ORANGE COUNTY HYDROLOGY WORKBOOK

PREFACE

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WILLIAMSON AND SCHMID, CIVIL ENGINEERS, IRVINE, CALIFORNIA

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TABLE OF CONTENTS

TABLE OF CONTENTS

List of Figures

TABLE OF CONTENTS

List of Figures

TABLE OF CONTENTS

List of Figures

TABLE OF CONTENTS

List of Tables

TABLE OF CONTENTS

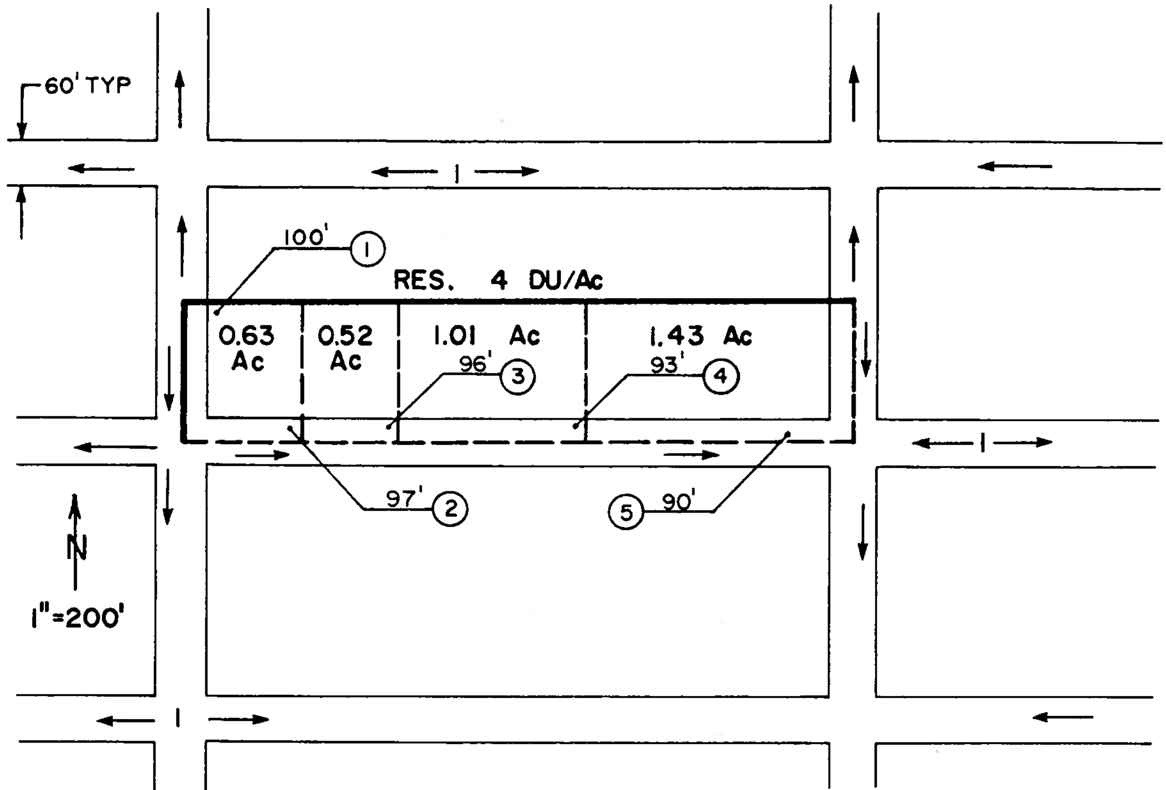
List of Tables

PROBLEM 1

Rational Method Initial Subarea and Street Flow Routing

Determine the peak flow rates for the catchment shown in Fig. 1. Note that the initial subarea time of concentration (T_c) is often the most significant factor leading to the T_c computation of a watershed. The Kirpich formula (which is used here) relates an initial subarea T_c to subarea slope, and development type. It is assumed that overland flow effects dominate the travel time hydraulics of the initial subarea.The data required for the initial subarea T_c calculation are: upstream elevation, downstream elevation, initial subarea flow-length, soil type, development type and area.

The data needed for streetflow travel time computations can be divided into two groups: streetflow hydraulic data, and subarea runoff data. In addition to the upstream elevation, downstream elevation, street length, symmetrical street half width (from crown to top of curb) and curb height (e.g., six inches or 8 inches), other hydraulic information includes the definition of the half-street section with two crossfalls (as shown in Fig. 2) by specifying the distance from the crown to the crossfall grade break and the interior and exterior crossfalls. Note that if the street has a raised median, it may be assumed that the crown is located at the median curb face. The second group of data describes the tributary subarea runoff characteristics. The needed information includes soil type, development type, and subarea acreage. An iteration process is used to estimate the average peak flowrate through the subarea until a good mean value is determined. Based on this average flowrate, the normal depth and velocity is calculated using Manning's Equation. The streetflow travel time is then calculated and added to the upstream T_c to obtain the T_c at the downstream point of concentration. The end-of-the-subarea peak flowrate and corresponding streetflow hydraulic data (i.e., depth, velocity, etc.) are then calculated based on the downstream peak flow rate.

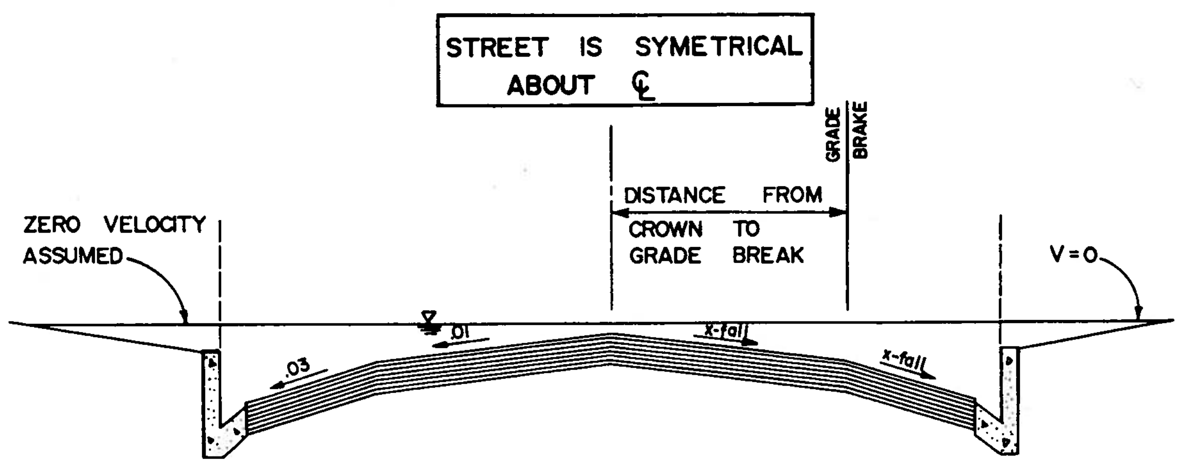


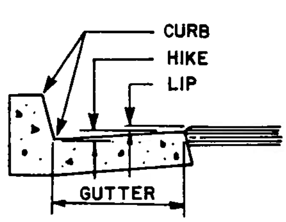
NOTE: entire catchment is in soil group B

LEGEND

———	Watershed boundary	——→	Street Flow
— — —	Subarea boundary	○	Node
RES.	Residential Development	90'	Elevation

FIGURE 1. PROBLEM 1 SCHEMATIC





ASSUMED VALUES:

	6" CURB	8" CURB
Curb	6.0"	8.0"
Gutter	1.5'	2.0'
Hike	0.125'	0.167'
Lip	0.03125'	0.03125'
Manning's n	0.015	0.015

FIGURE 2. STREETFLOW HYDRAULIC DATA FOR EXAMPLE

STUDY NAME: **EXAMPLE PROBLEM 1**

CALCULATED BY: TRW
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PAGE NUMBER / OF /

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D E N G I N E E R I N G S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
2.00	.6	.6	2	8	..	7.9	4.77	.18	.180	2.6	200	.0150	..	INITIAL SUBAREA
60. ft-STREET FLOW TO PT.# 3.00	.5	1.1	2	8	.9	8.9	4.50	.180	.180	4.5	130	.0077	2.5	*Qav= 3.6cfs DEPTH= .40 ft. FLOODWIDTH= 9.7
60. ft-STREET FLOW TO PT.# 4.00	1.0	2.2	2	8	1.2	10.1	4.14	.180	.180	7.7	240	.0125	3.5	*Qav= 6.3cfs DEPTH= .44 ft. FLOODWIDTH=11.0
60. ft-STREET FLOW TO PT.# 5.00	1.4	3.6	2	8	1.3	11.4	3.89	.180	.180	12.0	270	.0111	3.7	*Qav= 10.1cfs DEPTH= .52 ft. FLOODWIDTH=13.5
5.00		3.6			----	11.4				12.0	----	----	----	STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 3.59 TOTAL STUDY AREA(ACRES)= 3.59 PEAK FLOW RATE(CFS)= 11.98

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC,
*8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, *
0.5=SPECIFIED RUNOFF COEFF. *

```
****************************************************************************
         RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE
            (Reference: 1986 OCEMA HYDROLOGY CRITERION)
```

EXAMPLE PROBLEM 1

```
----------------------------------------------------------------------------

============================================================================
  USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:
============================================================================
                  --*TIME-OF-CONCENTRATION MODEL*--

  USER SPECIFIED STORM EVENT(YEAR) =  100.00
  SPECIFIED MINIMUM PIPE SIZE(INCH) =  18.00
  SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE =  .95
  *DATA BANK RAINFALL USED*

****************************************************************************
  FLOW PROCESS FROM NODE     1.00 TO NODE     2.00 IS CODE =   2
----------------------------------------------------------------------------
  >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
============================================================================
  DEVELOPMENT IS  SINGLE FAMILY RESIDENTIAL -> 3-4 DWELLINGS/ACRE

  TC = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]** .20
  INITIAL SUBAREA FLOW-LENGTH =   200.00
  UPSTREAM ELEVATION =     100.00
  DOWNSTREAM ELEVATION =      97.00
  ELEVATION DIFFERENCE =       3.00
  TC =  .412*[(  200.00** 3.00)/(      3.00)]** .20 =     7.945
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  4.768
  SOIL CLASSIFICATION IS "B"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
  SUBAREA RUNOFF(CFS) =       2.60
  TOTAL AREA(ACRES) =        .63   PEAK FLOW RATE(CFS) =       2.60

****************************************************************************
  FLOW PROCESS FROM NODE     2.00 TO NODE     3.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =      97.00   DOWNSTREAM ELEVATION =      96.00
  STREET LENGTH(FEET) =    130.00   CURB HEIGTH(INCHES) = 6.
  STREET HALFWIDTH(FEET) = 30.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  15.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .010
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .030

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1
```

```
        **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =     3.61
   STREETFLOW MODEL RESULTS:
        STREET FLOWDEPTH(FEET) =    .40
        HALFSTREET FLOODWIDTH(FEET) =     9.73
        AVERAGE FLOW VELOCITY(FEET/SEC.) =     2.37
        PRODUCT OF DEPTH&VELOCITY =     .95
  STREETFLOW TRAVELTIME(MIN) =    .92    TC(MIN) =    8.86

   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  4.497
  SOIL CLASSIFICATION IS "B"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
  SUBAREA AREA(ACRES) =     .52   SUBAREA RUNOFF(CFS) =     2.02
  EFFECTIVE AREA(ACRES) =     1.15
  AVERAGED Fm(INCH/HR) =    .180
  TOTAL AREA(ACRES) =     1.15    PEAK FLOW RATE(CFS) =        4.47
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =   .43   HALFSTREET FLOODWIDTH(FEET) = 10.57
  FLOW VELOCITY(FEET/SEC.) =  2.51    DEPTH*VELOCITY =    1.07


****************************************************************************
  FLOW PROCESS FROM NODE      3.00 TO NODE      4.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =      96.00   DOWNSTREAM ELEVATION =      93.00
  STREET LENGTH(FEET) =    240.00   CURB HEIGTH(INCHES) = 6.
  STREET HALFWIDTH(FEET) = 30.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  15.00
  INTERIOR STREET CROSSFALL(DECIMAL) =    .010
  OUTSIDE STREET CROSSFALL(DECIMAL)  =    .030

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =   1

        **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =     6.27
   STREETFLOW MODEL RESULTS:
        STREET FLOWDEPTH(FEET) =    .44
        HALFSTREET FLOODWIDTH(FEET) =    10.99
        AVERAGE FLOW VELOCITY(FEET/SEC.) =     3.27
        PRODUCT OF DEPTH&VELOCITY =     1.44
  STREETFLOW TRAVELTIME(MIN) =    1.22    TC(MIN) =   10.08

   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  4.143
  SOIL CLASSIFICATION IS "B"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
  SUBAREA AREA(ACRES) =     1.01   SUBAREA RUNOFF(CFS) =     3.60
  EFFECTIVE AREA(ACRES) =     2.16
  AVERAGED Fm(INCH/HR) =    .180
  TOTAL AREA(ACRES) =     2.16    PEAK FLOW RATE(CFS) =        7.70
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =   .47   HALFSTREET FLOODWIDTH(FEET) = 11.84
  FLOW VELOCITY(FEET/SEC.) =  3.49    DEPTH*VELOCITY =    1.63


****************************************************************************
  FLOW PROCESS FROM NODE      4.00 TO NODE      5.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
```

```
UPSTREAM ELEVATION =      93.00   DOWNSTREAM ELEVATION =      90.00
STREET LENGTH(FEET) =    270.00   CURB HEIGTH(INCHES) = 6.
STREET HALFWIDTH(FEET) = 30.00

DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  15.00
INTERIOR STREET CROSSFALL(DECIMAL) =   .010
OUTSIDE STREET CROSSFALL(DECIMAL)  =   .030

SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

       **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   10.09
  STREETFLOW MODEL RESULTS:
       NOTE: STREETFLOW EXCEEDS TOP OF CURB.
       THE FOLLOWING STREETFLOW RESULTS ARE BASED ON THE ASSUMPTION
       THAT NEGLIBLE FLOW OCCURS OUTSIDE OF THE STREET CHANNEL.
       THAT IS, ALL FLOW ALONG THE PARKWAY, ETC., IS NEGLECTED.
       STREET FLOWDEPTH(FEET) =   .52
       HALFSTREET FLOODWIDTH(FEET) =   13.52
       AVERAGE FLOW VELOCITY(FEET/SEC.) =    3.54
       PRODUCT OF DEPTH&VELOCITY =    1.83
STREETFLOW TRAVELTIME(MIN) =   1.27   TC(MIN) =  11.35

 100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.889
SOIL CLASSIFICATION IS "B"
RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
SUBAREA AREA(ACRES) =    1.43   SUBAREA RUNOFF(CFS) =    4.77
EFFECTIVE AREA(ACRES) =    3.59
AVERAGED Fm(INCH/HR) =   .180
TOTAL AREA(ACRES) =    3.59   PEAK FLOW RATE(CFS) =     11.98
END OF SUBAREA STREETFLOW HYDRAULICS:
DEPTH(FEET) =   .54   HALFSTREET FLOODWIDTH(FEET) = 14.37
FLOW VELOCITY(FEET/SEC.) =  3.74   DEPTH*VELOCITY =   2.03
============================================================================
END OF STUDY SUMMARY:
TOTAL AREA(ACRES)      =      3.59
EFFECTIVE AREA(ACRES) =      3.59
PEAK FLOW RATE(CFS)    =     11.98
============================================================================
END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 2

Proposed Pipe Flow Routing

Using the watershed from problem 1, route the peak runoff through a reinforced concrete pipe from node 5 to node 6 as shown in Fig. 3. The pipe hydraulic data required are the upstream elevation, downstream elevation, pipe length, and Manning's friction factor. The pipe size is estimated by first calculating the "exact" pipe diameter (using Manning's equation) corresponding to capacity flow at 0.82 diameter of the pipe, and then choosing the next largest "logical" pipe size. For example, storm drain design pipe sizes usually begin with an 18-inch diameter and increase in 3-inch increments up to 72-inches, and then in 6-inch or 12-inch increments. The travel time is computed using the normal depth velocity in the design pipe size. Because the normal depth flow hydraulics assumes that all available energy is utilized towards friction losses, one may wish to allow for other losses by reducing the friction slope.

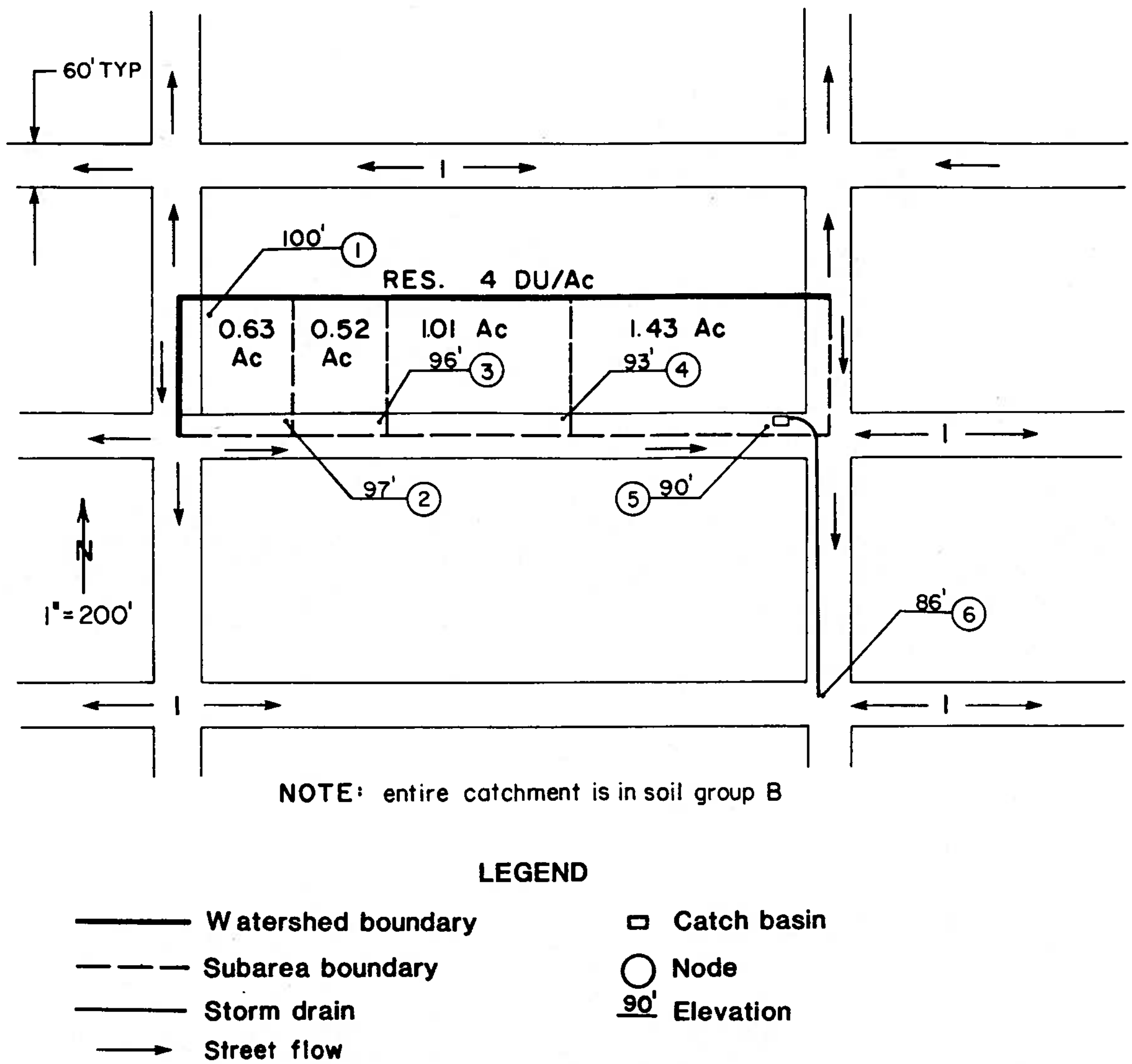

FIGURE 3. PROBLEM 2 SCHEMATIC

STUDY NAME: **EXAMPLE PROBLEM 2**

100.0-YEAR STORM RATIONAL METHOD STUDY

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 1 OF 1

[ADVANCED ENGINEERING SOFTWARE]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						200	.0150	..	INITIAL SUBAREA
2.00	.6	.6	2	8		7.9	4.77	.18	.180	2.6				
											130	.0077	2.5	*Qav= 3.6cfs
60. ft-STREET														DEPTH= .40 ft.
FLOW TO PT.#					.9									FLOODWIDTH= 9.7
3.00	.5	1.1	2	8		8.9	4.50	.180	.180	4.5				
											240	.0125	3.5	*Qav= 6.3cfs
60. ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					1.2									FLOODWIDTH=11.0
4.00	1.0	2.2	2	8		10.1	4.14	.180	.180	7.7				
											270	.0111	3.7	*Qav= 10.1cfs
60. ft-STREET														DEPTH= .52 ft.
FLOW TO PT.#					1.3									FLOODWIDTH=13.5
5.00	1.4	3.6	2	8		11.4	3.89	.180	.180	12.0				
											410	.0098	7.0	*Qav= 12.0cfs
														n=.0130 Dn= 1.2
					1.0									21.0"-PIPE
6.00		3.6				12.3				12.0				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 3.59 TOTAL STUDY AREA(ACRES)= 3.59 PEAK FLOW RATE(CFS)= 11.98

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, SOIL TYPES: 1=A, 2=B, 3=C, 4=D, *

EXAMPLE PROBLEM 2

(SEE EXAMPLE PROBLEM 1 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE      5.00 TO NODE      6.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  21.0 INCH PIPE IS  14.0 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =    7.0
  UPSTREAM NODE ELEVATION =     90.00
  DOWNSTREAM NODE ELEVATION =     86.00
  FLOWLENGTH(FEET) =   410.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  21.00    NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =      11.98
  TRAVEL TIME(MIN.) =    .97    TC(MIN.) =  12.33
============================================================================
  END OF STUDY SUMMARY:
  TOTAL AREA(ACRES)       =       3.59
  EFFECTIVE AREA(ACRES) =       3.59
  PEAK FLOW RATE(CFS)     =      11.98
============================================================================
  END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 3

Existing Pipe Flow Routing

Again using the watershed from problem 1, route the peak runoff through a reinforced concrete pipe. However this time assume an existing 24-inch reinforced concrete pipe is to be used between nodes 5 and 6. The required pipe hydraulic data are: upstream elevation, downstream elevation, pipe length, Manning's friction factor, and the number of pipes. If the pipe size specified is assumed to be flowing under pressure, then the travel time is based on the flow velocity computed by the entire flow divided by the cross-sectional area of the pipe.

Note that ground elevations may be used to calculate the pipeflow friction slope for proposed storm drains. Usually, the storm drain profile and the corresponding friction slope parallels the ground profile; therefore, the travel time can be estimated using the land gradient as an estimate of the energy gradient. In the case of a sump being on the alignment of the storm drain, it may be necessary to use estimates of the storm drain energy head elevations in order to develop a friction slope for use in pipe sizing. For studies of existing storm drains, the friction slopes may be estimated from the as-built plans or other survey data.

STUDY NAME: **EXAMPLE PROBLEM 3**

CALCULATED BY: TRW
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PAGE NUMBER OF

100.0-YEAR STORM RATIONAL METHOD STUDY

[ADVANCED ENGINEERING SOFTWARE]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						200	.0150	..	INITIAL SUBAREA
2.00	.6	.6	2	8		7.9	4.77	.18	.180	2.6				
											130	.0077	2.5	*Qav= 3.6cfs
60.ft-STREET														DEPTH= .40 ft.
FLOW TO PT.#					.9									FLOODWIDTH= 9.7
3.00	.5	1.1	2	8		8.9	4.50	.180	.180	4.5				
											240	.0125	3.5	*Qav= 6.3cfs
60.ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					1.2									FLOODWIDTH=11.0
4.00	1.0	2.2	2	8		10.1	4.14	.180	.180	7.7				
											270	.0111	3.7	*Qav= 10.1cfs
60.ft-STREET														DEPTH= .52 ft.
FLOW TO PT.#					1.3									FLOODWIDTH=13.5
5.00	1.4	3.6	2	8		11.4	3.89	.180	.180	12.0				
											410	.0098	7.1	*Qav= 12.0cfs
														n=.0130 Dn= 1.1
					1.0									24.0"-PIPE
6.00		3.6				12.3				12.0				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 3.59 TOTAL STUDY AREA(ACRES)= 3.59 PEAK FLOW RATE(CFS)= 11.98

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, SOIL TYPES: 1=A, 2=B, 3=C, 4=D, *
*8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC 0, 5=SPECIFIED RUNOFF COEFF. *

EXAMPLE PROBLEM 3

(SEE EXAMPLE PROBLEM 1 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE      5.00 TO NODE      6.00 IS CODE =    4
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING USER-SPECIFIED PIPESIZE<<<<<
============================================================================
  DEPTH OF FLOW IN  24.0 INCH PIPE IS  12.7 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =    7.1
  UPSTREAM NODE ELEVATION =     90.00
  DOWNSTREAM NODE ELEVATION =     86.00
  FLOWLENGTH(FEET) =    410.00   MANNINGS N =  .013
  GIVEN PIPE DIAMETER(INCH) =  24.00    NUMBER OF PIPES =    1
  PIPEFLOW THRU SUBAREA(CFS) =      11.98
  TRAVEL TIME(MIN.) =    .96    TC(MIN.) =  12.32
============================================================================
  END OF STUDY SUMMARY:
  TOTAL AREA(ACRES)      =      3.59
  EFFECTIVE AREA(ACRES)  =      3.59
  PEAK FLOW RATE(CFS)    =     11.98
============================================================================
  END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 4

Rational Method Addition of Subarea

Using the example catchment from problem 3, add the subarea runoff tributary to the mainline at node 6. The easiest method is to first add the 7.11 acres of residential development and then the 2.41 acres of apartments as depicted in Fig. 4. The input data required are the soil type, development type, and subarea acreage. Another method is to determine the composite loss rate (F_m) for the total tributary subarea and use only one data set for subarea runoff calculations. Both approaches are demonstrated in this example problem.

$$\text{Composite } F_m = \frac{(\text{AREA}_1 \times \text{subarea 1 } F_m) + (\text{AREA}_2 \times \text{subarea 2 } F_m)}{\text{Area}_1 + \text{Area}_2}$$

$$\text{Composite } F_m = [(7.11 \text{ Ac} \times 0.18) + (2.41 \text{ Ac} \times 0.06)] / [7.11 \text{ Ac} + 2.41 \text{ Ac}]$$

Generally, up to 50% of the total upstream area can be added to the mainline without confluencing the flows. However you should confluence the catchments regardless of subarea size if it appears that an effective area calculation is needed.

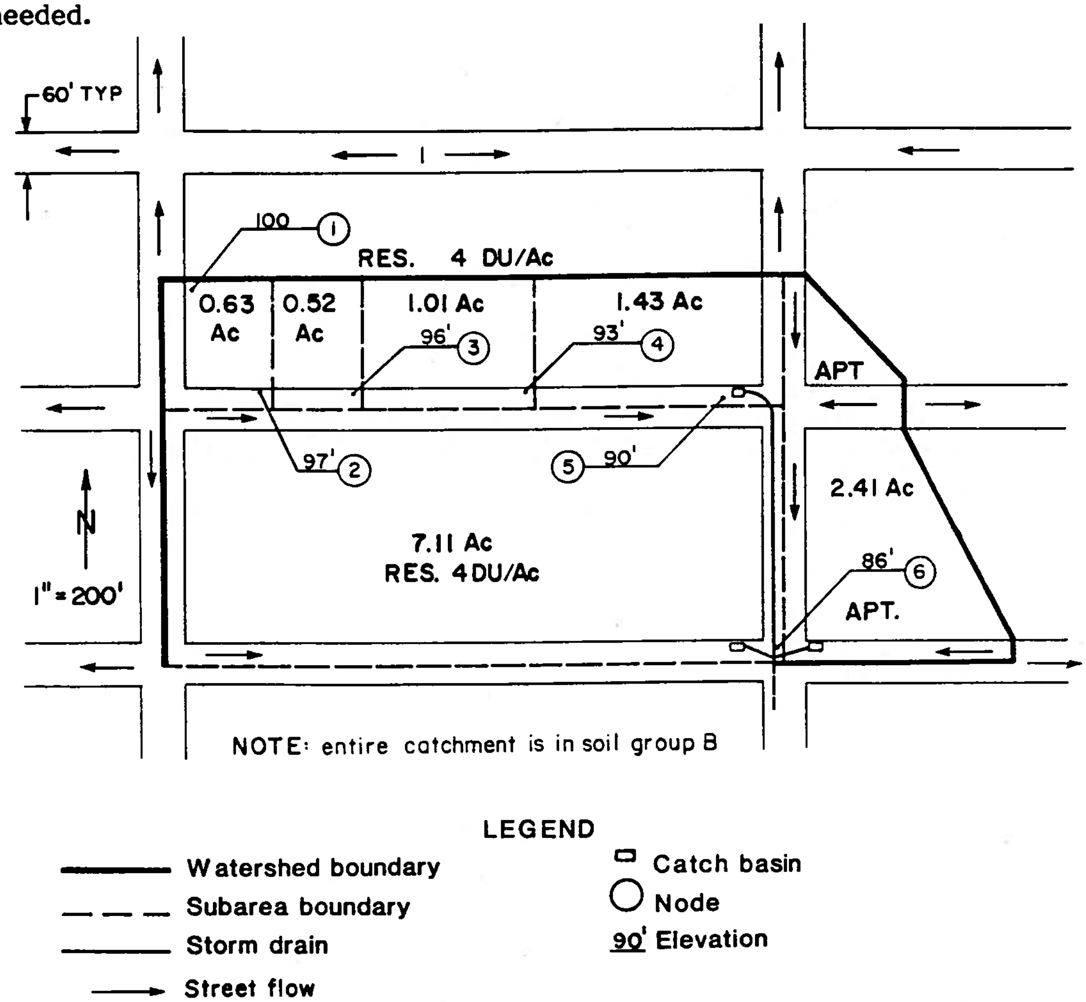

FIGURE 4. PROBLEM 4 SCHEMATIC

STUDY NAME: **EXAMPLE PROBLEM 4A**

CALCULATED BY: TRW
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PAGE NUMBER 1 OF 1

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
2.00	.6	.6	2	8	..	7.9	4.77	.18	.180	2.6	200	.0150	..	INITIAL SUBAREA
60. ft-STREET FLOW TO PT.# 3.00	.5	1.1	2	8	.9	8.9	4.50	.180	.180	4.5	130	.0077	2.5	*Qav= 3.6cfs DEPTH= .40 ft. FLOODWIDTH= 9.7
60. ft-STREET FLOW TO PT.# 4.00	1.0	2.2	2	8	1.2	10.1	4.14	.180	.180	7.7	240	.0125	3.5	*Qav= 6.3cfs DEPTH= .44 ft. FLOODWIDTH=11.0
60. ft-STREET FLOW TO PT.# 5.00	1.4	3.6	2	8	1.3	11.4	3.89	.180	.180	12.0	270	.0111	3.7	*Qav= 10.1cfs DEPTH= .52 ft. FLOODWIDTH=13.5
					1.0						410	.0098	7.1	*Qav= 12.0cfs n=.0130 Dn= 1.1 24.0"-PIPE
6.00	7.1	10.7	2	8	----	12.3	3.70	.180	.180	33.9				
6.00	2.4	13.1	2	3	----	12.3	3.70	.060	.158	41.8				
6.00		13.1			----	12.3				41.8				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 13.11   TOTAL STUDY AREA(ACRES)= 13.11   PEAK FLOW RATE(CFS)= 41.75

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, *8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0.5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: **EXAMPLE PROBLEM 4B**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 1 OF 1

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D E N G I N E E R I N G S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
2.00	.6	.6	2	8	..	7.9	4.77	.18	.180	2.6	200	.0150	..	INITIAL SUBAREA
60. ft-STREET FLOW TO PT.# 3.00	.5	1.1	2	8	.9	8.9	4.50	.180	.180	4.5	130	.0077	2.5	*Qav= 3.6cfs DEPTH= .40 ft. FLOODWIDTH= 9.7
60. ft-STREET FLOW TO PT.# 4.00	1.0	2.2	2	8	1.2	10.1	4.14	.180	.180	7.7	240	.0125	3.5	*Qav= 6.3cfs DEPTH= .44 ft. FLOODWIDTH=11.0
60. ft-STREET FLOW TO PT.# 5.00	1.4	3.6	2	8	1.3	11.4	3.89	.180	.180	12.0	270	.0111	3.7	*Qav= 10.1cfs DEPTH= .52 ft. FLOODWIDTH=13.5
6.00	9.5	13.1	5	8	1.0	12.3	3.70	.150	.158	41.7	410	.0098	7.1	*Qav= 12.0cfs n=.0130 Dn= 1.1 24.0"-PIPE
6.00		13.1				12.3				41.7				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 13.11 TOTAL STUDY AREA(ACRES)= 13.11 PEAK FLOW RATE(CFS)= 41.75

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, *8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, * 0, 5=SPECIFIED RUNOFF COEFF. *

EXAMPLE PROBLEM 4A

(SEE EXAMPLE PROBLEM 2 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE      5.00 TO NODE      6.00 IS CODE =    4
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING USER-SPECIFIED PIPESIZE<<<<<
============================================================================
  DEPTH OF FLOW IN  24.0 INCH PIPE IS  12.7 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =    7.1
  UPSTREAM NODE ELEVATION =     90.00
  DOWNSTREAM NODE ELEVATION =     86.00
  FLOWLENGTH(FEET) =   410.00   MANNINGS N =  .013
  GIVEN PIPE DIAMETER(INCH) =  24.00     NUMBER OF PIPES =    1
  PIPEFLOW THRU SUBAREA(CFS) =      11.98
  TRAVEL TIME(MIN.) =     .96    TC(MIN.) =  12.32

****************************************************************************
  FLOW PROCESS FROM NODE      6.00 TO NODE      6.00 IS CODE =    8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.697
  SOIL CLASSIFICATION IS "B"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
  SUBAREA AREA(ACRES) =     7.11   SUBAREA RUNOFF(CFS) =    22.50
  EFFECTIVE AREA(ACRES) =    10.70
  AVERAGED Fm(INCH/HR) =    .180
  TOTAL AREA(ACRES) =    10.70
  PEAK FLOW RATE(CFS) =    33.86
  TC(MIN) =   12.32

****************************************************************************
  FLOW PROCESS FROM NODE      6.00 TO NODE      6.00 IS CODE =    8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.697
  SOIL CLASSIFICATION IS "B"
  APARTMENTS SUBAREA LOSS RATE, Fm(INCH/HR) =  .0600
  SUBAREA AREA(ACRES) =     2.41   SUBAREA RUNOFF(CFS) =     7.89
  EFFECTIVE AREA(ACRES) =    13.11
  AVERAGED Fm(INCH/HR) =    .158
  TOTAL AREA(ACRES) =    13.11
  PEAK FLOW RATE(CFS) =    41.75
  TC(MIN) =   12.32
============================================================================
  END OF STUDY SUMMARY:
  TOTAL AREA(ACRES)         =      13.11
  EFFECTIVE AREA(ACRES)  =      13.11
  PEAK FLOW RATE(CFS)       =      41.75
============================================================================
  END OF RATIONAL METHOD ANALYSIS
```

EXAMPLE PROBLEM 4B

(SEE EXAMPLE PROBLEM 2 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
 FLOW PROCESS FROM NODE      5.00 TO NODE      6.00 IS CODE =    4
----------------------------------------------------------------------------
 >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
 >>>>>USING USER-SPECIFIED PIPESIZE<<<<<
============================================================================
 DEPTH OF FLOW IN  24.0 INCH PIPE IS  12.7 INCHES
 PIPEFLOW VELOCITY(FEET/SEC.) =    7.1
 UPSTREAM NODE ELEVATION =      90.00
 DOWNSTREAM NODE ELEVATION =     86.00
 FLOWLENGTH(FEET) =   410.00   MANNINGS N =  .013
 GIVEN PIPE DIAMETER(INCH) =  24.00     NUMBER OF PIPES =    1
 PIPEFLOW THRU SUBAREA(CFS) =      11.98
 TRAVEL TIME(MIN.) =     .96    TC(MIN.) =  12.32

****************************************************************************
 FLOW PROCESS FROM NODE      6.00 TO NODE      6.00 IS CODE =    8
----------------------------------------------------------------------------
 >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
  100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.697
 *USER SPECIFIED(SUBAREA):
 RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
 SUBAREA AREA(ACRES) =    9.52   SUBAREA RUNOFF(CFS) =   30.39
 EFFECTIVE AREA(ACRES) =   13.11
 AVERAGED Fm(INCH/HR) =   .158
 TOTAL AREA(ACRES) =   13.11
 PEAK FLOW RATE(CFS) =   41.75
 TC(MIN) =  12.32
============================================================================
 END OF STUDY SUMMARY:
 TOTAL AREA(ACRES)       =      13.11
 EFFECTIVE AREA(ACRES) =      13.11
 PEAK FLOW RATE(CFS)    =      41.75
============================================================================
 END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 5

Rational Method Confluence

Route the peak runoff from problem 4 to node 7 and confluence this runoff with the peak flow rate from the shopping center south of node 6 (see Fig. 5). Approximately size the reinforced concrete pipe between nodes 6 and 7 using the gradient of the land as an estimate of the pipe friction slope. Note that between nodes 11 and 13, a V-gutter is specified as the conveyance section. The data input required for computing V-gutter flow through a subarea are: upstream elevation, downstream elevation, length, development type, soil group, and subarea acreage. The V-gutter geometric features are shown in Fig. 6. Similar to street flow calculations, V-gutter analysis generally includes the estimation of an average peak flow rate through the subarea.

From node 13 to node 14, a trapezoidal channel is specified. Unlike the analysis of streetflow and V-gutter flow, the trapezoidal channel calculations do not usually account for the addition of runoff from a subarea. If there is a significant subarea tributary to the trapezoidal channel whose runoff could affect the trapezoidal channel flow travel time, then one may wish to increase the number of concentration points along the trapezoidal channel.

