APPENDIX A-3

PROCEDURAL GUIDE FOR COMPUTING RUN-OFF BY RATIONAL METHOD

The Rational Method is a method for determining run-off in terms of cubic feet per second at the drainage structure. It is based on the direct relationship between rainfall and run-off and may be expressed by the formula:

$$Q = CIA$$

Q = the run-off in cu. ft. per sec. from a given area.

C = a coefficient representing the ratio of run-off to rainfall (related to impervious area) i.e., 1.0 - 100% run-off.

I = the intensity of rainfall in inches per hour for a duration equal to the time of concentration and for a stated frequency.

A = the drainage area in acres.

		SOIL CLASSIFICATION			
SLOPE	LAND USE	SAND OR SANDY LOAM SOILS (Pervious) Min.	Max.	HIGH CLAY SOILS (Impervious) Min.	Max.
Flat (0% - 3%)	Woodlands	0.15	0.20	0.20	0.25
	Pasture	0.20	0.25	0.25	0.30
	Paved	0.95		0.95	
	Residential	0.35	0.60	0.50	0.60
	Commercial	0.60	0.95	0.60	0.95
Rolling (3% - 7%)	Woodlands	0.15	0.20	0.18	0.25
	Pasture	0.30	0.40	0.35	0.45
	Paved	0.95		0.95	
	Residential	0.50	0.60	0.50	0.60
	Commercial	0.60	0.95	0.60	0.95
Hilly (7% - 11%)	Woodlands	0.20	0.25	0.25	0.30
	Pasture	0.35	0.45	0.45	0.55
	Paved	0.95		0.95	
	Residential	0.50	0.60	0.50	0.60
	Commercial	0.60	0.95	0.60	0.95
Mountainous (11% +)	Woodlands			0.70	0.80
	Bare		0.80	0.80	0.95
Steep Grassed Slopes	Pasture	0.70		0.70	

Table A-3.1

1. Determine "C" by observation in the field of culture and soils and by use of Table A-3.1, p. A-3-1.

2. Determine "I" (intensity rate) from the time of Concentration Figure A-3.1, p. A-3-3 and Rainfall Figures A-3.3 through A-3.7, p. A-3-5 through A-3-9.

NOTE:

a. Height (ft.) is determined in the field or from contour maps. Height is the difference in elevation of the most remote point in the drainage area and the inlet flow line of the structure.

b. Maximum length of travel is determined in the field or from the contour maps. It is the greatest distance the water will travel from the most remote point of the drainage area to the inlet of the drainage structure.

c. Use height and length to determine the time of concentration by use of Figure A-3.1. Use a minimum of 10 minutes for rural and urban areas.

d. Now refer to rainfall figures - Atlanta, Macon, Augusta, Thomasville and Savannah (use figure nearest to project or combination of two figures) and by scaling the time of concentration, which is equal to the rainfall duration, along the bottom of the table and moving up to the selected return period, (10-25-50 yr.), move horizontally to the left and read the intensity "I".

3. Determine the time of concentration using the "Kinematic Wave Nomograph," Figure A-3.2, p. A-3-4. The kinematic wave table incorporates variables, the rainfall intensity and mannings "n." In using the nomograph, the designer has two unknowns starting the computations, the time of concentration and the rainfall density. The problem is attempting to determine a rainfall intensity which, in turn, actually determines the time of concentration. Thus, the problem is one of iteration. A value of "i" must be assumed, compute a time of concentration and then check back to see if the rainfall intensity that was assumed is consistent with the frequency curve of Figures A-3.3 through A-3.7. If one is the given length, slope, roughness coefficient, and intensity-duration-frequency curve the steps are as follows:

a. Assume rainfall intensity.
b. Use kinematic wave nomograph or equation to obtain first estimate of time concentration.
c. Using the time of concentration obtained from Step "b", enter Figures A-3.3 through A-3.7 for appropriate area and find rainfall intensity corresponding to the computed time of concentration. If this rainfall intensity corresponds with the assumed intensity, the problem is solved. If not, proceed to Step "d".
d. Assume a new rainfall intensity that is betwen that assumed in Step "a" and that determined in Step "c."
e. Repeat Steps "a" through "c" until there is good agreement between the assumed rainfall intensity and that obtained from Figures A-3.3 through A-3.7. Experience has shown that a solution can be found on the third iteration with little difficulty.

