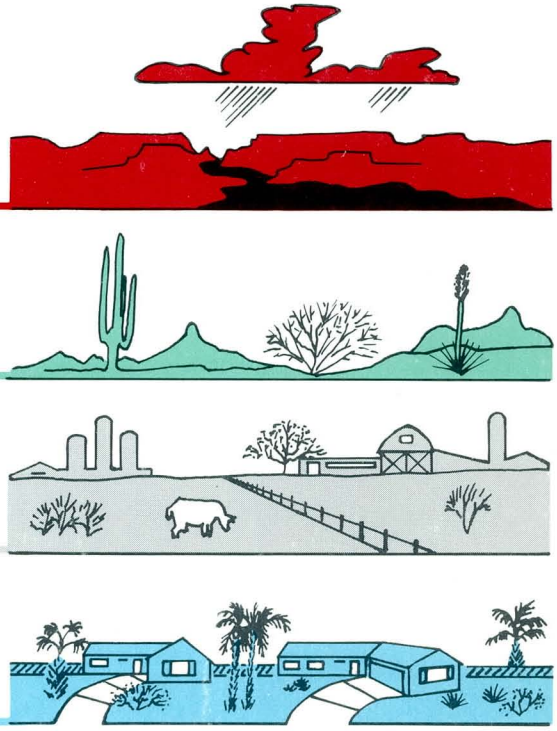

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

A HYDROLOGIC ANALYSIS
OF
GRASS WASH WATERSHED

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Report on

A HYDROLOGIC ANALYSIS OF GRASS WASH WATERSHED

Prepared by

Flood Control District of Maricopa County
Hydrology Division
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May 1989

A HYDROLOGIC ANALYSIS
OF
GRASS WASH WATERSHED

TABLE OF CONTENTS

List of Tables iii

List of Figures v

I. INTRODUCTION 1

A. Purpose 1

B. Study Area 1

II. MODELING ASSUMPTIONS 3

A. Watershed Delineation 3

B. Soils 4

C. Topography 4

III. MODEL INPUT 5

A. Precipitation 5

B. Rainfall Excess 5

C. Unit Hydrographs 6

D. Channel Routing 6

IV. DISCUSSION 9

V. CONCLUSION 11

VI. REFERENCES 12

Appendix A : Precipitation Data App-1

Appendix B : Clark Unit Hydrograph Determination App-6

Appendix C : S-Graph Unit Hydrograph Determination App-9

Appendix D : Channel Routing Determination App-28

Appendix E : HEC-1 Output App-30

Plate 1 : Drainage Map

LIST OF TABLES

Table		Page
1	Summary Table Estimated Input Parameters for HEC-1 Program	7
2	Summary Table Estimated Input Parameters for HEC-1 Program Continued for Muskingum Routing	8
3	Unit Dischage and Excess Grass Wash Watershed	10
A-1	100 Year Precipitation for Grass Wash Watershed	App-2
A-2	SCS Type II Rainfall Distribution	App-4
B-1	Storage Coefficient Estimation	App-8
C-1	Basin Lag Estimation	App-10
C-2	Manning's n Coefficient Grass Wash Hydrology	App-11
C-3	Unit Hydrograph for Watershed 1 Grass Wash Hydrology	App-13
C-4	Unit Hydrograph for Watershed 2 Grass Wash Hydrology	App-14
C-5	Unit Hydrograph for Watershed 3 Grass Wash Hydrology	App-15
C-6	Unit Hydrograph for Watershed 4a Grass Wash Hydrology	App-16
C-7	Unit Hydrograph for Watershed 4b Grass Wash Hydrology	App-17
C-8	Unit Hydrograph for Watershed 5 Grass Wash Hydrology	App-18

Table		Page
C-9	Unit Hydrograph for Watershed 6 Grass Wash Hydrology	App-19
C-10	Unit Hydrograph for Watershed 7b Grass Wash Hydrology	App-20
C-11	Unit Hydrograph for Watershed 8a Grass Wash Hydrology	App-21
C-12	Unit Hydrograph for Watershed 8b Grass Wash Hydrology	App-22
C-13	Unit Hydrograph for Watershed 10 Grass Wash Hydrology	App-23
C-14	Unit Hydrograph for Watershed 11 Grass Wash Hydrology	App-24
C-15	Unit Hydrograph for Watershed 14 Grass Wash Hydrology	App-25
C-16	Unit Hydrograph for Watershed 15 Grass Wash Hydrology	App-26
C-17	Unit Hydrograph for Watershed 18 Grass Wash Hydrology	App-27

LIST OF FIGURES

Figure		Page
1	Location Map Grass Wash Watershed	2
A-1	100 Year, 24 Hour Precipitation Grass Wash Hydrology	App-3
A-1	Depth-Area Ratio Areal Reduciton	App-5
B-1	Time of Concentration Clark Method	App-7
C-1	SCS Dimensionless Unit Hydrograph #75	App-12
D-1	Estimation of Velocity Muskingum Routing	App-29

I. INTRODUCTION

A. Purpose

The purpose of this study is to develop estimates of the flood generated by a 100-year, 24 hour storm. This hydrology will be used initially for a flood insurance study for Grass Wash, and in the future for drainage master studies, or public projects that might occur in this watershed.

B. Study Area

Grass Wash is an ephemeral stream in northwest Maricopa County. The town of Aguila, located 25 miles west of Wickenburg, is located near the confluence for Grass Wash and Centennial Wash (see Figure 1). Grass Wash flows northwesterly through Aguila to its confluence with Centennial Wash.

The Grass Wash watershed, is contained within the Flood Control District's planning area, Upper Centennial (#5). The watershed is roughly 143 square miles in size at Aguila. The length of the main channel is less than 9 miles in length. The mean elevation of the watershed is estimated at 2260 feet, ranging from 2160 to 4490 feet with an average slope is 0.52 %.

The watershed is characterized by broad alluvial slopes prone to sheet flow. Generally, the channels on this watershed are of a distributary nature. It is anticipated that significant ponds will form in the vicinity of roadway, railroad and irrigation ditch embankments. It should be noted that for the purposes of this study we had insufficient data from which to flood route through these ponded areas, but anticipate with the development of a flood insurance study that these features might be considered for inclusion to the model. The vegetation is predominantly desert brush and cactus with varying cover densities.

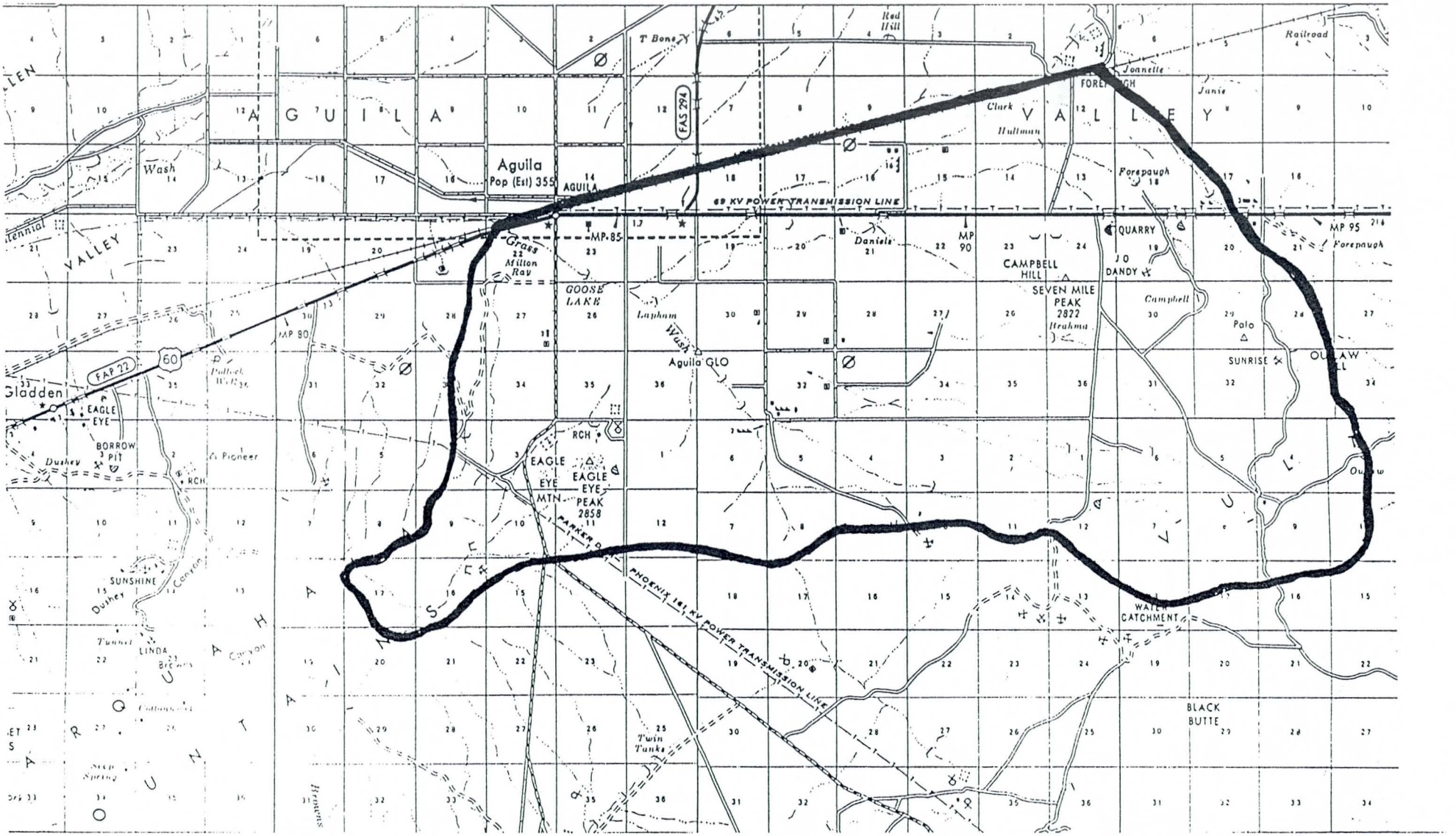


Figure - 1
Location Map
Grass Wash Watershed

II. MODELING ASSUMPTIONS

The hydrologic analysis simulated the rainfall/runoff response for the 100 year, 24 hour storm. This relationship was simulated using the U.S. Army Corps of Engineers HEC-1 computer program (Reference 1).

A. Watershed Delineation

The delineation of the Grass Wash watershed and subwatershed boundaries was determined using two 15 minute USGS topographic maps. They were the Aguila, Ariz. and the Vulture Mountains, Ariz. quadrangles (see Plate 1).

The following assumptions were made in the watershed delineation:

- Natural topographic high points formed the watershed boundary to the south, east and west, however the north boundary was the Atchison, Topeka and Santa Fe Railway.

