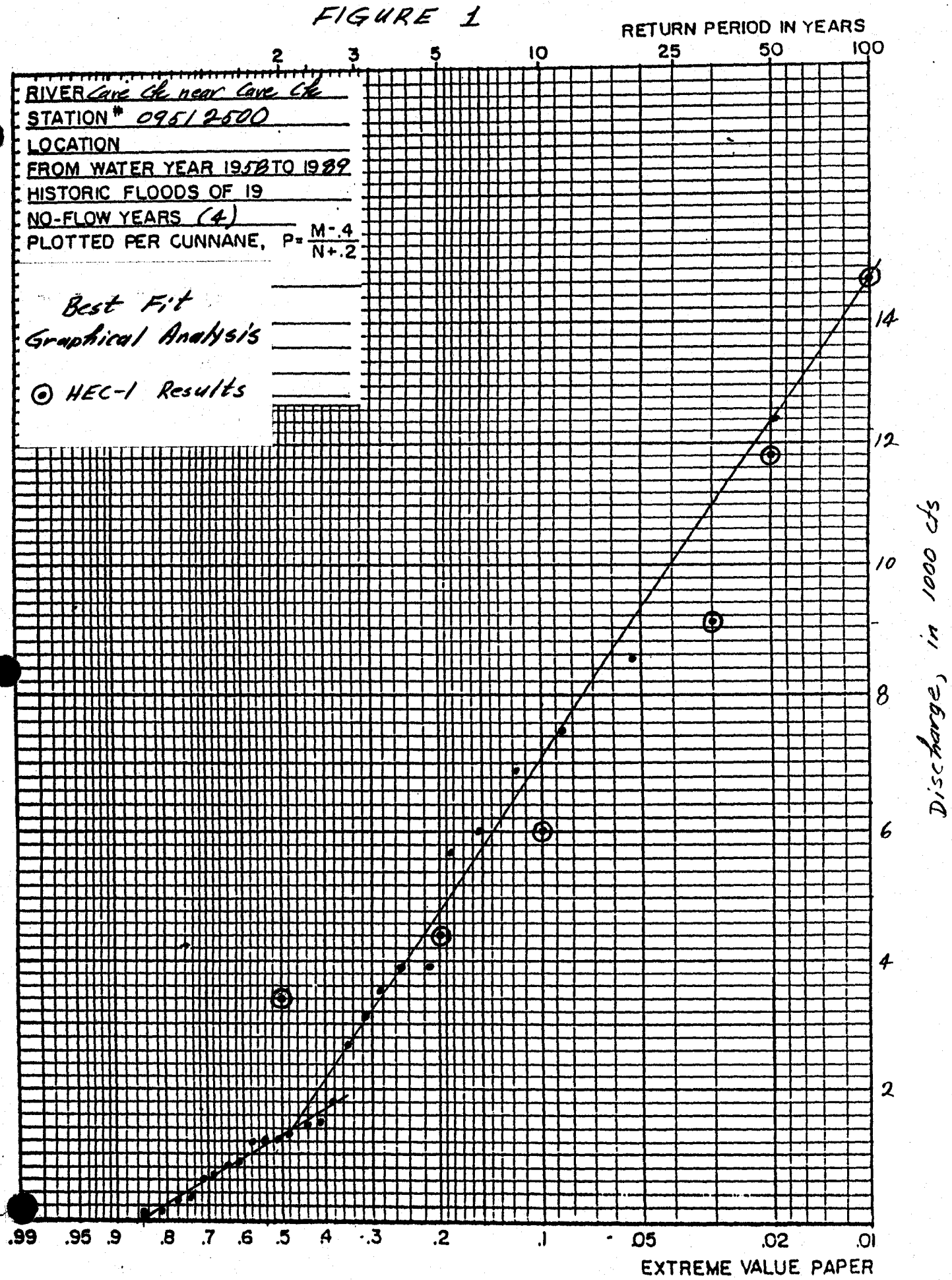
Project Model Verification
Station Name Cave Creek near Cave Creek, AZ
Station No. 09512300 Drainage Area 121 sq. mi.
Period of Systematic Record 1958-79, 1981-86, 1988-89

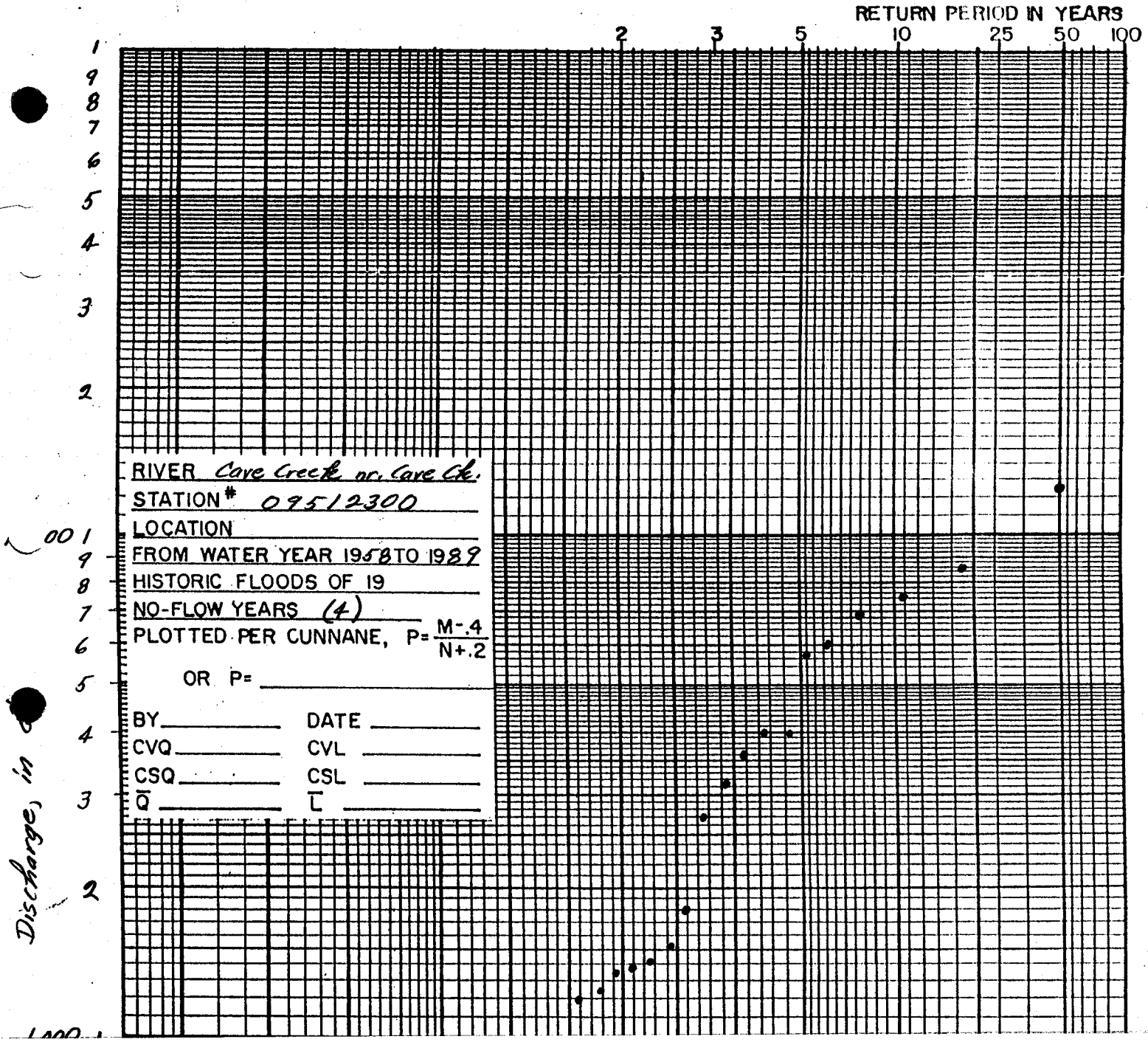
Broken Record X Mixed Population ___ High Outliers ___
Historic Data ___ Zero Flow Year X Low Outliers ___

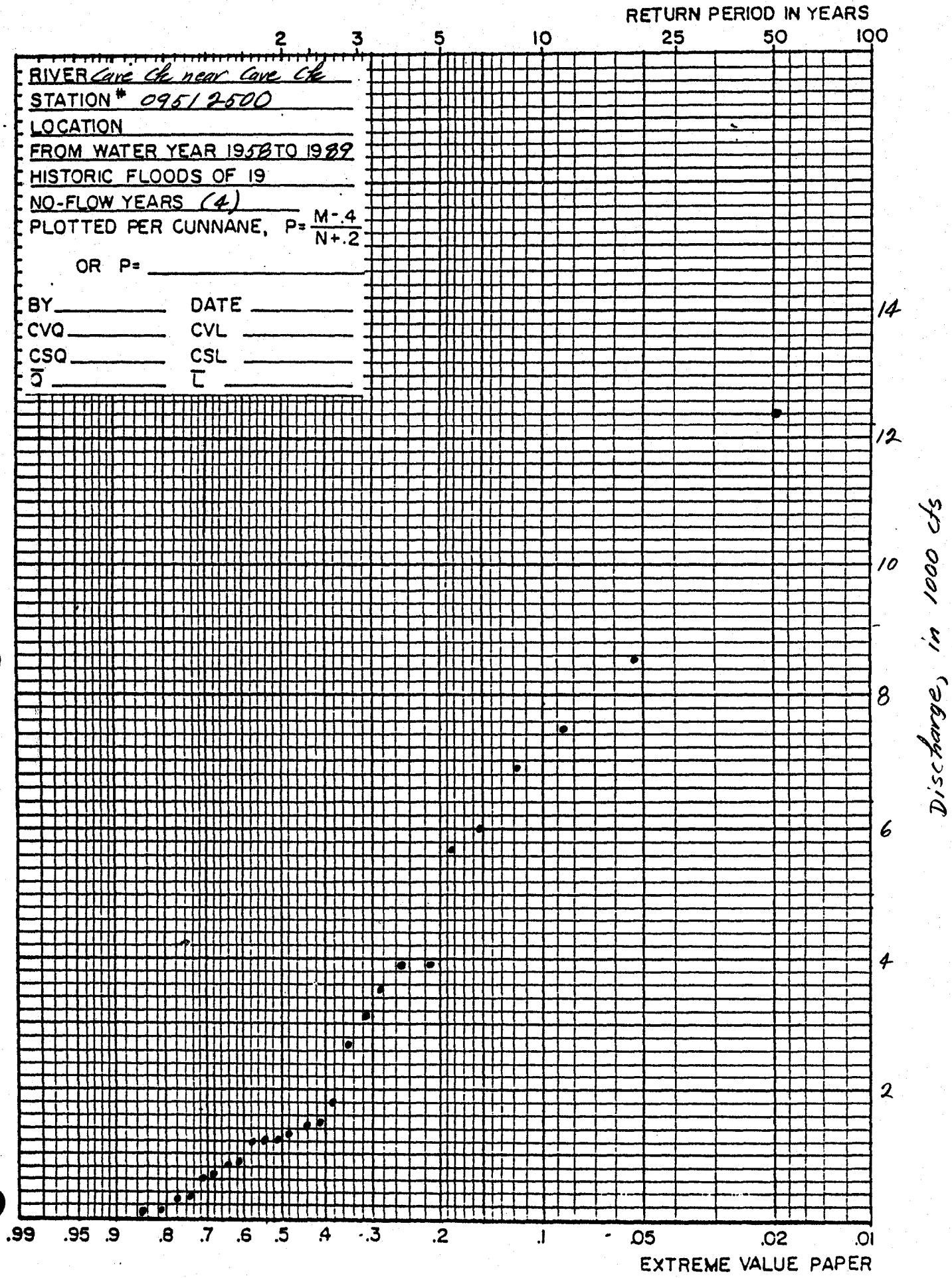
Document the Plotting Position Eq'n. or data treatment on a separate sheet.

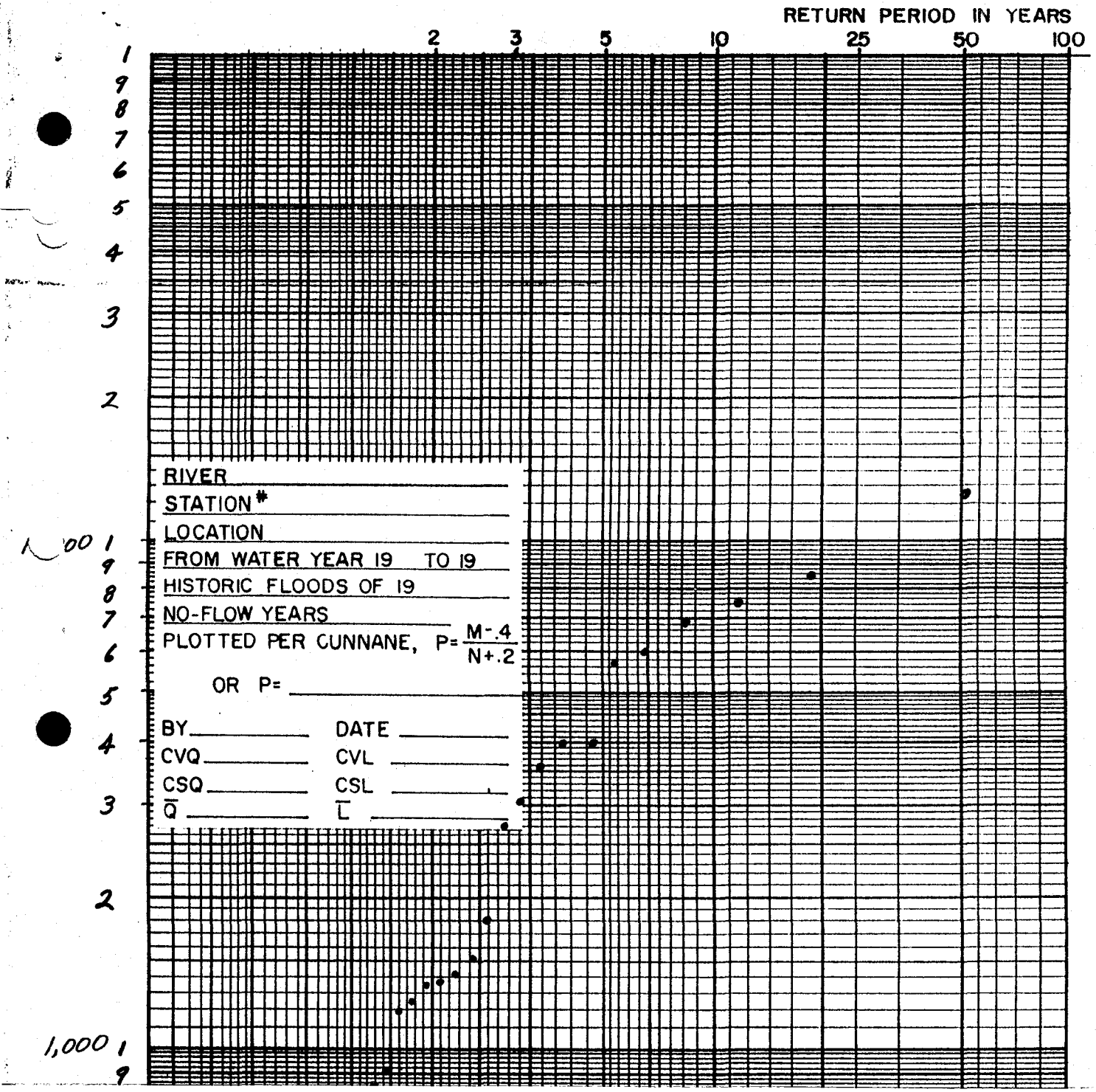
Flood Peak Discharge cfs (1)	Rank (2)	Plotting Position P_e (3)	Plotting Position T_r (4)
12,400	1	.0198	50.4
8,570	2	.0529	18.9
7,500	3	.0860	11.6
6,900	4	.1191	8.4
6,000	5	.1522	6.6
5,680	6	.1852	5.4
3,950	7	.2183	4.6
3,950	8	.2514	4.0
3,590	9	.2845	3.5
3,120	10	.3176	3.1
2,700	11	.3506	2.8
1,800	12	.3837	2.6
1,510	13	.4168	2.4
1,420	14	.4499	2.2
1,390	15	.4830	2.1
1,350	16	.5160	1.94
1,260	17	.5491	1.82
1,200	18	.5822	1.72
910	19	.6153	1.62
856	20	.6483	1.54
696	21	.6814	1.47
610	22	.7145	1.40
364	23	.7476	1.34
280	24	.7807	1.28
170	25	.8137	1.23
148	26	.8468	1.18

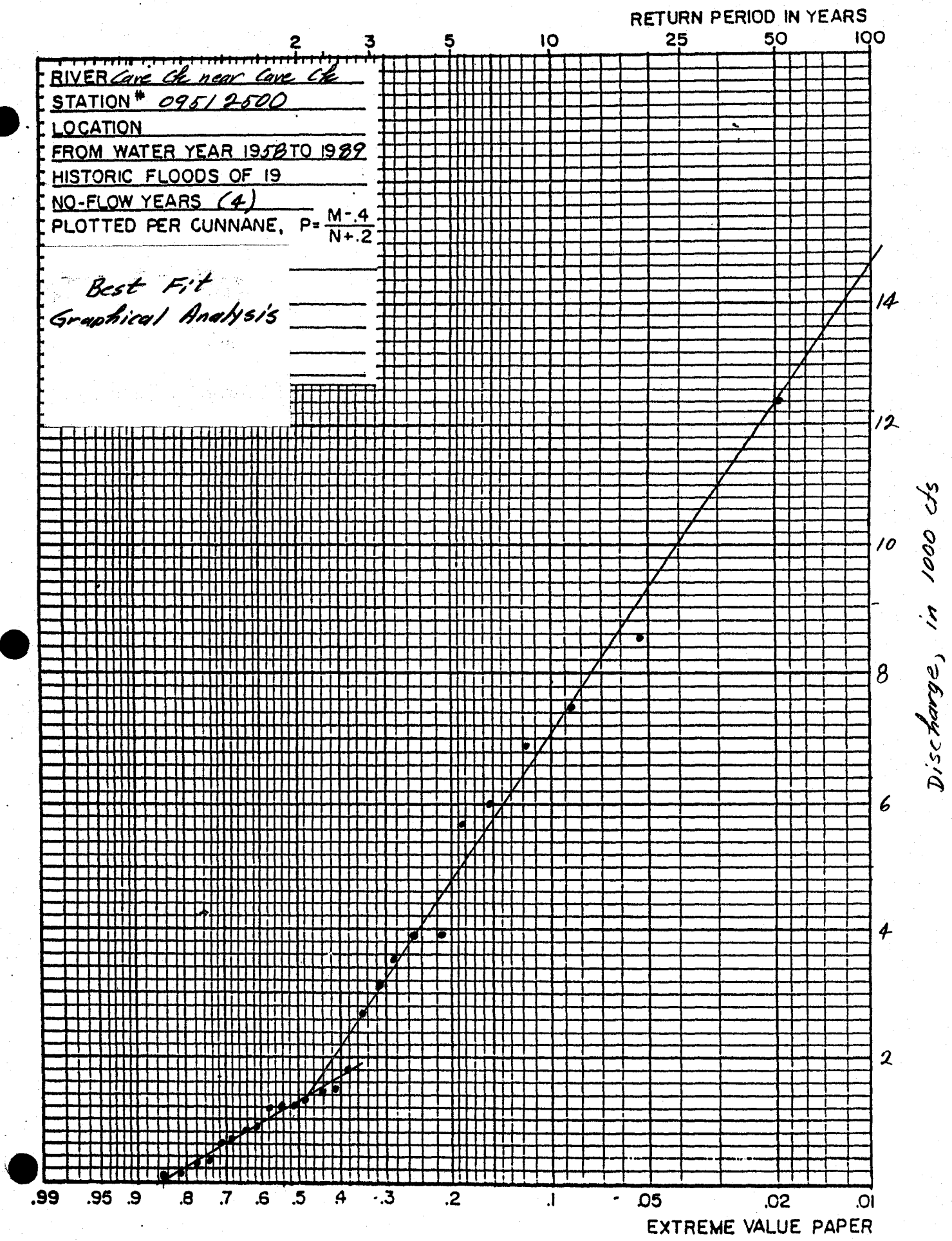
FIGURE 1

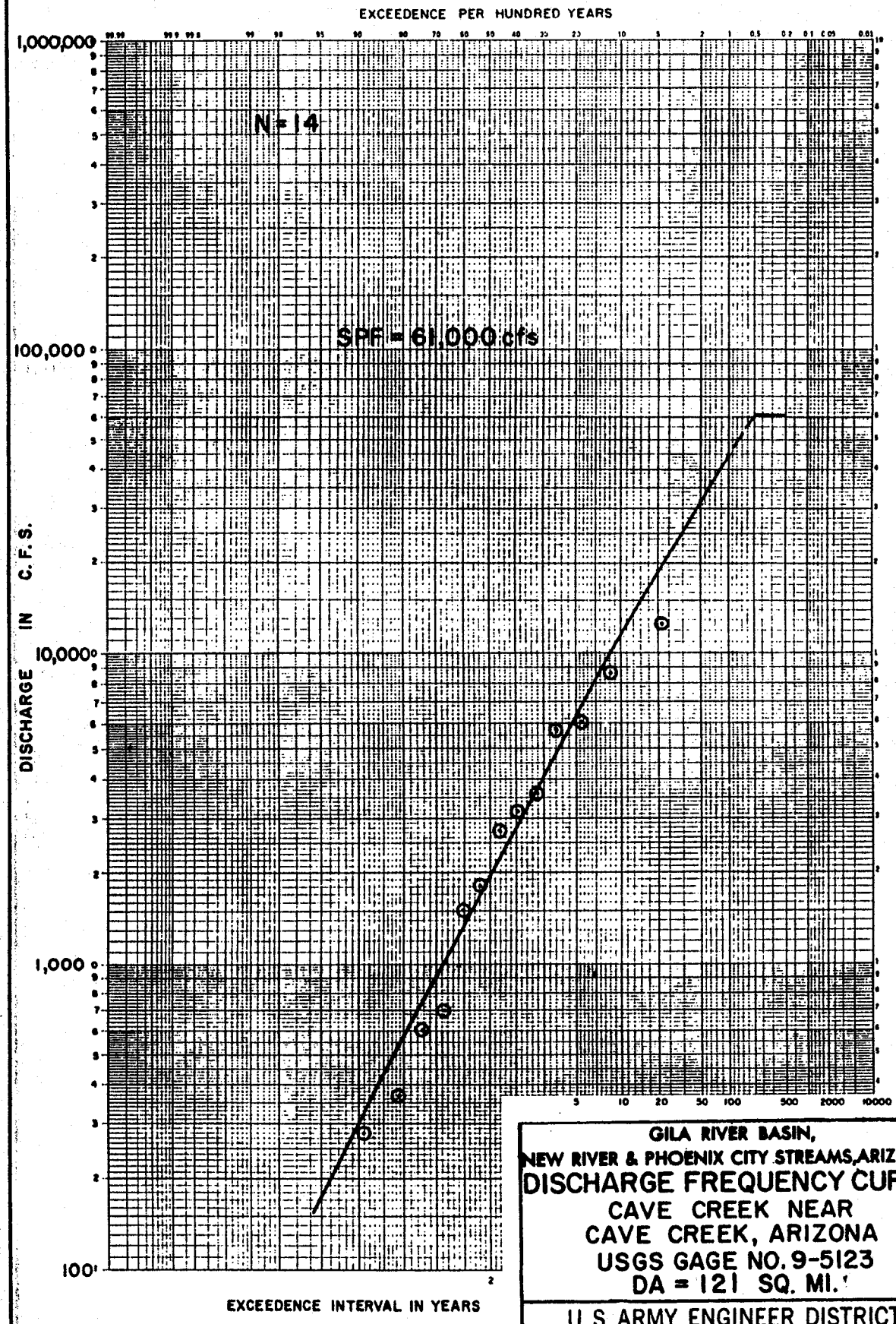

RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
RIVER Cave Ck near Cave Ck
STATION # 09512500
LOCATION
FROM WATER YEAR 1958 TO 1989
HISTORIC FLOODS OF 19
NO-FLOW YEARS (4)
PLOTTED PER CUNNANE, P= M-.4 / N+.2
Best Fit
Graphical Analysis
HEC-1 Results
14
12
10
8
6
4
2
Discharge, in 1000 cfs
.99
.95
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
EXTREME VALUE PAPER


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
1
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
Discharge, in
RIVER Cave Creek nr. Cave Ck.
STATION # 09512300
LOCATION
FROM WATER YEAR 1958 TO 1989
HISTORIC FLOODS OF 19
NO-FLOW YEARS (4)
PLOTTED PER CUNNANE, P= M-.4 / N+.2
OR P=
BY
DATE
CVQ
CVL
CSQ
CSL
Q̄
L̄


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
RIVER Cave Ck near Cave Ck
STATION # 09512500
LOCATION
FROM WATER YEAR 1958 TO 1989
HISTORIC FLOODS OF 19
NO-FLOW YEARS (4)
PLOTTED PER CUNNANE, P= M-.4 / N+.2
OR P=
BY
DATE
CVQ
CVL
CSQ
CSL
Q̄
L̄
14
12
10
8
6
4
2
Discharge, in 1000 cfs
.99
.95
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
EXTREME VALUE PAPER


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
1
9
8
7
6
5
4
3
2
1,000
RIVER
STATION #
LOCATION
FROM WATER YEAR 19 TO 19
HISTORIC FLOODS OF 19
NO-FLOW YEARS
PLOTTED PER GUNNANE, P= (M-.4)/(N+.2)
OR P=
BY
DATE
CVQ
CVL
CSQ
CSL
Q̄
L̄


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
RIVER Cave Ck near Cave Ck
STATION # 09512500
LOCATION
FROM WATER YEAR 1958 TO 1989
HISTORIC FLOODS OF 19
NO-FLOW YEARS (4)
PLOTTED PER CUNNANE, P= M-.4 / N+.2
Best Fit
Graphical Analysis
14
12
10
8
6
4
2
Discharge, in 1000 cfs
.99
.95
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
EXTREME VALUE PAPER



GILA RIVER BASIN,
NEW RIVER & PHOENIX CITY STREAMS, ARIZONA
DISCHARGE FREQUENCY CURVE
CAVE CREEK NEAR
CAVE CREEK, ARIZONA
USGS GAGE NO. 9-5123
DA = 121 SQ. MI.

