# APPENDIX B
# Hydrological Methodology and Calculations

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FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

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THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

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

  1       ID       GENERAL DRAINAGE PLAN FOR CHINLE AIRPORT , EXISTING  CONDITIONS
  2       ID       MODEL CH   I.D99- SUB-BASIN SERIES A TO C
  3       ID       100-YEAR, 24-HOUR STORM, USING SCS TYPE II  RAINFALL DISTRIBUTION
  4       ID       RAINFALL FROM U.S. WEATHER BUREAU
          *DIAGRAM
  5       IT     10 16JUL90       0     300
  6       IO      5       0
  7       IN     15 16JUL90       0

  8       KK   SUB A
  9       KM       RUNOFF FROM SUB- BASIN A
 10       BA   248.0
 11       PB    2.80
 12       PC      0    .002    .005    .008    .011    .014    .017    .020    .023    .026
 13       PC   .029    .032    .035    .038    .041    .044    .048    .052    .056    .060
 14       PC   .064    .068    .072    .076    .080    .085    .090    .095    .100    .105
 15       PC   .110    .115    .120    .126    .133    .140    .147    .155    .163    .172
 16       PC   .181    .191    .203    .218    .236    .257    .283    .387    .663    .707
 17       PC   .735    .758    .776    .791    .804    .815    .825    .834    .842    .849
 18       PC   .856    .863    .869    .875    .881    .887    .893    .898    .903    .908
 19       PC   .913    .918    .922    .926    .930    .934    .938    .942    .946    .950
 20       PC   .953    .956    .959    .962    .965    .968    .971    .974    .977    .980
 21       PC   .983    .986    .989    .992    .995    .998   1.000
 22       LS             89
 23       UD    4.72

 24       KK   SUB B
 25       KM       RUNOFF FROM SUB- BASIN B
 26       BA   27.41
 27       LS             89
 28       UD    2.09

 29       KK   CPA&B
 30       KM       COMBINE HYDROGRAPH SUB-BASIN A & B
 31       HC      2

 32       KK   SUB C
 33       KM       RUNOFF FROM SUB-BASIN C
 34       BA    2.91
 35       LS             89
 36       UD    0.79
 37       ZZ
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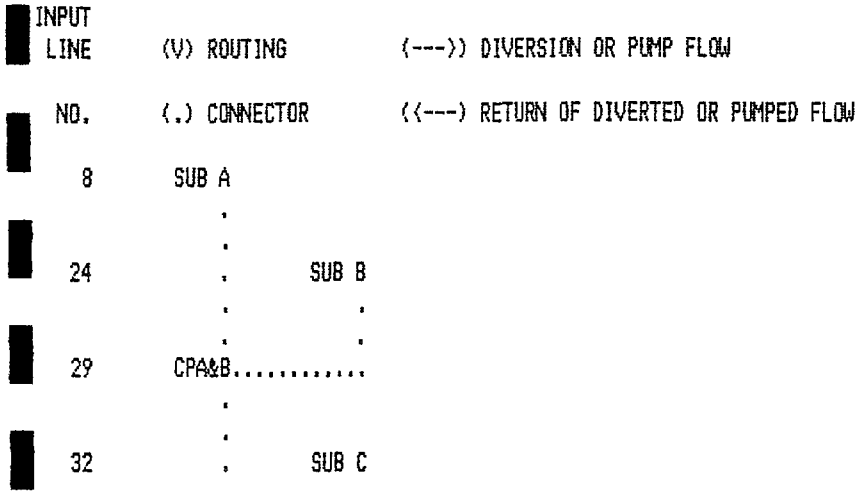
SCHEMATIC DIAGRAM OF STREAM NETWORK




(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

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GENERAL DRAINAGE PLAN FOR CHINLE AIRPORT , EXISTING CONDITIONS
MODEL CH I.D99- SUB-BASIN SERIES A TO C
100-YEAR, 24-HOUR STORM, USING SCS TYPE II RAINFALL DISTRIBUTION
RAINFALL FROM U.S. WEATHER BUREAU

6 IO OUTPUT CONTROL VARIABLES

| | | |
|---|---|---|
| IPRNT | 5 | PRINT CONTROL |
| IPLOT | 0 | PLOT CONTROL |
| QSCAL | 0. | HYDROGRAPH PLOT SCALE |

IT HYDROGRAPH TIME DATA

| | | |
|---|---|---|
| NMIN | 10 | MINUTES IN COMPUTATION INTERVAL |
| IDATE | 16JUL90 | STARTING DATE |
| ITIME | 0000 | STARTING TIME |
| NQ | 300 | NUMBER OF HYDROGRAPH ORDINATES |
| NDDATE | 18JUL90 | ENDING DATE |
| NDTIME | 0150 | ENDING TIME |