- Internal boundaries to the overall watershed were determined based on topographic high points as identified on USGS quadrangles. An exception to this rule was an agricultural berm located in T7N, R8W, Sec 10 & 15. The impact this berm had was to divert flows in the vicinity of this berm south of US 60 versus a natural flow path north of US 60.

- Due to the significant differences in modeling assumptions for agricultural fields versus desert range land uses, the agricultural fields were modeled as separate subbasins rather than lumping them into a larger mixed land use subbasin.

These assumptions were confirmed by field work or by the use of 1974 aerial photos on file at the Maricopa County Highway Department. The aerial photos were helpful in determining the direction of flow for channels that were discontinuous on the topographic map, or obliterated by other uses.

The total watershed area was 143.03 square miles as measured by a planimeter. The watershed was subdivided into 21 subwatersheds ranging in size from 0.73 square miles (468 acres) to 11.67 square miles (7466 acres).

B. Soils

The general soil group in the Grass Wash Watershed was the Mohave-Continental-Guest unit, as was determined using the Soil Survey of Aquila-Carefree Area, Parts of Maricopa And Pinal County, Arizona (Reference 2). Mohave-Continental-Guest soils are characterized by dominantly gently sloping to moderately steep, very gravelly, clayey and loamy soils; on fan terraces. The unit consists of approximately 41 percent Mohave soils , 21 percent Continental soils, 22 percent Guest soils, and the remaining 16 percent are components of minor extent.

The Mohave soils and the Continental soils are on fan terraces, whereas the Guest soils are on flood plains. All were formed in alluvium derived dominantly from acid and basic igneous rocks. Of minor extent were the Eba soils on fan terraces and Anthony, Arizo, and Gila soils on flood plains.

C. Topography

Estimates of subbasin slope, were developed from the USGS quadrangles for the area. The initial estimates for slope were in the units feet/mile. Values of percent slope in this model were converted from these initial estimates.

III. MODEL INPUT

A. Precipitation

The 100 year, 24 hour storm was estimated as 4.10 inches total depth, utilizing precipitation determination procedures as described in the manual Hydrologic Design for Highway Drainage in Arizona (see Appendix A). Rainfall was temporaly distributed using the SCS Type II rainfall with a 15 minute input step.

Areal Reduction was used to adjust point rainfall to the entire watershed. The procedure recommended for areal reduction is from the NOAA Technical Memorandum NWS HYDRO - 40 (see Appendix A). The memo utilizes the data from the Walnut Gulch Experimental watershed to develop the curves to be used from the Southwest region of the United States. The memo did not provide a regression equation for the curves, but only a graph. As a result, a uniform set of ratios for a storm with a duration of 24 hours was determined In-house. The ratios used for areal reduction are listed below.

Square Mile	Ratio
10	.95
20	.92
30	.90
40	.89
50	.88
60	.87
70	.86
80	.86
90	.85
100	.85

B. Rainfall Excess

The "initial and uniform" loss rate method of HEC-1 was utilized to generate rainfall excess. The parameters for the initial and uniform rates were developed as outlined in the Preliminary Outline - Maricopa County Hydrology Manual (Reference 4) referred to as the Hydrology Manual. The range of values used in this method were 0.65 - 1.00 inches for the initial loss, and 0.12 - 0.27 inches/hour for the uniform loss rate.

C. Unit Hydrograph

The modeling procedures for Grass Wash were based on the methods described in the draft Hydrology Manual for Maricopa County. The Hydrology Manual suggests unit hydrograph procedures which are based on basin area. It is suggested that the Clark Unit Hydrograph be used for basins of less than 5 square miles. For areas larger than 5 square miles unit hydrographs are converted from appropriate S-graphs.

Two input variables were needed for the Clark Unit Hydrograph, time of concentration (Tc), and the storage coefficient (R). The Tc parameter for subwatersheds of less than 5 square miles in area was determined graphically from Figure B-1, Time of Concentration for Drainage Area Less than 10 Square Miles (see Appendix B). This parameter was then used to calculate R using the equation R=0.37*Tc**1.11*A**-0.57*L**0.80 A definition of the variables is included in Appendix B.

The S-Graph method was used for basins exceeding 5 square miles. The conversion of an S-Graph to a unit hydrograph requires an estimate of lag. By definition lag is the elapsed time from the beginning of an assumed continuous series of unit rainfall excess increments over the entire basin to the instant when the rate of resulting runoff equals 50 percent of the basin ultimate discharge. The lag was estimated by the equation LAG=20n(L*Lca/S**0.5)**0.38, an explanation of the variables is included in Appendix C. The variables were determined directly from the delineated map and the Manning's coefficient n was taken from a table of uniform flow in open channels from the Handbook of Hydraulics (see Appendix C).

The conversion of the S-Graph to a unit hydrograph can be a tedious hand calculation. This process was facilitated by the computer program NUMB75.HEC, a program written by Tim Sutko, and modified by Tom Hieb of the Flood Control District. The S-Graph (#75) was used and is based on the SCS dimensionless curve (see Appendix C).

D. Channel Routing

Muskingum routing was used to simulate channel flow through each subwatershed. The Muskingum 'X' coefficient was set equal to 0.2. Due to the broad shallow sheet flow conditions travel times were estimated using overland flow velocities as defined on Average velocities for estimating travel time for shallow concentrated flow (see Appendix D).

This travel time was assumed to be the 'K' value used in the method. Once detailed cross-sections are developed in the flood insurance study it would be beneficial to examine the use of normal depth routing for Grass Wash, possibly including a loss rate parameter to better account flood volume and peak attenuation.

Table 1

Summary Table
Estimated Input Parameters
for HEC-1 Program

Time Specification (IT) = 10 minutes
Time Interval - Input Data (IN) = 15 minutes

Subbasin	Basin Area	Clark Parameters		S-Graph Parameters	Loss Rate Parameters	
	sq.mi.	Tc hours	R -	Lag minutes	STRTL inches	CNSTL in/hr
1	6.87	-	-	138.60	0.846	0.25
2	11.67	-	-	172.20	0.816	0.23
3	10.67	-	-	178.20	0.840	0.25
4A	5.76	-	-	1156.00	0.648	0.17
4B	10.88	-	-	141.00	0.850	0.25
5	7.22	-	-	162.00	0.850	0.25
6	7.22	-	-	181.80	1.000	0.25
7A	4.06	0.48	0.18	-	0.650	0.05
7B	9.56	-	-	134.40	0.816	0.23
8A	5.20	-	-	105.60	0.716	0.12
8B	9.71	-	-	174.00	0.850	0.25
9	4.33	1.94	1.25	-	0.840	0.25
10	10.73	-	-	181.80	0.830	0.24
11	11.58	-	-	193.80	0.850	0.25
12	3.62	1.88	0.70	-	1.000	0.25
13	2.46	1.75	0.72	-	0.960	0.25
14	5.70	-	-	124.80	0.850	0.27
15	5.12	-	-	110.40	0.846	0.25
16	0.73	0.40	0.24	-	0.850	0.25
17	4.71	1.98	0.89	-	1.000	0.25
18	5.23	-	-	136.20	0.840	0.26

Table 2

Summary Table
Estimated Input Parameters
for HEC-1 Program
Continued for Muskingum Routing

NMIN = 10
X-Coeff = 0.2

Routing Reach	Length feet	Integer Steps	K-Coeff hours
R1	1030	1	0.24
R2	6000	5	1.67
R4A	24300	18	6.75
R7A	21500	10	3.73
R8A	26500	16	5.66
R9	1500	2	0.42
R11	6800	6	1.89
R16	24500	19	6.81
R17	19500	15	5.42
RA	11700	9	3.25
RB	7600	6	2.11
RC	3100	3	0.86
RD	20000	15	5.56
RE	10800	8	3.00
RF	50	1	0.01
RI	2000	2	0.56
RJ	7700	6	2.14

IV. DISCUSSION

Peak discharge for Grass Wash at Aquila was estimated to be 11,401 cfs with areal reduction, which seemed reasonable. The discharge per square mile for this 143 square mile watershed was 79 cfs per square mile, with a total excess of 1.38 inches. The excess rainfall volume was equivalent to the excess generated by a curve number of approximately 75.

Subbasin discharges likewise were reasonable with the discharge per square mile varying based on subbasin size, and watershed condition. The highest unit discharge was 1635 cfs per square mile from subbasin 7A, which was a mountainous area roughly 4.1 square miles in size. The lowest subbasin unit discharge was 252 cfs per square mile from subbasin 11, which was 11.6 square miles in size and was mainly an alluvial area. A more detailed look at unit discharge and excess is provided on Table 1.

As a final check on the discharge at Aquila, comparisons were made with previous studies, and regional regression equations. The first source was Methods for Estimating the Magnitude and Frequency of Floods in Arizona, which produced an estimate of 14,385 cfs. The second source was entitled Estimation of Magnitude and Frequency of Floods in Pima County, Arizona, with Comparisons of Alternative Methods. Initially we felt that the second estimate would provide an upper boundary for our results since Pima County receives significantly more rainfall than Maricopa County, and we would not expect our results to exceed these values. This method yielded a peak flow value of 8,445 cfs, however it was realized later that our shape factor (Sh), was outside the population used in the method, thus invalidating this application. Finally, the peak discharge for Grass Wash without areal reduction was 14,660 cfs, and in the previous FEMA study for Grass Wash the peak discharge was 14,440 cfs.

As noted in this analysis two modifications to these results might be reviewed once detailed topographic data is obtained. The first would be a flood storage routing of Grass Wash at U.S. 60. The second would be use of a normal depth routing, possibly incorporating a channel loss rate function for the main channel of Grass Wash.

Table 3

Unit Discharge and Excess
Grass Wash Watershed

SUBBASIN	PEAK Q	AREA	UNIT DISHCARGE	TOTAL EXCESS
	cfs	sq.mi.	cfs/sq.mi.	inches
1	2422	6.87	352.55	1.61
2	3378	11.67	289.46	1.63
3	2952	10.67	276.66	1.61
4A	2032	5.76	352.78	1.86
4B	3747	10.88	344.39	1.60
5	2198	7.22	304.43	1.61
6	1934	7.22	267.87	1.58
7A	6638	4.06	1634.98	2.58
7B	3536	9.56	369.87	1.65
8A	2752	5.20	529.23	2.06
8B	2747	9.71	282.90	1.61
9	1849	4.33	427.02	1.63
10	2935	10.73	273.53	1.62
11	2923	11.58	252.42	1.59
12	1977	3.62	546.13	1.59
13	1390	2.46	565.04	1.60
14	2221	5.70	389.65	1.62
15	2248	5.12	439.06	1.62
16	1073	0.73	1469.86	1.65
17	2277	4.71	483.44	1.59
18	1862	5.23	356.02	1.60

V. CONCLUSIONS

The peak flow obtained using the HEC-1 model with areal reduction yielded 11,401 cfs for the 100 year flood at the junction of Grass Wash and the Atchison, Topeka, and Santa Fe Railroad. This estimate seems reasonable when compared to other study results, and with regional regression models. The HEC-1 model also provided subbasin peaks at various concentration points on the watershed and should be considered in floodplain mapping or watershed planning models.