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO. 2

PLATE 50

TABLE 12

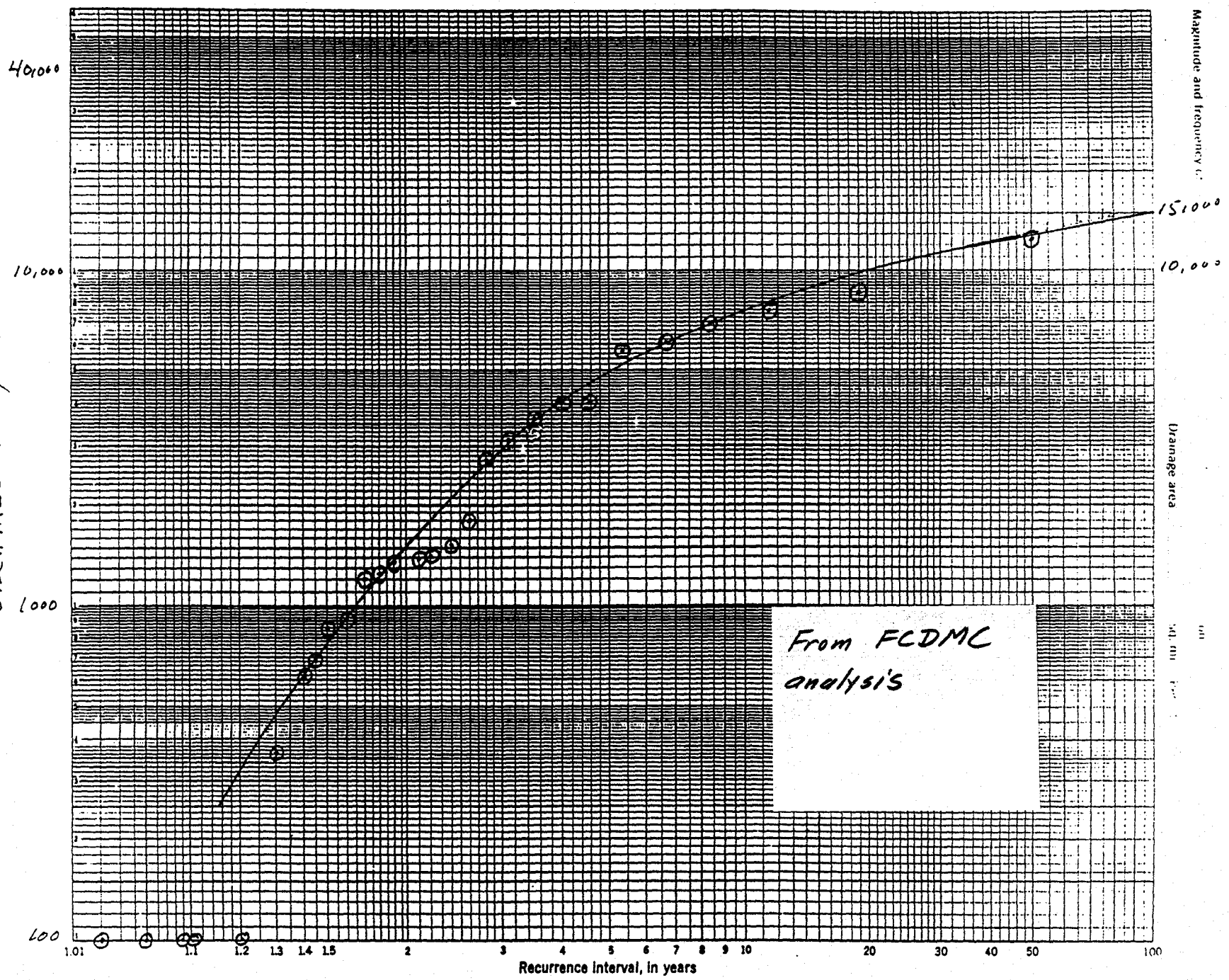
Discharge Frequency Values For Present
Without Project Conditions

Discharge in C.F.S.

Exceedence Interval

Location	2 year	5 year	10 year	25 year	50 year	100 year	SPF	500 year*
Gage 95123 Cave Creek near Cave Creek, AZ	2000	6500	12000	22000	33000	45000	61000	–
Cave Creek at Cave Creek Dam. Upstream face. CP112U	1700	8500	17000	33000	47000	63000	86000	–
Cave Creek at Cave Creek Dam. Downstream face. CP112D	500	600	600	700	19000	40000	71000	242000
Cave Creek at CP113	500	600	700	900	19000	40000	69000	198000
Cave Creek at Greenway Road CP114	500	700	1400	5500	14000	29000	57000	130000
Gage 95124 Cave Creek at Arizona Canal CP115	500	900	2400	7000	14000	26000	50000	115000
Cave Creek at Grand Canal CP116	700	1600	3000	7500	14000	24000	45000	96000
Cave Creek at Buckeye Road CP117	1100	2500	4100	7800	13000	22000	36000	79000
Gage 95138.6 Skunk Creek near Phoenix	1100	5400	1000	19000	26000	35000	54000	–
Skunk Creek at Hedgpeth Hills CP101	1200	6600	13000	23000	26000	37000	60000	–
Skunk Creek above New River Confluence CP102	1200	6600	13000	23000	26000	37000	60000	–
Gage 95137.8 New River near Rock Springs	2400	9000	15000	25000	33000	41000	49000	–
Gage 95138 New River at New River	2800	10000	18000	28000	37000	45000	55000	–
New River near West Wing Mountain CP103	1500	7400	15000	28000	39000	53000	76000	–
Gage 95138.35 New River at Bell Road near Peoria CP104	1500	7400	15000	28000	39000	53000	75000	–
New River below confluence with Skunk Creek CP167	1700	8400	17000	31000	44000	58000	86000	–

CUNANE PLOT


9-179b
Extreme log data plot
April 1955
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Magnitude and frequency of
Drainage area
sq. mi.
File
Sheet No. of Sheets Prepared by Date Checked by Date
GPO 863751
DISCHARGE (CFS)
40,000
10,000
1000
100
15,000
10,000
From FCDMC analysis
1.01
1.1
1.2
1.3
1.4
1.5
2
3
4
5
6
7
8
9
10
20
30
40
50
100
Recurrence interval, in years

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT ____

DATE 10 May 91

PROJECT ____

BY GVS

SUBJECT ____

PROJECT NO. S-5-F

Results of flood frequency analysis for Cave Ck. nr. Cave Ck.

The Extreme Value (EV) graph was selected because the larger floods plot most nearly as a straight line on that probability paper.

The smaller floods (less than 2,000 cfs) plot as a separate straight line – indicating a mixed population of floods. This may be the result of partial area rainfall on the watershed, type of rainfall event, transmission losses being more significant for smaller floods, etc.

The graphical flood frequency results and results by others are listed below:

Return Period years	Flood Magnitude			
	Graphical EV	Corps of Eng.[a]	FCDMC[b]	FCDMC[c]
2	1,300	2,000		1,500
5	4,800	6,500		5,000
10	7,000	12,000		7,600
25	10,000	22,000		10,900
50	12,400	33,000		13,000
100	14,600	45,000	20,000	15,000

a – by graphical analysis for N=14, on LN paper

b – by LP III for N=30, by Russ Cruff

c – by graphical analysis for N=30, on LEV paper (curvilinear)

Discussion of analysis & results:

1. 30 years of systematic data are available, containing 4 years of zero flow and 2 years of missing data.
2. High and low outliers were investigated and no outliers are suspected.
3. The annual flood peak discharges were plotted (bar graph and line graph), and the flood series appears to be stationary.
4. The Cunnane plotting position equation was used with a conditional probability correction for zero flow years.
5. The flood series data was plotted on LN, EV, and LEV papers.
6. The EV plot appears to produce a linear graph for the larger floods and a straight line was fit to the data.
7. A comparison of flood frequency results is made between these graphical analysis results and the results by 3 other independent studies.
8. The graphical EV results are similar to the FCDMC LEV results. The FCDMC LPIII results may overpredict the $Q_{100\text{-yr}}$. The Corps' analysis seems to be seriously affected by the short period of record that was used.

Appendix B

*** O U T P U T D A T A ***

REVISED JUNE 1988 TO UPDATE COMPUTATION OF SHORT-DURATION VALUES

PRECIPITATION FREQUENCY VALUES FOR UPPER CAVE CREEK
PRIMARY ZONE NUMBER= 7
SHORT-DURATION ZONE NUMBER= 8

POINT VALUES

RETURN PERIOD

DURATION	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	
5-MIN	.37	.46	.52	.62	.69	.76	.92	5-MIN
10-MIN	.55	.70	.80	.94	1.05	1.16	1.42	10-MIN
15-MIN	.67	.87	1.01	1.20	1.35	1.49	1.84	15-MIN
30-MIN	.89	1.16	1.35	1.62	1.82	2.03	2.50	30-MIN
1-HR	1.09	1.44	1.68	2.01	2.27	2.53	3.13	1-HR
2-HR	1.26	1.66	1.93	2.31	2.60	2.90	3.58	2-HR
3-HR	1.38	1.80	2.09	2.50	2.82	3.14	3.87	3-HR
6-HR	1.60	2.08	2.41	2.88	3.24	3.60	4.43	6-HR
12-HR	1.90	2.45	2.83	3.37	3.78	4.20	5.16	12-HR
24-HR	2.20	2.82	3.25	3.86	4.33	4.80	5.89	24-HR

* IF YOUR SITE IS IN ARIZONA OR NEW MEXICO, PLEASE CONSULT THE FOLLOWING PAPER FOR REVISED DEPTH-AREA VALUES:
DEPTH-AREA RATIOS IN THE SEMI-ARID SOUTHWEST UNITED STATES
NOAA TECHNICAL MEMORANDUM NWS HYDRO-40
ZEHR AND MYERS
AUGUST 1984

INPUT DATA

PROJECT NAME=UPPER CAVE CREEK
ZONE= 7 SHORT-DURATION ZONE= 8
LATITUDE= .00 LONGITUDE= 100.00 ELEVATION= 0
2-YR, 6-HR PCPN= 1.60 100-YR, 6-HR PCPN= 3.60
2-YR, 24-HR PCPN= 2.20 100-YR, 24-HR PCPN= 4.80

* * * * E N D O F R U N * * * *

Appendix C

Worksheet for Estimating S-graph K_n and Calculation of Lag

Watershed Upper Cave Creek Subbasin A

A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$
80.28	22.0	15.0	105	32.2

Comparable Watersheds:

Ref.	Name	A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$	K_n	Lag	
Corps	New River @ New River, AZ	85.7	23.2	13.6	145	26.2	.045	3.7	← similar watershed
Corps	Skunk Ck nr. Phoenix, AZ	64.6	17.6	10.0	89	18.7	.033	2.4	
USBR	New R. @ New River, AZ	85.7	—	—	—	26.3	.048	3.7	
Corps	Tujunga Ck. @ Big Tujunga Dam CA	81.4	15.1	7.3	290	6.5	.050	2.5	
Corps	Murrieta Ck @ Temecula, CA	220	27.2	10.3	95	28.9	.050	4.0	

Selected K_n (100-yr): .045

$$Lag = C\left(LL_{ca}/S^{1/2}\right)^m$$

__ USBR – $C = 26K_n$ and $m = .33$

✓ Corps – $C = 24K_n$ and $m = .38$

$$Lag = 24(.045)(32.2)^{.38} = 4.05\ hr$$

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

CLIENT

PROJECT

SUBJECT

SHEET ___ OF

DATE

BY

PROJECT NO.

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

CLIENT
PROJECT
SUBJECT

SHEET ___ OF ___
DATE
BY
PROJECT NO.

Worksheet for Estimating S-graph K_n and Calculation of Lag

Watershed Upper Cave Creek Subbasin B

A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$
34.86	9.33	5.67	152	4.29

Comparable Watersheds:

Ref.	Name	A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$	K_n	Lag
Corps	Pacoima Wash, CA	27.8	15.0	8.0	315	6.8	.050	2.4
Corps	Tujunga Ck @ Big Tujunga Dam	81.4	15.1	7.3	290	6.5	.050	2.5

Selected K_n (100-yr): .05

$$Lag = C\left(\frac{LL_{ca}}{S^{1/2}}\right)^m$$

___ USBR – $C = 26K_n$ and $m = .33$
✓ Corps – $C = 24K_n$ and $m = .38$

$$Lag = 24(.05)(4.29)^{.38} = 2.09 \text{ hrs}$$

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

CLIENT
PROJECT
SUBJECT

SHEET ___ OF ___
DATE
BY
PROJECT NO.

Worksheet for Estimating S-graph K_n and Calculation of Lag

Watershed Upper Cave Ck Subbasin C

A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$
6.38	6.33	3.41	94.7	2.22

Comparable Watersheds:

Ref.	Name	A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$	K_n	Lag
Corps	Eaton Wash	9.5	7.3	4.4	600	1.31	.050	1.3

Selected K_n (100-yr): .05

$$Lag = C\left(\frac{LL_{ca}}{S^{1/2}}\right)^m$$

___ USBR – $C = 26K_n$ and $m = .33$
✓ Corps – $C = 24K_n$ and $m = .38$

$$Lag = 24(.05)(2.22)^{.38} = 1.62 \text{ hrs}$$

Worksheet for Estimating S-graph K_n and Calculation of Lag

Watershed Upper Cave Ck Subbasin D & E

	A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$
D	4.81	8.33	5.05	120	3.84
E	.59	2.84	.95	83	.30

Comparable Watersheds:

Ref.	Name	A	L	L_{ca}	S	$LL_{ca}/S^{1/2}$	K_n	Lag
Corps	Live Oak Ck, CA	2.3	2.9	1.5	700	.16	.07	.8
USBR	Santa Anita Ck @ Santa Anita	10.8				.6	.05	1.1
Corps	San Dimas Ck @ San Dimas D.	16.2	8.6	4.8	440	1.97	.05	1.5
Corps	Eaton Wash @ Eaton Wash D.	9.5	7.3	4.4	600	1.31	.05	1.3

Selected K_n (100-yr): .05

$$Lag = C\left(\frac{LL_{ca}}{S^{1/2}}\right)^m$$

__ USBR – $C = 26K_n$ and $m = .33$
✓ Corps – $C = 24K_n$ and $m = .38$

$$Lag = 24(.05)(3.84)^{.38} = 2.00 \text{ hrs}$$

$$= 24(.05)(.30)^{.38} = .76 \text{ hr}$$

Table 7.- Watershed characteristics for the individual S-graphs that were developed from flood reconstitutions and have been compiled in this report.

S-graph No.	A	L	L_{ca}	S	n[1]	Lag	RIMP	Watershed Elevation Min	Watershed Elevation Max	Type of Watershed or Geographical Name
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	187.0	47.6	20.7	83.4	.062	8.85	5	1,190	5,160	New River Mtns. and alluvial fan
2	187.0	47.6	20.7	83.4	.038	5.38	5	1,190	5,160	New River Mtns. and alluvial fan
3	64.6	17.6	9.9	101.9	.042	2.95	5	1,460	3,250	Tonto National Forest and alluvial fan
4	64.6	17.6	9.9	101.9	.031	2.19	5	1,460	3,250	Tonto National Forest and alluvial fan
5	70.0[2]	26.0	11.8	75.9	.054	4.99	5	1,243	3,220	Union Hills and alluvial fan
6	70.0[2]	26.0	11.8	75.9	.063	5.88	5	1,243	3,220	Union Hills and alluvial fan
7	0.51	1.5	.75	67.0	.076	.86	5	1,720	1,820	Alluvial fan
8	0.51	1.5	.75	67.0	.084	.95	5	1,720	1,820	Alluvial fan
9	0.51	1.5	.75	67.0	.070	.79	5	1,720	1,820	Alluvial fan
10	0.13	.77	.39	16.0	.107	.96	25	----	----	Fully urbanized, residential
11	0.13	.77	.39	16.0	.111	1.00	25	----	----	Fully urbanized, residential
12	67.3	20.2	9.7	141.4	.037	2.59	5	2,310	5,170	New River Mountains
13	67.3	20.2	9.7	141.4	.036	2.50	5	2,310	5,170	New River Mountains
14	85.7	26.2	12.4	121.6	.049	4.25	5	1,973	5,160	New River Mountains
15	85.7	26.2	12.4	121.6	.031	2.72	5	1,973	5,160	New River Mountains
16	142.0	27.7	13.6	64.2	.077	8.02	5	1,280	3,060	Phoenix Mountain and alluvial fan
17	142.0	27.7	13.6	64.2	.070	7.31	5	1,280	3,060	Phoenix Mountain and alluvial fan
18	142.0	27.7	13.6	64.2	.030	3.10	5	1,280	3,060	Phoenix Mountain and alluvial fan
19	323.0	55.5	20.6	73.6	.069	10.59	5	1,046	4,080	New River Mtns. and alluvial fan
20	323.0	55.5	20.6	73.6	.045	6.90	5	1,046	4,080	New River Mtns. and alluvial fan
21	718.0[3]	61.0	27.2	68.9	.059	10.68	5	950	5,150	New River Mtns. and alluvial fan
22	718.0[3]	61.0	27.2	68.9	.043	7.80	5	950	5,150	New River Mtns. and alluvial fan

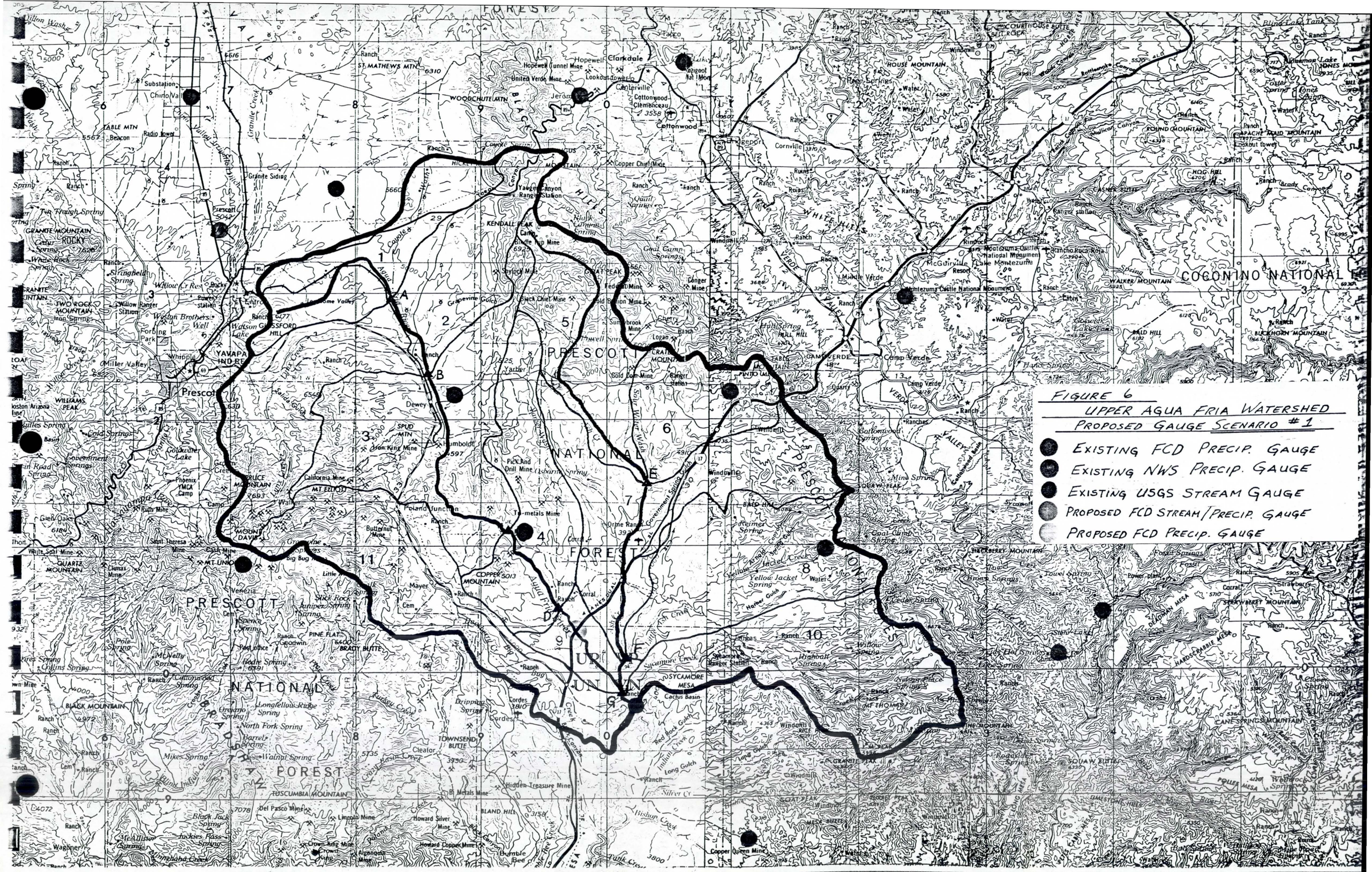
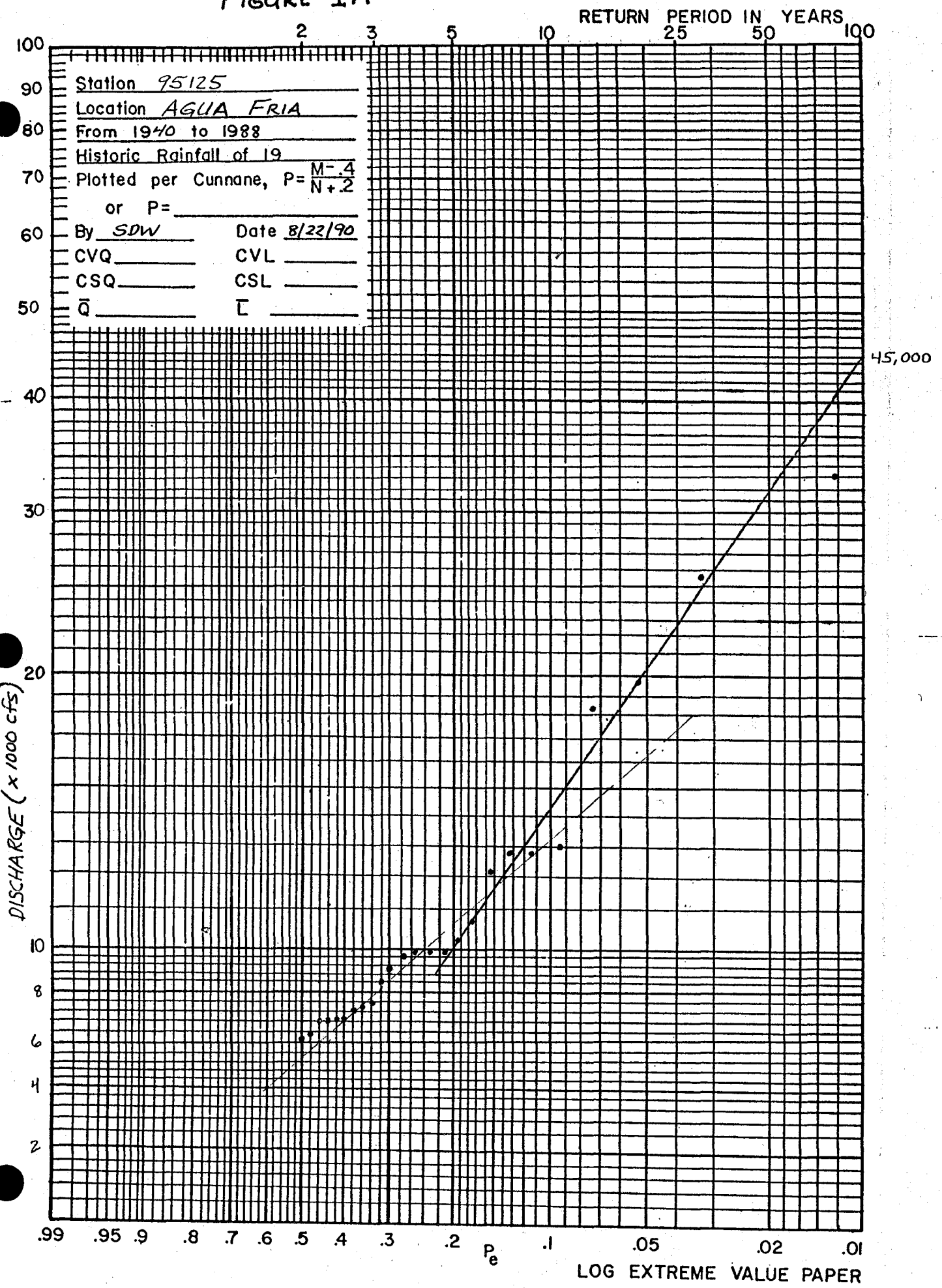


