USE OF THE RATIONAL FORMULA IN AIRPORT DRAINAGE

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SUMMARY

This report presents limited data on airport surface drainage obtained from the Rome, Georgia project of the Civil Aeronautics Administration. The applicability of the Rational Formula in estimating surface runoff from airports is evaluated by an analysis of the Rome data and other data previously published by the Corps of Engineers. The basic data used in the analysis are summarized in Appendix I. It is concluded that this formula can be used successfully if certain precautions are observed and if design assumptions are based upon a reasonable record of experience in the area involved. Recommended runoff coefficients are given for use under certain specified conditions, and empirical methods of estimating ponding requirements are developed.

INTRODUCTION

Airport surface drainage is a field of engineering design in which one can find wide differences of opinion, both as to the importance of the problem and as to the best method of solving it. Although often considered a minor item of construction, the drainage system may account for ten per cent or more of the entire cost of an airport (not including buildings). More important, the maintenance cost and the utility of the airport may be determined to a great extent by the adequacy of the drainage design.

The principal problem in the design of a surface drainage system is to estimate correctly the maximum runoff flow which must be accommodated by each part of the system. Once these estimates have been made, the determination of pipe sizes and dimensions of drainage structures is covered by hydraulic principles and formulas already well established.

The principles upon which the runoff estimates should be based are not so well known, and estimates prepared independently by two or more engineers may be widely at variance. Although the so-called Rational Formula[1] has been in use for many years, and is widely accepted in airport drainage design and elsewhere, there are many engineers who feel that it represents an oversimplification of a very complex relationship and that its use therefore is dangerous. This view has been strengthened by the fact that the Rational Formula often has been misused by persons who did not have sufficient experience and knowledge of local conditions to use it correctly. Another weakness of this formula is that it provides no direct method of evaluating the effect of ponding upon peak flow conditions.

One of the most comprehensive and best-known attempts to develop a better method of estimating surface runoff is outlined in Part XIII, Chapter 1, "Engineering Manual," Corps of Engineers. This method is based on Horton's studies of overland flow. By means of a series of graphs the computations have been reduced to a point where the labor involved in using this method for design of a drainage system compares reasonably well with that involved in using the Rational Formula. For the sake of brevity and convenience the design procedure outlined in the "Engineering Manual" will be referred to as the Army Method in the remainder of this report.

In view of the importance of the problem, and the lack of agreement as to the ade-

[1] The Rational Formula is often expressed in the form $Q = CIA$, where

Q = maximum runoff rate in cubic feet per second or in acre-inches per hour,

C = a coefficient which is dependent upon surface roughness, surface slope, imperviousness, and other factors,

I = average rainfall rate in inches per hour during the time of concentration,

A = drainage area in acres.

The time of concentration (T.O.C.) is the time required for overland flow to reach the drainage inlet or other point of concentration from the farthest extremity of the drainage area.

quacy of design methods, it appears worthwhile at this time to attempt a comparative evaluation of the Rational Formula and the Army Method. This study is based primarily on data published by the Corps of Engineers,[2] and also includes previously unpublished data from the Rome, Georgia drainage project of the Civil Aeronautics Administration.

The Rome project was started in 1945, as the initial project of a comprehensive airport drainage study. Due to budgetary limitations the Rome project was curtailed long before its planned completion, and the expansion of the program to other sites was never realized. Although the Rome data are too limited to support any conclusions by themselves, they are presented as an addition to the available knowledge on the subject.

THE ROME DRAINAGE PROJECT

Description of Site

Russel Field, Rome, Georgia is located at latitude 34° 20' N, longitude 85° 10' W, in a rolling foothill section in the northwestern corner of the state. The Department of Agriculture soil classification describes the prevailing surface soil as Colbert Silt Loam with smaller areas of Shackelton Gravelly Loam. The soil is derived from the weathering of interbedded shale and limestone, and is found on relatively flat tableland areas in an otherwise rolling topography. The subsoil is dense and plastic with poor natural drainage.

During construction heavy cuts were made in the center of the field and the excavated material was used for embankment at the borders of the field area and at the ends of runways. As a result, none of the original surface soil was used in place.

Description of Drainage Plots

Six areas were selected for rainfall and runoff measurements. Boundaries were fairly well defined by definite grade breaks and by low dikes constructed on the unpaved portions. Fig. 1 is a plan of Russel Field showing the locations of the drainage plots. Individual plot details and the locations of measuring equipment are shown in Figs. 2, 3 and 4. Note that Area A includes three subareas joined by pipes, and Area B includes two subareas. Runoff measurements were not made for individual subareas, however, although the combined runoff from Subareas A_1 and A_2 was recorded.

The paved, unpaved and total areas for each plot are given in Table I. The size of plots ranges from 2.36 acres for Area F to 10.72 acres for Area A. The proportion of paved area varies from 23 per cent on Area D to 34 per cent on Area A.

All of the unpaved areas had been seeded to Bermuda and Red Top about one year prior to the start of the project. At the start of operations, in the summer of 1946, all areas had a very thin stand of grass and weeds. At the close of operations Areas A, E and F still had only a sparse cover, Area B had about 25 per cent cover, and Areas C and D had about 50 per cent of good grass cover. All grass was cut in the spring of 1946, prior to the start of project operations, and was not maintained further throughout the life of the project. Fig. 5 is a photographic view of the field showing the generally bare condition at the beginning of the project.

Equipment

The measuring and recording equipment installed for each area is listed in Table II, and the elevations of drainage structures are given in Table III. All equipment was of standard manufacture and of types in general use.

The recording rain gages were Friez Survey Type, Model 775-B. A gage was placed near each drainage area in order to record local fluctuations in rainfall. One control recorder was located adjacent to the nonrecording standard Weather Bureau rain gage. The local office of the Weather Bureau co-operated in the operation of the gages, and furnished hourly precipitation readings throughout the term of the project.

All drainage flows were measured by Type H sheet-metal flumes of the type used by the Soil Conservation Service, except the combined flow of Subareas A_1 and A_2 which

[2]"Report on Drainage Verification at Military Establishments," June 1947, hereinafter referred to as the Army Report. This report includes data from airfields in Ohio, Indiana and Kentucky.

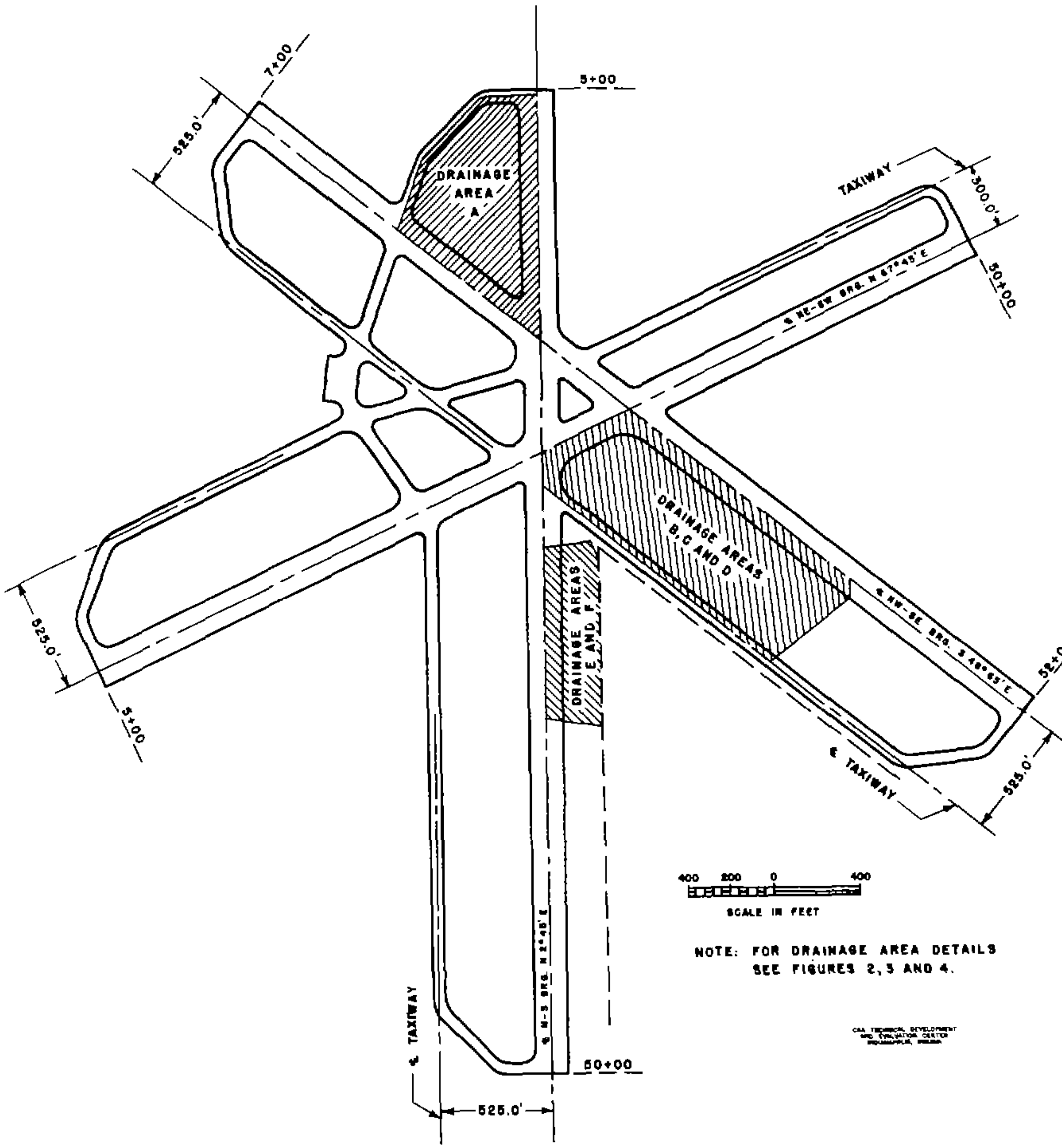

Fig. 1 Plan of Russel Field

was measured by a Parshall flume. The flumes were precalibrated and automatic flow records were obtained through the use of Friez Model FW-1 portable water-level recorders. The latter type of instrument also was installed at inlet basins in order to record any ponding which might occur.

Operation

Routine operations involved replacing and checking recorder charts, inspecting and repairing dikes, and removing sediment from the float wells. When rain gage charts were removed from the recorders the water in the collection bucket was measured and checked

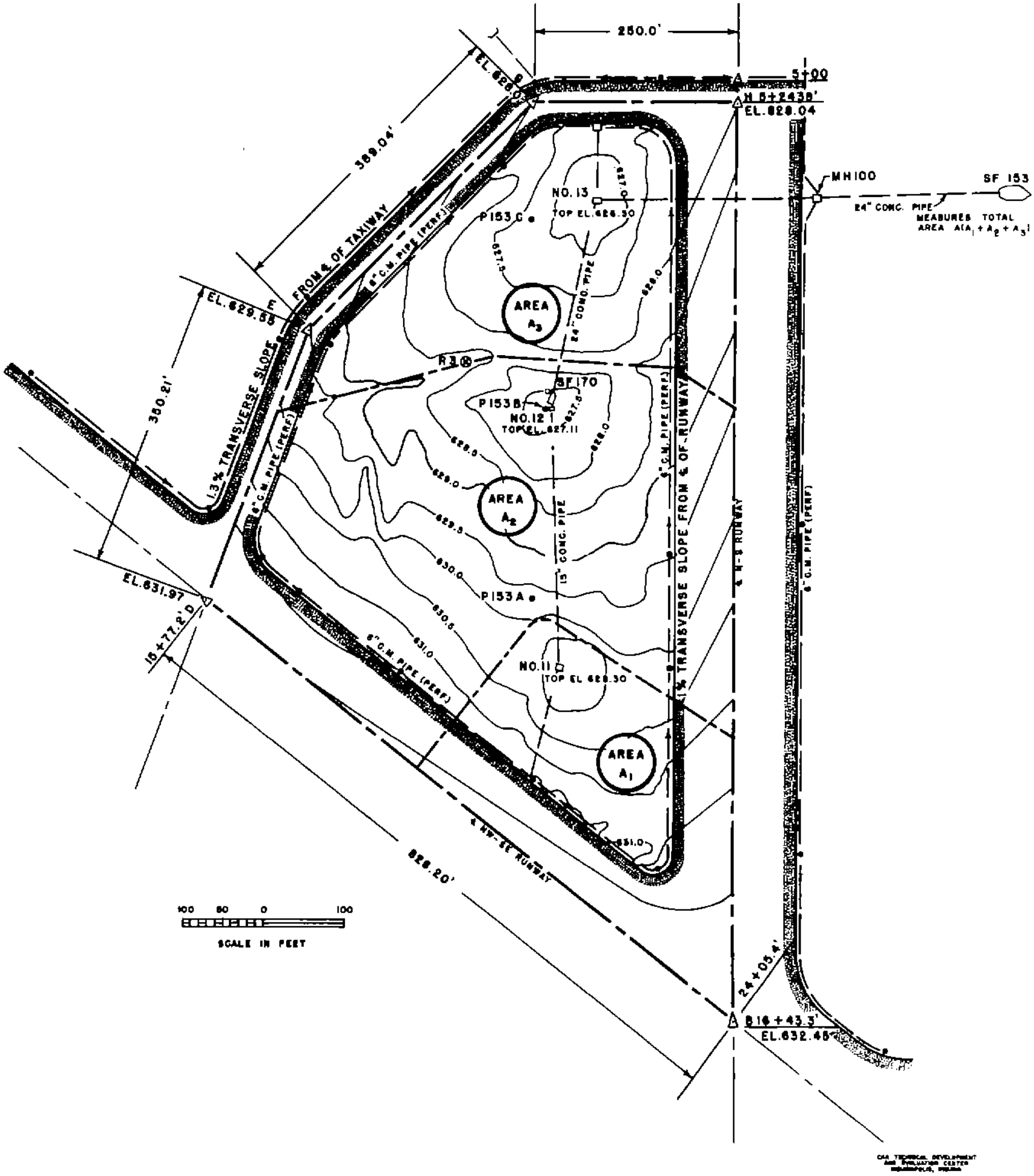

Fig. 2 Detail of Drainage Area A ($A_1 + A_2 + A_3$)

against the recorded value. Very few corrections were required. Any snow found on the receiver was melted and added to the collection bucket. The snowfall at this locality is insufficient to affect precipitation or runoff values appreciably.

The principal operating difficulties encountered were: (1) lack of dimensional

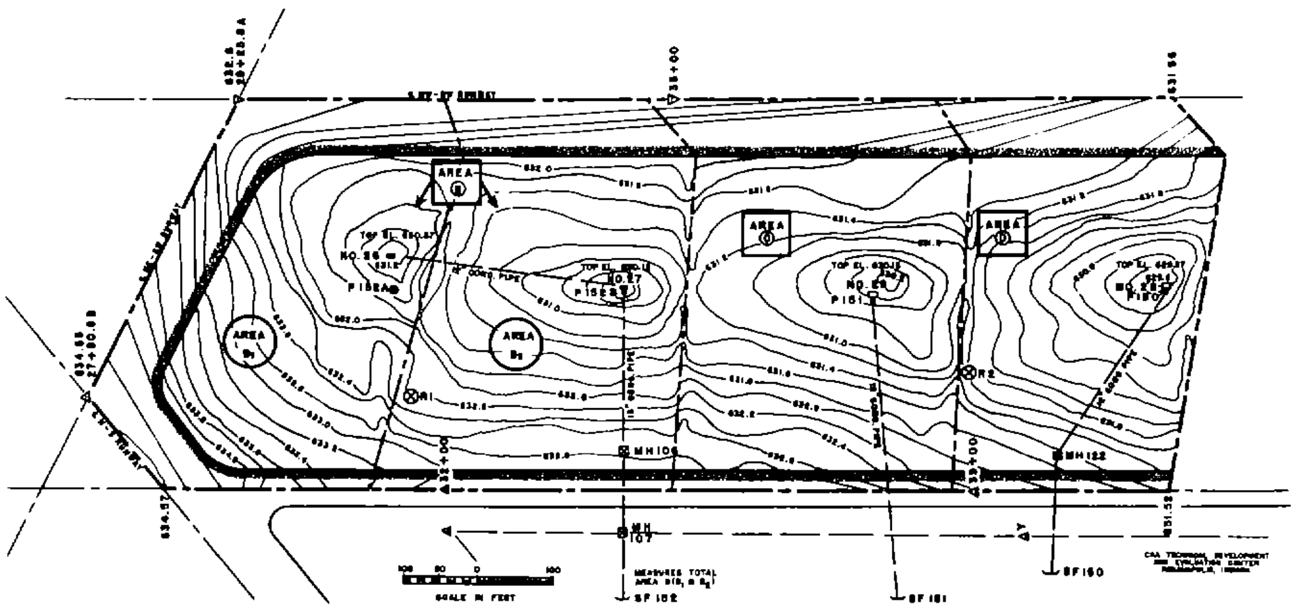

Fig. 3 Detail of Drainage Areas B ($B_1 + B_2$), C and D

stability of the paper charts, (2) a variation in inking characteristics with changing humidity, (3) vibration of the recorders due to high winds, (4) wetting, due to rain, and (5) accumulation of foreign matter in the float wells of the water-level recorders. The dimensional stability and inkability of the charts were greatly improved by the use of a Roscolene mat, a commercial material normally used for pencil tracings. The recordings were made directly on this material which, being transparent, could be placed over the original chart from which the background scale could easily be read.

Many early records were lost due to the operational difficulties previously mentioned and due to irregular maintenance schedules, but such losses were gradually reduced to a minimum.

Area A was equipped first. The first usable record from this area was from the storm of October 25, 1946, and the last was on June 20, 1947. Due to operational difficulties and the early curtailment of the project the data from Area D cover only a 3-month period and those from Area E only five months. Only one usable record was obtained from Area B and none from Areas C and F.