REFERENCES

1. U.S. Army Corp of Engineers, Hydrologic Engineering Center, Hec-1 Flood Hydrograph Package User's Manual, Davis, California, September 1981, revised March 1987.

2. U.S. Department of Agriculture, Soil Conservation Service, in cooperation with U.S. Department of the Interior, Bureau of Indian Affairs and Bureau of Land Management, and the Arizona Agricultural Experiment Station, Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal County, Arizona , Issued April 1986.

3. Arizona Highway Department Bridge Division, Hydrologic Design for Highway Drainage in Arizona, December 1968, revised June 1985.

4. Flood Control District of Maricopa County, Preliminary Outline - Maricopa County Hydrology Manual, January 1989.

5. King, H.W., and Brater, E.F., Handbook of Hydraulics, Fifth edition, McGraw-Hill, 1963.

6. Sabol, George V., S-Graph Study, Flood Control District of Maricopa County, Brighton, CO., 1987.

7. U.S. Department of Agriculture, and the Soil Conservation Service Engineering Division, Urban Hydrology for Small Watersheds, Technical Release 55, Second Edition, 1986.

8. Roeske, R.H., Methods for Estimating the Magnitude and Fraquency of Floods in Arizona, United States Geological Survey Water Resources Division, September 1978.

9. U.S. Geological survey, Estimation of Magnitude and Frequency of Floods in Pima County, Arizona, with Comparisons of Alternative Methods, Water-Resources Incestigations Report 84-4142, August 1984.

10. Zehr, Raymond M., and Myers, Vance A., Depth-Area Ratios in the Semi-Arid Southwest United States, NOAA Technical Memorandum NWS HYDRO-40, Silver Spring, Md., August 1984.

APPENDIX A

PRECIPITATION DATA

Steps to be used to determine precipitation values for various durations and return periods.

STEP 1. From the precipitation maps in the manual "Hydrologic Design for Highway Drainage in Arizona", determine the precipitation values for the 6 and 24 hour duration storms for return periods of 2, 5, 10, 25, 50 and 100 years. Tabulate these values in Table 1 in the column headed 'Map Values'

Table A-1
100 Year Precipitation for
Grass Wash Watershed
(Reference 3)

Return Period (Years)	Precipitation Values (inches)			
	6 hour duration		24 hour duration	
	Map Value	Corrected Value	Map Value	Corrected Value
2			1.53	1.52
5			2.10	2.17
10			2.60	2.58
25			3.20	3.10
50			3.62	3.60
100			4.11	4.10

NOTE: There is a possibility of making an error while reading the maps because, (1) a site is not easy to locate precisely on a series of 12 maps, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. In order to minimize any errors in reading the maps, these values should be plotted on the diagram "Precipitation Depth versus Return Period" Fig. 1.

Project No. _____ Station _____

Figure A-1
100 year, 24 hour Precipitation
Grass Wash Hydrology
(Reference 3)

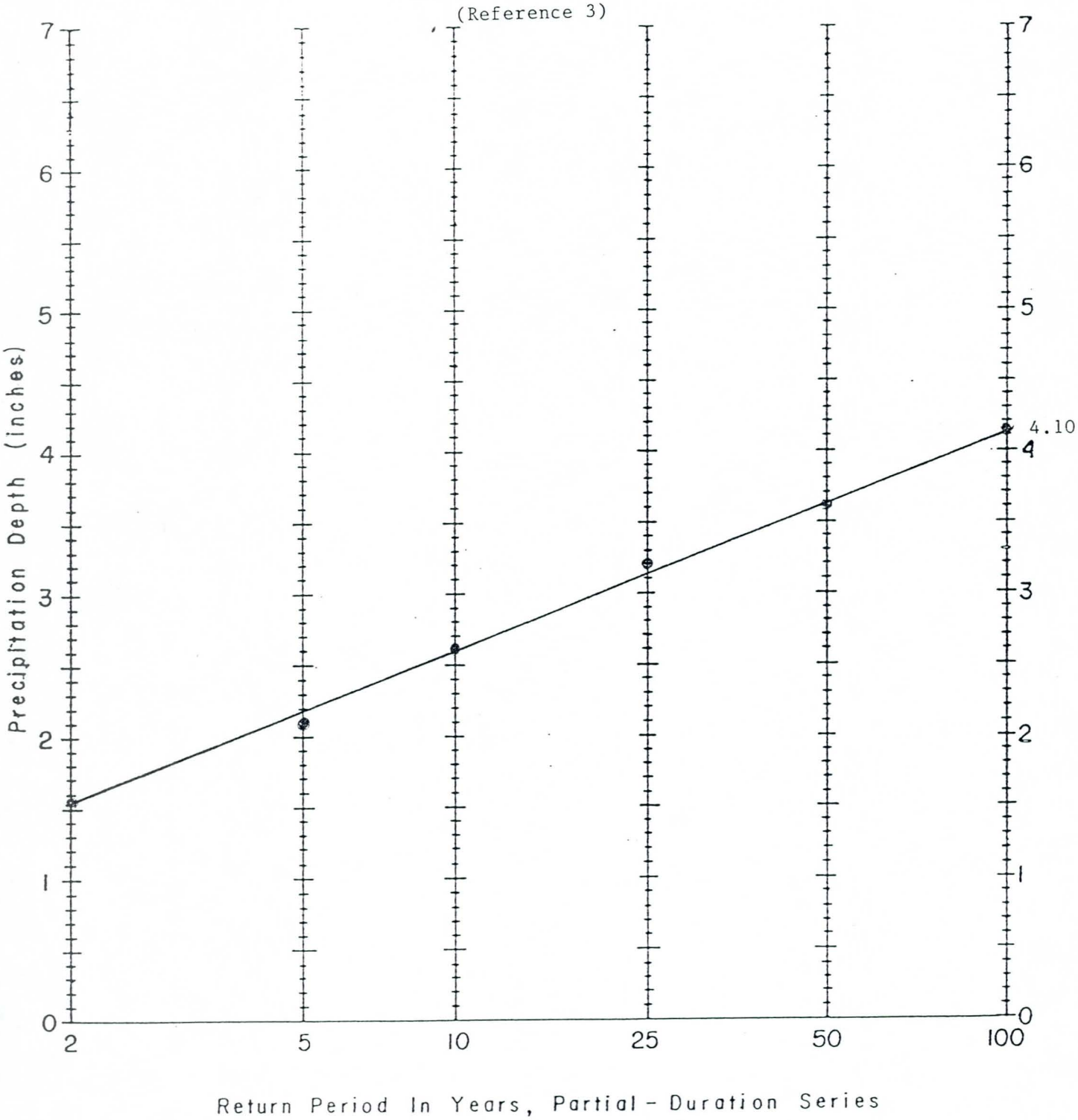


Figure 1 Precipitation Depth Versus Return Period for Partial – Duration Series

Table A-2

SCS Type II Rainfall Distribution
Grass Wash Hydrology

IN	15									
PB	4.10									
PC	.00	.01	.02	.03	.05	.06	.07	.08	.09	.11
PC	.12	.13	.14	.16	.17	.18	.20	.21	.23	.25
PC	.26	.28	.30	.31	.33	.35	.37	.39	.41	.43
PC	.45	.47	.49	.52	.55	.57	.60	.64	.67	.71
PC	.74	.78	.83	.89	.97	1.05	1.16	1.59	2.72	2.90
PC	3.01	3.11	3.18	3.24	3.30	3.34	3.38	3.42	3.45	3.48
PC	3.51	3.54	3.56	3.59	3.61	3.64	3.66	3.68	3.70	3.72
PC	3.74	3.76	3.78	3.80	3.81	3.83	3.85	3.86	3.88	3.89
PC	3.91	3.92	3.93	3.94	3.96	3.97	3.98	3.99	4.01	4.02
PC	4.03	4.04	4.05	4.07	4.08	4.09	4.10	4.10	4.10	4.10

Figure A-2

Depth-Area Ratio
Areal Reduction

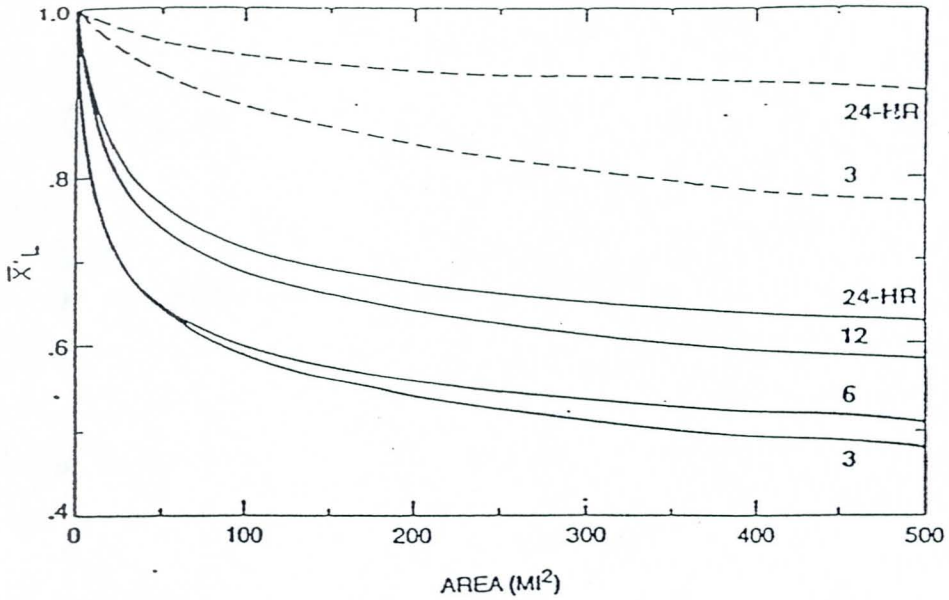


Figure 14.—$\bar{X}'_L$ (2.54-yr depth-area ratio, see sec. 4.3) for 3-, 6-, 12-, and 24-hr in southeast Arizona. Dashed lines are 3-hr and 24-hr Chicago $\bar{X}'_L$ (from TR 24)