FIGURE 6
UPPER AGUA FRIA WATERSHED
PROPOSED GAUGE SCENARIO #1
EXISTING FCD PRECIP. GAUGE
EXISTING NWS PRECIP. GAUGE
EXISTING USGS STREAM GAUGE
PROPOSED FCD STREAM/PRECIP. GAUGE
PROPOSED FCD PRECIP. GAUGE
A
B
C
D
E
F
G
PRESCOTT
Prescott
Clarkdale
Jerome
Cottonwood
Camp Verde
COCONINO NATIONAL F
PRESCOTT NATIONAL F
PRESCOTT NATIONAL
PRESCOTT FOREST
UPPER AGUA FRIA WATERSHED

UPPER AGUA FRIA WATERSHED - SUMMARY OF HEC-1 RUNS

Run #	Precip. Depth (in)	Precip. Dist.	Pattern #	Frequency	S-Graph	Peak Q (cfs)	Comments
1	3.35	6-hour	2 - 5	100-year	New River/ Az. Mtn.	21,156	JD card used
2	1.86	6-hour	5	100-year	New River/ Az. Mtn.	21,156	
3	2.68	24-hour	Type-II	100-year	New River/ Az. Mtn.	49,077	
4	1.86	6-hour	5	100-year	Average Az.	32,525	
5	2.68	24-hour	Type-II	100-year	Average Az.	76,117	
6	Varies	6-hour	2 - 5	100-year	Average Az.	70,090	"centered"
7	Theissen	FCD Gauges	Theissen	NA	Average Az.	17,841	
8	Isohyetal	FCD Gauges	Theissen	NA	Average Az.	15,230	
9	3.17	6-hour	3.82	100-year	Average Az.	18,091	Area = 65.6 sq.mi.
10	3.52	6-hour	4.13	100-year	Average Az.	34,189	Area = 124.1 sq.mi.
11	3.47	6-hour	4.52	100-year	Average Az.	48,082	Area = 199.0 sq.mi.
12	3.44	6-hour	4.60	100-year	Average Az.	48,949	Area = 216.6 sq.mi.
13	3.44	6-hour	4.62	100-year	Average Az.	40,800	Area = 261.2 sq.mi.
14	3.42	6-hour	4.72	100-year	Average Az.	44,731	Area = 320.3 sq.mi.
FREQUENCY DISTRIBUTION AT USGS GAUGE ----> (Log Extreme Value Plot)						45,000	Area = 588.0 sq.mi.

FIGURE 1A


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
Station 95125
Location AGUA FRIA
From 1940 to 1988
Historic Rainfall of 19
Plotted per Cunnane, P= (M-.4)/(N+.2)
or P=
By SDW
Date 8/22/90
CVQ
CVL
CSQ
CSL
Q̄
C̄
45,000
DISCHARGE (x 1000 cfs)
100
90
80
70
60
50
40
30
20
10
8
6
4
2
.99
.95
.9
.8
.7
.6
.5
.4
.3
.2
Pe
.1
.05
.02
.01
LOG EXTREME VALUE PAPER

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1****************************************
****************************************
 *                                    *                                    *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                    *   U.S. ARMY CORPS OF ENGINEE
 *             FEBRUARY 1981             *                                    *  THE HYDROLOGIC ENGINEERING C
 *           REVISED 05 DEC 88           *                                    *         609 SECOND STREET *
 *                                       *                                    *      DAVIS, CALIFORNIA 95616
 *  RUN DATE  04/13/1990  TIME  06:38:36 *                                    *          (916) 551-1748 *
 *                                       *                                    *
*
 ****************************************
****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X       X     X        XX
X     X  X       X              X
XXXXXXX  XXXX    X       XXXXX  X
X     X  X       X              X
X     X  X       X     X        X
X     X  XXXXXXX   XXXXX        XXX
```

UAF1

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTUR
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1 HEC-1 INPUT PAGE 1

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   ***** UPPER AGUA FRIA WATERSHED ******************************************
  2           ID   ***** SPECIAL PROJECTS BRANCH -  HYDROLOGY DIV. - FCD OF MARICOPA COUNTY ***
  3           ID   ***** WATERSHED UPSTREAM OF USGS GAUGE # 95125 ****************************
  4           ID   ***** FEBRUARY, 1990 ******************************************************
  5           ID   ***** JD RECORDS USED WITH CORRESPONDING DEPTHS AND PATTEREN NUMBERS
  6           ID   ***** 6HR - 100YEAR DESIGN STORM
              * ******************************************************************************
  7           IT      10 26FEB90    0000     150
  8           IO       5
              * ******************************************************************************
  9           IN      15 26FEB90    0000
 10           JD    3.35     3.0
```

```
11        PC     0.     .6    1.2     2.    3.1    3.9    4.9    5.7    6.7    7.6
12        PC    8.7    10.    12.   16.3   25.2   45.1   69.4   83.7    90.   93.8
13        PC   96.7   98.5    99.    99.   100.
14        JD   3.21    16.
15        PC     0.    1.5     2.     3.    4.8    6.3    7.6    9.0   10.5   11.9
16        PC   13.5   15.2   17.5   22.2   30.4   47.2    67.   79.6   86.8   91.2
17        PC   94.6   97.4    98.   98.7   100.
18        JD   2.74    90.
19        PC     0.    2.1    3.5    5.1    7.1    8.7   10.5   12.5   14.3    16.
20        PC   17.9   20.1   23.2   28.1   36.4    50.   65.8   77.3   84.1   88.8
21        PC   92.7   95.8   96.5   97.6   100.
22        JD   1.86   588.
23        PC      0    2.4    4.3    5.9    7.8    9.8   11.9   14.1   16.2   18.6
24        PC   21.2   23.9   27.1   32.1   40.8   51.5   62.7   73.5   81.4   86.4
25        PC   90.7   94.5   95.5   96.9   100.
          * ******************************************************************************

26        KK   QSUB1
27        KM   RUNOFF FROM SUBBASIN 1
28        BA    37.8
29        LG    .25    .34    4.3    .30    5.5
30        UI      0   1733   2994   6363  12198  14185  15577  13958  12373  10737
31        UI   8648   7431   6434   5219   4529   3989   3102   2767   2385   1804
32        UI   1634   1343   1254    842    700    600    480    328    300    250
33        UI    200    150    100     50     25      0
          * ******************************************************************************

34        KK  RT A-B
35        KM   ROUTE SUB1 FROM A TO B
36        RM      5   .849    .35
          * ******************************************************************************

37        KK   QSUB2
38        KM   RUNOFF FROM SUBBASIN 2
39        BA    85.4
40        LG    .25    .34    4.2    .33     8.
41        UI      0   3528   3627   4312   5042   6430   8824  11991   9068  12908
42        UI  15141  12632  11038  12937  12937  11819  11850  10862  11356   9537
43        UI   8215   8631   6857   6468   5863   5544   5358   4851   4363   4152
44        UI   3881   3800   3700   3541   3460   2772   2750   2700   2675   2662
45        UI   2426   2400   2300   2200   2100   2005   1941   1900   1860   1764
46        UI   1700   1600   1532   1437   1425   1400   1398   1078   1000    950
47        UI    900    850    800    728    719    700    650    550    500    475
```



```
LINE      ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

48        UI    450    400    328    213    200    175    125    100     50      0
          * ******************************************************************************

49        KK  COMB-B
50        KM   COMBINE 1+2 @ B
51        HC      2
          * ******************************************************************************
```

```
52          KK  RT B-C
53          KM   ROUTE (1&2) FROM B TO C
54          RM      11   1.933     .35
            * ******************************************************************************

55          KK   QSUB3
56          KM   RUNOFF FROM SUBBASIN 3
57          BA    80.3
58          LG     .25     .35     3.9     .35     8.5
59          UI       0    3318    3410    4055    4741    6046    8297   11275    8526   12138
60          UI   14237   11877   10379   12164   11500   11113   10500   10213   10678    8967
61          UI    7725    8116    6447    6082    5513    5213    5038    4562    4102    3904
62          UI    3649    3500    3400    3329    3253    2607    2570    2535    2520    2503
63          UI    2281    2250    2200    2100    2000    1886    1825    1776    1749    1659
64          UI    1600    1500    1441    1352    1340    1325    1315    1014    1000     900
65          UI     850     800     730     684     676     650     600     550     500     450
66          UI     400     300     201     150     125     100      75      50      25       0
            * ******************************************************************************

67          KK  COMB-C
68          KM   COMBINE (1&2)+3 @ C
69          HC       2
            * ******************************************************************************

70          KK  RT C-D
71          KM   ROUTE (1&2&3) FROM C TO D
72          RM       5    .927     .35
            * ******************************************************************************

73          KK   QSUB4
74          KM   RUNOFF FROM SUBBASIN 4
75          BA    46.1
76          LG     .25     .35     4.0     .34     7.5
77          UI       0    1533    3000    3938    5587   10019   11224   13327   13903   12655
78          UI   12299   10482    9665    8310    7550    6492    5938    5094    4503    4077
79          UI    3663    3208    2737    2540    2172    2025    1589    1400    1222    1188
80          UI     900     786     745     730     715     692     290     200     100       0
            * ******************************************************************************

81          KK  COMB-D
82          KM   COMBINE (1-3)+4 @ D
83          HC       2
            * ******************************************************************************
```



```
LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

84          KK  RT D-G
85          KM   ROUTE (1-4) FROM D TO G
86          RM       6   1.082     .30
            * ******************************************************************************
```

```
 87          KK   QSUB5
 88          KM   RUNOFF FROM SUBBASIN 5
 89          BA    44.6
 90          LG     .25     .34     4.4     .32     10.
 91          UI       0    2145    2330    2675    3434    5090    7110    5784    7864    9015
 92          UI    6713    7864    7400    7059    7518    6713    6054    5034    5388    4168
 93          UI    3932    3402    3370    2994    2712    2515    2359    2300    2257    2145
 94          UI    1747    1685    1660    1600    1524    1474    1460    1455    1450    1180
 95          UI    1170    1163    1072    1000     900     887     874     660     655     650
 96          UI     600     575     525     500     437     400     350     300     275     250
 97          UI     200     190     130     120     100      80      60      40      20       0
             * ******************************************************************************

 98          KK   QSUB6
 99          KM   RUNOFF FROM SUBBASIN 6
100          BA    30.6
101          LG     .25     .29     6.9     .17     10.
102          UI       0    2272    2838    4200    6895    7288    9122    7542    8332    7542
103          UI    7051    5657    5344    4159    3571    3265    2782    2500    2459    2207
104          UI    1785    1725    1678    1562    1500    1423    1250    1187    1136    1038
105          UI     926     800     716     694     625     580     463     400     380     360
106          UI     341     137     120     100      80      60      40      30      15       0
             * ******************************************************************************

107          KK  COMB-E
108          KM   COMBINE 5+6 @ E
109          HC       2
             * ******************************************************************************

110          KK  RT E-F
111          KM   ROUTE (5&6) FROM E TO F
112          RM       9   1.701     .30
             * ******************************************************************************

113          KK   QSUB7
114          KM   RUNOFF FROM SUBBASIN 7
115          BA    61.9
116          LG     .25     .28     7.2     .15     6.3
117          UI       0    1637    1800    1911    5465    6043   10289   11929   12698   14672
118          UI   14864   13651   13181   12895   10455   10322    9277    8078    7991    6457
119          UI    6339    5667    4942    4781    4154    3911    3670    2997    2808    2712
120          UI    2299    2252    1825    1697    1400    1292    1268    1200    1191     796
121          UI     780     770     760     740     728     310     250     200     100       0
             * ******************************************************************************
```



```
LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

122          KK   QSUB8
123          KM   RUNOFF FROM SUB8
124          BA    58.5
125          LG     .25     .24     8.8     .05     6.5
126          UI       0    3316    3783    4650    6605   10873    8992   12431   13240   10804
```

```
127        UI   12158   11189   11384   10251    8729    8201    6718    6079    5224    5051
128        UI    4432    3998    3648    3500    3432    3114    2605    2500    2400    2343
129        UI    2280    2200    2000    1900    1824    1766    1658    1550    1469    1351
130        UI    1300    1262    1013     950     900     800     746     675     670     665
131        UI     660     650     635     200     180     140     100      60      40       0
           * ******************************************************************************

132        KK  COMB-F
133        KM   COMBINE (5&6)+7+8 @ F
134        HC       3
           * ******************************************************************************

135        KK  RT F-G
136        KM   ROUTE (5-8) FROM F TO G
137        RM       2    .349     .25
           * ******************************************************************************

138        KK   QSUB9
139        KM   RUNOFF FROM SUB9
140        BA     13.
141        LG     .25     .28     6.5     .19     4.3
142        UI       0     582     950    2094    3971    4651    5268    4757    4300    3682
143        UI    3017    2655    2255    1812    1623    1391    1131     979     832     692
144        UI     603     469     451     342     283     270     267     110      50       0
           * ******************************************************************************

145        KK  COMB-G
146        KM   COMBINE (5-8) +9 +(1-4) @ G
147        HC       3
           * ******************************************************************************

148        KK  RT G-H
149        KM   ROUTE (1-9) FROM G TO H
150        RM       1    .178     .25
           * ******************************************************************************

151        KK  QSUB10
152        KM   RUNOFF FROM SUBBASIN 10
153        BA    65.6
154        LG     .25     .25     8.2     .09     8.0
155        UI       0    2673    2731    3266    3774    4762    6571    9252    6717    9502
156        UI   11383    9909    8106    9799    9600    9458    8447    8792    8620    7350
157        UI    6145    6896    5488    4900    4671    4200    4000    3724    3461    3266
158        UI    2950    2940    2900    2803    2673    2322    2100    2075    2050    1950
159        UI    1897    1837    1800    1776    1750    1747    1470    1430    1390    1365
160        UI    1336    1300    1200    1092    1089    1075    1050    1001     817     800
161        UI     796     792     789     544     500     480     440     400     360     320
162        UI     290     270     250     162     150     130     110      90      50       0
           * ******************************************************************************
```



```
LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10
```

```
163          KK  QSUB11
164          KM   RUNNOFF FROM SUBBASIN 11
165          BA    64.2
166          LG     .25     .35     3.8     .36      9.
167          UI       0    1951    2100    2148    2385    2636    3067    3983    4925    7639
168          UI    4338    5572    7155    7264    8704    6838    5816    7155    7100    7050
169          UI    7008    5646    7155    5784    6610    5367    5053    4438    5143    4258
170          UI    3578    3500    3439    3067    3060    3056    2683    2631    2385    2363
171          UI    2147    2100    2080    2060    2057    1951    1950    1570    1533    1530
172          UI    1500    1490    1480    1470    1452    1342    1341    1340    1339    1338
173          UI    1338    1337    1073    1060    1040    1000     976     970     960     940
174          UI     924     795     794     793     792     790     788     596     590     580
175          UI     540     520     500     490     470     458     398     395     390     385
176          UI     380     375     370     365     360     355     350     344     118       0
             * ******************************************************************************

177          KK  COMB-H
178          KM   COMBINE (1-9) +10 +11 @ H
179          HC       3
             * ******************************************************************************
180          ZZ
1*****************************************
*****************************************
 *                                    *                                        *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                     *   U.S. ARMY CORPS OF ENGINEE
 *            FEBRUARY 1981              *                                     *  THE HYDROLOGIC ENGINEERING C
 *          REVISED 05 DEC 88            *                                     *          609 SECOND STREET *
 *                                       *                                     *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  04/13/1990  TIME  06:38:36 *                                     *          (916) 551-1748 *
 *                                       *                                     *
*
 *****************************************
*****************************************

                    ***** UPPER AGUA FRIA WATERSHED ********************************************
                    ***** SPECIAL PROJECTS BRANCH -  HYDROLOGY DIV. - FCD OF MARICOPA COUNTY ***
                    ***** WATERSHED UPSTREAM OF USGS GAUGE # 95125 ****************************
                    ***** FEBRUARY, 1990 ******************************************************
                    ***** JD RECORDS USED WITH CORRESPONDING DEPTHS AND PATTEREN NUMBERS
                    ***** 6HR - 100YEAR DESIGN STORM

  8 IO        OUTPUT CONTROL VARIABLES
                  IPRNT          5  PRINT CONTROL
                  IPLOT          0  PLOT CONTROL
                  QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT         HYDROGRAPH TIME DATA
                   NMIN         10  MINUTES IN COMPUTATION INTERVAL
                  IDATE     26FEB90  STARTING DATE
```

```
          ITIME        0000  STARTING TIME
             NQ         150  NUMBER OF HYDROGRAPH ORDINATES
         NDDATE     27FEB90  ENDING DATE
         NDTIME        0050  ENDING TIME
          ICENT          19  CENTURY MARK

     COMPUTATION INTERVAL     .17 HOURS
          TOTAL TIME BASE   24.83 HOURS

ENGLISH UNITS
    DRAINAGE AREA          SQUARE MILES
    PRECIPITATION DEPTH    INCHES
    LENGTH, ELEVATION      FEET
    FLOW                   CUBIC FEET PER SECOND
    STORAGE VOLUME         ACRE-FEET
    SURFACE AREA           ACRES
    TEMPERATURE            DEGREES FAHRENHEIT

10 JD      INDEX STORM NO. 1
                STRM       3.35  PRECIPITATION DEPTH
                TRDA       3.00  TRANSPOSITION DRAINAGE AREA

11 PI       PRECIPITATION PATTERN
              .40     .40     .40     .53     .63     .73     .53     .60     .67     .53
              .60     .67     .60     .67     .73     .87    1.10    1.33    2.87    4.40
             5.93   13.27   14.73   16.20    9.53    6.87    4.20    2.53    2.23    1.93
             1.20     .77     .33     .00     .33     .67

14 JD      INDEX STORM NO. 2
                STRM       3.21  PRECIPITATION DEPTH
                TRDA      16.00  TRANSPOSITION DRAINAGE AREA

15 PI       PRECIPITATION PATTERN
             1.00     .67     .33     .67     .93    1.20    1.00     .93     .87     .93
              .97    1.00     .93    1.00    1.07    1.13    1.33    1.53    3.13    4.30
             5.47   11.20   12.20   13.20    8.40    6.60    4.80    2.93    2.60    2.27
             1.87    1.13     .40     .47     .67     .87

18 JD      INDEX STORM NO. 3
                STRM       2.74  PRECIPITATION DEPTH
                TRDA      90.00  TRANSPOSITION DRAINAGE AREA

19 PI       PRECIPITATION PATTERN
             1.40    1.17     .93    1.07    1.20    1.33    1.07    1.13    1.20    1.33
             1.27    1.20    1.13    1.20    1.27    1.47    1.77    2.07    3.27    4.40
             5.53    9.07    9.80   10.53    7.67    6.10    4.53    3.13    2.87    2.60
             2.07    1.27     .47     .73    1.17    1.60

22 JD      INDEX STORM NO. 4
                STRM       1.86  PRECIPITATION DEPTH
                TRDA     588.00  TRANSPOSITION DRAINAGE AREA

23 PI       PRECIPITATION PATTERN
             1.60    1.43    1.27    1.07    1.17    1.27    1.33    1.37    1.40    1.47
```

1.43	1.40	1.60	1.67	1.73	1.80	1.97	2.13	3.33	4.57
5.80	7.13	7.30	7.47	7.20	6.23	5.27	3.33	3.10	2.87
2.53	1.60	.67	.93	1.50	2.07				

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

+	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAG
+	HYDROGRAPH AT	QSUB1	12438.	5.00	3835.	976.	944.	37.80		
+	ROUTED TO	RT A-B	11693.	5.83	3833.	976.	944.	37.80		
+	HYDROGRAPH AT	QSUB2	8849.	5.67	5361.	1655.	1599.	85.40		
+	2 COMBINED AT	COMB-B	14633.	5.83	6948.	2027.	1959.	123.20		
+	ROUTED TO	RT B-C	13796.	7.83	6916.	2027.	1959.	123.20		
+	HYDROGRAPH AT	QSUB3	8385.	5.67	5061.	1564.	1511.	80.30		
+	2 COMBINED AT	COMB-C	13796.	7.67	8476.	2659.	2570.	203.50		
+	ROUTED TO	RT C-D	12742.	8.67	7966.	2509.	2425.	203.50		
+	HYDROGRAPH AT	QSUB4	10615.	5.33	4234.	1098.	1061.	46.10		
+	2 COMBINED AT	COMB-D	12733.	8.67	9099.	2946.	2847.	249.60		
+	ROUTED TO	RT D-G	11160.	9.67	8150.	2663.	2574.	249.60		
+	HYDROGRAPH AT	QSUB5	6991.	5.50	3864.	1128.	1090.	44.60		
+	HYDROGRAPH AT	QSUB6	9876.	5.17	4141.	1094.	1058.	30.60		
+	2 COMBINED AT	COMB-E	13329.	5.33	6530.	1832.	1770.	75.20		

	ROUTED TO							
+		RT E-F	12363.	7.17	6476.	1832.	1770.	75.20
	HYDROGRAPH AT							
+		QSUB7	14931.	5.67	7102.	1882.	1819.	61.90
	HYDROGRAPH AT							
+		QSUB8	18328.	5.67	9473.	2641.	2553.	58.50
	3 COMBINED AT							
+		COMB-F	25329.	6.00	15408.	4347.	4201.	195.60
	ROUTED TO							
+		RT F-G	25171.	6.33	15378.	4347.	4201.	195.60
	HYDROGRAPH AT							
+		QSUB9	6275.	5.00	1974.	497.	480.	13.00
	3 COMBINED AT							
+		COMB-G	25078.	6.50	17982.	5611.	5423.	458.20
	ROUTED TO							
+		RT G-H	19429.	6.50	13567.	4227.	4085.	458.20
	HYDROGRAPH AT							
+		QSUB10	13139.	6.17	8049.	2473.	2390.	65.60
	HYDROGRAPH AT							
+		QSUB11	5643.	6.33	3929.	1376.	1330.	64.20
	3 COMBINED AT							
+		COMB-H	21156.	6.50	14082.	4438.	4289.	588.00

*** NORMAL END OF HEC-1 ***

G.V. Sabol
18 July 1991

TESTING AND VERIFICATION
UPPER AGUA FRIA R. WATERSHED

Previous Testing and Verification

Testing and verification of the procedures in the Maricopa County Hydrologic Design Manual (Manual) previously were performed by the staff of the Flood Control District of Maricopa County (District). The testing and verification as reported, herein, is to expand on those previous tests. The information on the watershed that was compiled by the District in its testing was used where appropriate in the present testing.