Results

The basic data from the Rome project are given in Appendix I. The rainfall and runoff records are displayed graphically in Figs. 1 to 30, and precipitation preceding each storm is shown in Table I. It will be noted that the horizontal and vertical scales of the graphs of rainfall and runoff are not the same for all figures; these having been varied for the sake of clarity and convenience of presentation.

No unusually heavy storms were recorded. For instance, the heaviest 1-hour rainfall on Area A was 1.3 inches whereas the maximum to be expected each two years is 1.6 inches. Due to the relatively light rainfall no ponding occurred.

COMPARATIVE EVALUATION OF RATIONAL FORMULA AND ARMY DESIGN METHOD

In designing bridges and certain other structures whose failure might cause loss of life or heavy property damage, the design engineer commonly introduces a large factor of safety by assuming the worst possible combination of loading conditions and then assuming a strength of material which is only a fraction of the ultimate strength of the material used. If this same approach were used in drainage design, any commonly used runoff formula or method would be adequate. The resulting designs, however, might be so expensive that it would be cheaper in the long run to suffer

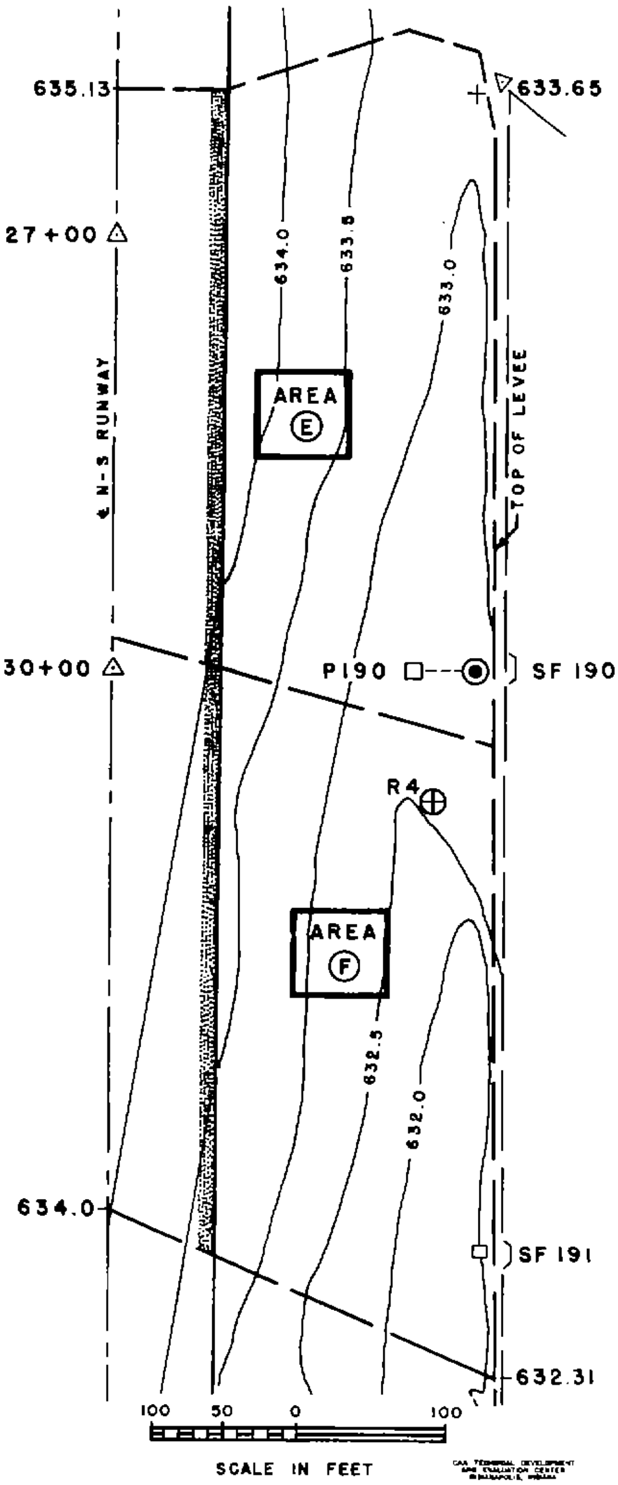

Fig. 4 Detail of Drainage Areas E and F

the operational inconveniences and the maintenance costs caused by occasional flooding.

For this reason the drainage engineer commonly designs on the basis of a calculated risk rather than a factor of safety. The design storm selected is one which on the average may be expected to be exceeded in intensity once in a given period of time - usually two or five years on airport drainage design. By assuming an average or median condition with respect to other factors affecting runoff, the designer may expect the capacity of his drainage structure to be exceeded with the same average frequency. If sufficient field data are available, therefore, it is possible to evaluate a method for estimating runoff by a simple statistical check as to whether the occurrence of excessive runoff followed the same pattern as the occurrence of excessive rainfall. This is the basis of evaluation used in this report.

The data from 113 storms used in the analysis have been summarized in Tables II to X of Appendix I. Some of the storms are indicated as "secondary storms," which simply means that they were associated closely with a burst of rainfall producing a higher rate of runoff. They were included primarily for the purpose of studying the effect of ground saturation prior to the rainfall. The basic data from the Army tests have been reported in detail in Appendices II and III of the Army Report[3] to which the reader is referred for any further information on that series of tests.

Three areas from the Rome project and six areas from the Army tests have been included in this study. These areas represent a fairly wide range of size (0.7 to 72.8 acres) and surface texture (100 per cent paved to 100 per cent sod). Geography, climate, soil type, and surface slopes do not vary widely enough to be considered primary factors.

Area Rome-B was omitted, as the record of a single storm would have little significance in this study. Subareas A_1 plus A_2 were omitted as being largely a duplication of Area A. Area St. Anne-2 of the Army Report was not used as the report stated that this plot was subject to overflow from other areas during the heaviest storms.

Area C at Lockbourne Field was included but the runoff records from this plot were adjusted to a compromise value between

[3]See footnote 2.

TABLE I

Description Of Drainage Areas
Rome, Georgia Project

Area A ($A_1 + A_2 + A_3$)

Sub Area A_1	
Bituminous Paving	1.24 A
Unpaved	1.07 A
Total	2.31 A
Sub Area A_2	
Bituminous Paving	1.39 A
Unpaved	3.90 A
Total	5.29 A
Sub Area A_3	
Bituminous Paving	0.98 A
Unpaved	2.14 A
Total	3.12 A
Total Area A	
Bituminous Paving	3.61 A
Unpaved	7.11 A
Total	10.72 A

Area B ($B_1 + B_2$)

Sub Area B_1	
Bituminous Paving	1.68 A
Unpaved	2.70 A
Total	4.38 A
Sub Area B_2	
Bituminous Paving	0.95 A
Unpaved	3.42 A
Total	4.37 A
Total Area B	
Bituminous Paving	2.63 A
Unpaved	6.12 A
Total	8.75 A

Area C

Bituminous Paving	1.06 A
Unpaved	3.56 A
Total	4.62 A

Area D

Bituminous Paving	0.88 A
Unpaved	3.01 A
Total	3.89 A

Area E

Bituminous Paving	0.67 A
Unpaved	1.87 A
Total	2.54 A

Area F

Bituminous Paving	0.62 A
Unpaved	1.74 A
Total	2.36 A

the records from Area C and those from Area F. Areas B to G at Lockbourne are contiguous and are practically identical in size, shape, and surface contour. Each is served by a separate inlet, but runoff measurements were made only for C and F. Records for the heavier storms consistently show a higher volume of runoff and a higher peak rate of runoff from Area F. It has been assumed that this was caused by partial bypassing of inlets for Areas C, D and E. On this basis, the runoff figures for Area C were increased by one third of the difference between the figures for C and F. Only those storms were used for which records of both areas were available. Admittedly this adjustment is somewhat arbitrary and further study indicates that it may not have been justified. This will be covered in later discussion.

Prior to the actual tabulation of data from the study areas, estimates of runoff were prepared by both the Rational Formula and the Army Method. These estimates were prepared by the senior author from detail descriptions, photographs, and sketches of the drainage areas, and from a general knowledge of the localities involved. None of the sites was visited.

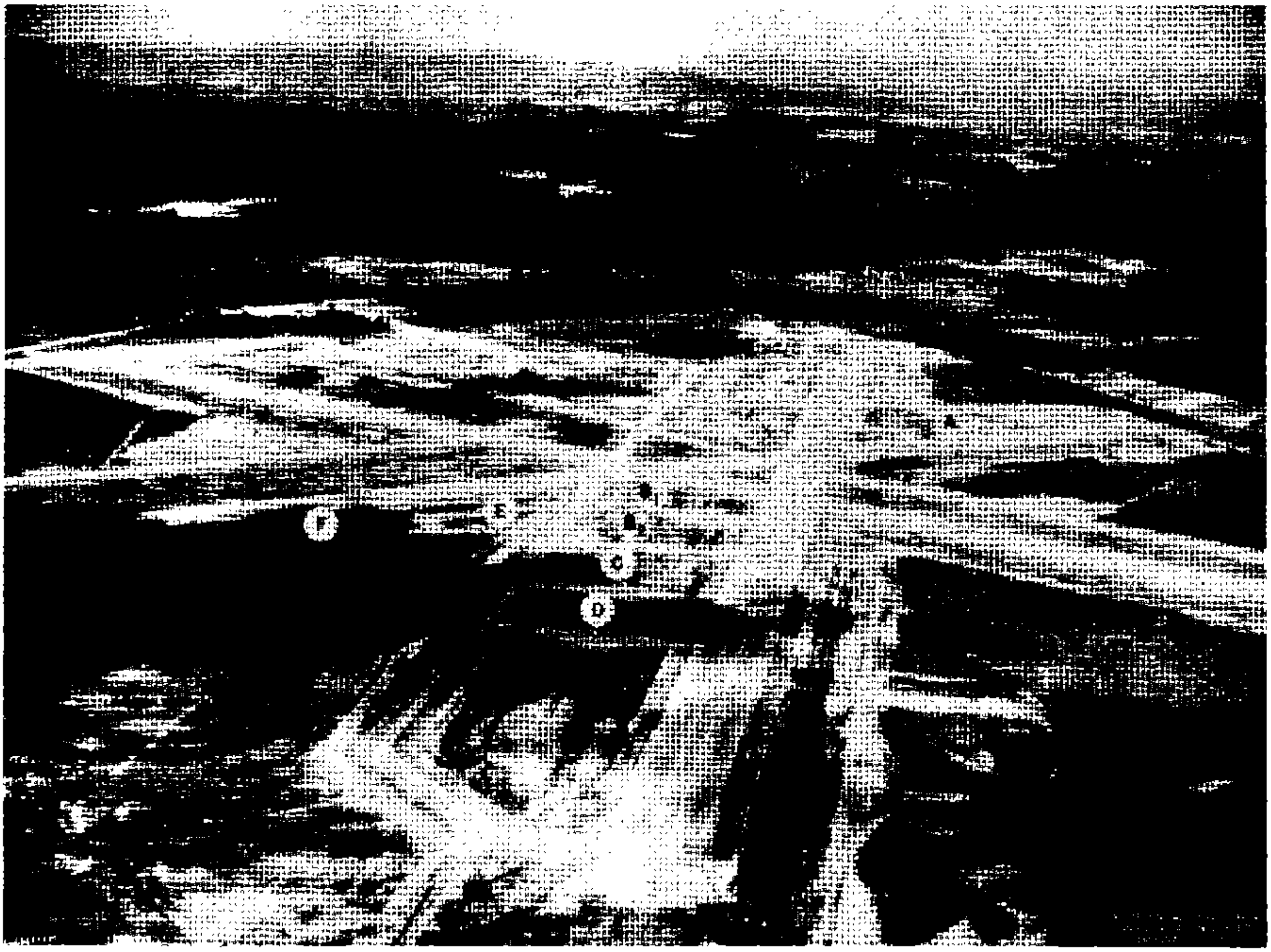

Fig. 5 Photographic View of Russel Field, May 1946

The runoff coefficients (C) for use in the Rational Formula were estimated purely on the basis of experience. The estimated times of concentration follow quite closely those given by the graphs in Fig. 12, Page 13, of "Airport Drainage" published in 1946 by the Civil Aeronautics Administration. The design rainfall rates were taken from the Department of Agriculture publication "Rainfall Intensity - Frequency Data" by Yarnell. The rainfall rates to be expected once in two years were used as this period of time corresponded closely with the average length of record (22 1/2 months) for the areas under study.

In estimating runoff by the Army Method, values for the effective length L, slope S, and roughness factor n applicable to the various areas on Freeman Field, St. Anne Field, Godman Field and Lockbourne Air Base were taken from Table 22, Page 193, of the Army Report. Values for the Rome areas were assumed by the authors on the basis of instructions given in Part XIII, Chapter 1, of the "Engineering Manual" of the Corps of Engineers.

Table IV compares the 10-minute and 1-hour rainfall rates taken from Yarnell's 2-year expectancy curves with those actually measured in the tests. At least the three heaviest storms are recorded for each area. With an average recording period of almost two years on nine different areas one might logically expect the assumed rainfall rate to be exceeded eight or nine times, with one storm approaching the 20-year rate. Actually, the 10-minute rate was exceeded 11 times and the 1-hour rate 8 times on the 9 areas. The normal 2-year expectancy for both the 10-minute and 1-hour rainfall was exceeded by about 75 per cent in the heaviest storm. This

TABLE II

Equipment Installed In Each Drainage Area
Rome, Georgia Project

Area A ($A_1 + A_2 + A_3$)

No.	Structure
SF153	3'-0" Deep Type H Flume & Recorder
I1	Inlet
P153A	Pond Level Recorder
I2	Inlet
P153B	Pond Level Recorder
R3	Rain Gage
SF170	Parshall Flume 1.0' x 2.5' Throat
I3	Inlet
153C	Pond Level Recorder

Area B ($B_1 + B_2$)

26	Inlet
P152A	Pond Level Recorder
27	Inlet
P152B	Pond Level Recorder
R1	Rain Gage
SF152	2.5' Type H Flume & Recorder

Area C

29	Inlet
P151	Pond Level Recorder
SF151	2.5' Type H Flume & Recorder

Area D

28	Inlet
P150	Pond Level Recorder
R2	Rain Gage
SF150	2.5' Type H Flume & Recorder

Area E

P190	Pond Level Recorder
SF190	2.5' Type H Flume & Recorder

Area F

SF191	2.5' Type H Flume & Recorder
R4	Rain Gage

is roughly equivalent to the 20-year expectancy.

The data from these field tests tend to confirm the statistical accuracy of Yarnell's predictions. They also emphasize the extreme variability in rainfall rates, even between points in one small geographic area.

The rates of runoff to be exceeded once in two years, as estimated by the Rational Formula, are given in Table V. This table also shows the assumed times of concentration, rainfall rates and runoff coefficients upon which the runoff estimates were based. The maximum instantaneous rates of runoff observed during the tests are included for comparison.

The estimated runoff rates were exceeded a total of seven times, and the maximum excess was 80 per cent. The recorded measurements on these areas thus agree very well with the assumed expectancies. The frequency of excess runoff also corresponds quite well with the frequency of excessive rainfall. It would appear, therefore, that the Rational Formula can be used with a considerable degree of confidence in its overall accuracy.

The 2-year maximum runoff rates obtained by the Army Method are shown in Table VI. The values of roughness factor, effective length, slope, rainfall and rate of supply upon which the runoff computations were based are listed also. No allowance was made for the effects of temporary pipe or channel storage as it was believed that these would be ignored in a practical design problem covering these areas.

The equivalent length of overland flow for Area Freeman-D is outside the limits of the charts given in the "Engineering Manual." The runoff rate for this area was extrapolated from the charts as accurately as possible as it did not appear that the added accuracy would justify the labor of computing it from the basic equation. Due to the fact that Area Rome-A is composed of three subareas joined by pipes it was necessary to compute the subareas separately and combine the results.

The maximum instantaneous rates of runoff recorded for each area, and already shown in Table V, are repeated in Table VI for ready comparison with the estimated values. Estimated rates of runoff were exceeded in eight instances. The statistical agreement with the number of anticipated floods therefore is very good. The overall quantitative agreement between estimated and recorded peak rates of runoff is not as good as those obtained with the Rational Formula. The apparent superiority of the Rational Formula in this

TABLE III

Drainage Structure Elevation Data
Rome, Georgia Project

Structure No.	From	To	Top Elev.	Invert Elev. Inlet	Invert Elev. Outlet
11	---	12	629.30	---	625.0
12	11	13	627.10	622.65	622.33
13	12	MH100	626.50	619.24	612.30
MH100	13	SF153	627.22	611.33	611.33
SF153	MH100	---	---	610.46	611.70*
26	---	27	630.87	---	628.19
27	26	MH106	630.12	626.52	626.08
MH106	27	MH107	632.49	626.05	626.05
MH107	MH106	SF152	632.46	624.52	624.52
SF152	MH107	---	---	624.26	623.04*
29	---	SF151	630.13	---	619.70
SF151	29	---	---	618.26	616.99*
28	---	MH122	629.37	---	626.18
MH122	28	SF150	631.54	624.17	624.17
SF150	MH122	---	---	621.97	620.74*
SF190	---	---	---	631.09	629.63*
SF191	---	---	---	629.95	628.49*

* Tip of Flume

TABLE IV

Occurrence Of Maximum Storms
(Compared to Yarnell's 2-Year Curves)

Drainage Plot	Length of Record	Rainfall Rate (Inches Per Hour) Yarnell 10-Min.	Yarnell 60-Min.	Observed 10-Min.			Observed 60-Min.		
Lockbourne-C	21 Mos.	3.85	1.25	4.26	2.52	1.98	1.10	0.67	0.64
Freeman-B	33	4.00	1.35	6.90	4.50	4.32	2.36	1.36	1.33
				4.14					
Rome-A	8	4.45	1.60	2.52	2.40	1.98	1.30	0.90	0.90
Rome-E	5	4.45	1.60	2.34	2.28	1.45	0.94	0.73	0.48
Rome-D	3	4.45	1.60	2.70	1.80	1.56	0.86	0.75	0.67
Godman-1	32	4.15	1.40	3.12	2.28	2.04	0.95	0.77	0.58
Freeman-A	33	4.00	1.35	4.44	3.72	3.24	2.00	1.49	1.13
St. Anne-1	33	4.00	1.35	4.56	4.26	4.26	1.42	1.41	1.06
Freeman-D	33	4.00	1.35	5.70	5.04	2.94	1.91	1.67	1.33

NOTE - Rates exceeding Yarnell's predictions are underlined.