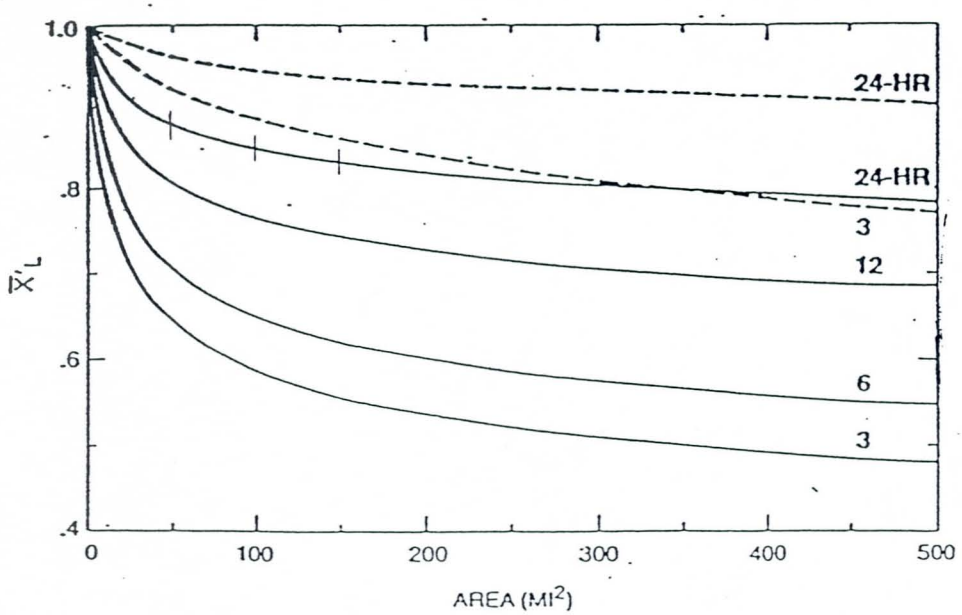
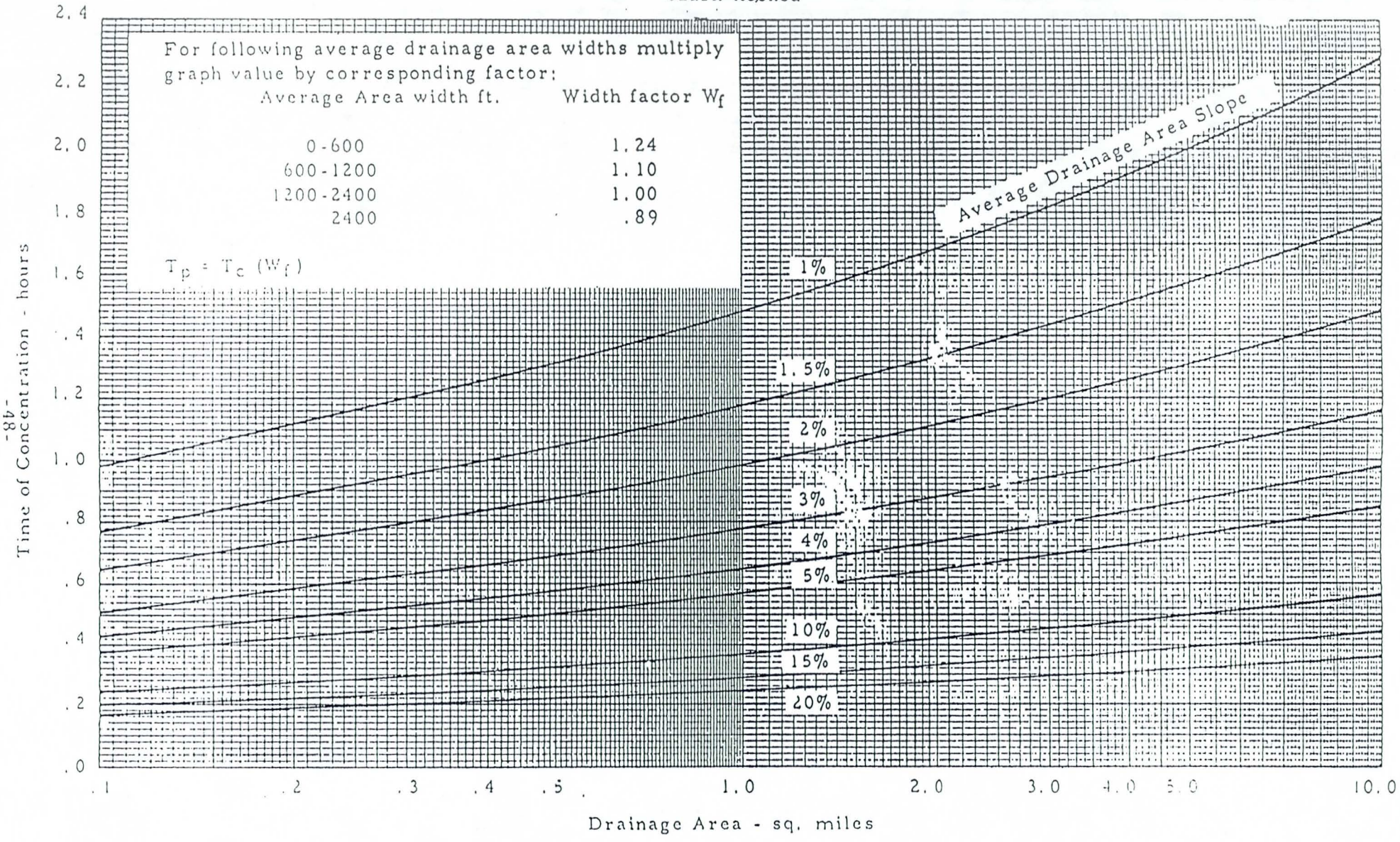


Figure 15.—Same as figure 14, but for central Arizona.

APPENDIX B

CLARK UNIT HYDROGRAPH DETERMINATION

Figure B-1
Time of Concentration
Clark Method



TIME OF CONCENTRATION
FOR
DRAINAGE AREAS LESS THAN 10 SQ. MILES

Soil Conservation Service
(Reference 3)

Storage Coefficient Estimation

(Reference 4)

$$R = 0.37\ Tc^{1.11}\ A^{-0.57}\ L^{0.80}$$

where R is the storage coefficient, in hours,
Tc is time of concentration, in hours,
A is drainage area, in square miles, and
L is length of flow path, in miles.

APPENDIX C

S-GRAPH UNIT HYDROGRAPH DETERMINATION

Basin Lag Estimation

(Reference 4)

$$Lag = C \frac{L*Lca^m}{S^p}$$

where Lag is basin lag, in hours,
L is length of the longest watercourse, in miles,
Lca is length along the watercourse to a point opposite the centroid, in miles,
S is watercourse slope, in feet per mile,
C is a coefficient, with C = 20n where 'n' is the estimated mean Manning's 'n' for all the channels within an area, and
m and p are exponents.

Table C-1

Manning's n Coefficient
Grass Wash Hydrology
(Reference 5)

STEADY UNIFORM FLOW IN OPEN CHANNELS 7-17

Values of n to Be Used with the Manning Equation

Surface	Best	Good	Fair	Bad
Cuvented cast-iron pipe	0.012	0.013	0.014	0.015
Coated cast-iron pipe	0.011	0.012*	0.013*	
Commercial wrought-iron pipe, black	0.012	0.013	0.014	0.015
Commercial wrought-iron pipe, galvanized	0.013	0.014	0.015	0.017
Smooth brass and glass pipe	0.009	0.010	0.011	0.013
Smooth lockbar and welded "OD" pipe	0.010	0.011*	0.013*	
Riveted and spiral steel pipe	0.013	0.015*	0.017*	
Vitrified sewer pipe	0.010 0.011	0.013*	0.015	0.017
Common clay drainage tile	0.011	0.012*	0.014*	0.017
Glazed brickwork	0.011	0.012	0.013*	0.015
Brick in cement mortar; brick sewers	0.012	0.013	0.015*	0.017
Neat cement surfaces	0.010	0.011	0.012	0.013
Cement mortar surfaces	0.011	0.012	0.013*	0.015
Concrete pipe	0.012	0.013	0.015*	0.016
Wood stave pipe	0.010	0.011	0.012	0.013
Plank Flumes:				
Planed	0.010	0.012*	0.013	0.014
Unplaned	0.011	0.013*	0.014	0.015
With battens	0.012	0.015*	0.016	
Concrete-lined channels	0.012	0.014*	0.016*	0.018
Cement-rubble surface	0.017	0.020	0.025	0.030
Dry-rubble surface	0.025	0.030	0.033	0.035
Dressed-ashlar surface	0.013	0.014	0.015	0.017
Semicircular metal flumes, smooth	0.011	0.012	0.013	0.015
Semicircular metal flumes, corrugated	0.0225	0.025	0.0275	0.030
Canals and Ditches:				
Earth, straight and uniform	0.017	0.020	0.0225*	0.025
Rock cuts, smooth and uniform	0.025	0.030	0.033*	0.035
Rock cuts, jagged and irregular	0.035	0.040	0.045	
Winding sluggish canals	0.0225	0.025*	0.0275	0.030
Dredged earth channels	0.025	0.0275*	0.030	0.033
Canals with rough stony beds, weeds on earth banks	0.025	0.030	0.035*	0.040
Earth bottom, rubble sides	0.028	0.030*	0.033*	0.035
Natural Stream Channels:				
(1) Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
(2) Same as (1), but some weeds and stones	0.030	0.033	0.035	0.040
(3) Winding, some pools and shoals, clean	0.033	0.035	0.040	0.045
(4) Same as (3), lower stages, more ineffective slope and sections	0.040	0.045	0.050	0.055
(5) Same as (3), some weeds and stones	0.035	0.040	0.045	0.050
(6) Same as (4), stony sections	0.045	0.050	0.055	0.060
(7) Sluggish river reaches, rather weedy or with very deep pools	0.050	0.060	0.070	0.080
(8) Very weedy reaches	0.075	0.100	0.125	0.150

* Values commonly used in designing.