Testing Objectives

The following were the objectives for hydrologic testing using this watershed:

1. Evaluate modeling procedures that could be used to simulate flood frequency relations for this large, mountainous watershed and other similar watersheds.
2. Test and evaluate various modeling techniques for such watersheds, specifically the following:
   a. selection of S-graphs,
   b. selection of K_1,
   c. comparison of results when the Green and Ampt parameters are estimated by linear-area weighted averaging and by log-area weighted averaging,
   d. evaluation of the effects of the vegetation correction factor for XKSAT,
   e. evaluation of the use of two 24-hour rainfall distributions for use on large watersheds, and
   f. evaluation of the effects of partial area rainfall over the watershed using three different rainfall distributions.

Watershed

The 588 square mile watershed is in Yavapai County and is drained by the Agua Fria River. The watershed is mountainous, with a minimum elevation of

3,434 ft at the outlet and maximum elevations greater than 7,000 ft along the watershed divide. The watershed is covered by forest, open rangeland, and high elevation desert.

HEC-1 Model

The HEC-1 model that was used was developed by the District as described in Upper Agua Fria River Watershed Analysis April 1990. The District model was modified (input of rainfall distributions, loss parameters, and S-graphs) to perform the various tests and evaluations.

Flood Frequency Analysis

Gaging station records are available for the Agua Fria River near Mayer, Arizona (09512500) for the period 1940 through 1989. A graphical flood frequency analysis is presented in Appendix A. The results of the flood frequency analysis, using log-normal graph paper are:

Return Period, years	Flood Peak, cfs
2	5,600
5	11,000
10	15,700
25	22,800
50	29,200
100	37,000

Description of Model Input

Rainfall

The rainfall statistics from NOAA Atlas 2 were areally averaged for the watershed. The rainfall worksheets are shown in Appendix B. The area weighted rainfall statistics are:

2-yr, 6-hr	1.55 inch
100-yr, 6-hr	3.37 inch
2-yr, 24-hr	2.06 inch
100-yr, 24-hr	4.68 inch.

Those statistics were input to the PREFRE Program and a depth-duration-frequency table was produced (Appendix B).

Three rainfall distributions were used for various tests;

a. The Maricopa County 6-hr patterns,

b. The SCS Type II, 24-hr distribution, and

c. The 24-hr hypothetical distribution.

The depth-area reduction curve from the Manual was used with the 6-hr distribution, and NWS HYDRO-40 depth-area reduction curves were used with the two 24-hr distributions.

The rainfall input to the various HEC-1 models is shown in Appendix B.

Rainfall Losses

Rainfall losses were calculated by the Green and Ampt infiltration equation. The parameters were calculated by two methods; by linear-area weighted average and by log-area weighted average. The values for the linear-area weighted average were calculated by the District and those values were used. The log-area weighted average values were calculated from the soils data that are contained in the District's report (April 1990).

The District's soils data and the log-area weighted averaging work sheets are shown in Appendix C. Parameter values are shown for each subbasin and for the whole watershed taken as a single unit.

The XKSAT values were adjusted for various percentages of vegetation cover (20, 30, 40 and 100%). The effect of incorporating vegetation cover into the watershed model was evaluated.

S-Graphs

The S-Graph Study November 1987, was reviewed in the selection of S-graphs for the watershed. This resulted in five S-graphs for possible application (S-graph number from the study is noted):

a. Phoenix Mountain, #57

b. Agua Fria R. At Avondale (Dec 1967), #21 (general storm)

c. Agua Fria R. at Avondale (Sept 1970), #22 (local storm)

d. Average for Arizona, #61

e. Average Mountain, #62.

The two Agua Fria R. S-graphs are nearly identical and only #21 was used in the evaluations.

The following data are available for selecting K_s:

a. K_s = .059 for S-graph #21 (S-Graph Report, Table 7),

b. K_s = .043 for S-graph #22 (S-Graph Report, Table 7), and

c. K_s = .053 for Agua Fria R. near Mayor (sic) (USBR Flood Hydrology Manual, Table 4-3).

Based on that information, K_s = .043 was selected for S-graphs when used with a 6-hr storm. This is the K_s for the short duration, high intensity Sept 1970 storm. K_s = .059 was selected for S-graphs when used with a 24-hr storm. This is the K_s for the longer, general storm of Dec 1967 storm.

The S-graph information and worksheets for the calculation of the subbasin lags are shown in Appendix D.

Results

Single Basin Models

The first tests involved the evaluation and selection of S-graphs. To simplify these tests, the watershed was modeled as a single basin. For these tests the Green and Ampt parameters were:

IA = .25 inch

DTHETA = .39

PSIF = 5.9 in/hr

XKSAT = .17 in/hr

RTIMP = 7.8%.

The S-graph Lag = 4.99 hr (K_s = .043) for 6-hr rainfalls, and Lag = 6.84 hr (K_s = .059) for 24-hr rainfalls.

The 100-yr rainfall depths were:

Duration, hrs	Point Rain, inches	Reduction Factor	Area Rain, inches
6	3.37	.57	1.92
24	4.68	.78	3.65

The 100-yr peak discharges for the various watershed models are:

S-Graph	Peak Discharge, cfs		
	Maricopa Co. 6-hr rain	SCS Type II 24-hr rain	Hypothetical 24-hr rain
(1)	(2)	(3)	(4)
Phoenix Mtn. #57	10,600	56,600	39,600
Agua Fria R. #21	9,200	54,500	----
Avg. Arizona #61	12,500	84,400	----
Avg. Mtn. #62	6,900	41,200	----

The following observations and conclusions were made based on these results:

1. The 6-hr rainfall does not produce a very large peak discharges. This is expected for a large (588 sq. mile) watershed.
2. The SCS Type II distribution produces peak discharges that are probably too high (the flood frequency analysis indicates 100-yr peak discharge of about 37,000 cfs). Past experience with the SCS Type II distribution indicates that this distribution is too severe (rainfall intensities too high) when the area is larger than about 100 square miles.
3. The hypothetical distribution results are reasonable when used with the Phoenix Mountain S-graph.
4. The Phoenix Mtn. (#57) and the Agua Fria R. (#21) S-graphs produce similar results.
5. The Average Arizona (#61) S-graph produces much larger discharges than the other S-graphs, and it may not be appropriate for this watershed.
6. The Average Mountain (#62) S-graph produces the lowest discharges. Use of that S-graphs with the SCS Type II distribution results in reasonable reproduction of the 100-yr flood, however, it is likely that that S-graph is overcompensating for the high rainfall intensities from the SCS Type II distribution. This S-graph is probably not appropriate for this watershed.
7. The Agua Fria R. S-graph (#21) is the most appropriate for this watershed. However, because it is so similar to the Phoenix Mountain S-graph and because they both produce about the same results, the Phoenix Mountain S-graph was selected for use with this watershed.

Subbasin Models

The subbasin model of the District (April 1990) was used for further testing. The first tests with the subbasin model were an attempt to reproduce the 100-yr peak discharge (37,000 cfs) using various rainfall distributions. The log-area weighted Green and Ampt parameters were used for each subbasin (Appendix C). The Phoenix Mountain S-graph was used with K_s = .059 for 24-hr rainfalls and K_s = .043 for 6-hr rainfalls (see Appendix D for subbasin Lags).

The results of the subbasin model for the three rainfall distributions are:

Maricopa County, 6-hr rainfall	27,100 cfs
SCS Type II, 24-hr rainfall	72,800 cfs
Hypothetical, 24-hr rainfall	45,6000 cfs.

Compared with the flood frequency analysis (37,000 cfs), none of these results are very attractive.

Subbasin Models with Partial Area Rainfall

The subbasin model was used with rainfall over only selected subbasins to investigate the effect of partial area rainfall. This was conducted to investigate the possibility that the flood frequency relation is due to rainfalls that occur over parts of the watershed and not over the whole watershed. Watersheds of various size (combinations of subbasins) were modeled using the three rainfall distributions. The results are shown in Table 1 and in Figure 1.

TABLE 1

Agua Fria R. Watershed

Partial Area Rainfall Results

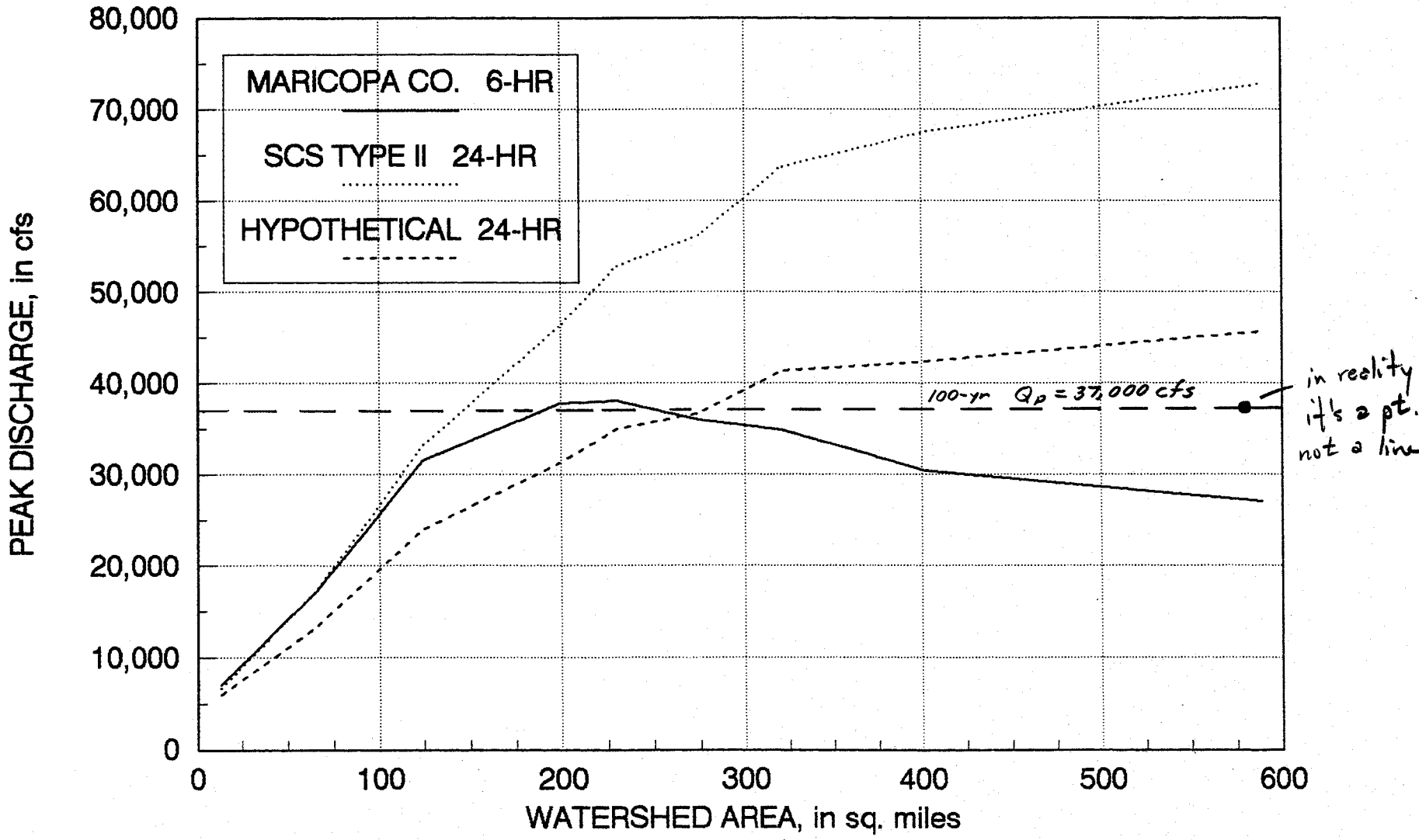
Subbasins	Area	Peak Discharge, cfs		
	sq.mi.	Maricopa Co. 6-hr rain	SCS Type II 24-hr rain	Hypothetical 24-hr rain
(1)	(2)	(3)	(4)	(5)
9	13.0	7,000	6,700	5,900
10	65.6	17,300	17,400	13,400
8+10	124.1	31,600	33,200	24,000
7-10	199.0	37,800	46,300	31,300
6-10	229.6	38,100	52,800	35,000
5-10	274.2	36,000	56,200	36,700
4-10	320.3	34,900	63,700	41,400
3-10	400.6	30,500	67,500	42,400
1-11	588.0	27,100	72,800	45,600

FIGURE 1

AGUA FRIA RIVER WATERSHED

PARTIAL AREA RAINFALL RESULTS

3 RAINFALL DISTRIBUTIONS



The partial area rainfall results are interesting in that they indicate that the observed floods for this watershed may be the result of local storms that occur over only parts of the watershed, rather than large general storms that cover the entire watershed.

The results also indicate that the SCS Type II distribution may result in unrealistically high peak discharges when the drainage area is much larger than 100 square miles. The peak discharges for the hypothetical distribution are less than those for the Maricopa County distribution for areas less than about 250 square miles and are greater for areas larger than 250 square miles.

Investigation of Rainfall Loss Parameters

The subbasin model was used to investigate two aspects of the Green and Ampt infiltration equation:

a. the effect of the two methods (linear and log) to obtain the area weighted parameter values, and

b. the effect of the vegetation correction on XKSAT. The subbasin model was used with the Green and Ampt parameters calculated by both the linear- and the log-area weighted methods. The linear-area weighted parameters were those calculated by the District (April 1990), and the log-area weighted parameters are as previously discussed and shown in Appendix C. The XKSAT value was adjusted for 20, 30, 40 and 100% vegetation cover (values in Appendix C). The results of these investigations are:

Linear-area weighted parameters	24,200 cfs
Log-area weighted parameters (bare ground)	27,100 cfs
with 20% vegetation cover	25,000 cfs
with 30% vegetation cover	24,400 cfs
with 40% vegetation cover	22,500 cfs
with 100% vegetation cover	16,300 cfs.

These results indicate that there is not a great difference in peak discharges for the two methods of calculating the area weighted parameter values; although the log-area weighted method results in about a 12% increase in peak discharge. Similarly, the use of the vegetation correction factor on XKSAT does not result in large reduction in the peak discharge for reasonable values of vegetation cover for this watershed (20 to 40%).

Conclusions

1. It is likely that the predominant floods in this watershed and possibly throughout Maricopa County are the result of local storms, possibly over only parts of large watersheds, and not the result of general storms over the entire watershed.
2. When modeling large watersheds, it may be desireable to consider partial area rainfall from local storms when attempting to reproduce flood discharges of 100-yr frequency and less. This is not particularly difficult once a subbasin model of the watershed is developed.
3. The SCS Type II rainfall distribution, when used with the NWS HYDRO-40 depth-area reduction factors probably results in flood peak discharges that are too great for watersheds larger than about 100 square miles. The use of the depth-area reduction factors from NOAA Atlas 2 would increase these discharges. The use by the District of the SCS Type II distribution for various hydrologic studies should be critically reviewed and evaluated.
4. The hypothetical distribution with the NWS HYDRO-40 depth-area reduction factors seems to result in more reasonable estimates of flood discharges from general storms.
5. The log-area weighting of the Green and Ampt parameters is theoretically ? more correct and results in somewhat higher discharges than the linear-area weighting method. The log-area weighting method should be reproducing runoff volume considered for adoption by the District.
6. The estimation of rainfall losses is not particularly sensitive to the vegetation correction factor. Use of that factor should be incorporated, however, when vegetation cover exceeds about 20%.
7. The Phoenix Mountain S-graph seems to be appropriate for use with this mountain watershed, and probably for other similar watersheds.
8. K_1 = .043 seems appropriate for this watershed (100-yr flood) for the local Storm. K_1 = .059 may be appropriate for this watershed for the general storm but this cannot be substantiated by the flood frequency analysis.
9. For large watersheds, there will probably be little need for estimating flood magnitudes other than for the 100-yr event. Therefore, there is

probably no need to develop techniques for adjusting K_a for more frequent floods for use with large watersheds. K_a should be adjusted upward when using S-graphs on small watersheds when attempting to estimate floods for return periods more frequent than 100-yr. Such guidance should be considered for inclusion in the Manual.

Appendix A

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET 1 OF 2

CLIENT

DATE

PROJECT Flood Frequency Analysis

BY

SUBJECT Data Compilation Form

PROJECT NO.

Project Model Verification
Station Name Agua Fria R. near Mayer, AZ
Station No. 9512500 Drainage Area 588 sq. mi.
Period of Systematic Record 1940-1989

Water Year (1)	Annual Peak Discharge cfs (2)	Date (3)	Flood Type[a] (4)	Comment (5)
40	5,920	26 Jun 40	R	
41	13,000	1 Mar 41	R	
42	6,280	6 Aug 42	R	
43	3,500	25 Sept 43	R	
44	3,810	16 Sept 44	R	
45	2,620	27 July 45	R	
46	4,930	22 July 46	R	
47	1,610	16 Aug 47	R	
48	6,830	4 Aug 48	R	
49	2,460	13 Jan 49	R	
50	2,170	17 July 50	R	
51	8,180	28 Aug 51	R	
52	7,500	18 Jan 52	R	
53	5,510	8 July 53	R	
54	4,570	3 Sept 54	R	
55	12,800	3 Aug 55	R	
56	6,880	25 July 56	R	
57	2,710	13 Aug 57	R	
58	4,620	21 Jun 58	R	
59	9,700	4 Aug 59	R	
60	4,820	8 Aug 60	R	
61	10,200	22 July 61	R	
62	2,470	13 Sept 62	R	
63	12,800	19 Aug 63	R	
64	9,000	24 July 64	R	
65	7,470	4 Apr 65	R	
66	15,100	22 Dec 65	R	
67	6,960	19 Aug 67	R	
68	3,850	19 Dec 67	R	
69	2,490	7 Aug 69	R	

a - rainfall (R), snowmelt (S), rain on snow (R/S), uncertain (U), other (X) - note in Comments

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET 2 OF 2

CLIENT

DATE

PROJECT Flood Frequency Analysis

BY

SUBJECT Data Compilation Form

PROJECT NO.

Project

Station Name

Station No. Drainage Area sq. mi.

Period of Systematic Record

Water Year (1)	Annual Peak Discharge cfs (2)	Date (3)	Flood Type[a] (4)	Comment (5)
70	19,800	5 Sept 70	R	
71	7,280	25 Aug 71	R	
72	6,800	12 Aug 72	R	
73	10,700	7 Oct 72	R	
74	740	20 July 74	R	
75	2,190	27 July 75	R	
76	9,700	9 Feb 76	R	
77	5,480	23 Aug 77	R	
78	9,900	1 Mar 78	R	
79	18,300	18 Dec 78	R	
80	33,100	19 Feb 80	R	
81	2,850	23 Sept 81	R	
82	3,040	10 Sept 82	R	
83	9,940	23 Sept 83	R	
84	3,620	14 Aug 84	R	
85	2,880	27 Dec 84	R	
86	3,970	26 Nov 85	R	
87	6,070	11 Oct 86	R	
88	25,500	29 Aug 88	R	
89	1,280	18 Aug 89	R	

	arith.	$\log_{10}$
mean	7,420	3.7433
std. dev.	6,180	.3334

a – rainfall (R), snowmelt (S), rain on snow (R/S), uncertain (U), other (X) – note in comments

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT

DATE 8 May 91

PROJECT

BY GVS

SUBJECT Agua Fria R. near Mayer

PROJECT NO. S-5

Test for high and low outliers

High Outliers:

$$\log Q_H = \overline{\log Q} + K_N S_{\log}$$

$$\overline{\log Q} = 3.7433$$

$$S_{\log} = .3334$$

$$N = 50$$

$$K_N = 2.786$$

$$\log Q_H = 3.7433 + (2.786)(.3334)$$

$$= 4.6722$$

$Q_H = 47{,}000$ cfs No Q's are larger than 47,000 cfs.

Therefore, no high outliers suspected.

Low Outliers:

$$\log Q_\ell = \overline{\log Q} - K_N S_{\log}$$

$$\overline{\log Q} = 3.7433$$

$$S_{\log} = .3334$$

$$N = 50$$

$$K_N = 2.786$$

$$\log Q_\ell = 3.7433 - (2.786)(.3334)$$

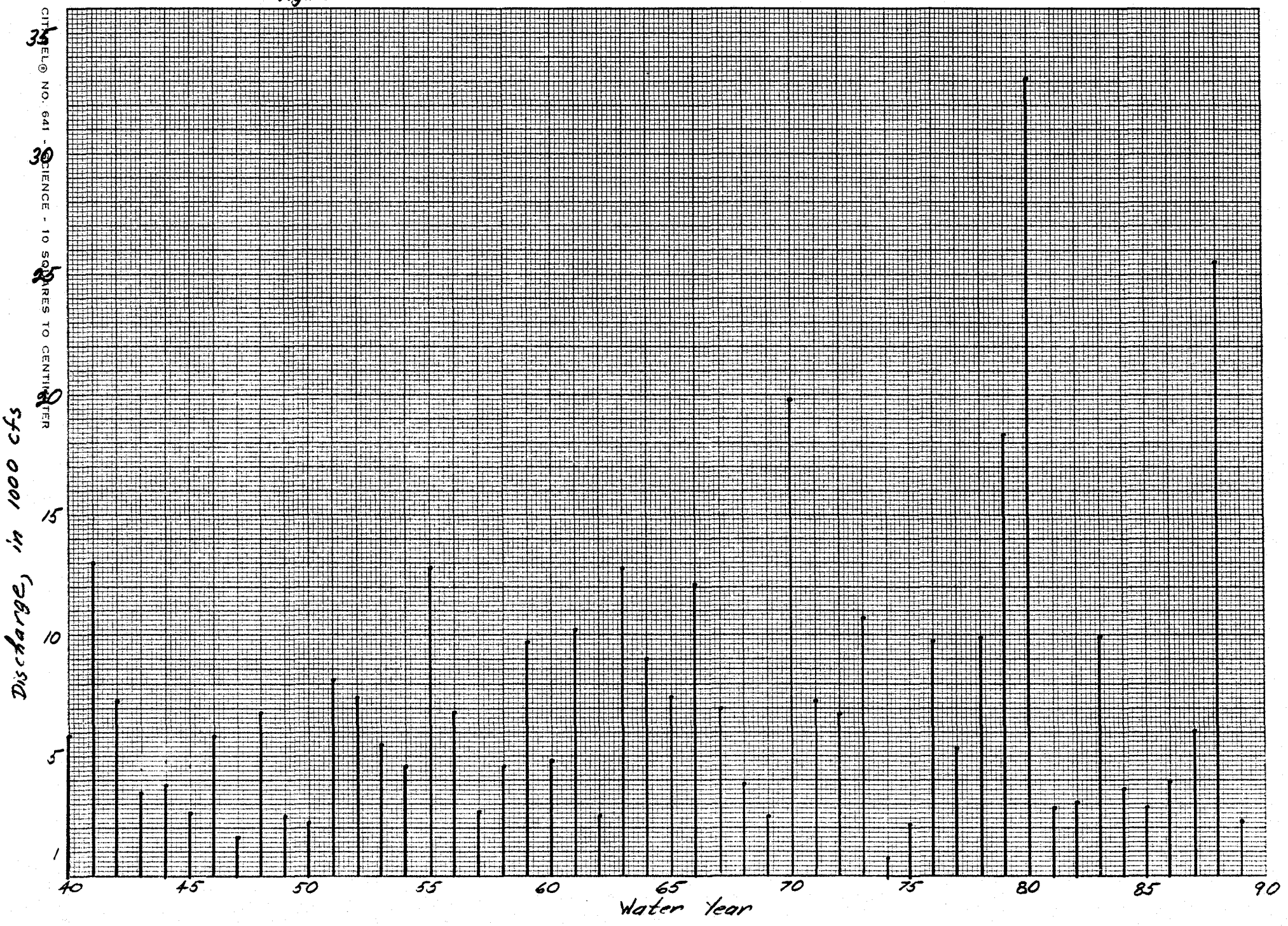
$$= 2.8144$$

$Q_\ell = 652$ cfs No Q's are smaller than 652 cfs.