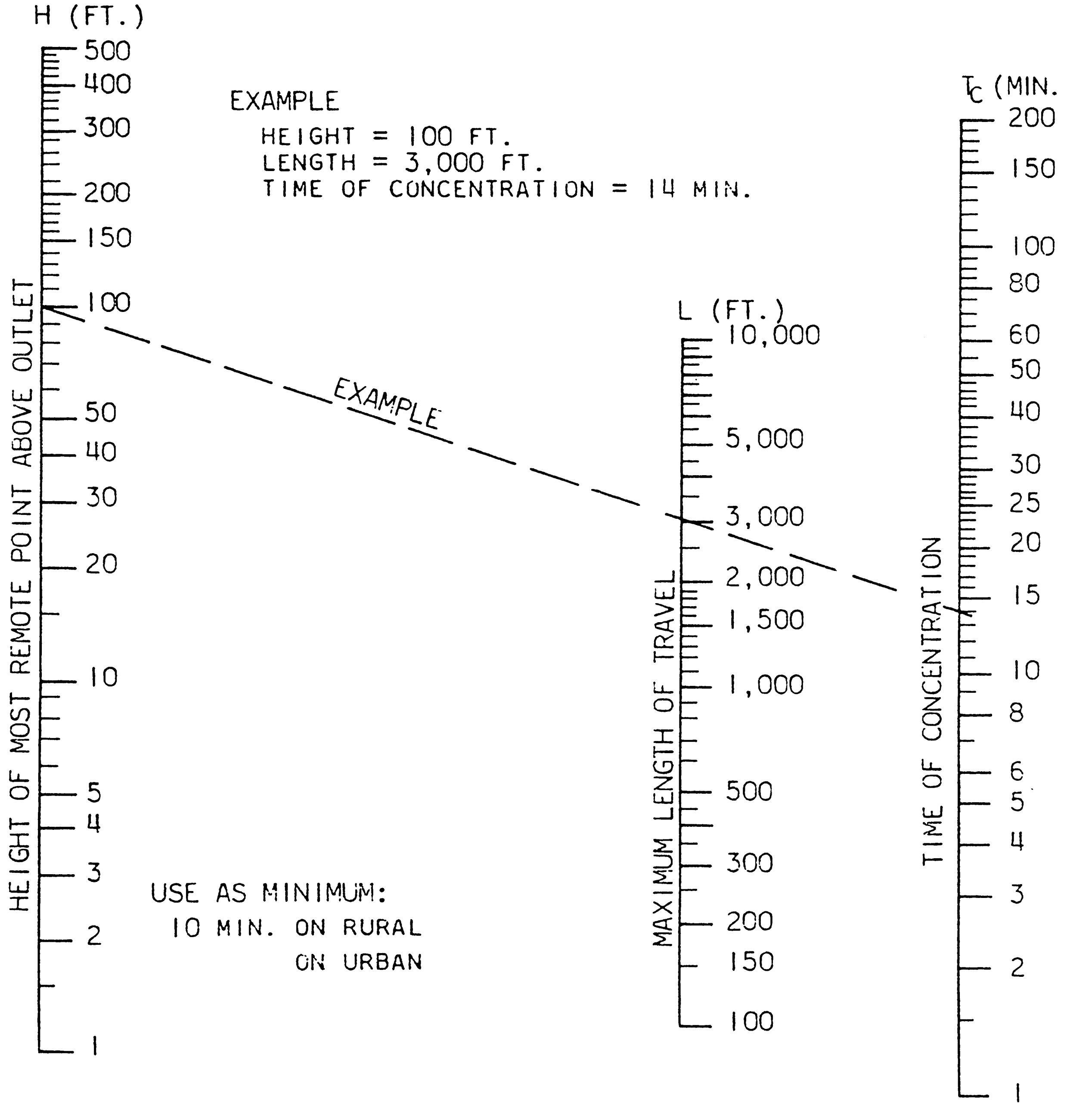
Generally, the time of concentration for overland flow is only a part of the overall design problem. Often one encounters swale flow, confined channel flow, and closed conduit flow-times that must be added as part of the overall time of concentration. When this situation is encountered, it is best to compute the confined flow-times as the first step in the overall determination of the time of concentration. This will give the designer a rough estimate of the time involved for the overland flow which will give a better first start on the rainfall intensity assumption. For example, if the flow time in a channel is 15 minutes and the overland flow time from this ridge line to the channels is 10 minutes, then the total time of concentration is 25 minutes. The channel flow can be determined by length divided by velocity.