Figure C-1

(Reference.6)

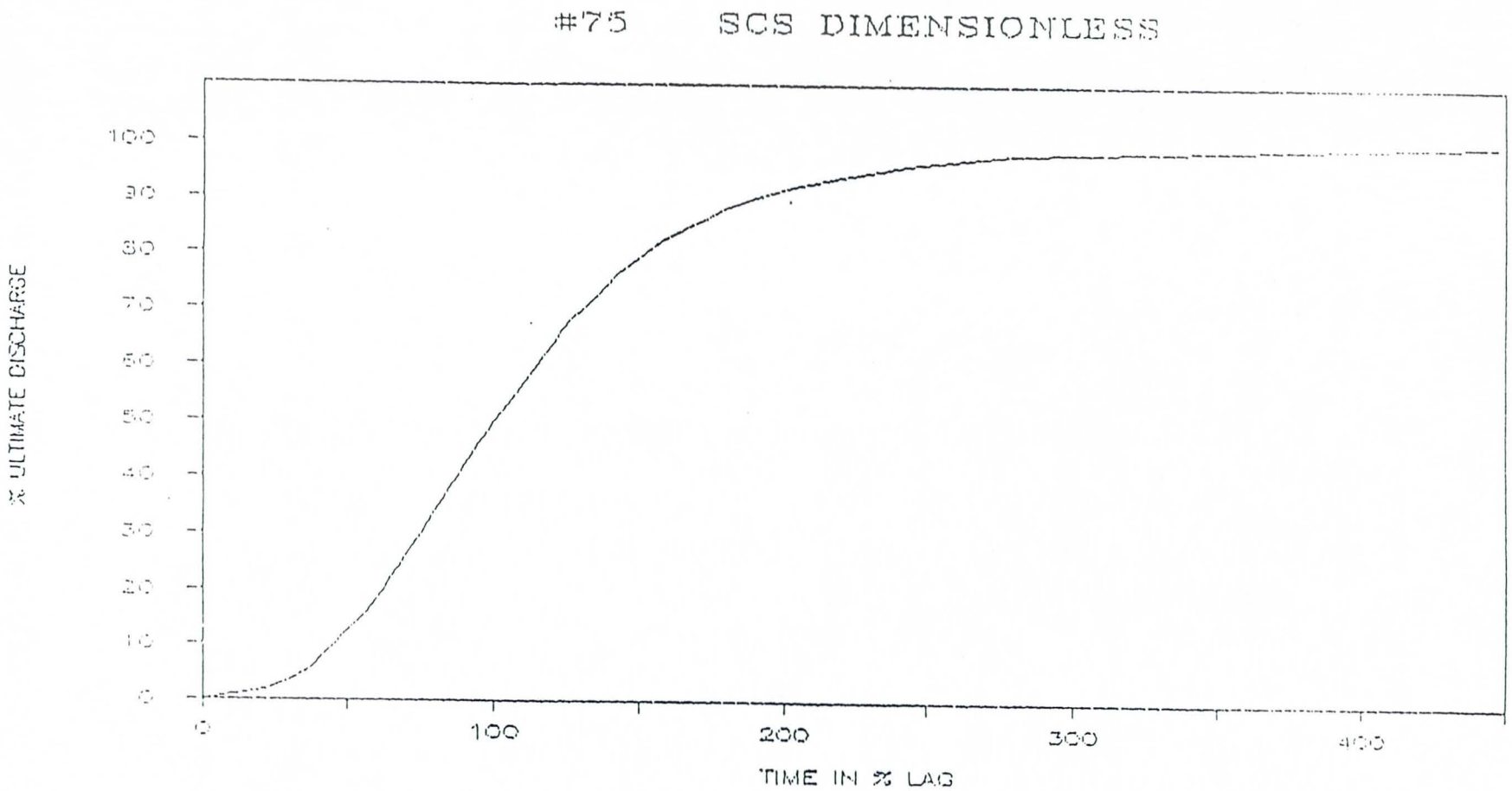


Table C-3
Unit Hydrograph for Watershed 1
Grass Wash Hydrology

UI	0.	183.	183.	201.	384.	564.	919.	1093.	1036.	1433.
UI	1379.	1535.	1535.	1535.	1500.	1279.	1295.	1429.	987.	990.
UI	1001.	724.	683.	544.	519.	544.	349.	313.	295.	235.
UI	226.	196.	167.	167.	147.	104.	104.	104.	104.	88.
UI	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
UI	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
UI	23.	23.	23.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-4
Unit Hydrograph for Watershed 2
Grass Wash Hydrology

UI	0.	250.	250.	250.	355.	525.	756.	1150.	1422.	1428.
UI	1468.	2032.	1749.	2099.	2099.	2099.	2099.	2099.	1826.	1749.
UI	1818.	1918.	1454.	1312.	1433.	1273.	984.	954.	792.	720.
UI	732.	749.	477.	456.	404.	400.	309.	309.	299.	228.
UI	228.	228.	215.	142.	142.	142.	142.	142.	142.	55.
UI	31.	31.	31.	31.	31.	31.	31.	31.	31.	31.
UI	31.	31.	31.	31.	31.	31.	31.	31.	31.	31.
UI	31.	31.	31.	31.	31.	31.	31.	31.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-5
Unit Hydrograph for Watershed 3
Grass Wash Hydrology

UI	0.	221.	221.	221.	283.	464.	611.	930.	1159.	1366.
UI	1167.	1546.	1690.	1840.	1855.	1855.	1855.	1855.	1799.	1546.
UI	1546.	1683.	1652.	1159.	1159.	1304.	1060.	860.	843.	691.
UI	636.	643.	684.	422.	412.	357.	357.	287.	273.	273.
UI	216.	202.	202.	202.	148.	125.	125.	125.	125.	125.
UI	115.	28.	28.	28.	28.	28.	28.	28.	28.	28.
UI	28.	28.	28.	28.	28.	28.	28.	28.	28.	28.
UI	28.	28.	28.	28.	28.	28.	28.	28.	28.	28.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-6
Unit Hydrograph for Watershed 4a
Grass Wash Hydrology

UI	0.	136.	136.	136.	245.	317.	531.	715.	826.	778.
UI	1100.	971.	1144.	1144.	1144.	1144.	1067.	953.	965.	1055.
UI	795.	715.	807.	609.	520.	481.	401.	387.	426.	260.
UI	246.	220.	203.	168.	168.	138.	124.	124.	120.	77.
UI	77.	77.	77.	77.	58.	17.	17.	17.	17.	17.
UI	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
UI	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-7
Unit Hydrograph for Watershed 4b
Grass Wash Hydrology

UI	0.	285.	285.	297.	598.	848.	1386.	1705.	1546.	2249.
UI	2068.	2390.	2390.	2390.	2390.	2032.	1992.	2136.	1801.	1494.
UI	1699.	1178.	1086.	918.	812.	880.	633.	526.	460.	419.
UI	351.	351.	262.	260.	260.	187.	161.	161.	161.	161.
UI	96.	36.	36.	36.	36.	36.	36.	36.	36.	36.
UI	36.	36.	36.	36.	36.	36.	36.	36.	36.	36.
UI	36.	36.	36.	36.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-8
Unit Hydrograph for Watershed 5
Grass Wash Hydrology

UI	0.	164.	164.	164.	272.	345.	572.	863.	1003.	863.
UI	1130.	1259.	1381.	1381.	1381.	1381.	1381.	1196.	1150.	1236.
UI	1230.	863.	875.	990.	680.	628.	573.	484.	464.	531.
UI	314.	303.	265.	258.	203.	203.	184.	150.	150.	150.
UI	114.	93.	93.	93.	93.	93.	47.	21.	21.	21.
UI	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
UI	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
UI	21.	21.	21.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-9
Unit Hydrograph for Watershed 6
Grass Wash Hydrology

UI	0.	146.	146.	146.	176.	308.	382.	583.	769.	909.
UI	769.	979.	1158.	1135.	1230.	1230.	1230.	1230.	1230.	1062.
UI	1025.	1044.	1118.	936.	769.	808.	841.	600.	559.	526.
UI	439.	410.	450.	385.	280.	260.	237.	231.	181.	181.
UI	181.	134.	134.	134.	134.	92.	83.	83.	83.	83.
UI	83.	77.	18.	18.	18.	18.	18.	18.	18.	18.
UI	18.	18.	18.	18.	18.	18.	18.	18.	18.	18.
UI	18.	18.	18.	18.	18.	18.	18.	18.	18.	18.
UI	18.	18.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-10
Unit Hydrograph for Watershed 7b
Grass Wash Hydrology

UI	0.	262.	262.	314.	551.	869.	1377.	1562.	1594.	1978.
UI	2158.	2203.	2203.	2203.	1998.	1836.	1960.	1744.	1377.	1542.
UI	1121.	1002.	837.	744.	827.	521.	465.	424.	352.	324.
UI	288.	239.	239.	209.	149.	149.	149.	149.	106.	33.
UI	33.	33.	33.	33.	33.	33.	33.	33.	33.	33.
UI	33.	33.	33.	33.	33.	33.	33.	33.	33.	33.
UI	33.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-11
Unit Hydrograph for Watershed 8a
Grass Wash Hydrology

UI	0.	182.	182.	338.	595.	1032.	1003.	1361.	1470.	1525.
UI	1525.	1413.	1271.	1402.	953.	1053.	730.	647.	524.	546.
UI	347.	297.	254.	224.	179.	166.	145.	103.	103.	103.
UI	68.	23.	23.	23.	23.	23.	23.	23.	23.	23.
UI	23.	23.	23.	23.	23.	23.	23.	23.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-12
Unit Hydrograph for Watershed 8b
Grass Wash Hydrology

UI	0.	206.	206.	206.	284.	432.	607.	923.	1142.	1207.
UI	1173.	1593.	1487.	1729.	1729.	1729.	1729.	1729.	1556.	1440.
UI	1440.	1575.	1341.	1080.	1142.	1144.	831.	786.	700.	605.
UI	576.	664.	433.	393.	336.	332.	279.	254.	254.	206.
UI	188.	188.	188.	137.	117.	117.	117.	117.	117.	91.
UI	26.	26.	26.	26.	26.	26.	26.	26.	26.	26.
UI	26.	26.	26.	26.	26.	26.	26.	26.	26.	26.
UI	26.	26.	26.	26.	26.	26.	26.	26.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-13
Unit Hydrograph for Watershed 10
Grass Wash Hydrology

UI	0.	218.	218.	218.	261.	457.	568.	866.	1143.	1350.
UI	1143.	1455.	1721.	1686.	1828.	1828.	1828.	1828.	1828.	1578.
UI	1524.	1552.	1662.	1390.	1143.	1201.	1250.	891.	831.	782.
UI	653.	609.	669.	571.	416.	386.	352.	344.	269.	269.
UI	269.	199.	199.	199.	199.	137.	124.	124.	124.	124.
UI	124.	114.	27.	27.	27.	27.	27.	27.	27.	27.
UI	27.	27.	27.	27.	27.	27.	27.	27.	27.	27.
UI	27.	27.	27.	27.	27.	27.	27.	27.	27.	27.
UI	27.	27.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-14
Unit Hydrograph for Watershed 11
Grass Wash Hydrology

UI	0.	220.	220.	220.	220.	446.	463.	769.	1091.	1264.
UI	1273.	1214.	1542.	1710.	1808.	1851.	1851.	1851.	1851.	1851.
UI	1660.	1542.	1542.	1692.	1629.	1157.	1157.	1275.	1152.	882.
UI	841.	773.	660.	617.	671.	622.	421.	409.	356.	356.
UI	301.	272.	272.	246.	201.	201.	201.	201.	132.	125.
UI	125.	125.	125.	125.	125.	53.	28.	28.	28.	28.
UI	28.	28.	28.	28.	28.	28.	28.	28.	28.	28.
UI	28.	28.	28.	28.	28.	28.	28.	28.	28.	28.
UI	28.	28.	28.	28.	28.	28.	28.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-15
Unit Hydrograph for Watershed 14
Grass Wash Hydrology