Therefore, no low outliers suspected.

amDg 8 May 91

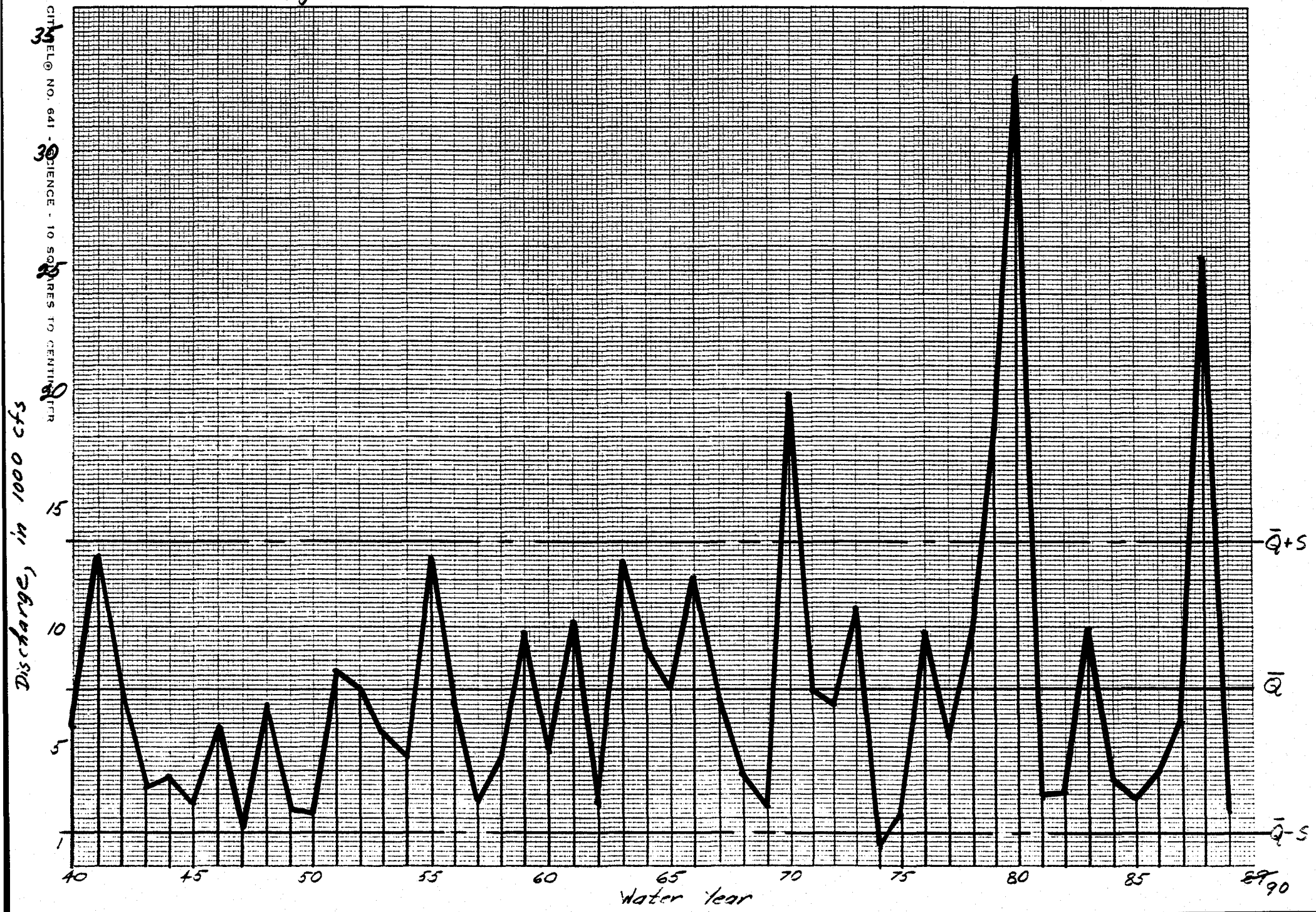
Agua Fria R. near Mayer, AZ 1940-1989



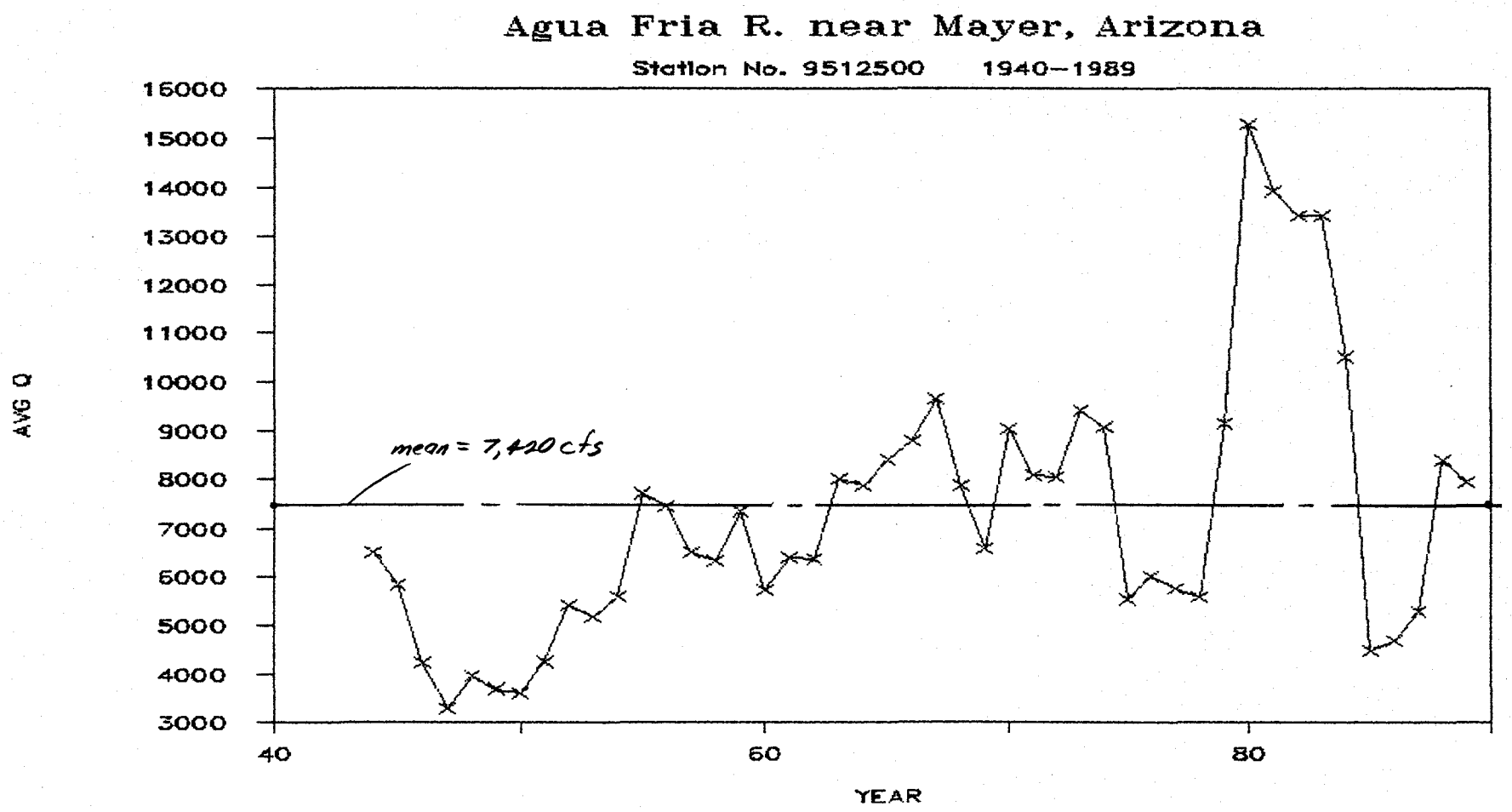
CITREL® NO. 641 - SCIENCE - 10 SQUARES TO CENTIMETER

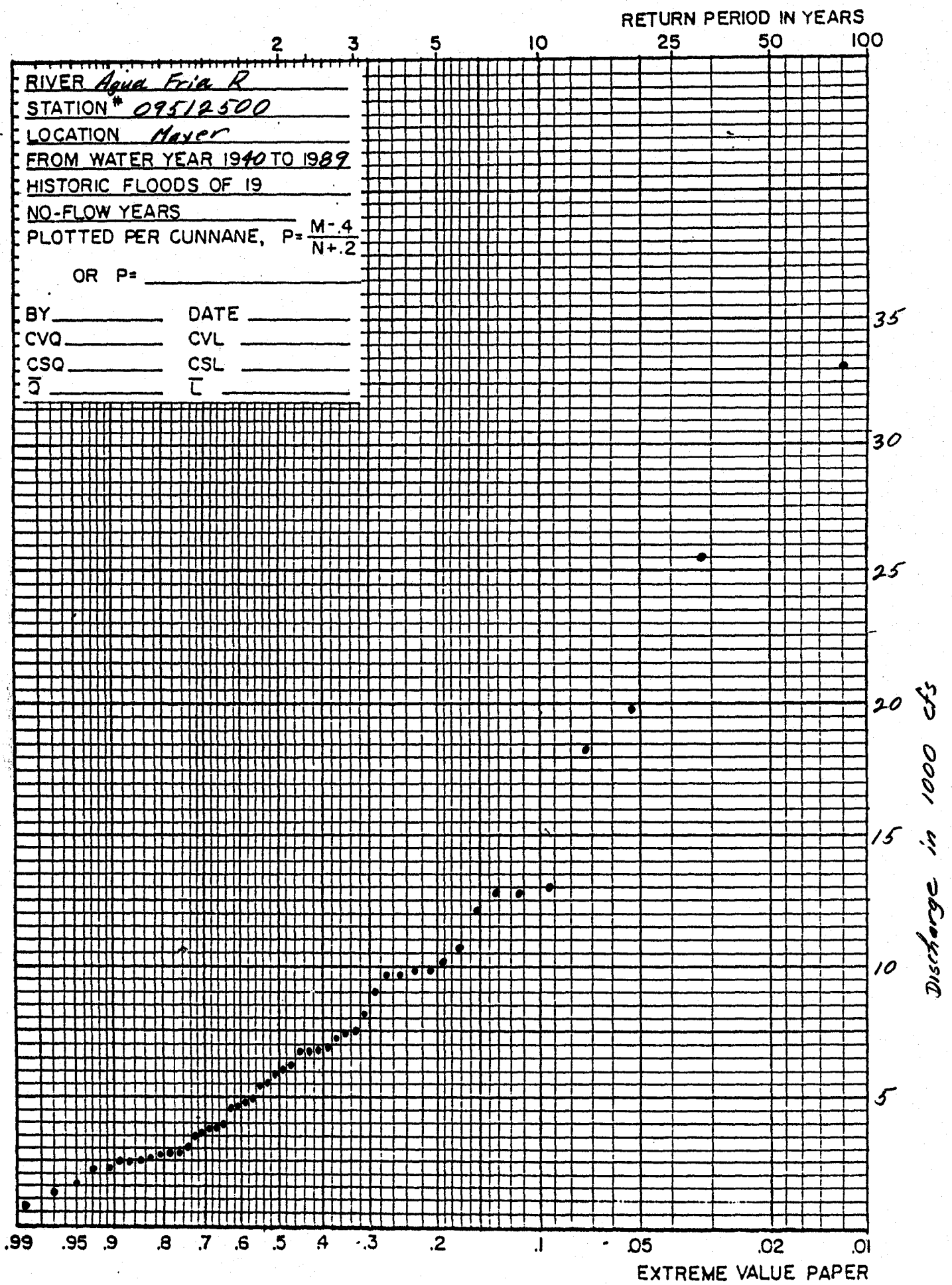
amDg 8 May 91

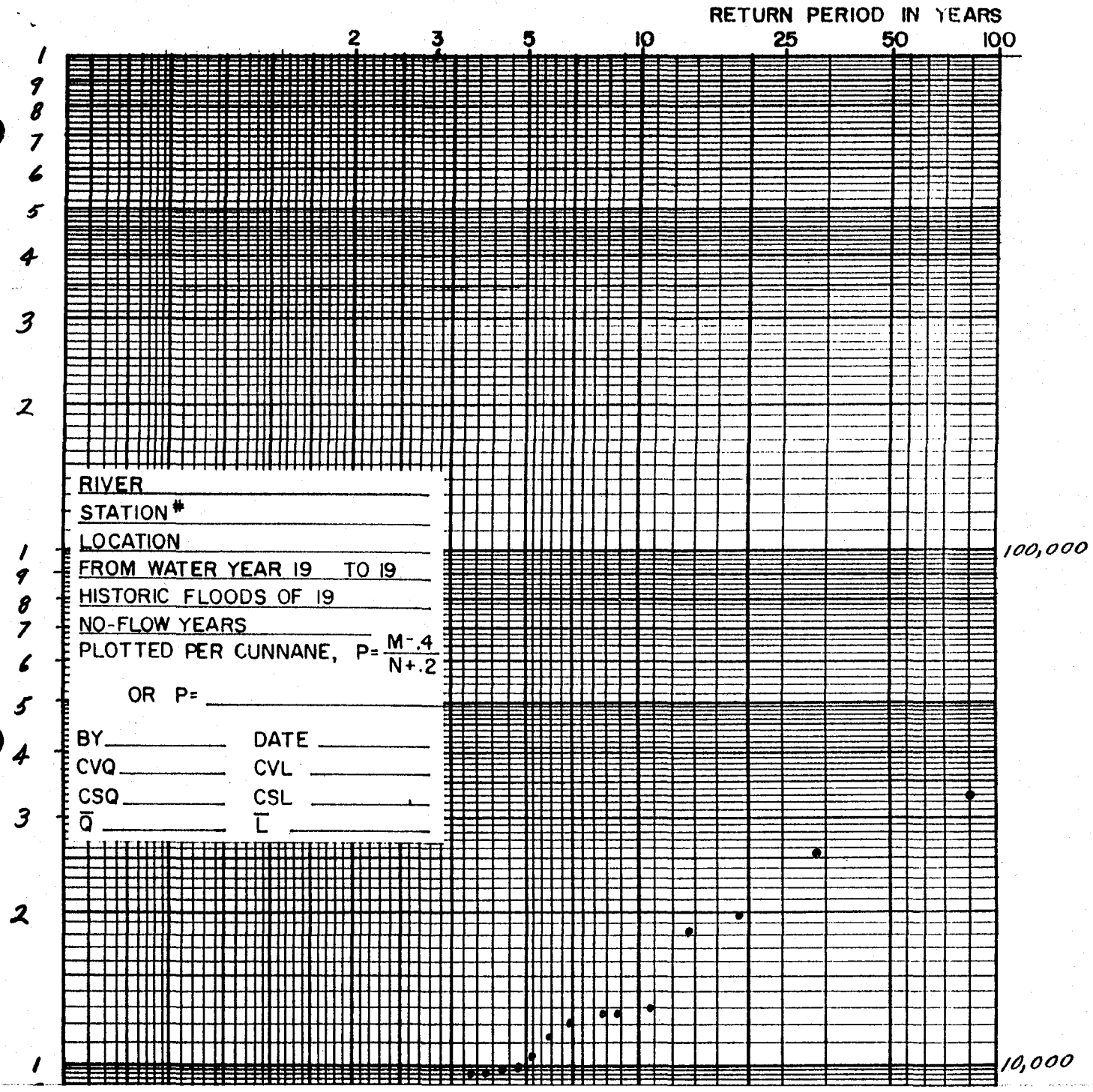
Agua Fria R. near Mayer, AZ 1940-1989

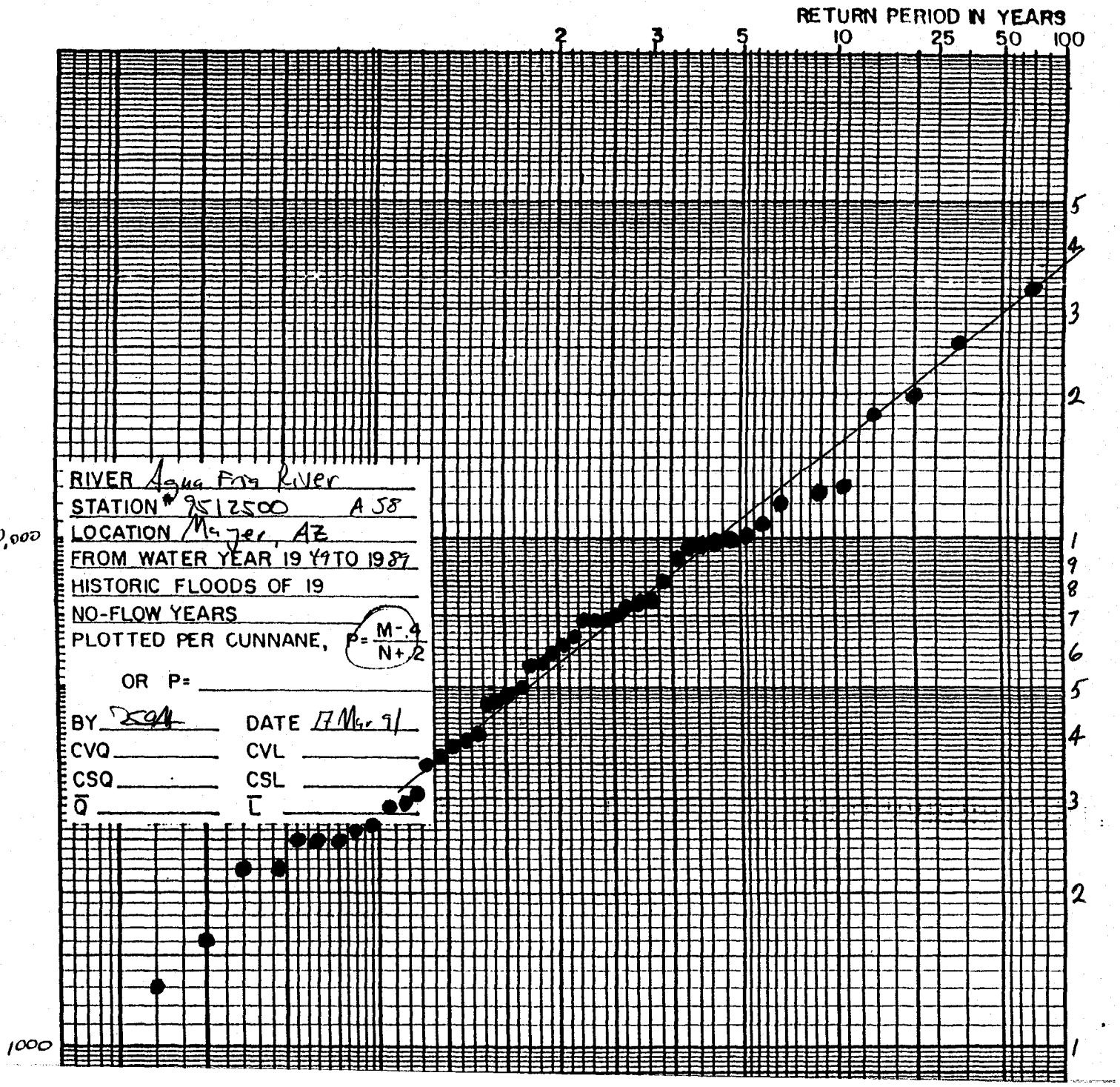


5-yr moving average




RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
RIVER Agua Fria R
STATION # 09512500
LOCATION Mayer
FROM WATER YEAR 1940 TO 1989
HISTORIC FLOODS OF 19
NO-FLOW YEARS
PLOTTED PER CUNNANE, P= M-.4 / N+.2
OR P=
BY
DATE
CVQ
CVL
CSQ
CSL
Q̄
L̄
35
30
25
20
15
10
5
Discharge in 1000 cfs
.99
.95
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
EXTREME VALUE PAPER


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
100,000
10,000
RIVER
STATION #
LOCATION
FROM WATER YEAR 19 TO 19
HISTORIC FLOODS OF 19
NO-FLOW YEARS
PLOTTED PER CUNNANE, P= (M-.4)/(N+.2)
OR P=
BY
DATE
CVQ
CVL
CSQ
CSL
Q̄
L̄


RETURN PERIOD IN YEARS
2
3
5
10
25
50
100
RIVER Agua Fria River
STATION # 9512500 A 58
LOCATION Mayer, AZ
FROM WATER YEAR 19 49 TO 1987
HISTORIC FLOODS OF 19
NO-FLOW YEARS
PLOTTED PER CUNNANE, P= M-.4 / N+.2
OR P=
BY
DATE 17 Mar 91
CVQ
CVL
CSQ
CSL
Q̄
L̄
10,000
1000

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT ____

DATE 13 May 91

PROJECT ____

BY GVS

SUBJECT ____

PROJECT NO. ____

Results of flood frequency analysis for Agua Fria R. near Mayer

The Log Normal (LN) graph was selected because most of the floods plot as a straight line on that probability paper.

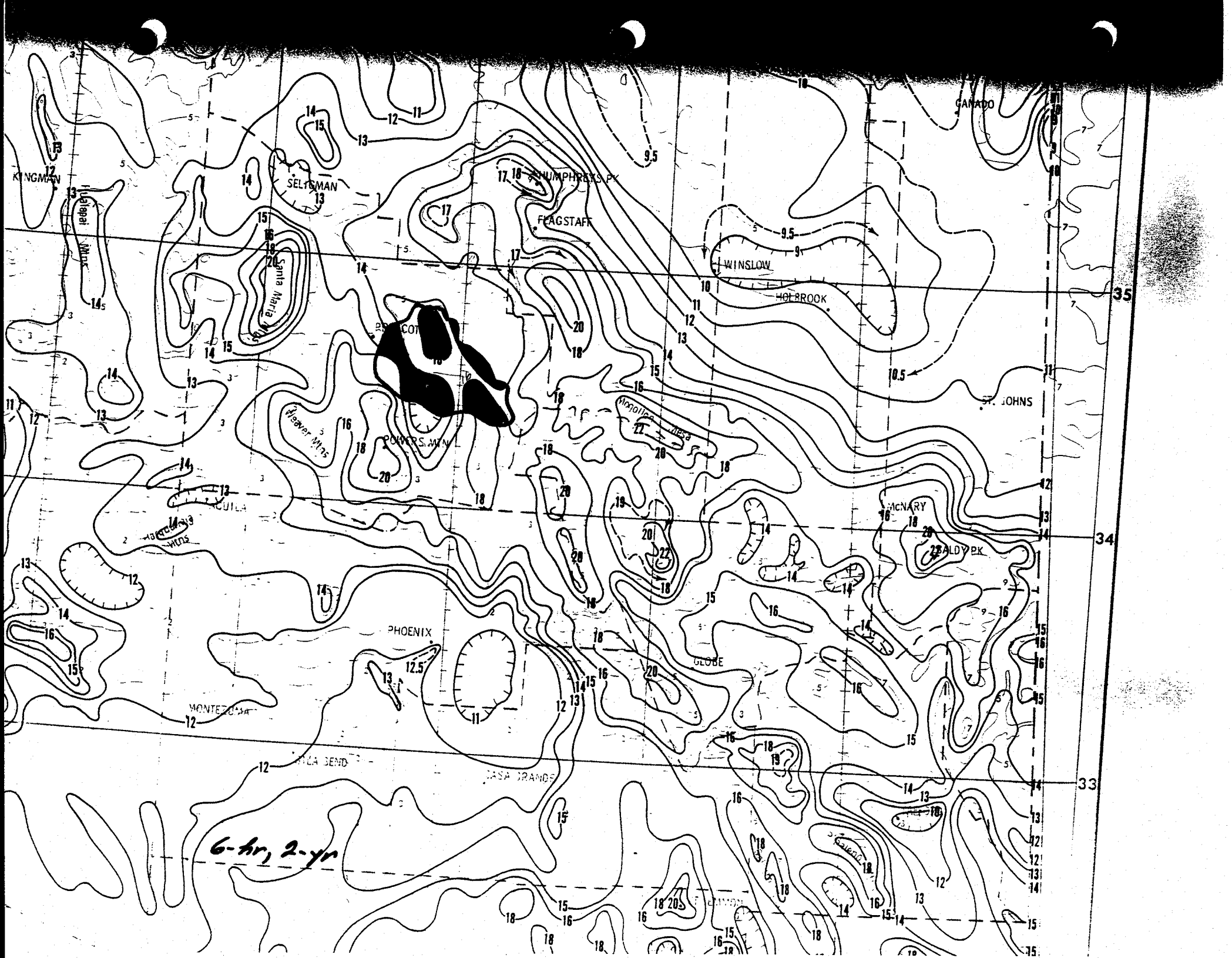
The graphical flood frequency analysis results are:

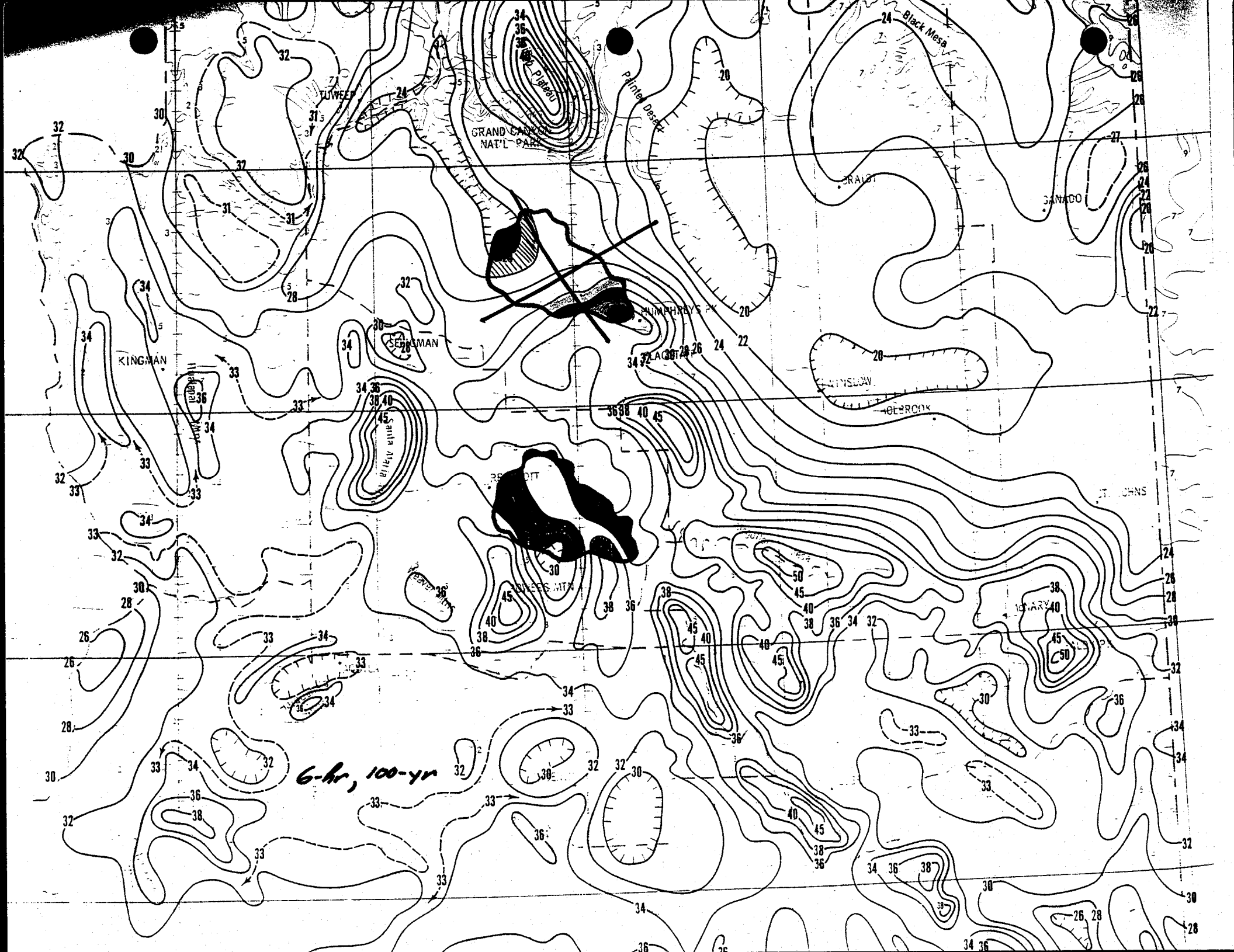
Return Period years	Flood Magnitude cfs
2	5,600
5	11,000
10	15,700
25	22,800
50	29,200
100	37,000

Discussion

1. A 50-year continuous record is available.
2. The record appears to be stationary.
3. No zero flow years exist.
4. No high or low flow outliers are suspected.

Appendix B


KINGMAN
SELIGMAN
HUMPHREYS PK
FLAGSTAFF
WINSLOW
HOLBROOK
CANADO
ST. JOHNS
Santa Maria Mts
Hualapai Mts
Hoggoller Mesa
POWERS MTN
McNARY
BALDY PK
PHOENIX
GLOBE
MONTEZUMA
CASA GRANDE
35
34
33
6-hr, 2-yr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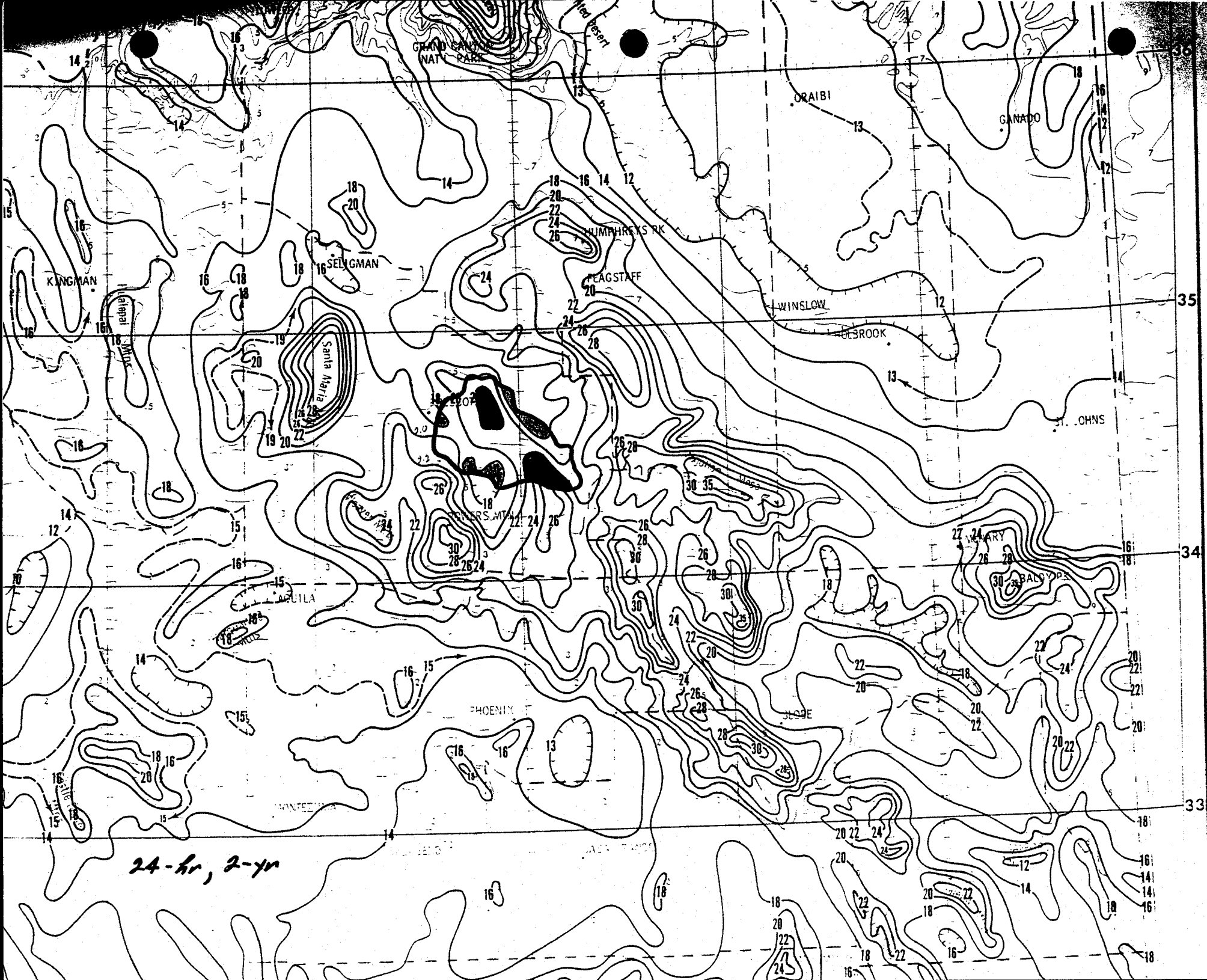
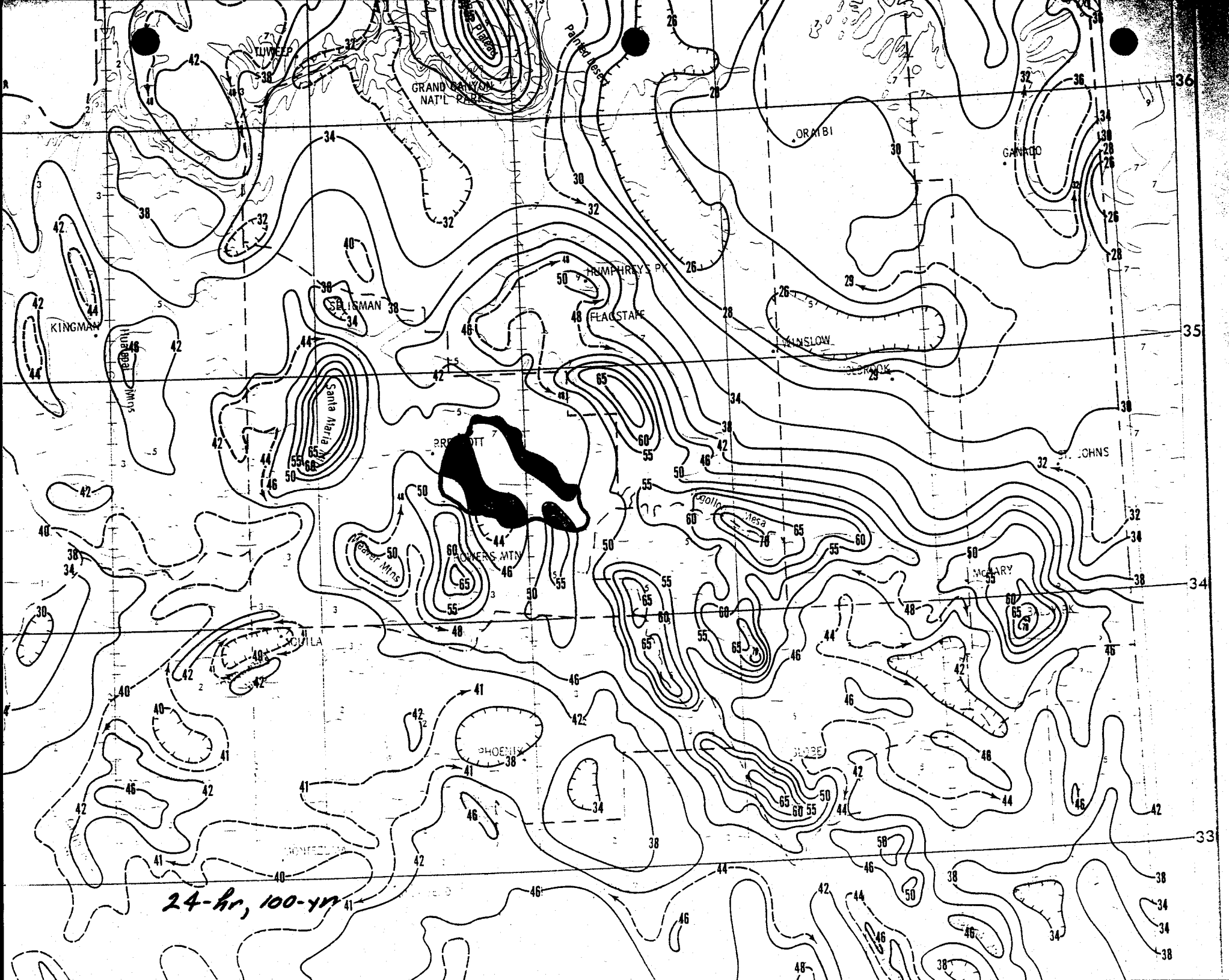
Plateau
Painted Desert
GRAND CANYON
NAT'L PARK
TUWEEP
CRAIG
CANADO
HUMPHREYS PK
SELIGMAN
KINGMAN
Hualapai
Mtn
Santa Maria
WINSLOW
HOLBROOK
ST. JOHNS
6-hr, 100-yr


GRAND CANYON NAT. PARK
ORAIBI
GANADO
HUMPHREYS PK
SELIGMAN
KINGMAN
FLAGSTAFF
WINSLOW
HOLBROOK
ST. JOHNS
Santa Maria
Hualapai Mtns
ZEPOL
TENERS MT
AGUILA
BALDY PK
PHOENIX
SLOPE
36
35
34
33

24-hr, 2-yr


TUWEEP
GRAND CANYON
NAT'L PARK
Painted Desert
ORAIBI
GANADO
HUMPHREYS PK
SELIGMAN
FLAGSTAFF
KINGMAN
Hualapai Mtns
Santa Maria Mts
PRESCOTT
WINSLOW
HOLBROOK
ST. JOHNS
Gallina Mesa
Weaver Mtns
BOWERS MTN
McNARY
ACUILA
PHOENIX
SUPERIOR
MONTEZUMA
36
35
34
33
24-hr, 100-yr

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET _____ OF _____

CLIENT _____

DATE 31 May 91

PROJECT Upper Agua Fria R. watershed

BY GVS amDg

SUBJECT Area Wt'd. Rainfall Depths

PROJECT NO. 5-5

6-hr, 2-yr

Rainfall Depth inches	squares	% Area	Avg. Depth	Depth × % area
1.8	3	4	1.8	.07
1.6 - 1.8	8	11	1.7	.18
1.6	11	15	1.6	.23
1.5 - 1.6	29	39	1.55	.60
1.4 - 1.5	18	24	1.45	.35
1.4	6	8	1.4	.11
	75			1.55

6-hr, 100-yr

3.8	~~3.6~~	1	1	3.8	~~3.6~~	.05
3.6 - 3.8	~~3.4 - 3.6~~	4	5	3.7	~~3.5~~	.20
3.4 - 3.6	~~3.2 - 3.4~~	26	35	3.5	~~3.3~~	1.21
3.2 - 3.4	~~3.0 - 3.2~~	33	44	3.3	~~3.1~~	1.45
3.0 - 3.2	~~2.8 - 3.0~~	9	12	3.1	~~2.9~~	.37
3.0	~~2.6 - 2.8~~	2	3	3.0	~~2.7~~	.08
	~~2.4 - 2.6~~				~~2.5~~	3.37
	~~2.4~~	75			~~2.4~~	

24-hr, 2-yr

2.6	1	1	2.6	.03
2.4 - 2.6	5	7	2.5	.17
2.2 - 2.4	10	13	2.3	.31
2.0 - 2.2	28	37	2.1	.78
1.8 - 2.0	19	25	1.9	.48
1.8	12	16	1.8	.29
	75			2.06

24-hr, 100-yr

5.5	1	1	5.5	.07
5.0 - 5.5	4	5	5.25	.28
4.6 - 5.0	33	44	4.8	2.11
4.4 - 4.6	31	41	4.5	1.86
4.4	6	8	4.4	.35
	75			4.68

*** O U T P U T D A T A ***

REVISED JUNE 1988 TO UPDATE COMPUTATION OF SHORT-DURATION VALUES

PRECIPITATION FREQUENCY VALUES FOR UPPER AGUA FRIA R WATERSHED
PRIMARY ZONE NUMBER= 7
SHORT-DURATION ZONE NUMBER= 8

POINT VALUES

RETURN PERIOD

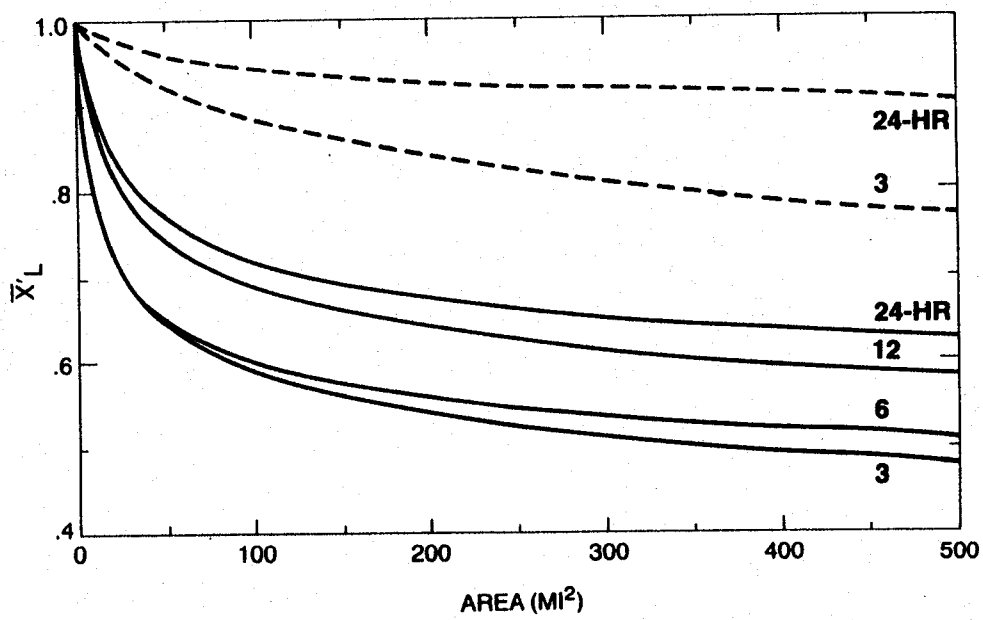
DURATION	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	
5-MIN	.37	.44	.50	.58	.64	.70	.84	5-MIN
10-MIN	.55	.67	.76	.88	.97	1.07	1.29	10-MIN
15-MIN	.67	.84	.95	1.12	1.24	1.37	1.67	15-MIN
30-MIN	.89	1.12	1.28	1.51	1.68	1.86	2.27	30-MIN
1-HR	1.09	1.38	1.58	1.87	2.10	2.33	2.85	1-HR
2-HR	1.25	1.59	1.82	2.16	2.42	2.68	3.28	2-HR
3-HR	1.35	1.72	1.98	2.35	2.64	2.92	3.58	3-HR
6-HR	1.55	1.98	2.28	2.71	3.04	3.37	4.13	6-HR
12-HR	1.80	2.34	2.70	3.22	3.62	4.02	4.95	12-HR
24-HR	2.06	2.69	3.13	3.73	4.21	4.68	5.77	24-HR

* IF YOUR SITE IS IN ARIZONA OR NEW MEXICO, PLEASE CONSULT THE FOLLOWING PAPER FOR REVISED DEPTH-AREA VALUES:
DEPTH-AREA RATIOS IN THE SEMI-ARID SOUTHWEST UNITED STATES
NOAA TECHNICAL MEMORANDUM NWS HYDRO-40
ZEHR AND MYERS
AUGUST 1984

INPUT DATA

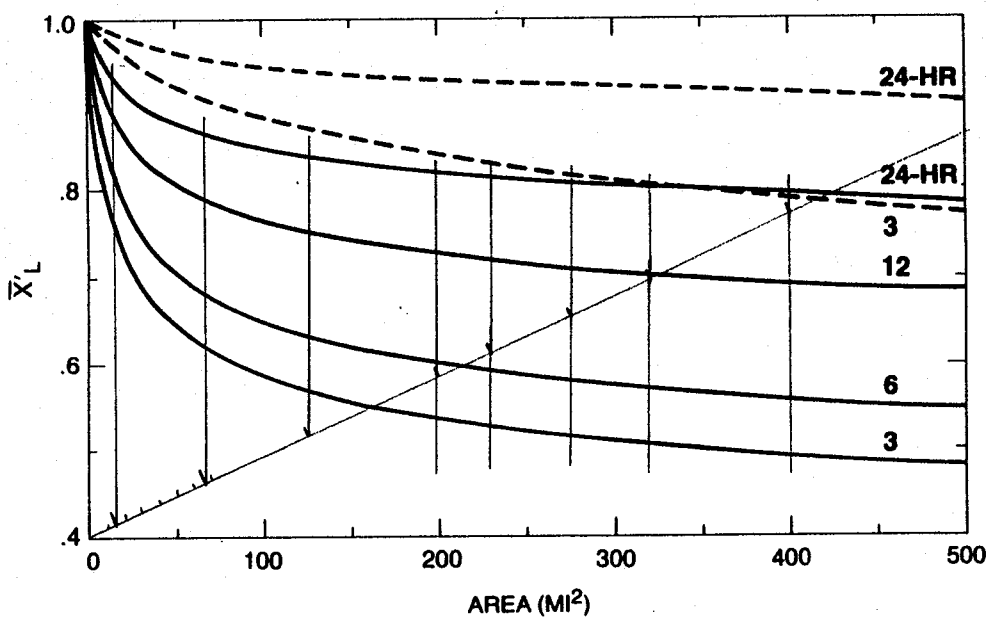
PROJECT NAME=UPPER AGUA FRIA R WATERSHED
ZONE= 7 SHORT-DURATION ZONE= 8
LATITUDE= .00 LONGITUDE= 100.00 ELEVATION= 0
2-YR, 6-HR PCPN= 1.55 100-YR, 6-HR PCPN= 3.37
2-YR, 24-HR PCPN= 2.06 100-YR, 24-HR PCPN= 4.68

**** E N D O F R U N ****



for Zones B & D

Figure 14.--$\bar{X}'_L$ (2.54-yr depth-area ratio, see sec. 4.3) for 3-, 6-, 12-, and 24-hr in southeast Arizona. Dashed lines are 3-hr and 24-hr Chicago $\bar{X}'_L$ (from TR 24)



for Zones A & C

Figure 15.--Same as figure 14, but for central Arizona.

be attributed to a mixture of storm types, but still different from these found in the central Plains.

The recorder-pair data for distances greater than 15 mi contain little information on the structure of 1- and 2-hr storms. This is supported by the low

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Agua Fria R. Watershed

Hypothetical Distributions for various return periods

Duration	Depth-Area Reduction Factor (HYDRO-40)	Rainfall Depth, inches							
		10-yr		25-yr		50-yr		100-yr	
		Point	Area	Point	Area	Point	Area	Point	Area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
5-min	.48	.50	.24	.58	.28	.64	.31	.70	.34
15-	↓	.95	.46	1.12	.54	1.24	.60	1.37	.66
1-hr	↓	1.58	.76	1.87	.90	2.10	1.01	2.33	1.12
2-	↓	1.82	.87	2.16	1.04	2.42	1.16	2.68	1.29
3-	↓	1.98	.95	2.35	1.13	2.64	1.27	2.92	1.40
6-	.55	2.28	1.25	2.71	1.49	3.04	1.67	3.37	1.85
12-	.68	2.70	1.84	3.22	2.19	3.62	2.46	4.02	2.73
24-	.78	3.13	2.44	3.73	2.91	4.21	3.28	4.68	3.65

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Partial Area Rainfall Depths

Area, sq. mi.	Maricopa County 100-yr, 6-hr = 3.37 in.			SCS Type II 100-yr, 24-hr = 4.68 in.	
	Depth-Area Factor	Area Rain in.	Pattern No.	Depth-Area Factor (HYDRO-40)	Area ~~Rain~~ Rain in.
(1)	(2)	(3)	(4)	(5)	(6)
13.0	.93	3.14	2.88	.94	4.40
65.6	.84	2.84	3.82	.86	4.02
124.1	.78	2.63	4.19	.83	3.88
199.0	.72	2.43	4.46	.82	3.84
229.6	.70	2.37	4.55	.815	3.81
274.2	.68	2.28	4.65	.81	3.79
320.3	.65	2.19	4.74	.80	3.74
400.6	.61	2.05	4.87	.79	3.70
588.	.53	1.80	5.0	.78	3.65

For Hypothetical Distribution, see next page

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Partial Area Rainfall

Hypothetical Distribution

Duration	100-yr Point Rain in.	Area, sq. mi. 13.0		65.6		124.1		199.0		229.6		274.2		320.3		400.6		588.	
		n.f.	P	n.f.	P	n.f.	P	n.f.	P	n.f.	P	n.f.	P	n.f.	P	n.f.	P	n.f.	P
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
5-min	.70	.76	.53	.62	.43	.57	.40	.53	.37	.52	.36	.51	.36	.51	.36	.49	.34	.48	.34
15-	1.37	↓	1.04	↓	.85	↓	.78	↓	.73	↓	.71	↓	.70	↓	.70	↓	.67	↓	.66
1-hr	2.33	↓	1.77	↓	1.44	↓	1.33	↓	1.23	↓	1.21	↓	1.19	↓	1.19	↓	1.14	↓	1.12
2	2.68	↓	2.04	↓	1.66	↓	1.53	↓	1.42	↓	1.39	↓	1.37	↓	1.37	↓	1.31	↓	1.29
3	2.92	↓	2.22	↓	1.81	↓	1.66	↓	1.55	↓	1.52	↓	1.49	↓	1.49	↓	1.43	↓	1.40
6	3.37	.82	2.76	.68	2.29	.63	2.12	.60	2.02	.58	1.95	.57	1.92	.56	1.89	.55	1.85	.55	1.85
12	4.02	.88	3.54	.79	3.18	.75	3.02	.73	2.93	.72	2.89	.71	2.85	.70	2.81	.69	2.77	.68	2.73
24	4.68	.93	4.35	.86	4.02	.83	3.88	.82	3.84	.81	3.79	.81	3.79	.80	3.74	.79	3.70	.78	3.65

n.f. = depth-area reduction factor from NWS HYDRO-40

P = area rainfall depth, in inches

Appendix C

Soils

Source: General Soil Map for Yavapai Co., Az. SCS 3/69

Soil Associations:

#	%	Texture	DTH	PSIF	XKSAT	RTIMP
4	65	S. Clay	.20	9.4	.02	
	35	S. Clay Loam	.25	8.6	.06	
			.22	9.1	.03	0
5	100	S. Clay Loam	.25	8.6	.06	
			.25	8.6	.06	10
7	75	S. Loam	.35	3.5	.40	
	25	Loam	.35	4.3	.25	
			.35	3.7	.36	10
8	75	Loam	.35	4.3	.25	
	25	S. Loam	.35	3.5	.40	
			.35	4.1	.29	10
10	100	Loam	.35	4.3	.25	
			.35	4.3	.25	0
11	70	S. Loam	.35	3.5	.40	
	15	C. Loam	.25	8.2	.04	
	15	Loam	.35	4.3	.25	
			.34	4.3	.32	5
12	85	S. Loam	.35	3.5	.40	
	15	Loam	.35	4.3	.25	
			.35	3.6	.38	10

SOILS (CONT.)