4. Determine drainage Area "A" in the field or from contour maps.

5. Multiply the values of C x I x A to determine Q (cu. ft. per sec.).

6. Using "Q" as determined above, solve for size of structure required by use of Culvert Capacity Charts or nomographs.

Table A-3.2, p. A-3-10 may be used for organizing computation.



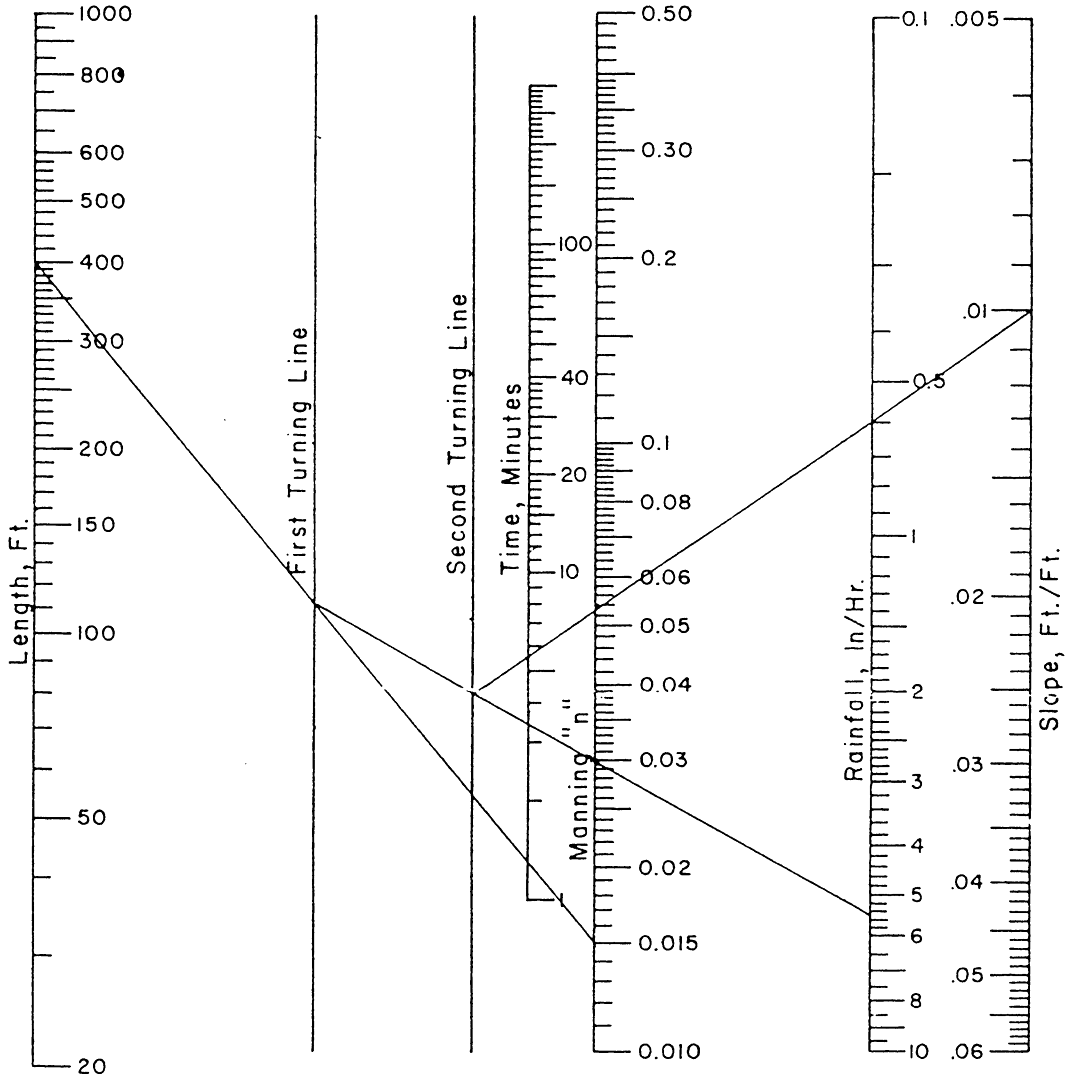
TIME OF CONCENTRATION
OF SMALL DRAINAGE BASINS

Based on study by P. Z. Kirpich,
Civil Engineering, Vol.10, No.6, June 1940, p.362

Figure A-3.1

Equation solved by nomograph:

$$t_c\,(\text{Sec}) = 56\,\frac{L_o^{.6}\,n^{.6}}{i^{.4}\,S_o^{.3}}$$



The initially assumed value of i and the nomograph value of t must be checked against the applicable intensity-duration-frequency curve by trial and error.