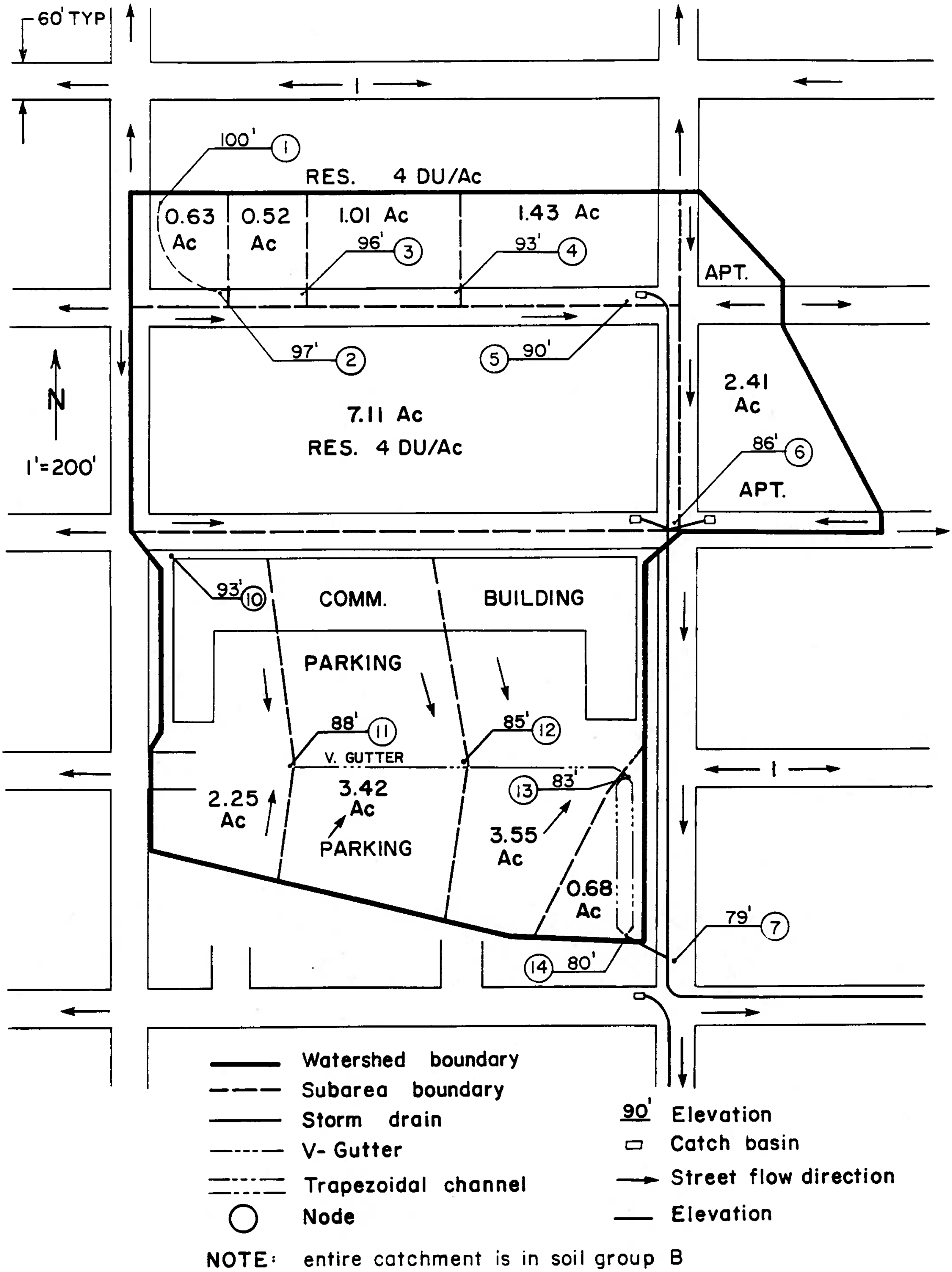
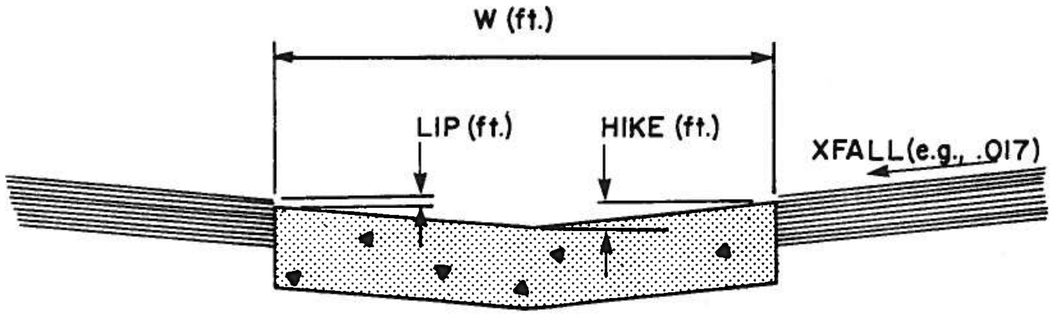
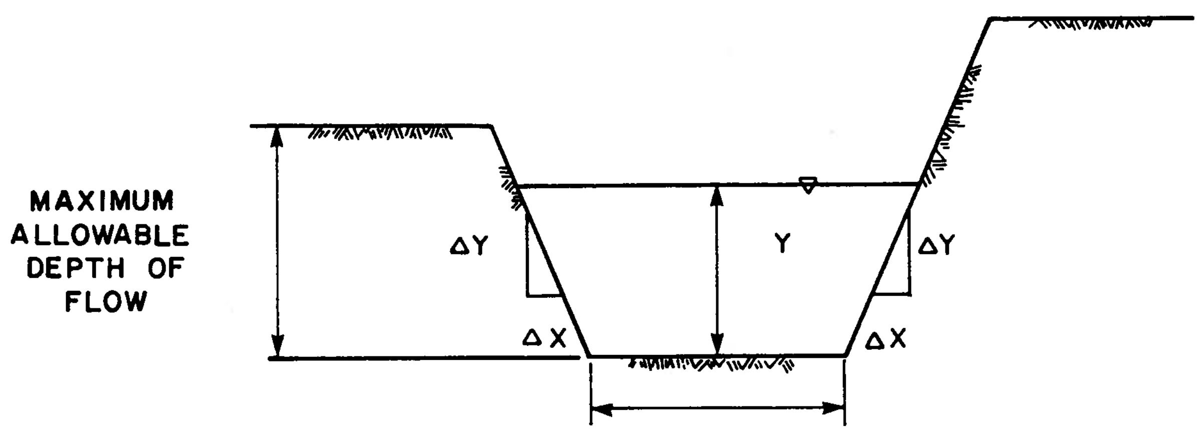


FIGURE 5. PROBLEM 5 SCHEMATIC



V - Gutter



$Z = \Delta X / \Delta Y$

Trapezoidal Channel

FIGURE 6. DATA REQUIREMENTS FOR FLOW TRAVELTIME CALCULATIONS

STUDY NAME: **EXAMPLE PROBLEM 5**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 1 OF 2

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						200	.0150	..	INITIAL SUBAREA
2.00	.6	.6	2	8	----	7.9	4.77	.18	.180	2.6				
											130	.0077	2.5	*Qav= 3.6cfs
60.ft-STREET														DEPTH= .40 ft.
FLOW TO PT.#					.9									FLOODWIDTH= 9.7
3.00	.5	1.1	2	8	----	8.9	4.50	.180	.180	4.5				
											240	.0125	3.5	*Qav= 6.3cfs
60.ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					1.2									FLOODWIDTH=11.0
4.00	1.0	2.2	2	8	----	10.1	4.14	.180	.180	7.7				
											270	.0111	3.7	*Qav= 10.1cfs
60.ft-STREET														DEPTH= .52 ft.
FLOW TO PT.#					1.3									FLOODWIDTH=13.5
5.00	1.4	3.6	2	8	----	11.4	3.89	.180	.180	12.0				
											410	.0098	7.0	*Qav= 12.0cfs
														n=.0130 Dn= 1.2
					1.0									21.0"-PIPE
6.00	7.1	10.7	2	8	----	12.3	3.69	.180	.180	33.8				
6.00	2.4	13.1	2	3	----	12.3	3.69	.060	.158	41.7				
											705	.0099	9.6	*Qav= 41.7cfs
														n=.0130 Dn= 1.9
					1.2									33.0"-PIPE
7.00		13.1			----	13.5	3.51			41.7	----	----	----	FOR CONFLUENCE
					..						460	.0109	..	INITIAL SUBAREA
11.00	2.3	2.3	2	1	----	8.7	4.54	.03	.030	9.1				
											275	.0109	3.6	*Qav= 15.4cfs
4.0ft-GUTTER														XFALL= .02000
FLOW TO PT.#					1.3									n=.0150 Dn= .4
12.00	3.4	5.7	2	1	----	10.1	4.15	.030	.030	21.0				

DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0, 5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: **EXAMPLE PROBLEM 5**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 2 OF 2

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
											260	.0077	3.4	*Qav= 27.2cfs
4.0ft-GUTTER														XFALL= .02000
FLOW TO PT.#					1.3									n=.0150 Dn= .5
13.00	3.5	9.2	2	1		11.4	3.88	.030	.030	32.0				
											245	.0163	9.6	*Qav= 32.0cfs
														n=.0150 Dn= 1.4
					.4									B= 1.0 Z= 1.0
14.00	.7	9.9	2	1		11.8	3.80	.030	.030	33.6				
											85	.0118	9.8	*Qav= 33.6cfs
														n=.0130 Dn= 1.7
					.1									30.0"-PIPE

CONFLUENCE ANALYSIS FOR POINT# 7.00							
	TC#1= 13.5	TC#2= 12.0	TC#3= .0	TC#4= .0	TC#5= .0	SUM OF STREAM	LARGEST
	Q#1= 41.7	Q#2= 33.6	Q#3= .0	Q#4= .0	Q#5= .0	AREAS= 21.47	CONFLUENCE
	I#1= 3.51	I#2= 3.77	I#3= .00	I#4= .00	I#5= .00	TOTAL	Q= 73.2
7.00	EA#1= 13.1	EA#2= 9.9	EA#3= .0	EA#4= .0	EA#5= .0	AREA = 23.01	
	Fm1= .158	Fm2= .030	Fm3= .000	Fm4= .000	Fm5= .000		
	Q1 = 73.0	Q2 = 73.2	Q3 = .0	Q4 = .0	Q5 = .0		

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
7.00		21.5				12.0				73.2				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 21.47   TOTAL STUDY AREA(ACRES)= 23.01   PEAK FLOW RATE(CFS)= 73.25

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC   SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0,5=SPECIFIED RUNOFF COEFF. *

EXAMPLE PROBLEM 5

(SEE EXAMPLE PROBLEM 4 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE     5.00 TO NODE     6.00 IS CODE =   4
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING USER-SPECIFIED PIPESIZE<<<<<
============================================================================
  DEPTH OF FLOW IN  21.0 INCH PIPE IS  14.0 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =    7.0
  UPSTREAM NODE ELEVATION =     82.00
  DOWNSTREAM NODE ELEVATION =     78.00
  FLOWLENGTH(FEET) =    410.00   MANNINGS N =  .013
  GIVEN PIPE DIAMETER(INCH) =  21.00     NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =      11.98
  TRAVEL TIME(MIN.) =    .97    TC(MIN.) =  12.33

****************************************************************************
  FLOW PROCESS FROM NODE     6.00 TO NODE     6.00 IS CODE =   8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.694
  SOIL CLASSIFICATION IS "B"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1800
  SUBAREA AREA(ACRES) =     7.11   SUBAREA RUNOFF(CFS) =    22.49
  EFFECTIVE AREA(ACRES) =   10.70
  AVERAGED Fm(INCH/HR) =    .180
  TOTAL AREA(ACRES) =   10.70
  PEAK FLOW RATE(CFS) =    33.84
  TC(MIN) =  12.33

****************************************************************************
  FLOW PROCESS FROM NODE     6.00 TO NODE     6.00 IS CODE =   8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.694
  SOIL CLASSIFICATION IS "B"
  APARTMENTS SUBAREA LOSS RATE, Fm(INCH/HR) =  .0600
  SUBAREA AREA(ACRES) =     2.41   SUBAREA RUNOFF(CFS) =     7.88
  EFFECTIVE AREA(ACRES) =   13.11
  AVERAGED Fm(INCH/HR) =    .158
  TOTAL AREA(ACRES) =   13.11
  PEAK FLOW RATE(CFS) =    41.73
  TC(MIN) =  12.33
```

```
****************************************************************************
 FLOW PROCESS FROM NODE      6.00 TO NODE      7.00 IS CODE =   3
----------------------------------------------------------------------------
 >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
 >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
 DEPTH OF FLOW IN  33.0 INCH PIPE IS  22.6 INCHES
 PIPEFLOW VELOCITY(FEET/SEC.) =   9.6
 UPSTREAM NODE ELEVATION =     86.00
 DOWNSTREAM NODE ELEVATION =    79.00
 FLOWLENGTH(FEET) =   705.00   MANNINGS N =  .013
 ESTIMATED PIPE DIAMETER(INCH) =  33.00    NUMBER OF PIPES =   1
 PIPEFLOW THRU SUBAREA(CFS) =     41.73
 TRAVEL TIME(MIN.) =   1.22    TC(MIN.) =  13.55


****************************************************************************
 FLOW PROCESS FROM NODE      7.00 TO NODE      7.00 IS CODE =   1
----------------------------------------------------------------------------
 >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
============================================================================
 CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  1 ARE:
 TIME OF CONCENTRATION(MINUTES) =  13.55
 RAINFALL INTENSITY (INCH./HOUR) =   3.51
 EFFECTIVE STREAM AREA(ACRES) =   13.11
 TOTAL STREAM AREA(ACRES) =   13.11
 PEAK FLOW RATE(CFS) AT CONFLUENCE =      41.73


****************************************************************************
 FLOW PROCESS FROM NODE     10.00 TO NODE     11.00 IS CODE =   2
----------------------------------------------------------------------------
 >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
============================================================================
 DEVELOPMENT IS COMMERCIAL

 TC = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]** .20
 INITIAL SUBAREA FLOW-LENGTH =    460.00
 UPSTREAM ELEVATION =      93.00
 DOWNSTREAM ELEVATION =      88.00
 ELEVATION DIFFERENCE =      5.00
 TC =  .304*[(  460.00** 3.00)/(      5.00)]** .20 =     8.724
  100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  4.538
 SOIL CLASSIFICATION IS "B"
 COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0300
 SUBAREA RUNOFF(CFS) =       9.13
 TOTAL AREA(ACRES) =       2.25   PEAK FLOW RATE(CFS) =       9.13
```

```
****************************************************************************
  FLOW PROCESS FROM NODE     11.00 TO NODE     12.00 IS CODE =   9
----------------------------------------------------------------------------
  >>>>>COMPUTE "V" GUTTER FLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM NODE ELEVATION =       88.00
  DOWNSTREAM NODE ELEVATION =       85.00
  CHANNEL LENGTH THRU SUBAREA(FEET) =    275.00
  "V" GUTTER WIDTH(FEET) =    4.00   GUTTER HIKE(FEET) =    .104
  PAVEMENT LIP(FEET) =    .020   MANNINGS N = .0150
  PAVEMENT CROSSFALL(DECIMAL NOTATION) =    .02
  MAXIMUM DEPTH(FEET) =    1.00
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  4.148
  SOIL CLASSIFICATION IS "B"
  COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0300
  TRAVELTIME THRU SUBAREA BASED ON VELOCITY(FEET/SEC) =   3.43
  AVERAGE FLOWDEPTH(FEET) =     .38   FLOODWIDTH(FEET) =   29.32
  "V" GUTTER FLOW TRAVEL TIME(MIN) =    1.34   TC(MIN) =  10.06
  SUBAREA AREA(ACRES) =     3.42   SUBAREA RUNOFF(CFS) =   12.67
  EFFECTIVE AREA(ACRES) =     5.67
  AVERAGED Fm(INCH/HR) =    .030
  TOTAL AREA(ACRES) =     5.67   PEAK FLOW RATE(CFS) =      21.01
  END OF SUBAREA "V" GUTTER HYDRAULICS:
  DEPTH(FEET) =    .42   FLOODWIDTH(FEET) =   33.43
  FLOW VELOCITY(FEET/SEC.) =    3.63   DEPTH*VELOCITY =   1.52


****************************************************************************
  FLOW PROCESS FROM NODE     12.00 TO NODE     13.00 IS CODE =   9
----------------------------------------------------------------------------
  >>>>>COMPUTE "V" GUTTER FLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM NODE ELEVATION =       85.00
  DOWNSTREAM NODE ELEVATION =       83.00
  CHANNEL LENGTH THRU SUBAREA(FEET) =    260.00
  "V" GUTTER WIDTH(FEET) =    4.00   GUTTER HIKE(FEET) =    .104
  PAVEMENT LIP(FEET) =    .020   MANNINGS N = .0150
  PAVEMENT CROSSFALL(DECIMAL NOTATION) =    .02
  MAXIMUM DEPTH(FEET) =    1.00
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.882
  SOIL CLASSIFICATION IS "B"
  COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0300
  TRAVELTIME THRU SUBAREA BASED ON VELOCITY(FEET/SEC) =   3.27
  AVERAGE FLOWDEPTH(FEET) =     .49   FLOODWIDTH(FEET) =   40.27
  "V" GUTTER FLOW TRAVEL TIME(MIN) =    1.33   TC(MIN) =  11.39
  SUBAREA AREA(ACRES) =     3.55   SUBAREA RUNOFF(CFS) =   12.31
  EFFECTIVE AREA(ACRES) =     9.22
  AVERAGED Fm(INCH/HR) =    .030
  TOTAL AREA(ACRES) =     9.22   PEAK FLOW RATE(CFS) =      31.97
  END OF SUBAREA "V" GUTTER HYDRAULICS:
  DEPTH(FEET) =    .51   FLOODWIDTH(FEET) =   43.01
  FLOW VELOCITY(FEET/SEC.) =    3.38   DEPTH*VELOCITY =   1.74
```

```
****************************************************************************
  FLOW PROCESS FROM NODE     13.00 TO NODE     14.00 IS CODE =   5
----------------------------------------------------------------------------
  >>>>>COMPUTE TRAPEZOIDAL-CHANNEL FLOW<<<<<
  >>>>>TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM NODE ELEVATION =      83.00
  DOWNSTREAM NODE ELEVATION =      80.00
  CHANNEL LENGTH THRU SUBAREA(FEET) =    245.00
  CHANNEL BASE(FEET) =    1.00   "Z" FACTOR =    1.000
  MANNINGS FACTOR =  .015   MAXIMUM DEPTH(FEET) =    3.00
  CHANNEL FLOW THRU SUBAREA(CFS) =       31.97
  FLOW VELOCITY(FEET/SEC) =    8.63   FLOW DEPTH(FEET) =    1.49
  TRAVEL TIME(MIN.) =     .47   TC(MIN.) =   11.86


****************************************************************************
  FLOW PROCESS FROM NODE     14.00 TO NODE     14.00 IS CODE =   8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
   100 YEAR RAINFALL INTENSITY(INCH/HOUR) =   3.788
  SOIL CLASSIFICATION IS "B"
  COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0300
  SUBAREA AREA(ACRES) =      .68   SUBAREA RUNOFF(CFS) =     2.30
  EFFECTIVE AREA(ACRES) =     9.90
  AVERAGED Fm(INCH/HR) =    .030
  TOTAL AREA(ACRES) =     9.90
  PEAK FLOW RATE(CFS) =     33.48
  TC(MIN) =   11.86


****************************************************************************
  FLOW PROCESS FROM NODE     14.00 TO NODE      7.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  30.0 INCH PIPE IS   19.8 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =    9.8
  UPSTREAM NODE ELEVATION =      80.00
  DOWNSTREAM NODE ELEVATION =      79.00
  FLOWLENGTH(FEET) =     85.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =   30.00     NUMBER OF PIPES =    1
  PIPEFLOW THRU SUBAREA(CFS) =       33.48
  TRAVEL TIME(MIN.) =     .15    TC(MIN.) =   12.01


****************************************************************************
  FLOW PROCESS FROM NODE      7.00 TO NODE      7.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
  >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
```

```
TIME OF CONCENTRATION(MINUTES) =  12.01
RAINFALL INTENSITY (INCH./HOUR) =   3.76
EFFECTIVE STREAM AREA(ACRES) =    9.90
TOTAL STREAM AREA(ACRES) =    9.90
PEAK FLOW RATE(CFS) AT CONFLUENCE =     33.48

CONFLUENCE INFORMATION:
STREAM   PEAK FLOW   TIME    INTENSITY     FM    EFFECTIVE
NUMBER   RATE(CFS)  (MIN.) (INCH/HOUR) (IN/HR) AREA(ACRES)
------------------------------------------------------------------
  1       41.73     13.55        3.509     .16        13.11
  2       33.48     12.01        3.759     .03         9.90

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
CONFLUENCE FORMULA USED FOR  2 STREAMS.
SUMMARY RESULTS:
STREAM   CONFLUENCE   EFFECTIVE
NUMBER     Q(CFS)    AREA(ACRES)
----------------------------------------------
  1       72.97        23.01
  2       73.22        21.52
COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
PEAK FLOW RATE(CFS) =     73.22   TIME(MINUTES) =    12.007
EFFECTIVE AREA(ACRES) =     21.52
TOTAL AREA(ACRES) =     23.01
==============================================================================
END OF STUDY SUMMARY:
TOTAL AREA(ACRES)     =     23.01
EFFECTIVE AREA(ACRES) =     21.52
PEAK FLOW RATE(CFS)   =     73.22
==============================================================================
END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 6

Proposed Pipe Flow Routing with Change in Grade

Using the catchment of problem 5, route the peak runoff from node 7 to node 9 using estimates of reinforced concrete pipe sizes based upon friction slopes set equal to the gradient of the land (see Fig. 7). Note the grade break at node 8.

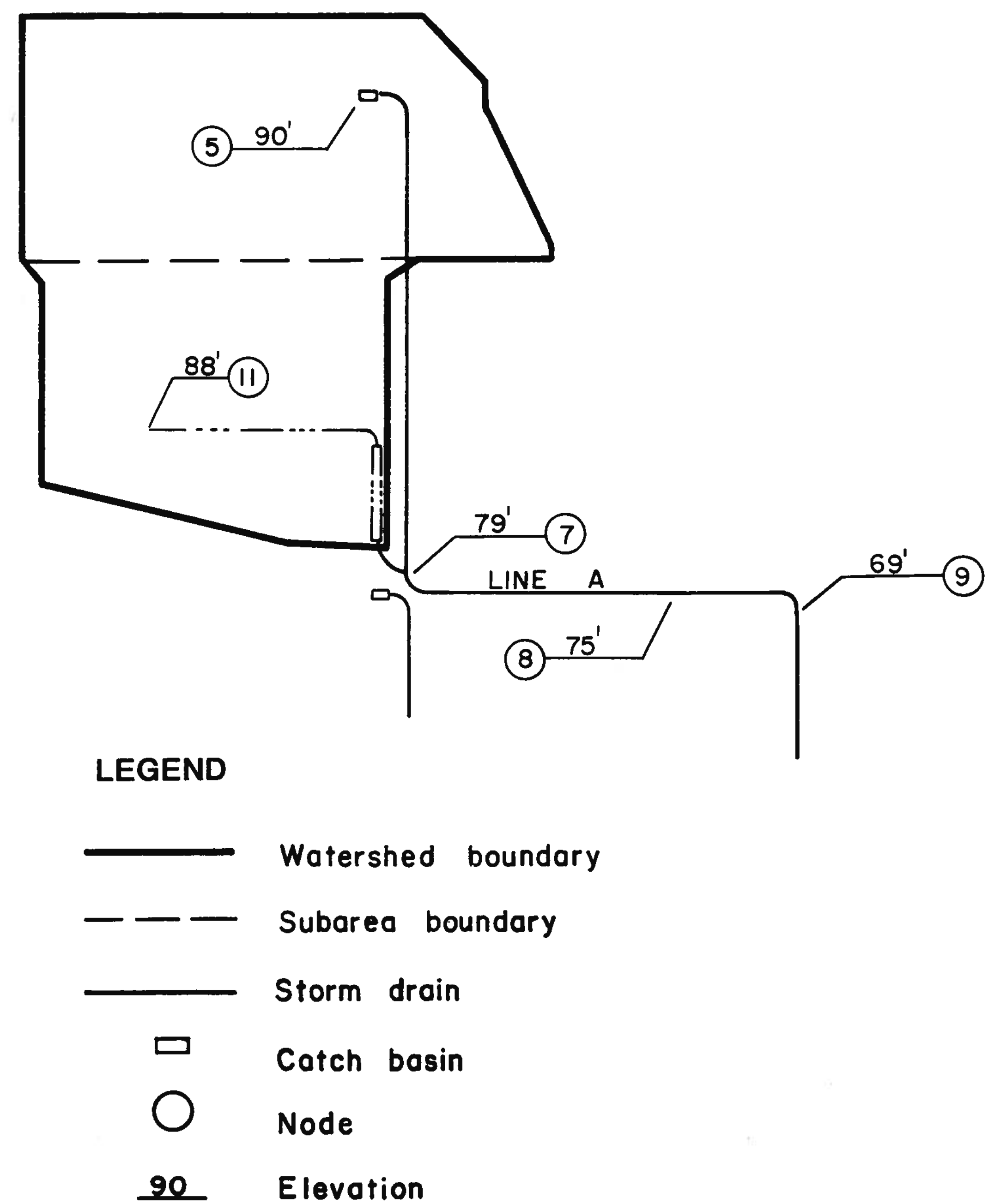


FIGURE 7. PROBLEM 6 SCHEMATIC

STUDY NAME: **EXAMPLE PROBLEM 6**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 1 OF 2

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						200	.0150	..	INITIAL SUBAREA
2.00	.6	.6	2	8		7.9	4.77	.18	.180	2.6				
											130	.0077	2.5	*Qav= 3.6cfs
60.ft-STREET														DEPTH= .40 ft.
FLOW TO PT.#					.9									FLOODWIDTH= 9.7
3.00	.5	1.1	2	8		8.9	4.50	.180	.180	4.5				
											240	.0125	3.5	*Qav= 6.3cfs
60.ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					1.2									FLOODWIDTH=11.0
4.00	1.0	2.2	2	8		10.1	4.14	.180	.180	7.7				
											270	.0111	3.7	*Qav= 10.1cfs
60.ft-STREET														DEPTH= .52 ft.
FLOW TO PT.#					1.3									FLOODWIDTH=13.5
5.00	1.4	3.6	2	8		11.4	3.89	.180	.180	12.0				
											410	.0098	7.0	*Qav= 12.0cfs
														n=.0130 Dn= 1.2
					1.0									21.0"-PIPE
6.00	7.1	10.7	2	8		12.3	3.69	.180	.180	33.8				
6.00	2.4	13.1	2	3		12.3	3.69	.060	.158	41.7				
											705	.0099	9.6	*Qav= 41.7cfs
														n=.0130 Dn= 1.9
					1.2									33.0"-PIPE
7.00		13.1				13.5	3.51			41.7				FOR CONFLUENCE
					..						460	.0109	..	INITIAL SUBAREA
11.00	2.3	2.3	2	1		8.7	4.54	.03	.030	9.1				
											275	.0109	3.6	*Qav= 15.4cfs
4.0ft-GUTTER														XFALL= .02000
FLOW TO PT.#					1.3									n=.0150 Dn= .4
12.00	3.4	5.7	2	1		10.1	4.15	.030	.030	21.0				

DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0,5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: **EXAMPLE PROBLEM 6**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 2 OF 2

100.0-YEAR STORM RATIONAL METHOD STUDY

[ADVANCED ENGINEERING SOFTWARE]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
4.0ft-GUTTER FLOW TO PT.#					1.3						260	.0077	3.4	*Qav= 27.2cfs XFALL= .02000 n=.0150 Dn= .5
13.00	3.5	9.2	2	1		11.4	3.88	.030	.030	32.0				
					.4						245	.0163	9.6	*Qav= 32.0cfs n=.0150 Dn= 1.4 B= 1.0 Z= 1.0
14.00	.7	9.9	2	1		11.8	3.80	.030	.030	33.6				
					.1						85	.0118	9.8	*Qav= 33.6cfs n=.0130 Dn= 1.7 30.0"-PIPE

CONFLUENCE ANALYSIS FOR POINT# 7.00						SUM OF STREAM	LARGEST CONFLUENCE
	TC#1= 13.5	TC#2= 12.0	TC#3= .0	TC#4= .0	TC#5= .0	SUM OF STREAM	LARGEST
	Q#1= 41.7	Q#2= 33.6	Q#3= .0	Q#4= .0	Q#5= .0	AREAS= 21.47	CONFLUENCE
	I#1= 3.51	I#2= 3.77	I#3= .00	I#4= .00	I#5= .00	TOTAL	Q= 73.2
	EA#1= 13.1	EA#2= 9.9	EA#3= .0	EA#4= .0	EA#5= .0	AREA = 23.01	
	Fm1= .158	Fm2= .030	Fm3= .000	Fm4= .000	Fm5= .000		
	Q1 = 73.0	Q2 = 73.2	Q3 = .0	Q4 = .0	Q5 = .0		

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					.4						310	.0129	11.9	*Qav= 73.2cfs n=.0130 Dn= 2.4 36.0"-PIPE
					.1						150	.0400	18.5	*Qav= 73.2cfs n=.0130 Dn= 1.9 30.0"-PIPE
9.00		21.5				12.5				73.2				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 21.47 TOTAL STUDY AREA(ACRES)= 23.01 PEAK FLOW RATE(CFS)= 73.25

DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, * 0, 5=SPECIFIED RUNOFF COEFF. *

EXAMPLE PROBLEM 6

(SEE EXAMPLE PROBLEM 5 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE      7.00 TO NODE      7.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
  >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
  TIME OF CONCENTRATION(MINUTES) =  12.01
  RAINFALL INTENSITY (INCH./HOUR) =   3.76
  EFFECTIVE STREAM AREA(ACRES) =    9.90
  TOTAL STREAM AREA(ACRES) =    9.90
  PEAK FLOW RATE(CFS) AT CONFLUENCE =     33.48

  CONFLUENCE INFORMATION:
  STREAM   PEAK FLOW   TIME   INTENSITY    FM    EFFECTIVE
  NUMBER   RATE(CFS)  (MIN.) (INCH/HOUR) (IN/HR) AREA(ACRES)
--------------------------------------------------------------
    1        41.73     13.55       3.509    .16       13.11
    2        33.48     12.01       3.759    .03        9.90

  RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
  CONFLUENCE FORMULA USED FOR  2 STREAMS.
  SUMMARY RESULTS:
  STREAM   CONFLUENCE   EFFECTIVE
  NUMBER     Q(CFS)    AREA(ACRES)
----------------------------------------------
    1        72.97        23.01
    2        73.22        21.52
  COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
  PEAK FLOW RATE(CFS) =      73.22   TIME(MINUTES) =    12.007
  EFFECTIVE AREA(ACRES) =      21.52
  TOTAL AREA(ACRES) =      23.01


****************************************************************************
  FLOW PROCESS FROM NODE      7.00 TO NODE      8.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  36.0 INCH PIPE IS  29.2 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =  11.9
  UPSTREAM NODE ELEVATION =    79.00
  DOWNSTREAM NODE ELEVATION =    75.00
  FLOWLENGTH(FEET) =   310.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  36.00    NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =     73.22
  TRAVEL TIME(MIN.) =    .43    TC(MIN.) =  12.44
```

```
*****************************************************************************
  FLOW PROCESS FROM NODE      8.00 TO NODE      9.00 IS CODE =   3
-----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
=============================================================================
  DEPTH OF FLOW IN  30.0 INCH PIPE IS  22.6 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =  18.5
  UPSTREAM NODE ELEVATION =    75.00
  DOWNSTREAM NODE ELEVATION =    69.00
  FLOWLENGTH(FEET) =   150.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  30.00    NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =     73.22
  TRAVEL TIME(MIN.) =     .14    TC(MIN.) =  12.58
=============================================================================
  END OF STUDY SUMMARY:
  TOTAL AREA(ACRES)       =      23.01
  EFFECTIVE AREA(ACRES) =      21.52
  PEAK FLOW RATE(CFS)    =      73.22
=============================================================================
  END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 7

Rational Method Effective Area

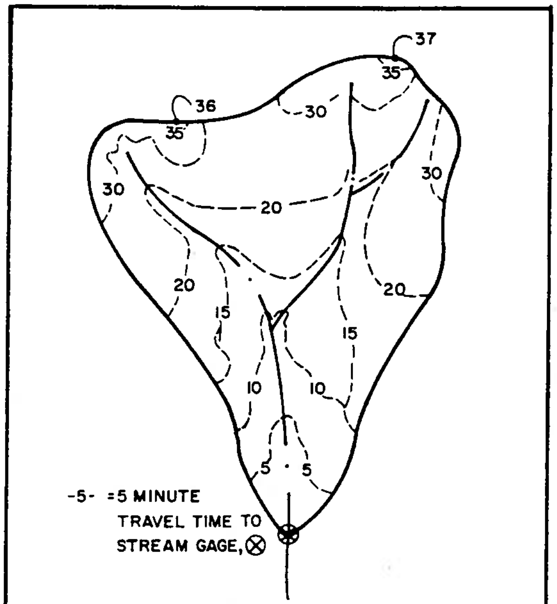


FIGURE 8. CONTRIBUTING AREA VS. TIME DIAGRAM

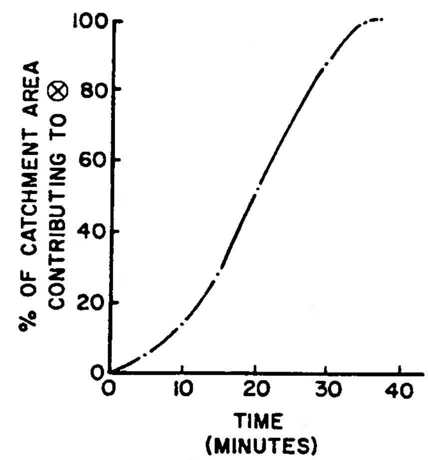


FIGURE 9. TIME AREA DIAGRAM

Effective Area

The rational method assumes that the peak flow rate corresponding to a T-year return frequency flood is related to a T-year return frequency rainfall of a uniform and constant intensity. For such a constant rainfall intensity, the timing for runoff throughout the catchment to reach the stream gage can be visualized by means of a time-area diagram (see Figs. 8 and 9). From the figures, it is seen that the entire catchment is contributing runoff to the stream gage by time 37 minutes.

A closer look at the time-area diagram reveals that the majority of the area is contributing runoff by time 30 minutes, and that a small fraction of additional catchment area is included during the next 7 minutes. However in the estimate of the peak flow rate, the rainfall intensity corresponding to the 37-minute critical duration is significantly less than a 30-minute rainfall intensity. Consequently, the peak flow rate may occur at a time of less than the 37 minutes needed for the entire catchment to deliver runoff to the stream gage;

that is, the effective area (or contributary area) associated to the peak flow rate is that area which contributes to the peak flow rate at its time of concentration.

Consider the following Table which includes the previous time-area diagram, the rainfall intensity (I) versus time, and the effective rainfall intensity (I-Fm) where the loss rate, Fm, is assumed to be 0.20 inch/hour. The peak flow rate, Q, is given by Q = 0.9 (I - 0.20) A where (A) is the effective area being considered. The tabulation of Q versus time is also included in the Table. In the Table, the catchment area is assumed to be 200 acres.

TABLE 1

DEMONSTRATION OF EFFECTIVE AREA

Time (Minutes)	Effective Area (percent)/(acres)		Intensity (in./hr.)	Effective Intensity	Q (cfs)
5	5%	10 Ac	4.06	3.86	35
10	14%	28 Ac	2.73	2.53	64
15	28%	56 Ac	2.16	1.96	99
20	52%	104 Ac	1.83	1.63	153
30	88%	176 Ac	1.45	1.25	198
35	99%	198 Ac	1.33	1.13	201
37	100%	200 Ac	1.29	1.09	196

From the Table, the peak Q occurs at about a time of concentration of 35 minutes, which has a corresponding effective area of 198 acres.

The rational method is a fast approximation of the time-area diagram technique. In the rational method confluence analyses, it is assumed that the percent of contributing catchment area (i.e., effective area) is a simple ratio with respect to time (see the confluence formulae); consequently, the analysis must include a verification of the effective area derived by the simple application of the peak flow rate and confluence formulae. Example problems 8, 9, and 10 demonstrate the effective area concept.

PROBLEM 8

Rational Method Effective Area at Confluence

Determine the effective area, peak discharge rate, and time of concentration, at the confluence of the three watersheds shown below in Fig. 10.

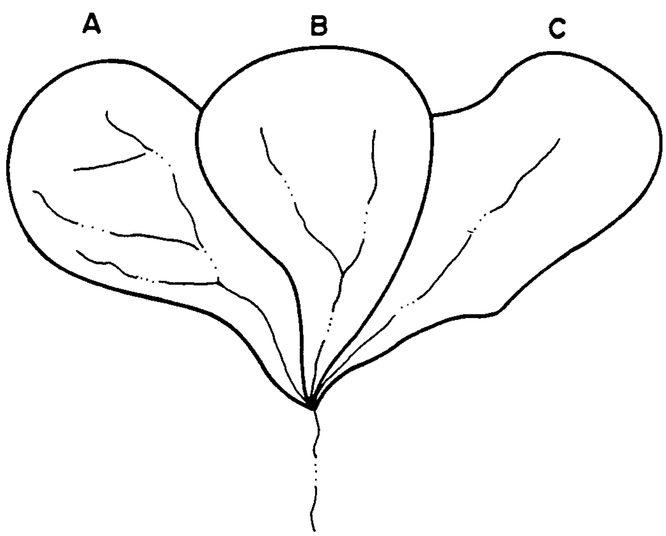


FIGURE 10. CONFLUENCE SCHEMATIC

TABLE 2

CONFLUENCE DATA

Watershed	Area (acres)	time of concentration (Minutes)	intensity (in./hr.)	maximum loss rate (in./hr.)	discharge (cfs)
A	100	30	2.22	0.2	182
B	100	45	1.76	0.2	140
C	100	60	1.45	0.4	95

8.1 Effective Area

The effective area at the confluence is dependent on the time of concentration. For example, only a portion of watersheds B and C are contributing runoff to the confluence at a 30 minute time of concentration. In the following are shown the calculations for the three watershed T_c's. It is noted that the estimation of the effective catchment area is only an approximation, and should be verified by the hydrologist by field inspection or a time-area diagram (see Figs. 11 and 12) if necessary

TABLE 3

EFFECTIVE AREA DATA

Time of Concentration (min.)	Watershed A Effective Area (acres)	Watershed B Effective Area (acres)	Watershed C Effective Area (acres)	Total Effective Area (acres)
30	100	(30M/45M)100	(30M/60M)100	217
45	100	100	(45M/60M)100	275
60	100	100	100	300

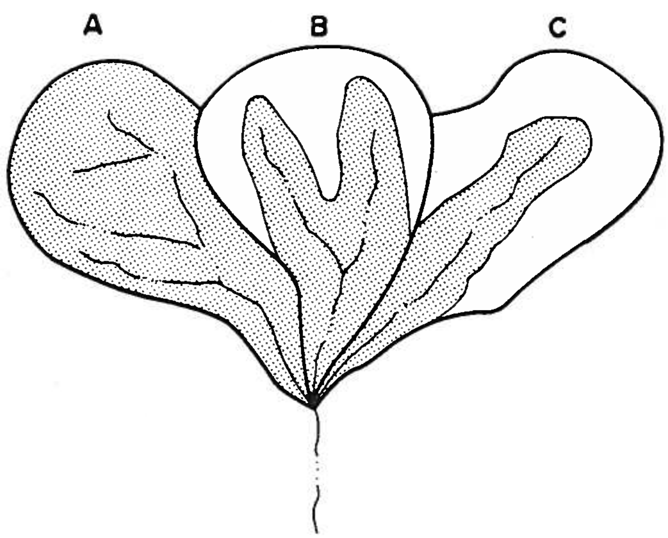


FIGURE 11. ACTUAL EFFECTIVE AREA FOR T_c OF 30 MINUTES

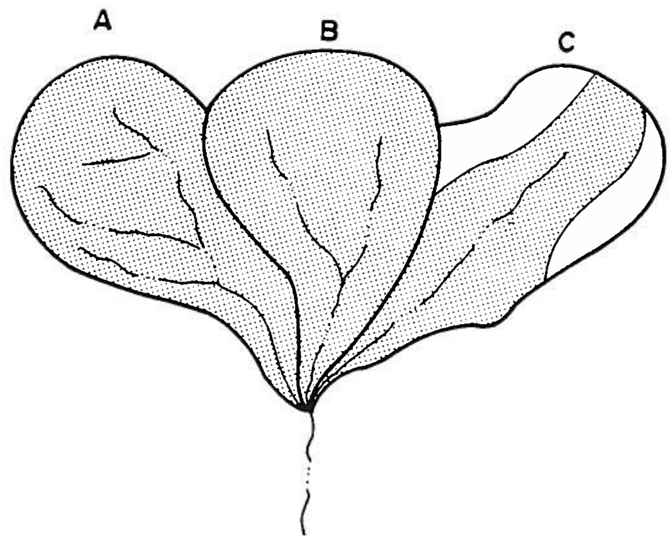


FIGURE 12. EFFECTIVE AREA FOR T_c OF 45 MINUTES

8.2. Runoff Flow Rate

The runoff flow rates are also calculated for the three times of concentration as shown below.