COMPUTATION INTERVAL .17 HOURS
TOTAL TIME BASE 49.83 HOURS

ENGLISH UNITS

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

| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD | | | BASIN AREA |
|---|---|---|---|---|---|---|---|
| | | | | 6-HOUR | 24-HOUR | 72-HOUR | |
| HYDROGRAPH AT | SUB A | 31994. | 17.00 | 26905. | 11403. | 5524. | 248.00 |
| HYDROGRAPH AT | SUB B | 6605. | 14.17 | 3847. | 1267. | 611. | 27.41 |
| 2 COMBINED AT | CPA&B | 34280. | 16.83 | 29509. | 12661. | 6135. | 275.41 |
| HYDROGRAPH AT | SUB C | 1391. | 12.67 | 431. | 135. | 65. | 2.91 |

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

ADDENDUM to "HYDROLOGIC DESIGN FOR HIGHWAY DRAINAGE IN ARIZONA" April 1975

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

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

TABLE 1

| Return Period (Years) | Precipitation Values (inches) | | | |
|---|---|---|---|---|
| | 6 hour duration | | 24 hour duration | |
| | Map Value | Corrected Value | Map Value | Corrected Value |
| 2 | .98 | .98 | .118 | .118 |
| 5 | .128 | .128 | .158 | .159 |
| 10 | .148 | .148 | .197 | .190 |
| 25 | .178 | .173 | .235 | .225 |
| 50 | .198 | .196 | .258 | .257 |
| 100 | .218 | .218 | .279 | .287 |

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

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$Y_c = -0.011 + 0.942 (x_1^2 / X_2)$

$= -0.011 + 0.942 ((.98)^2 / (1.18))$

$= 0.7557$

$Y = 0.494 + 0.755 (X_3^2 / X_4)$

$= 0.494 + 0.755 ((2.18^2 / 2.87))$

$= 1.74$

Phoenix
5080 North 40th Street
Suite 300
85018
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7675 Dagget Street
Suite 350
92111
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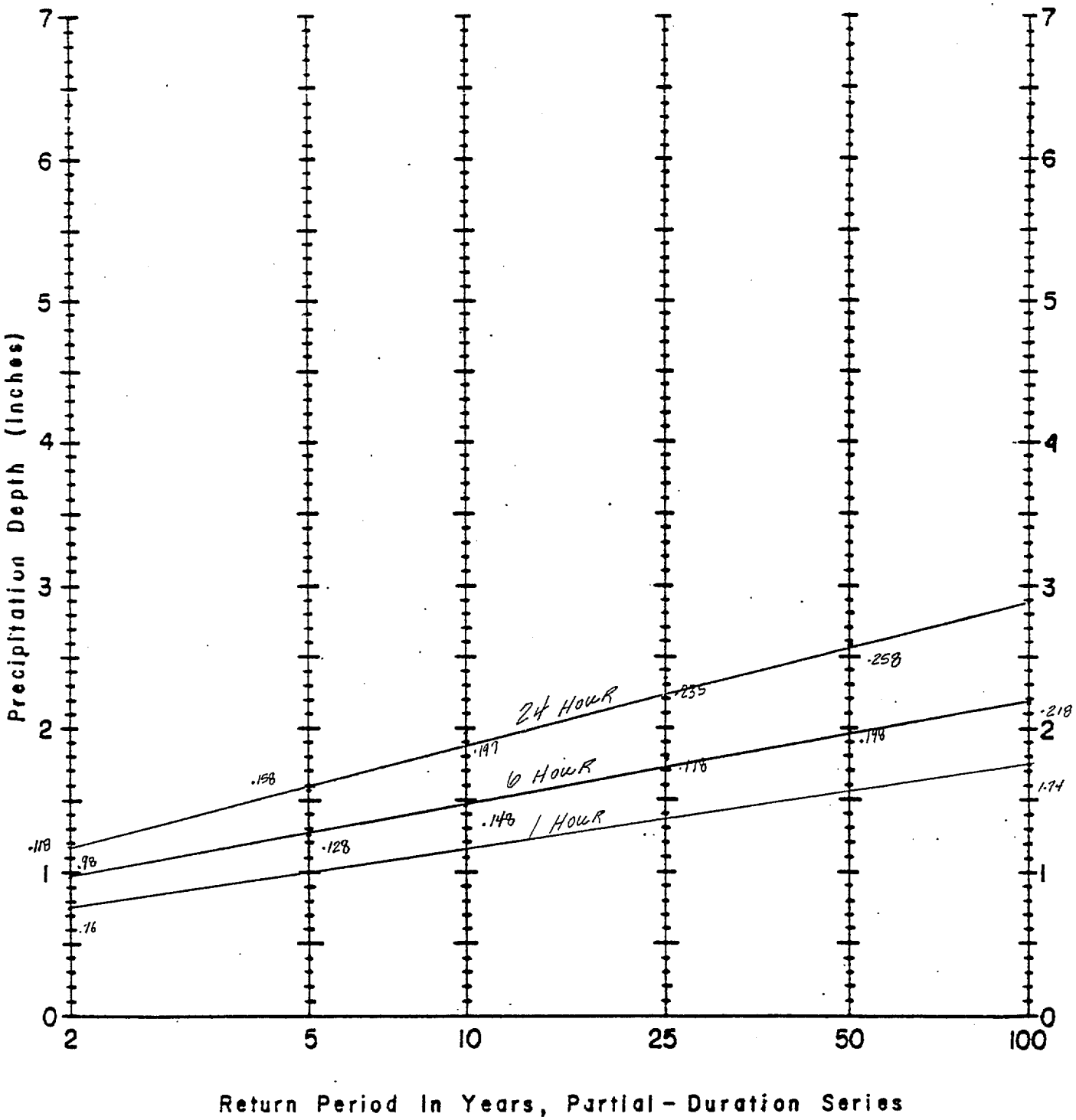