TABLE V

Runoff Calculations By Rational Formula (2-Year Storm)

Drainage Plot	Assumed T.O.C.	Assumed I In./Hr.	Assumed C	Estimated Max. Runoff Rate In./Hr.	Observed Max. Runoff Rate In./Hr.
Lockbourne-C	10-Min.	3.90	0.95	3.70	5.73
Freeman-B	15	3.25	0.95	3.08	3.86 3.56 3.52 3.31
Rome-A	30	2.65	0.75	1.99	1.32
Rome-E	30	2.65	0.70	1.85	0.91
Rome-D	30	2.65	0.65	1.72	0.60
Godman-1	45	1.65	0.65	1.07	0.56
Freeman-A	30	2.20	0.68	1.50	2.70
St. Anne-1	60	1.35	0.60	0.81	0.94
Freeman-D	60	1.35	0.55	0.74	0.65

NOTE - Runoff rates exceeding the estimate are underlined.

respect is not considered conclusive, and may be due largely to chance or to the authors' greater familiarity with the use of this formula.

USE OF THE RATIONAL FORMULA IN STORM DRAINAGE DESIGN

The preceding section has shown that the Rational Formula can be used successfully in predicting runoff rates provided that the design engineer has sufficient experience and knowledge of local conditions upon which to base his design assumptions. In view of the widespread use of this formula it might be very helpful at this point to review and discuss the field data for the purpose of determining the range of design values most applicable to the reported test conditions and to disclose any trends which might increase the accuracy of assumptions made for other conditions. Each major factor involved in the use of this design method will be discussed separately.

Time of Concentration

It is assumed that the storm producing the highest instantaneous runoff rate from an area is the one which has the highest average rainfall rate over the period of time required for water to flow from the farthest extremity of the area to the point of concentration. The time of concentration obviously should vary with the length of overland flow, the slope of the ground, its surface roughness, and the extent of vegetative cover. These are the parameters used in preparing the graphs for the CAA drainage manual. Other factors of possible importance are the rainfall rate, the nature of the storm (gradually increasing, sudden, intermittent, etc.), the imperviousness of the soil, the degree of previous saturation, the season of the year and the degree of local channelization.

The actual time of concentration for each storm included in this study was determined as closely as possible from the graphs of rainfall and runoff, and the values obtained by one observer have been included in Tables II to X of Appendix I. Selection of the proper values was a very difficult task, and those selected by different observers often varied widely. Even for the same observer there was a wide spread in the values for any given drainage area. This suggests the effect of some of the "other factors" noted previously.

In the belief that the rainfall rate itself might be a major factor in determining the time of concentration, the storms were divided arbitrarily into two groups - heavy and light[4] - and the average values for each group are shown in Table VII.

[4]The heavy storms are those whose intensity equals or exceeds one half the 2-year design storm intensity for the average observed time of concentration for the area under consideration.

TABLE VI

Runoff Calculations By Army Method (2-Year Storm)

Drainage Plot	n	L	S	Equiv. L	Est. 1-Hour Rainfall Rate In./Hr.	Est. Rate of Supply In./Hr.	Max. Est. Runoff Rate In./Hr.	Observed Max. Runoff Rate In./Hr.
Lockbourne-C	0.02	220	0.006	15	1.3	1.3	3.95	5.73
Freeman-B	0.02	840	0.004	70	1.4	1.4	2.75	3.86 3.56 3.52 3.31
Rome-A_1	0.10	230	0.009	65	1.6	1.6	3.15	
Rome-A_2	0.15	350	0.011	125	1.6	1.5	2.45	
Rome-A_3	0.14	220	0.008	90	1.6	1.5	2.75	
Rome-A	(Equals weighted ave. of $A_1 + A_2 + A_3$, with corrections for lag in pipes)						2.60	1.32
Rome-E	0.15	300	0.004	180	1.6	1.5	2.10	0.91
Rome-D	0.30	250	0.010	190	1.6	1.4	1.95	0.60
Godman-1	0.36	570	0.015	420	1.4	1.2	1.10	0.56
Freeman-A	0.36	550	0.009	530	1.4	1.2	1.00	2.70
St. Anne-1	0.20	1685	0.008	960	1.4	1.2	0.70	0.94
Freeman-D	0.40	1200	0.005	1700	1.4	1.0	0.20*	0.65

* Extrapolated value.

NOTE - Runoff rates exceeding the estimate are underlined.

From a study of Table VII it is apparent that the rainfall rate is an important variable in determining the concentration time as the values for the light storms average about 30 per cent more than those for the heavy storms. A study of individual storms also indicates that the time of concentration may be shortened by a high Saturation Factor[5] or by frozen ground and loss of vegetation in winter. These factors are generally secondary to those previously discussed, but in some cases are helpful in explaining results which otherwise seem inconsistent.

The data at hand are not sufficiently extensive to warrant any general conclusion regarding the effect of other variables. If th drainage design provides for definite channeling of overland flow before it reaches the inlet, the concentration time will be the sum of the time for overland sheet flow to the channel plus the flow time in the channel, which should be computed or estimated separately. Local channelization also may occur due to erosion or rutting of the surface. It is not likely to be an important factor except for poorly maintained areas greater than ten acres in extent.

The graphs given in the CAA drainage manual are reasonably adequate for estimatin times of concentration under average conditions for design storms used in the general area covered by this study.

Rainfall Rate

Yarnell's curves of rainfall intensity-frequency data, printed in Miscellaneous Publication No. 204 by the U. S. Department

[5] The Saturation Factor is used in this report as a convenient means of describing the degree of ground saturation immediately preceding a storm. Mathematically, S.F. = Rainfall (in inches) immediately preceding the concentration period, +1/2 Rainfall during preceding 24 hours, +1/4 Rainfall during next preceding 24 hours, +1/8 Rainfall during next preceding 24 hours. The prefixes W, V, S, and F indicate the season during which the storm occurred - W for winter (Dec., Jan., Feb.), V for spring, etc.

TABLE VII

Comparison Of Assumed And Observed Times Of Concentration

Drainage Plot	Assumed T.O.C. Min.	Heavy Storms No. of Observ.	Heavy Storms Ave. T.O.C. Min.	Light Storms No. of Observ.	Light Storms Ave. T.O.C. Min.	All Storms No. of Observ.	All Storms Ave. T.O.C. Min.
Lockbourne-C	10	4	9	3	10	7	9
Freeman-B	15	12	11	11	14	23	12
Rome-A	30	4	43	12	59	16	55
Rome-E	30	1	40	6	46	7	45
Rome-D	30	1	65	4	56	5	60
Godman-1	45	2	55	12	67	14	60
Freeman-A	30	5	37	10	54	15	50
St. Anne-1	60	5	60	10	86	15	80
Freeman-D	60	4	40	8	59	12	50

of Agriculture, have been used quite universally in preparing drainage estimates. Their accuracy is confirmed by the present study. There are certain localities, however, particularly in western states, where the recording stations used by Yarnell were not spaced closely enough to reflect local variations. Any local data available should be considered by the design engineer.

He should remember also that Yarnell's curves or any similar collection of historical data can indicate only the statistical probability of occurrence of any particular storm intensity. Most experienced designers at some time in their career have had the sad experience of witnessing the 25-year or 50-year storm just after completion of a drainage structure based on the 5-year intensity. If prevention of temporary flooding is important, the average expectancy rate for the design storm must be selected accordingly.

Yarnell's data not only include intensity-frequency relationships but also show the monthly distribution of excessive storms. For the areas considered in the present study the curves indicated that almost 80 per cent of the excessive storms would occur in the summer and fall, when runoff rates would be lowest, and less than five per cent in the winter when the runoff rate would be high due to frozen ground and lack of vegetation. The accuracy of this prediction is confirmed by the field data. Of the 55 maximum storms listed in Table IV a total of 42 (76 per cent) occurred during the summer and fall and none occurred during the winter months. All of the storms which exceeded the design rainfall rate were summer and fall rains. This seasonal character of rainfall occurrence must be kept in mind when selecting runoff coefficients and times of concentration for design purposes.

Runoff Coefficient

The runoff coefficient, usually designated as C, is the ratio of the maximum instantaneous runoff rate to the average rainfall rate for the time of concentration. If the runoff rate is plotted against the rainfall rate, the Rational Formula can be represented graphically by a straight line passing through the origin; the slope of the line being equal to C.

Runoff coefficients are assumed to vary widely with surface perviousness, surface roughness, surface slope, degree of saturation and vegetative cover. The latter item is particularly important as the presence of heavy turf increases temporary surface detention and materially reduces the peak runoff rate. This emphasizes again the necessity for considering the season during which the major storms may be expected. Values of C given in Table I of the CAA manual, "Airport Drainage" range from 0.35 to 0.95 for various pavement types, from 0.15 to 0.40 for slightly pervious soils without turf, and from 0.00 to 0.10 for moderately pervious soils with turf.

In using the Rational Formula the numerical difference between C and unity expresses the proportion of rainfall being lost either temporarily or permanently through infiltration, surface detention, depression storage,

TABLE VIII

Comparison Of Runoff Coefficients For Heavy And Light Storms

Drainage Plot	Paved Area Per Cent	Heavy Storms No. of Observ.	Heavy Storms Ave. C	Light Storms No. of Observ.	Light Storms Ave. C	All Storms No. of Observ.	All Storms Ave. C
Lockbourne-C	100	4	1.24	3	1.02	7	1.15
Freeman-B	100	12	0.80	11	0.58	23	0.69
Rome-A	34	4	0.99	12	1.03	16	1.02
Rome-E	26	1	0.78	6	0.65	7	0.67
Rome-D	23	1	0.36	4	0.58	5	0.53
Godman-1	22	2	0.06	12	0.66	14	0.57
Freeman-A	22	5	0.71	10	0.48	15	0.56
St. Anne-1	5	5	0.57	10	0.44	15	0.[illegible]
Freeman-D	0	4	0.29	8	0.25	12	0.26

NOTE - Computations of C were based on average rainfall rate for average time of concentration for all storms on a given area.

etc. The formula states, in effect, that the sum total of these losses is directly proportional to the rainfall rate. This has been attacked vigorously by many, who contend that some of these losses at least are constant in nature and independent of the rainfall rate. This might apply particularly to the infiltration loss.

If this argument is valid, the runoff coefficient for a given area should be less for light storms than for heavy storms; other factors remaining constant. This is confirmed by Table VIII, which shows average values of C for light and heavy storms for each area included in this study. With the exception of Area Rome-A values for the heavy storms are consistently higher than those for the light storms in all cases where there are sufficient observations to give a reasonable average. This applies to both paved and unpaved areas.

It should be noted that the rainfall rates used in computing the runoff coefficients for Table VIII are the average rates corresponding to the average time of concentration for all storms on a given area. If the rainfall rates corresponding to individual concentration periods had been used, the spread in values of C would have been somewhat less.

The previous discussion suggests that the Rational Formula might possibly be modified to the form $Q = C\,(I-b)\,A$, in which b represents the rate of loss which is independent of the rainfall rate. In Figs. 6 to 9 the rainfall versus runoff rates for each storm have been plotted and the runoff equation for each drainage area has been established by using the method of least squares to draw the best straight line through each group of points. Data from three drainage plots were combined to form one graph in Fig. 8 as the physical characteristics of the three areas were similar and since two of them did not have sufficient range in rainfall intensity to establish a definite slope for their graphs.

In all instances except one, the derived equations follow the modified form suggested in the last paragraph, with values of b ranging from 0.02 to 0.43. Rather surprisingly, the single exception is a sodded area (Freeman-D), which has a negative intercept on the horizontal axis. This is due largely to the effect of the unusually high runoff recorded in storm No. 5, which occurred in early spring on a surface highly saturated by preceding rainfall.

In all of the derived equations the intercept is too small to be of practical significance in studying the heavier rainfalls ordinarily used in design problems for the general area covered by this study. No significant error should result from establishing design values of C by averaging values computed from runoff records, provided that the intensities of the recorded storms are even one half that of

TABLE IX

Recommended Values Of Runoff Coefficient
(For slopes of 1/2 to 1 1/2 per cent and temperate climate)

1-Hour Rainfall Rate	Season	Portland Cement or Asphaltic Concrete	Slightly Pervious Soils		
			Bare Earth	Fair Turf	Good Turf
1.5 - 3.0	Winter	0.95 - 1.15	0.85 - 1.05	0.70 - 0.90	0.50 - 0.70
	Spring	0.90 - 1.10	0.80 - 1.00	0.65 - 0.85	0.40 - 0.60
	Summer	0.85 - 1.05	0.75 - 0.95	0.60 - 0.80	0.25 - 0.45
	Fall	0.85 - 1.05	0.75 - 0.95	0.60 - 0.80	0.25 - 0.45
0.5 - 1.5	Winter	0.90 - 1.10	0.80 - 1.00	0.65 - 0.85	0.45 - 0.65
	Spring	0.85 - 1.05	0.75 - 0.95	0.60 - 0.80	0.35 - 0.55
	Summer	0.80 - 1.00	0.65 - 0.85	0.50 - 0.70	0.20 - 0.40
	Fall	0.80 - 1.00	0.65 - 0.85	0.50 - 0.70	0.20 - 0.40
0.2 - 0.5	Winter	0.75 - 0.95	0.60 - 0.80	0.50 - 0.70	0.30 - 0.50
	Spring	0.70 - 0.90	0.55 - 0.75	0.40 - 0.60	0.20 - 0.40
	Summer	0.65 - 0.85	0.50 - 0.70	0.35 - 0.55	0.10 - 0.30
	Fall	0.65 - 0.85	0.50 - 0.70	0.35 - 0.55	0.10 - 0.30

the design storm. It would be incorrect, of course, to select values for very high rainfall rates on the basis of experience with low-intensity storms, or vice versa.

Study of the data included in this report does not justify any change in the basic form of the Rational Formula. The effects of large variations in rainfall rates must be kept in mind, however, in selecting runoff coefficients and estimating times of concentration.

It has been the experience of the authors that runoff coefficients recommended and used for design purposes often are dangerously low. This might be explained on the theory that the Rational Formula probably originated as a volume formula and later was converted to a rate formula simply by dividing both sides of the equation by a time factor. It is quite evident that the proper coefficient for determining the volume of runoff from a watershed, or the average runoff rate over a considerable period of time, would be much lower than that for determining the maximum instantaneous runoff rate.

There is another possible explanation for the low values of C often given in engineering handbooks. There are certain factors, such as the short duration of peak runoff rates and the leveling effect of ponding, pipe storage and channel storage, which often operate to prevent disastrous results from underestimation of runoff coefficients. It is entirely possible that, consciously or unconsciously, an effort has been made to incorporate these factors into the design tables.

This should be discouraged. Selection of a proper runoff coefficient is difficult enough at best, and should not be complicated by introducing extraneous factors. After the estimate of maximum instantaneous runoff has been made the designer still can make allowances for ponding, temporary storage or temporary flooding if such allowances actually are justified by the existing circumstances.

The average runoff coefficients computed from field data and listed in Table VIII are substantially higher than those given in most engineering handbooks for similar conditions. Having been computed directly from discharge measurements, they already have made allowances for any temporary storage which existed. One should remember also that these coefficients apply generally to summer and fall rains when the runoff rate should be lowest. Based on these tests and the drainage experience of the authors, it is recommended that values given in Table IX be used for design purposes.

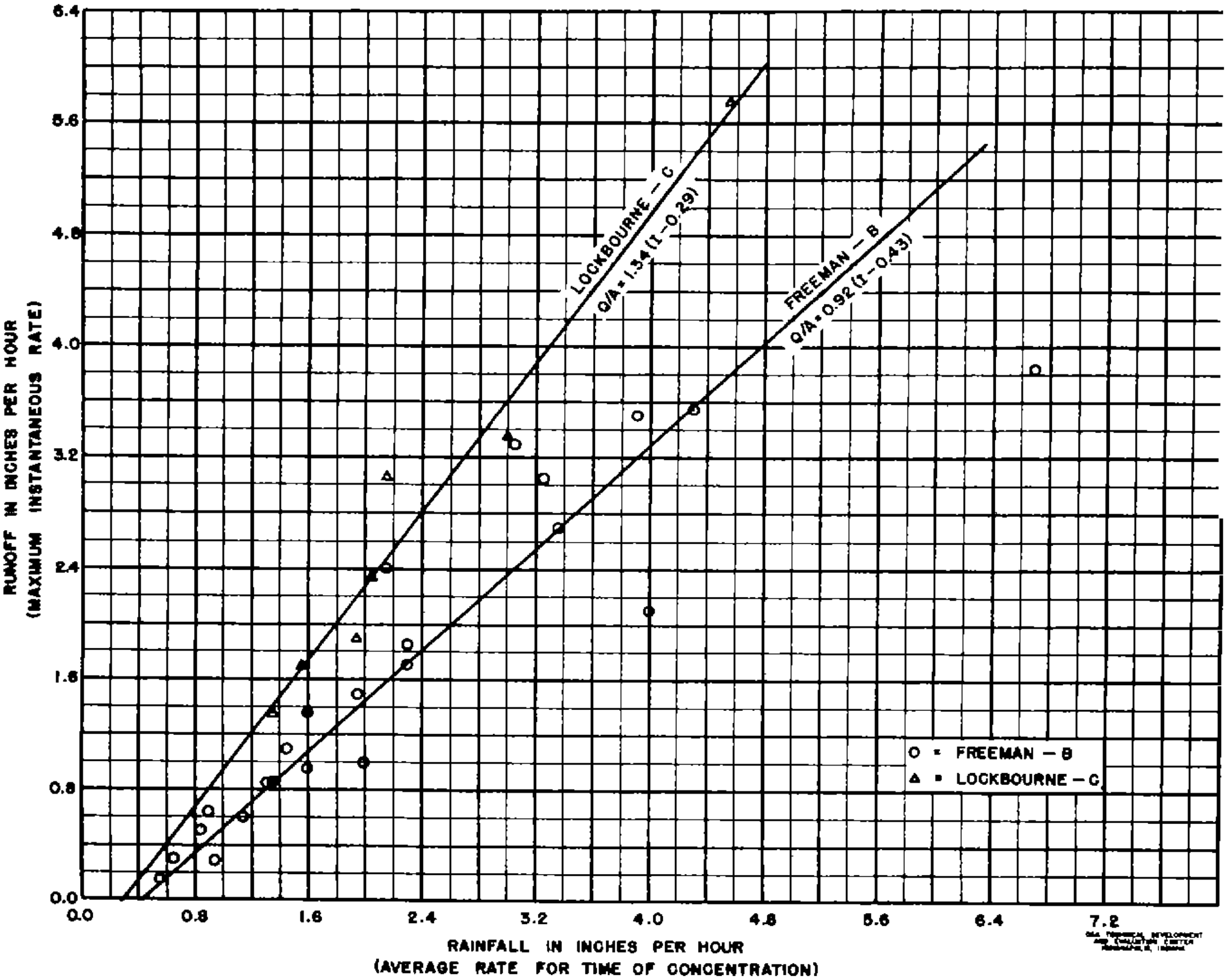

Fig. 6 Runoff Equations Determined from Field Data

In Fig. 10 the runoff rates for individual storms estimated by use of this table are compared graphically with those recorded in the field data.