Time of Concentration (min)	Watershed A peak flow rate (cfs)		Watershed B peak flow rate (cfs)		Watershed C peak flow rate (cfs)		Confluenced peak flow rate (cfs)
30	182	+	$\left(\frac{2.22 - 0.2}{1.76 - 0.2}\right)\left(\frac{30}{45}\right)(140)$	+	$\left(\frac{2.22 - 0.4}{1.45 - 0.4}\right)\left(\frac{30}{60}\right)(95)$	=	385
45	$\left(\frac{1.76 - 0.2}{2.22 - 0.2}\right)(182)$	+	140	+	$\left(\frac{1.76 - 0.4}{1.45 - 0.4}\right)\left(\frac{45}{60}\right)(95)$	=	373
60	$\left(\frac{1.45 - 0.2}{2.22 - 0.2}\right)(182)$	+	$\left(\frac{1.45 - 0.2}{1.76 - 0.2}\right)(140)$	+	95	=	319

8.3. Time of Concentration

Generally the time of concentration corresponding to the largest confluenced flow rate is chosen for subsequent use in downstream calculations. However, the hydrologist should inspect the entire catchment's hydrology to ensure that the most critical confluence data are used. For example, if a large subarea is to be added immediately downstream of a confluence, then it may be appropriate to select the confluence data with a slightly smaller peak discharge rate and a significantly smaller time of concentration rather than the confluence data with the slightly larger peak discharge rate and the significantly larger time of concentration because the addition of the large subarea immediately downstream of the confluence will generate a higher peak discharge rate with the smaller time of concentration. Consequently, each point of concentration needs to be reviewed to guarantee that the most critical combination of confluence values are used to develop the design peak flow rates.

PROBLEM 9

Rational Method Multi-Confluence

Using the catchment shown in Fig. 13, determine the peak flow rate at the confluence of storm drain lines A and B. Because of the rational method's "cascading logic", confluences must be solved as one proceeds downstream. For example, the confluence at node 9 can only be solved when the peak flow rates in storm drain lines A and B are known. Consequently, the confluences at nodes 7 and 20 must be solved first.

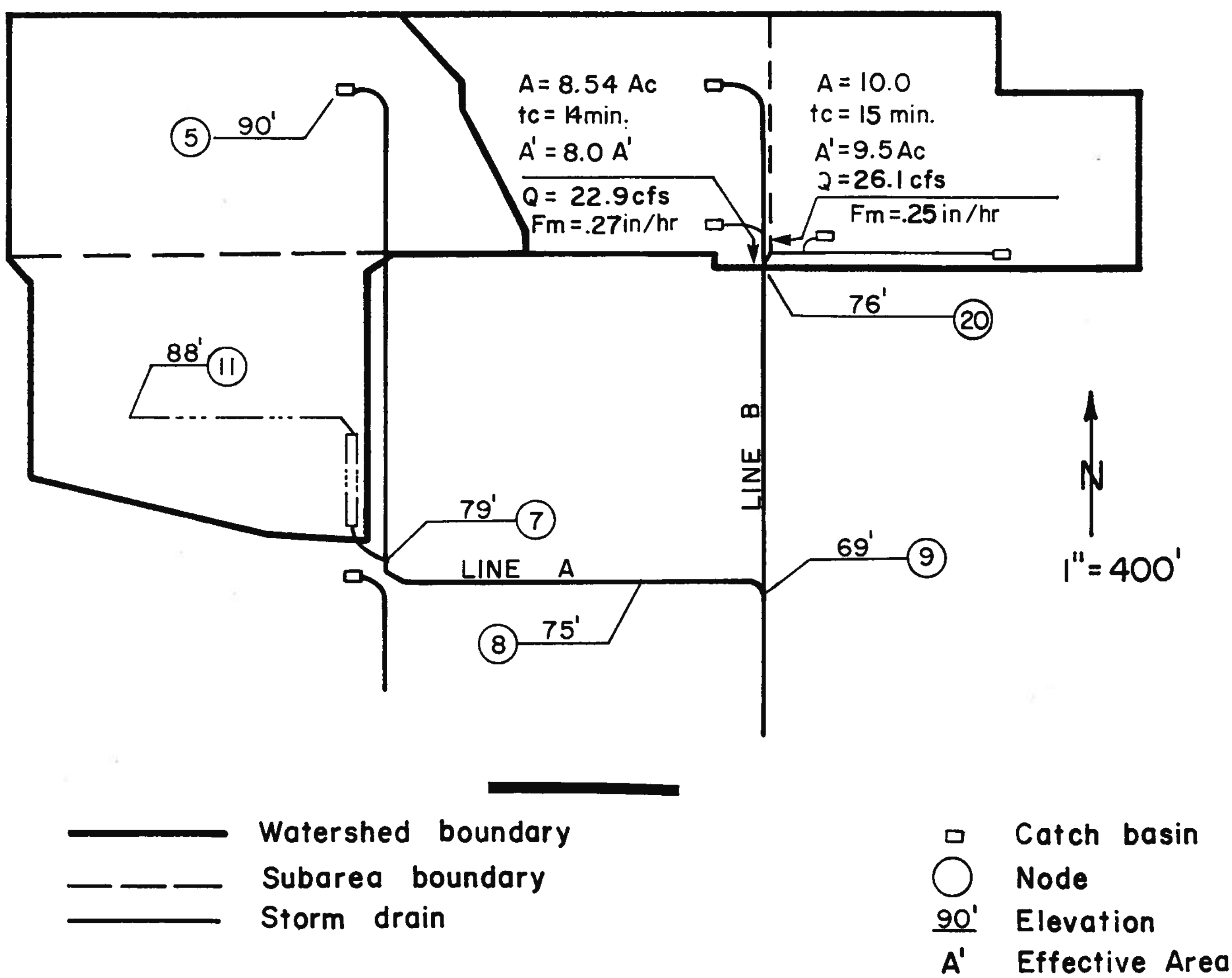


FIGURE 13. PROBLEM 9 SCHEMATIC

STUDY NAME: **EXAMPLE PROBLEM 9**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER 1 OF 3

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D E N G I N E E R I N G S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	AREA (ACRES) SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						200	.0150	..	INITIAL SUBAREA
2.00	.6	.6	2	8	----	7.9	4.77	.18	.180	2.6				
											130	.0077	2.5	*Qav= 3.6cfs
60. ft-STREET														DEPTH= .40 ft.
FLOW TO PT.#					.9									FLOODWIDTH= 9.7
3.00	.5	1.1	2	8	----	8.9	4.50	.180	.180	4.5				
											240	.0125	3.5	*Qav= 6.3cfs
60. ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					1.2									FLOODWIDTH=11.0
4.00	1.0	2.2	2	8	----	10.1	4.14	.180	.180	7.7				
											270	.0111	3.7	*Qav= 10.1cfs
60. ft-STREET														DEPTH= .52 ft.
FLOW TO PT.#					1.3									FLOODWIDTH=13.5
5.00	1.4	3.6	2	8	----	11.4	3.89	.180	.180	12.0				
											410	.0098	7.0	*Qav= 12.0cfs
														n=.0130 Dn= 1.2
					1.0									21.0"-PIPE
6.00	7.1	10.7	2	8	----	12.3	3.69	.180	.180	33.8				
6.00	2.4	13.1	2	3	----	12.3	3.69	.060	.158	41.7				
											705	.0099	9.6	*Qav= 41.7cfs
														n=.0130 Dn= 1.9
					1.2									33.0"-PIPE
7.00		13.1			----	13.5	3.51			41.7	----	-----	----	FOR CONFLUENCE
					..						460	.0109	..	INITIAL SUBAREA
11.00	2.3	2.3	2	1	----	8.7	4.54	.03	.030	9.1				
											275	.0109	3.6	*Qav= 15.4cfs
4.0ft-GUTTER														XFALL= .02000
FLOW TO PT.#					1.3									n=.0150 Dn= .4
12.00	3.4	5.7	2	1	----	10.1	4.15	.030	.030	21.0				

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, SOIL TYPES: 1=A, 2=B, 3=C, 4=D, *
*8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC 0, 5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: **EXAMPLE PROBLEM 9**

CALCULATED BY: TRW
CHECKED BY:
PAGE NUMBER OF

100.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D E N G I N E E R I N G S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
4.0ft-GUTTER FLOW TO PT.#					1.3						260	.0077	3.4	*Qav= 27.2cfs XFALL= .02000 n=.0150 Dn= .5
13.00	3.5	9.2	2	1		11.4	3.88	.030	.030	32.0				
					.4						245	.0163	9.6	*Qav= 32.0cfs n=.0150 Dn= 1.4 B= 1.0 Z= 1.0
14.00	.7	9.9	2	1		11.8	3.80	.030	.030	33.6				
					.1						85	.0118	9.8	*Qav= 33.6cfs n=.0130 Dn= 1.7 30.0"-PIPE
CONFLUENCE ANALYSIS FOR POINT# 7.00	TC#1= 13.5 Q#1= 41.7 I#1= 3.51 EA#1= 13.1 Fm1= .158 Q1 = 73.0	TC#2= 12.0 Q#2= 33.6 I#2= 3.77 EA#2= 9.9 Fm2= .030 Q2 = 73.2			TC#3= .0 Q#3= .0 I#3= .00 EA#3= .0 Fm3= .000 Q3 = .0		TC#4= .0 Q#4= .0 I#4= .00 EA#4= .0 Fm4= .000 Q4 = .0		TC#5= .0 Q#5= .0 I#5= .00 EA#5= .0 Fm5= .000 Q5 = .0		SUM OF STREAM AREAS= 21.47 TOTAL AREA = 23.01			LARGEST CONFLUENCE Q= 73.2
					.4						310	.0129	11.9	*Qav= 73.2cfs n=.0130 Dn= 2.4 36.0"-PIPE
					.1						150	.0400	18.5	*Qav= 73.2cfs n=.0130 Dn= 1.9 30.0"-PIPE
20.00		8.0			..	14.0			.27	22.9				ASSUMED DATA
20.00		8.0				14.0	3.44			22.9				FOR CONFLUENCE
20.00		9.5			..	15.0			.25	26.1				ASSUMED DATA

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, *8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0, 5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: **EXAMPLE PROBLEM 9**

```
| STUDY NAME: EXAMPLE PROBLEM  9                                           | CALCULATED BY:                |
|                                                                          |    CHECKED BY:                |
| 100.0-YEAR STORM RATIONAL METHOD STUDY                                   | PAGE NUMBER      OF           |
|---------------------[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]-------------------------|
|CONCENTRATION| AREA (ACRES) |SOIL|DEV.| Tt |  Tc  | I  | Fm |  Fm  |   Q   |PATH|SLOPE| V  |  HYDRAULICS   |
| POINT NUMBER|SUBAREA|  SUM |TYPE|TYPE|MIN.| MIN. |in/h|    |(Avg) |  SUM  |(ft)|ft/ft|FPS.|  AND NOTES    |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
| CONFLUENCE  |TC#1=  14.0 TC#2=  15.0 TC#3=    .0 TC#4=    .0 TC#5=      .0 SUM OF STREAM |   LARGEST     |
|  ANALYSIS   |Q#1=   22.9 Q#2=   26.1 Q#3=     .0 Q#4=     .0 Q#5=       .0 AREAS=   16.87|  CONFLUENCE   |
| FOR POINT#  |I#1=   3.44 I#2=   3.30 I#3=    .00 I#4=    .00 I#5=      .00 TOTAL         |  Q=  48.4     |
|       20.00 |EA#1=   8.0 EA#2=   9.5 EA#3=    .0 EA#4=    .0 EA#5=      .0 AREA =   18.54|               |
|             |Fm1=   .270 Fm2=   .250 Fm3=   .000 Fm4=   .000 Fm5=     .000----|-----|----|---------------|
|             |Q1 =   48.4 Q2 =   48.0 Q3 =     .0 Q4 =     .0 Q5 =       .0----|-----|----|---------------|
|-------------|-------|------|----|----|----|------|----|----|------|-------|    |     |    |               |
|-------------|-------|------|----|----|    |------|----|----|------|-------| 375|.0187|12.6| *Qav=  48.4cfs|
|             |       |      |    |    |    |      |    |    |      |       |    |     |    |n=.0130 Dn= 1.8|
|             |       |      |    |    |  .5|      |    |    |      |       |    |     |    |   30.0"-PIPE  |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
|        9.00 |       |  16.9|    |    |----| 14.5 |3.37|    |      |   48.4|----|-----|----|FOR CONFLUENCE |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
|             |       |      |    |    | .. |      |    |    |      |       |    |     |    | ASSUMED DATA  |
|        9.00 |       |  21.5|    |    |----| 12.6 |    |    |   .10|   73.2|----|-----|----|---------------|
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
| CONFLUENCE  |TC#1=  14.5 TC#2=  12.6 TC#3=    .0 TC#4=    .0 TC#5=      .0 SUM OF STREAM |   LARGEST     |
|  ANALYSIS   |Q#1=   48.4 Q#2=   73.2 Q#3=     .0 Q#4=     .0 Q#5=       .0 AREAS=   36.16|  CONFLUENCE   |
| FOR POINT#  |I#1=   3.37 I#2=   3.65 I#3=    .00 I#4=    .00 I#5=      .00 TOTAL         |  Q= 119.0     |
|        9.00 |EA#1=  16.9 EA#2=  21.5 EA#3=    .0 EA#4=    .0 EA#5=      .0 AREA =   41.55|               |
|             |Fm1=   .259 Fm2=   .103 Fm3=   .000 Fm4=   .000 Fm5=     .000----|-----|----|---------------|
|             |Q1 =  115.9 Q2 =  119.0 Q3 =     .0 Q4 =     .0 Q5 =       .0----|-----|----|---------------|
|-------------|-------|------|----|----|----|------|----|----|------|-------|    |     |    |               |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
|        9.00 |       |  36.2|    |    |----| 12.6 |    |    |      |  119.0|----|-----|----|STREAM SUMMARY |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
| EFFECTIVE AREA(ACRES)=    36.16   TOTAL STUDY AREA(ACRES)=    41.55   PEAK FLOW RATE(CFS)=     118.95 |
|-------------|-------|------|----|----|----|------|----|----|------|-------|----|-----|----|---------------|
|             |       |      |    |    |    |      |    |    |      |       |    |     |    |               |
|---------------------------------------------------------------------------------------------------------|
*DEV TYPES:    1=Com,2=MF,3=Apt,4=Con,5=SFR 11+ D/AC,6=8-10D/AC,7=5-7D/AC,   SOIL TYPES: 1=A,2=B,3=C,4=D,*
*8=3-4D/AC,9=2D/AC,10=1D/AC,11=0.4D/AC,12=Sch,13=PK,14=Ag,15=PC,16=AC,17=DC  0,5=SPECIFIED RUNOFF COEFF. *
```

EXAMPLE PROBLEM 9

(SEE EXAMPLE PROBLEM 6 FOR UPSTREAM CALCULATIONS)

```
****************************************************************************
  FLOW PROCESS FROM NODE     7.00 TO NODE     7.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
  >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
  TIME OF CONCENTRATION(MINUTES) =  12.01
  RAINFALL INTENSITY (INCH./HOUR) =   3.76
  EFFECTIVE STREAM AREA(ACRES) =    9.90
  TOTAL STREAM AREA(ACRES) =    9.90
  PEAK FLOW RATE(CFS) AT CONFLUENCE =     33.48

  CONFLUENCE INFORMATION:
  STREAM   PEAK FLOW   TIME   INTENSITY    FM    EFFECTIVE
  NUMBER   RATE(CFS)  (MIN.) (INCH/HOUR) (IN/HR) AREA(ACRES)
--------------------------------------------------------------
    1       41.73     13.55      3.509     .16       13.11
    2       33.48     12.01      3.759     .03        9.90

  RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
  CONFLUENCE FORMULA USED FOR  2 STREAMS.
  SUMMARY RESULTS:
  STREAM   CONFLUENCE   EFFECTIVE
  NUMBER     Q(CFS)     AREA(ACRES)
---------------------------------------------
    1       72.97        23.01
    2       73.22        21.52
  COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
  PEAK FLOW RATE(CFS) =     73.22   TIME(MINUTES) =   12.007
  EFFECTIVE AREA(ACRES) =     21.52
  TOTAL AREA(ACRES) =     23.01


****************************************************************************
  FLOW PROCESS FROM NODE     7.00 TO NODE     8.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  36.0 INCH PIPE IS  29.2 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =  11.9
  UPSTREAM NODE ELEVATION =    79.00
  DOWNSTREAM NODE ELEVATION =    75.00
  FLOWLENGTH(FEET) =   310.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  36.00    NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =     73.22
  TRAVEL TIME(MIN.) =    .43    TC(MIN.) =  12.44
```

```
****************************************************************************
  FLOW PROCESS FROM NODE      8.00 TO NODE      9.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  30.0 INCH PIPE IS  22.6 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =  18.5
  UPSTREAM NODE ELEVATION =     75.00
  DOWNSTREAM NODE ELEVATION =     69.00
  FLOWLENGTH(FEET) =   150.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  30.00    NUMBER OF PIPES =   1
  PIPEFLOW THRU SUBAREA(CFS) =     73.22
  TRAVEL TIME(MIN.) =    .14    TC(MIN.) =  12.58
  FLOW PROCESS FROM NODE     20.00 TO NODE     20.00 IS CODE =   7
----------------------------------------------------------------------------
  >>>>>USER SPECIFIED HYDROLOGY INFORMATION AT NODE<<<<<
============================================================================
  USER-SPECIFIED VALUES ARE AS FOLLOWS:
  TC(MIN) =  14.00   RAIN INTENSITY(INCH/HOUR) =  3.44
  EFFECTIVE AREA(ACRES) =      8.00
  TOTAL AREA(ACRES) =      8.54   PEAK FLOW RATE(CFS) =      22.90
  AVERAGED LOSS RATE, Fm(IN/HR) =   .270


****************************************************************************
  FLOW PROCESS FROM NODE     20.00 TO NODE     20.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  1 ARE:
  TIME OF CONCENTRATION(MINUTES) =  14.00
  RAINFALL INTENSITY (INCH./HOUR) =   3.44
  EFFECTIVE STREAM AREA(ACRES) =    8.00
  TOTAL STREAM AREA(ACRES) =    8.54
  PEAK FLOW RATE(CFS) AT CONFLUENCE =     22.90


****************************************************************************
  FLOW PROCESS FROM NODE     20.00 TO NODE     20.00 IS CODE =   7
----------------------------------------------------------------------------
  >>>>>USER SPECIFIED HYDROLOGY INFORMATION AT NODE<<<<<
============================================================================
  USER-SPECIFIED VALUES ARE AS FOLLOWS:
  TC(MIN) =  15.00   RAIN INTENSITY(INCH/HOUR) =  3.30
  EFFECTIVE AREA(ACRES) =      9.50
  TOTAL AREA(ACRES) =     10.00   PEAK FLOW RATE(CFS) =      26.10
  AVERAGED LOSS RATE, Fm(IN/HR) =   .250
```

```
****************************************************************************
  FLOW PROCESS FROM NODE     20.00 TO NODE     20.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
  >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
  TIME OF CONCENTRATION(MINUTES) =  15.00
  RAINFALL INTENSITY (INCH./HOUR) =   3.30
  EFFECTIVE STREAM AREA(ACRES) =    9.50
  TOTAL STREAM AREA(ACRES) =   10.00
  PEAK FLOW RATE(CFS) AT CONFLUENCE =      26.10

  CONFLUENCE INFORMATION:
  STREAM   PEAK FLOW   TIME   INTENSITY     FM    EFFECTIVE
  NUMBER   RATE(CFS)  (MIN.) (INCH/HOUR) (IN/HR) AREA(ACRES)
-----------------------------------------------------------------
    1        22.90     14.00       3.444     .27         8.00
    2        26.10     15.00       3.300     .25         9.50

  RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
  CONFLUENCE FORMULA USED FOR  2 STREAMS.
  SUMMARY RESULTS:
  STREAM   CONFLUENCE   EFFECTIVE
  NUMBER     Q(CFS)     AREA(ACRES)
--------------------------------------------
    1        48.41        16.87
    2        47.96        17.50
  COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
  PEAK FLOW RATE(CFS) =      48.41    TIME(MINUTES) =    14.000
  EFFECTIVE AREA(ACRES) =      16.87
  TOTAL AREA(ACRES) =      18.54


****************************************************************************
  FLOW PROCESS FROM NODE     20.00 TO NODE      9.00 IS CODE =   3
----------------------------------------------------------------------------
  >>>>>COMPUTE PIPEFLOW TRAVELTIME THRU SUBAREA<<<<<
  >>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<<<<<
============================================================================
  DEPTH OF FLOW IN  30.0 INCH PIPE IS  22.0 INCHES
  PIPEFLOW VELOCITY(FEET/SEC.) =  12.6
  UPSTREAM NODE ELEVATION =     76.00
  DOWNSTREAM NODE ELEVATION =     69.00
  FLOWLENGTH(FEET) =   375.00   MANNINGS N =  .013
  ESTIMATED PIPE DIAMETER(INCH) =  30.00    NUMBER OF PIPES =    1
  PIPEFLOW THRU SUBAREA(CFS) =      48.41
  TRAVEL TIME(MIN.) =     .50    TC(MIN.) =  14.50


****************************************************************************
  FLOW PROCESS FROM NODE      9.00 TO NODE      9.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  1 ARE:
  TIME OF CONCENTRATION(MINUTES) =  14.50
  RAINFALL INTENSITY (INCH./HOUR) =   3.37
  EFFECTIVE STREAM AREA(ACRES) =   16.87
  TOTAL STREAM AREA(ACRES) =   18.54
  PEAK FLOW RATE(CFS) AT CONFLUENCE =      48.41
```

```
****************************************************************************
  FLOW PROCESS FROM NODE      9.00 TO NODE      9.00 IS CODE =   7
----------------------------------------------------------------------------
  >>>>>USER SPECIFIED HYDROLOGY INFORMATION AT NODE<<<<<
============================================================================
  USER-SPECIFIED VALUES ARE AS FOLLOWS:
  TC(MIN) =   12.58    RAIN INTENSITY(INCH/HOUR) =  3.65
  EFFECTIVE AREA(ACRES) =      21.52
  TOTAL AREA(ACRES) =      23.01    PEAK FLOW RATE(CFS) =      73.22
  AVERAGED LOSS RATE, Fm(IN/HR) =    .103


****************************************************************************
  FLOW PROCESS FROM NODE      9.00 TO NODE      9.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
  >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
  TIME OF CONCENTRATION(MINUTES) =   12.58
  RAINFALL INTENSITY (INCH./HOUR) =    3.65
  EFFECTIVE STREAM AREA(ACRES) =    21.52
  TOTAL STREAM AREA(ACRES) =    23.01
  PEAK FLOW RATE(CFS) AT CONFLUENCE =      73.22

  CONFLUENCE INFORMATION:
  STREAM    PEAK FLOW    TIME    INTENSITY     FM    EFFECTIVE
  NUMBER    RATE(CFS)   (MIN.)  (INCH/HOUR)  (IN/HR) AREA(ACRES)
-------------------------------------------------------------------
     1        48.41      14.50       3.372     .26        16.87
     2        73.22      12.58       3.648     .10        21.52

  RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
  CONFLUENCE FORMULA USED FOR  2 STREAMS.
  SUMMARY RESULTS:
  STREAM    CONFLUENCE    EFFECTIVE
  NUMBER      Q(CFS)     AREA(ACRES)
-----------------------------------------------
     1       115.93         38.39
     2       118.95         36.16
  COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
  PEAK FLOW RATE(CFS) =      118.95   TIME(MINUTES) =    12.580
  EFFECTIVE AREA(ACRES) =      36.16
  TOTAL AREA(ACRES) =      41.55
============================================================================
  END OF STUDY SUMMARY:
  TOTAL AREA(ACRES)       =      41.55
  EFFECTIVE AREA(ACRES) =      36.16
  PEAK FLOW RATE(CFS)     =     118.95
============================================================================
  END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 10 - Part 1

Rational Method Effective Area for Two Flowpaths

Determine the peak flow rates within the watershed shown below in Fig. 14. This example problem further demonstrates the concept of effective area in rational method peak flow rate calculations. The example problem also demonstrates the importance of the initial subarea assumptions used in the link-node model.

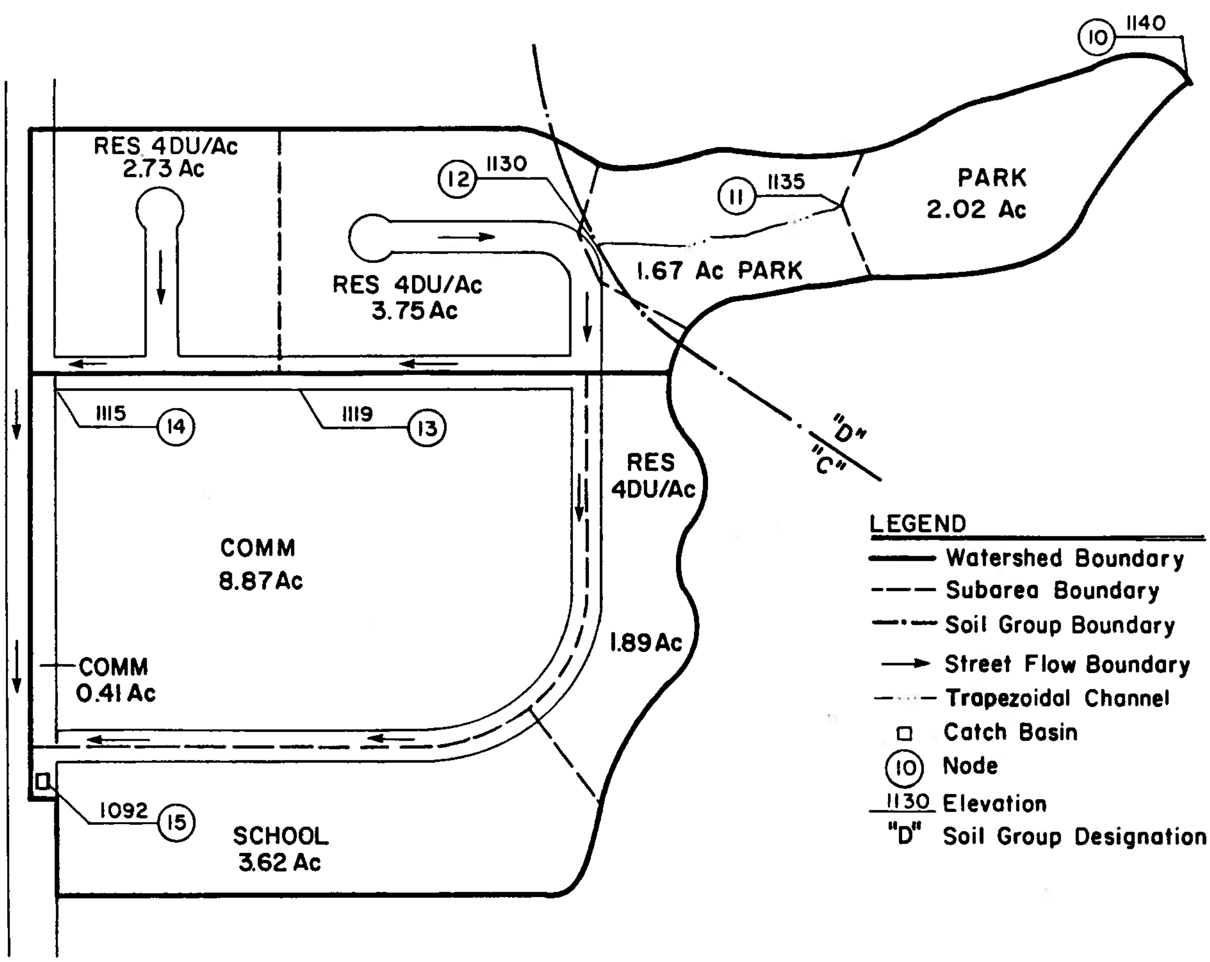


FIGURE 14. PROBLEM 10 SCHEMATIC (PART 1)

STUDY NAME: **EXAMPLE PROBLEM 10 (PART 1)**

CALCULATED BY: TRV
CHECKED BY:
PAGE NUMBER 1 OF 1

25.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						530	.0094	..	INITIAL SUBAREA
11.00	2.0	2.0	4	13		15.1	2.58	.17	.170	4.4				
											380	.0132	2.8	*Qav= 4.4cfs
														n=.0300 Dn= .6
					2.3									B= 1.0 Z= 3.0
12.00	1.7	3.7	4	13		17.4	2.38	.170	.170	7.3				
											620	.0177	4.2	*Qav= 10.8cfs
40.ft-STREET														DEPTH= .48 ft.
FLOW TO PT.#					2.8									FLOODWIDTH=18.1
13.00	3.8	7.4	3	8		20.2	2.19	.150	.160	13.6				
											330	.0121	3.3	*Qav= 16.0cfs
40.ft-STREET														DEPTH= .51 ft.
FLOW TO PT.#					1.7									FLOODWIDTH=20.0
14.00	2.7	10.2	3	8		21.8	2.10	.150	.157	17.8				
											550	.0418	6.4	*Qav= 18.1cfs
60.ft-STREET														DEPTH= .51 ft.
FLOW TO PT.#					1.4									FLOODWIDTH=14.4
15.00	.4	10.6	3	1		23.2	2.03	.025	.152	17.8				
15.00	8.9	19.5	3	1		23.2	2.03	.025	.094	33.8				
15.00	3.6	23.1	3	12		23.2	2.03	.150	.103	39.9				
15.00	1.9	25.0	3	8		23.2	2.03	.150	.106	43.1				
15.00		25.0				23.2				43.1				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 24.96 TOTAL STUDY AREA(ACRES)= 24.96 PEAK FLOW RATE(CFS)= 43.11

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, SOIL TYPES: 1=A, 2=B, 3=C, 4=D, *
*8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC 0.5=SPECIFIED RUNOFF COEFF. *

```
****************************************************************************
           RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE
              (Reference: 1986 OCEMA HYDROLOGY CRITERION)
```

EXAMPLE PROBLEM 10 (PART 1)

```
----------------------------------------------------------------------------
  FILE NAME: TRW.NO2
  TIME/DATE OF STUDY: 13:43   4/16/1987
============================================================================
  USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:
============================================================================
                   --*TIME-OF-CONCENTRATION MODEL*--

  USER SPECIFIED STORM EVENT(YEAR) =   25.00
  SPECIFIED MINIMUM PIPE SIZE(INCH) =  18.00
  SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE =  .90
  *DATA BANK RAINFALL USED*


****************************************************************************
  FLOW PROCESS FROM NODE    10.00 TO NODE    11.00 IS CODE =   2
----------------------------------------------------------------------------
  >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
============================================================================
  DEVELOPMENT IS PUBLIC PARK

  TC = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]** .20
  INITIAL SUBAREA FLOW-LENGTH =   530.00
  UPSTREAM ELEVATION =   1140.00
  DOWNSTREAM ELEVATION =   1135.00
  ELEVATION DIFFERENCE =      5.00
  TC =  .483*[(  530.00** 3.00)/(     5.00)]** .20 =   15.091
   25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.582
  SOIL CLASSIFICATION IS "D"
  PUBLIC PARK SUBAREA LOSS RATE, Fm(INCH/HR) =  .1700
  SUBAREA RUNOFF(CFS) =      4.38
  TOTAL AREA(ACRES) =      2.02   PEAK FLOW RATE(CFS) =      4.38


****************************************************************************
  FLOW PROCESS FROM NODE    11.00 TO NODE    12.00 IS CODE =   5
----------------------------------------------------------------------------
  >>>>>COMPUTE TRAPEZOIDAL-CHANNEL FLOW<<<<<
  >>>>>TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM NODE ELEVATION =   1135.00
  DOWNSTREAM NODE ELEVATION =   1130.00
  CHANNEL LENGTH THRU SUBAREA(FEET) =   380.00
  CHANNEL BASE(FEET) =    1.00   "Z" FACTOR =   3.000
  MANNINGS FACTOR =  .030   MAXIMUM DEPTH(FEET) =   2.00
  CHANNEL FLOW THRU SUBAREA(CFS) =      4.38
  FLOW VELOCITY(FEET/SEC) =   2.77   FLOW DEPTH(FEET) =    .58
  TRAVEL TIME(MIN.) =   2.28   TC(MIN.) =  17.37
```

```
****************************************************************************
  FLOW PROCESS FROM NODE    12.00 TO NODE    12.00 IS CODE =   8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.381
  SOIL CLASSIFICATION IS "D"
  PUBLIC PARK SUBAREA LOSS RATE, Fm(INCH/HR) =  .1700
  SUBAREA AREA(ACRES) =     1.67   SUBAREA RUNOFF(CFS) =    3.32
  EFFECTIVE AREA(ACRES) =     3.69
  AVERAGED Fm(INCH/HR) =   .170
  TOTAL AREA(ACRES) =    3.69
  PEAK FLOW RATE(CFS) =    7.34
  TC(MIN) =  17.37


****************************************************************************
  FLOW PROCESS FROM NODE    12.00 TO NODE    13.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1130.00   DOWNSTREAM ELEVATION =   1119.00
  STREET LENGTH(FEET) =   620.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 20.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  10.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .020

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

         **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   10.79
    STREETFLOW MODEL RESULTS:
         STREET FLOWDEPTH(FEET) =   .48
         HALFSTREET FLOODWIDTH(FEET) =   18.13
         AVERAGE FLOW VELOCITY(FEET/SEC.) =    3.72
         PRODUCT OF DEPTH&VELOCITY =    1.79
  STREETFLOW TRAVELTIME(MIN) =   2.78   TC(MIN) =  20.15

    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.191
  SOIL CLASSIFICATION IS "C"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
  SUBAREA AREA(ACRES) =     3.75   SUBAREA RUNOFF(CFS) =    6.89
  EFFECTIVE AREA(ACRES) =     7.44
  AVERAGED Fm(INCH/HR) =   .160
  TOTAL AREA(ACRES) =    7.44   PEAK FLOW RATE(CFS) =      13.60
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =  .50   HALFSTREET FLOODWIDTH(FEET) = 19.38
  FLOW VELOCITY(FEET/SEC.) =  4.18   DEPTH*VELOCITY =   2.08


****************************************************************************
  FLOW PROCESS FROM NODE    13.00 TO NODE    14.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1119.00   DOWNSTREAM ELEVATION =   1115.00
  STREET LENGTH(FEET) =   330.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 20.00
```

```
  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  10.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .020

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

         **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   16.00
  ***STREETFLOW SPLITS OVER STREET-CROWN***
    FULL DEPTH(FEET) =      .51   FLOODWIDTH(FEET) =   20.00
    FULL HALF-STREET VELOCITY(FEET/SEC.) =    3.31
    SPLIT DEPTH(FEET) =      .41   SPLIT FLOODWIDTH(FEET) =   13.13
    SPLIT VELOCITY(FEET/SEC.) =    2.66
    STREETFLOW MODEL RESULTS:
         STREET FLOWDEPTH(FEET) =   .51
         HALFSTREET FLOODWIDTH(FEET) =   20.00
         AVERAGE FLOW VELOCITY(FEET/SEC.) =    3.31
         PRODUCT OF DEPTH&VELOCITY =    1.68
  STREETFLOW TRAVELTIME(MIN) =   1.66   TC(MIN) =  21.81

    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.098
  SOIL CLASSIFICATION IS "C"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
  SUBAREA AREA(ACRES) =     2.73   SUBAREA RUNOFF(CFS) =    4.79
  EFFECTIVE AREA(ACRES) =   10.17
  AVERAGED Fm(INCH/HR) =   .157
  TOTAL AREA(ACRES) =    10.17   PEAK FLOW RATE(CFS) =     17.77
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =  .51   HALFSTREET FLOODWIDTH(FEET) = 20.00
  FLOW VELOCITY(FEET/SEC.) =  3.31   DEPTH*VELOCITY =   1.68


****************************************************************************
  FLOW PROCESS FROM NODE    14.00 TO NODE    15.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1115.00   DOWNSTREAM ELEVATION =   1092.00
  STREET LENGTH(FEET) =   550.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 30.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  15.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .025

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

         **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   18.14
    STREETFLOW MODEL RESULTS:
         STREET FLOWDEPTH(FEET) =   .51
         HALFSTREET FLOODWIDTH(FEET) =   14.39
         AVERAGE FLOW VELOCITY(FEET/SEC.) =    6.55
         PRODUCT OF DEPTH&VELOCITY =    3.33
  STREETFLOW TRAVELTIME(MIN) =   1.40   TC(MIN) =  23.21

    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.026
  SOIL CLASSIFICATION IS "C"
  COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0250
  SUBAREA AREA(ACRES) =      .41   SUBAREA RUNOFF(CFS) =     .74
  EFFECTIVE AREA(ACRES) =   10.58
```

```
AVERAGED Fm(INCH/HR) =    .152
TOTAL AREA(ACRES) =    10.58   PEAK FLOW RATE(CFS) =      17.84
END OF SUBAREA STREETFLOW HYDRAULICS:
DEPTH(FEET) =  .51   HALFSTREET FLOODWIDTH(FEET) = 14.39
FLOW VELOCITY(FEET/SEC.) =  6.45   DEPTH*VELOCITY =   3.27


****************************************************************************
FLOW PROCESS FROM NODE    15.00 TO NODE    15.00 IS CODE =   8
----------------------------------------------------------------------------
>>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
  25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.026
SOIL CLASSIFICATION IS "C"
COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0250
SUBAREA AREA(ACRES) =     8.87   SUBAREA RUNOFF(CFS) =    15.97
EFFECTIVE AREA(ACRES) =    19.45
AVERAGED Fm(INCH/HR) =    .094
TOTAL AREA(ACRES) =    19.45
PEAK FLOW RATE(CFS) =    33.81
TC(MIN) =  23.21


****************************************************************************
FLOW PROCESS FROM NODE    15.00 TO NODE    15.00 IS CODE =   8
----------------------------------------------------------------------------
>>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
  25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.026
SOIL CLASSIFICATION IS "C"
SCHOOL SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
SUBAREA AREA(ACRES) =     3.62   SUBAREA RUNOFF(CFS) =     6.11
EFFECTIVE AREA(ACRES) =    23.07
AVERAGED Fm(INCH/HR) =    .103
TOTAL AREA(ACRES) =    23.07
PEAK FLOW RATE(CFS) =    39.92
TC(MIN) =  23.21


****************************************************************************
FLOW PROCESS FROM NODE    15.00 TO NODE    15.00 IS CODE =   8
----------------------------------------------------------------------------
>>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
  25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.026
SOIL CLASSIFICATION IS "C"
RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
SUBAREA AREA(ACRES) =     1.89   SUBAREA RUNOFF(CFS) =     3.19
EFFECTIVE AREA(ACRES) =    24.96
AVERAGED Fm(INCH/HR) =    .106
TOTAL AREA(ACRES) =    24.96
PEAK FLOW RATE(CFS) =    43.11
TC(MIN) =  23.21
============================================================================
END OF STUDY SUMMARY:
TOTAL AREA(ACRES)     =       24.96
EFFECTIVE AREA(ACRES) =       24.96
PEAK FLOW RATE(CFS)   =       43.11
============================================================================
END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 10 - Part 2

From part 1 it is seen that the initial area time of concentration is somewhat high. Recalculate the peak discharge rate for the watershed from problem 1 with 2 flow paths as shown below in Fig. 15. Note that by having two flow paths, the peak flow rate increases while the time of concentration decreases. This problem demonstrates that the peak flow rate can increase with a smaller effective area. Also note that the initial subarea is dominating the hydrology in part 1.