Figure 1 Precipitation Depth Versus Return Period for Partial – Duration Series

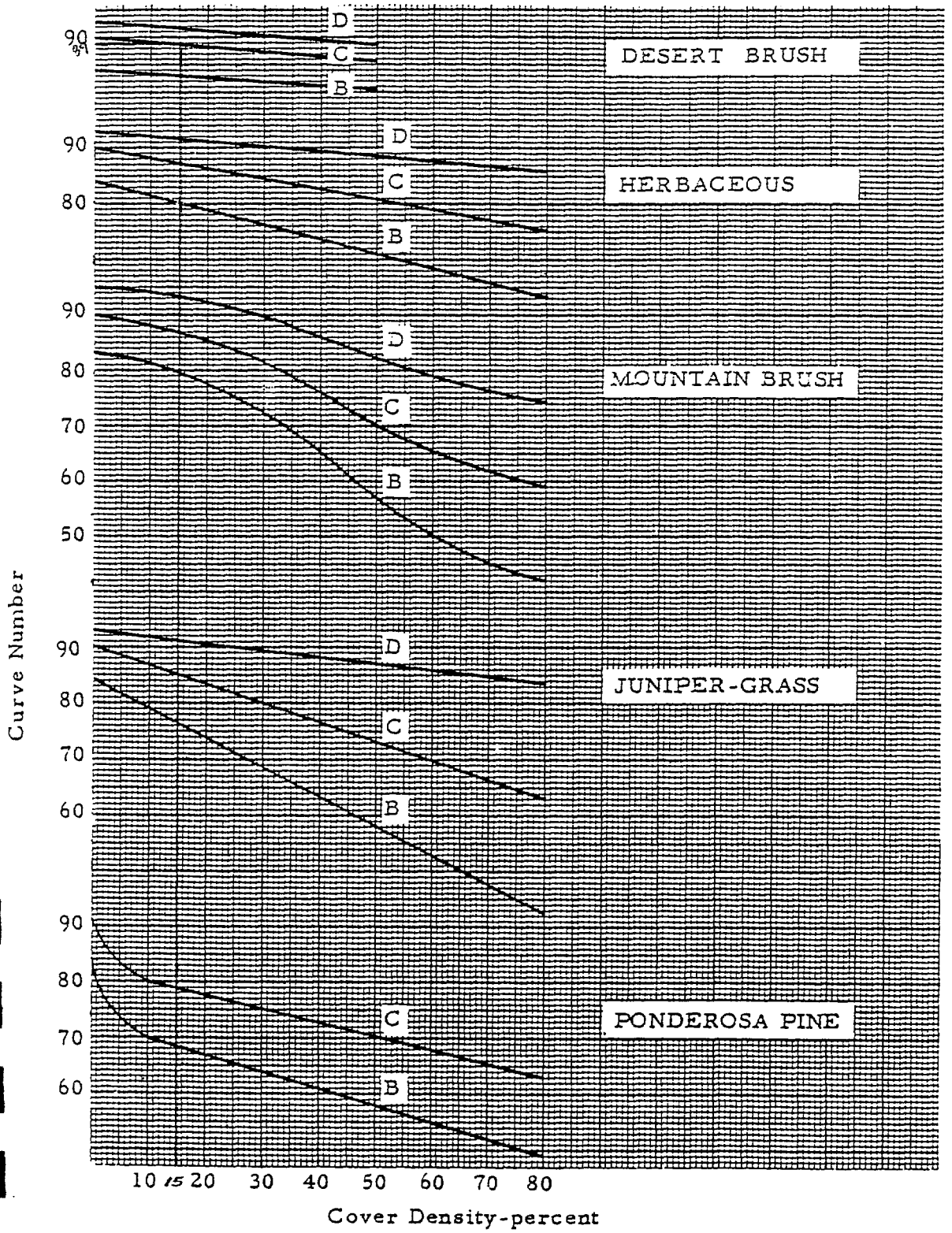
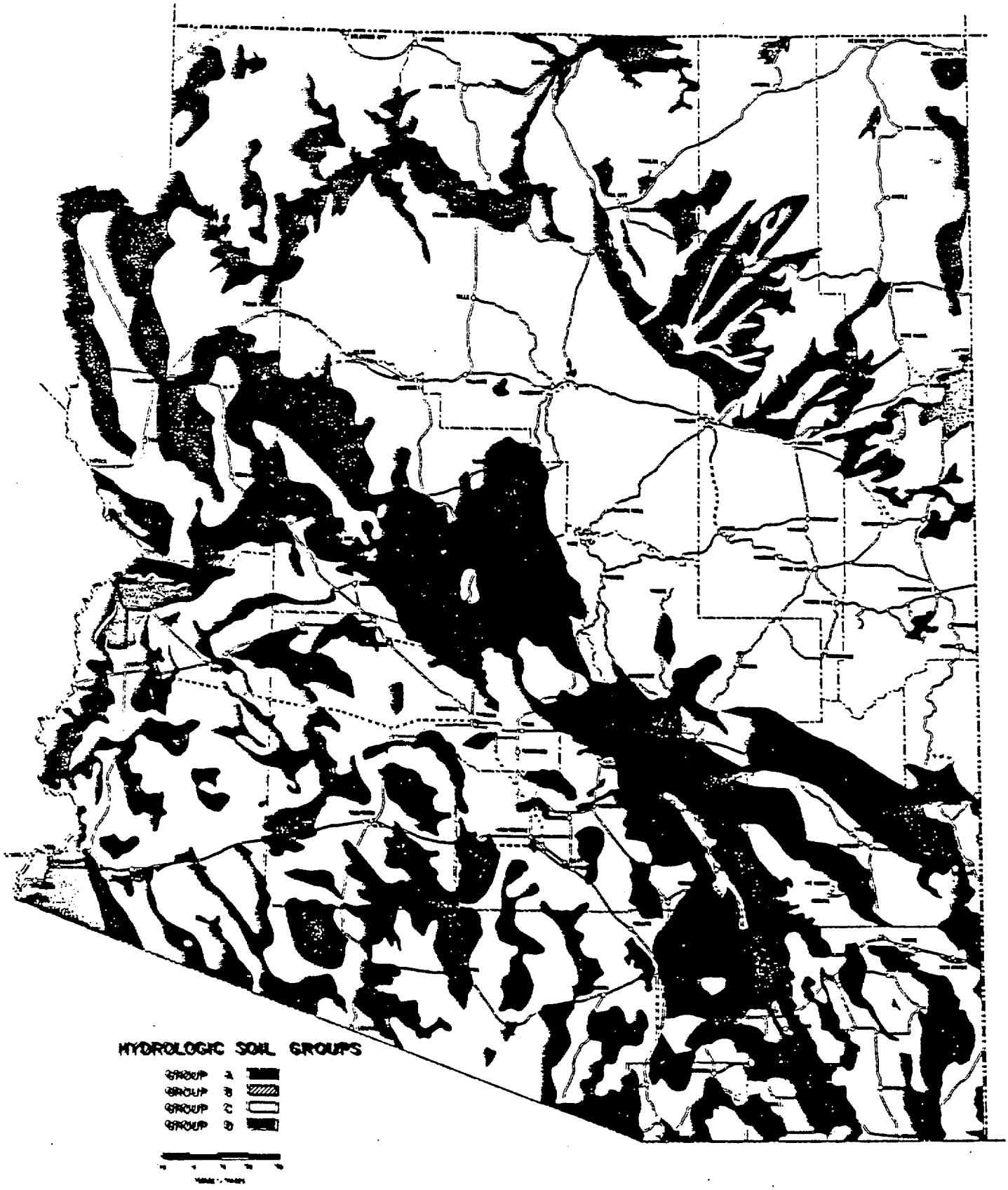