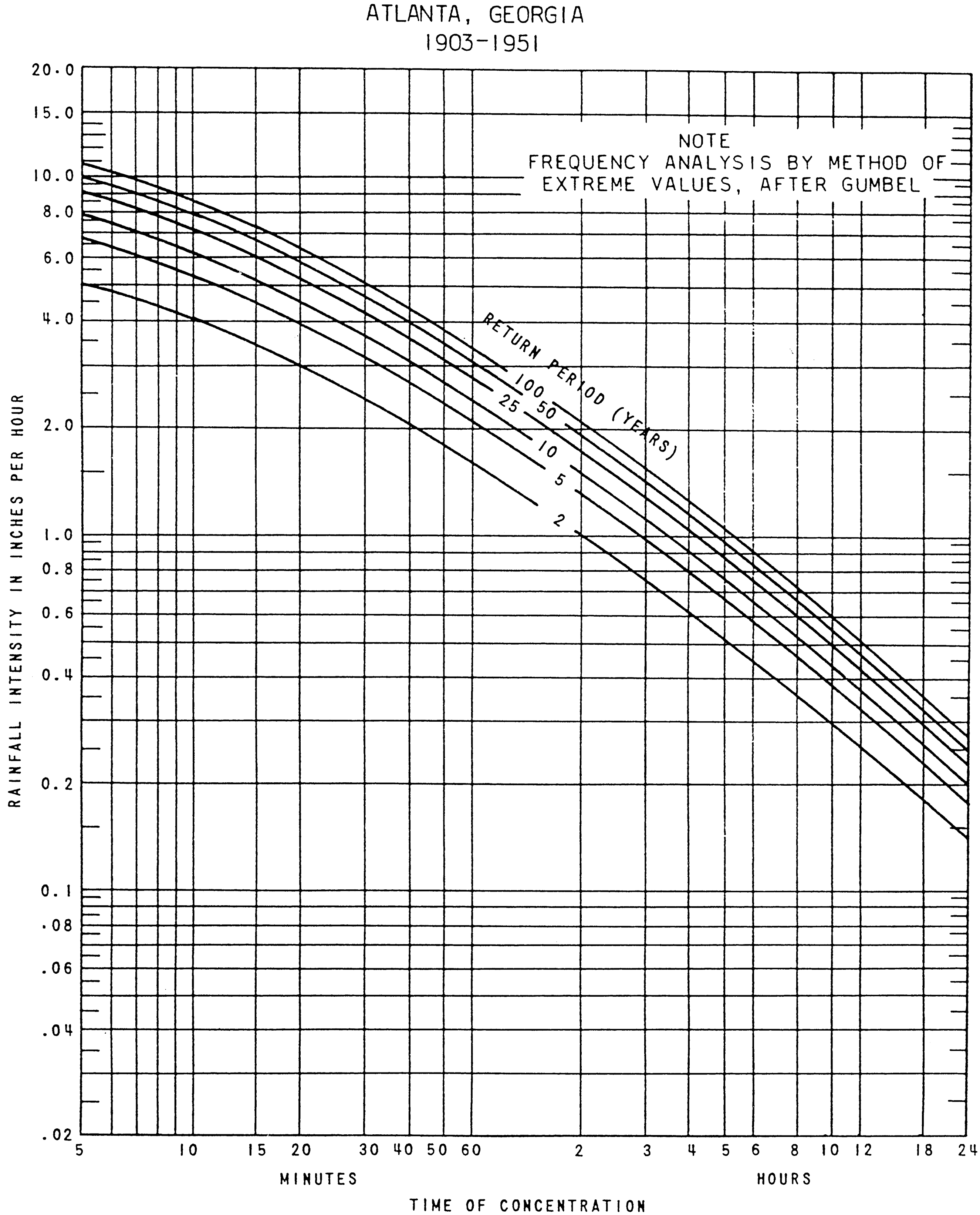
Example:

L_o = 400 ft.
n = 0.015
i = 5.5 in./hr.
S_o = 0.01
t = 5.5 min.