The estimated values are based on the rainfall rate for the average time of concentration, which tends to make the estimates for the heaviest storms a little low and those for the lightest storms a little high. The scatter among the plotted points is caused primarily by individual variations in soil saturation, vegetative cover, and other factors which cannot be covered in a general table. The Saturation Factor is particularly important. The shape of the runoff curve and the momentary peak rate of runoff also are affected by the distribution of rainfall throughout the period of concentration.

The estimated values for Area Lockbourne-C are generally below the straight line which represents perfect agreement between estimated and computed values, while those for Freeman-B are generally too high. These consistent differences between twc paved areas cannot be explained satisfactorily on the basis of accidental variations of storm conditions but there are other possible reasons for them.

The reader will recall that the recordec runoff values used for Area Lockbourne-C were adjusted to a weighted average betwe... the records for Areas C and F. It is entirely possible that the excess runoff recorded for Area F was due only to bypassing of the inlets for Areas D and E, both of which wer smaller than the special one installed for Are

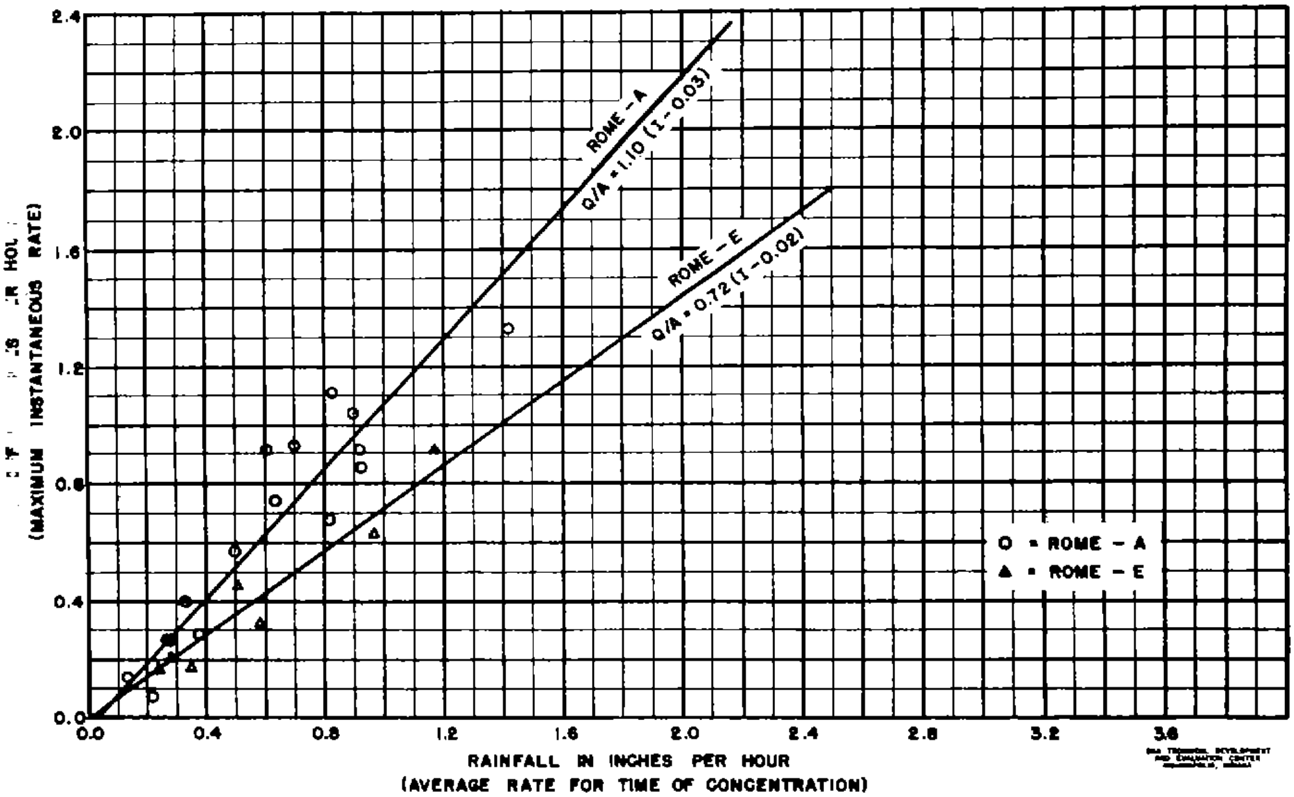

Fig. 7 Runoff Equations Determined from Field Data

C and much smaller than the special one installed for Area F. In that event, the recorded values for Area C should have been ed without correction.

It is possible also that the recorded peak runoff rates for Area Freeman-B were modified somewhat by the small amount of temporary storage available in the collecting trench along the edge of the apron.

Until further confirming data are avail- it seems best to select design values of C for paved surfaces somewhere between the extremes computed for these two areas, with t weight being given to the field data from Freeman-B.

Ponding

Up to this point the discussion has been concerned with the problem of determining the maximum instantaneous runoff rate to be expected from a given design storm. If no ponding capacity is available, and if no temporary flooding can be permitted, the capacity of the drainage lines, inlets and other components of the drainage system must be large enough to handle this peak flow. Due to the very short duration of maximum flow conditions, however, it is possible to achieve substantial economies in design if even a small amount of temporary storage can be provided. This permits the use of a smaller pipe size with a subsequent flattening of the peak of the outflow hydrograph.

The possibilities of economy in this direction may be visualized somewhat by referring to Tables II to X of Appendix I. In addition to showing the maximum runoff rate these tables also give the rate which is maintained for a period of at least ten minutes. For small paved areas, such as Lockbourne-C, the latter rate often is only a third of the maximum.

Although these facts are generally recognized, the Rational Formula provides no direct means of evaluating the effect of ponding on the runoff rate. Some designers have made allowances for this effect simply on the basis of their experience. Others have adopted an arbitrary modification of the formula whereby the right-hand portion of the equation is divided by a number, usually between one and three, which supposedly represents in hours the

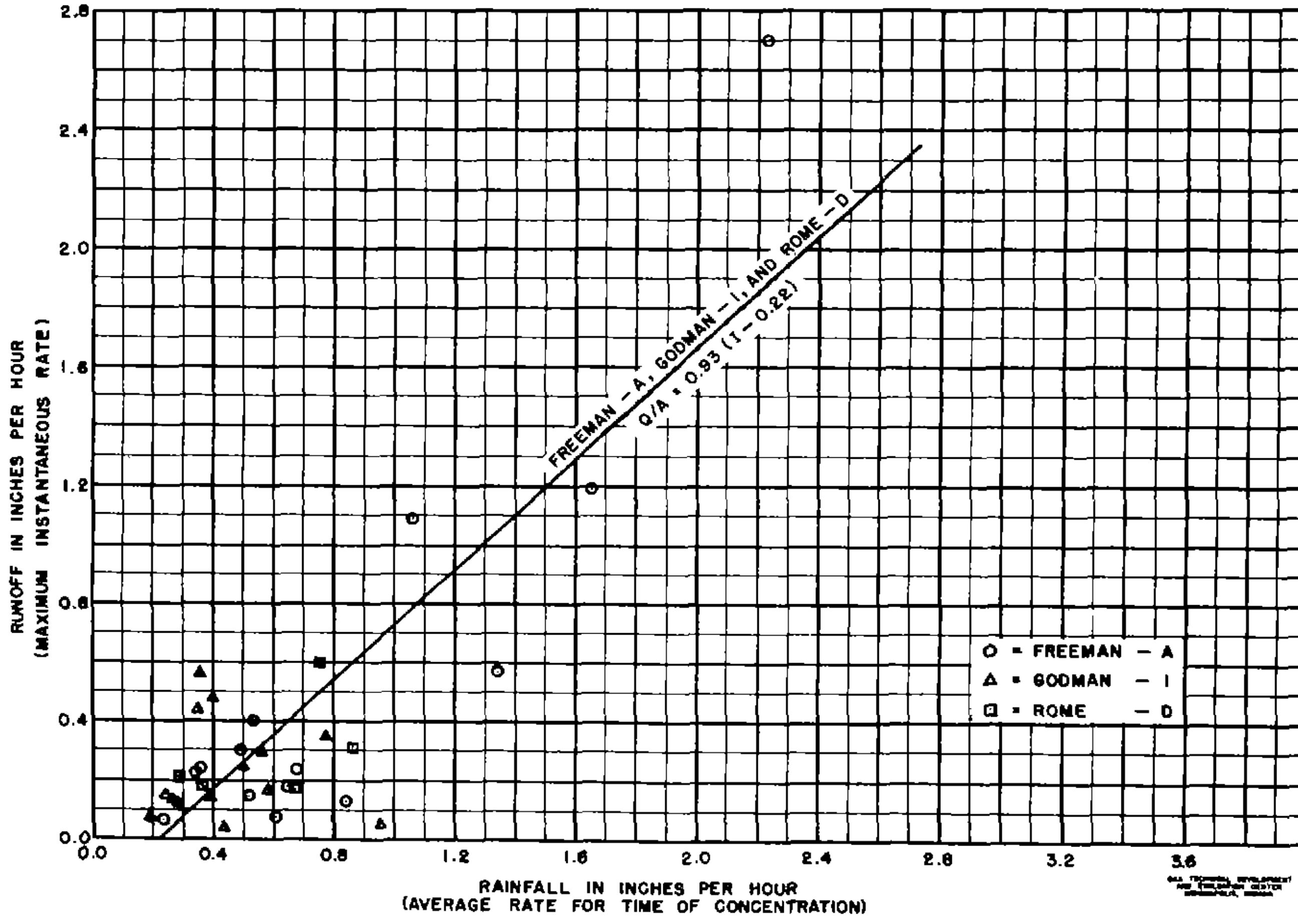

Fig. 8 Runoff Equations Determined from Field Data

total period of rainfall and runoff. This convention has little to recommend it except simplicity. Also, the modified formula sometimes has been used in error where no storage capacity actually exists.

Figs. 11 and 12 are presented as convenient means of estimating the pipe capacity required for any maximum runoff rate in order to stay within the storage capacity available in the ponding area, and to limit the duration of ponding to any given time interval. The relationships shown by these graphs are purely empirical. The parametric curves were established by plotting values computed from the field runoff data, about 70 individual points being used for each set of curves. By expressing storage volume as inches of depth over the drainage area, and runoff and pipe flows as inches of depth per hour, it was possible to eliminate the size of drainage plot as a variable.

It must be recognized, of course, that the values for both storage requirements and duration of ponding will vary quite widely for individual storms, depending upon the shape of the runoff hydrograph. Values obtained from the graphs can represent only an average from which certain particular values may vary by 50 to 100 per cent. Fortunately, in instances where the design provides for ponding there usually is sufficient capacity to allow a substantial reduction in pipe sizes and still leave some margin for such fluctuations.

Fig. 13 shows an alternate method for empirical determination of storage requirements. The curve in Fig. 13 may be expressed by the equation:

$$\text{Storage (in inches of depth)} = \frac{100 - (\text{Pipe Capacity Ratio})}{6\,(\text{Pipe Capacity Ratio})}$$

in which the "Pipe Capacity Ratio" is the ratio of the drain-line capacity to the maximum in-

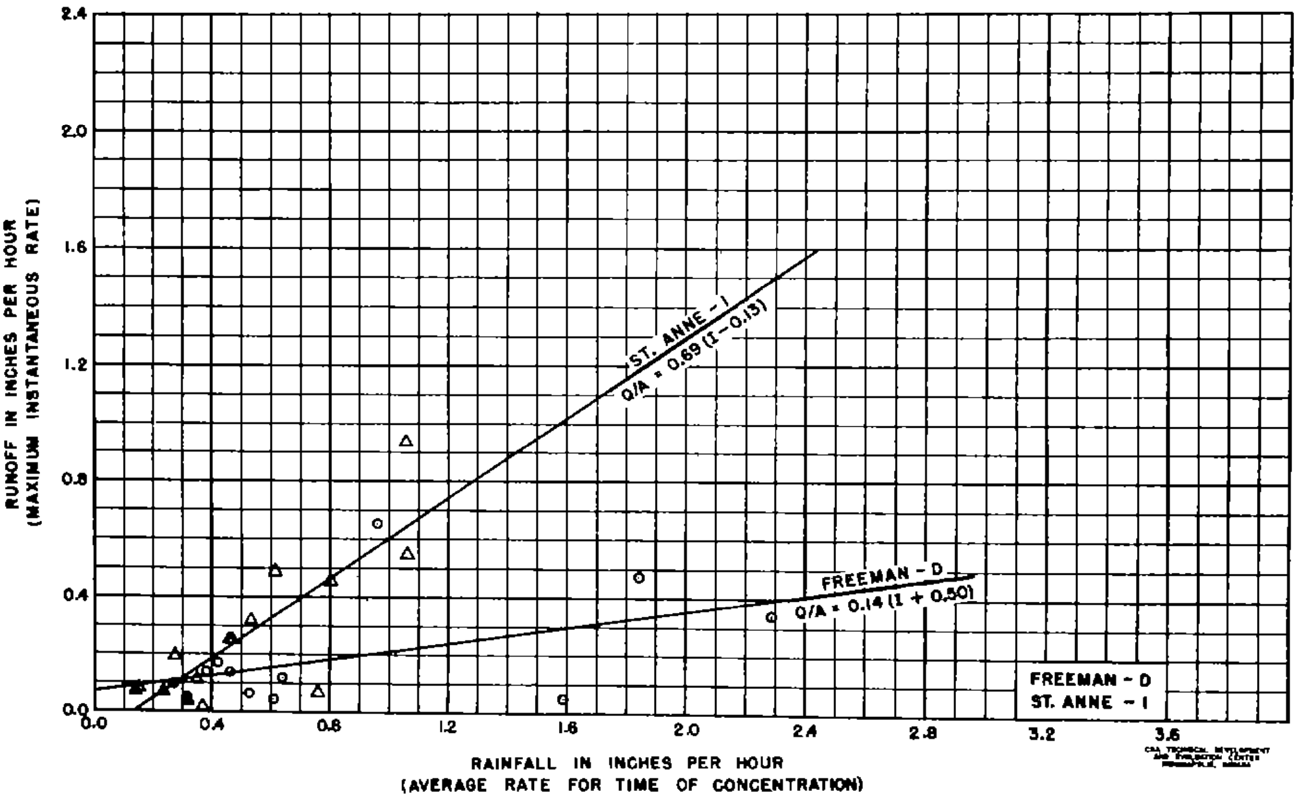

Fig. 9 Runoff Equations Determined from Field Data

stantaneous runoff rate, expressed in per cent. In certain cases this graph is somewhat more simple to use than those given in Fig. 11. Values obtained by this method will vary somewhat from the ones obtained by using Fig. 11, but the overall accuracy in applying them to individual storms is about the same. In a series of over 120 check determinations, using both methods, the maximum error in the pondage estimate was 0.6 inch and the average error was less than 0.2 inch. The greatest amount of pondage actually required in this trial series was 1.6 inches.

Pipe or Channel Storage and Temporary Flooding

The small amount of storage needed to reduce materially the peak flow from a drainage area has been demonstrated in the preceding subsection. Even the comparatively small volume of temporary storage in a pipe line or surface drainage channel can have a noticeable leveling effect on the flow from a small area. On such areas it may be good practice to underdesign deliberately as the small volume involved in the temporary overflow is not likely to cause serious damage or inconvenience. For example, the storm of June 16, 1946, produced an instantaneous runoff rate of 5.73 inches per hour on drainage area Lockbourne-C. Had the drainage line for this area been designed for only 2.00 inches per hour the momentary overflow would have amounted to only 2.6 cubic feet per second, with a total flood volume of about 1,100 cubic feet.

The Army Report mentions, on page 305, a practice which has been used successfully in cases where several drainage inlets are spaced at intervals along a natural or artificial drainage channel. By deliberately underdesigning the pipes connecting these inlets the excess peak flow can be carried along the ground surface to the last inlet. One must take care, of course, that the capacities of the last inlet and the remaining pipe line are ample to handle the total flow, and that the surface flow is not sufficient to cause undue erosion.