Fig. 2-3

HYDROLOGIC SOIL - COVER COMPLEXES
AND ASSOCIATED CURVE NUMBERS



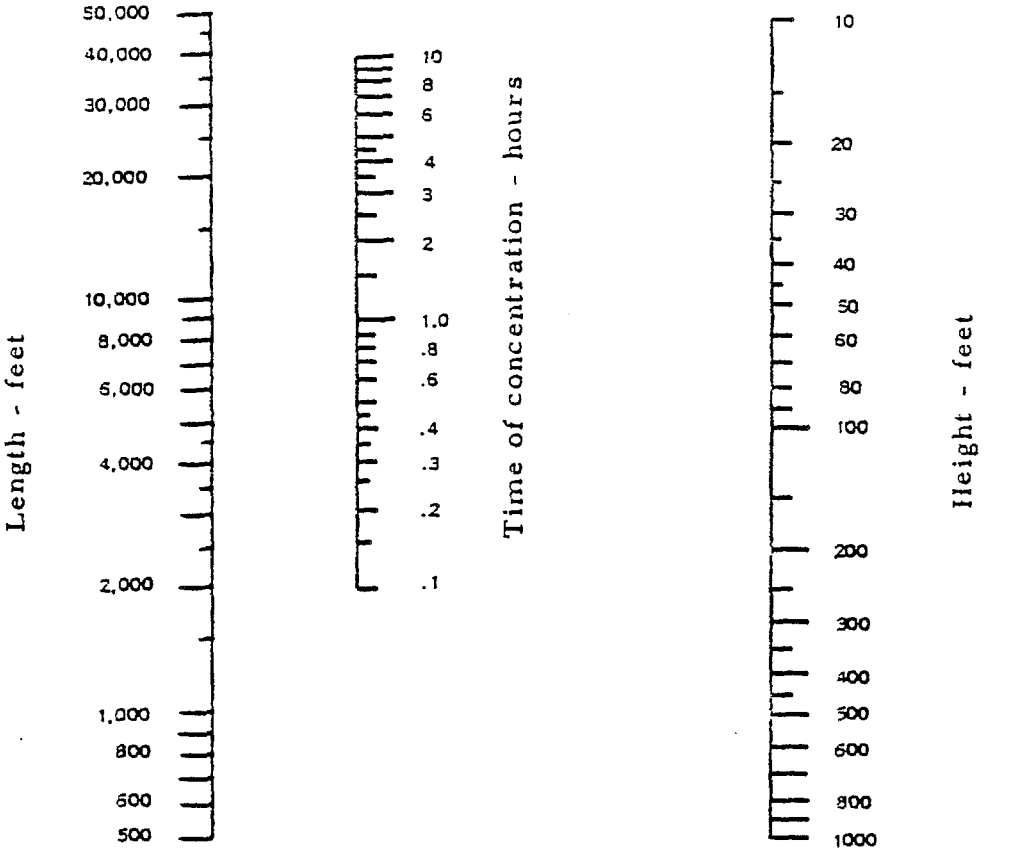

REVISED MARCH 1969

FIG. 2-1

GENERALIZED HYDROLOGIC SOIL MAP

FOR GENERAL PLANNING ONLY
ON SITE INSPECTION NECESSARY
FOR DETAILED PLANNING

DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE
PHOENIX, ARIZONA




$$T_c = \frac{L^{1.15}}{7700\ H^{.38}}$$

$T_c$ = time of concentration - hours
L = length of drainage area - feet
H = elevation - feet