SUB. #	ASSOC. #	%	DTH	PSIF	XKSAT	RTIMP
1:	5	5	.25	8.6	.06	10
	7	5	.35	3.7	.36	10
	8	10	.35	4.1	.29	10
	10	10	.35	4.3	.25	0
	11	70	.34	4.3	.32	5
		SUBBASIN AVERAGE →	.34	4.3	.30	5.5
2:	5	5	.25	8.6	.06	10
	7	30	.35	3.7	.36	10
	8	5	.35	4.1	.29	10
	11	40	.34	4.3	.32	5
	12	20	.35	3.6	.38	10
			.34	4.2	.33	8.0
3:	12	5	.35	3.6	.38	10
	7	65	.35	3.7	.36	10
	11	30	.34	4.3	.32	5
			.35	3.9	.35	8.5
4:	7	50	.35	3.7	.36	10
	11	50	.34	4.3	.32	5
			.35	4.0	.34	7.5

SOILS (CONT)

SUB #	ASSOC. #	%	DTH	PSIF	XKSAT	RTIMP
5:	5	15	.25	8.6	.06	10
	7	65	.35	3.7	.36	10
	12	20	.35	3.6	.38	10
			.34	4.4	.32	10
6:	5	65	.25	8.6	.06	10
	7	35	.35	3.7	.36	10
			.29	6.9	.17	10
7:	4	20	.22	9.1	.03	0
	5	45	.25	8.6	.06	10
	11	35	.34	4.3	.32	5
			.28	7.2	.15	6.3
8:	4	35	.22	9.1	.03	0
	5	65	.25	8.6	.06	10
			.24	8.8	.05	6.5
9:	4	50	.22	9.1	.03	0
	11	15	.34	4.3	.32	5
	7	35	.35	3.7	.36	10
			.28	6.5	.19	4.3

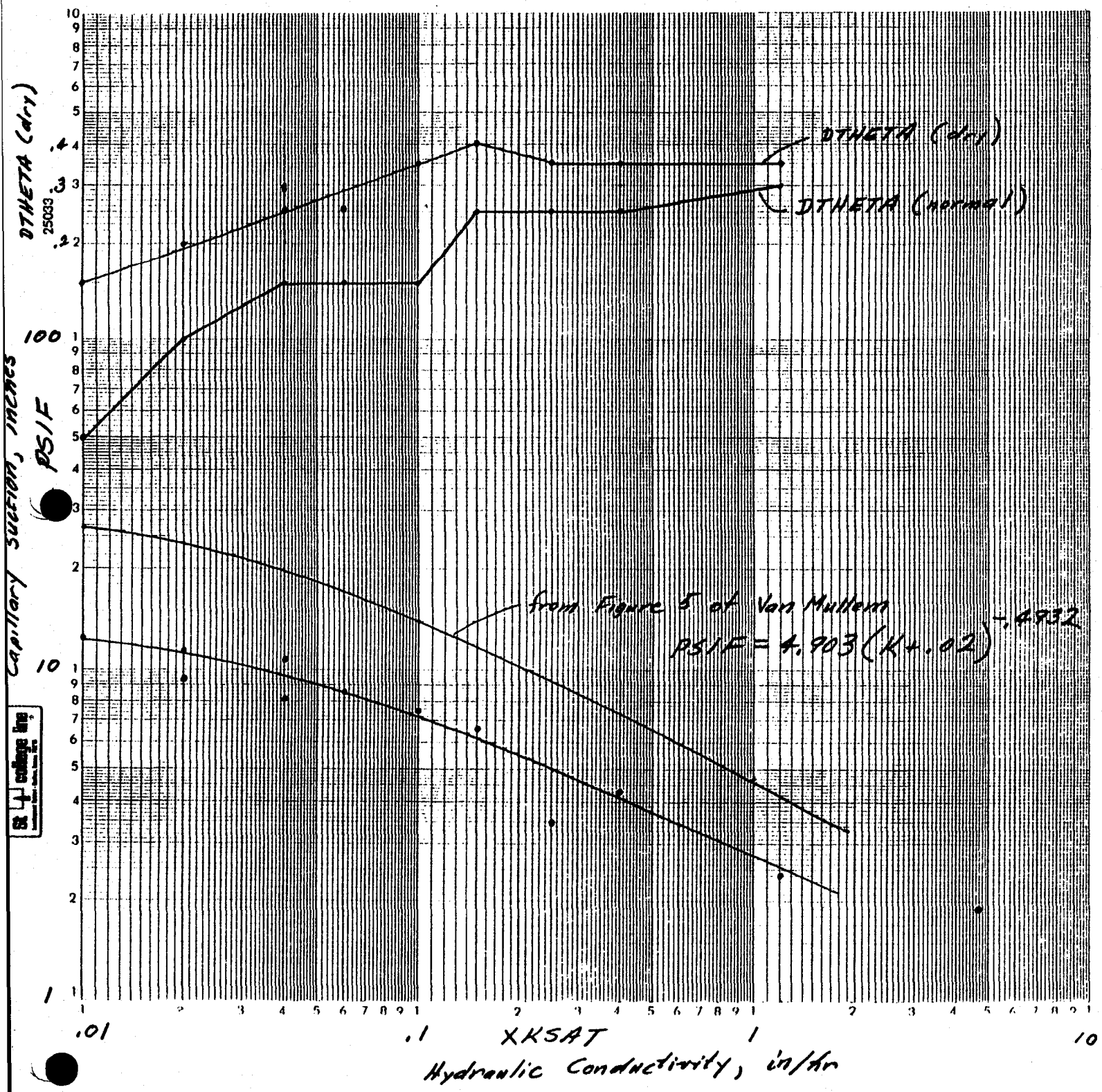
Soils (cont.)

Sub #	Assoc. #	%	DTH	PSIF	XKSAT	RTIMP
10:	4	20	.22	9.1	.03	0
	5	70	.25	8.6	.06	10
	12	10	.35	3.6	.38	10
			.25	8.2	.09	8.0
11:	7	60	.35	3.7	.36	10
	11	20	.34	4.3	.32	5
	12	20	.35	3.6	.38	10
			.35	3.8	.36	9.0

am29
25 April 91

FIGURE 1

Comparison of XKSAT vs PSIF from Table 4.2 and the relation by Van Mullem (1989)



Logarithmic 3 X 3 Cycles

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 1

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65	0	.02
		s. clay loam	35	0	.06
5	5	s. clay loam	100	5.0	.06
7	5	sandy loam	75	3.75	.40
		loam	25	1.25	.25
8	10	loam	75	7.5	.25
		sandy loam	25	2.5	.40
10	10	loam	100	10.0	.25
11	70	sandy loam	70	49.0	.40
		clay loam	15	10.5	.04
		loam	15	10.5	.25
12	0	sandy loam	85	0	.40
		loam	15	0	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	55.25
loam	.25	29.25
s. clay loam	.06	5.0
clay loam	.04	10.5
sandy clay	.02	0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.5525) + \log .25(.2925) + \log \overset{.06}{(.05)} + \log .04(.105)\right]$$
$$= .25$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	5.0	.25	5.5
linear wt'd.	.25	.34	4.3	.30	5.5

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PROJECT NO. S-5

Subbasin 2

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65	0	.02
		s. clay loam	35	0	.06
5	5	s. clay loam	100	5.0	.06
7	30	sandy loam	75	22.5	.40
		loam	25	7.5	.25
8	5	loam	75	3.75	.25
		sandy loam	25	1.25	.40
10	0	loam	100	0	.25
11	40	sandy loam	70	28.0	.40
		clay loam	15	6.0	.04
		loam	15	6.0	.25
12	20	sandy loam	85	17.0	.40
		loam	15	3.0	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	68.75
loam	.25	20.25
s. clay loam	.06	5.0
clay loam	.04	6.0
sandy clay	.02	0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.6875) + \log .25(.2025) + \log .06(.05) + \log .04(.06)\right]$$

$$\overline{XKSAT} = .29$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	4.7	.29	8.0
linear wt'd.	.25	.34	4.2	.33	8.0

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SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 3

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65		.02
		s. clay loam	35		.06
5	0	s. clay loam	100		.06
7	65	sandy loam	75	48.75	.40
		loam	25	16.25	.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	30	sandy loam	70	21.0	.40
		clay loam	15	4.5	.04
		loam	15	4.5	.25
12	5	sandy loam	85	4.25	.40
		loam	15	.75	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	74.0
loam	.25	21.5
s. clay loam	.06	0
clay loam	.04	4.5
sandy clay	.02	0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.74) + \log .25(.215) + \log .04(.045)\right]$$

$$\overline{XKSAT} = .326$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	4.5	~~.326~~ .33	8.5
linear wt'd.	.25	.35	3.9	.35	8.5

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PROJECT upper Agua Fria R. watershed

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SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 4

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65		.02
		s. clay loam	35		.06
5	0	s. clay loam	100		.06
7	50	sandy loam	75	37.5	.40
		loam	25	12.5	.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	50	sandy loam	70	35.0	.40
		clay loam	15	7.5	.04
		loam	15	7.5	.25
12	0	sandy loam	85		.40
		loam	15		.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	72.5
loam	.25	20.0
s. clay loam	.06	0
clay loam	.04	7.5
sandy clay	.02	0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.725) + \log .25(.20) + \log .04(.075)\right]$$

$$\overline{XKSAT} = .306$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	4.6	.31	7.5
linear wt'd.	.25	.35	4.0	.34	7.5

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 5

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65		.02
		s. clay loam	35		.06
5	15	s. clay loam	100	15.0	.06
7	65	sandy loam	75	48.75	.40
		loam	25	16.25	.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	0	sandy loam	70		.40
		clay loam	15		.04
		loam	15		.25
12	20	sandy loam	85	17.0	.40
		loam	15	3.0	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	65.75
loam	.25	19.25
s. clay loam	.06	15.0
clay loam	.04	
sandy clay	.02	
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.6575) + \log .25(.1925) + \log .06(.15)\right]$$

$$\overline{XKSAT} = .275$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	4.8	.28	10
linear wt'd.	.25	.34	4.4	.32	10

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SHEET ____ OF ____

CLIENT FCDMC

DATE 29 May 91

PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 6

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65		.02
		s. clay loam	35		.06
5	65	s. clay loam	100	65	.06
7	35	sandy loam	75	26.25	.40
		loam	25	8.75	.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	0	sandy loam	70		.40
		clay loam	15		.04
		loam	15		.25
12	0	sandy loam	85		.40
		loam	15		.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	26.25
loam	.25	8.75
s. clay loam	.06	65.0
clay loam	.04	
sandy clay	.02	
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.2625) + \log .25(.0875) + \log .06(.65)\right]$$

$$\overline{XKSAT} = .12$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.36	6.9	.11	10
linear wt'd.	.25	.29	6.9	.17	10

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CLIENT FCDMC

DATE 29 May 91

PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. 5-5

Subbasin 7

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	20	sandy clay	65	13.0	.02
		s. clay loam	35	7.0	.06
5	45	s. clay loam	100	45.0	.06
7	0	sandy loam	75		.40
		loam	25		.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	35	sandy loam	70	24.5	.40
		clay loam	15	5.25	.04
		loam	15	5.25	.25
12	0	sandy loam	85		.40
		loam	15		.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	24.5
loam	.25	5.25
s. clay loam	.06	52.0
clay loam	.04	5.25
sandy clay	.02	13.0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.245) + \log .25(.0525) + \log .06(.52) + \log .04(.0525) + \log .02(.13)\right]$$

$$\overline{XKSAT} = .087$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.33	7.5	.09	6.3
linear wt'd.	.25	.28	7.2	.15	6.3

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 8

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	35	sandy clay	65	22.75	.02
		s. clay loam	35	12.25	.06
5	65	s. clay loam	100	65.0	.06
7	0	sandy loam	75		.40
		loam	25		.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	0	sandy loam	70		.40
		clay loam	15		.04
		loam	15		.25
12	0	sandy loam	85		.40
		loam	15		.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	
loam	.25	
s. clay loam	.06	77.25
clay loam	.04	22.75
sandy clay	.02	~~22.84~~ ~~23.05~~
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .06(.7725) + \log .02(.2275)\right]$$

$$\overline{XKSAT} = .047$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.27	9.0	.05	6.5
linear wt'd.	.25	.24	8.8	.05	6.5

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 9

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	50	sandy clay	65	32.5	.02
		s. clay loam	35	17.5	.06
5		s. clay loam	100		.06
7	35	sandy loam	75	26.25	.40
		loam	25	8.75	.25
8		loam	75		.25
		sandy loam	25		.40
10		loam	100		.25
11	15	sandy loam	70	10.5	.40
		clay loam	15	2.25	.04
		loam	15	2.25	.25
12		sandy loam	85		.40
		loam	15		.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	36.75
loam	.25	11.0
s. clay loam	.06	17.5
clay loam	.04	2.25
sandy clay	.02	32.5
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.3675) + \log .25(.11) + \log .06(.175) + \log .04(.0225) + \log .02(.325)\right]$$

$\overline{XKSAT} = .098$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	7.2	.10	4.3
linear wt'd.	.25	.28	6.5	.19	4.3

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 10

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	20	sandy clay	65	13.0	.02
		s. clay loam	35	7.0	.06
5	70	s. clay loam	100	70.0	.06
7	0	sandy loam	75		.40
		loam	25		.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	0	sandy loam	70		.40
		clay loam	15		.04
		loam	15		.25
12	10	sandy loam	85	8.5	.40
		loam	15	1.5	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	8.5
loam	.25	1.5
s. clay loam	.06	77.0
clay loam	.04	
sandy clay	.02	13.0
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.085) + \log .25(.015) + \log .06(.77) + \log .02(.13)\right]$$

$$\overline{XKSAT} = .062$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.29	8.6	.06	8.0
linear wt'd.	.25	.25	8.2	.09	8.0

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PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT calculation of Green & Ampt parameters

PROJECT NO. S-5

Subbasin 11

Soil Association (1)	% of Assoc. in subbasin (2)	Texture in Assoc. (3)	% of Texture in Assoc. (4)	% of Texture in subbasin (5)	XKSAT (6)
4	0	sandy clay	65		.02
		s. clay loam	35		.06
5	0	s. clay loam	100		.06
7	60	sandy loam	75	45.0	.40
		loam	25	15.0	.25
8	0	loam	75		.25
		sandy loam	25		.40
10	0	loam	100		.25
11	20	sandy loam	70	14.0	.40
		clay loam	15	3.0	.04
		loam	15	3.0	.25
12	20	sandy loam	85	17.0	.40
		loam	15	3.0	.25
	100			100	

Texture	XKSAT	%
sandy loam	.40	76.0
loam	.25	21.0
s. clay loam	.06	
clay loam	.04	3.0
sandy clay	.02	
		100

$$\overline{XKSAT} = \text{antilog} \sum_i \frac{\log XKSAT_i \cdot A_i}{A_t}$$

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.76) + \log .25(.21) + \log .04(.03)\right]$$

$$\overline{XKSAT} = .338$$

Green & Ampt Parameter Values

	IA	DTHETA	PSIF	XKSAT	RTIMP
log wt'd.	.25	.35	4.4	.34	9.0
linear wt'd.	.25	.35	3.8	.36	9.0

Calculation of Single-Basin Green and Ampt parameter values

Subbasin # (1)	Subbasin Area (2)	% of each Texture in Subbasin: sandy loam (3)	loam (4)	s. clay loam (5)	clay loam (6)	sandy clay (7)	RTIMP (8)
1	37.8	55.25	29.25	5.0	10.5	0	5.5
2	85.4	68.75	20.25	5.0	6.0	0	8.0
3	80.3	74.0	21.5	0	4.5	0	8.5
4	46.1	72.5	20.0	0	7.5	0	7.5
5	44.6	65.75	19.25	15.0	0	0	10.0
6	30.6	26.25	8.75	65.0	0	0	10.0
7	61.9	24.5	5.25	52.0	5.25	13.0	6.3
8	58.5	0	0	77.25	0	22.75	6.5
9	13.0	36.75	11.0	17.5	2.25	32.5	4.3
10	65.6	8.5	1.5	77.0	0	13.0	8.0
11	64.2	76.0	21.0	0	3.0	0	9.0
							7.8 = area wt'd. avg.
Area of each Texture =		284.1	85.2	162.9	21.6	34.1	Total = 587.9 OK
% of each Texture =		48.3	14.5	27.7	3.7	5.8	Total = 100.0 OK

$$\overline{XKSAT} = \text{antilog}\left[\log .40(.483) + \log .25(.145) + \log .06(.277) + \log .04(.037) + \log .02(.058)\right] = .171$$

$$\overline{XKSAT} = .17$$

Single-Basin Green & Ampt parameters

IA	DTHETA	PSIF	XKSAT	RTIMP
.25	.39	5.9	.17	7.8

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Agua Fria R. Watershed

Green and Ampt Parameters

Subbasin	IA	RTIMP	Linear Area Wt'd. Avg.			Log. Area Wt'd. Avg.			XKSAT (log. avg.) with various % Vegetation Cover			
			DTHETA	PSIF	XKSAT	DTHETA	PSIF	XKSAT	20%	30%	40%	100%
	in.	%		in.	in/hr		in.	in/hr				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	.25	5.5	.34	4.3	.30	.35	5.0	.25	.28	.31	.33	.50
2	.25	8.0	.34	4.2	.33	.35	4.7	.29	.32	.35	.39	.58
3	.25	8.5	.35	3.9	.35	.35	4.5	.33	.37	.40	.44	.66
4	.25	7.5	.35	4.0	.34	.35	4.6	.31	.34	.38	.41	.62
5	.25	10.0	.34	4.4	.32	.35	4.8	.28	.31	.34	.37	.56
6	.25	10.0	.29	6.9	.17	.36	6.9	.11	.12	.13	.15	.22
7	.25	6.3	.28	7.2	.15	.33	7.5	.09	.10	.11	.12	.18
8	.25	6.5	.24	8.8	.05	.27	9.0	.05	.06	.06	.07	.10
9	.25	4.3	.28	6.5	.19	.35	7.2	.10	.11	.12	.13	.20
10	.25	8.0	.25	8.2	.09	.29	8.6	.06	.07	.07	.08	.12
11	.25	9.0	.35	3.8	.36	.35	4.4	.34	.38	.42	.45	.68

Appendix D

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

SHEET ____ OF ____

CLIENT ____

DATE 30 May 91

PROJECT upper Agua Fria R. watershed

BY GVS amDg

SUBJECT S-Graphs

PROJECT NO. 5-5

The following S-graphs are viable candidates for the watershed:

1. Phoenix Mtn. #57
2. Agua Fria R. at Avondale (Dec 1967) #21
3. Agua Fria R. at Avondale (Sept 1970) #22
4. Avg. for Arizona #61
5. Avg. Mtn. #62

Selection of K_n: The following data are available for estimating K_n:

1. $K_n = .059$ for S-graph #21 (Ref.- S-Graph Report, Table 7)
2. $K_n = .043$ for S-graph #22 (Ref.- S-Graph Report, Table 7)
3. $K_n = .053$ for Agua Fria R. nr. Mayer (Ref.- USBR Flood Hydrology Manual, Table 4-3)

An $K_n = .043$ will be used for all S-graphs when used with a 6-hr storm. This is consistent with the rainfall duration for Sept. 1970.

$K_n = .059$ will be used for all S-graphs when used with a 24-hr storm. This is consistent with the rainfall duration for Dec. 1967.