ONE INCH is 25.4mm
ONE FOOT is 0.3048m

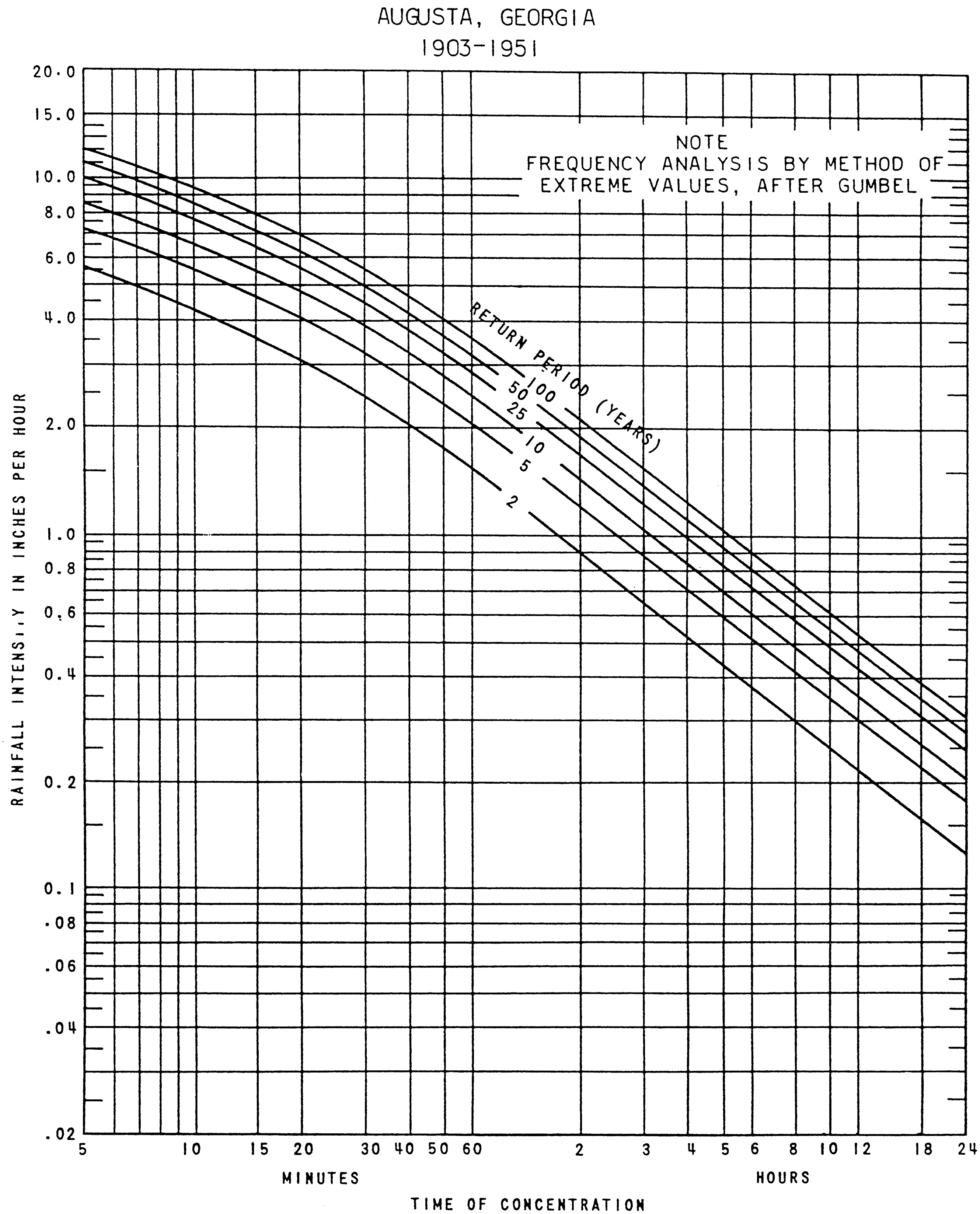
Nomograph for determining time of concentration for overland flow, Kinematic Wave Formulation. *(After Ragan.)*