Fig. 2-7

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

Soil Conservation Service

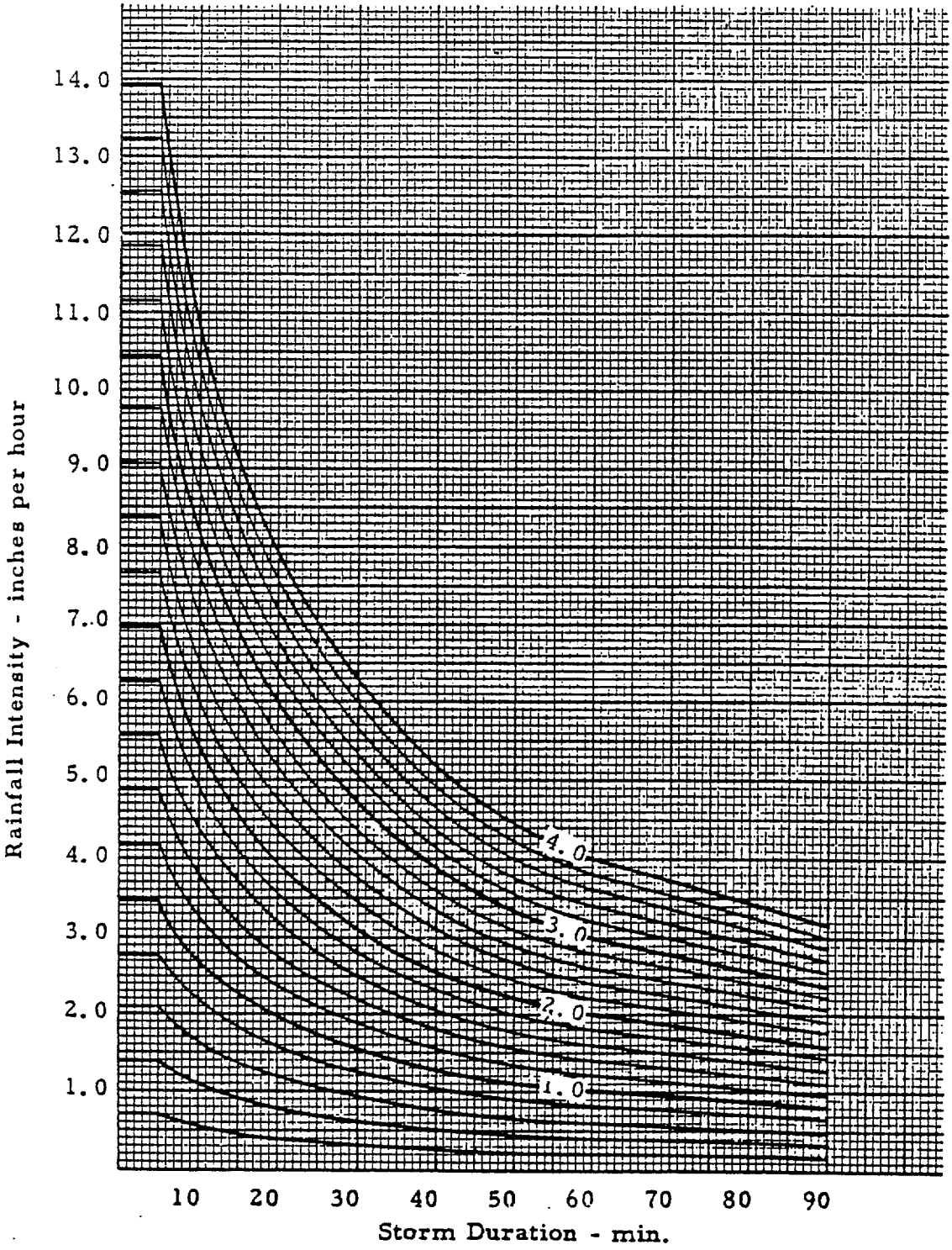



Fig. 3-2

STANDARD DURATION RAINFALL - INTENSITY CURVES

Based on:
Weather Bureau
Technical Paper No. 40

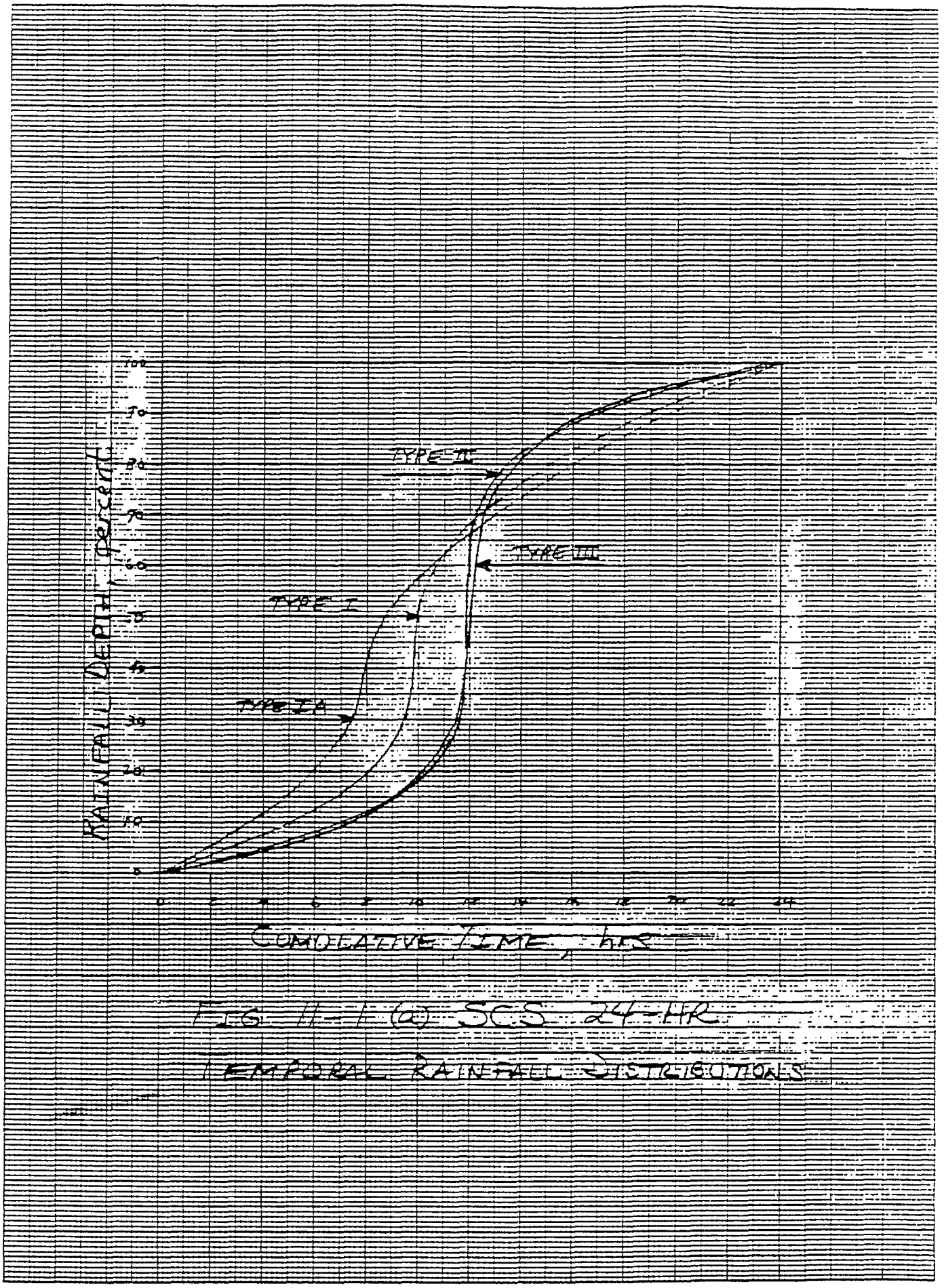



FIG II-1(a) SCS 24-HR

EMPIRICAL RAINFALL DISTRIBUTIONS

10 Millimeters to the Centimeter

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AREA A

18.9 IN$^2$ x 8,202 FT/IN = 155,018 FT

UPSTREAM ELEVATION = 1291; DOWNSTREAM ELEVATION = 5560

1291 x 3.2809 = 4,236 = 4236

ELEVATION DIFFERENTIAL (H) = 1,324 FT

SLOPE = 1,324 FT / (155,018)$^2$ = .0085 ft/ft

AREA = 102.89 IN$^2$ = 67,272,804 FT$^2$/IN$^2$ = 158,900 AC

$$T_c = \frac{155{,}018^{1.15}}{(7{,}700)(1324)^{.38}} = 7.87 \text{ HRS}$$

AREA B