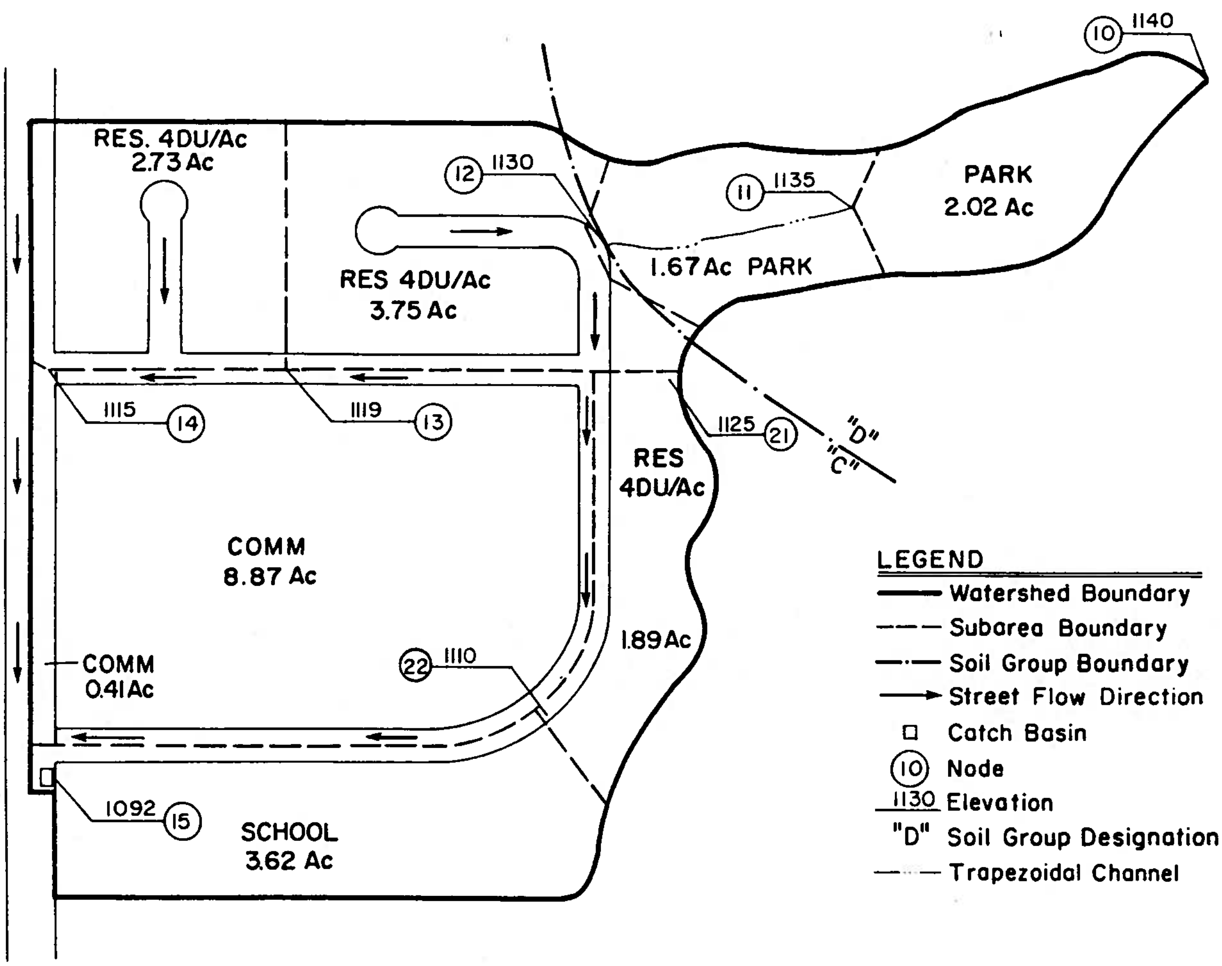


FIGURE 15. PROBLEM 10 SCHEMATIC (PART 2)

STUDY NAME: **EXAMPLE PROBLEM 10 (PART 2)**

CALCULATED BY: TK

CHECKED BY:

PAGE NUMBER / OF

25.0-YEAR STORM RATIONAL METHOD STUDY

[A D V A N C E D E N G I N E E R I N G S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
					..						530	.0094	..	INITIAL SUBAREA
11.00	2.0	2.0	4	13	----	15.1	2.58	.17	.170	4.4				
											380	.0132	2.8	*Qav= 4.4cfs
														n=.0300 Dn= .6
					2.3									B= 1.0 Z= 3.0
12.00	1.7	3.7	4	13	----	17.4	2.38	.170	.170	7.3				
											620	.0177	4.2	*Qav= 10.8cfs
40. ft-STREET														DEPTH= .48 ft.
FLOW TO PT.#					2.8									FLOODWIDTH=18.1
13.00	3.8	7.4	3	8	----	20.2	2.19	.150	.160	13.6				
											330	.0121	3.3	*Qav= 16.0cfs
40. ft-STREET														DEPTH= .51 ft.
FLOW TO PT.#					1.7									FLOODWIDTH=20.0
14.00	2.7	10.2	3	8	----	21.8	2.10	.150	.157	17.8				
											550	.0418	6.4	*Qav= 18.1cfs
60. ft-STREET														DEPTH= .51 ft.
FLOW TO PT.#					1.4									FLOODWIDTH=14.4
15.00	.4	10.6	3	1	----	23.2	2.03	.025	.152	17.8				
15.00		10.6			----	23.2	2.03			17.8	----	----	----	FOR CONFLUENCE
					..						560	.0268	..	INITIAL SUBAREA
22.00	1.9	1.9	3	8	----	10.7	3.15	.15	.150	5.1				
											630	.0286	4.9	*Qav= 20.7cfs
40. ft-STREET														DEPTH= .44 ft.
FLOW TO PT.#					2.3									FLOODWIDTH=15.6
15.00	12.5	14.4	5	1	----	13.0	2.82	.061	.073	35.5				

*DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0,5=SPECIFIED RUNOFF COEFF. *

STUDY NAME: TRW.N2A | CALCULATED BY: TRW
CHECKED BY:
25.0-YEAR STORM RATIONAL METHOD STUDY | PAGE NUMBER 2 OF 2

[A D V A N C E D   E N G I N E E R I N G   S O F T W A R E]

CONCENTRATION POINT NUMBER	AREA (ACRES) SUBAREA	SUM	SOIL TYPE	DEV. TYPE	Tt MIN.	Tc MIN.	I in/h	Fm	Fm (Avg)	Q SUM	PATH (ft)	SLOPE ft/ft	V FPS.	HYDRAULICS AND NOTES
CONFLUENCE	TC#1=	23.2	TC#2=	13.0	TC#3=	.0	TC#4=	.0	TC#5=	.0	SUM OF STREAM			LARGEST
ANALYSIS	Q#1=	17.8	Q#2=	35.5	Q#3=	.0	Q#4=	.0	Q#5=	.0	AREAS=	20.30		CONFLUENCE
FOR POINT#	I#1=	2.03	I#2=	2.82	I#3=	.00	I#4=	.00	I#5=	.00	TOTAL			Q= 49.7
15.00	EA#1=	10.6	EA#2=	14.4	EA#3=	.0	EA#4=	.0	EA#5=	.0	AREA =	24.96		
	Fm1=	.152	Fm2=	.073	Fm3=	.000	Fm4=	.000	Fm5=	.000				
	Q1 =	43.1	Q2 =	49.7	Q3 =	.0	Q4 =	.0	Q5 =	.0				
15.00		20.3				13.0				49.7				STREAM SUMMARY

EFFECTIVE AREA(ACRES)= 20.30 TOTAL STUDY AREA(ACRES)= 24.96 PEAK FLOW RATE(CFS)= 49.69

DEV TYPES: 1=Com, 2=MF, 3=Apt, 4=Con, 5=SFR 11+ D/AC, 6=8-10D/AC, 7=5-7D/AC, 8=3-4D/AC, 9=2D/AC, 10=1D/AC, 11=0.4D/AC, 12=Sch, 13=PK, 14=Ag, 15=PC, 16=AC, 17=DC

SOIL TYPES: 1=A, 2=B, 3=C, 4=D, 0, 5=SPECIFIED RUNOFF COEFF. *

```
******************************************************************************
            RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE
                 (Reference: 1986 OCEMA HYDROLOGY CRITERION)
```

EXAMPLE PROBLEM 10 (PART 2)

```
------------------------------------------------------------------------------
  FILE NAME: TRW.N2A
  TIME/DATE OF STUDY: 13:14    4/16/1987
==============================================================================
  USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:
==============================================================================
                    --*TIME-OF-CONCENTRATION MODEL*--

  USER SPECIFIED STORM EVENT(YEAR) =    25.00
  SPECIFIED MINIMUM PIPE SIZE(INCH) =   18.00
  SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE =  .90
  *DATA BANK RAINFALL USED*


******************************************************************************
  FLOW PROCESS FROM NODE     10.00 TO NODE     11.00 IS CODE =   2
------------------------------------------------------------------------------
  >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
==============================================================================
  DEVELOPMENT IS PUBLIC PARK

  TC = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]** .20
  INITIAL SUBAREA FLOW-LENGTH =    530.00
  UPSTREAM ELEVATION =   1140.00
  DOWNSTREAM ELEVATION =   1135.00
  ELEVATION DIFFERENCE =      5.00
  TC =  .483*[(  530.00** 3.00)/(      5.00)]** .20 =   15.091
    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.582
  SOIL CLASSIFICATION IS "D"
  PUBLIC PARK SUBAREA LOSS RATE, Fm(INCH/HR) =  .1700
  SUBAREA RUNOFF(CFS) =       4.38
  TOTAL AREA(ACRES) =       2.02   PEAK FLOW RATE(CFS) =       4.38


******************************************************************************
  FLOW PROCESS FROM NODE     11.00 TO NODE     12.00 IS CODE =   5
------------------------------------------------------------------------------
  >>>>>COMPUTE TRAPEZOIDAL-CHANNEL FLOW<<<<<
  >>>>>TRAVELTIME THRU SUBAREA<<<<<
==============================================================================
  UPSTREAM NODE ELEVATION =   1135.00
  DOWNSTREAM NODE ELEVATION =   1130.00
  CHANNEL LENGTH THRU SUBAREA(FEET) =   380.00
  CHANNEL BASE(FEET) =    1.00   "Z" FACTOR =   3.000
  MANNINGS FACTOR =  .030   MAXIMUM DEPTH(FEET) =   2.00
  CHANNEL FLOW THRU SUBAREA(CFS) =      4.38
  FLOW VELOCITY(FEET/SEC) =   2.77   FLOW DEPTH(FEET) =    .58
  TRAVEL TIME(MIN.) =   2.28   TC(MIN.) =  17.37
```

```
****************************************************************************
  FLOW PROCESS FROM NODE    12.00 TO NODE    12.00 IS CODE =   8
----------------------------------------------------------------------------
  >>>>>ADDITION OF SUBAREA TO MAINLINE PEAK FLOW<<<<<
============================================================================
    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.381
  SOIL CLASSIFICATION IS "D"
  PUBLIC PARK SUBAREA LOSS RATE, Fm(INCH/HR) =  .1700
  SUBAREA AREA(ACRES) =    1.67   SUBAREA RUNOFF(CFS) =    3.32
  EFFECTIVE AREA(ACRES) =    3.69
  AVERAGED Fm(INCH/HR) =   .170
  TOTAL AREA(ACRES) =    3.69
  PEAK FLOW RATE(CFS) =    7.34
  TC(MIN) =  17.37


****************************************************************************
  FLOW PROCESS FROM NODE    12.00 TO NODE    13.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1130.00   DOWNSTREAM ELEVATION =   1119.00
  STREET LENGTH(FEET) =   620.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 20.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  10.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .020

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

         **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   10.79
    STREETFLOW MODEL RESULTS:
         STREET FLOWDEPTH(FEET) =   .48
         HALFSTREET FLOODWIDTH(FEET) =   18.13
         AVERAGE FLOW VELOCITY(FEET/SEC.) =    3.72
         PRODUCT OF DEPTH&VELOCITY =    1.79
  STREETFLOW TRAVELTIME(MIN) =   2.78   TC(MIN) =  20.15

    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.191
  SOIL CLASSIFICATION IS "C"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
  SUBAREA AREA(ACRES) =    3.75   SUBAREA RUNOFF(CFS) =    6.89
  EFFECTIVE AREA(ACRES) =    7.44
  AVERAGED Fm(INCH/HR) =   .160
  TOTAL AREA(ACRES) =    7.44   PEAK FLOW RATE(CFS) =     13.60
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =  .50   HALFSTREET FLOODWIDTH(FEET) = 19.38
  FLOW VELOCITY(FEET/SEC.) =  4.18   DEPTH*VELOCITY =   2.08


****************************************************************************
  FLOW PROCESS FROM NODE    13.00 TO NODE    14.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1119.00   DOWNSTREAM ELEVATION =   1115.00
  STREET LENGTH(FEET) =   330.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 20.00
```

```
DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  10.00
INTERIOR STREET CROSSFALL(DECIMAL) =    .015
OUTSIDE STREET CROSSFALL(DECIMAL)  =    .020

SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

       **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   16.00
***STREETFLOW SPLITS OVER STREET-CROWN***
  FULL DEPTH(FEET) =      .51   FLOODWIDTH(FEET) =   20.00
  FULL HALF-STREET VELOCITY(FEET/SEC.) =    3.31
  SPLIT DEPTH(FEET) =      .41   SPLIT FLOODWIDTH(FEET) =   13.13
  SPLIT VELOCITY(FEET/SEC.) =    2.66
  STREETFLOW MODEL RESULTS:
       STREET FLOWDEPTH(FEET) =   .51
       HALFSTREET FLOODWIDTH(FEET) =   20.00
       AVERAGE FLOW VELOCITY(FEET/SEC.) =    3.31
       PRODUCT OF DEPTH&VELOCITY =    1.68
STREETFLOW TRAVELTIME(MIN) =   1.66   TC(MIN) =  21.81

  25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.098
SOIL CLASSIFICATION IS "C"
RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
SUBAREA AREA(ACRES) =     2.73   SUBAREA RUNOFF(CFS) =     4.79
EFFECTIVE AREA(ACRES) =   10.17
AVERAGED Fm(INCH/HR) =   .157
TOTAL AREA(ACRES) =   10.17   PEAK FLOW RATE(CFS) =     17.77
END OF SUBAREA STREETFLOW HYDRAULICS:
DEPTH(FEET) =  .51   HALFSTREET FLOODWIDTH(FEET) = 20.00
FLOW VELOCITY(FEET/SEC.) =  3.31   DEPTH*VELOCITY =   1.68


****************************************************************************
  FLOW PROCESS FROM NODE    14.00 TO NODE    15.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1115.00   DOWNSTREAM ELEVATION =   1092.00
  STREET LENGTH(FEET) =   550.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 30.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  15.00
  INTERIOR STREET CROSSFALL(DECIMAL) =    .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =    .025

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  1

         **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   18.14
    STREETFLOW MODEL RESULTS:
         STREET FLOWDEPTH(FEET) =   .51
         HALFSTREET FLOODWIDTH(FEET) =   14.39
         AVERAGE FLOW VELOCITY(FEET/SEC.) =    6.55
         PRODUCT OF DEPTH&VELOCITY =    3.33
  STREETFLOW TRAVELTIME(MIN) =   1.40   TC(MIN) =  23.21

    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.026
  SOIL CLASSIFICATION IS "C"
  COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0250
  SUBAREA AREA(ACRES) =      .41   SUBAREA RUNOFF(CFS) =      .74
  EFFECTIVE AREA(ACRES) =   10.58
```

```
  AVERAGED Fm(INCH/HR) =   .152
  TOTAL AREA(ACRES) =   10.58   PEAK FLOW RATE(CFS) =     17.84
  END OF SUBAREA STREETFLOW HYDRAULICS:
  DEPTH(FEET) =  .51   HALFSTREET FLOODWIDTH(FEET) = 14.39
  FLOW VELOCITY(FEET/SEC.) =  6.45   DEPTH*VELOCITY =   3.27


****************************************************************************
  FLOW PROCESS FROM NODE    15.00 TO NODE    15.00 IS CODE =   1
----------------------------------------------------------------------------
  >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
============================================================================
  CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  1 ARE:
  TIME OF CONCENTRATION(MINUTES) =  23.21
  RAINFALL INTENSITY (INCH./HOUR) =   2.03
  EFFECTIVE STREAM AREA(ACRES) =   10.58
  TOTAL STREAM AREA(ACRES) =   10.58
  PEAK FLOW RATE(CFS) AT CONFLUENCE =     17.84


****************************************************************************
  FLOW PROCESS FROM NODE    21.00 TO NODE    22.00 IS CODE =   2
----------------------------------------------------------------------------
  >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
============================================================================
  DEVELOPMENT IS  SINGLE FAMILY RESIDENTIAL -> 3-4 DWELLINGS/ACRE

  TC = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]** .20
  INITIAL SUBAREA FLOW-LENGTH =   560.00
  UPSTREAM ELEVATION =   1125.00
  DOWNSTREAM ELEVATION =   1110.00
  ELEVATION DIFFERENCE =     15.00
  TC =  .412*[(  560.00** 3.00)/(    15.00)]** .20 =   10.681
    25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  3.154
  SOIL CLASSIFICATION IS "C"
  RESIDENTIAL-> 3-4 DWELLINGS/ACRE SUBAREA LOSS RATE, Fm(INCH/HR) =  .1500
  SUBAREA RUNOFF(CFS) =       5.11
  TOTAL AREA(ACRES) =       1.89   PEAK FLOW RATE(CFS) =      5.11


****************************************************************************
  FLOW PROCESS FROM NODE    22.00 TO NODE    15.00 IS CODE =   6
----------------------------------------------------------------------------
  >>>>>COMPUTE STREETFLOW TRAVELTIME THRU SUBAREA<<<<<
============================================================================
  UPSTREAM ELEVATION =   1110.00   DOWNSTREAM ELEVATION =   1092.00
  STREET LENGTH(FEET) =   630.00   CURB HEIGTH(INCHES) = 8.
  STREET HALFWIDTH(FEET) = 20.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK =  10.00
  INTERIOR STREET CROSSFALL(DECIMAL) =   .015
  OUTSIDE STREET CROSSFALL(DECIMAL)  =   .020

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  2

       **TRAVELTIME COMPUTED USING MEAN FLOW(CFS) =   20.68
    STREETFLOW MODEL RESULTS:
       STREET FLOWDEPTH(FEET) =   .44
       HALFSTREET FLOODWIDTH(FEET) =   15.63
       AVERAGE FLOW VELOCITY(FEET/SEC.) =    4.55
```

```
       PRODUCT OF DEPTH&VELOCITY =     2.02
 STREETFLOW TRAVELTIME(MIN) =   2.31   TC(MIN) =  12.99

  25 YEAR RAINFALL INTENSITY(INCH/HOUR) =  2.816
 *USER SPECIFIED(SUBAREA):
 COMMERCIAL SUBAREA LOSS RATE, Fm(INCH/HR) =  .0610
 SUBAREA AREA(ACRES) =   12.49   SUBAREA RUNOFF(CFS) =   30.96
 EFFECTIVE AREA(ACRES) =   14.38
 AVERAGED Fm(INCH/HR) =   .073
 TOTAL AREA(ACRES) =   14.38   PEAK FLOW RATE(CFS) =     35.50
 END OF SUBAREA STREETFLOW HYDRAULICS:
 DEPTH(FEET) =  .52   HALFSTREET FLOODWIDTH(FEET) = 20.00
 FLOW VELOCITY(FEET/SEC.) =  4.88   DEPTH*VELOCITY =   2.53


****************************************************************************
 FLOW PROCESS FROM NODE    15.00 TO NODE    15.00 IS CODE =   1
----------------------------------------------------------------------------
 >>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<<<<<
 >>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<<<<<
============================================================================
 CONFLUENCE VALUES USED FOR INDEPENDENT STREAM  2 ARE:
 TIME OF CONCENTRATION(MINUTES) =  12.99
 RAINFALL INTENSITY (INCH./HOUR) =   2.82
 EFFECTIVE STREAM AREA(ACRES) =   14.38
 TOTAL STREAM AREA(ACRES) =   14.38
 PEAK FLOW RATE(CFS) AT CONFLUENCE =     35.50

 CONFLUENCE INFORMATION:
 STREAM   PEAK FLOW   TIME   INTENSITY    FM    EFFECTIVE
 NUMBER   RATE(CFS)  (MIN.) (INCH/HOUR) (IN/HR) AREA(ACRES)
-----------------------------------------------------------------
   1        17.84     23.21       2.026     .15       10.58
   2        35.50     12.99       2.816     .07       14.38

 RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO
 CONFLUENCE FORMULA USED FOR  2 STREAMS.
 SUMMARY RESULTS:
 STREAM   CONFLUENCE   EFFECTIVE
 NUMBER     Q(CFS)    AREA(ACRES)
---------------------------------------------
   1        43.12       24.96
   2        49.69       20.30
 COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
 PEAK FLOW RATE(CFS) =      49.69   TIME(MINUTES) =   12.986
 EFFECTIVE AREA(ACRES) =     20.30
 TOTAL AREA(ACRES) =     24.96
============================================================================
 END OF STUDY SUMMARY:
 TOTAL AREA(ACRES)      =     24.96
 EFFECTIVE AREA(ACRES) =     20.30
 PEAK FLOW RATE(CFS)    =     49.69
============================================================================
 END OF RATIONAL METHOD ANALYSIS
```

PROBLEM 11

Small Area Runoff Hydrograph

Determine the runoff hydrograph from a 15 acre residential site for a 25-year design storm event. The runoff hydrograph will be used to test a detention basin located adjacent to the residential site. Because the catchment is small, the time of concentration will probably be less than 25 minutes, therefore the design storm runoff hydrograph can be developed using the rational method for flow rate estimates. The procedure to be used in constructing a runoff hydrograph for small areas includes: 1) determine watershed acreage, time of concentration, maximum loss rate (Fm), and low loss fraction ($\bar{Y}$); 2) set the unit interval equal to the T_c and determine the rainfall depth for the significant unit periods when "rounding off" the unit interval size, always use a unit interval at least as large as the T_c. For example for a T_c of 13-minutes a unit interval of 15-minutes is acceptable whereas a 10-minute unit interval is unacceptable (due to runoff volume discrepancies); 3) determine the loss rate, net rainfall, effective rainfall, and flow rate for each unit period; 4) develop the runoff hydrograph. It is noted that for the small area runoff hydrograph method, the total catchment area shall be used in the calculations even though the T_c used corresponds to an effective area.

1) Assume that from a rational method study the following is determined:

    total area = 15 acres
    effective area = 12 acres
    time of concentration = 13 minutes (for effective area of 12 acres)
    soil group B
    curve number* = 56
    single family residential, 4 DU/Ac
    F_m = 0.18 inches/hour or 0.05 inches/unit period
    $\bar{Y}$ = 0.82
    (see example problem #12 for F_m and $\bar{Y}$ calculations)

* Note: Use AMC 1 for the 2- and 5-year storm events; AMC II for the 10-, 25-, and 50-year storm events; and AMC III for the 100-year storm event.

2) unit interval = time of concentration

= 13 minutes, say 15 minutes

TABLE 4.

RUNOFF CALCULATIONS

Rainfall Unit Number	Mass[1] Rainfall (inches)	Unit[2] Rainfall (inches)	Unit[3] Loss (inches)	Net[4] Rainfall (inches)	Effective[5] Rainfall Intensity (inch/hr)	Flow[6] Rate (cfs)
1	0.65	0.65	0.05	0.60	2.40	32.4
2	0.88	0.23	0.05	0.18	0.72	9.7
3	1.04	0.16	0.05	0.11	0.44	5.9
4	1.18	0.14	0.05	0.09	0.36	4.9
5	1.30	0.12	0.05	0.07	0.28	3.8
6	1.41	0.11	0.05	0.06	0.24	3.2
7	1.51	0.10	0.05	0.05	0.20	2.7
8	1.60	0.09	0.05	0.04	0.16	2.2
9	1.68	0.08	0.05	0.03	0.12	1.6
10	1.76	0.08	0.05	0.03	0.12	1.6
11	1.83	0.07	0.05	0.02	0.08	1.1
12	1.90	0.07	0.05	0.02	0.08	1.1
13	1.97	0.07	0.05	0.02	0.08	1.1
14	2.04	0.07	0.05	0.02	0.08	1.1
15	2.10	0.06	0.05	0.01	0.04	0.5

1 mass rainfall = $D_{25} = 0.200T^{0.434}$

2 unit rainfall = unit rainfall for that period (e.g., for unit number 2, mass rainfall$_2$ - mass rainfall$_1$ = unit rainfall$_2$)

3 unit loss = F_m(0.05 in./hr.) or Y(0.82) x unit rainfall , whichever is lower

4 net rainfall = unit rainfall - unit loss

5 effective rainfall (in./hr.) =net rainfall x 60 min./unit period (minutes)

6 flow rate = $0.9\ (I - F_m)\ A$

= 0.9 (effective rainfall intensity) (15 Acres)

The design storm pattern is composed of unit rainfalls nested in a symmetrical 2/3 to 1/3 distribution about hour 16 of the 24-hour storm pattern. The unit hydrograph is defined to be a triangle with a base of $2T_c$, and a peak occurring at time T_c. The following tabulation demonstrates the nesting distribution for this example problem. The runoff hydrograph is plotted in Figure 16 for the calculations included in Table 5.

TABLE 5.

DESIGN STORM RUNOFF

Peak Rainfall Unit Number	Start of Unit Runoff (Hr.)	Peak of Unit Runoff (Hr.)	End of Unit Runoff (Hr.)	Peak Flow Rate (cfs)
1	16.00	16.25	16.50	32.4
2	15.75	16.00	16.25	9.7
3	15.50	15.75	16.00	5.9
4	16.25	16.50	16.75	4.9
5	15.25	15.50	15.75	3.8
6	15.00	15.25	15.50	3.2
7	16.50	16.75	17.00	2.7
8	14.75	15.00	15.25	2.2
9	14.50	14.75	15.00	1.6
10	16.75	17.00	17.25	1.6
11	14.25	14.50	14.75	1.1
12	14.00	14.25	14.50	1.1
13	17.00	17.25	17.50	1.1
14	13.75	14.00	14.25	1.1
15	13.50	13.75	14.00	0.5

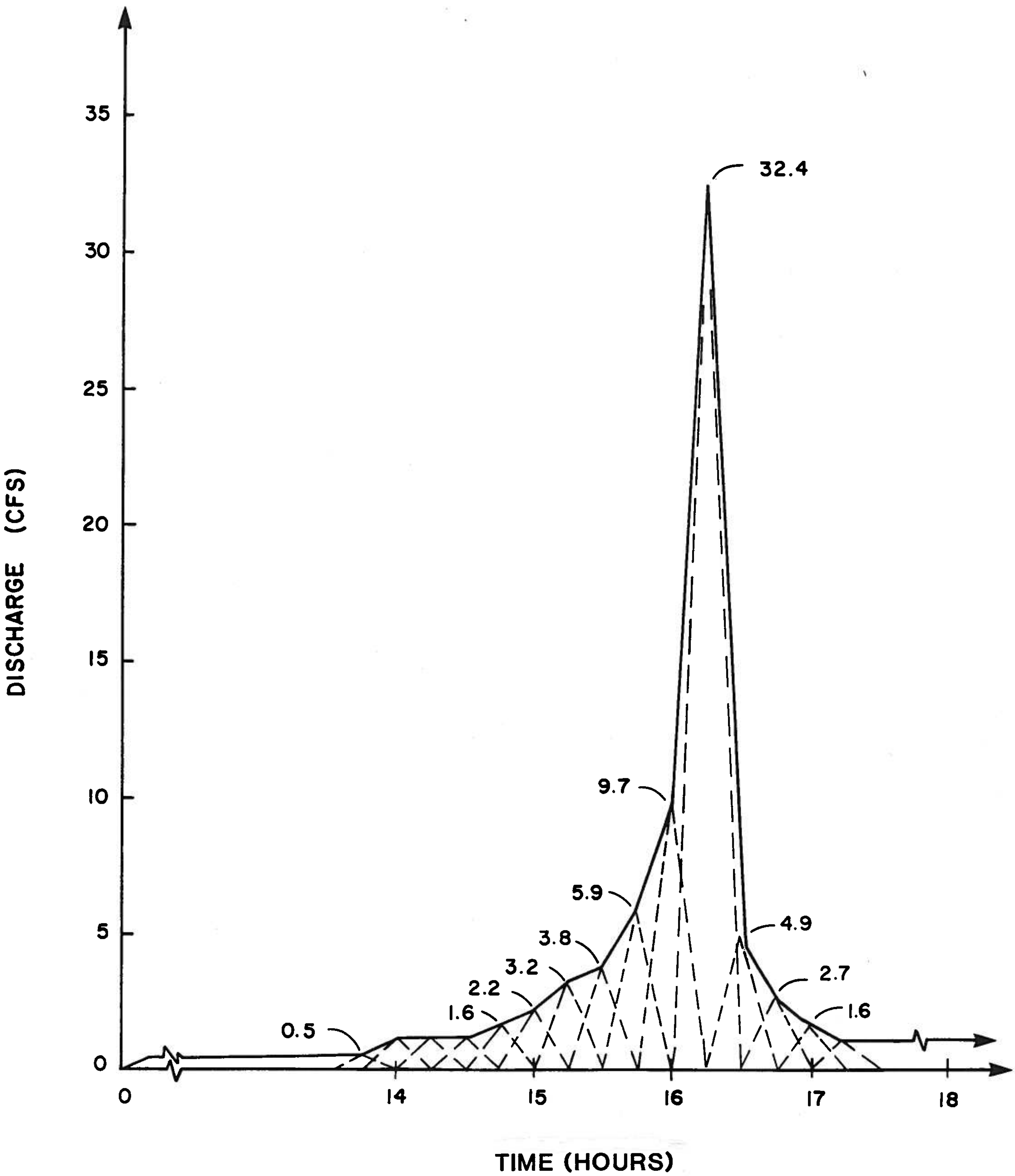


FIGURE 16. PROBLEM 11 DESIGN STORM RUNOFF HYDROGRAPH

PROBLEM 12

Synthetic Unit Hydrograph

INSTRUCTIONS FOR SYNTHETIC UNIT HYDROGRAPH METHOD HYDROLOGY CALCULATIONS (FROM HYDROLOGY MANUAL TEXT)

I. Synthetic Unit Hydrograph Development

A. On a USGS topographic quadrangle sheet or other topographic map of suitable scale, outline the watershed boundary.

B. Calculate the catchment time of concentration (T_c) by using either a rational method analysis for the T-year storm, or by using the peak flowrate curves of section L.

1. Catchment lag is computed by

$$\text{lag} = 0.8T_c$$

2. For certain large scale natural condition catchment studies, the Agency may use the lag relationship given by

$$\text{lag (hours)} = 24\bar{n}(L \cdot L_{ca}/S^{0.50})^{0.38}$$

where

A	=	drainage area (square miles)
L	=	length of longest watercourse (miles)
L_{ca}	=	length along the longest watercourse, measured upstream to point opposite the centroid of the area (miles)
H	=	difference in elevation between the concentration point and the most remote point of the basin (feet)
S	=	overall slope of longest watercourse between headwaters and concentration point (S = H/L, feet per mile)
$\bar{n}$	=	visually estimated average basin factor from Hydrology Manual Figure E-2.

C. Select a unit time period. To adequately define the unit hydrograph the unit time period should be about 20 percent of lag time, and never more than 25 percent of lag time. If possible, use the unit time of the synthetic critical storm pattern of 5-minutes.

D. Select the S-graph applicable to the drainage basin (Hydrology Manual Figures E-3a,b,c,d). Determine the average percentage of the ultimate discharge for each unit period. In reading the percentage of ultimate discharge from the S-graph, the average ordinate over the time increment should be determined rather than the mean of the ordinates at the beginning and end of the time increment (see Figure 17).

E. Compute the unit distribution graph by subtracting from the percentage of ultimate discharge for each unit time period, the percentage of ultimate discharge for the previous time period (see Figure 18). The first five values of the unit distribution graph are calculated below.

TABLE 6.
UNIT DISTRIBUTION GRAPH

Unit Interval	S-graph mean value	unit distribution graph percent of ultimate discharge	
1	0.635	0.635 - 0	= 0.635
2	1.965	1.965 - 0.635	= 1.330
3	3.911	3.911 - 1.965	= 1.946
4	7.648	7.648 - 3.911	= 3.737
5	13.300	13.300 - 7.648	= 5.652

F. Compute the ordinates of the synthetic unit hydrograph (unit graph) by multiplying the distribution graph values by the ultimate discharge K, using:

$$K(cfs) = 645A/T$$

where

A = drainage area (square miles)

T = unit time period (hours)

A summary of the unit hydrograph ordinates are shown in figure 17. The calculations for the first five unit hdyrograph ordinates are shown below in Table 7.

TABLE 7.

UNIT HYDROGRAPH ORDINATES

Interval	unit distribution graph percent of ultimate discharge		k		unit hydrograph ordinate (cfs)
1	0.635	x	38,700	=	245.7
2	1.330	x	38,700	=	514.7
3	1.946	x	38,700	=	753.1
4	3.737	x	38,700	=	1,446.2
5	5.652	x	38,700	=	2,187.3

G. Enter the unit hydrograph ordinates calculated in step F in the first column of the flood hydrograph calculation form, as shown in Figure 21.

II. T-Year Design Storm Pattern Development

A. Using the appropriate T-year point precipitation values from the Hydrology Manual Table B.2, compute the area-averaged precipitation values for the 5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour durations. Area averaging of precipitation depths is only required when the study catchment contains areas both above and below 2000 feet in elevation. Otherwise, the point precipitation data of the Hydrology Manual's Table B.2 can be used directly for catchments which are entirely above or entirely below 2000 feet in elevation.

B. Adjust all point precipitation values for areal effect by using the Hydrology Manual Figure B-6.

C. Develop a synthetic critical storm peak rainfall mass plot using Figure B-7 from the Hydrology Manual (see Figure 19 for demonstration).

D. Using the unit interval duration for the unit hydrograph development, calculate the synthetic storm unit interval rainfall quantities by successive subtraction of mass peak rainfall values, each offset in time by one unit period as shown in Table 8.

TABLE 8

UNIT HYDROGRAPH STUDY:
EXAMPLE PROBLEM UNIT RAINFALL DETERMINATION

(Example Unit Period = 5 minutes)

Peak Rainfall Unit Number	Adjusted Mass Rainfall (inches)	Unit Rainfall (inches)
1	0.45	0.45
2	0.60	0.15
3	0.71	0.11
4	0.80	0.09
5	0.88	0.08
6	0.95	0.07
7	1.02	0.07
8	1.08	0.06
9	1.13	0.05
10	1.19	0.06
11	1.24	0.05
12	1.28	0.04
13	1.33	0.05
14	1.39	0.05
15	1.45	0.06
16	1.50	0.05
17	1.55	0.05
18	1.60	0.05
19	1.65	0.05
20	1.70	0.05
21	1.74	0.04
22	1.79	0.05
23	1.84	0.05
24	1.89	0.05
25	1.93	0.04
26	1.97	0.04
27	2.01	0.04
28	2.05	0.04
29	2.09	0.04
30	2.13	0.04
31	2.17	0.04
32	2.21	0.04
33	2.25	0.04
34	2.29	0.04
35	2.33	0.04
36	2.38	0.04

TIME = 3 HOURS TOTAL = 2.38 INCHES

E. Arrange the unit rainfall quantities determined in step D into the critical storm pattern using Figures B-5a,b,c of the Hydrology Manual as shown in Figure 20. For most hydrology studies, only the peak 3-hours of the synthetic critical storm need consideration.