UI	0.	168.	168.	239.	385.	702.	995.	888.	1324.	1243.
UI	1415.	1415.	1415.	1292.	1179.	1253.	1061.	899.	930.	665.
UI	604.	492.	506.	397.	307.	272.	229.	208.	179.	154.
UI	154.	115.	96.	96.	96.	91.	21.	21.	21.	21.
UI	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
UI	21.	21.	21.	21.	21.	21.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-16
Unit Hydrograph for Watershed 15
Grass Wash Hydrology

UI	0.	171.	171.	299.	497.	882.	987.	1235.	1302.	1437.
UI	1437.	1437.	1207.	1263.	1137.	907.	929.	668.	575.	486.
UI	495.	325.	276.	238.	211.	172.	156.	146.	97.	97.
UI	97.	90.	21.	21.	21.	21.	21.	21.	21.	21.
UI	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table C-17
Unit Hydrograph for Watershed 18
Grass Wash Hydrology

UI	0.	142.	142.	163.	297.	452.	734.	845.	836.	1086.
UI	1124.	1189.	1189.	1189.	1114.	991.	1058.	998.	743.	800.
UI	690.	542.	485.	410.	427.	341.	265.	229.	210.	175.
UI	173.	129.	129.	129.	85.	80.	80.	80.	80.	26.
UI	18.	18.	18.	18.	18.	18.	18.	18.	18.	18.
UI	18.	18.	18.	18.	18.	18.	18.	18.	18.	18.
UI	18.	18.	0.	0.	0.	0.	0.	0.	0.	0.
UI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

APPENDIX D

CHANNEL ROUTING DETERMINATION

Graph D-1

Estimation of Velocity
Muskingum Routing
(Reference 7)

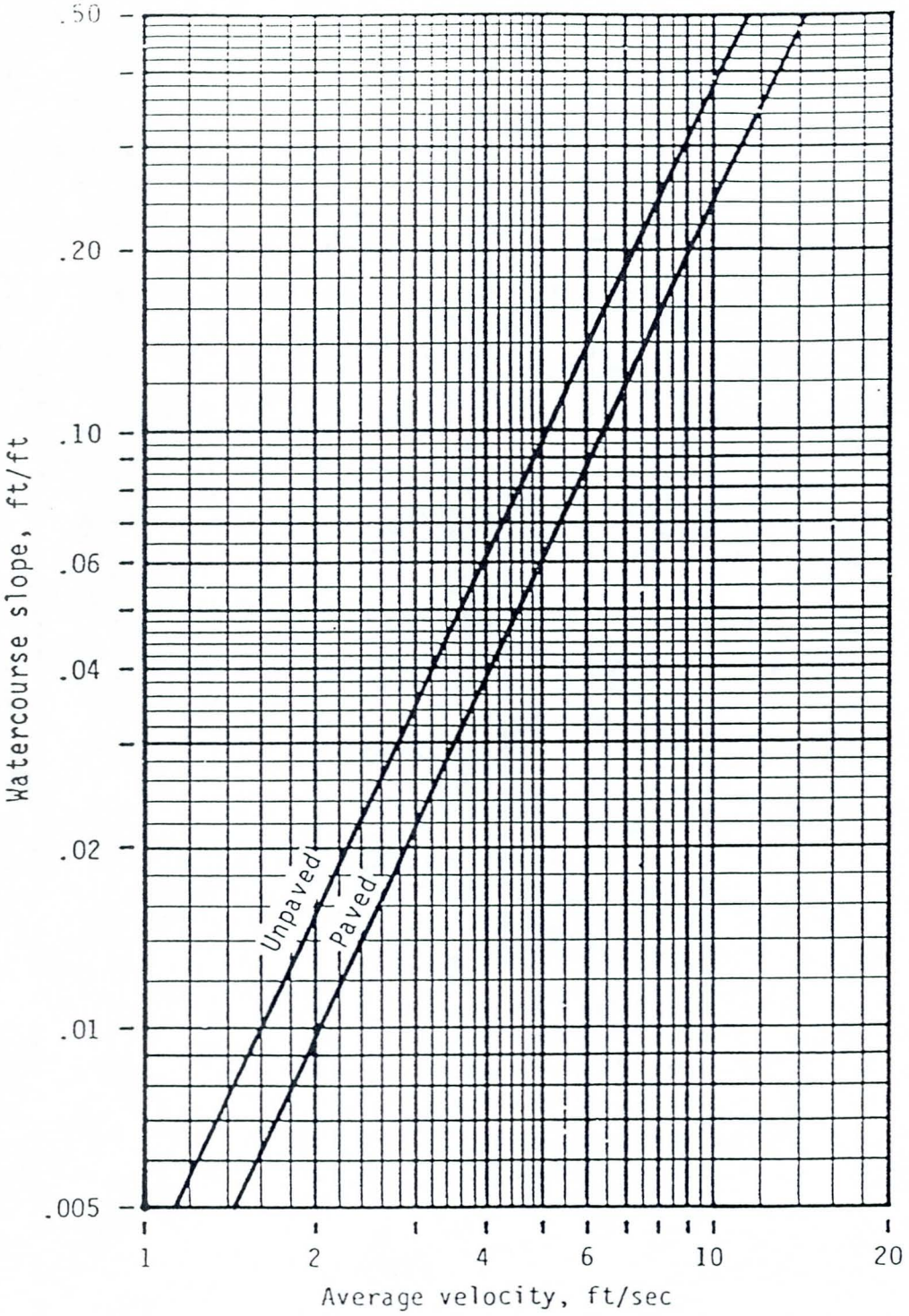


Figure 3-1.—Average velocities for estimating travel time for shallow concentrated flow.

APPENDIX E

HEC-1 OUTPUT

```
1****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*             FEBRUARY 1981            *
*           REVISED 05 DEC 88          *
*                                      *
*  RUN DATE  05/09/1989  TIME  12:44:25 *
*                                      *
****************************************
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****************************************
*                                      *
*    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

1 HEC-1 INPUT PAGE 1

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

  1           ID     GRASS WASH WATERSHED
  2           ID     100 YEAR, 24 HOUR STORM
```

```
 3          ID     FCDMC,  30 MARCH, 1989
 4          ID     IN HOUSE PROJECT   DONE BY SANDY SHILLITO
 5          ID     THIS RUN DONE USING S-GRAPH OR LAG IN WATERSHEDS OF MORE THAN 5 SQUARE
 6          ID     MILES, AND USING THE CLARK ESTIMATION OF TC FOR THOSE WATERSHEDS OF LESS
 7          ID     THAN 5 SQUARE MILES.
            *DIAGRAM
 8          IT      10 30MAR89    0000     300
 9          IO       5       0

10          KK    SUB1
11          BA    6.87
12          IN      15
13          PB    4.10
14          PC     .00     .01     .02     .03     .05     .06     .07     .08     .09     .11
15          PC     .12     .13     .14     .16     .17     .18     .20     .21     .23     .25
16          PC     .45     .47     .49     .52     .55     .57     .60     .64     .67     .71
17          PC     .74     .78     .83     .89     .97    1.05    1.16    1.59    2.72    2.90
18          PC    3.01    3.11    3.18    3.24    3.30    3.34    3.38    3.42    3.45    3.48
19          PC    3.51    3.54    3.56    3.59    3.61    3.64    3.66    3.68    3.70    3.72
20          PC    3.74    3.76    3.78    3.80    3.81    3.83    3.85    3.86    3.88    3.89
21          PC    3.91    3.92    3.93    3.94    3.96    3.97    3.98    3.99    4.01    4.02
22          PC    4.03    4.04    4.05    4.07    4.08    4.09    4.10    4.10    4.10    4.10
23          LU    .846    .250
24          UI      0.     183.    183.    201.    384.    564.    919.   1093.   1036.   1433.
25          UI   1379.   1535.   1535.   1535.   1500.   1279.   1295.   1429.    987.    990.
26          UI   1001.    724.    683.    544.    519.    544.    349.    313.    295.    235.
27          UI    226.    196.    167.    167.    147.    104.    104.    104.    104.     88.
28          UI     23.     23.     23.     23.     23.     23.     23.     23.     23.     23.
29          UI     23.     23.     23.     23.     23.     23.     23.     23.     23.     23.
30          UI     23.     23.     23.      0.      0.      0.      0.      0.      0.      0.

31          KK      R1
32          KM     ROUTE SUBBASIN 1 TO B
33          RM       1     .24      .2

34          KK    SUB2
35          BA   11.67
36          LU    .816    .233
37          UI      0.    250.    250.    250.    355.    525.    756.   1150.   1422.   1428.
38          UI   1468.   2032.   1749.   2099.   2099.   2099.   2099.   2099.   1826.   1749.
```

```
 39          UI   1818.   1918.   1454.   1312.   1433.   1273.    984.    954.    792.    720.
 40          UI    732.    749.    477.    456.    404.    400.    309.    309.    299.    228.
 41          UI    228.    228.    215.    142.    142.    142.    142.    142.    142.     55.
 42          UI     31.     31.     31.     31.     31.     31.     31.     31.     31.     31.
 43          UI     31.     31.     31.     31.     31.     31.     31.     31.     31.     31.
 44          UI     31.     31.     31.     31.     31.     31.     31.     31.      0.      0.

 45          KK      R2
 46          KM     ROUTE SUBBASIN 2 TO A
 47          RM       5    1.67      .2
1                                          HEC-1 INPUT                                          PAGE  2

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


 48          KK    SUB3
 49          BA   10.67
 50          LU    .840    .246
 51          UI      0.    221.    221.    221.    283.    464.    611.    930.   1159.   1366.
 52          UI   1167.   1546.   1690.   1840.   1855.   1855.   1855.   1855.   1799.   1546.
 53          UI   1546.   1683.   1652.   1159.   1159.   1304.   1060.    860.    843.    691.
 54          UI    636.    643.    684.    422.    412.    357.    357.    287.    273.    273.
 55          UI    216.    202.    202.    202.    148.    125.    125.    125.    125.    125.
 56          UI    115.     28.     28.     28.     28.     28.     28.     28.     28.     28.
 57          UI     28.     28.     28.     28.     28.     28.     28.     28.     28.     28.
 58          UI     28.     28.     28.     28.     28.     28.     28.     28.     28.     28.
 59          UI      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

 60          KK       A
 61          KM     COMBINE HYDROGRAPHS FROM SUBBASIN 2 & SUBBASIN 3
 62          HC       2

 63          KK      RA
 64          KM     ROUTE A TO B
 65          RM       9    3.25      .2

 66          KK   SUB4A
 67          BA    5.76
 68          LU    .684    .167
 69          UI      0.    136.    136.    136.    245.    317.    531.    715.    826.    778.
```

```
 70          UI   1100.    971.   1144.   1144.   1144.   1144.   1067.    953.    965.   1055.
 71          UI    795.    715.    807.    609.    520.    481.    401.    387.    426.    260.
 72          UI    246.    220.    203.    168.    168.    138.    124.    124.    120.     77.
 73          UI     77.     77.     77.     77.     58.     17.     17.     17.     17.     17.
 74          UI     17.     17.     17.     17.     17.     17.     17.     17.     17.     17.
 75          UI     17.     17.     17.     17.     17.     17.     17.     17.     17.     17.
 76          UI      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

 77          KK     R4A
 78          KM     ROUTE SUBBASIN 4A TO B
 79          RM      18    6.75      .2

 80          KK   SUB4B
 81          BA   10.88
 82          LU    .850    .250
 83          UI      0.    285.    285.    297.    598.    848.   1386.   1705.   1546.   2249.
 84          UI   2068.   2390.   2390.   2390.   2390.   2032.   1992.   2136.   1801.   1494.
 85          UI   1699.   1178.   1086.    918.    812.    880.    633.    526.    460.    419.
 86          UI    351.    351.    262.    260.    260.    187.    161.    161.    161.    161.
 87          UI     96.     36.     36.     36.     36.     36.     36.     36.     36.     36.
 88          UI     36.     36.     36.     36.     36.     36.     36.     36.     36.     36.
 89          UI     36.     36.     36.     36.      0.      0.      0.      0.      0.      0.

 90          KK       B
 91          KM     COMBINE HYDROGRAPHS FOR SUBBASINS A, 1, 4A, & 4B
 92          HC       4
```