AREA = 11.36 IN$^2$ x 67,272,804 FT$^2$/IN$^2$ ÷ 43,560 FT$^2$/AC = 17,544 AC.

UPSTREAM = 2049 x 3.2808 = 6,719 ; DOWNSTREAM = 5523 = 1,196 FT

HYDRAULIC LENGTH = 9 IN x 8,202 FT/IN = 73,818 FT

SLOPE = 1,196 FT / 73,818 FT = .0162 ft/ft

$$T_c = \frac{L^{1.15}}{7{,}700\ H^{.38}} = \frac{73{,}818^{1.15}}{7{,}700\ (1{,}196)^{.38}} = 3.48$$

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5080 North 40th Street
Suite 300
85018
(602) 955-0900

San Diego
7675 Dagget Street
Suite 350
92111
(619) 292-6161

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AREA C

AREA = 20.29 IN² x 4,000,000 IN²/FT² ÷ 43,560 FT²/AC = 1863 AC

LENGTH = 11 IN x 2000 FT/IN = 22,000 FT

UPSTREAM = 5,920; DOWNSTREAM = 5,515 = 405 FT

SLOPE = 405' / 22,000 FT = .0184'/'

$$T_c = \frac{L^{1.15}}{7,700\ H^{.38}} = \frac{22,000^{1.15}}{(7,700)(405)^{.38}} = 1.31 \text{ HR}$$