III. Runoff Hydrograph Development

A. Find the pervious area loss rates for subareas within the drainage area using Figures C-3 and C-4 of the Hydrology Manual. Adjust these rates to account for impervious area using the relationship below, and then compute an area-averaged maximum loss rate for the catchment.

$$F_m = a_p F_p$$

where

F_m = maximum loss rate (inches/hour)

a_p = pervious area fraction (decimal percent of total area). See Hydrology Manual Figure C-4.

F_p = maximum loss rate for pervious areas fraction. See Section Hydrology Manual C.6.4.

Table 9 contains the F_m calculations for the example problem.

B. Compute the low loss fraction, $\bar{Y}$. Use F^* in each unit time period where the maximum loss rate F_m exceeds the low rate F^*, ($F^* = \bar{Y} \cdot I$). Table 10 demonstrates the $\bar{Y}$ calculations for the example problem.

C. Compute the unit effective rainfall for each unit time period by subtracting the unit loss from the unit rainfall as shown in Table 11.

D. List the unit effective rainfall calculated in step C in the first row of the flood hdyrograph calculation form as shown in Figure 21.

TABLE 9

UNIT HYDROGRAPH STUDY:
EXAMPLE PROBLEM WATERSHED LOSS DETERMINATIONS

Area-Averaged Maximum Loss Rate, F_m

1. Using the watershed soil and development characteristics, estimate the area-averaged maximum loss rate:

Land Use and Condition	Area Fraction	Soil Group	F_p (inch/hour) (Table C.2.)	a_p (Fig. C-4)	F_m (inch/hour)
Woodland; good cover (100% pervious)	.15	B	0.30	1.0	0.30
Woodland; good cover (100% pervious)	.15	D	0.20	1.0	0.20
Residential:S.F. (1/2 acre) Lots (60% pervious*)	.42	A	0.40	0.60	0.24
Residential:S.F. (1/2 acre) Lots (60% pervious*)	.03	B	0.30	0.60	0.18
Commercial: (10% pervious)	.23	A	0.40	0.10	0.04
Commercial: (10% pervious)	.02	B	0.30	0.10	0.03

Area-Averaged Adjusted Loss Rate (inch/hour) = 0.19

* Field conditions indicate use of the lower end of the suggested percent pervious range.

TABLE 10

UNIT HYDROGRAPH STUDY:
EXAMPLE PROBLEM WATERSHED LOSS DETERMINATIONS

Area-Averaged Low Loss Rate Fraction, $\bar{Y}$

1. Referring to watershed soil group maps, estimate area-averaged composite curve numbers (see Section C):

Land Use and Condition	Area Fraction	Soil Group	Curve Number CN(1) (Fig. C-3)		S(2)	Pervious Area Yield Fraction Y(3)
Woodland; good cover (100% pervious)	.15	B	55	(75)	3.33	0.53
Woodland; good cover (100% pervious)	.15	D	77	(93)	0.75	0.86
Residential: S.F. (1/2 acre) Lots (60% pervious)(5)	.25	A	32	(52)	9.23	0.20
	.17	A	98		0.20	0.96
Residential: S.F. (1/2 acre) Lots (60% pervious)(5)	.018	B	56	(76)	3.16	0.54
	.012	B	98		0.20	0.96
Commercial: (10% pervious)	.023	A	32	(52)	9.23	0.20
	.207	A	98		0.20	0.96
Commercial: (10% pervious)	.002	B	56	(76)	3.16	0.54
	.018	B	98		0.20	0.96

Area-Averaged Catchment Yield Fraction (Y) = 0.663

Area-Averaged Low Loss Fraction ($\bar{Y}$)(4) = 0.337

NOTES:

(1): (75) indicates AMC III CN (Table C.1)

(2): S = (1000/CN)-10

(3): $Y = (P24-0.2S)^2/((P24+0.8S)P24)$

(4): $\bar{Y} = 1-Y$

(5): Field conditions indicate use of the lower end of the suggested pervious range

(6): impervious areas are assigned CN 98 for all AMC

TABLE 11

UNIT HYDROGRAPH STUDY:
EXAMPLE PROBLEM 3-HOUR STORM
EFFECTIVE RAINFALL DETERMINATION

(Example Unit Period = 5 minutes)

Unit Period Number	Unit Rainfall (inches)	Unit Loss (inches)	Effective Rainfall (inches)
1	.04	.013	.025
2	.04	.013	.026
3	.04	.013	.026
4	.04	.014	.027
5	.04	.014	.027
6	.04	.014	.028
7	.04	.015	.029
8	.04	.015	.029
9	.05	.015	.030
10	.05	.016 *	.031
11	.04	.015	.029
12	.05	.016 *	.034
13	.05	.016 *	.036
14	.05	.016 *	.037
15	.06	.016 *	.040
16	.05	.016 *	.042
17	.04	.015	.029
18	.05	.016 *	.031
19	.05	.016 *	.037
20	.06	.016 *	.042
21	.07	.016 *	.053
22	.08	.016 *	.062
23	.11	.016 *	.094
24	.15	.016 *	.135
25	.45	.016 *	.438
26	.09	.016 *	.074
27	.07	.016 *	.054
28	.06	.016 *	.034
29	.05	.016 *	.044
30	.05	.016 *	.039
31	.05	.016 *	.035
32	.05	.016 *	.032
33	.04	.015	.030
34	.04	.014	.028
35	.04	.014	.027
36	.04	.013	.026
TOTAL =	2.38	0.55	1.83

*Unit low loss exceeds unit adjusted loss

E. Compute the flood hydrograph.

1. Multiply the effective unit rainfall for the first unit time period by each synthetic unit hydrograph value to determine the flood hydrograph which would result from that rainfall increment.

2. Repeat the above process for each succeeding effective rainfall value, advancing the resultant flood hydrograph one unit time period for each computation cycle as shown in Figure 21. Shown below are the calculations for the first five flood hydrograph values.

TABLE 12.

FLOOD HYDROGRAPH

unit period	convolution process	flood hydrograph(cfs)
1	0.025 x 246	= 6
2	0.025 x 515 + 0.026 x 246	= 19
3	0.025 x 753 + 0.26 x 515 + 0.026 x 246	= 38
4	0.025 x 1,446 + 0.026 x 515 + 0.026 x 753 + 0.027 x 246	= 76
5	0.025 x 2,187 + 0.026 x 1,446 + + 0.026 x 753 + 0.027 x 515 + + 0.027 x 246	= 134

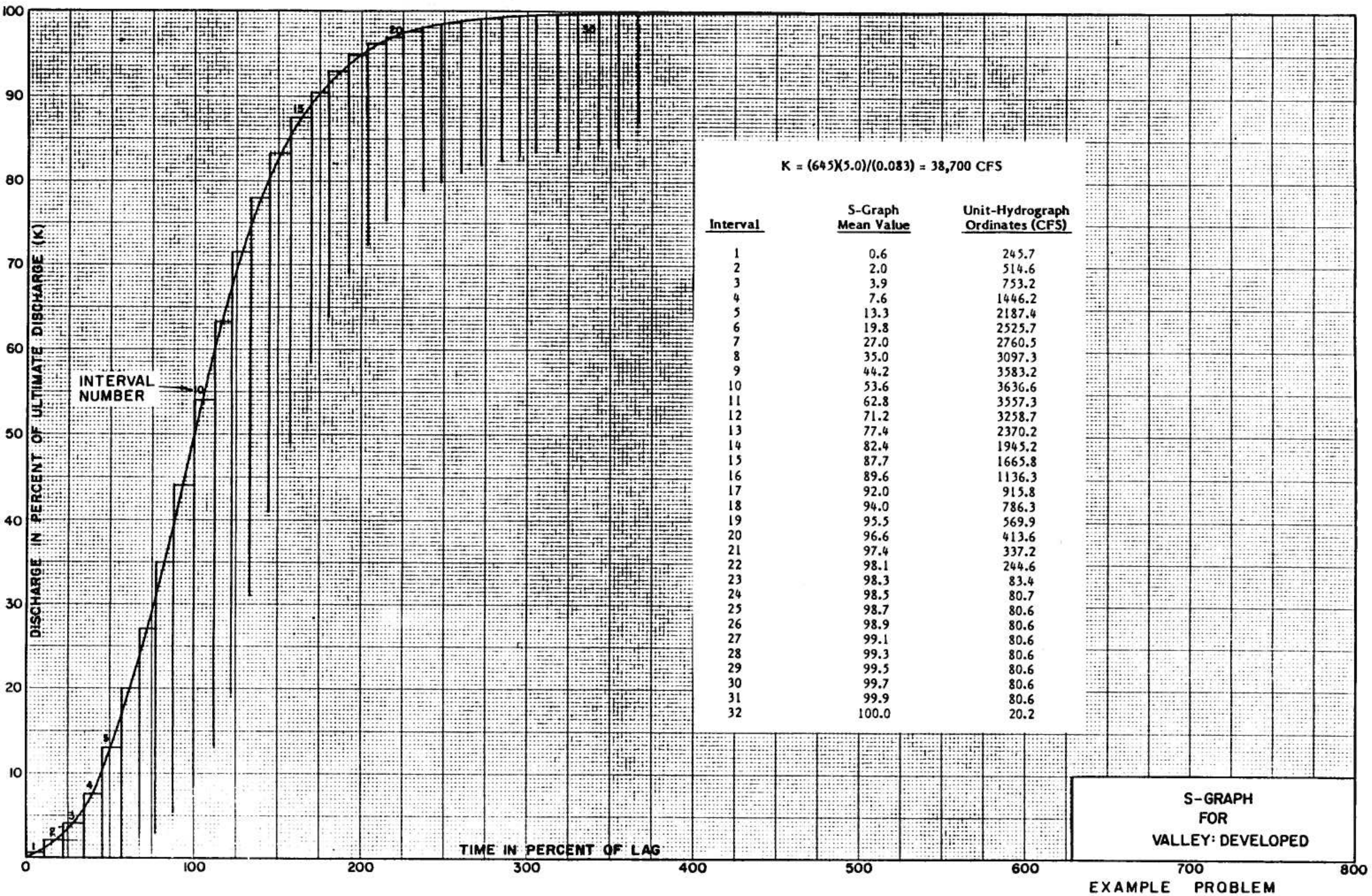
3. Sum the flow ordinates found in the steps above to determine the average flow ordinate per unit period for the design storm flood hydrograph.

F. Add the appropriate base flow to the flood hydrograph ordinates determined in Step E.

G. Plot the runoff hydrograph values calculated in step F as shown in Figure 22.

IV. Required Format

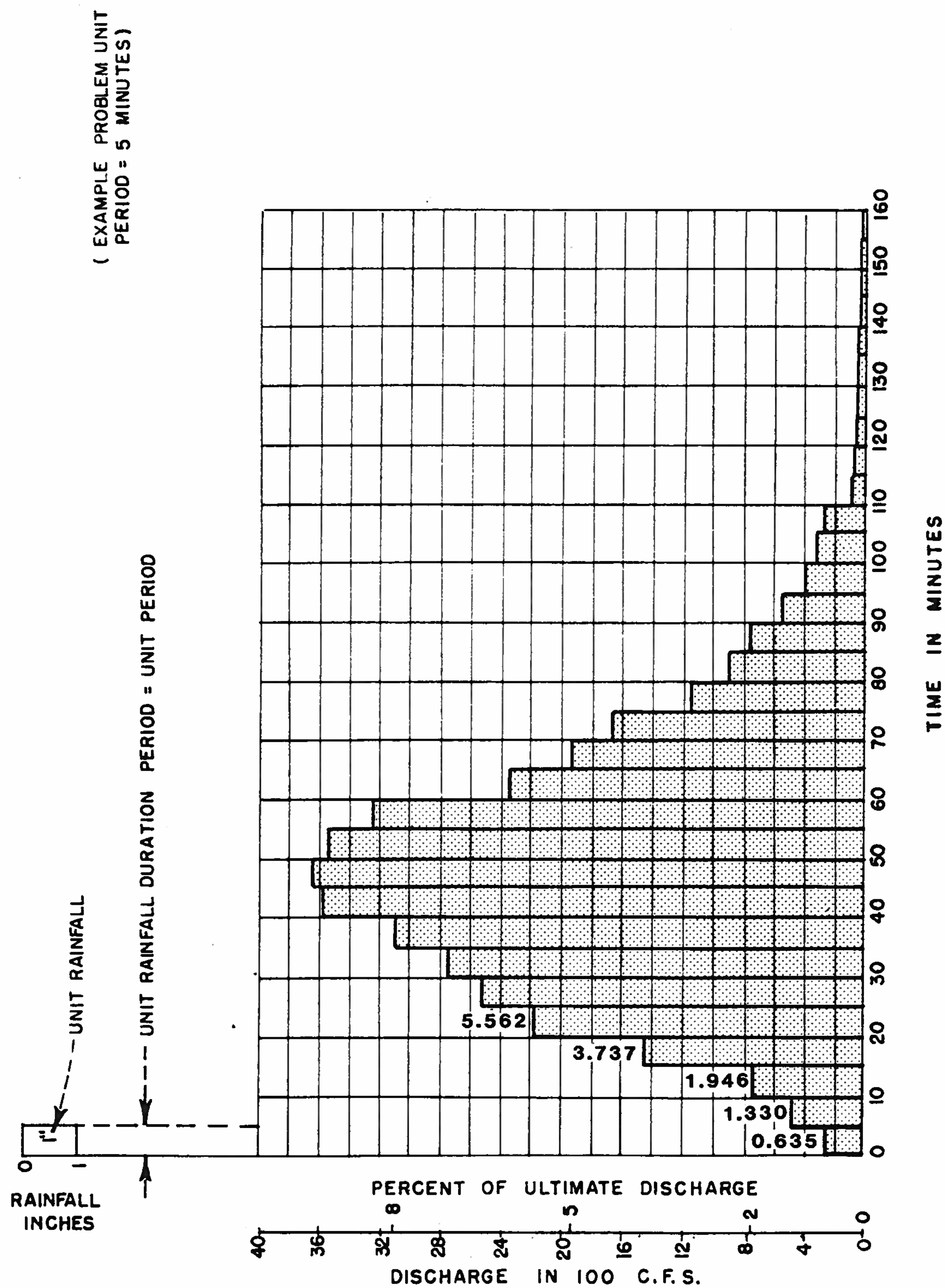
A. Figure 23 illustrate the required format for submitting unit hydrograph study results for review.



K = (645)(5.0)/(0.083) = 38,700 CFS

Interval	S-Graph Mean Value	Unit-Hydrograph Ordinates (CFS)
1	0.6	245.7
2	2.0	514.6
3	3.9	753.2
4	7.6	1446.2
5	13.3	2187.4
6	19.8	2525.7
7	27.0	2760.5
8	35.0	3097.3
9	44.2	3583.2
10	53.6	3636.6
11	62.8	3557.3
12	71.2	3258.7
13	77.4	2370.2
14	82.4	1945.2
15	87.7	1665.8
16	89.6	1136.3
17	92.0	915.8
18	94.0	786.3
19	95.5	569.9
20	96.6	413.6
21	97.4	337.2
22	98.1	244.6
23	98.3	83.4
24	98.5	80.7
25	98.7	80.6
26	98.9	80.6
27	99.1	80.6
28	99.3	80.6
29	99.5	80.6
30	99.7	80.6
31	99.9	80.6
32	100.0	20.2

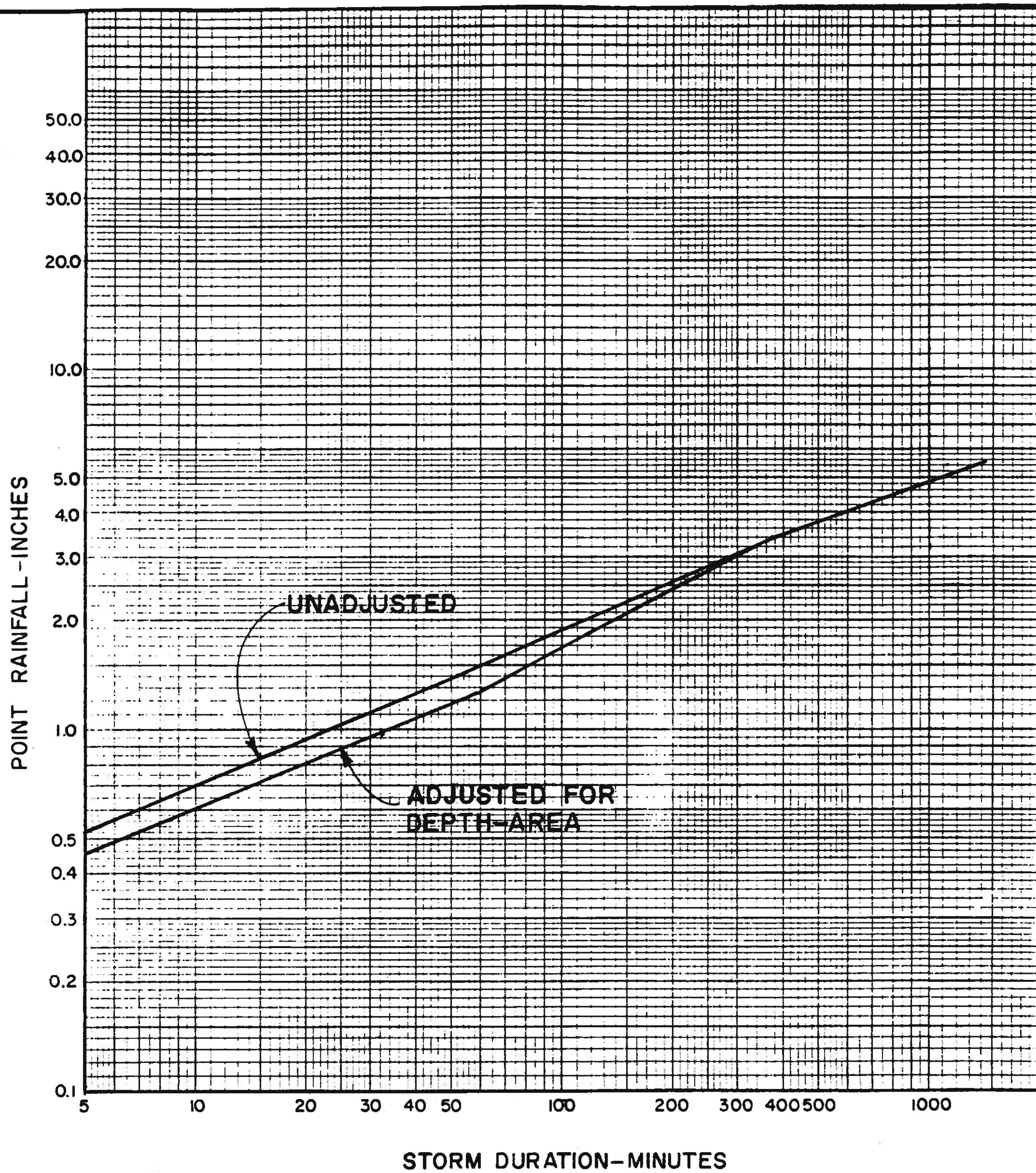
FIGURE 17. VALLEY: DEVELOPED S-GRAPH



ORANGE COUNTY
HYDROLOGY MANUAL

EXAMPLE PROBLEM
UNIT DISTRIBUTION GRAPH

FIGURE 18. UNIT DISTRIBUTION GRAPH



PROJECT LOCATION *EXAMPLE PROBLEM*

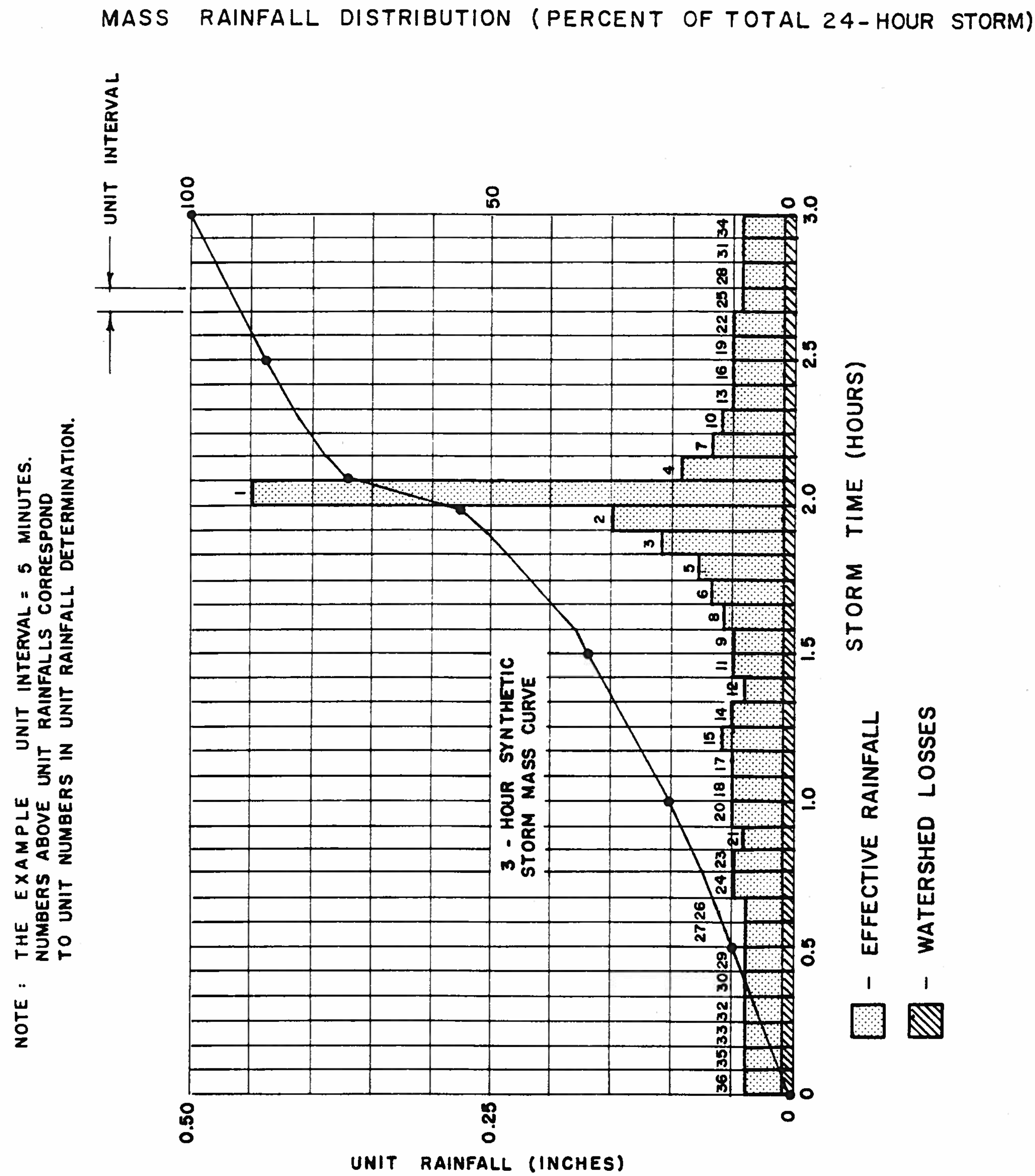
NOTES *100-YEAR STORM*

ORANGE COUNTY

HYDROLOGY MANUAL

AREA - AVERAGED MASS RAINFALL PLOTTING SHEET

FIGURE 19. MASS RAINFALL PLOT



ORANGE COUNTY

HYDROLOGY MANUAL

EXAMPLE

SYNTHETIC 3-HOUR CRITICAL STORM

FIGURE 20. 3-HOUR CRITICAL STORM PATTERN

ORANGE COUNTY

HYDROLOGY MANUAL

SYNTHETIC UNIT HYDROGRAPH METHOD

Flood Hydrograph Calculation Form

Project EXAMPLE PROBLEM

By TRW Date 5-15-86

Checked MHS Date 5-15-86

Sheet 1 / 2

UNIT GRAPH (cfs)	UNIT PER.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	FLOOD HYDRO-GRAPH (cfs)	BASE-FLOW (cfs)	DESIGN FLOOD HYDRO-GRAPH (cfs)
	EFFEC RAIN (In)	.025	.026	.026	.027	.027	.028	.029	.029	.030	.031	.029	.034	.036	.037	.040	.042	.029	.031	.037	.042	.053	.062	.094	.135			
246	1	6																								6	50	56
515	2	13	6																							19	50	69
753	3	19	13	6																						38	50	88
1446	4	36	20	13	7																					76	50	126
2187	5	55	38	20	14	7																				134	50	184
2526	6	63	57	38	20	14	7																			199	50	249
2761	7	69	66	57	39	20	14	7																		272	50	322
3097	8	77	72	66	59	39	21	15	7																	356	50	406
3583	9	90	81	72	68	59	40	22	15	7																454	50	504
3637	10	91	93	81	75	68	61	42	22	15	8															556	50	606
3557	11	89	95	93	84	75	71	63	42	23	16	7														658	50	708
3259	12	81	92	95	97	84	77	73	63	43	23	15	8													751	50	801
2370	13	59	85	92	98	97	87	80	73	66	45	22	18	9												831	50	881
1945	14	49	62	85	96	98	100	90	80	76	68	42	26	19	9											900	50	950
1666	15	42	51	62	88	96	102	104	90	83	78	63	49	27	19	10										964	50	1014
1136	16	28	43	51	64	88	100	105	164	93	86	73	74	52	28	21	10									1020	50	1070
916	17	23	30	43	53	64	91	103	105	107	96	80	86	79	54	30	22	7								1073	50	1023
786	18	20	24	30	45	53	66	95	103	109	111	90	94	91	81	58	32	15	8							1125	50	1175
570	19	14	26	24	31	45	54	69	95	107	113	104	105	99	93	87	61	22	16	9						1168	50	1218
414	20	10	15	20	25	31	47	56	69	98	110	105	122	111	102	101	92	42	23	19	10					1208	50	1258
337	21	8	11	15	21	25	32	48	56	71	101	103	124	129	115	110	106	63	45	28	22	13				1246	50	1296
245	22	6	9	11	15	21	26	33	48	58	73	95	121	131	133	124	116	73	68	54	32	27	15			1289	50	1339
83	23	2	6	9	11	15	22	27	33	50	60	69	111	128	135	143	130	80	78	81	61	40	32	23		1346	50	1396
81	24	2	2	6	9	11	16	23	27	34	52	56	81	117	132	145	150	90	86	93	92	77	47	48	33	1429	50	1479
81	25	2	2	2	7	9	12	17	23	27	35	48	66	85	121	142	153	104	96	102	106	116	90	71	70			
81	26	2	2	2	2	7	9	12	17	24	28	33	57	70	88	130	149	105	111	115	116	134	136	136	102			
81	27	2	2	2	2	2	7	10	12	17	24	27	39	60	72	95	137	103	113	133	130	146	157	206	195			
81	28	2	2	2	2	2	2	7	10	12	18	23	31	41	62	78	100	95	110	135	150	164	171	237	295			
81	29	2	2	2	2	2	2	2	7	10	13	17	27	33	42	67	82	69	101	132	153	190	192	260	341			
81	30	2	2	2	2	2	2	2	2	7	10	12	19	28	34	45	70	56	73	121	149	193	222	291	373			
81	31	2	2	2	2	2	2	2	2	2	7	10	14	21	29	37	48	48	60	88	137	189	225	337	418			
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				1	2	2	2	2	2	2	3	2	3	9	12	17	24	23	28	42	70	103	147	306	480			
					1	2	2	2	2	2	3	2	3	3	9	13	17	17	24	34	48	88	121	223	440			
						1	2	2	2	2	3	2	3	3	3	10	14	12	18	29	38	60	103	183	320			
							1	2	2	2	3	2	3	3	3	3	10	10	13	21	33	49	70	157	263			
								1	2	2	3	2	3	3	3	3	3	7	10	15	24	42	57	107	225			
									1	2	3	2	3	3	3	3	3	2	7	12	17	30	49	86	153			
										1	3	2	3	3	3	3	3	2	3	9	14	22	35	74	124			
											1	2	3	3	3	3	3	2	3	3	10	18	26	54	106			
												1	3	3	3	3	3	2	3	3	3	13	21	39	77			
													1	3	3	3	3	2	3	3	3	4	15	32	56			
														1	3	3	3	2	3	3	3	4	5	23	45			
															1	3	3	2	3	3	3	4	5	8	33			
																1	3	2	3	3	3	4	5	8	11			
																	1	2	3	3	3	4	5	8	11			
																		1	3	3	3	4	5	8	11			
																			1	3	3	4	5	8	11			
																				1	3	4	5	8	11			
																					1	4	5	8	11			
																						1	5	8	11			
																							1	8	11			
																								2	11			
																									3			

ORANGE COUNTY

HYDROLOGY MANUAL

FLOOD HYDROGRAPH CALCULATION FORM

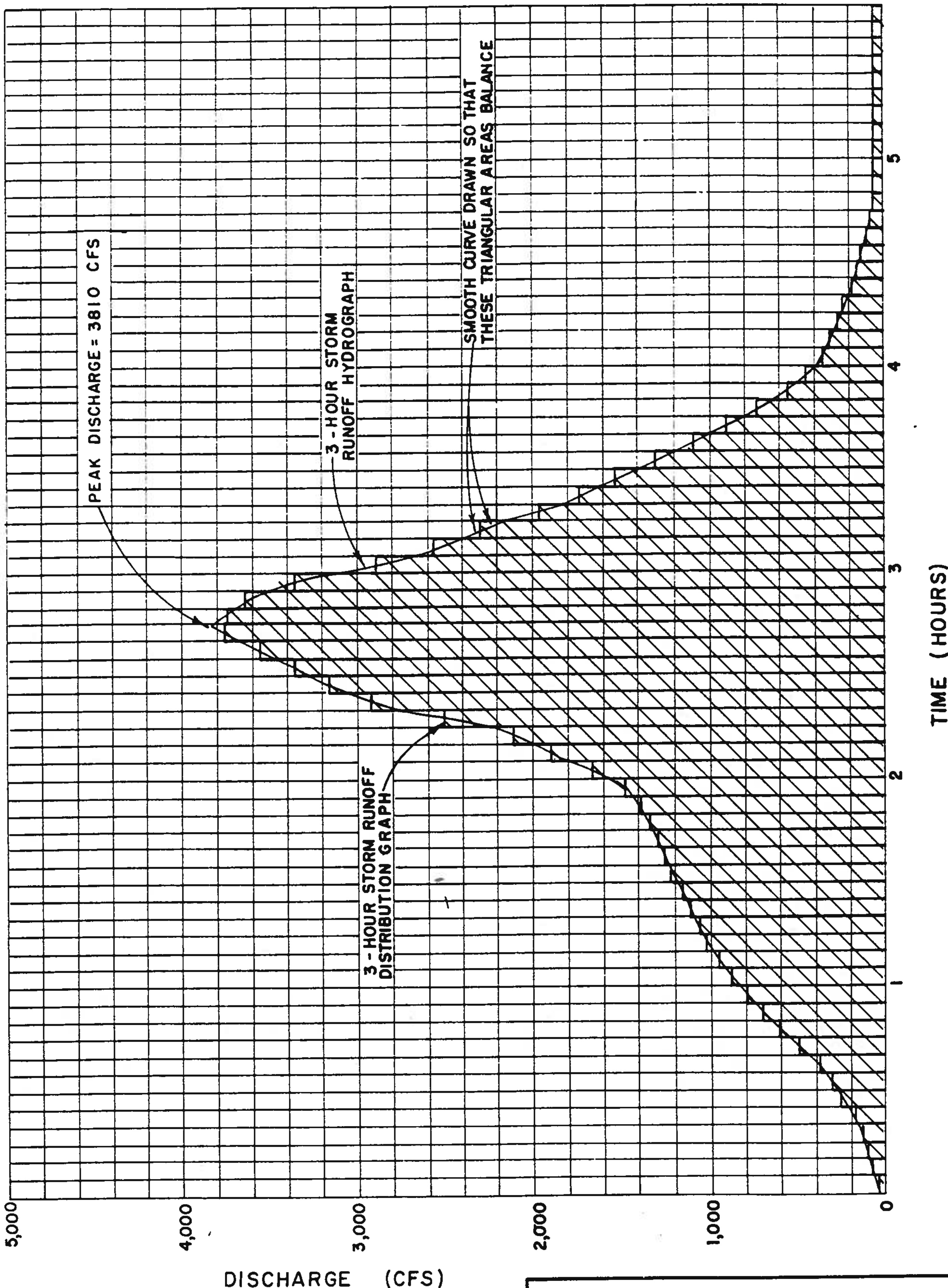
FIGURE 21A. FLOOD HYDROGRAPH CALCULATION FORM

ORANGE COUNTY HYDROLOGY MANUAL	SYNTHETIC UNIT HYDROGRAPH METHOD Flood Hydrograph Calculation Form	Project EXAMPLE PROBLEM By TRW Date 5-15-86 Checked MHS Date 5-15-86	Sheet 2 / 2

UNIT GRAPH (cfs)	EFFEC RAIN (In) / UNIT PER.	.438	.074	.054	.034	.044	.039	.035	.032	.030	.028	.027	.026	FLOOD HYDRO-GRAPH (cfs)	BASE-FLOW (cfs)	DESIGN FLOOD HYDRO-GRAPH (cfs)
		25	26	27	28	29	30	31	32	33	34	35	36			
246	1	108												1614	50	1664
515	2	226	18											1831	50	1881
753	3	330	38	13										2074	50	2124
1446	4	633	56	28	8									2476	50	2526
2187	5	958	107	41	18	11								2885	50	2935
2526	6	1106	162	78	26	23	10							3124	50	3174
2761	7	1209	187	118	49	33	20	9						3311	50	3361
3097	8	1356	204	136	74	64	29	18	8					3509	50	3559
3583	9	1569	229	149	86	96	56	26	16	7				3704	50	3754
3637	10	1593	265	167	94	111	85	51	24	15	7			3694	50	3744
3557	11	1558	269	193	105	121	99	77	46	23	14	7		3568	50	3618
3259	12	1427	263	196	122	136	108	88	70	43	21	14	6	3304	50	3354
2370	13	1038	241	192	124	158	121	97	81	66	40	20	13	2841	50	2891
1945	14	852	175	176	121	160	140	108	88	76	61	39	20		50	
1666	15	730	144	128	111	157	142	125	99	83	71	59	38		50	
1136	16	498	123	105	81	143	139	127	115	93	77	68	57		50	
916	17	401	84	90	66	104	127	124	116	107	87	75	66		50	
786	18	344	68	61	57	86	92	114	114	109	100	84	72		50	
570	19	250	58	49	39	73	76	83	104	107	102	97	81		50	
414	20	181	42	42	31	50	65	68	76	98	100	98	93		50	
337	21	148	31	31	27	40	44	58	62	71	91	96	95		50	
245	22	107	25	22	19	35	36	40	53	58	66	88	92		50	
83	23	36	18	18	14	25	31	32	36	50	54	64	85		50	
81	24	35	6	13	11	18	22	28	29	34	47	53	62		50	
81	25	35	6	4	8	15	16	20	25	27	32	45	51		50	
81	26	35	6	4	3	11	13	14	18	24	26	31	43		50	
81	27	35	6	4	3	4	10	12	13	17	22	25	30		50	
81	28	35	6	4	3	4	3	9	11	12	16	21	24		50	
81	29	35	6	4	3	4	3	3	8	10	12	15	20		50	
81	30	35	6	4	3	4	3	3	3	7	9	11	15		50	
81	31	35	6	4	3	4	3	3	3	2	7	9	11		50	
20	32	9	6	4	3	4	3	3	3	2	2	7	9		50	
			1	4	3	4	3	3	3	2	2	2	6		50	
				1	3	4	3	3	3	2	2	2	2		50	
					1	4	3	3	3	2	2	2	2		50	
						1	3	3	3	2	2	2	2		50	
							1	3	3	2	2	2	2		50	
								1	3	2	2	2	2		50	
									1	2	2	2	2		50	
										1	2	2	2		50	
											1	2	2		50	
												1	2		50	
													1		50	

ORANGE COUNTY
HYDROLOGY MANUAL
FLOOD HYDROGRAPH
CALCULATION FORM

FIGURE 21B. FLOOD HYDROGRAPH CALCULATION FORM



ORANGE COUNTY

HYDROLOGY MANUAL

EXAMPLE PROBLEM

3 - HOUR STORM

RUNOFF HYDROGRAPH

FIGURE 22. 3-HOUR RUNOFF HYDROGRAPH

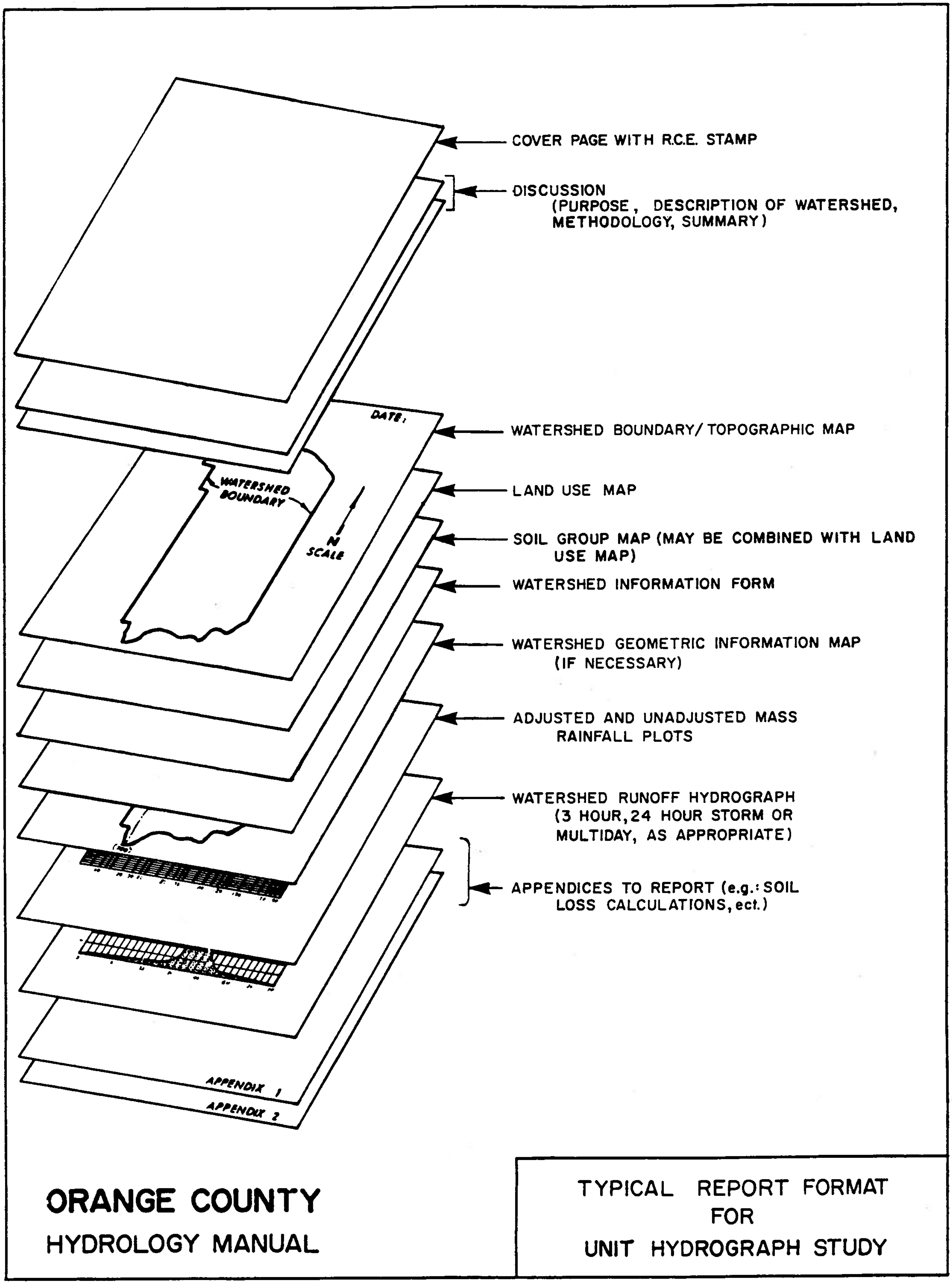


FIGURE 23. UNIT HYDROGRAPH STUDY REPORT FORMAT

PROBLEM 13

Flow-through Detention Basin Hydrograph Routing

Detention Basin Hydrograph Routing (Flow-through Basin)

Required information:

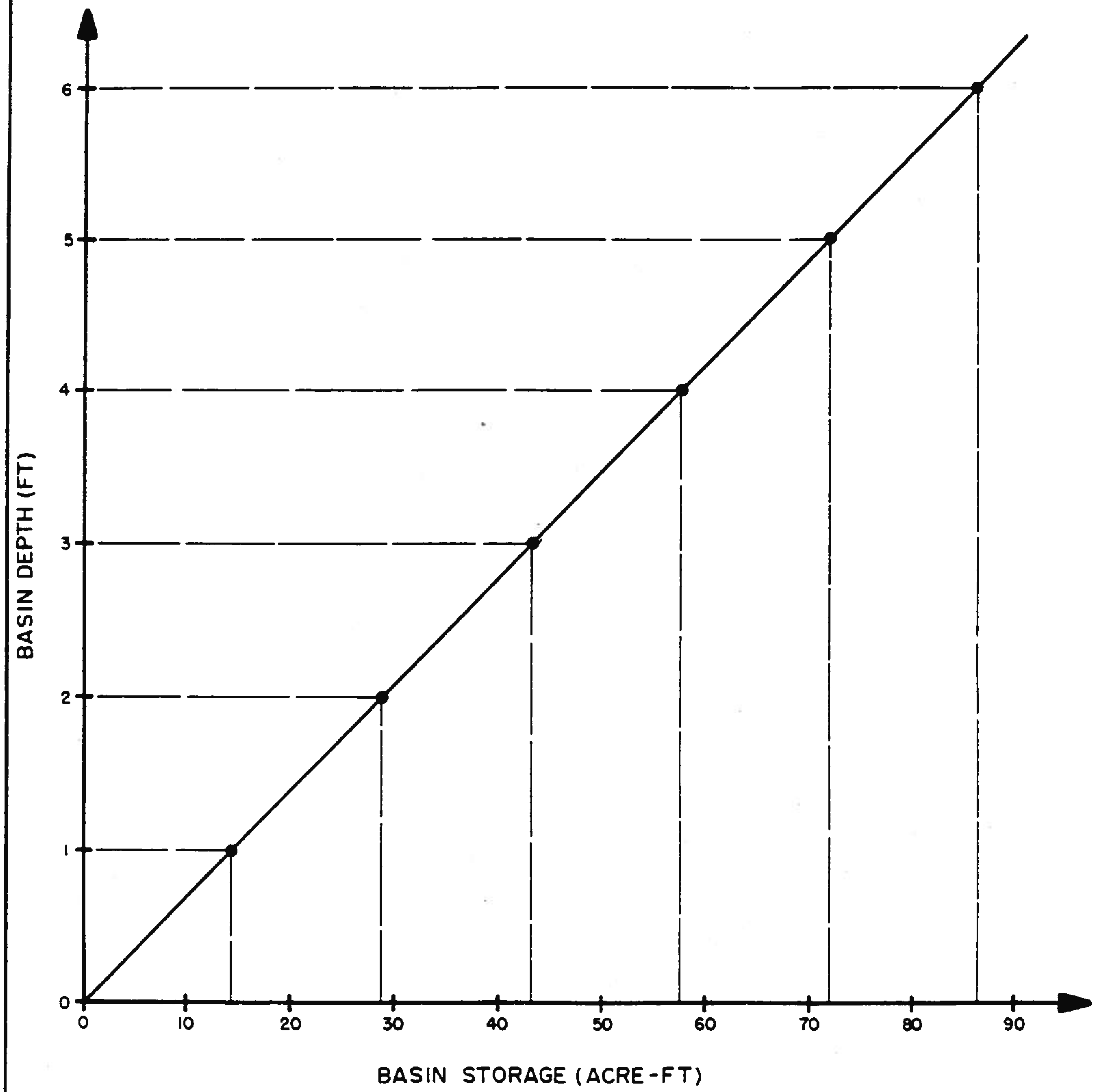
1. Known initial conditions of basin storage and outflow.
2. A routing timestep, Δt.
3. The basin inflow hydrograph.
4. Basin volume vs. depth and outflow vs. depth relationships.