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


 93          KK       RB
 94          KM     ROUTE B TO C
 95          RM       6    2.11      .2

 96          KK    SUB5
 97          BA    7.22
 98          LU    .850    .250
 99          UI      0.    164.    164.    164.    272.    345.    572.    863.   1003.    863.
100          UI   1130.   1259.   1381.   1381.   1381.   1381.   1381.   1196.   1150.   1236.
```

```
101        UI   1230.   863.   875.   990.   680.   628.   573.   484.   464.   531.
102        UI    314.   303.   265.   258.   203.   203.   184.   150.   150.   150.
103        UI    114.    93.    93.    93.    93.    93.    47.    21.    21.    21.
104        UI     21.    21.    21.    21.    21.    21.    21.    21.    21.    21.
105        UI     21.    21.    21.    21.    21.    21.    21.    21.    21.    21.
106        UI     21.    21.    21.     0.     0.     0.     0.     0.     0.     0.

107        KK    SUB6
108        BA    7.22
109        LU    1.00   .250
110        UI      0.   146.   146.   146.   176.   308.   382.   583.   769.   909.
111        UI    769.   979.  1158.  1135.  1230.  1230.  1230.  1230.  1230.  1062.
112        UI   1025.  1044.  1118.   936.   769.   808.   841.   600.   559.   526.
113        UI    439.   410.   450.   385.   280.   260.   237.   231.   181.   181.
114        UI    181.   134.   134.   134.   134.    92.    83.    83.    83.    83.
115        UI     83.    77.    18.    18.    18.    18.    18.    18.    18.    18.
116        UI     18.    18.    18.    18.    18.    18.    18.    18.    18.    18.
117        UI     18.    18.    18.    18.    18.    18.    18.    18.    18.    18.
118        UI     18.    18.     0.     0.     0.     0.     0.     0.     0.     0.

119        KK       C
120        KM     COMBINE HYDROGRAPHS FOR SUBBASINS B, 5, & 6
121        HC       3

122        KK      RC
123        KM     ROUTE C TO I
124        RM       3    0.86      .2

125        KK   SUB7A
126        BA    4.06
127        LU    .650    .050
128        UC    0.48    0.18

129        KK     R7A
130        KM     ROUTE SUBBASIN 7A TO I
131        RM      10    3.73      .2

132        KK   SUB7B
133        BA    9.56
134        LU    .816    .233
```

```
135        UI      0.    262.    262.    314.    551.    869.   1377.   1562.   1594.   1978.
136        UI   2158.   2203.   2203.   2203.   1998.   1836.   1960.   1744.   1377.   1542.
137        UI   1121.   1002.    837.    744.    827.    521.    465.    424.    352.    324.
138        UI    288.    239.    239.    209.    149.    149.    149.    149.    106.     33.
139        UI     33.     33.     33.     33.     33.     33.     33.     33.     33.     33.
```



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

140        UI     33.     33.     33.     33.     33.     33.     33.     33.     33.     33.
141        UI     33.      0.      0.      0.      0.      0.      0.      0.      0.      0.

142        KK       I
143        KM     COMBINE HYDROGRAPHS FOR SUBBASINS 7A, 7B, & C
144        HC       3

145        KK      RI
146        KM     ROUTE I TO E
147        RM       2    0.56      .2

148        KK   SUB8A
149        BA    5.20
150        LU    .716    .116
151        UI      0.    182.    182.    338.    595.   1032.   1003.   1361.   1470.   1525.
152        UI   1525.   1413.   1271.   1402.    953.   1053.    730.    647.    524.    546.
153        UI    347.    297.    254.    224.    179.    166.    145.    103.    103.    103.
154        UI     68.     23.     23.     23.     23.     23.     23.     23.     23.     23.
155        UI     23.     23.     23.     23.     23.     23.     23.     23.      0.      0.

156        KK     R8A
157        KM     ROUTE SUBBBASIN 8A TO J
158        RM      16    5.66      .2

159        KK   SUB8B
160        BA    9.71
161        LU    .850    .250
162        UI      0.    206.    206.    206.    284.    432.    607.    923.   1142.   1207.
163        UI   1173.   1593.   1487.   1729.   1729.   1729.   1729.   1729.   1556.   1440.
164        UI   1440.   1575.   1341.   1080.   1142.   1144.    831.    786.    700.    605.
165        UI    576.    664.    433.    393.    336.    332.    279.    254.    254.    206.
```

```
166        UI    188.    188.    188.    137.    117.    117.    117.    117.    117.     91.
167        UI     26.     26.     26.     26.     26.     26.     26.     26.     26.     26.
168        UI     26.     26.     26.     26.     26.     26.     26.     26.     26.     26.
169        UI     26.     26.     26.     26.     26.     26.     26.     26.      0.      0.

170        KK      J
171        KM     COMBINE HYDROGRAPHS FOR SUBBASIN 8A & SUBBASIN 8B
172        HC      2

173        KK     RJ
174        KM     ROUTE J TO D
175        RM      6    2.14      .2

176        KK    SUB9
177        BA    4.33
178        LU    .840    .245
179        UC    1.94    1.25

180        KK     R9
181        KM     ROUTE SUBBASIN 9 TO D
182        RM      2    0.42      .2
```



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

183        KK   SUB10
184        BA   10.73
185        LU    .830    .240
186        UI      0.    218.    218.    218.    261.    457.    568.    866.   1143.   1350.
187        UI   1143.   1455.   1721.   1686.   1828.   1828.   1828.   1828.   1828.   1578.
188        UI   1524.   1552.   1662.   1390.   1143.   1201.   1250.    891.    831.    782.
189        UI    653.    609.    669.    571.    416.    386.    352.    344.    269.    269.
190        UI    269.    199.    199.    199.    199.    137.    124.    124.    124.    124.
191        UI    124.    114.     27.     27.     27.     27.     27.     27.     27.     27.
192        UI     27.     27.     27.     27.     27.     27.     27.     27.     27.     27.
193        UI     27.     27.     27.     27.     27.     27.     27.     27.     27.     27.
194        UI     27.     27.      0.      0.      0.      0.      0.      0.      0.      0.

195        KK      D
```

```
196        KM     COMBINE HYDROGRAPHS FROM SUBBASINS D, 9, & 10
197        HC       3

198        KK      RD
199        KM     ROUTE D TO E
200        RM      15    5.56      .2

201        KK   SUB11
202        BA   11.58
203        LU    .850    .250
204        UI      0.    220.    220.    220.    220.    446.    463.    769.   1091.   1264.
205        UI   1273.   1214.   1542.   1710.   1808.   1851.   1851.   1851.   1851.   1851.
206        UI   1660.   1542.   1542.   1692.   1629.   1157.   1157.   1275.   1152.    882.
207        UI    841.    773.    660.    617.    671.    622.    421.    409.    356.    356.
208        UI    301.    272.    272.    246.    201.    201.    201.    201.    132.    125.
209        UI    125.    125.    125.    125.    125.     53.     28.     28.     28.     28.
210        UI     28.     28.     28.     28.     28.     28.     28.     28.     28.     28.
211        UI     28.     28.     28.     28.     28.     28.     28.     28.     28.     28.
212        UI     28.     28.     28.     28.     28.     28.     28.      0.      0.      0.

213        KK     R11
214        KM     ROUTE SUBBASIN 11 TO E
215        RM       6    1.89      .2

216        KK   SUB12
217        BA    3.62
218        LU    1.00    .250
219        UC    1.88    0.70

220        KK       E
221        KM     COMBINE HYDROGRAPHS FOR SUBBASINS D, 11, & 12
222        HC       4

223        KK      RE
224        KM     ROUTE E TO F
225        RM       8    3.00      .2
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LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10
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```
226     KK   SUB13
227     BA    2.46
228     LU    .960    .256
229     UC    1.75    0.72

230     KK   SUB14
231     BA    5.70
232     LU    .850    .250
233     UI      0.    168.    168.    239.    385.    702.    995.    888.   1324.   1243.
234     UI   1415.   1415.   1415.   1292.   1179.   1253.   1061.    899.    930.    665.
235     UI    604.    492.    506.    397.    307.    272.    229.    208.    179.    154.
236     UI    154.    115.     96.     96.     96.     91.     21.     21.     21.     21.
237     UI     21.     21.     21.     21.     21.     21.     21.     21.     21.     21.
238     UI     21.     21.     21.     21.     21.     21.      0.      0.      0.      0.