Although a designer is justified in utilizing ponding capacity, channel or pipe storage, and temporary flooding in providing an

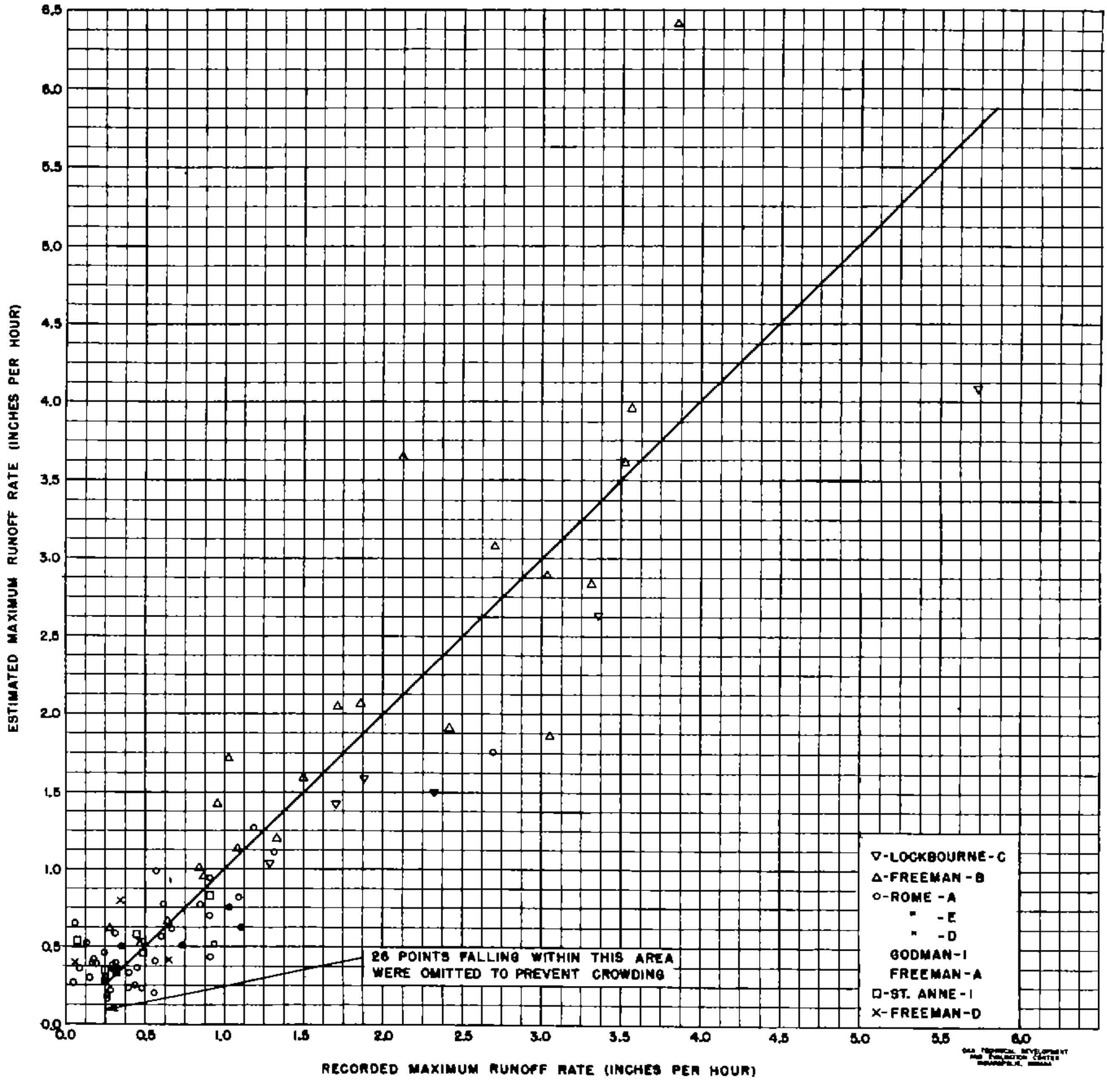

Fig. 10 Recorded vs. Estimated Runoff Rates, Using Recommended Values of C

economical design he also should consider the possible effects of extraordinary storms occurring at times when local conditions are such as to produce exceptionally high runoff. The maximum instantaneous runoff rate from such a storm may be twice that anticipated for the design storm.

Although this is an event which may happen only once in 25 years - or 100 years - there always is the possibility that it may happen tomorrow. The relative frequency of such a combination of circumstances may be determined from Yarnell's tabular data. The careful designer will keep this possibility in mind and will weigh economy of design against the probable damaging effect of such an eventuality. This is particularly important on large areas as the volume of excess runoff is the important factor in considering possible flood damage.

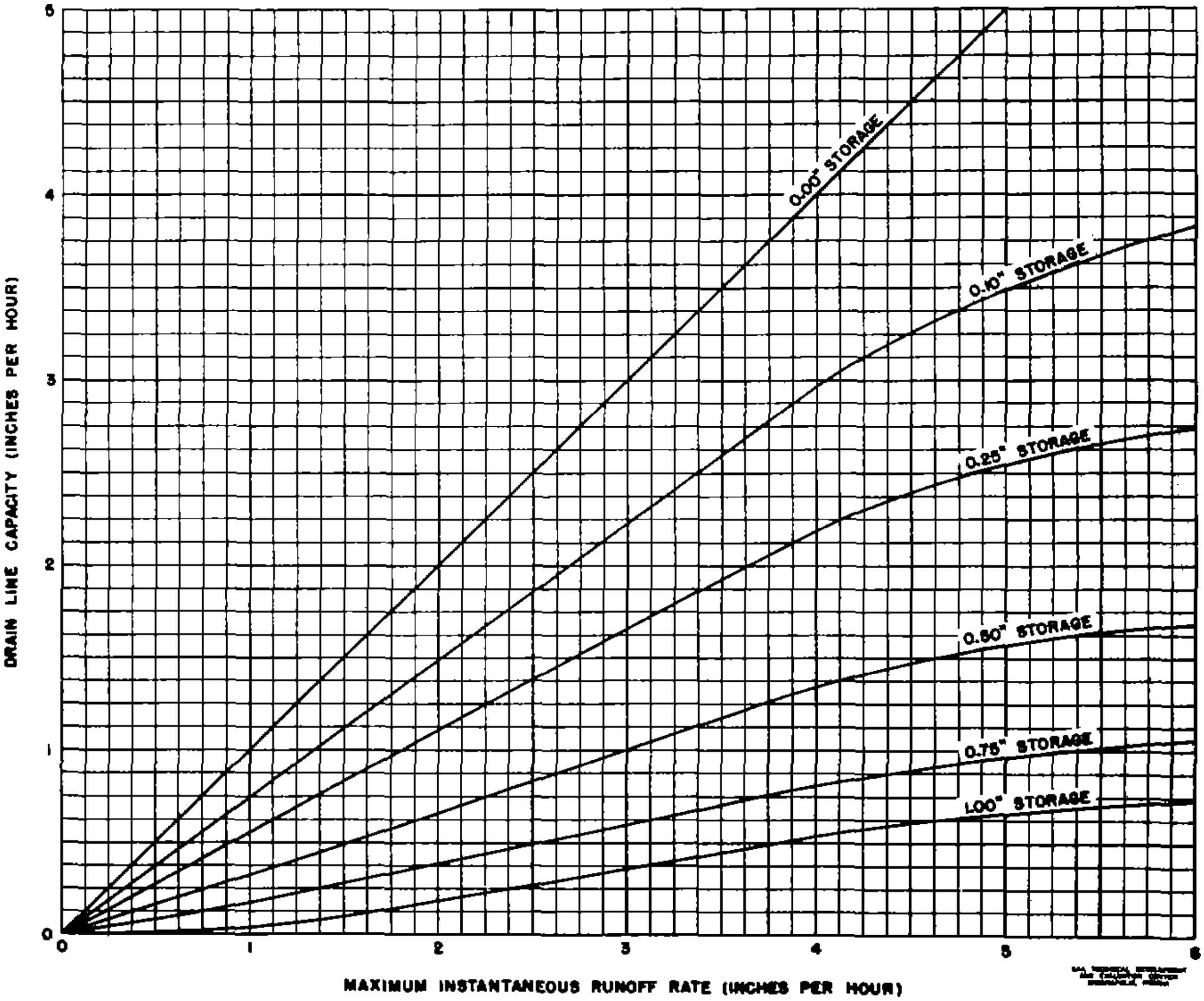

Fig. 11 Graph for Determination of Surface Storage Requirements

Combined Flow from Several Areas

It is a rather common practice to compute the drainage flow from a large area as the arithmetical sum of the maximum flows from its subareas. When one considers the varying times of concentration for the subareas and the varying periods of pipe flow before a common point of concentration is reached it is quite evident that this practice is incorrect. Because of the sharp peaks characteristic of outflow hydrographs of small areas, a time displacement of only a few minutes in these peaks will reduce materially the peak flow from the combined areas. The best practice, therefore, is to estimate a new time of concentration, a new design storm rate, and a new coefficient of runoff for the larger area. An exception to this rule may be made when ponding is provided for the subareas. In such case, the flattened peaks of the outflow hydrographs make possible the direct addition of peak flows without serious error.

Peak Flows from Irregular Areas

There are occasional instances where the peak flow computed for a certain area may be higher than that computed for the larger area of which it is a part. This ordinarily will happen only in the case of an irregular large area with a long concentration period which has a subarea of short concentration

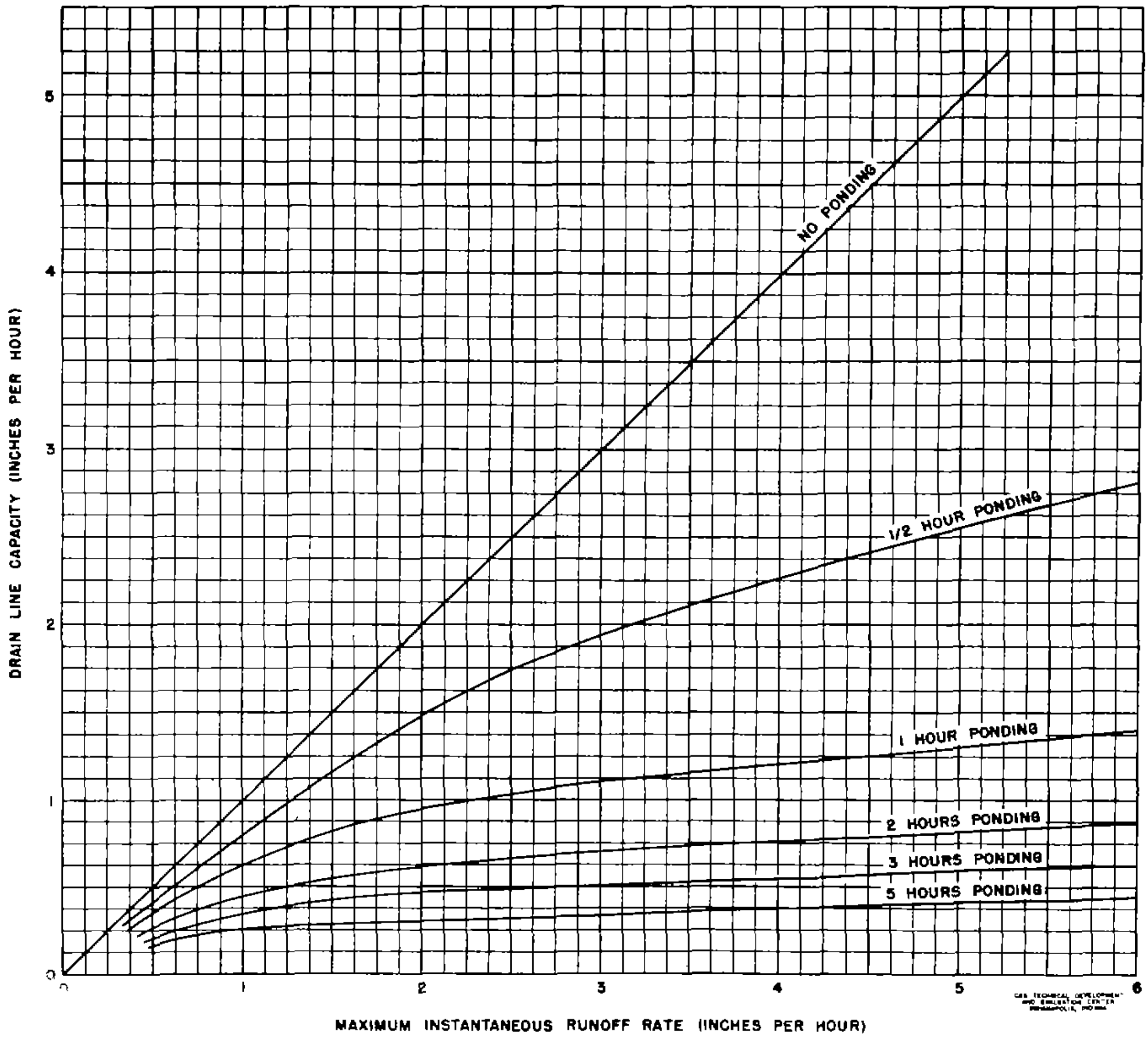

Fig. 12 Graph for Determining Duration of Ponding

time and high runoff coefficient adjacent to the drainage outlet serving the entire area.

Effect of Snow

In areas of heavy snowfall, peak runoff rates and required ponding capacities may be augmented by the simultaneous occurrence of melting snow and rainfall. The field data indicate that this is not a serious consideration in the temperate zone covered by this report. Its effect already is allowed for in the values of C recommended for winter use. More data are needed in order to study its possible importance in more northerly areas.

CONCLUSIONS

This report is not intended to set up a detail design procedure nor to provide a simplified and foolproof method of computing runoff. On the contrary, the authors have attempted to accent the complexity and difficulty of the problem. Through the discussion of available field data an effort was made to evaluate the effect of certain variables and to point out some of the common errors which should be guarded against in airport surface drainage design. The data, although somewhat limited in number and coverage, support

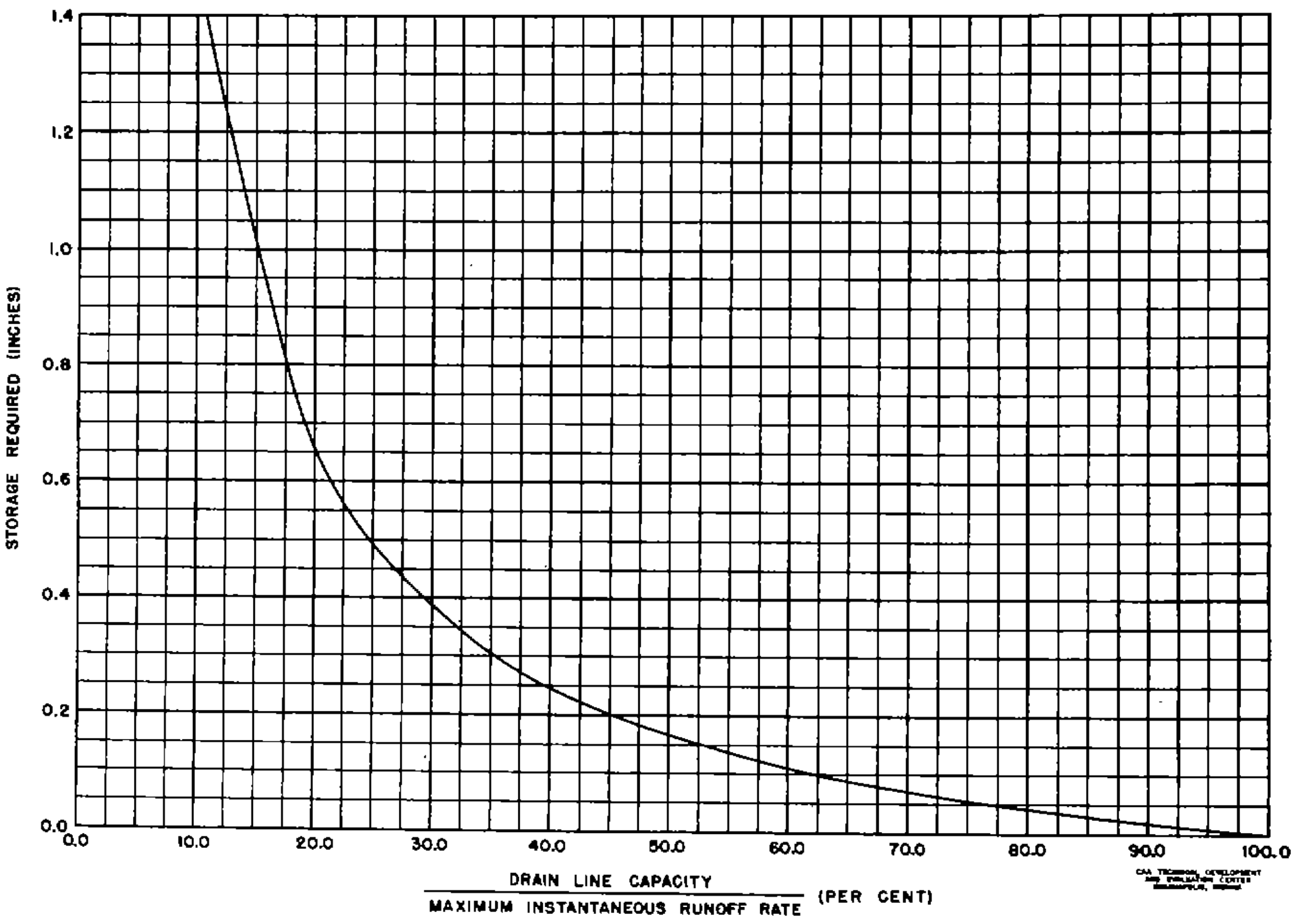

Fig. 13 Alternate Graph for Estimating Surface Storage Requirements

the following conclusions:

1. The statistical accuracy of Yarnell's rainfall intensity-frequency graphs and his charts showing the seasonal distribution of heavy storms has been substantiated.

2. The utility of the Rational Formula and the Army Method in estimating surface runoff has been demonstrated.

3. The graphs given in the CAA drainage manual for determining concentration time are satisfactory for the heavier storms used in design computations for the area covered by this report. For low intensity storms the times of concentration will be considerably longer. Variations between individual storms are large.

4. Runoff coefficients commonly recommended for design purposes are generally too low. New recommended values are given in Table IX. These values are applicable only under the conditions stated.