For the example problem, assume we have the following:

1. The initial conditions of basin storage is zero storage, therefore, the outflow is zero cfs.
2. A timestep of 60 minutes is used for calculations.
3. The basin inflow hydrograph is tabulated in Table 13.
4. Basin volume vs. depth and outflow vs. depth are depicted in Figs. 24 and 25, respectively.

TABLE 13.
BASIN INFLOW HYDROGRAPH VERSUS TIME

Time (min).	Inflow (cfs)
0	0
60	60
120	120
180	280
240	250
300	220
360	120
420	100
480	60
540	0
600	0

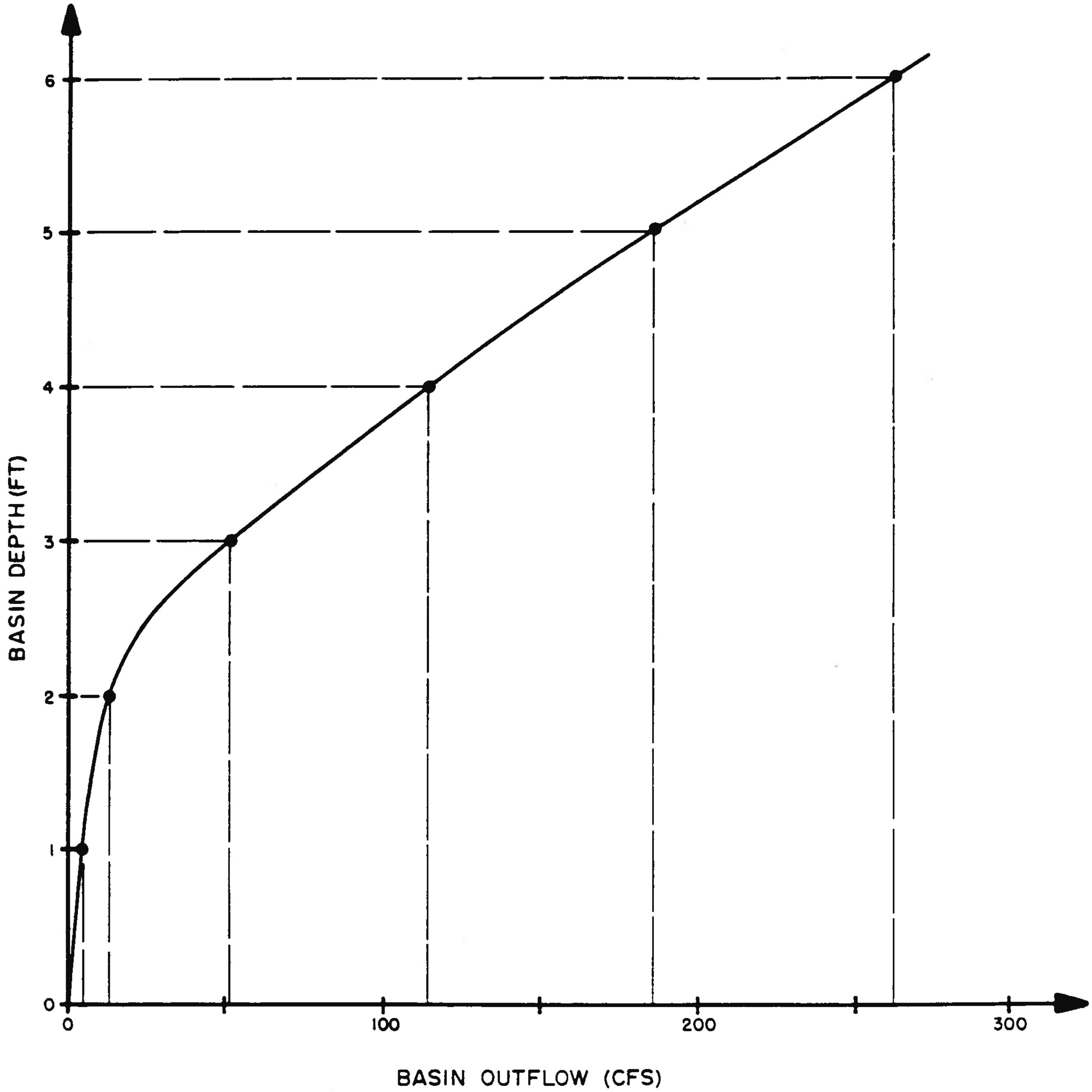


ORANGE COUNTY

HYDROLOGY MANUAL

EXAMPLE PROBLEM
DETENTION BASIN STORAGE (AF)
AS A FUNCTION OF DEPTH (FT)

FIGURE 24. BASIN VOLUME VS. DEPTH



ORANGE COUNTY

HYDROLOGY MANUAL

EXAMPLE PROBLEM

DETENTION BASIN OUTFLOW (CFS)

AS A FUNCTION OF DEPTH (FT)

FIGURE 25. BASIN OUTFLOW VS. DEPTH

Solution Procedures:

1. Determine the average inflow volume from the inflow hydrograph during the timestep t (60 minute.); i.e., calculate $(I_1 + I_2)\Delta t/2$. The average inflow volume is determined by calculating the average inflow rate for the timestep and converting it to a volume. Using the first 60 minutes of the example problem inflow hydrograph, the procedure is as follows:

$$\left(\frac{0 \text{ Ft.}^3}{\text{SEC}} + \frac{60 \text{ Ft.}^3}{\text{SEC}} \right) / 2 = 30 \frac{\text{Ft.}^3}{\text{SEC}}$$

$$30 \frac{\text{Ft.}^3}{\text{SEC}} \times \frac{60 \text{ SEC}}{1 \text{ MIN.}} \times \frac{1 \text{ Ac-Ft}}{43{,}560 \text{ Ft.}^3} \times 60 \text{ MIN} = 2.48 \text{ Ac-Ft}$$

This procedure is carried out for the entire inflow hydrograph. The example results are tabulated in Table 14.

Notes: I_1 = preceding inflow rate

I_2 = following inflow rate

TABLE 14.

AVERAGE INFLOW VOLUME

Time (min.)	Inflow (cfs)	Average Inflow (cfs)	$(I_1+I_2)\Delta t/2$ (AF)
0	0		
		30	2.48
60	60		
		90	7.44
120	120		
		200	16.53
180	280		
		265	21.90
240	250		
		235	19.42
300	220		
		170	14.05
360	120		
		110	9.09
420	100		
		80	6.61
480	60		
		30	2.48
540	0		
		0	0
600	0		
		0	0

2. Construct basin storage-indication relationship as shown in Table 15 using the detention basin outflow (0) from Fig. 25 and detention basin storage data from Fig. 24.

TABLE 15.

EXAMPLE PROBLEM STORAGE-INDICATION CURVE DEVELOPMENT

Depth (ft.)	O (cfs)	S (AF)	S–O $\Delta t/2$ (AF)	S+O $\Delta t/2$ (AF)
0	0	0	0	0
1	4.2	14.4	14.22	14.57
2	12.0	28.8	28.30	29.30
3	51.7	43.2	41.06	45.34
4	114.7	57.6	52.86	62.34
5	186.8	72.0	64.28	79.72
6	263.2	86.4	75.52	97.28

The storage-indication curve is developed for a depth of 2 feet (i.e., outflow 0 = 12 cfs) as follows:

$$S - 0\,\frac{\Delta t}{2} = 28.8\ \text{Ac-Ft} - \frac{12.0\ \text{Ft.}^3}{\text{SEC}}\left(\frac{60\ \text{SEC}}{\text{MIN}} \times \frac{1\ \text{Ac-Ft}}{43{,}560\ \text{Ft.}^3} \times \underline{60\ \text{MIN}}\right) / 2$$

$$S - 0\,\frac{\Delta t}{2} = 28.8\ \text{Ac-Ft} - 0.5\ \text{Ac-Ft} \quad = \quad 28.3\ \text{Ac-Ft}$$

$$S + 0\,\frac{\Delta t}{2} = 28.8\ \text{Ac-Ft} + 0.5\ \text{Ac-Ft} \quad = \quad 29.3\ \text{Ac-Ft.}$$

Figure 26 depicts the basin storage-indication curve.

3. The basin hydrograph routing procedure is schematically illustrated in Table 16.

Note:

1. O_I and S_I indicate the initial basin outflow and storage, respectively.
2. Value of column (2) is calculated by taking value of column (6) minus the product of column (4) (converted to volume) and t/2.
3. Value of column 3 is calculated by use of the following equation:

$$S_2 + O_2\,\frac{\Delta t}{2} = (S_1 - O_1\,\Delta t/2) + (I_1 + I_2)/\Delta t$$

(i.e., sum of column (1) and (2).

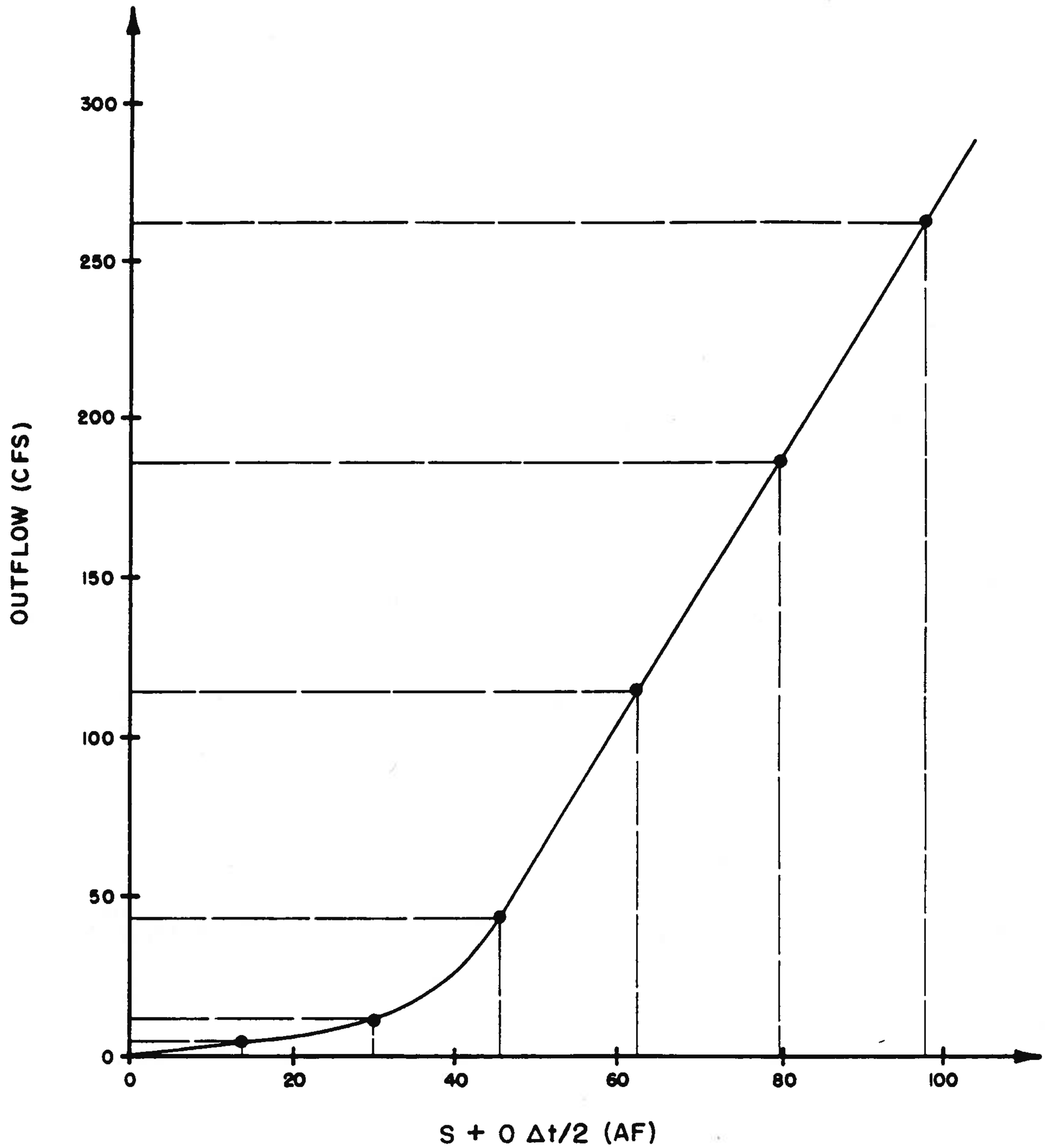
4. Using the value of column 3, the basin outflow (col. 4) can be directly obtained from Fig. 26.
5. Then the basin depth (col. 5) can be obtained from Fig. 25 for the corresponding basin outflow (col. 4).
6. Finally, the basin storage can be obtained from Fig. 24 for the corresponding basin depth (col. 5).

This procedure is repeated until the basin inflow hydrograph has been completely analyzed and basin outflow becomes negligible.

TABLE 16.

BASIN HYDROGRAPH SEQUENCE

Col.(1) $(I_1+I_2)\,\Delta t/2$ (AF)	Col.(2) $S_1 - D_1\,\Delta t/2$ (AF)	Col.(3) $S_2 + O_2\Delta t/2$ (AF)	Col.(4) Outflow (cfs)	Col.(5) Depth (cfs)	Col.(6) Storage (AF)
			O_I		S_I
$(I_1 + I_2)\,\frac{\Delta t}{2}$	$S_I - O_I\,\frac{\Delta t}{2} \xrightarrow{(1)+(2)}$	$S_2 + O_2\frac{\Delta t}{2}$ Fig. 3			
			$O_1 \xrightarrow{\text{Fig. 1}}$	$D_1 \xrightarrow{\text{Fig. 2}}$	S_1
$(I_1 + I_2)\,\frac{\Delta t}{2}$	$S_1 - O_1\,\frac{\Delta t}{2} \xrightarrow{(1)+(2)}$	$S_2 + O_2\frac{\Delta t}{2}$ Fig. 3			
			$O_1 \xrightarrow{\text{Fig. 1}}$	$D_1 \xrightarrow{\text{Fig. 2}}$	S_1
⋮	⋮	⋮	⋮	⋮	



ORANGE COUNTY

HYDROLOGY MANUAL

EXAMPLE PROBLEM

STORAGE-INDICATION CURVE

FIGURE 26. STORAGE-INDICATION CURVE

The basin inflow hydrograph (unit period of 60 minutes) is routed using the modified Pul's method in the tabulation of Table 17. The 60-minute timestep is used for demonstration purposes only. Typically, a 5-minute timestep is needed in order to adequately describe the runoff hydrograph peak flow rates.

TABLE 17.
EXAMPLE PROBLEM BASIN ROUTING TABLULATION

Time (min.)	Inflow (cfs)	Average Inflow (cfs)	$(I_1+I_2)\Delta t/2$ (AF)	$S_1-O_1\Delta t/2$ (AF)	$S_2+O_2\Delta t/2$ (AF)	Outflow (cfs)	Storage (AF)
0	0					0	0
		30	2.48	0	2.48		
60	60					.7	2.45
		90	7.44	2.42	9.86		
120	120					2.8	9.74
		200	16.53	9.62	26.16		
180	280					10.3	25.73
		265	21.90	25.31	47.21		
240	250					58.6	44.79
		235	19.42	42.37	61.79		
300	220					112.7	57.14
		170	14.05	52.48	66.53		
360	120					132.1	61.07
		110	9.09	55.61	64.70		
420	100					124.5	59.56
		80	6.61	54.41	61.02		
480	60					109.8	56.48
		30	2.48	51.94	54.42		
540	0					85.4	50.89
		0	0	47.36	47.36		
600	0					59.20	44.91
		0	0	42.46	42.46		

PROBLEM 14

Convex Channel Routing

Convex Channel Routing

Required Information:

Inflow hydrograph, channel geometries, and reach length of the channel.

Example Problem:

The example problem channel is a rectangular concrete section with a base of 10 feet, a Manning friction factor of 0.015, length of 3000 feet, and a mean slope of 0.005 ft./ft. The problem inflow hydrograph is tabulated in Table 18. From this table, the average flow rate in excess of the 50-percent peak flow rate value is 783.2 cfs which is calculated as follows:

1. Calculate the 50 percent peak flowrate:

$$Q_{50\%} = 1186.7 \times 0.50 = 593.35 \text{ cfs}$$

2. Sum the inflow hydrograph ordinates that are greater than $Q_{50\%}$:

$$\begin{aligned} \text{SUM} &= 602.9 + 653.7 + 600.9 + 608.0 + 917.1 \\ &\quad + 1186.7 + 1001.2 + 763.6 + 714.9 \\ &= 7049.0 \text{ cfs (for 9 unit intervals)} \end{aligned}$$

3. The average flowrate in excess of the 50-percent peak flow rate ($Q_{50\%}$) is

$$Q_{avg} = \text{SUM}/9 = 783.2 \text{ cfs}$$

Next, a normal depth flow velocity is calculated by using the Manning's equation and the Q_{avg}:

$$V = (1.486\ R_h^{0.67} S_o^{0.50})/n$$

where R_h is the hydraulic radius, and S_o is the channel slope. For the example problem, the average flowrate in excess of $Q_{50\%}$ (Q_{avg} = 783.2 cfs) corresponds to a normal depth flow velocity of 13.5 fps.

The routing coefficient C may be estimated by

$$C = V/(V + 1.7) = (13.5)/(13.5 + 1.7) = 0.89$$

The average travel time (K) through the channel is estimated by

$$K = L/V = (3000 \text{ ft})/(13.5 \text{ fps}) (3600 \text{ sec/hr}) = 0.062 \text{ hr.}$$

The routing timestep, dT, is given by

$$dT = \frac{CL}{3600V} = CK = (0.89)(0.062) = 0.055 \text{ hr.}$$

The value dT is used as the timing offset between inflow and outflow.
The modified routing coefficient, C*, is obtained from

$$C^* = 1 - (1-C)^E$$

where E = (dT* + 0.5dT)/(1.5dT) in which dT* = (0.0833 hr.) is the unit period of inflow hydrograph (say 5 minutes in this example problem). Therefore,

$$E = (0.0833 + 0.5 \times 0.055)/(1.5 \times 0.055)$$

$$= 0.1108/0.0825$$

$$= 1.343$$

and

$$C^* = 1 - (1 - 0.89)^{1.343}$$

$$= 0.948$$

Finally, the appropriate convex method routing approximation statement is

$$O_{T+dT} = (1-C^{*})O_{T+dT-dT^{*}} + C^{*}I_{T}$$

where for the example problem,

$$O_{T+dT} = (0.052)O_{T+dT-dT^{*}} + (0.948)I_{T}$$

Table 19 illustrates convex channel routing computation procedure.

TABLE 18.

EXAMPLE PROBLEM INFLOW HYDROGRAPH

Storm Time (minutes)	Inflow (cfs)
0	.0
5	.8
10	.9
15	40.5
20	202.7
25	445.1
30	602.9
35	653.7
40	600.9
45	608.0
50	917.1
55	1186.7
60	1001.1
65	763.6
70	714.9

The detailed calculation of the convex routing is illustrated as follows:

> First we use the routing timestep dT (0.055 hr.) to determine the travel time for each of the inflow hydrograph unit runoffs of duration, dT* (0.0833 hr.). In this example, the ratio of dT/dT* is 0.6568. Therefore, about 66 percent of the outflow calculated at time interval T is forwarded to time interval T+dT and 34 percent of the outflow remains in time interval T. Repeat the above process for each unit time interval, and sum up the outflow at each time interval to obtain the outflow hydrograph.

Table 19 shows the outflow hydrograph. For storm time T = 5 minutes, the total outflow rate is calculated as

$$O_5 = 0.052\, O_o + 0.948 I_5$$
$$= (0.052)\,(0) + 0.948(0.8)$$
$$= 0.7584 \text{ cfs}$$

Then O_5 is distributed into the intervals 5 min. and 10 min as follows:

$$O'_5 = DA\,(0.7584) = 0.26 \text{ cfs}$$

and

$$O'_{10} = DB\,(0.7584) = 0.50 \text{ cfs}$$

where DB = 0.6568 and DA = 0.3432.

Next, the 10 minutes storm interval outflow is calculated as

$$O_{10} = (0.052)\,O_5 + (0.948)\,I_{10}$$
$$= (0.052)(.7584) + (0.948)(0.9)$$
$$= 0.89 \text{ cfs}$$

The new outflow for time intervals 10 min. and 15 min. are:

$$O'_{10} = 0.50 + DA\,(0.89) = 0.80 \text{ cfs}$$

and

$$O'_{15} = DB\,(0.89) = 0.59 \text{ cfs}$$

For storm interval 15 minutes,

$$O_{15} = (0.052)\,O_{10} + (0.948)\,I_{15}$$
$$= (0.052)(0.89) + (0.948)(40.5)$$
$$= 38.44 \text{ cfs}$$

Therefore,

$$O'_{15} = 0.59 + DA\ (38.44) = 13.78 \text{ cfs}$$

and

$$O'_{20} = DB\ (38.44) = 25.25 \text{ cfs}$$

For storm interval 20 minutes,

$$\begin{aligned} O_{20} &= (0.052)\ O_{15} + (0.948)\ I_{20} \\ &= (0.052)(38.44) + (0.948)(202.7) \\ &= 194.16 \text{ cfs} \end{aligned}$$

Then

$$O'_{20} = 25.25 + DA\ (194.16) = 91.88 \text{ cfs}$$

$$O'_{25} = DB\ (194.16) = 127.52 \text{ cfs}$$

This procedure is repeated until the inflow hydrograph has been completely analyzed.

TABLE 19.

CONVEX ROUTING EXAMPLE PROBLEM SOLUTION

Storm Time (minutes)	I Inflow (cfs)	O Outflow (cfs)
0	0	0
5	.8	0. + 0.26 = 0.26
10	.9	0.5 + 0.3 = 0.80
15	40.5	0.59 + 13.19 = 13.78
20	202.7	25.25 + 66.63 = 91.88
25	445.1	127.52 + 148.28 = 275.8
30	602.9	283.77 + 203.86 = 487.63
35	653.7	390.15 + 223.28 = 613.43
40	600.9	427.31 + 207.12 = 634.43
45	608.0	396.37 + 208.58 = 604.95
50	917.1	399.18 + 309.22 = 708.40
55	1186.7	591.78 + 402.17 = 993.95
60	1001.1	769.66 + 346.62 = 1116.28
65	763.6	663.36 + 266.47 = 929.83
70	714.9	509.95 + 246.45 = 756.40

Note that the outflow is offset by dT = 3.3 minutes (routing timestep) due to a computed mean flow velocity of 13.5 fps.

PROBLEM 15

Flow-through Basin Multi-day Storm

A flow-through basin is to be analyzed using a 3-day 100-year storm. Because the runoff volume is needed to analyze the detention basin, a runoff hydrograph is required. The watershed tributary to the flow-through basin is below elevation 2000 feet, therefore the precipitation depths of Table B.2 in the Hydrology Manual can be used without area averaging.

The extended design storm is constructed in ascending order of precipitation depth as shown in Figure 27. Each of the 24-hour storm patterns are constructed by a simple scaling of the peak 24-hour design pattern according to a ratio of the respective 24-hour precipitation values. Following is an example of this technique.

From the Hydrology Manual Table B.2 the 5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour 100-year precipitation depths are obtained for the third day.

5-min.	30-min.	1-hr.	3-hr.	6-hr.	24-hr.
0.52"	1.09"	1.45"	2.43"	3.36"	5.63"

Table B.1 of the Hydrology Manual provides the maximum precipitation depths of 9.35 inches and 8.22 inches for the first day and second day respectively. The precipitation data for the runoff hydrograph durations are calculated below in Table 20 using the appropriate ratios.

TABLE 20.

FLOW-THROUGH BASIN 3-DAY UNIT HYDROGRAPH RAINFALL DEPTHS

Precipitation depth (inches)

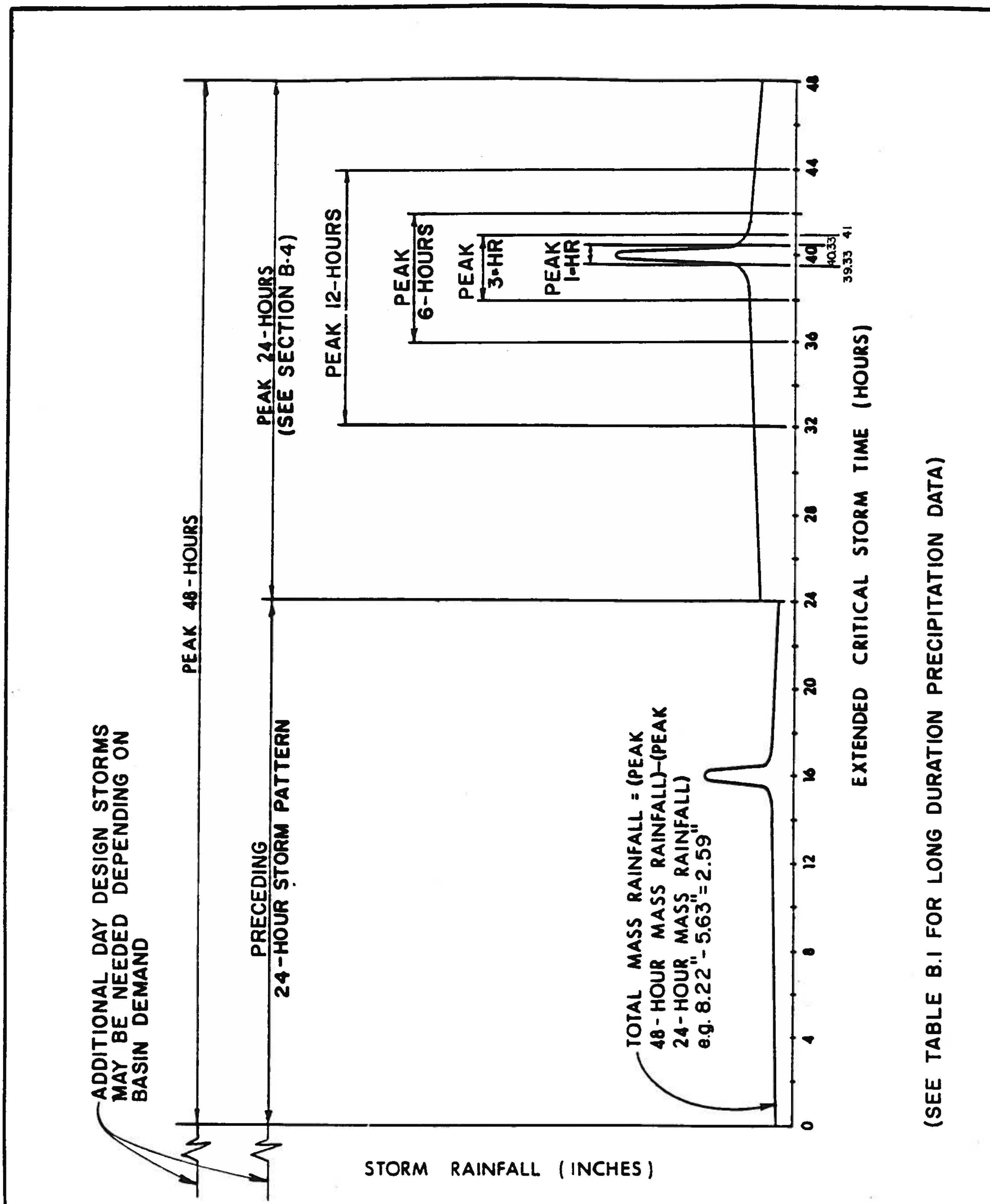
day	ratio	5-min.	30-min.	1-hr.	3-hr.	6-hr.	24-hr.
3	$\frac{5.63''}{5.63''}$	0.52	1.09	1.45	2.43	3.36	5.63
2	$\frac{8.22'' - 5.63''}{5.63''}$	0.24	0.50	0.67	1.12	1.55	2.59
1	$\frac{9.35'' - 8.22''}{5.63''}$	0.10	0.22	0.29	0.49	0.67	1.13

Knowing the precipitation depths for the three day design storm, the runoff hydrographs for the three days are calculated as shown in Problem 12.

When a complex watershed model (e.g., a "link-node" schematic involving subareas linked by channel routing) is to be used, a single area runoff hydrograph model is also to be developed for comparison purposes. Should detention basins be planned, the complex model without the basins (i.e., "free-draining") is to be compared to a single subarea model.

Should the peak Q from the free-draining complex model be greater than the single area runoff hydrograph model, then the complex model peak Q is to be used as a design Q. The use of a higher Q for design purposes aids in accommodating for the increased uncertainty in the complex model.

Should the peak Q from the free-draining complex model be less than the single area runoff hydrograph model, then the design storm for the complex model is to be modified by uniformly increasing the rainfall used in the design storm until the peak Q values match between the two models.



ORANGE COUNTY
HYDROLOGY MANUAL

EXTENDED DESIGN STORM: FLOW-THROUGH BASIN

FIGURE 27. FLOW-THROUGH BASIN EXTENDED DESIGN STORM

PROBLEM 16

Flow-by Basin Multi-day Storm

Determine the three day design storm to be used in the analysis of a flow-by detention basin. A runoff hydrograph of the mountainous watershed is required for the analysis. Consequently, the precipitation data of Hydrology Manual Table B.2 may be used directly.

The multi-day design storm is constructed to create as high a peak flow rate as possible (i.e., the second day 5-minute precipitation equals the third day 5-minute precipitation) as shown in Figure 28. Following is an example of this technique.

From Table B.2 the 5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour 100-year precipitation depths are obtained for the third day.

5-min.	30-min.	1-hr.	3-hr.	6-hr.	24-hr.
0.78"	1.34"	1.94"	3.96"	6.19"	11.27"

Table B.1 from the Hydrology Manual provides the maximum precipitation depths of 18.98 inches and 16.52 inches for the first day and second day respectively. The precipitation data for the runoff hydrograph duration are calculated below in Table 21 by putting the maximum allowable depths in the smallest duration first.

TABLE 21.
FLOW-BY BASIN 3-DAY UNIT HYDROGRAPH RAINFALL DEPTHS

Precipitation depths (inches)

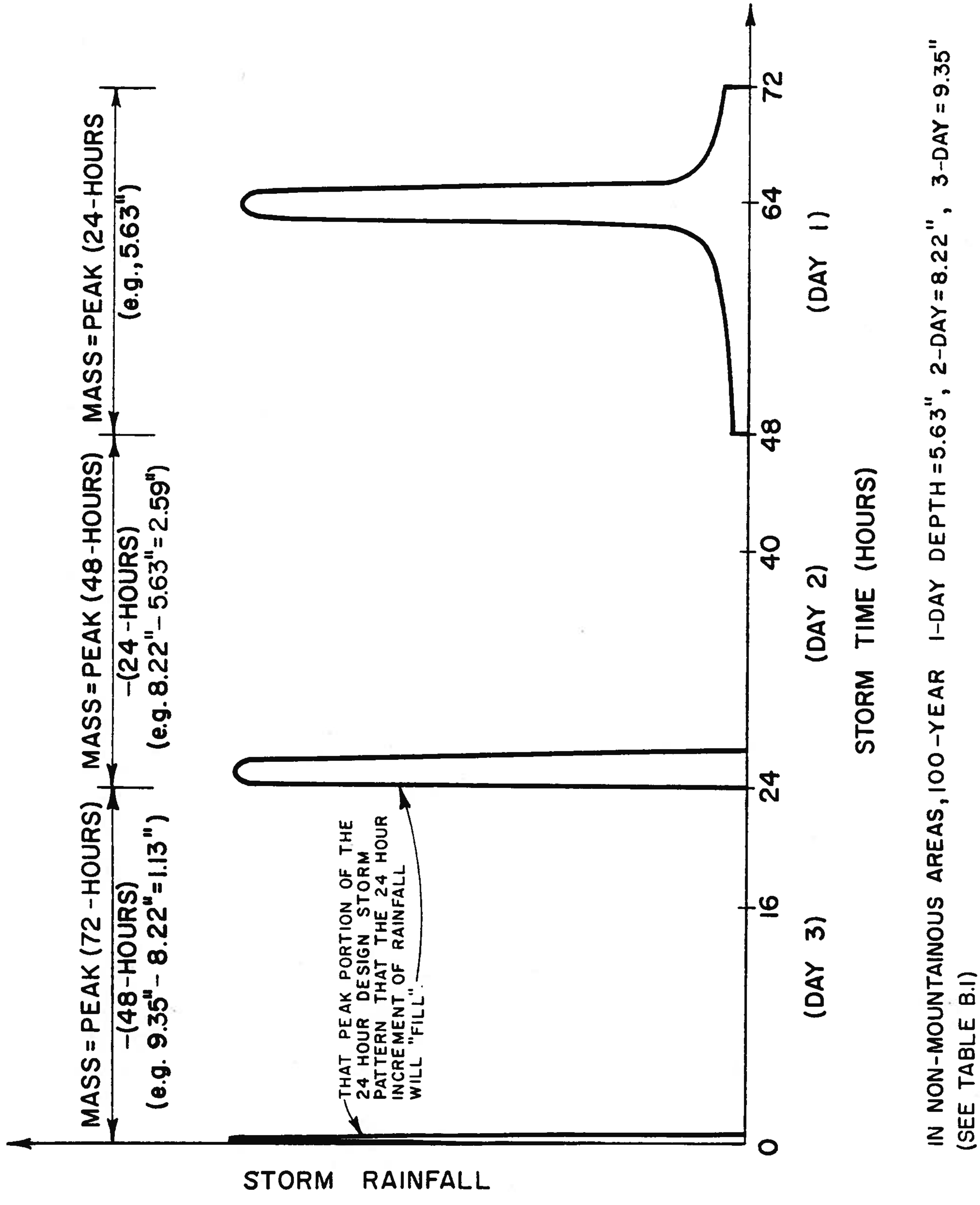
day		5-min.	30-min.	1-hr.	3-hr.	6-hr.	24-hr.
3	11.27	0.78	1.34	1.94	3.96	6.19	11.27
2	16.52 - 11.27	0.78	1.34	1.94	3.96	5.25	5.25
1	18.98 - 16.52	0.78	1.34	1.94	2.46	2.46	2.46

Knowing the precipitation depths for the three day design storm, the runoff hydrographs for the three days are calculated as shown in Problem 12.