239     KK   SUB15
240     BA    5.12
241     LU    .846    .250
242     UI      0.    171.    171.    299.    497.    882.    987.   1235.   1302.   1437.
243     UI   1437.   1437.   1207.   1263.   1137.    907.    929.    668.    575.    486.
244     UI    495.    325.    276.    238.    211.    172.    156.    146.     97.     97.
245     UI     97.     90.     21.     21.     21.     21.     21.     21.     21.     21.
246     UI     21.     21.     21.     21.     21.     21.     21.     21.     21.     21.
247     UI      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

248     KK      F
249     KM     COMBINE HYDROGRAPHS FOR SUBBASINS E, 13, 14, & 15
250     HC      4

251     KK     RF
252     KM     ROUTE F TO H
253     RM      1    0.01      .2

254     KK   SUB16
255     BA    0.73
256     LU    .850    .250
257     UC    0.40    0.24

258     KK     R16
```

```
 259          KM     ROUTE SUBBASIN 16 TO G
 260          RM      19    6.81      .2

 261          KK   SUB17
 262          BA    4.71
 263          LU    1.00    .250
 264          UC    1.98    0.89

 265          KK     R17
 266          KM     ROUTE SUBBASIN 17 TO G
 267          RM      15    5.42      .2
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LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 268          KK   SUB18
 269          BA    5.23
 270          LU    .840    .258
 271          UI      0.    142.    142.    163.    297.    452.    734.    845.    836.   1086.
 272          UI   1124.   1189.   1189.   1189.   1114.    991.   1058.    998.    743.    800.
 273          UI    690.    542.    485.    410.    427.    341.    265.    229.    210.    175.
 274          UI    173.    129.    129.    129.     85.     80.     80.     80.     80.     26.
 275          UI     18.     18.     18.     18.     18.     18.     18.     18.     18.     18.
 276          UI     18.     18.     18.     18.     18.     18.     18.     18.     18.     18.
 277          UI     18.     18.      0.      0.      0.      0.      0.      0.      0.      0.

 278          KK      G
 279          KM     COMBINE SUBBASINS 16, 17, & 18
 280          HC      3

 281          KK      H
 282          KM     COMBINE G & F
 283          HC      2
 284          ZZ
```

1

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT
LINE (V) ROUTING (--->) DIVERSION OR PUMP FLOW

```
NO.     (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

10        SUB1
             V
             V
31           R1
              .
              .
34            .        SUB2
              .           V
              .           V
45            .          R2
              .           .
              .           .
48            .           .        SUB3
              .           .           .
              .           .           .
60            .           A............
              .           V
              .           V
63            .          RA
              .           .
              .           .
66            .           .       SUB4A
              .           .           V
              .           .           V
77            .           .         R4A
              .           .           .
              .           .           .
80            .           .           .       SUB4B
              .           .           .           .
              .           .           .           .
90           B.................................
             V
             V
93          RB
              .
              .
96            .        SUB5
              .           .
```

```
        .          .
107     .          .        SUB6
        .          .          .
        .          .          .
119     C.......................
        V
        V
122    RC
        .
        .
125     .      SUB7A
        .          V
        .          V
129     .        R7A
        .          .
        .          .
132     .          .       SUB7B
        .          .          .
        .          .          .
142     I.......................
        V
        V
145    RI
        .
        .
148     .      SUB8A
        .          V
        .          V
156     .        R8A
        .          .
        .          .
159     .          .       SUB8B
        .          .          .
        .          .          .
170     .          J............
        .          V
        .          V
173     .         RJ
        .          .
        .          .
```

```
176     .         .       SUB9
        .         .         V
        .         .         V
180     .         .        R9
        .         .         .
        .         .         .
183     .         .         .       SUB10
        .         .         .          .
        .         .         .          .
195     .        D.......................
        .        V
        .        V
198     .       RD
        .         .
        .         .
201     .         .      SUB11
        .         .         V
        .         .         V
213     .         .       R11
        .         .         .
        .         .         .
216     .         .         .       SUB12
        .         .         .          .
        .         .         .          .
220    E.................................
       V
       V
223    RE
        .
        .
226     .     SUB13
        .         .
        .         .
230     .         .      SUB14
        .         .         .
        .         .         .
239     .         .         .       SUB15
        .         .         .          .
        .         .         .          .
248    F.................................
```

```
              V
              V
  251        RF
              .
              .
  254         .       SUB16
              .          V
              .          V
  258         .         R16
              .          .
              .          .
  261         .          .       SUB17
              .          .          V
              .          .          V
  265         .          .         R17
              .          .          .
              .          .          .
  268         .          .          .       SUB18
              .          .          .          .
              .          .          .          .
  278         .          G.......................
              .          .
              .          .
  281        H............
```

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

```
1****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*             FEBRUARY 1981            *
*           REVISED 05 DEC 88          *
*                                      *
*  RUN DATE  05/09/1989  TIME  12:44:25 *
*                                      *
****************************************
```

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

GRASS WASH WATERSHED
100 YEAR, 24 HOUR STORM
FCDMC, 30 MARCH, 1989
IN HOUSE PROJECT DONE BY SANDY SHILLITO
THIS RUN DONE USING S-GRAPH OR LAG IN WATERSHEDS OF MORE THAN 5 SQUARE MILES, AND USING THE CLARK ESTIMATION OF TC FOR THOSE WATERSHEDS OF LESS THAN 5 SQUARE MILES.

```
9 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     30MAR89  STARTING DATE
                 ITIME        0000  STARTING TIME
                    NQ         300  NUMBER OF HYDROGRAPH ORDINATES
                NDDATE      1APR89  ENDING DATE
                NDTIME        0150  ENDING TIME
                 ICENT          19  CENTURY MARK

            COMPUTATION INTERVAL     .17 HOURS
                 TOTAL TIME BASE   49.83 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
1
                                        RUNOFF SUMMARY
                                   FLOW IN CUBIC FEET PER SECOND
                                 TIME IN HOURS,  AREA IN SQUARE MILES

                                 PEAK   TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD      BASIN     MAXIMUM     TIME OF
      OPERATION       STATION    FLOW    PEAK                                           AREA      STAGE     MAX STAGE
```

					6-HOUR	24-HOUR	72-HOUR	
+	HYDROGRAPH AT	SUB1	2584.	11.50	1230.	319.	154.	6.87
+	ROUTED TO	R1	2543.	11.67	1228.	319.	154.	6.87
+	HYDROGRAPH AT	SUB2	3653.	12.00	2058.	556.	268.	11.67
+	ROUTED TO	R2	3325.	13.67	2026.	556.	268.	11.67
+	HYDROGRAPH AT	SUB3	3177.	12.00	1831.	498.	240.	10.67
+	2 COMBINED AT	A	5722.	13.00	3741.	1054.	507.	22.34
+	ROUTED TO	RA	5025.	16.33	3589.	1054.	507.	22.34
+	HYDROGRAPH AT	SUB4A	2156.	11.67	1153.	306.	147.	5.76
+	ROUTED TO	R4A	1546.	18.67	1066.	306.	147.	5.76
+	HYDROGRAPH AT	SUB4B	4034.	11.50	1944.	505.	243.	10.88
+	4 COMBINED AT	B	6556.	11.50	5147.	2184.	1052.	45.85
+	ROUTED TO	RB	5703.	13.83	5045.	2184.	1052.	45.85
+	HYDROGRAPH AT	SUB5	2348.	11.83	1259.	335.	161.	7.22

	HYDROGRAPH AT							
+		SUB6	2074.	12.17	1211.	331.	159.	7.22
	3 COMBINED AT							
+		C	8317.	13.17	6182.	2849.	1372.	60.29
	ROUTED TO							
+		RC	8045.	14.17	6158.	2849.	1372.	60.29
	HYDROGRAPH AT							
+		SUB7A	6954.	9.67	1128.	300.	144.	4.06
	ROUTED TO							
+		R7A	2404.	13.17	1108.	300.	144.	4.06
	HYDROGRAPH AT							
+		SUB7B	3781.	11.33	1762.	455.	219.	9.56
	3 COMBINED AT							
+		I	11005.	13.50	8160.	3604.	1736.	73.91
	ROUTED TO							
+		RI	10798.	14.17	8125.	3604.	1736.	73.91
	HYDROGRAPH AT							
+		SUB8A	2904.	11.00	1197.	307.	148.	5.20
	ROUTED TO							
+		R8A	1896.	16.67	1145.	307.	148.	5.20
	HYDROGRAPH AT							
+		SUB8B	2945.	12.00	1667.	451.	217.	9.71
	2 COMBINED AT							
+		J	2946.	12.00	2098.	757.	365.	14.91
	ROUTED TO							
+		RJ	2617.	14.17	2041.	757.	365.	14.91

	HYDROGRAPH AT							
+		SUB9	1960.	11.00	790.	202.	97.	4.33
	ROUTED TO							
+		R9	1889.	11.33	789.	202.	97.	4.33
	HYDROGRAPH AT							
+		SUB10	3156.	12.17	1847.	505.	243.	10.73
	3 COMBINED AT							
+		D	5326.	12.17	4084.	1464.	705.	29.97
	ROUTED TO							
+		RD	4775.	18.33	3806.	1464.	705.	29.97
	HYDROGRAPH AT							
+		SUB11	3164.	12.33	1935.	538.	259.	11.58
	ROUTED TO							
+		R11	2916.	14.17	1899.	538.	259.	11.58
	HYDROGRAPH AT							
+		SUB12	2096.	10.83	660.	165.	79.	3.62
	4 COMBINED AT							
+		E	13988.	14.17	11889.	5770.	2779.	119.08
	ROUTED TO							
+		RE	13191.	17.33	11688.	5768.	2779.	119.08
	HYDROGRAPH AT							
+		SUB13	1466.	10.67	448.	112.	54.	2.46
	HYDROGRAPH AT							
+		SUB14	2364.	11.17	1034.	264.	127.	5.70
	HYDROGRAPH AT							
+		SUB15	2388.	11.00	934.	237.	114.	5.12
	4 COMBINED AT							

+		F	13262.	17.33	11719.	6372.	3075.	132.36
	ROUTED TO							
+		RF	13260.	17.33	11718.	6372.	3075.	132.36
	HYDROGRAPH AT							
+		SUB16	1113.	9.67	135.	34.	16.	.73
	ROUTED TO							
+		R16	261.	16.33	133.	34.	16.	.73
	HYDROGRAPH AT							
+		SUB17	2424.	10.83	857.	215.	103.	4.71
	ROUTED TO							
+		R17	1457.	16.33	826.	215.	103.	4.71
	HYDROGRAPH AT							
+		SUB18	1981.	11.33	929.	240.	116.	5.23
	3 COMBINED AT							
+		G	1981.	11.33	1355.	489.	235.	10.67
	2 COMBINED AT							
+		H	14660.	17.17	12522.	6860.	3310.	143.03

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

PLATE 1
GRASS WASH WATERSHED

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AGUILA QUADRANGLE
ARIZONA
15 MINUTE SERIES (TOPOGRAPHIC)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

VULTURE MOUNTAINS QUADRANGLE
ARIZONA
15 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
Topography by photogrammetric methods from aerial photographs taken 1951 and 1960. Field checked 1962
Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

SCALE 1:62500

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

AGUILA, ARIZ.
N3345—W11300/15
1962
AMS 3351 I—SERIES V798

VULTURE MOUNTAINS, ARIZ.
N3345—W11245/15
1961
3451 IV—SERIES V798