5. Great economies in design can be effected by providing even a limited amount of ponding, by utilizing temporary channel or pipe storage, or by allowing temporary overflow from small drainage areas.

6. Rough estimates of ponding requirements and duration of ponding can be determined from graphs such as those shown in Figs. 11, 12 and 13.

7. The possible damaging effect of unusual combinations of excessive rainfall and favorable runoff conditions must be considered, particularly on large areas.

8. Runoff from a large area cannot be estimated correctly by adding the estimated rates for the smaller subareas, unless ponding is provided in the subareas, but must be computed on the basis of the concentration time and runoff coefficient applying to the total area.

9. The effect of melting snow can be ignored in the geographic area covered by this report.

10. A large amount of additional runoff data from actual airport installations covering a wide variety of local conditions is urgently needed.

ACKNOWLEDGMENT

This study has been based largely on field data compiled and published by the Corps of Engineers. That organization deserves the thanks of the entire civil engineering profession for making such a wealth of carefully compiled and authoritative data available. The authors also wish to acknowledge their personal debt to Mr. Kenneth Eff, Chief, Airfields Branch, Office of the Chief of Engineers, and to Mr. Arthur E. Scala of the Paving and Soils Branch, Office of Airports, Civil Aeronautics Administration, for their review and constructive criticism of the preliminary draft of this report.

APPENDIX I

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TABLE I

Antecedent Moisture Conditions
Rome, Georgia Project

Storm No.	Date	Total Precipitation in Inches Prior to Beginning of Storm During Period Shown: 6-hr.	12-hr.	1-day	2-day	3-day	4-day
5	10-25-46	0	0	0	0	0	0
7	11-10-46	0	0	0	0	0.02	1.12
15	12-19-46	0	0	0	0.2	0.47	0.47
22	1-11-47	0	0	0	0	0	0.26
25	1-15-47	0	0	0	1.48	1.48	1.48
28	1-30-47	0	0	0	0	0	0
40	3-23-47	0	0	0	0	0	0
46	4-13-47	0	0	0	0	1.15	1.26
47	4-15-47	0	0	0	1.68	2.29	2.29
53	5-20-47	0	0	0.33	0.36	0.36	0.36
58	6-11-47	0	0	0	0	0	0
60	6-20-47	0	0	0	0	0	0

TABLE II

Lockbourne-C - 0.70 Acre - 100 Per Cent Paved

Storm No.		1	2	3	4	5	6	7
Date (Max. Runoff)		5-17-45	6-10-45	6-15-45	6-16-45	5-24-46	6-13-46	6-16-46
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.47	0.10	0.06	0.00	0.00	0.02	0.03
1st Day	in.	0.36	--	--	0.02	--	--	--
2nd Day	in.	0.37	--	0.35	0.56	--	0.03	--
3rd Day	in.	0.11	--	0.98	0.35	0.06	0.05	--
Saturation Factor**		V-0.75	S-0.10	S-0.27	S-0.19	V-0.01	S-0.04	S-0.03
Temp. Range - 3-day	°F	51-81	--	65-91	66-91	46-79	62-90	51-85
Rainfall								
10-min. Max. rate	in./hr.	1.50	1.98	1.86	1.86	1.20	2.52	4.26
T.O.C.* Max. rate	in./hr.	1.53	2.13	1.93	2.06	1.33	3.00	4.54
1-hr. Max. rate	in./hr.	0.67	0.64	0.49	0.31	0.29	0.63	1.10
Total Amt.	in.	1.12	0.75	0.56	0.31	0.29	1.20	1.85
Runoff								
Max. inst. rate***	in./hr.	1.71	3.06	1.89	2.33	1.28	3.36	5.73
Max. 10-min. rate***	in./hr.	0.98	1.23	1.14	0.60	0.48	1.47	1.89
Total***	in.	0.91	0.76	0.50	0.28	0.23	1.05	1.69
Observed Time of Conc.	min.	4	13	10	13	15	4	4
Computed Runoff Co-efficient	per cent	112	145	98	113	96	112	126

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

*** Weighted value = Discharge for Area C ±1/3 diff. between C and F.

TABLE III

Freeman-B - 8.94 Acres - 100 Per Cent Paved

Storm No.		1	2	3	4	5	6	7	8	9	10	11	12	13
Date (Max. Runoff)		8-16-44	8-31-44	9-4-44	9-12-44	3-19-45	5-14-45	6-13-45	6-16-45	6-30-45	7-31-45	9-22-45	11-18-45	5-15-46
Prev. Rainfall														
Prev. to T.O.C.*	in.	0.00	0.02	0.45	0.03	0.36	0.00	0.00	0.45	0.02	0.01	0.07	0.26	0.03
1st Day	in.	--	--	--	0.05	0.39	--	--	0.06	--	--	0.18	--	--
2nd Day	in.	0.27	--	--	0.05	0.60	--	0.17	0.17	--	--	--	0.27	--
3rd Day	in.	--	--	--	--	--	0.02	0.32	0.28	--	0.07	--	--	--
Saturation Factor**		S-0.07	S-0.02	F-0.45	F-0.07	V-0.70	V-0.00	S-0.08	S-0.56	S-0.02	S-0.02	F-0.16	F-0.33	V-0.03
Temp. Range - 3-day	°F	70-95	55-83	61-92	49-85	47-81	42-83	60-87	67-89	67-93	63-92	52-80	28-61	40-82
Rainfall														
10-min. Max. rate	in./hr.	1.62	1.38	6.90	2.22	3.60	2.40	1.50	4.14	4.50	1.86	3.54	1.02	2.52
T.O.C.* Max. rate	in./hr.	1.45	1.15	6.70	1.95	3.05	2.00	1.30	3.90	4.30	1.60	3.25	0.90	2.30
1-hr. Max. rate	in./hr.	0.41	0.35	2.36	0.52	0.68	0.44	0.28	1.23	1.33	0.38	0.83	0.29	0.52
Total Amt.	in.	0.90	0.66	3.25	0.89	1.91	0.46	0.28	3.28	2.27	0.38	1.01	1.24	0.55
Runoff														
Max. inst. rate	in./hr.	1.09	0.59	3.86	1.50	3.31	1.02	0.87	3.52	3.56	1.33	3.03	0.65	1.86
Max. 10-min. rate	in./hr.	0.70	0.40	3.60	0.99	1.24	0.77	0.67	3.14	2.52	0.79	2.01	0.47	1.04
Total	in.	0.78	0.47	2.91	0.68	1.62	0.26	0.24	2.65	1.90	0.31	0.84	1.02	0.46
Observed Time of Conc.	min.	13	13	14	9	10	5	13	8	12	11	10	15	7
Computed Runoff Co-efficient	per cent	75	51	58	77	108	51	67	90	83	83	93	72	81

								Secondary Storms			
Storm No.		14	15	16	17	18	19	1-a	9-a	12-a	15-a
Date (Max. Runoff)		5-31-46	6-13-46	7-8-46	7-11-46	8-3-46	8-5-46	8-16-44	6-30-45	11-18-45	6-13-46
Prev. Rainfall											
Prev. to T.O.C.*	in.	0.01	0.05	0.20	0.02	0.02	0.43	0.46	0.37	0.00	0.76
1st Day	in.	--	0.15	--	--	--	--	--	1.33	--	0.15
2nd Day	in.	--	0.04	--	--	--	--	0.27	--	0.27	0.04
3rd Day	in.	--	--	0.19	--	--	0.15	--	--	--	--
Saturation Factor**		V-0.01	S-0.14	S-0.22	S-0.02	S-0.02	S-0.45	S-0.53	S-1.04	F-0.07	S-0.84
Temp. Range - 3-day	°F	50-80	64-92	64-92	65-92	62-89	66-92	--	--	--	--
Rainfall											
10-min. Max. rate	in./hr.	0.72	2.28	2.22	3.48	0.60	4.32	--	--	--	--
T.O.C.* Max. rate	in./hr.	0.65	2.30	2.15	3.35	0.56	4.00	1.35	1.60	0.95	0.85
1-hr. Max. rate	in./hr.	0.17	0.76	0.85	1.36	0.14	1.17	0.33	0.78	0.21	0.17
Total Amt.	in.	0.24	0.93	0.97	1.39	0.15	2.32	--	--	--	--
Runoff											
Max. inst. rate	in./hr.	0.31	1.72	2.42	2.70	0.16	2.12	0.84	0.95	0.28	0.49
Max. 10-min. rate	in./hr.	0.28	1.45	1.53	1.92	0.15	1.70	0.63	0.79	0.20	0.32
Total	in.	0.15	0.80	0.91	1.14	0.07	1.61	--	--	--	--
Observed Time of Conc.	min.	7	9	13	13	20	22	12	15	21	10
Computed Runoff Co-efficient	per cent	48	75	112	81	29	53	62	59	29	58

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE IV

Rome-A - 10.72 Acres - 34 Per Cent Paved

Storm No.		5-c	7-b	15-b	22	28	40	46-b	47
Date (Max. Runoff)		10-25-46	11-11-46	12-20-46	1-11-47	1-30-47	3-24-47	4-14-47	4-16-47
Prev. Rainfall									
Prev. to T.O.C.*	in.	0.60	1.38	0.86	0.36	0.00	0.62	0.08	0.20
1st Day	in.	0.00	--	0.00	--	--	--	0.58	--
2nd Day	in.	--	--	0.20	--	--	--	--	1.68
3rd Day	in.	--	0.02	0.27	--	--	--	1.15	0.61
Saturation Factor**		F-0.60	F-1.38	W-0.94	W-0.36	W-0.00	V-0.62	V-0.51	V-0.70
Temp. Range - 3-day	°F	--	--	--	--	--	--	--	--
Rainfall									
10-min. Max. rate	in./hr.	1.98	1.32	0.42	0.61	1.14	0.54	1.62	1.14
T.O.C.* Max. rate	in./hr.	0.83	0.70	0.34	0.50	0.22	0.27	0.90	0.64
1-hr. Max. rate	in./hr.	0.81	0.66	0.32	0.50	0.20	0.27	0.90	0.61
Total Amt.	in.	1.40	2.68	1.54	1.45	0.25	0.80	1.66	0.85
Runoff									
Max. inst. rate	in./hr.	1.11	0.93	0.39	0.57	0.07	0.26	1.03	0.74
Max. 10-min. rate	in./hr.	0.98	0.85	0.37	0.57	0.07	0.25	0.94	0.70
Total	in.	1.11	2.39	1.21	1.32	0.07	0.52	1.66	0.73
Observed Time of Conc.	min.	75	50	75	60	45	60	45	45
Computed Runoff Co-efficient	per cent	134	133	115	114	32	96	114	116

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE IV (CONTINUED)

Storm No.		53	58	60-c	7-a	7-c	15-a	46-a	60-d
				Secondary Storms					
Date (Max. Runoff)		5-20-47	6-11-47	6-20-47	11-10-46	11-11-46	12-20-46	4-13-47	6-21-47
Prev. Rainfall									
Prev. to T.O.C.*	in.	0.00	0.00	0.49	0.45	2.11	0.27	0.26	0.05
1st Day	in.	0.33	--	--	--	--	0.00	--	2.50
2nd Day	in.	0.03	--	--	--	--	0.20	--	--
3rd Day	in.	--	--	--	0.02	0.02	0.27	1.15	--
Saturation Factor**		V-0.17	S-0.00	S-0.49	F-0.45	F-2.11	W-0.35	V-0.40	S-1.30
Temp. Range - 3-day	°F	--	--	--	--	--	--	--	--
Rainfall									
10-Min. Max. rate	in./hr.	2.40	2.52	1.32	1.20	1.38	0.14	0.72	0.60
T.O.C.* Max. rate	in./hr.	0.93	1.42	0.82	0.92	0.61	0.14	0.28	0.38
1-hr. Max. rate	in./hr.	0.86	1.30	0.77	0.90	0.56	0.14	0.27	0.36
Total Amt.	in.	0.86	1.31	1.52	--	--	--	0.59	1.25
Runoff									
Max. inst. rate	in./hr.	0.85	1.32	0.67	0.91	0.91	0.14	0.26	0.28
Max. 10-min. rate	in./hr.	0.70	1.12	0.60	0.84	0.87	0.14	0.25	0.26
Total	in.	0.50	0.74	0.77	--	--	--	0.42	0.87
Observed Time of Conc.	min.	35	40	25	50	45	70	90	65
Computed Runoff Coefficient	per cent	91	93	82	99	149	100	93	74

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE V

Rome-E - 2.54 Acres - 26 Per Cent Paved

Storm No.		22	46-a	46-b	53	60-a	60-b	60-c
Date (Max. Runoff)		1-11-47	4-13-47	4-14-47	5-20-47	6-20-47	6-21-47	6-21-47
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.45	0.22	0.17	0.05	0.26	0.62	0.05
1st Day	in.	--	--	0.54	0.33	--	1.10	2.14
2nd Day	in.	--	--	--	0.03	--	--	--
3rd Day	in.	--	1.15	1.15	--	--	--	--
Saturation Factor**		W-0.45	V-0.36	V-0.58	V-0.22	S-0.26	S-1.17	S-1.12
Temp. Range - 3-day	°F	--	--	--	--	--	--	--
Rainfall								
10-min. Max. rate	in./hr.	0.78	0.48	2.34	2.28	1.45	0.25	0.54
T.O.C.* Max. rate	in./hr.	0.51	0.28	1.17	0.97	0.59	0.25	0.35
1-hr. Max. rate	in./hr.	0.47	0.28	0.94	0.73	0.48	0.25	0.35
Total Amt.	in.	1.40	0.54	1.80	0.78	1.10	1.04	1.10
Runoff								
Max. inst. rate	in./hr.	0.45	0.20	0.91	0.62	0.32	0.16	0.17
Max. 10-min. rate	in./hr.	0.44	0.20	0.90	0.60	0.30	0.16	0.16
Total	in.	1.03	0.35	1.41	0.44	0.34	0.52	0.83
Observed Time of Conc.	min.	30	35	40	35	45	60	70
Computed Runoff Coefficient	per cent	89	71	78	64	54	64	49

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE VI

Rome-D - 3.89 Acres - 23 Per Cent Paved

Storm No.		40	53	58	60-a	60-c
Date (Max. Runoff)		3-24-47	5-20-47	6-11-47	6-20-47	6-21-47
Prev. Rainfall						
Prev. to T.O.C.*	in.	0.25	0.10	0.00	0.10	0.02
1st Day	in.	--	0.33	--	--	2.12
2nd Day	in.	--	0.03	--	--	--
3rd Day	in.	--	--	--	--	--
Saturation Factor**		V-0.25	V-0.27	S-0.00	S-0.10	S-1.08
Temp. Range - 3-day	°F	--	--	--	--	--
Rainfall						
10-min. Max. rate	in./hr.	0.54	2.70	1.80	1.56	0.66
T.O.C.* Max. rate	in./hr.	0.29	0.75	0.86	0.67	0.36
1-hr. Max. rate	in./hr.	0.29	0.75	0.86	0.67	0.36
Total Amt.	in.	0.80	0.85	0.88	1.04	1.20
Runoff						
Max. inst. rate	in./hr.	0.22	0.60	0.31	0.17	0.18
Max. 10-min. rate	in./hr.	0.21	0.54	0.30	0.16	0.17
Total	in.	0.52	0.42	0.22	0.15	0.32
Observed Time of Conc.	min.	70	30	65	50	75
Computed Runoff Coefficient	per cent	76	80	36	25	50

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE VII

Godman-1 - 13.10 Acres - 22 Per Cent Paved

Storm No.		1	2	3	4	5	6	7
Date (Max. Runoff)		2-26-45	3-2-45	3-18-45	3-20-45	3-30-45	4-2-45	9-13-45
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.75	0.03	0.06	0.14	0.00	0.57	0.00
1st Day	in.	--	0.88	--	0.07	--	--	--
2nd Day	in.	--	--	0.41	0.46	0.16	0.09	--
3rd Day	in.	--	0.07	--	0.41	--	0.49	--
Saturation Factor**		W-0.75	V-0.48	V-0.16	V-0.34	V-0.04	V-0.65	F-0.00
Temp. Range - 3-day	°F	28-60	28-60	52-84	52-79	55-80	47-68	54-83
Rainfall								
10-min. Max. rate	in./hr.	0.54	0.78	1.80	0.96	2.28	1.38	1.56
T.O.C.* Max. rate	in./hr.	0.35	0.40	0.39	0.28	0.44	0.35	0.77
1-hr. Max. rate	in./hr.	0.35	0.40	0.39	0.28	0.44	0.35	0.77
Total Amt.	in.	2.87	1.69	0.46	0.83	0.48	1.35	0.82
Runoff								
Max. inst. rate	in./hr.	0.44	0.48	0.14	0.13	0.04	0.56	0.03
Max. 10-min. rate	in./hr.	0.42	0.45	0.13	0.12	0.04	0.52	0.03
Total	in.	1.95	1.27	0.21	0.48	0.08	0.86	0.08
Observed Time of Conc.	min.	150	50	40	40	55	30	65
Computed Runoff Co-efficient	per cent	125	120	36	46	9	160	5

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE VII (CONTINUED)

					Secondary Storms			
Storm No.		8	9	10	1-a	2-a	4-a	8-a
Date (Max. Runoff)		5-17-46	6-19-46	7-6-46	2-26-45	3-2-45	3-20-45	5-17-46
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.63	0.00	0.16	0.25	0.53	0.43	0.00
1st Day	in.	--	--	1.03	--	--	0.07	--
2nd Day	in.	0.47	--	--	--	--	0.46	0.47
3rd Day	in.	0.62	--	--	--	0.07	0.41	0.62
Saturation Factor**		V-0.83	S-0.00	S-0.68	W-0.25	V-0.54	V-0.63	V-0.20
Temp. Range - 3-day	°F	57-82	72-94	61-88	--	--	--	--
Rainfall								
10-min. Max. rate	in./hr.	2.04	3.12	1.44	--	--	--	--
T.O.C.* Max. rate	in./hr.	0.56	0.95	0.50	0.26	0.24	0.19	0.58
1-hr. Max. rate	in./hr.	0.56	0.95	0.50	0.26	0.24	0.19	0.58
Total Amt.	in.	1.20	1.40	1.23	--	--	--	--
Runoff								
Max. inst. rate	in./hr.	0.30	0.06	0.25	0.14	0.16	0.08	0.17
Max. 10-min. rate	in./hr.	0.30	0.06	0.25	0.14	0.16	0.08	0.17
Total	in.	0.92	0.11	0.60	--	--	--	--
Observed Time of Conc.	min.	20	45	25	120	150	50	75
Computed Runoff Coefficient	per cent	54	6	50	54	67	42	29