When a complex watershed model (e.g., a "link-node" schematic involving subareas linked by channel routing) is to be used, a single area runoff hydrograph model is also to be developed for comparison purposes. Should detention basins be planned, the complex model without the basins (i.e., "free-draining") is to be compared to a single subarea model.

Should the peak Q from the free-draining complex model be greater than the single area runoff hydrograph model, then the complex model peak Q is to be used as a design Q. The use of a higher Q for design purposes aids in accommodating for the increased uncertainty in the complex model.

Should the peak Q from the free-draining complex model be less than the single area runoff hydrograph model, then the design storm for the complex model is to be modified by uniformly increasing the rainfall used in the design storm until the peak Q values match between the two models.



ORANGE COUNTY
HYDROLOGY MANUAL

FLOW-BY BASIN CRITICAL STORM PATTERN (3-DAY EXAMPLE)

FIGURE 28. FLOW-BY BASIN EXTENDED DESIGN STORM

PROBLEM 17 (Part 1)

Peak Flow Rate Curves

Using the Peak Flowrate curves of Section L from the Orange County Hydrology Manual, determine the 100-year peak flow rate for a 3 square mile catchment with a 1.5 hour time of concentration, a F_m of 0.4 and $\bar{Y}$ of 0.5.

From Figure 29 the peak flow rate is 0.8 cfs/acre for a 1 square mile watershed. From Figure 30 the peak flow rate is 0.725 cfs/acre for a 5 square mile watershed. Using straight line interpolation the peak flow rate for a 3 square mile watershed is:

0.075

x

$$\frac{0.8 \text{ cfs/Ac}}{1 \text{ sq. mi.}} \qquad \frac{? \text{ cfs/Ac}}{3 \text{ sq. mi.}} \qquad \frac{0.725 \text{ cfs/Ac}}{5 \text{ sq. mi.}}$$

2

4

$$\frac{x}{0.075} = \frac{2}{4} \qquad x = 0.0375$$

$$? = 0.8 \text{ cfs/Ac} - 0.0375 \text{ cfs/Ac} = 0.7625 \text{ cfs/Ac}$$

The peak discharge rate for the three square mile watershed is:

$$0.7625 \text{ cfs/Ac} \times 3 \text{ sq. mi.} \times \frac{640 \text{ Ac}}{1 \text{ sq.mi.}} = 1{,}464 \text{ cfs.}$$

PROBLEM 17 (Part 2)

Again using the Peak Flowrate curve of Section L from the Orange County Hydrology Manual, the 100-year peak flow for a 3 square mile catchment with a 1.5 hour time of concentration, a F_m of 0.25 and a $\bar{Y}$ of 0.30 is determined.

From Figure 29 the peak flow rate of 0.96 cfs/acre for the study watershed (assuming equal weighting of F_m and $\bar{Y}$) is obtained. From Figure 30 the peak flow rate is found to be 0.89 cfs/acre for a 5 square mile watershed. Using straight line interpolation the peak flow rate for a 3 square mile watershed is:

0.07

x

$$\frac{0.96\text{ cfs/AC}}{1\text{ sq.mi.}} \qquad \frac{?\text{ cfs/AC}}{3\text{ sq.mi.}} \qquad \frac{0.89\text{ cfs/Ac}}{5\text{ sq.mi.}}$$

2

4

$$\frac{x}{0.07} = \frac{2}{4} \qquad x = 0.035$$

? = 0.96 cfs/Ac - 0.035 cfs/Ac = 0.925 cfs/Ac

The peak discharge rate for the three square mile watershed is:

0.925 cfs/acre x 1,920 acres = 1,776 cfs.

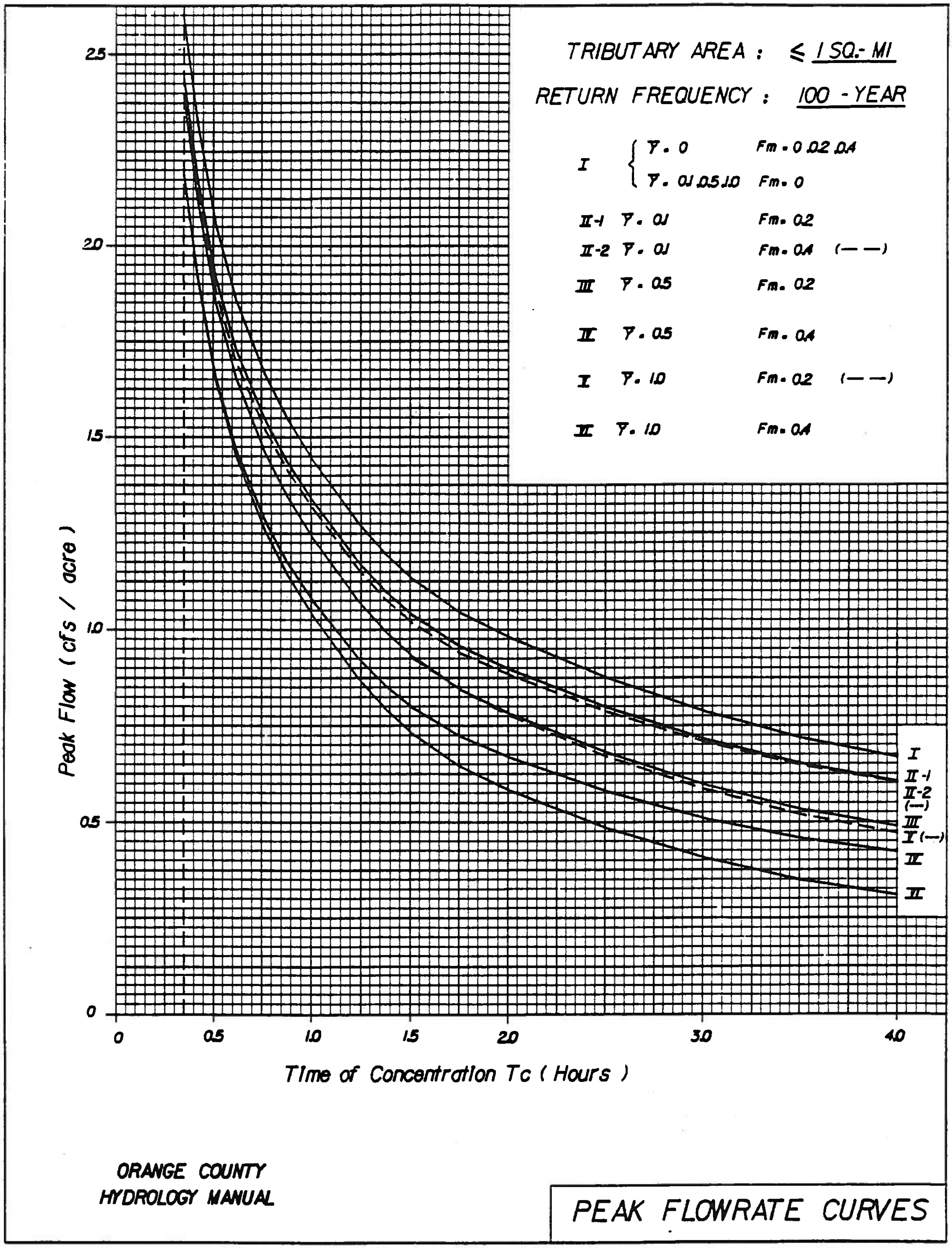


FIGURE 29. ONE SQUARE MILE TRIBUTARY AREA PEAK FLOWRATE CURVES

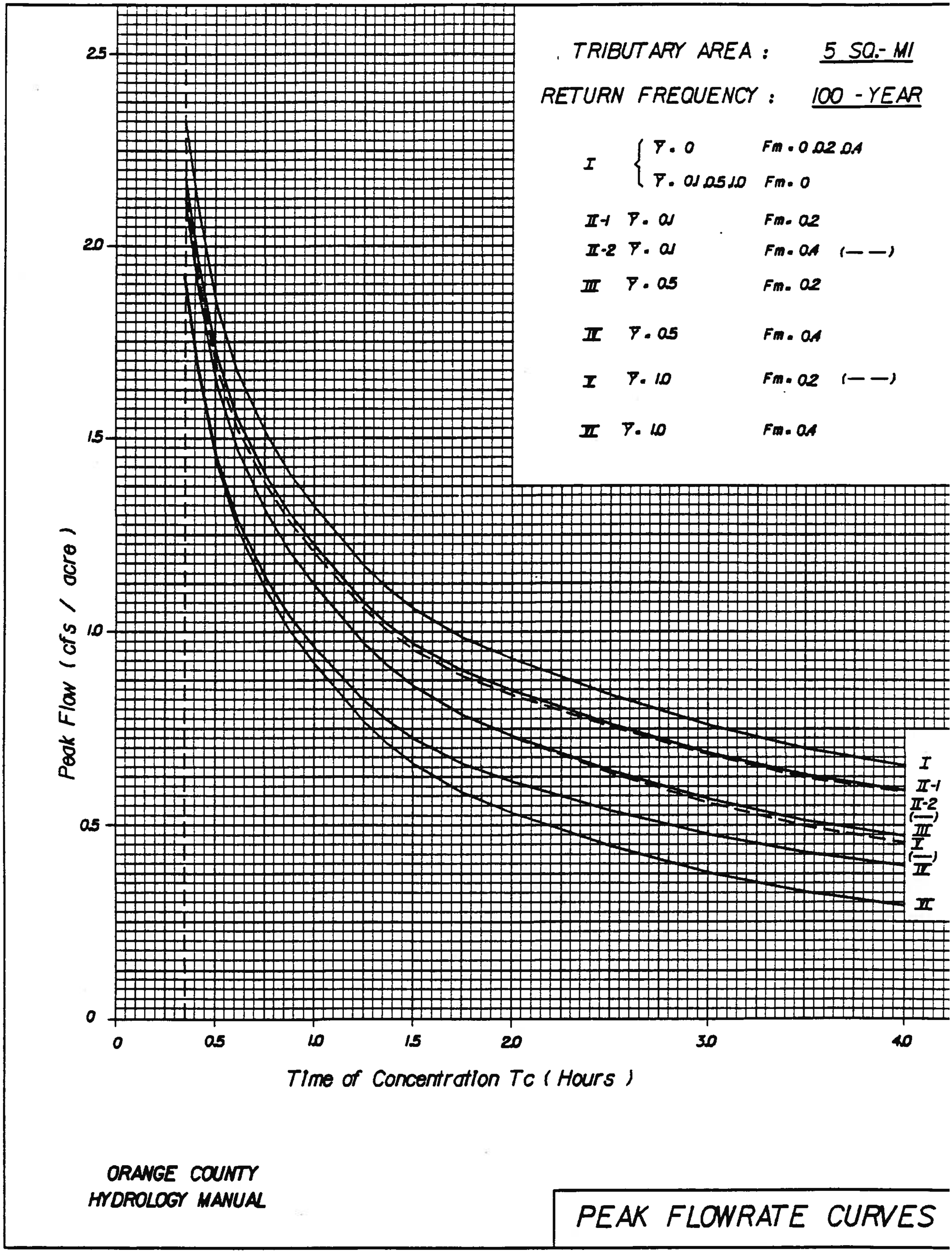


FIGURE 30. FIVE SQUARE MILE TRIBUTARY AREA PEAK FLOWRATE CURVES

PROBLEM 18

Watershed Response to Urbanization

For environmentally or aestheticly sensitive watersheds or watersheds with undersized downstream flood control facilities a thorough hydrologic model may be required to estimate the changes in peak flow rates, runoff volumes, channel aggregation and/or degradation, and water quality due to urbanization. A complete model of a catchment would reflect existing conditions and ultimate conditions and may also include proposed mitigative measures.

The typical effects of urbanization on a watershed's hydrologic regimen has long been recognized. Urbanization of a watershed changes its response to precipitation. The typical effects are; reduced infiltration, concentration of runoff, and decreased travel time which result in significantly higher peak rates of runoff and greater runoff volumes. However, urbanization does not always result in increased peak rates of runoff and greater runoff volumes. For example the runoff volume can be greater for a watershed with soil type D (high runoff potential) under natural conditions than when the same watershed is developed for single family land use. Because the impervious surfaces within the watershed will increase with urbanization, it appears contradictory that the runoff volume will decrease. However, a comparison of the loss rates (F_m and $\bar{Y}$) of the runoff hydrographs indicate that while the impervious area does increase with urbanization, the vegetal cover associated with an urban watershed compensates for the decreased pervious area (i.e.: the initial abstraction increases with urbanization). This is particularly true for watersheds with low precipitation depths where the initial abstraction can absorb a large percent of the total rainfall.

The typical approach used to evaluate hydrologic changes in a watershed is to determine the peak flow rates for 2-, 5-, 10-, 25-, 50-, and 100-year storm events (flood flow frequency curve) for; existing conditions, developed conditions without mitigative measures, and developed conditions with mitigative measures.

Runoff volumes for the various return periods are also typically required, consequently a unit hydrograph procedure is necessary.

Following is an itemization of the major components needed to fully evaluate the hydrologic changes anticipated of a watershed. This problem encompasses all of the preceding concepts, including: rational method, effective area, unit hydrograph channel routing and basin routing. Excerpts from the "Tijeras Canyon Mitigative Measure Hydrologic/Sedimentation Analysis" report prepared by Williamson and Schmid in October, 1986 are used as examples in the problem. The complete Tijeras Canyon report is on file and available for review at OCEMA. A pre-study meeting with County staff should be held before starting a detailed study.

1. An overall evaluation of the study catchment is first made. The cursory evaluation should be used to define, in general terms, the opportunities and constraints of the catchment and develop possible mitigative measures. This first step is critical in setting up the hydrologic models (i.e.: ensuring critical concentration points coincide for the various hydrologic models).

2. Generally the unit hydrograph lag is calculated from the watershed time of concentration T_c, therefore the second step is to complete rational method studies (and hence T_c estimates) for 2-, 5-, 10-, 25-, 50-, and 100-year return periods using first existing conditions and then developed conditions without mitigative measures. Shown in figures 31 and 32 are typical hydrology maps for existing and developed conditions respectively. Corresponding T_c summaries for varying return periods are shown in table 22 for existing and developed conditions.

3. The next step is to determine the loss rates (F_m and $\bar{Y}$) for existing and developed conditions as shown in table 23. It is noted that a format such as shown in figure 33 should be used to organize the loss rate calculations.

4. The fourth step is to determine the S-graph fractions to represent the watershed for existing and developed conditions as shown in table 24.

5. After determining the rainfall (table 25) the fifth step is to calculate the watershed runoff hydrographs for existing and developed conditions for the various return periods. An exhibit (such as figure 34) depicting the significant concentration points is often helpful in visualizing the watershed. It is often convenient to prepare watershed schematics for both existing and developed conditions as shown in figures 35 and 36. The watershed schematics are intended to depict all of the salient features of routing the runoff hydrographs through the catchment.

6. The sixth step is to compare the developed condition flood flow frequency curve with the existing condition flood flow frequency curve at the critical concentral points. This is normally done by plotting the peak discharge rates on log-probability paper (figure 37). As can be seen from figure 37, the developed condition flood flow frequency curve is considerably higher. Consequently a variety of mitigative measures were investigated for Tijeras Canyon. Figure 38 is a schematic of one option studied to lower the developed condition flood flow frequency curve. Figures 39 through 42 are the resulting flood flow frequency curves at critical concentration points.

TABLE 22.

EXISTING AND DEVELOPED CONDITIONS TIMES OF CONCENTRATION

Existing (Historic Condition) Times of Concentration (T_c) for Tributary Channels

RATIONAL METHOD NODE	HYDRO-GRAPH NODE	100-YR	50-YR*	RETURN PERIOD 25-YR	10-YR	5-YR*	2-YR
109	103	48	49	51	53	56	61
209	104	68	69	71	72	77	85
311	105	65	67	69	70	75	83
410	106	35	34	33	39	41	45

* interpolated values

Ultimate Condition Times of Concentration (T_c) for Tributary Channels

RATIONAL METHOD NODE	HYDRO-GRAPH NODE	100-YR	25-YR	10-YR*	2-YR
179	4	21.9	22.3	22.5	23.5
212	5	18.7	19.2	19.7	19.8
226	6	14.8	15.0	15.1	15.6

*time of concentration used for runoff hydrographs.

TABLE 23.

EXISTING AND DEVELOPED CONDITIONS LOSS RATES

LOSS RATES FOR EXISTING (HISTORIC) CONDITIONS
FOR TIJERAS CANYON

1. $F_m = F_p\, a_p = F_p \cdot 1 = F_p = 0.2$ for soil group D, which covers the entire area.

2.

T-YR	R_{24}	AMC	CN	S	I_a	$\bar{Y}$
100	5.63	III	94	0.64	0.13	0.12
50	5.07	II	80	2.5	0.50	0.42
25	4.49	II	80	2.5	0.50	0.45
10	3.68	II	80	2.5	0.50	0.52
5	3.03	I	63	5.9	1.17	0.85
2	2.05	I	63	5.9	1.17	0.95

LOSS RATES FOR ULTIMATE CONDITIONS FOR TIJERAS CANYON
(ALL SOIL GROUP "G")

NODE 2

1. $F_m = 0.63(1.0 + \underbrace{0.37(0.6)}_{\frac{1}{4}\,A_c \text{ lots}}\ \underbrace{(0.20)}_{A_p\ F_p} = 0.85(0.20) = 0.17$

2. $\bar{Y}$ (0.63 undeveloped, 0.37 SF)

	T-YR	100	50	25	10	5	2
	R_{24}	5.63	5.07	4.49	3.68	3.03	2.05
	AMC	III	II	II	II	I	I
CN	undev.	94	80	80	80	63	63
CN	S.F.	91/98	75/98	75/98	75/98	57/98	57/98
S	undev.	0.64	2.5	2.5	5.9	7.54/.20	7.54/.20
S	S.F.	0.99/.20	3.33/.20	3.33/.20	7.54/.20	7.54/.20	7.54/.20
$\bar{Y}$	undev.	0.12	0.42	0.45	0.52	0.85	0.95
$\bar{Y}$	S.F.	0.18/.04	0.51/.05	0.54/.05	0.61/.06	0.92/.08	0.98/.11
$\bar{Y}$		.12	0.39	0.41	0.47	0.75	0.83

TABLE 24.

EXISTING AND DEVELOPED CONDITIONS S-GRAPH FRACTIONS

Existing (Historic conditions) S-graph percentages

Hydrograph Node	Area (Acres)	Decimal Percentage Valley	Decimal Percentage Foothill
103	812	0.46	0.54
104	520	0.51	0.49
105	974	0.55	0.45
106	416	0	1.00

Ultimate conditions S-graph percentages

Hydrograph Node	Area (Acres)	Decimal Percentage Urban	Decimal Percentage Foothill
2	175	0	1.00
3	170	1.00	0
4	910	0.90	0.10
5	810	0.60	0.40
6	370	0.45	0.55
7	420	0.33	0.67

TABLE 25.

RAINFALL (INCHES) FOR EXISTING AND DEVELOPED CONDITIONS

	100-YR	50-YR	25-YR	10-YR	5-YR	2-YR
5 Min	.52	.45	.40	.34	.26	.19
30 Min.	1.09	.98	.87	.72	.59	.40
1 Hr.	1.45	1.30	1.15	.95	.78	.53
3 Hr.	2.43	2.19	1.94	1.59	1.31	.89
6 Hr.	3.36	3.02	2.71	2.20	1.81	1.22
24 Hr.	5.63	5.07	4.49	3.68	3.03	2.05

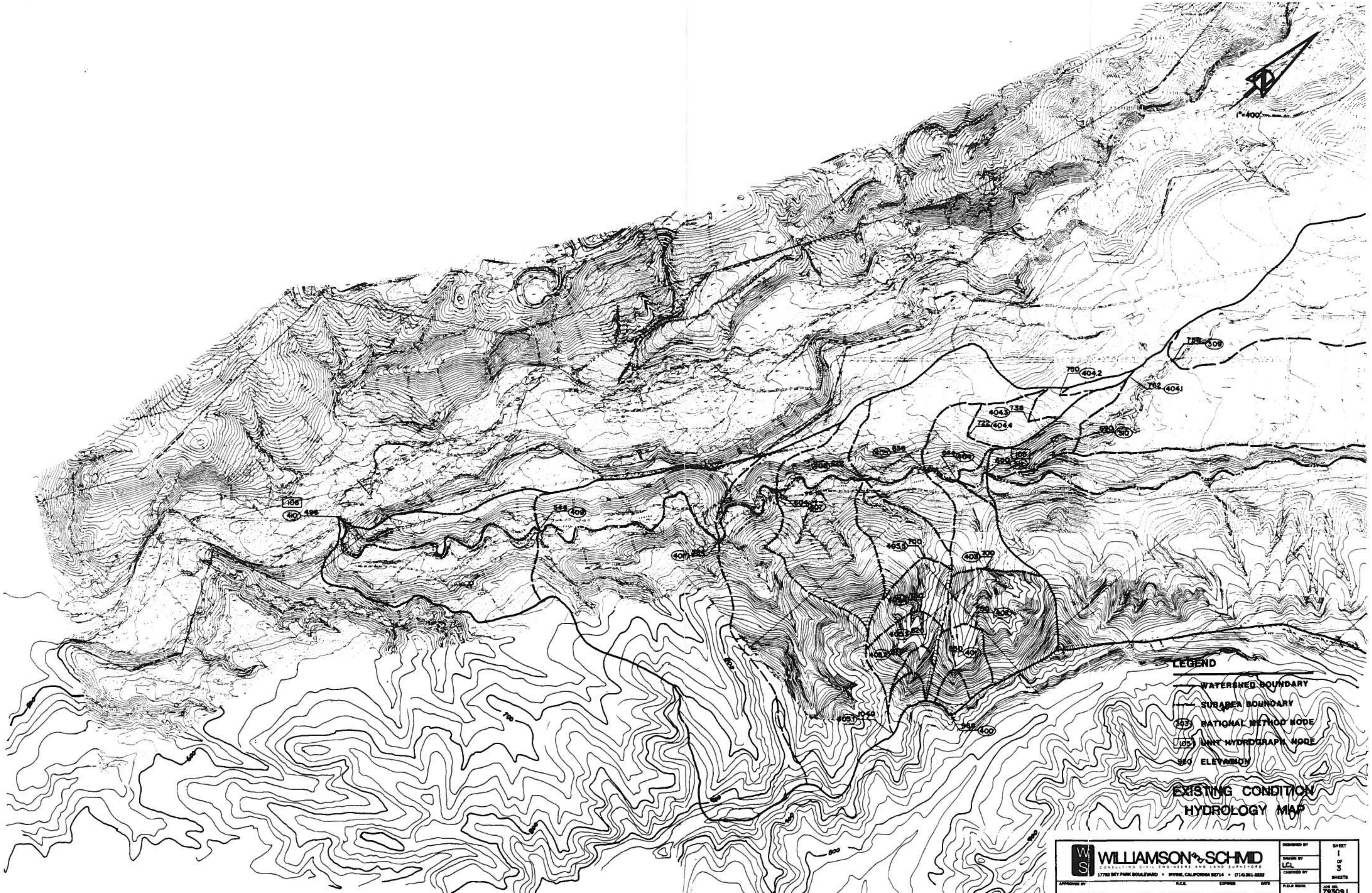


FIGURE 31A. EXISTING CONDITION HYDROLOGY MAP

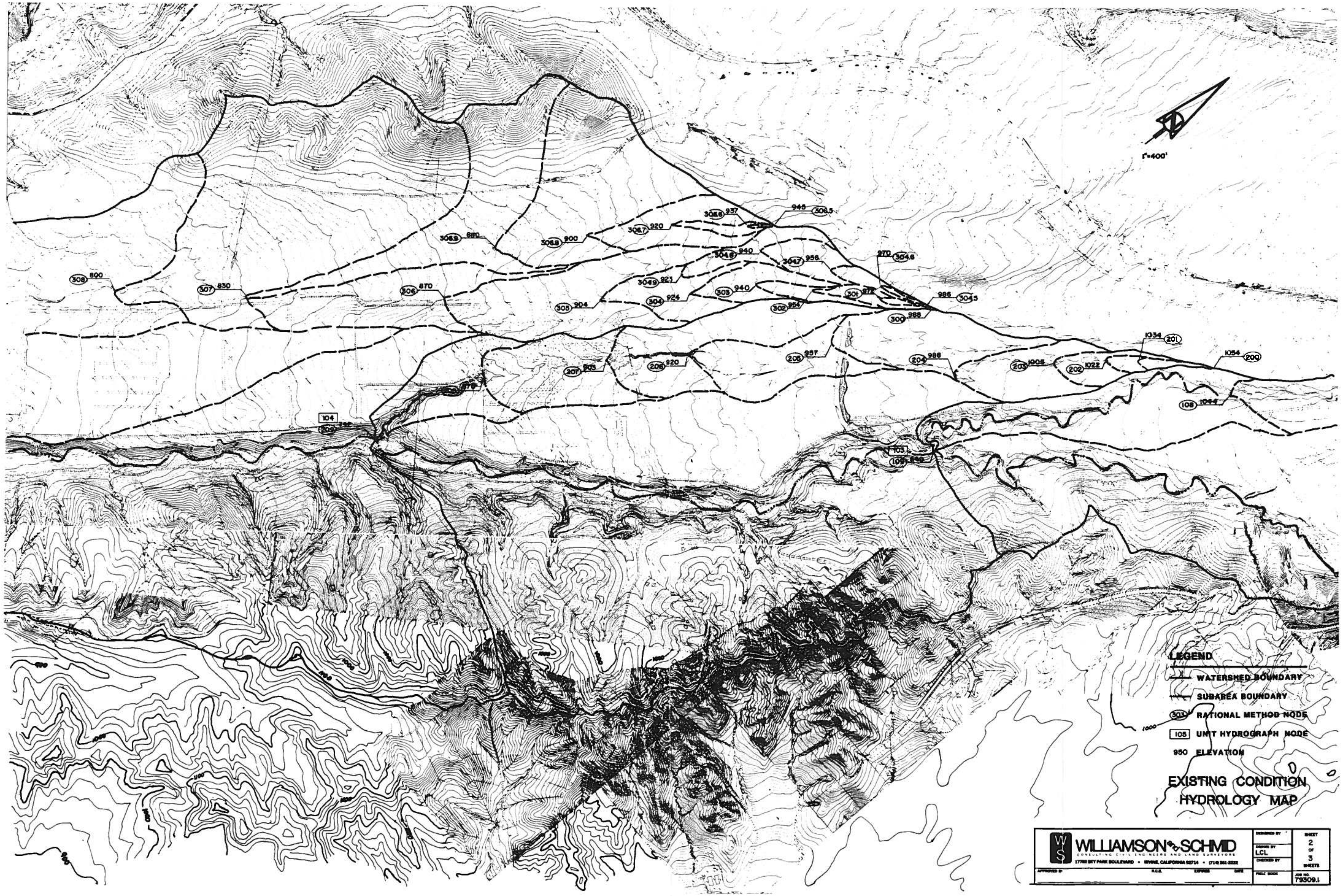


FIGURE 31B. EXISTING CONDITION HYDROLOGY MAP

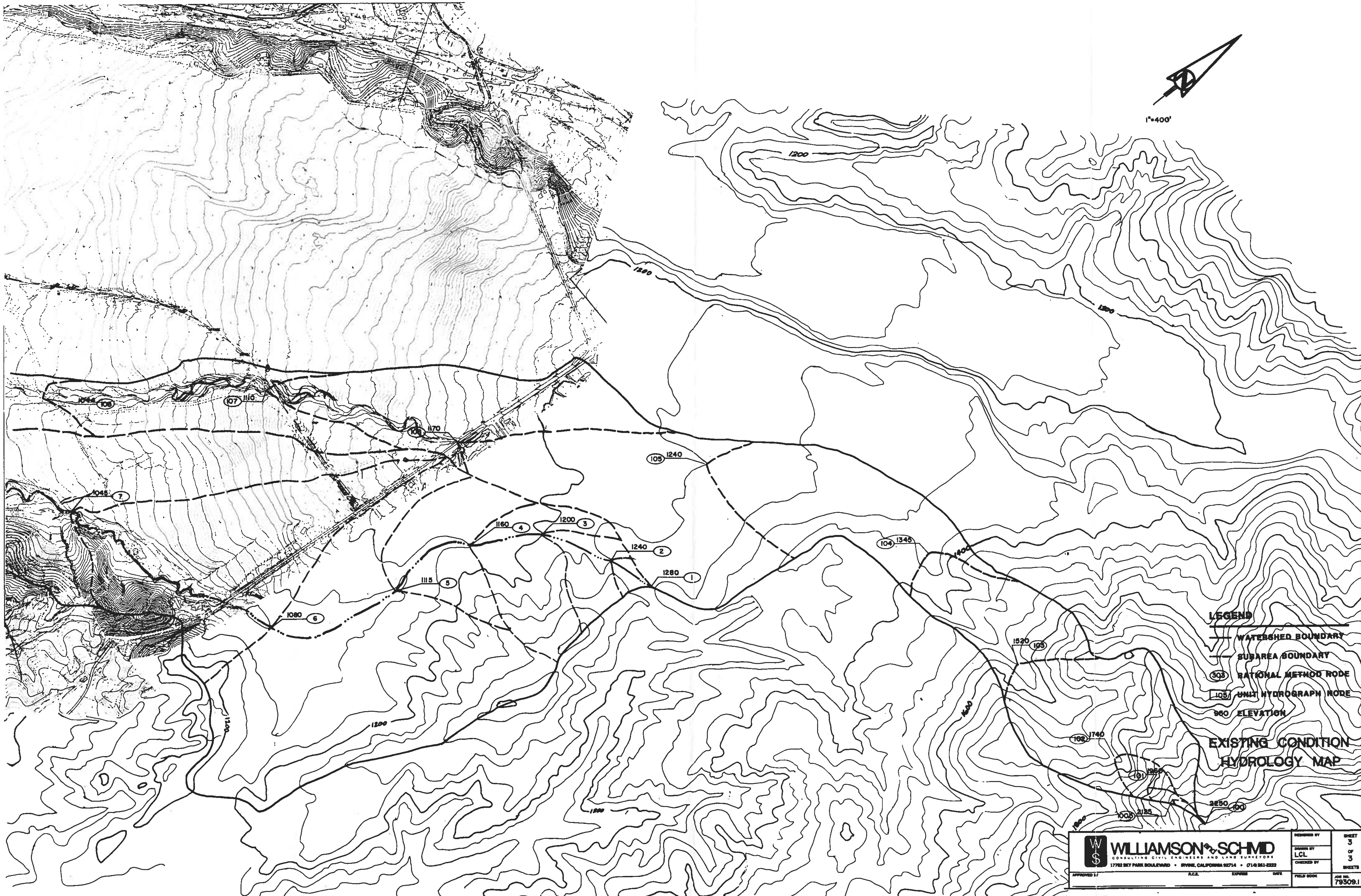


FIGURE 31C. EXISTING CONDITION HYDROLOGY MAP

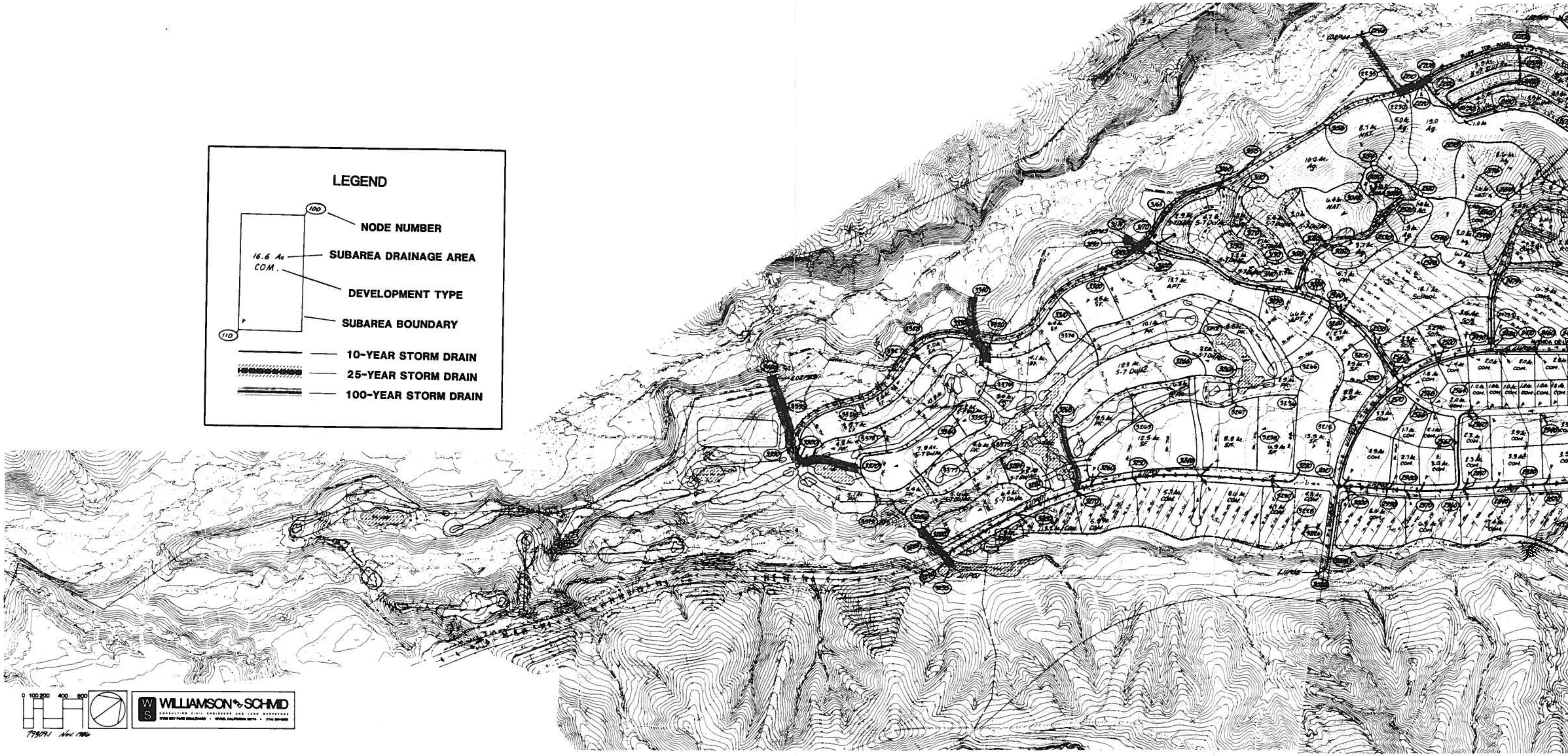
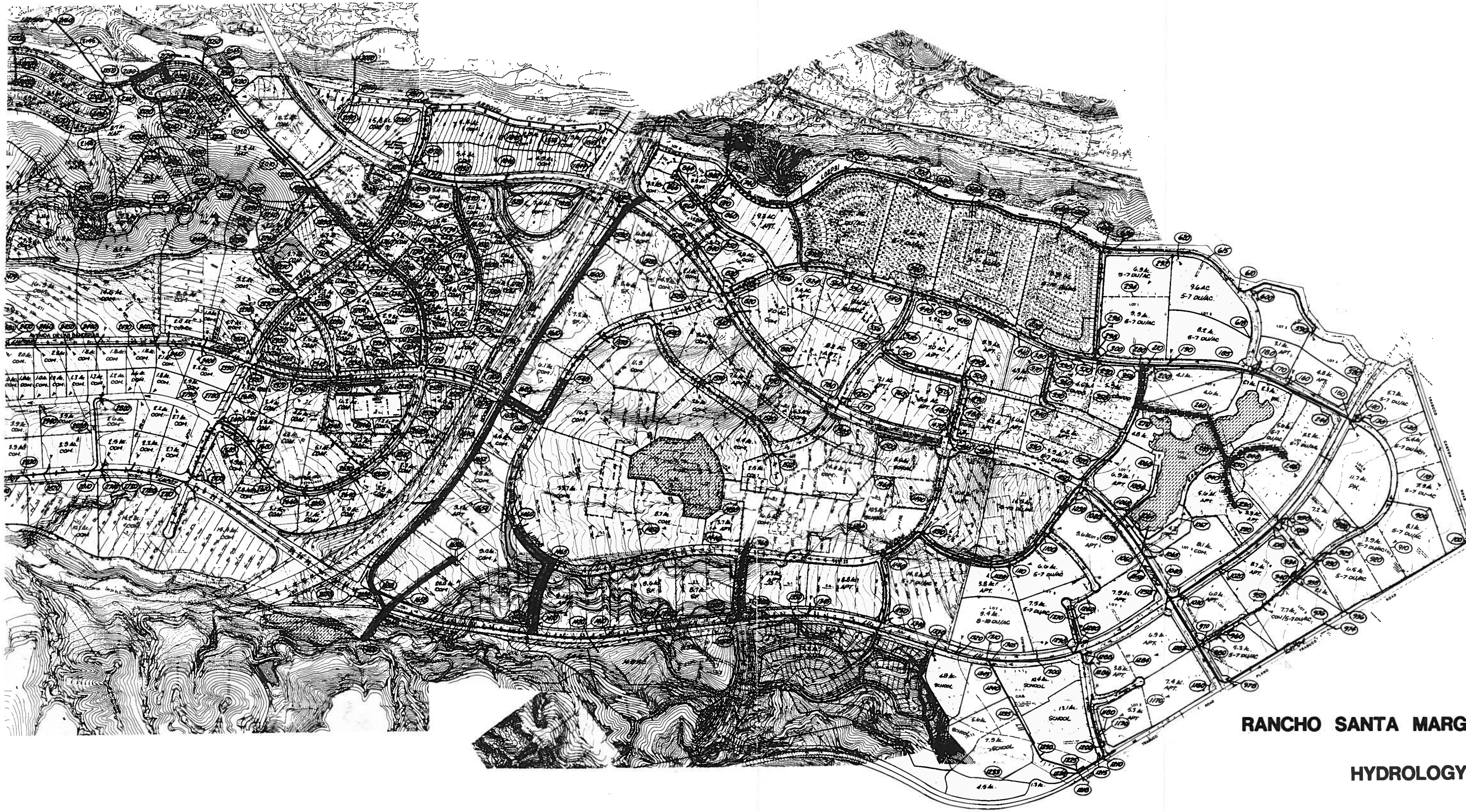