Figure A-3.2



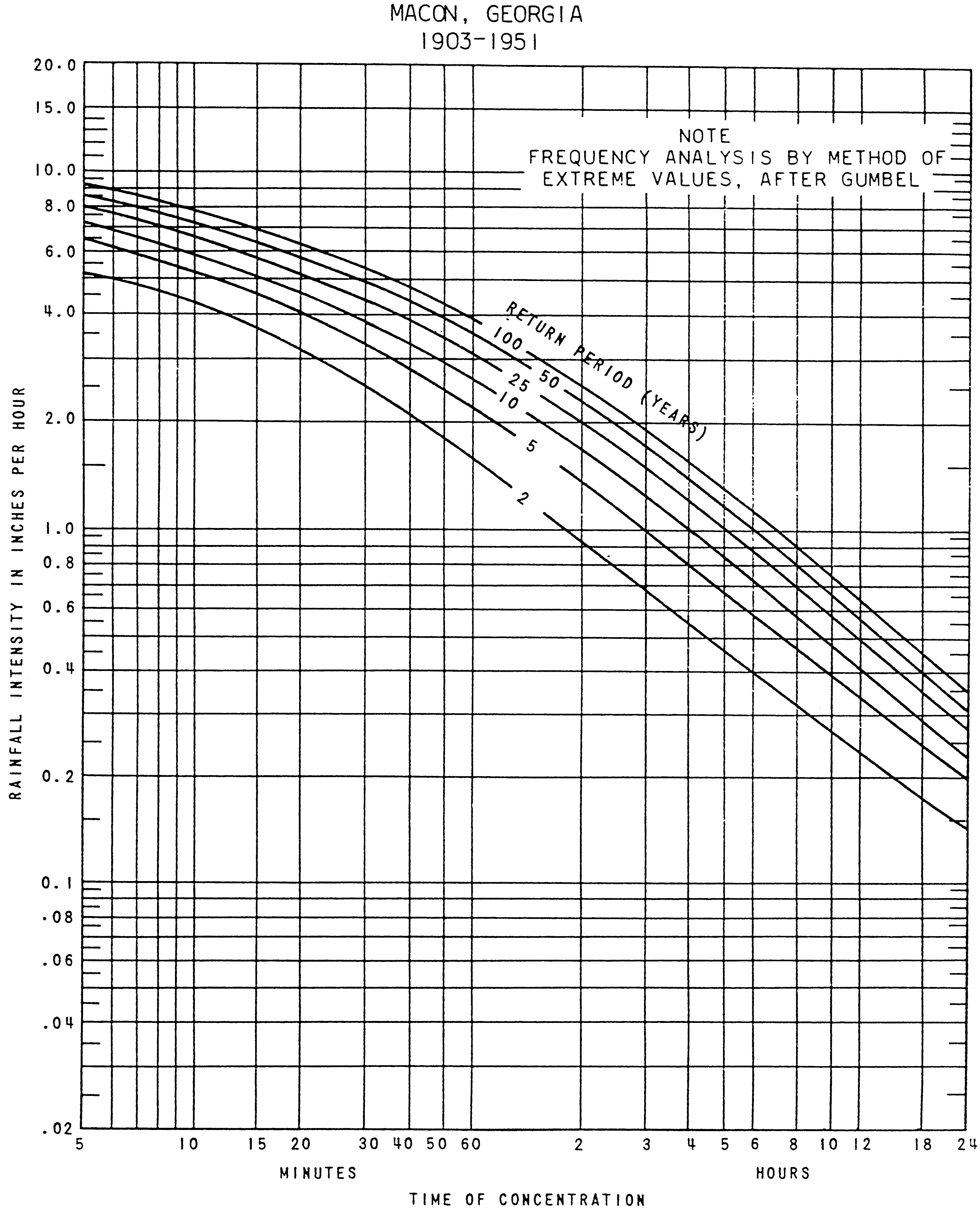
WEATHER BUREAU
TECHNICAL PAPER 25

Figure A-3.3



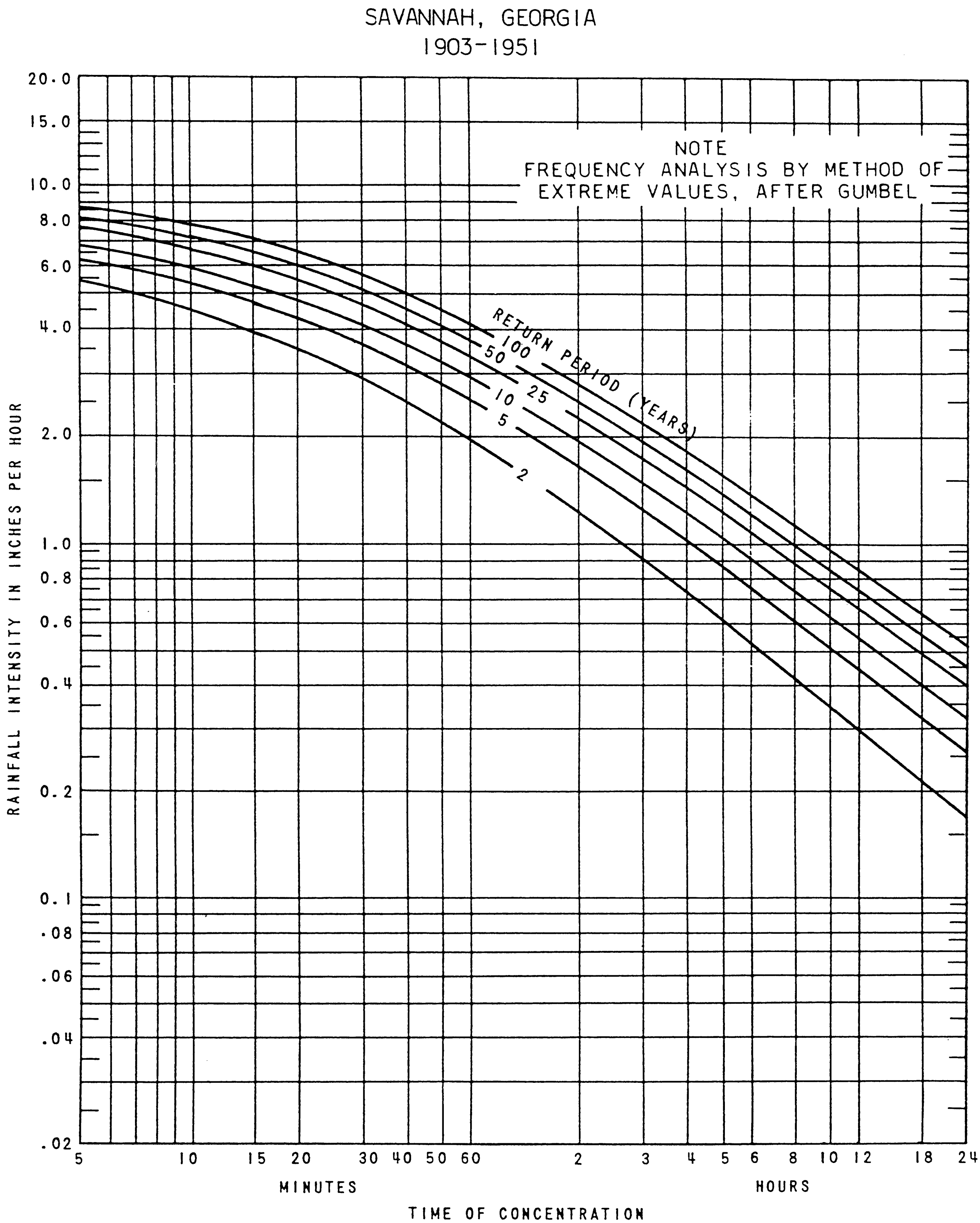
WEATHER BUREAU
TECHNICAL PAPER 25

Figure A-3.4



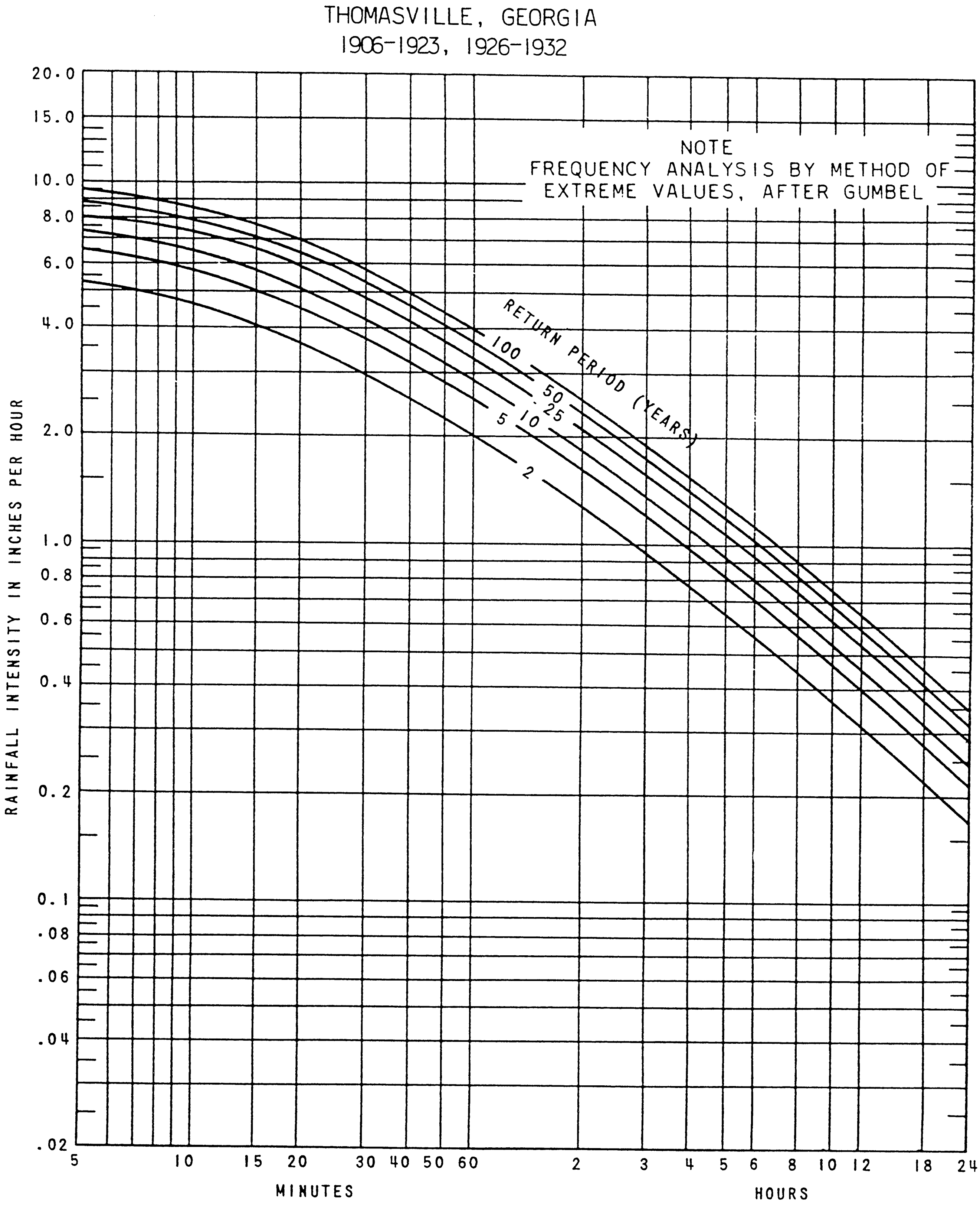
WEATHER BUREAU
TECHNICAL PAPER 25

Figure A-3.5



WEATHER BUREAU
TECHNICAL PAPER 25

Figure A-3.6



WEATHER BUREAU
TECHNICAL PAPER 25

Figure A-3.7

DRAINAGE DESIGN COMPUTATIONS

DISCHARGE “Q” COMPUTED BY RATIONAL METHOD

PROJ. NO.____________

DESIGN RETURN PERIOD______YR.

COUNTY____________

DESCRIPTION		HYDROLOGY									HYDRAULICS							
LOCATION	SKEW	DRAINAGE AREA (ACRES)	RUNOFF "C"	LENGTH (FEET)	HEIGHT (FEET)	TIME OF CONC: (MIN)	INTENSITY "I"$_{50}$ IN/HR	INTENSITY "I"$_{100}$ IN/HR	DISCHARGE "Q"$_{50}$ (CFS)	DISCHARGE "Q"$_{100}$ (CFS)	STRUCTURE SLOPE "So" (FT./FT.)	STRUCTURE LENGTH "L" (FT.)	$\frac{L}{100S_o}$	ALLOWABLE HEADWATER "AHW" (FT.)	HEADWATER "HW"$_{50}$	HEADWATER "HW"$_{100}$	SIZE AND TYPE STRUCTURE	REMARKS

Table A-3.2

APPENDIX B-1

Soil Series Interpretations