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

CLIENT ____ PROJECT ____ SUBJECT ____

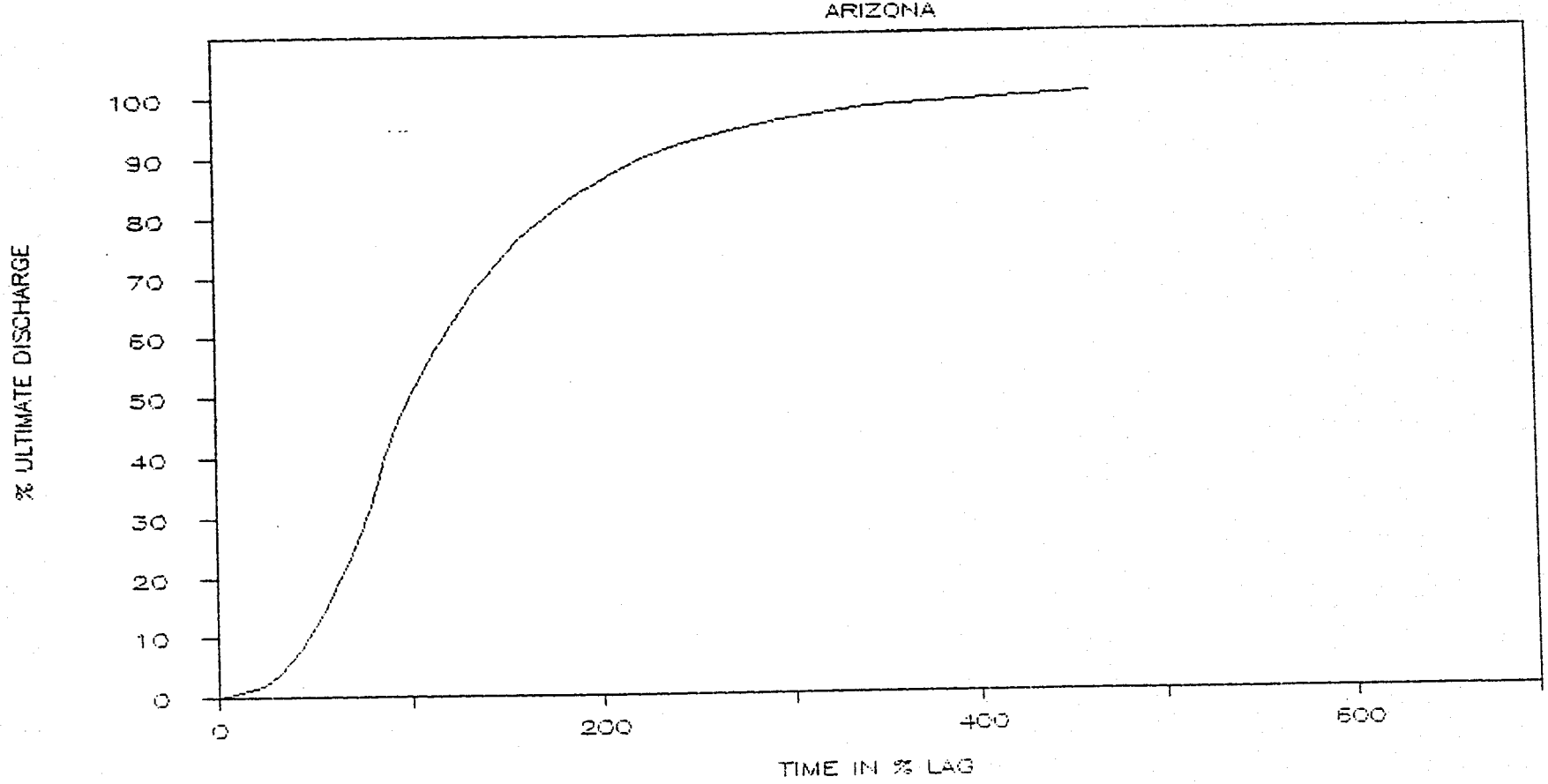
SHEET ____ OF ____ DATE ____ BY ____ PROJECT NO. ____

Calculation of S-graph $Lag = 24 K_n \left(L L_{ca} / S^{1/2} \right)^{.38}$

Subbasin #	A sq. mi.	L mi.	L_{ca} mi.	S ft/mi	6-hr storm K_n	6-hr storm Lag hrs	24-hr storm K_n	24-hr storm Lag hrs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	37.8	9.67	4.33	175	.043	1.60	.059	2.20
2	85.4	18.15	10.26	142	↓	2.93	↓	4.02
3	80.3	17.56	9.47	113	↓	2.93	↓	4.02
4	46.1	14.20	6.51	155	↓	2.21	↓	3.03
5	44.6	15.59	8.68	167	↓	2.52	↓	3.46
6	30.6	8.29	3.95	97	↓	1.63	↓	2.24
7	61.9	14.20	8.68	84	↓	2.77	↓	3.80
8	58.5	12.11	7.89	198	↓	2.14	↓	2.94
9	13.0	5.52	2.25	47	↓	1.29	↓	1.77
10	65.6	17.36	11.84	161	↓	2.97	↓	4.08
11	64.2	23.67	14.20	93	↓	3.98	↓	5.46
	588							
Single-basin	588	$L L_{ca} / S^{1/2} = 63.2$ (USBR- Table 4-3)						
		42.0	14.0	87.1	.043	4.99	.059	6.84

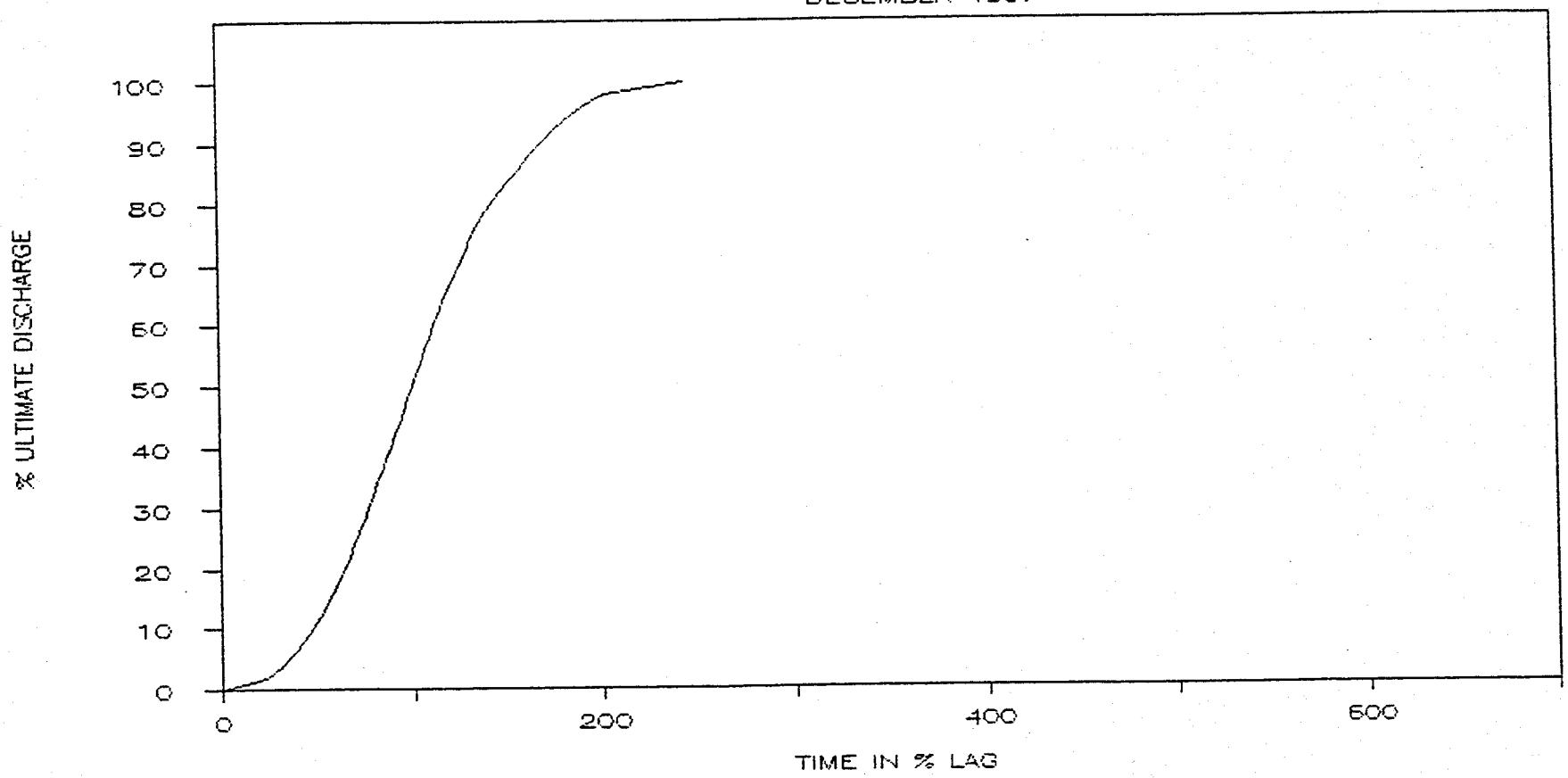
#57 PHOENIX MOUNTAIN

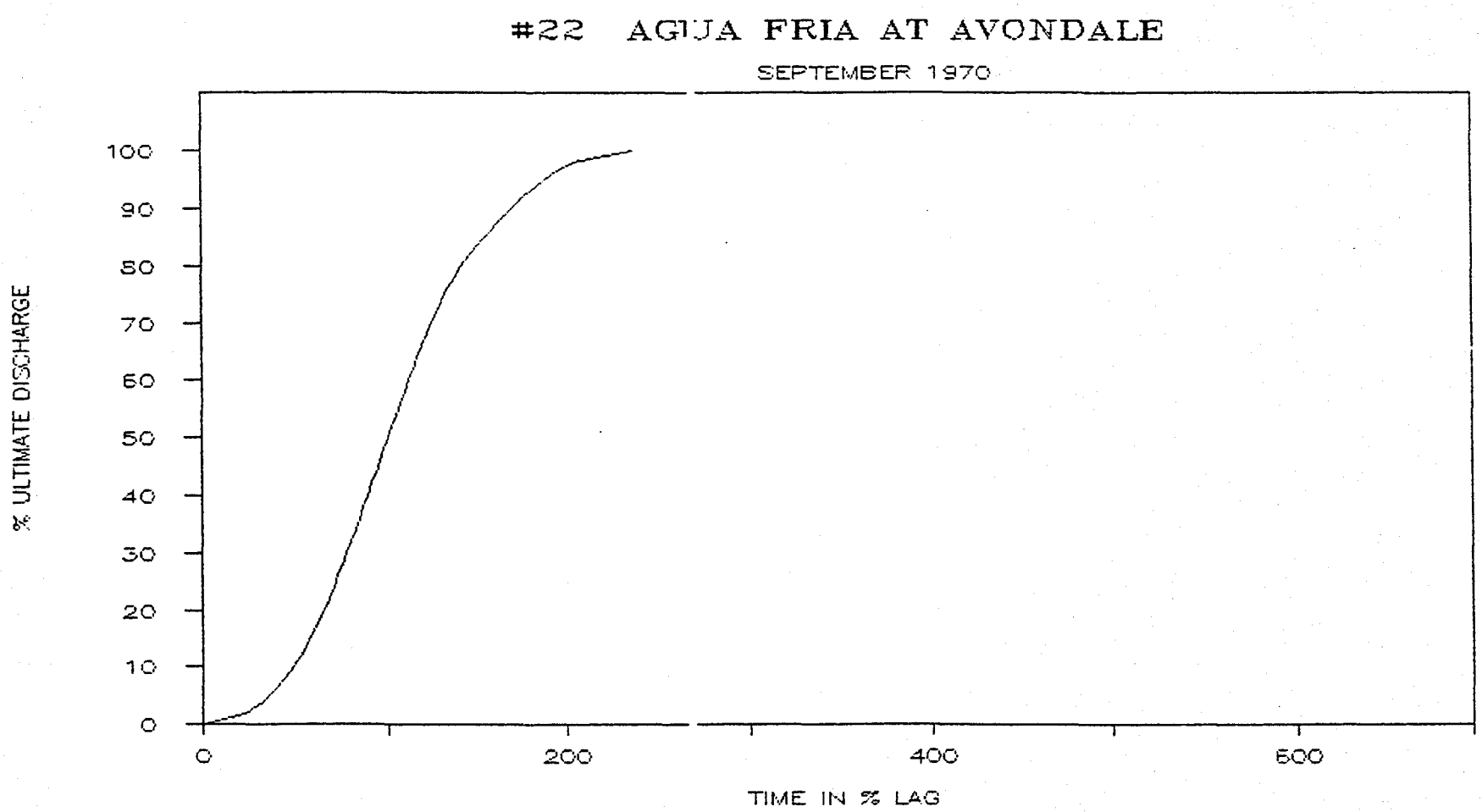
ARIZONA

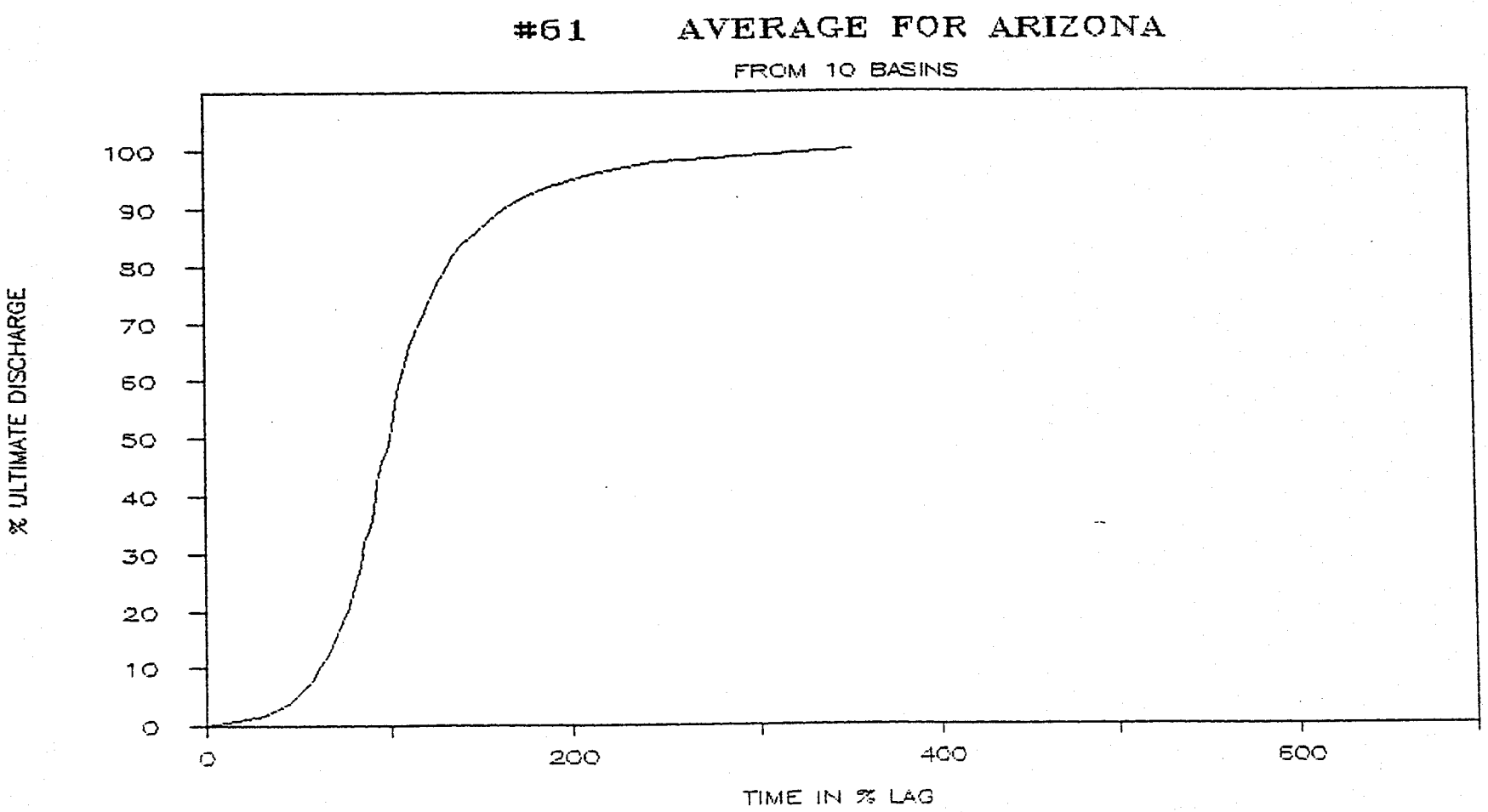


#21 AGUA FRIA AT AVONDALE

DECEMBER 1967




#22 AGUA FRIA AT AVONDALE
SEPTEMBER 1970
% ULTIMATE DISCHARGE
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
TIME IN % LAG


#61 AVERAGE FOR ARIZONA
FROM 10 BASINS
% ULTIMATE DISCHARGE
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
TIME IN % LAG

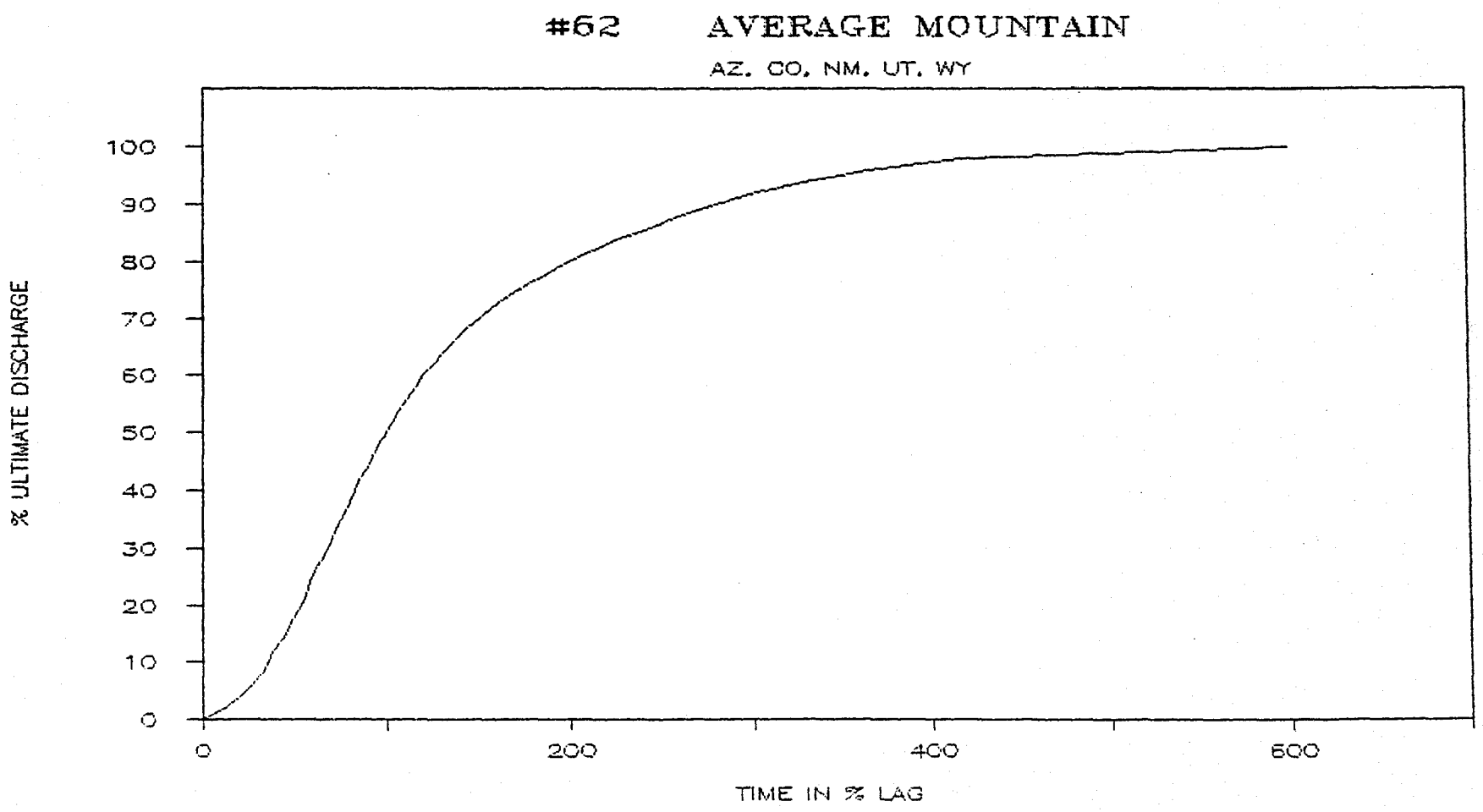

#62 AVERAGE MOUNTAIN
AZ. CO. NM. UT. WY
% ULTIMATE DISCHARGE
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
TIME IN % LAG

Table 7.- Watershed characteristics for the individual S-graphs that were developed from flood reconstitutions and have been compiled in this report.

S-graph No.	A	L	L_{ca}	S	n[1]	Lag	RIMP	Watershed Elevation Min	Watershed Elevation Max	Type of Watershed or Geographical Name
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	187.0	47.6	20.7	83.4	.062	8.85	5	1,190	5,160	New River Mtns. and alluvial fan
2	187.0	47.6	20.7	83.4	.038	5.38	5	1,190	5,160	New River Mtns. and alluvial fan
3	64.6	17.6	9.9	101.9	.042	2.95	5	1,460	3,250	Tonto National Forest and alluvial fan
4	64.6	17.6	9.9	101.9	.031	2.19	5	1,460	3,250	Tonto National Forest and alluvial fan
5	70.0[2]	26.0	11.8	75.9	.054	4.99	5	1,243	3,220	Union Hills and alluvial fan
6	70.0[2]	26.0	11.8	75.9	.063	5.88	5	1,243	3,220	Union Hills and alluvial fan
7	0.51	1.5	.75	67.0	.076	.86	5	1,720	1,820	Alluvial fan
8	0.51	1.5	.75	67.0	.084	.95	5	1,720	1,820	Alluvial fan
9	0.51	1.5	.75	67.0	.070	.79	5	1,720	1,820	Alluvial fan
10	0.13	.77	.39	16.0	.107	.96	25	----	----	Fully urbanized, residential
11	0.13	.77	.39	16.0	.111	1.00	25	----	----	Fully urbanized, residential
12	67.3	20.2	9.7	141.4	.037	2.59	5	2,310	5,170	New River Mountains
13	67.3	20.2	9.7	141.4	.036	2.50	5	2,310	5,170	New River Mountains
14	85.7	26.2	12.4	121.6	.049	4.25	5	1,973	5,160	New River Mountains
15	85.7	26.2	12.4	121.6	.031	2.72	5	1,973	5,160	New River Mountains
16	142.0	27.7	13.6	64.2	.077	8.02	5	1,280	3,060	Phoenix Mountain and alluvial fan
17	142.0	27.7	13.6	64.2	.070	7.31	5	1,280	3,060	Phoenix Mountain and alluvial fan
18	142.0	27.7	13.6	64.2	.030	3.10	5	1,280	3,060	Phoenix Mountain and alluvial fan
19	323.0	55.5	20.6	73.6	.069	10.59	5	1,046	4,080	New River Mtns. and alluvial fan
20	323.0	55.5	20.6	73.6	.045	6.90	5	1,046	4,080	New River Mtns. and alluvial fan
21	718.0[3]	61.0	27.2	68.9	.059	10.68	5	950	5,150	New River Mtns. and alluvial fan
22	718.0[3]	61.0	27.2	68.9	.043	7.80	5	950	5,150	New River Mtns. and alluvial fan

Table 4-3.—Unit hydrograph lag data for the Southwest Desert, Great Basin, and Colorado Plateau.

Index No.	Station and location	Drainage area, mi²	Basin factor, $LL_{ca}/S^{0.5}$	Lag time, L_g, hours	K_n	C_t
1	Salt River at Roosevelt, AZ	4341.0	1261.0	16.0	0.058	1.51
2	Verde R. above E. Verde and below Jerome, AZ	3190.0	760.0	12.0	.052	1.35
3	Tonto Cr. above Gun Cr., AZ	678.0	66.3	6.5	.063	1.64
4	Agua Fria R. nr. Mayor, AZ	590.0	63.2	5.4	.053	1.38
5	San Gabriel R. at San Gabriel Dam, CA	162.0	14.4	3.3	.053	1.38
6	West Fk. San Gabriel R. at Cogswell Dam, CA	40.4	1.8	1.6	.051	1.33
7	Santa Anita Cr. at Santa Anita Dam, CA	10.8	0.6	1.1	.050	1.30
8	Sand Dimas Cr. at San Dimas Dam, CO	16.2	2.0	1.5	.046	1.20
9	Eaton Wash at Eaton Wash Dam, CA	9.5	1.3	1.3	.046	1.20
10	San Antonio Cr. nr. Claremont, CA	16.9	0.6	1.2	.055	1.43
11	Santa Clara R. nr. Saugus, CA	355.0	48.2	5.6	.060	1.56
12	Temecula Cr. at Pauba Canyon, CA	168.0	24.1	3.7	.050	1.30
13	Santa Margarita R. nr. Fallbrook, CA	645.0	99.2	7.3	.062	1.61
14	Santa Margarita R. at Ysidora, CA	740.0	228.0	9.5	.061	1.59
15	Live Oak Cr. at Live Oak Dam, CA	2.3	0.2	0.8	.052	1.35
16	Tujunga Cr. at Big Tujunga Dam, CA	81.4	6.5	2.5	.052	1.35
17	Murrieta Cr. at Temecula, CA	220.0	28.9	4.0	.051	1.33
18	Los Angeles R. at Sepulveda Dam, CA	152.0	14.3	3.5	.056	1.46
19	Pacoima Wash at Pacoima Dam, CA	27.8	6.8	2.4	.049	1.27
20	East Fullerton Cr. at Fullerton Dam, CA	3.1	0.5	0.6	.029	0.75
21	San Jose Cr. at Workman Mill Rd. CA	81.3	24.8	2.4	.032	0.83
22	San Vincente Cr. at Foster, CA	75.0	12.8	3.2	.053	1.38
23	San Diego R. nr. Santee, CA	380.0	95.4	9.2	.078	2.03
24	Deep Cr. nr. Hesperia, CA	137.0	28.1	2.8	.036	0.94
25	Bill Williams R. at Planet, AZ	4730.0	1476.0	16.2	.056	1.46
26	Gila R. at Conner No. 4 Damsite, AZ	2840.0	1722.0	21.5	.071	1.85
27	San Francisco R. at Jct. with Blue R., AZ	2000.0	1688.0	20.6	.068	1.77
28	Blue R., nr. Clifton, AZ	790.0	352.0	10.3	.057	1.48
29	Moencopi Wash nr. Tuba City, AZ	2490.0	473.0	9.2	.046	1.20
30	Clear Cr. nr. Winslow, AZ	607.0	570.0	11.2	.053	1.38
31	Puerco R. nr. Admana, AZ	2760.0	1225.0	15.9	.058	1.51
32	Plateau Cr. nr. Cameo, CO	604.0	89.9	7.9	.069	1.79
33	White R. nr. Watson, UT	4020.0	1473.0	15.7	.054	1.40
34	Paria R. at Lees Ferry, AZ	1570.0	296.0	10.2	.060	1.56
35	New River at Rock Springs, AZ	67.3	16.5	3.1	.047	1.22
36	New River at New River, AZ	85.7	26.3	3.7	.048	1.25
37	New R. at Bell Road nr. Phoenix, AZ	187.0	108.0	5.3	.043	1.12
38	Skunk Cr. nr. Phoenix, AZ	64.6	18.7	2.4	.035	0.91

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