FIGURE 32A. DEVELOPED CONDITION HYDROLOGY MAP



RANCHO SANTA MARGARITA

HYDROLOGY MAP

FIGURE 32B. DEVELOPED CONDITION HYDROLOGY MAP

ENVIRONMENTAL MANAGEMENT AGENCY

BY ______ DATE ______ SUBJECT DRAINAGE AREA SOIL GROUP COVER COMPLEX MATRIX SHEET NO. ______ OF ______

CHKD. BY ______ DATE ______ REPORT NO. ______

CONCENTRATION POINT:

LAG:

LAND USE		TOTAL	IMPERVIOUS COVER	SOIL GROUP A	SOIL GROUP B	SOIL GROUP C	SOIL GROUP D
AGRICULTURAL							
OPEN SPACE							
SCHOOL							
SINGLE FAMILY RESIDENTIAL	2.5 ACRE LOT						
SINGLE FAMILY RESIDENTIAL	1 ACRE LOT						
SINGLE FAMILY RESIDENTIAL	2 DU/ACRE						
SINGLE FAMILY RESIDENTIAL	3-4 DU/ACRE						
SINGLE FAMILY RESIDENTIAL	5-7 DU/ACRE						
SINGLE FAMILY RESIDENTIAL	8-10 DU/ACRE						
SINGLE FAMILY RESIDENTIAL	10+DU/ACRE						
MULTIPLE FAMILY RES.	CONDOMINIUM						
MULTIPLE FAMILY RES.	APARTMENT						
MOBILE HOME							
COMMERCIAL							
TOTAL (ac)							

a_p =

F_p =

F_m =

COVER TYPE:

CN_{II} =

CN_{III} =

S =

I_a =

$\bar{Y}$ =

33. OCEMA LOSS RATE CALCULATION FORM

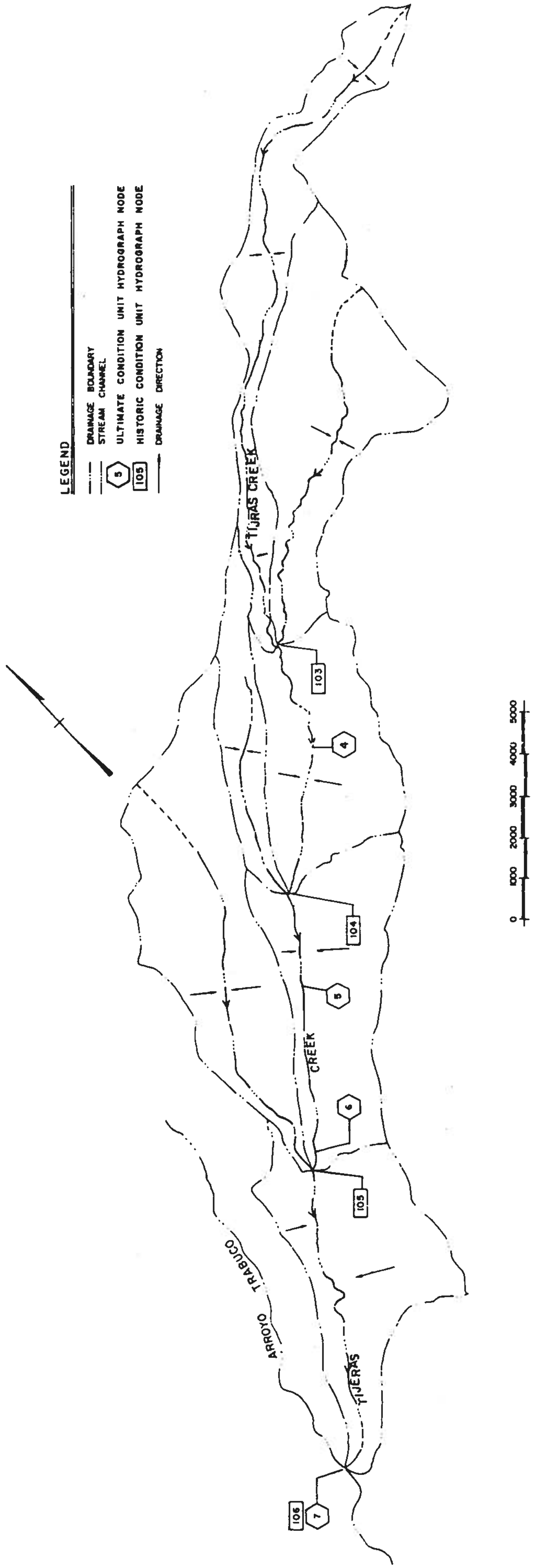


FIGURE 34. NODAL LOCATIONS

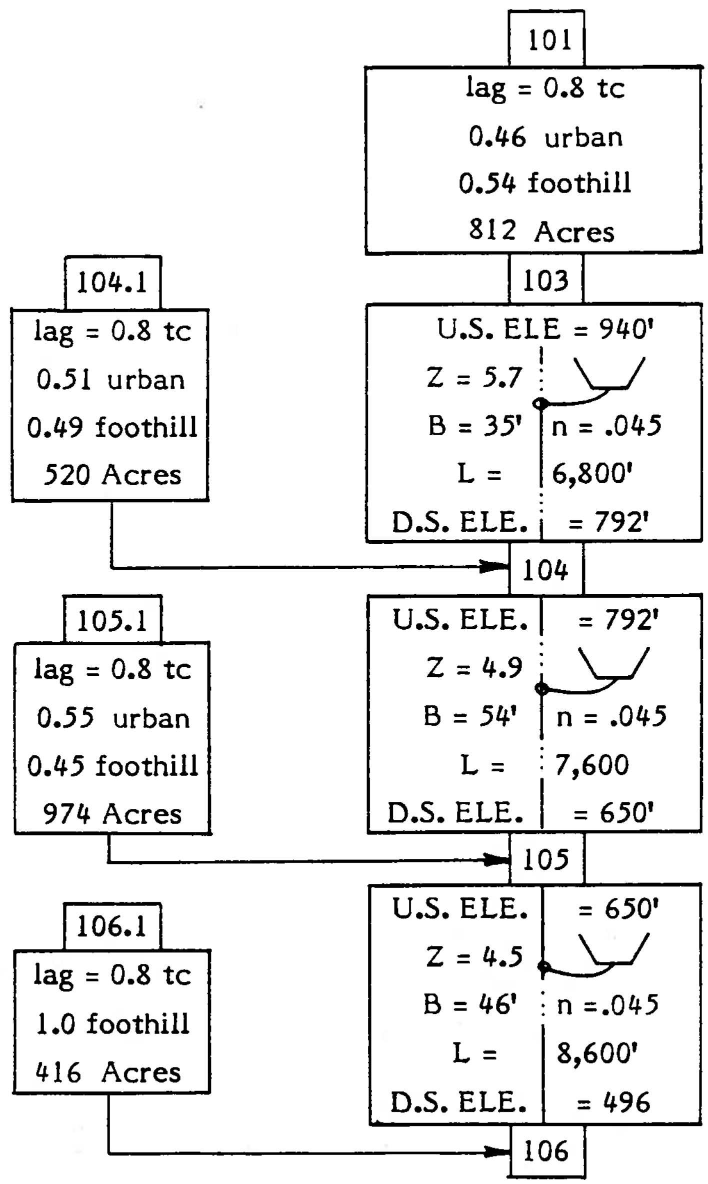


FIGURE 35. EXISTING CONDITION SCHEMATIC

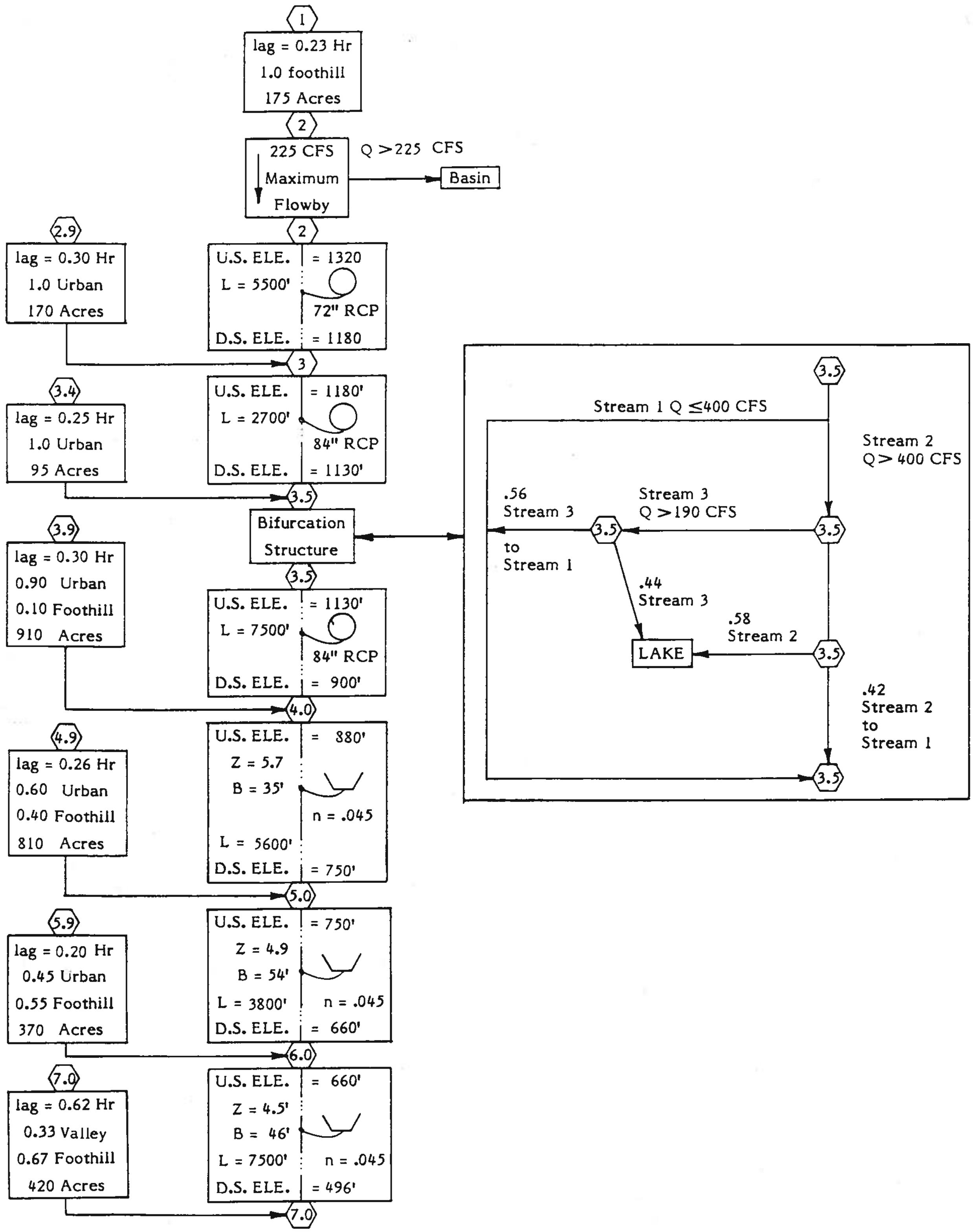


FIGURE 36. DEVELOPED CONDITION SCHEMATIC

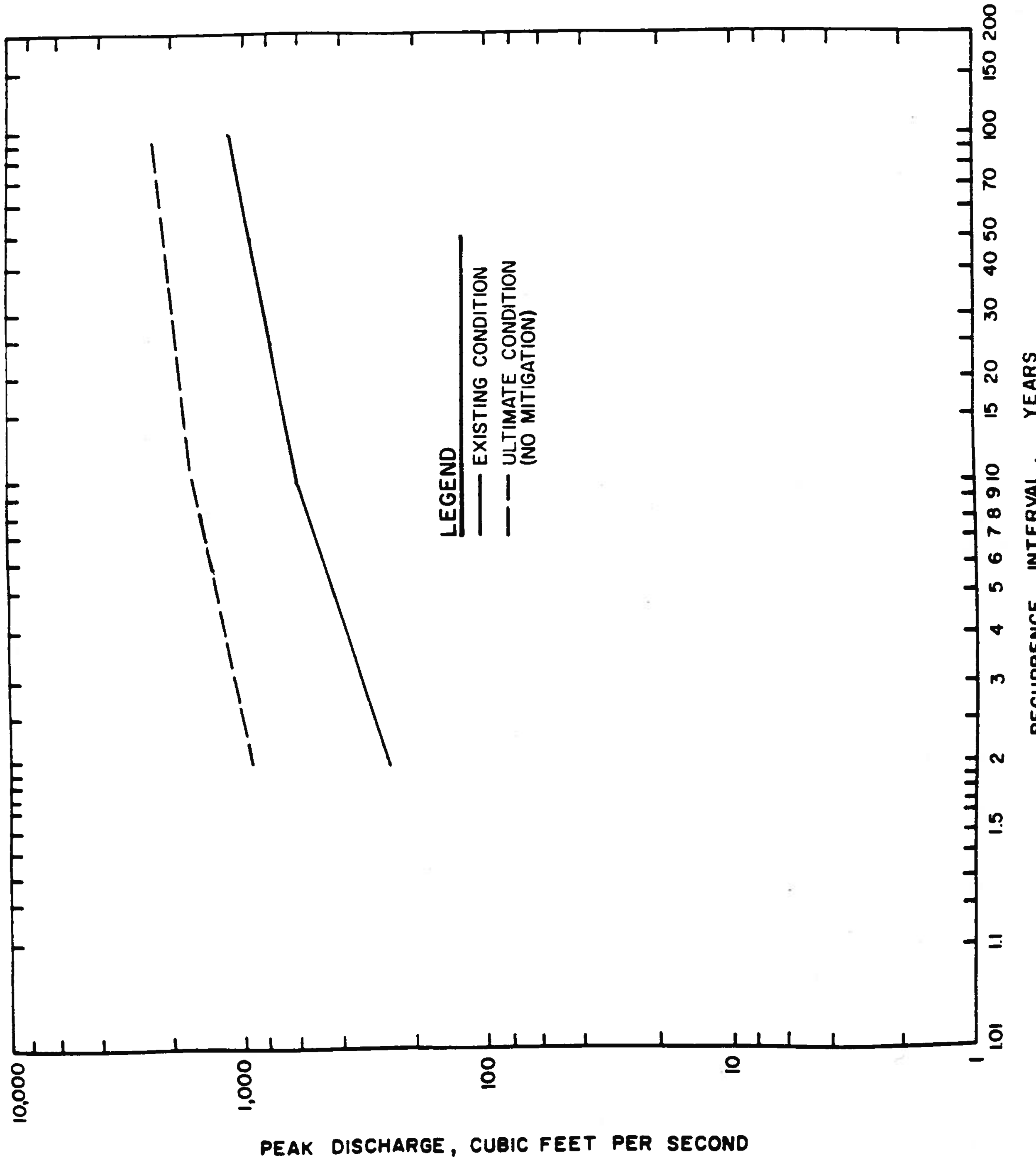


FIGURE 37. FLOOD FREQUENCY CURVE

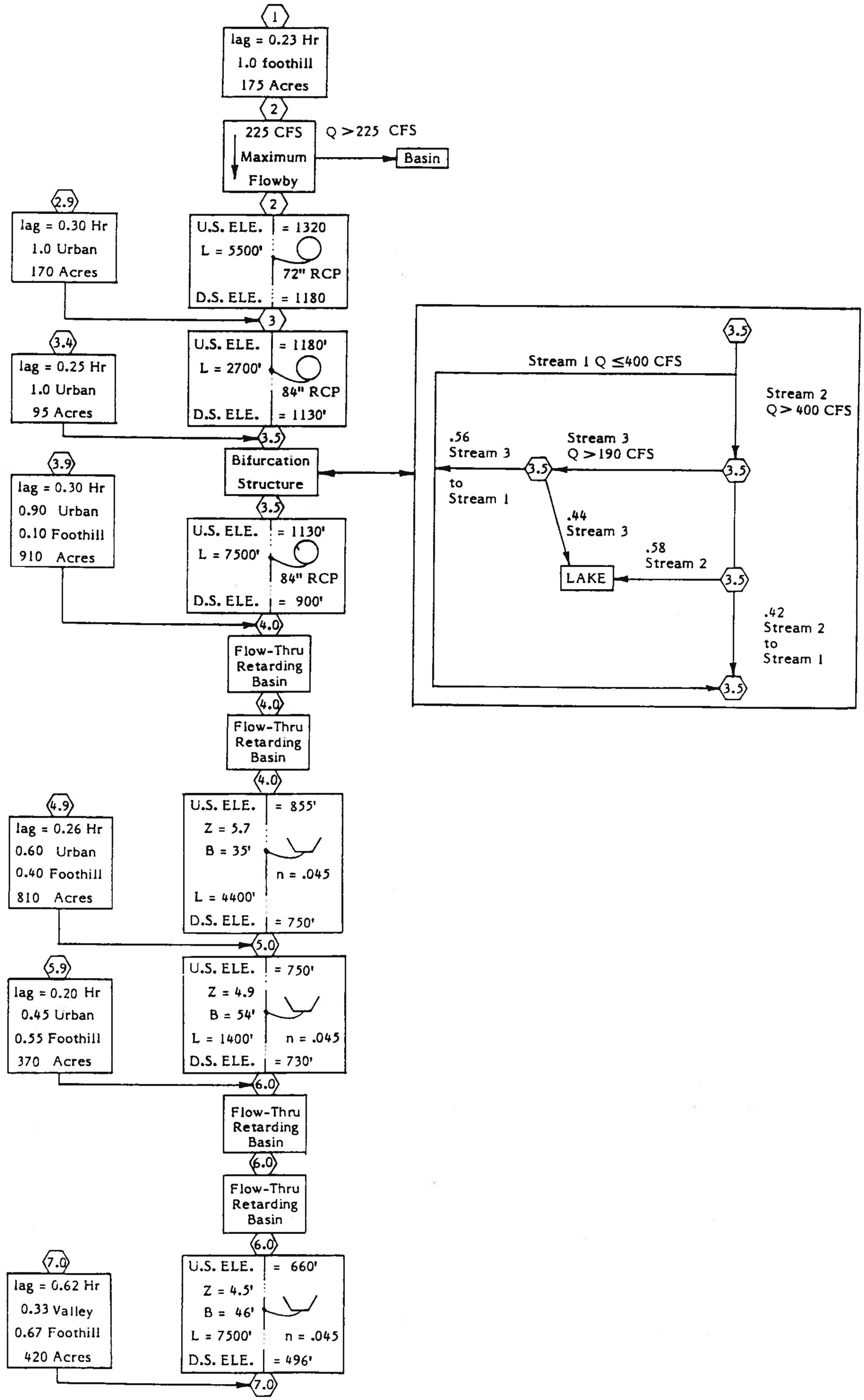


FIGURE 38. MITIGATED CONDITION SCEMATIC

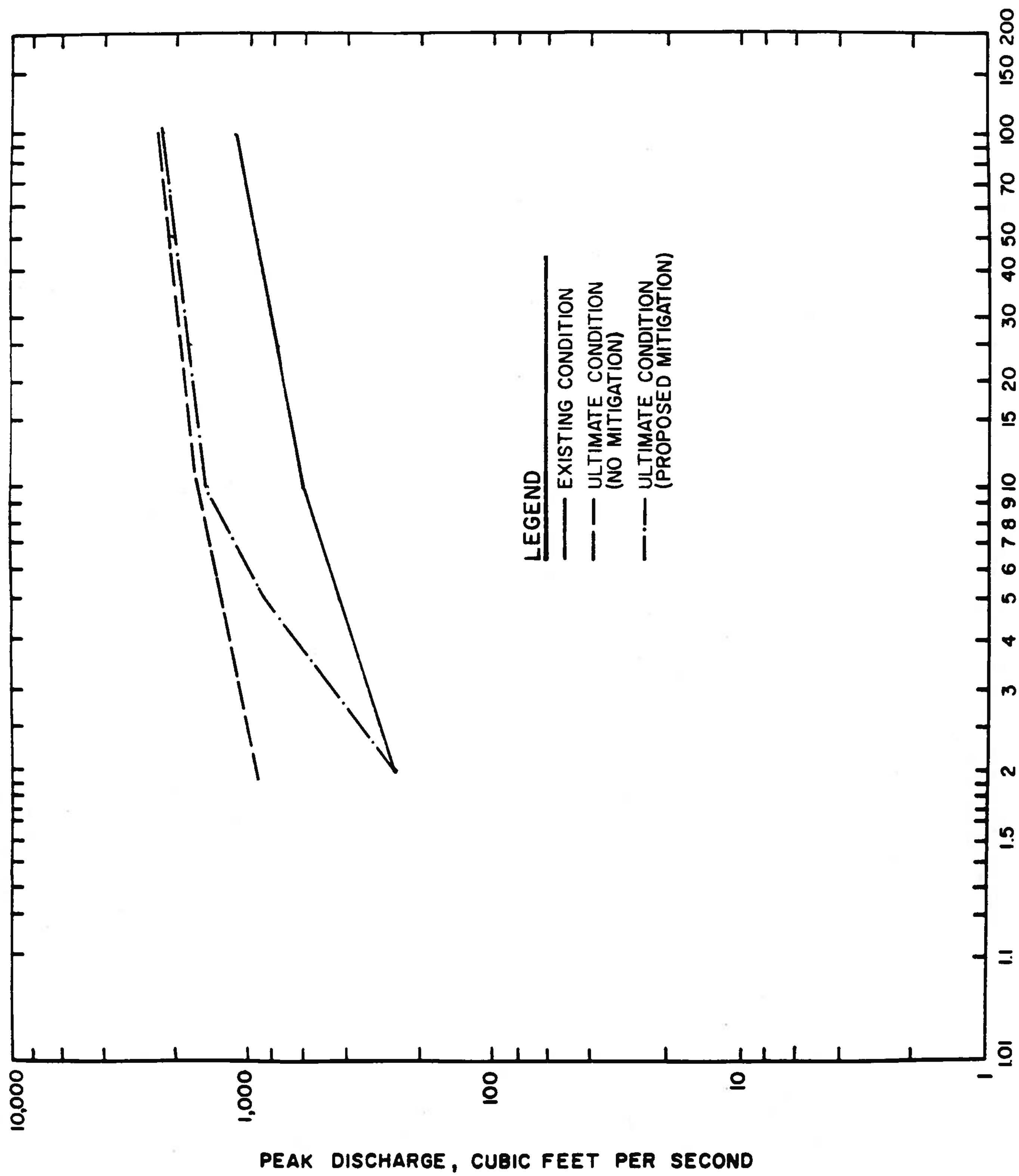


FIGURE 39. MITIGATED CONDITION FLOOD FREQUENCY CURVE

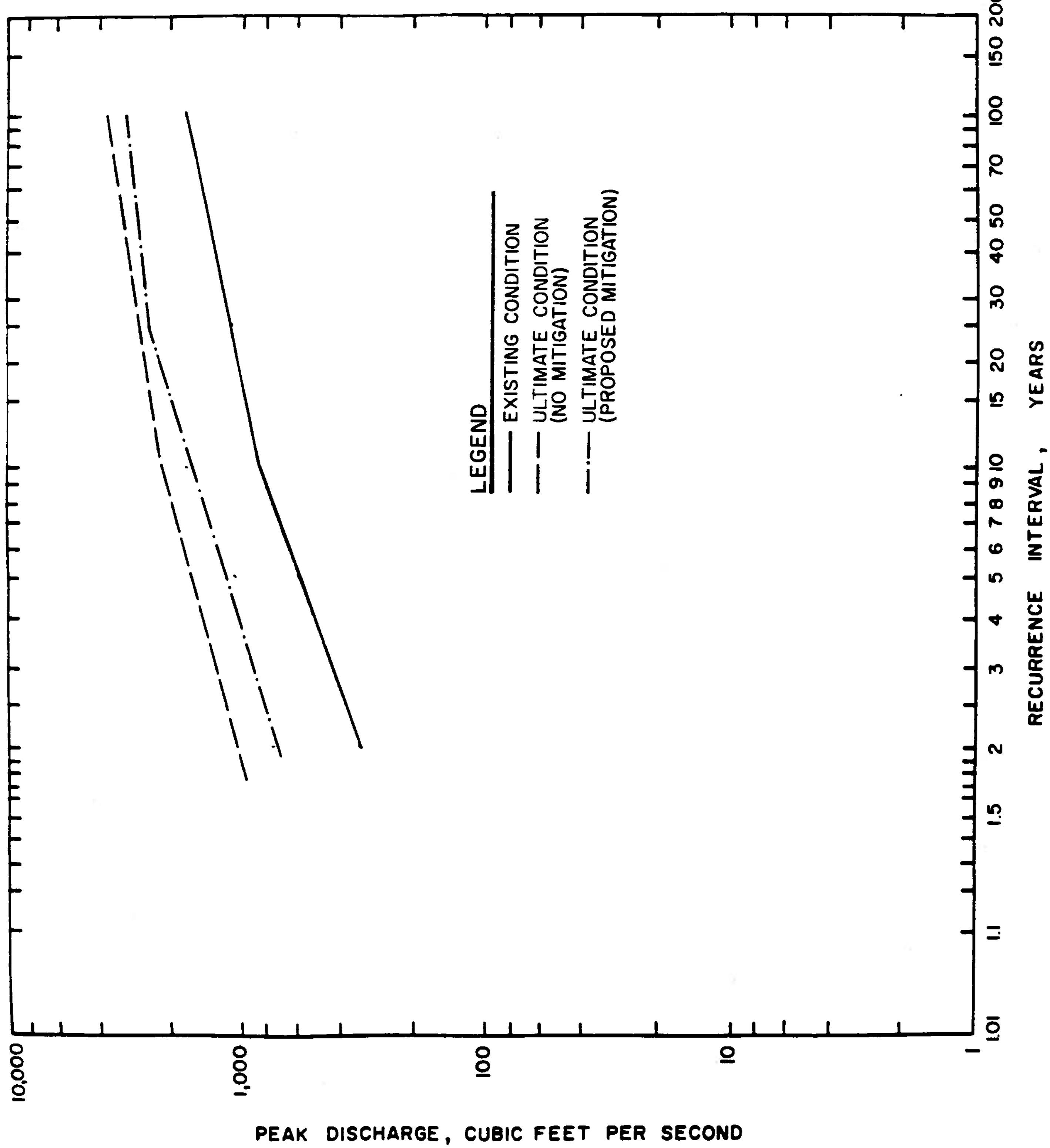


FIGURE 40. MITIGATED CONDITION FLOOD FREQUENCY CURVE

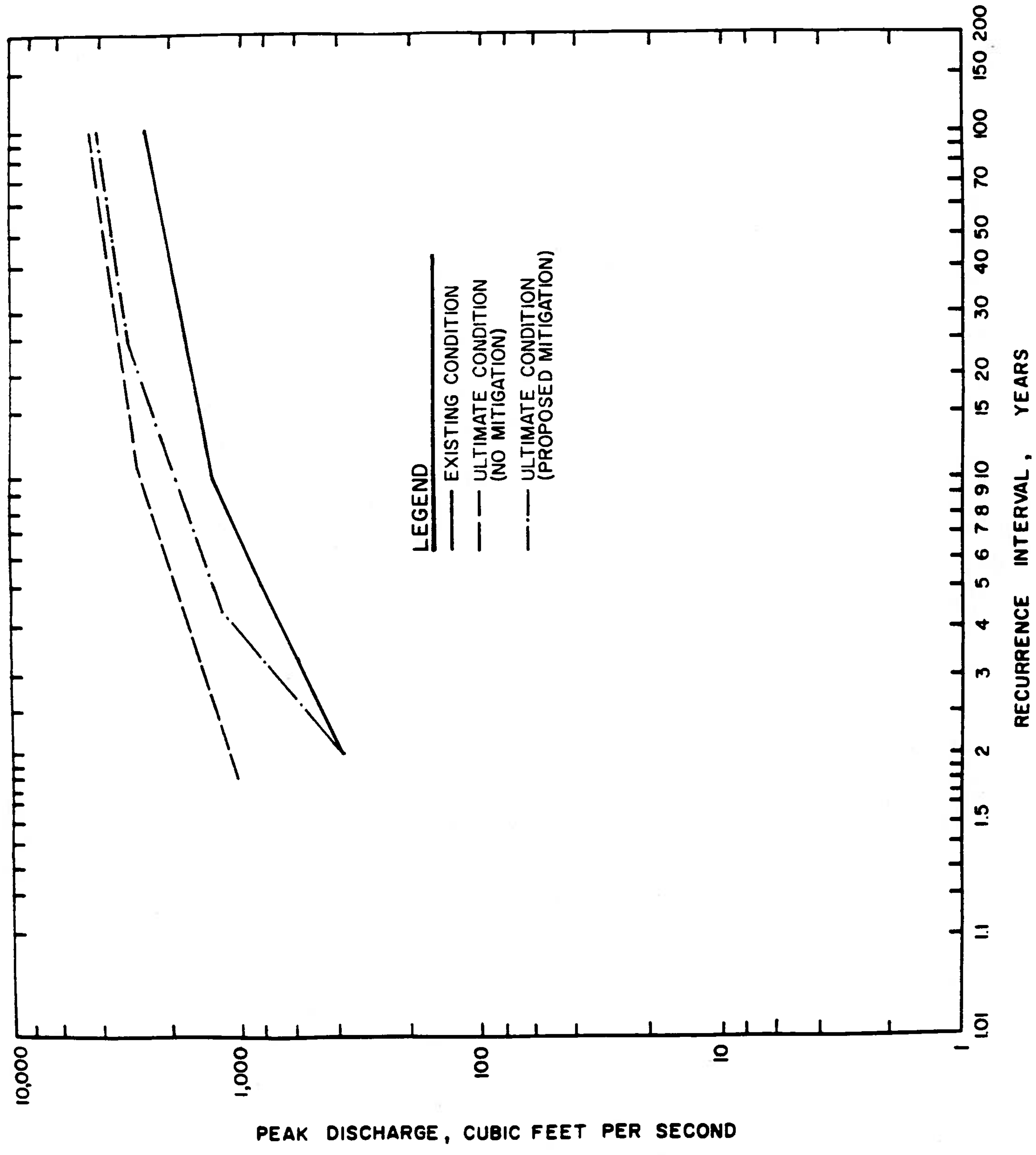


FIGURE 41. MITIGATED CONDITION FLOOD FREQUENCY CURVE

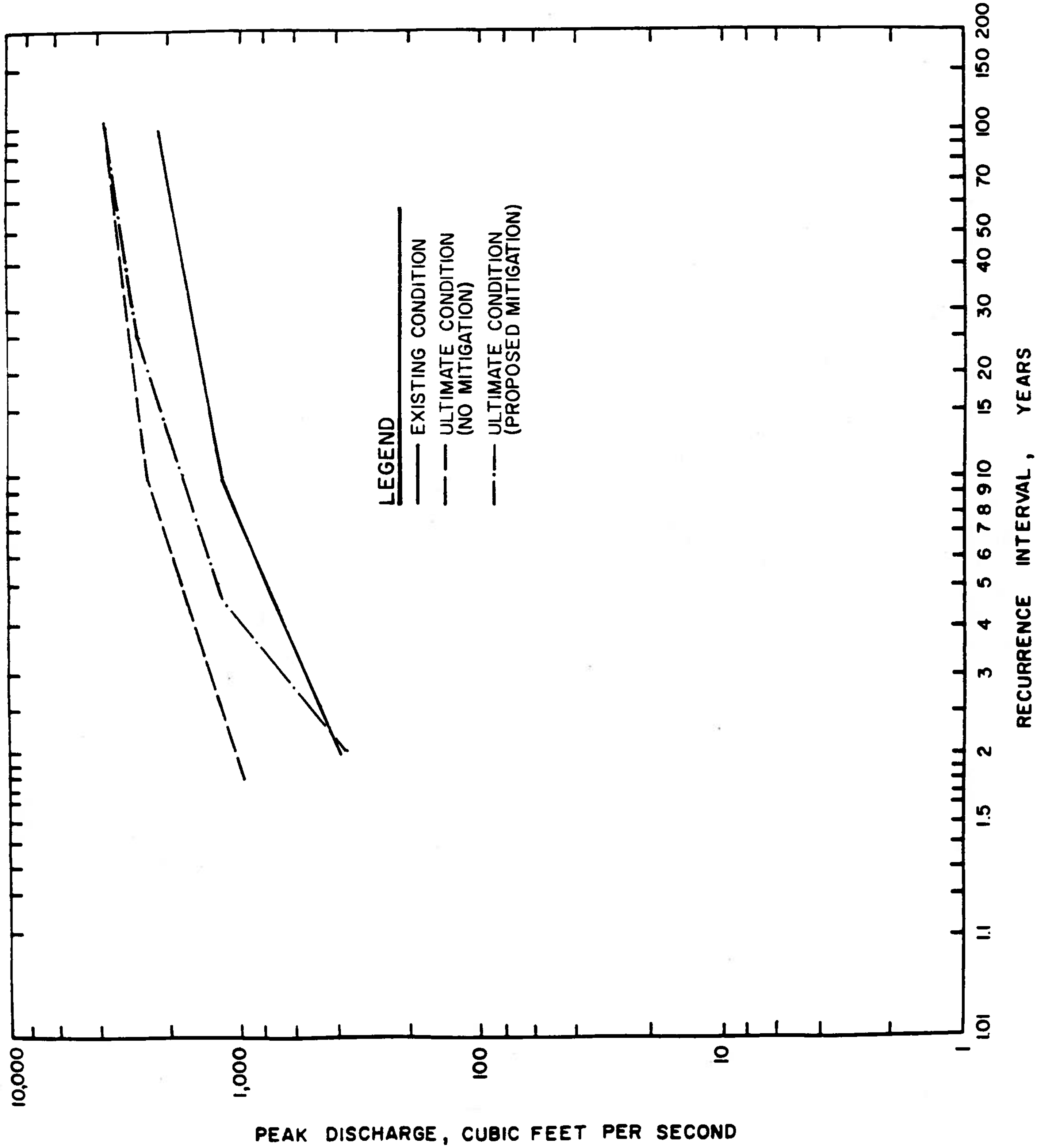


FIGURE 42. MITIGATED CONDITION FLOOD FREQUENCY CURVE

GLOSSARY

Antecedent Moisture Condition (AMC). The amount of moisture already in the soil when the study design storm begins. For the purposes of design hydrology AMC I will be used for the 2-year and 5-year storm events; AMC II will be used for the 10-year, 25-year, and 50-year storm events; and AMC III will be used for the 100-year storm event.

Coefficient of Runoff (C). The coefficient accounts for losses between rainfall and runoff. The rainfall losses are: interception by vegetation; infiltration into permeable soils; retention in surface depressions; evaporation; and transpiration.

Critical Duration. The critical duration of a storm event for a hydraulic structure is usually the "time of concentration," which is the time for water deposited at the most remote part of a watershed to flow to the structure, outlet or spillway.

Distribution Graph. A distribution graph is a unit hydrograph whose ordinates are expressed in terms of percent of ultimate discharge. A distribution graph is generally developed as a block graph with each block representing its associated percent of unit runoff which occurs during the specified unit time. The unit time used in the distribution graph is identical to the unit time specified for the unit hydrograph.

Duration. Duration is the specified length of storm time under study. Duration may be expressed in any time unit such as seconds, minutes, hours, days or season.

Effective Rainfall. Effective rainfall is that part of rainfall that runs off in a relatively brief time period. (Here, the brief time period is selected sufficiently small such that the significant hydrologic effects are adequately represented by the time-period's average values.) Effective rainfall is the total rainfall less infiltration, evaporation, transpiration, absorption, and detention.

Exceedance (cumulative) Probability. The probability that a precipitation event of a specified depth and duration will be exceeded in one year.

Frequency. The frequency of occurrence of events with the specified precipitation depth and duration. This is expressed in terms of either the return period or exceedance probability.

Initial Abstraction. Initial abstraction consists of interception; infiltration and depression storage which must be satisfied before runoff begins.

Intensity-duration. By dividing precipitation depth by duration, an average intensity for a specified duration is obtained.

Lag. Lag for a watershed is the time (hours) from the beginning of a continuous series of unit period effective rainfalls over the watershed area (tributary to a point of concentration) to the instant when the rate of resulting tributary watershed runoff (at the point of concentration) equals 50 percent of the ultimate rate of the resulting runoff.

Low Loss Rate (F*). The low loss rate is an estimate of the rainfall losses infiltration. Typically in 100-year storm studies, the low loss rate serves as the only loss rate for the entire storm pattern except for the most intense rainfalls where the maximum loss rate (F_m) would apply.

Maximum Loss Rate (F_m). The maximum loss rate limits the amount of rainfall losses during the storm event. Typically in 100-year storm studies, the maximum loss rate is reached only during the most intense rainfalls.

Precipitation Depth. Precipitation depth is the amount of precipitation occurring during a specified duration of storm time. Precipitation depth is usually expressed in units of inches.

Return Period (recurrence interval). Return period is the long term average number of years between occurrences of an event of a given depth and duration, either equaled or exceeded. The return period (T) and exceedance probability (p) are related by

$$p = 1/T$$

S-Graph. A S-graph is a summation hydrograph developed by plotting watershed discharge expressed in percent of ultimate discharge as a function of time expressed in percent of lag.

Summation Hydrograph. A summation hydrograph for a point of concentration on a given stream is a curve (hydrograph) showing the time distribution of the rates of runoff that would result from a continuous series of unit period effective rainfalls over the tributary watershed upstream of the subject point of concentration. The ordinates of the summation hydrograph are expressed in percent of the ultimate discharge.

Ultimate Discharge. Ultimate discharge is the maximum rate of watershed runoff which can result from a specified effective rainfall intensity. Ultimate discharge from a watershed occurs when the rate of runoff on the summation hydrograph is equivalent to the rate of effective rainfall. For an effective rainfall rate of one inch occurring in a unit period of one hour, the ultimate discharge is 645 cfs for every square mile of watershed. Utlimate discharge for different unit periods is given by dividing 645 by the unit period in hours, and multiplying by the watershed area in square miles.

Unit Hydrograph. A unit hydrograph (or unit graph) for a point of concentration on a watershed (catchment) stream is a curve (hydrograph) showing the time disbribution of rates of runoff which results from one inch of effective rainfall during a unit period of time over the tributary watershed upstream of the point of concentration. The unit effective rainfall is generally assumed to occur as an equivalent constant rainfall intensity during a specified unit period of time (such as 5, 10, 15 or 30-minutes). Figure E-1 illustrates the general formulation of the unit hydrograph.