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE VIII

Freeman-A - 9.57 Acres - 22 Per Cent Paved

Storm No.		1	2	3	4	5	6	7	8
Date (Max. Runoff)		8-22-44	9-4-44	2-26-45	3-2-45	3-5-45	3-19-45	6-16-45	6-18-45
Prev. Rainfall									
Prev. to T.O.C.*	in.	0.76	0.00	0.73	1.03	1.30	0.42	0.11	0.78
1st Day	in.	0.25	--	--	--	0.10	0.24	0.06	0.64
2nd Day	in.	--	--	--	--	--	0.08	0.20	2.86
3rd Day	in.	--	--	--	0.02	0.12	0.50	0.28	0.33
Saturation Factor**		S-0.88	F-0.00	W-0.73	V-1.03	V-1.36	V-0.62	S-0.23	S-1.86
Temp. Range - 3-day	°F	54-90	61-92	27-58	26-60	31-66	47-77	67-89	64-89
Rainfall									
10-min. Max. rate	in./hr.	2.46	4.44	0.42	0.72	1.92	2.28	3.72	1.80
T.O.C.* Max. rate	in./hr.	1.65	2.23	0.34	0.36	1.06	0.53	1.34	0.52
1-hr. Max. rate	in./hr.	1.49	2.00	0.34	0.33	0.94	0.44	1.13	0.47
Total Amt.	in.	3.15	2.76	2.93	2.49	4.42	1.37	3.14	0.77
Runoff									
Max. inst. rate	in./hr.	1.19	2.70	0.23	0.24	1.09	0.40	0.57	0.15
Max. 10-min. rate	in./hr.	1.15	2.26	0.22	0.24	0.85	0.38	0.51	0.15
Total	in.	1.70	2.18	1.66	1.24	3.09	0.52	1.19	0.29
Observed Time of Conc.	min.	34	34	45	45	24	30	36	70
Computed Runoff Co-efficient	per cent	72	121	68	67	103	76	43	29

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE VIII (CONTINUED)

				Secondary Storms				
Storm No.		9	10	3-a	4-a	5-a	7-a	9-a
Date (Max. Runoff)		6-30-45	2-13-46	2-26-45	3-2-45	3-5-45	6-16-45	6-30-45
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.00	1.38	2.54	0.47	0.00	0.00	0.00
1st Day	in.	--	0.29	--	--	0.10	1.84	0.70
2nd Day	in.	--	--	--	--	--	0.20	--
3rd Day	in.	--	--	--	0.02	0.12	0.28	--
Saturation Factor**		S-0.00	W-1.52	W-2.54	V-0.47	V-0.06	S-1.01	S-0.35
Temp. Range - 3-day	°F	67-92	18-60	--	--	--	--	--
Rainfall								
10-min. Max. rate	in./hr.	3.24	0.78	--	--	--	--	--
T.O.C.* Max. rate	in./hr.	0.84	0.49	0.29	0.24	0.68	0.65	0.61
1-hr. Max. rate	in./hr.	0.70	0.48	0.29	0.20	0.35	0.60	0.54
Total Amt.	in.	1.37	2.33	--	--	--	--	--
Runoff								
Max. inst. rate	in./hr.	0.13	0.30	0.22	0.07	0.24	0.18	0.08
Max. 10-min. rate	in./hr.	0.13	0.30	0.22	0.07	0.24	0.18	0.08
Total	in.	0.36	0.97	--	--	--	--	--
Observed Time of Conc.	min.	55	50	45	55	70	65	65
Computed Runoff Co-efficient	per cent	16	61	76	29	35	28	13

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm +1/2 1st prev. day + 1/4 2nd etc.

TABLE IX

St. Anne-1 - 72.8 Acres - 5 Per Cent Paved

Storm No.		1	2	3	4	5	6	7
Date (Max. Runoff)		8-1-44	11-15-44	2-21-45	3-19-45	5-17-45	6-16-45	6-17-45
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.00	0.03	0.03	0.48	0.02	0.03	0.00
1st Day	in.	--	0.50	0.84	0.25	0.00	1.05	2.39
2nd Day	in.	--	--	--	0.04	0.31	0.48	0.11
3rd Day	in.	--	--	--	0.47	0.76	0.22	0.48
Saturation Factor* *		S-0.00	F-0.28	W-0.45	V-0.68	V-0.20	S-0.70	S-1.29
Temp. Range - 3-day	°F	67-96	32-67	11-38	47-77	52-78	--	--
Rainfall								
10-min. Max. rate	in./hr.	4.26	1.08	1.32	1.98	0.84	2.64	4.56
T.O.C.* Max. rate	in./hr.	1.06	0.35	0.28	0.61	0.46	0.53	1.06
1-hr. Max. rate	in./hr.	1.42	0.40	0.35	0.80	0.51	0.66	1.41
Total Amt.	in.	1.42	1.16	1.31	2.07	0.84	2.40	1.97
Runoff								
Max. inst. rate	in./hr.	0.55	0.12	0.20	0.49	0.25	0.32	0.94
Max. 10-min. rate	in./hr.	0.54	0.12	0.20	0.49	0.25	0.32	0.91
Total	in.	0.80	0.72	1.53	2.00	0.76	1.91	1.80
Observed Time of Conc.	min.	60	120	80	60	70	60	40
Computed Runoff Coefficient	per cent	52	34	71	80	54	60	89

* *Average observed value.*

* * S.F. = Rainfall prior to T.O.C. in same storm +1/2 1st prev. day + 1/4 2nd etc.

TABLE IX (CONTINUED)

				Secondary Storms				
Storm No.		8	9	3-a	4-a	4-b	7-a	9-a
Date (Max. Runoff)		3-18-46	6-13-46	11-14-44	2-21-45	2-21-45	6-16-45	6-13-46
Prev. Rainfall								
Prev. to T.O.C.*	in.	0.00	0.01	0.00	0.00	0.01	0.01	0.00
1st Day	in.	--	1.02	--	0.10	0.45	0.10	--
2nd Day	in.	0.28	--	--	--	--	0.48	--
3rd Day	in.	--	--	--	--	--	0.22	--
Saturation Factor**		V-0.07	S-0.52	F-0.00	W-0.05	W-0.24	S-0.21	S-0.00
Temp. Range - 3-day	°F	51-71	56-92	--	--	--	--	--
Rainfall								
10-min. Max. rate	in./hr.	1.26	4.26	--	--	--	--	--
T.O.C.* Max. rate	in./hr.	0.23	0.80	0.34	0.14	0.15	0.47	0.76
1-hr. Max. rate	in./hr.	0.29	1.06	0.37	0.14	0.15	0.47	1.00
Total Amt.	in.	0.33	2.09	--	--	--	--	--
Runoff								
Max. inst. rate	in./hr.	0.07	0.45	0.04	0.08	0.09	0.25	0.07
Max. 10-min. rate	in./hr.	0.07	0.44	0.04	0.08	0.09	0.25	0.07
Total	in.	0.30	1.01	--	--	--	--	--
Observed Time of Conc.	min.	110	60	180	70	60	40	80
Computed Runoff Coefficient	per cent	30	56	12	57	60	53	9

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE X

Freeman-D - 9.54 Acres - 0 Per Cent Paved

Storm No.		1	2	3	4	5	6
Date (Max. Runoff)		8-22-44	9-4-44	2-26-45	3-2-45	3-5-45	3-19-45
Prev. Rainfall							
Prev. to T.O.C.*	in.	1.35	0.00	0.75	1.00	1.40	1.00
1st Day	in.	0.25	--	--	--	0.02	0.23
2nd Day	in.	--	--	--	--	--	0.05
3rd Day	in.	--	--	--	--	0.11	0.40
Saturation Factor**		S-1.48	F-0.00	W-0.75	V-1.00	V-1.42	V-1.18
Temp. Range - 3-day	°F	54-90	61-92	27-58	26-60	31-66	47-77
Rainfall							
10-min. Max. rate	in./hr.	2.40	5.70	0.42	0.66	1.74	2.94
T.O.C.* Max. rate	in./hr.	1.84	2.28	0.38	0.42	0.95	0.64
1-hr. Max. rate	in./hr.	1.67	1.91	0.34	0.38	0.87	0.54
Total Amt.	in.	3.66	2.79	2.88	2.47	4.25	1.55
Runoff							
Max. inst. rate	in./hr.	0.47	0.34	0.14	0.17	0.65	0.12
Max. 10-min. rate	in./hr.	0.42	0.33	0.14	0.17	0.64	0.12
Total	in.	0.91	1.21	1.17	1.04	2.74	0.43
Observed Time of Conc.	min.	30	40	30	60	50	100
Computed Runoff Co-efficient	per cent	26	15	37	40	68	19

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

TABLE X (CONTINUED)

				Secondary Storms			
Storm No.		7	8	3-a	6-a	7-a	7-b
Date (Max. Runoff)		6-15-45	2-13-46	2-26-45	3-19-45	6-16-45	6-16-45
Prev. Rainfall							
Prev. to T.O.C.*	in.	0.00	1.11	2.52	0.06	1.40	0.00
1st Day	in.	0.05	--	--	0.23	0.05	1.70
2nd Day	in.	0.12	--	--	0.05	0.12	0.12
3rd Day	in.	0.33	--	--	0.40	0.33	0.33
Saturation Factor**		S-0.10	W-1.11	W-2.52	V-0.24	S-1.49	S-0.92
Temp. Range - 3-day	°F	67-89	25-60	--	--	--	--
Rainfall							
10-min. Max. rate	in./hr.	5.04	0.66	--	--	--	--
T.O.C.* Max. rate	in./hr.	1.59	0.46	0.26	0.52	0.31	0.60
1-hr. Max. rate	in./hr.	1.33	0.46	0.25	0.45	0.26	0.52
Total Amt.	in.	2.79	2.34	--	--	--	--
Runoff							
Max. inst. rate	in./hr.	0.05	0.14	0.09	0.07	0.05	0.05
Max. 10-min. rate	in./hr.	0.05	0.14	0.09	0.07	0.05	0.05
Total	in.	0.36	0.55	--	--	--	--
Observed Time of Conc.	min.	40	40	30	110	30	70
Computed Runoff Coefficient	per cent	3	30	35	13	16	8

* Average observed value.