Phoenix
5080 North 40th Street
Suite 300
85018
(602) 955-0900

San Diego
7675 Dagget Street
Suite 350
92111
(619) 292-6161

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 17, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second) | 31994.0 |
| Channel Bottom Slope (feet per foot) | 0.0030 |
| Manning's Roughness Coefficient (n-value) | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical) | 15.00 |
| Channel Side Slope - Right Side (horizontal/vertical) | 100.00 |
| Channel Bottom Width (feet) | 400.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet) | 5.56 |
| Flow Velocity (feet per second) | 8.00 |
| Froude Number (Flow is Sub-Critical) | 0.718 |
| Velocity Head (feet) | 0.99 |
| Energy Head (feet) | 6.55 |
| Cross-Sectional Area of Flow (square feet) | 4001.32 |
| Top Width of Flow (feet) | 1039.38 |

H.W. = 5545.56

CROSS-SECTION A-A

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 17, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second) | 31994.0 |
| Channel Bottom Slope (feet per foot) | 0.0018 |
| Manning's Roughness Coefficient (n-value) | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical) | 100.00 |
| Channel Side Slope - Right Side (horizontal/vertical) | 100.00 |
| Channel Bottom Width (feet) | 350.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet) | 5.82 |
| Flow Velocity (feet per second) | 5.90 |
| Froude Number (Flow is Sub-Critical) | 0.550 |
| Velocity Head (feet) | 0.54 |
| Energy Head (feet) | 6.36 |
| Cross-Sectional Area of Flow (square feet) | 5419.85 |
| Top Width of Flow (feet) | 1513.42 |

H.W. = 5535.82

CROSS-SECTION B-B

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 17, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second) | 34280.0 |
| Channel Bottom Slope (feet per foot) | 0.0038 |
| Manning's Roughness Coefficient (n-value) | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical) | 60.00 |
| Channel Side Slope - Right Side (horizontal/vertical) | 15.00 |
| Channel Bottom Width (feet) | 150.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet) | 7.68 |
| Flow Velocity (feet per second) | 10.18 |
| Froude Number (Flow is Sub-Critical) | 0.834 |
| Velocity Head (feet) | 1.61 |
| Energy Head (feet) | 9.29 |
| Cross-Sectional Area of Flow (square feet) | 3366.06 |
| Top Width of Flow (feet) | 726.23 |

H.W = 5527.68

CROSS - SECTION C-C

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 17, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second) | 34280.0 |
| Channel Bottom Slope (feet per foot) | 0.0018 |
| Manning's Roughness Coefficient (n-value) | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical) | 30.00 |
| Channel Side Slope - Right Side (horizontal/vertical) | 5.00 |
| Channel Bottom Width (feet) | 100.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet) | 11.93 |
| Flow Velocity (feet per second) | 9.31 |
| Froude Number (Flow is Sub-Critical) | 0.615 |
| Velocity Head (feet) | 1.35 |
| Energy Head (feet) | 13.27 |
| Cross-Sectional Area of Flow (square feet) | 3681.24 |
| Top Width of Flow (feet) | 517.38 |

HW = 5521.93

CROSS-SECTION D-D

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 17, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second) | 1391.0 |
| Channel Bottom Slope (feet per foot) | 0.0027 |
| Manning's Roughness Coefficient (n-value) | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical) | 30.00 |
| Channel Side Slope - Right Side (horizontal/vertical) | 30.00 |
| Channel Bottom Width (feet) | 100.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet) | 2.10 |
| Flow Velocity (feet per second) | 4.07 |
| Froude Number (Flow is Sub-Critical) | 0.583 |
| Velocity Head (feet) | 0.26 |
| Energy Head (feet) | 2.35 |
| Cross-Sectional Area of Flow (square feet) | 341.79 |
| Top Width of Flow (feet) | 225.86 |

CROSS-SECTION E-E

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION
July 19, 1990

PROGRAM INPUT DATA:

| DESCRIPTION | VALUE |
|---|---|
| Flow Rate (cubic feet per second)..... | 1391.0 |
| Channel Bottom Slope (feet per foot)..... | 0.0030 |
| Manning's Roughness Coefficient (n-value)..... | 0.0250 |
| Channel Side Slope - Left Side (horizontal/vertical).... | 30.00 |
| Channel Side Slope - Right Side (horizontal/vertical)... | 30.00 |
| Channel Bottom Width (feet)..... | 110.0 |

PROGRAM RESULTS:

| DESCRIPTION | VALUE |
|---|---|
| Normal Depth (feet)..... | 1.97 |
| Flow Velocity (feet per second)..... | 4.18 |
| Froude Number (Flow is Sub-Critical)..... | 0.611 |
| Velocity Head (feet)..... | 0.27 |
| Energy Head (feet)..... | 2.24 |
| Cross-Sectional Area of Flow (square feet)..... | 332.44 |
| Top Width of Flow (feet)..... | 228.02 |

CROSS-SECTION F-F