** S.F. = Rainfall prior to T.O.C. in same storm + 1/2 1st prev. day + 1/4 2nd etc.

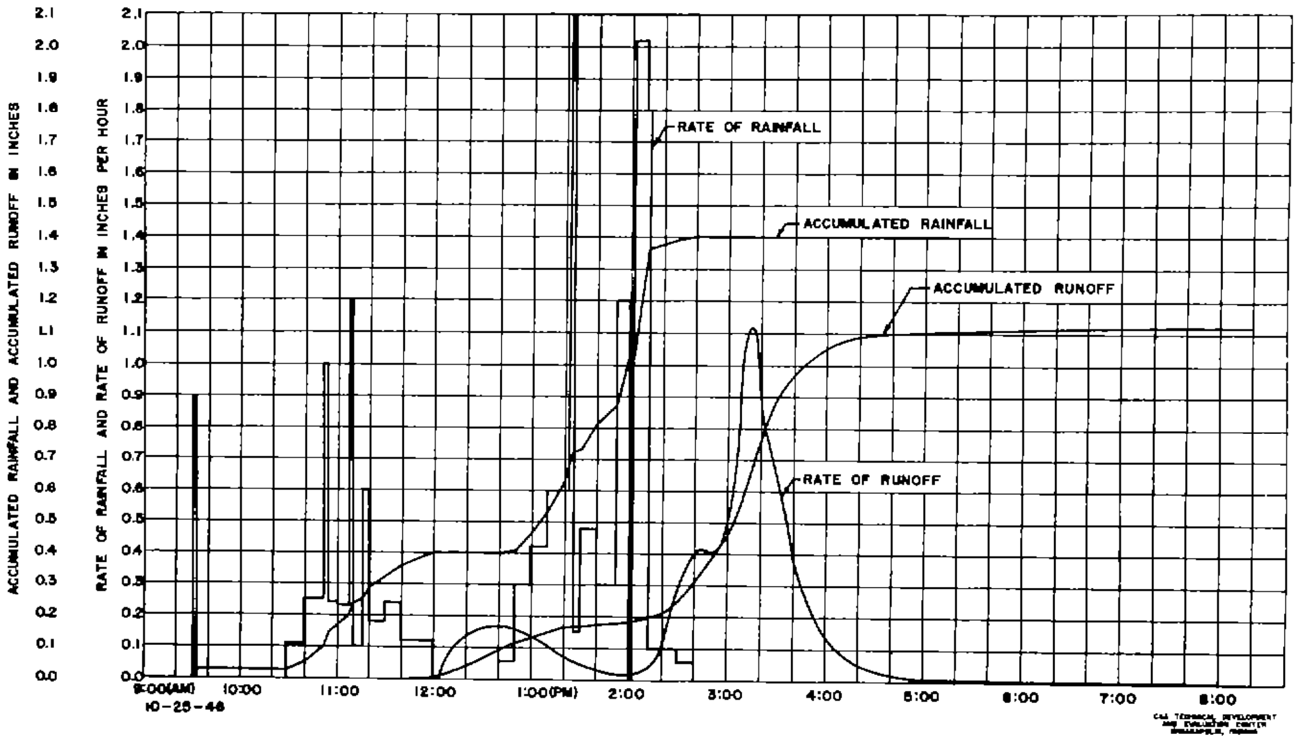

Fig. 1 Rainfall and Runoff Data, Area A, Rome, Georgia

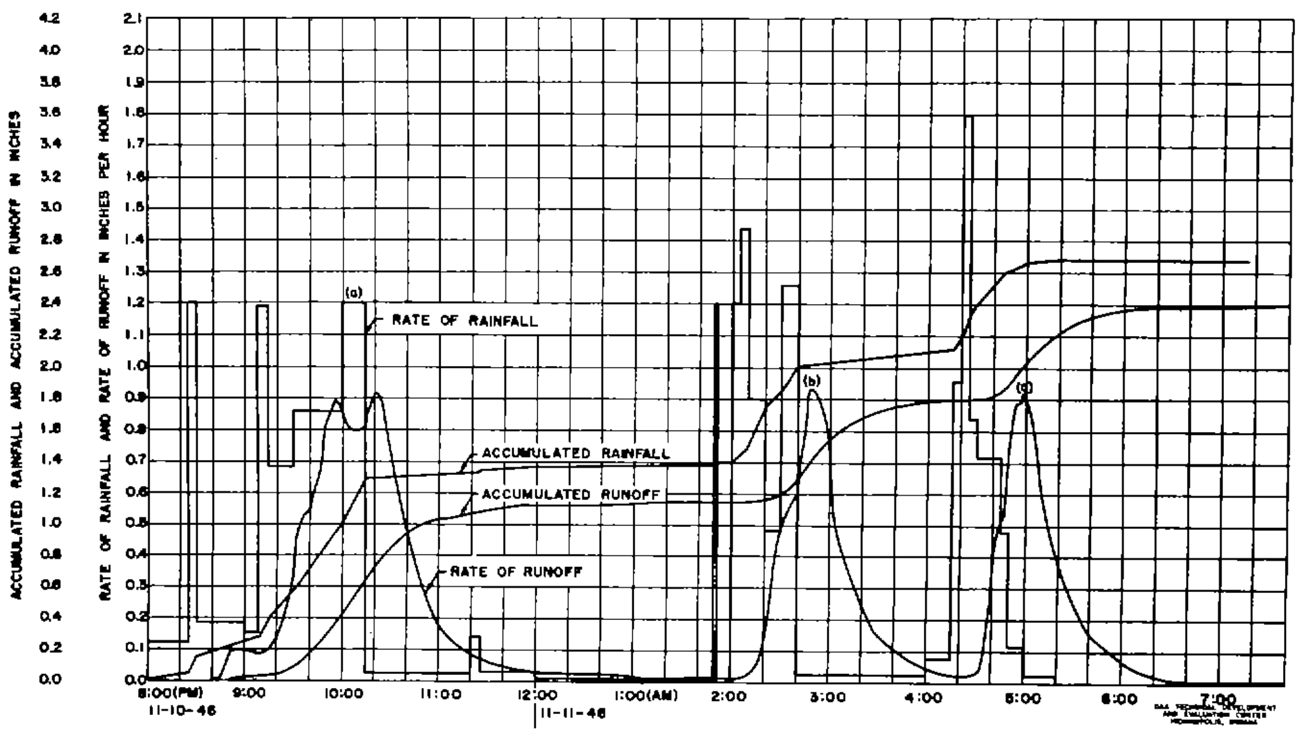

Fig. 2 Rainfall and Runoff Data, Area A, Rome, Georgia

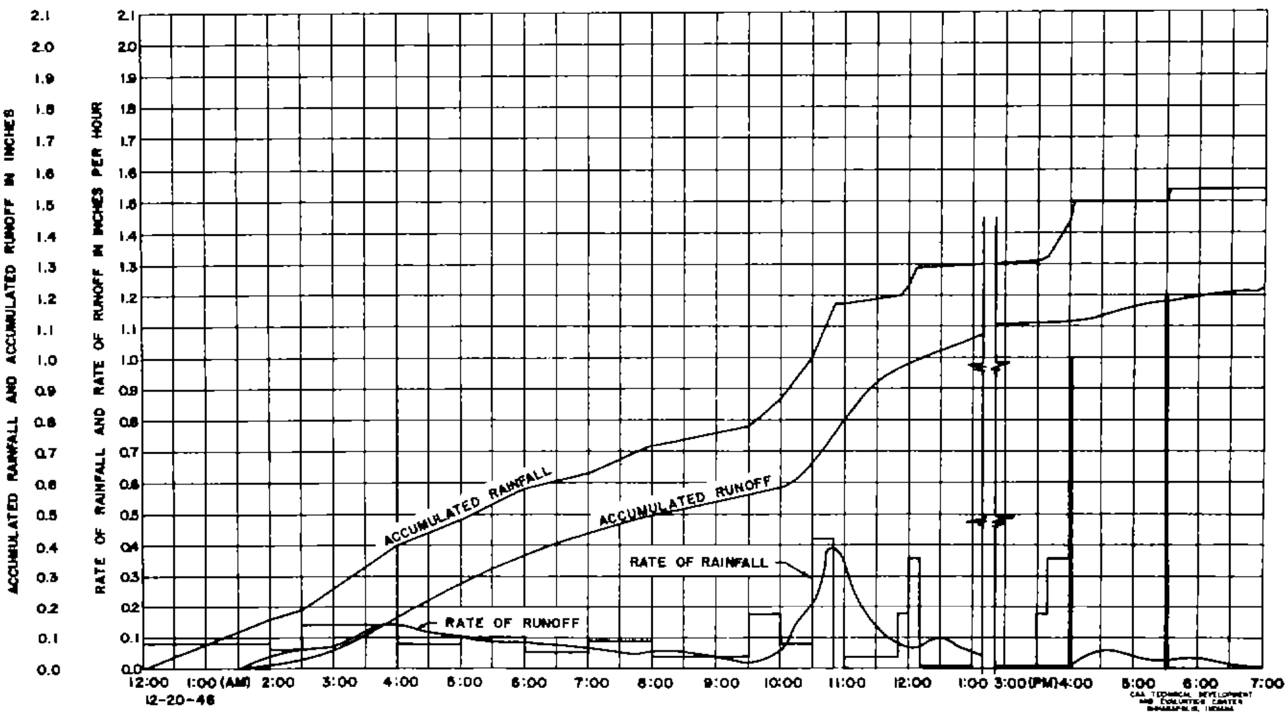

Fig. 3 Rainfall and Runoff Data, Area A, Rome, Georgia

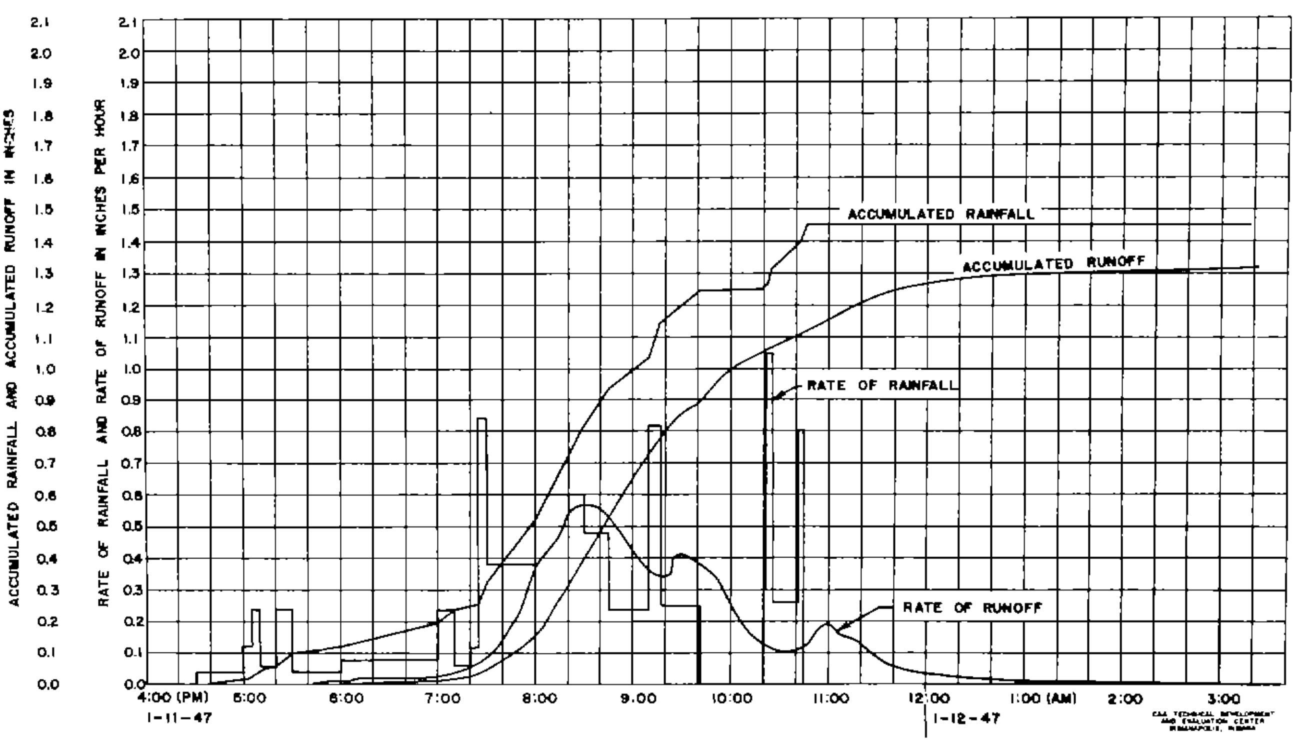

Fig. 4 Rainfall and Runoff Data, Area A, Rome, Georgia

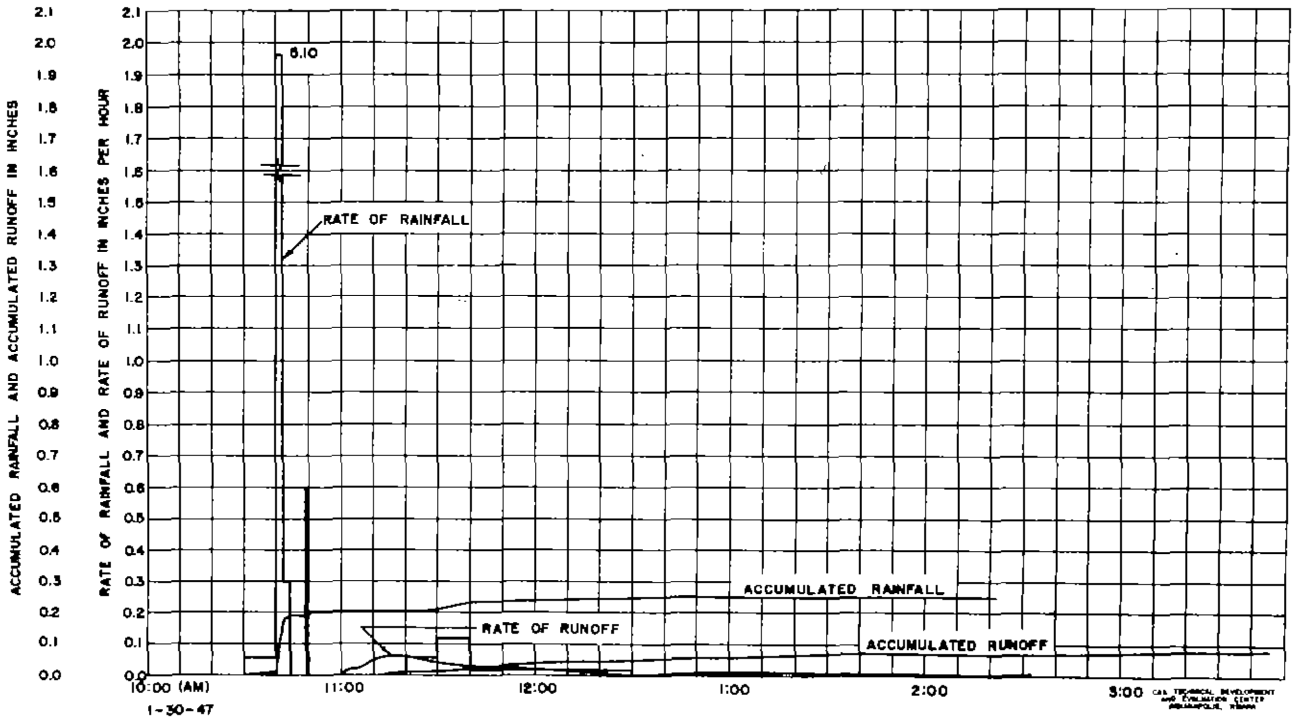

Fig. 5 Rainfall and Runoff Data, Area A, Rome, Georgia

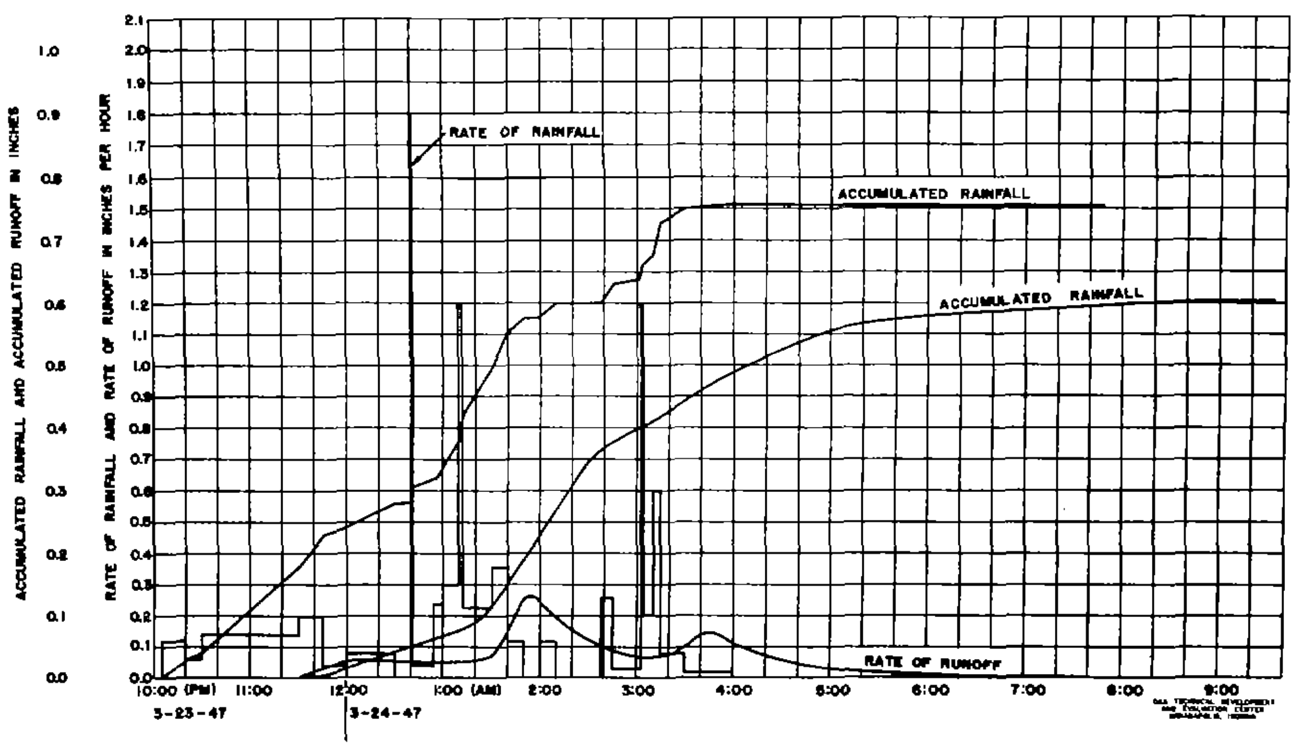

Fig. 6 Rainfall and Runoff Data, Area A, Rome, Georgia

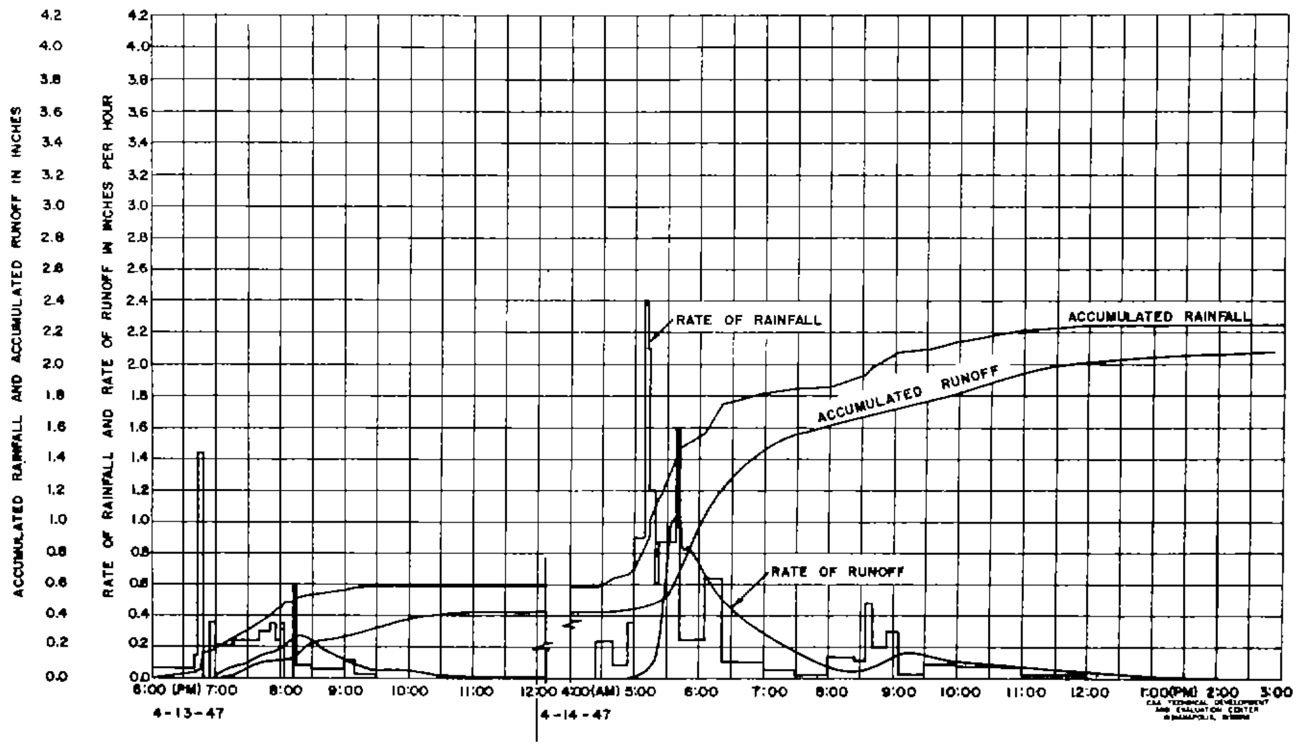

Fig. 7 Rainfall and Runoff Data, Area A, Rome, Georgia

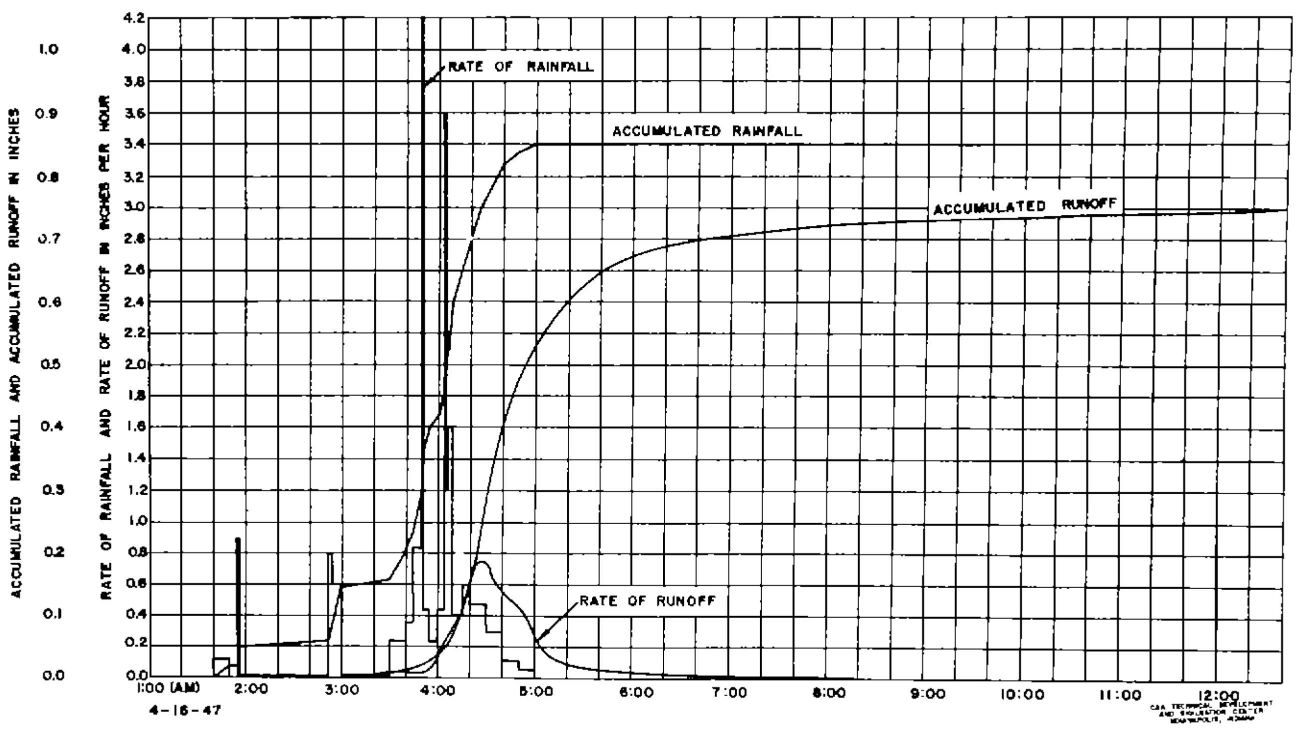

Fig. 8 Rainfall and Runoff Data, Area A, Rome, Georgia

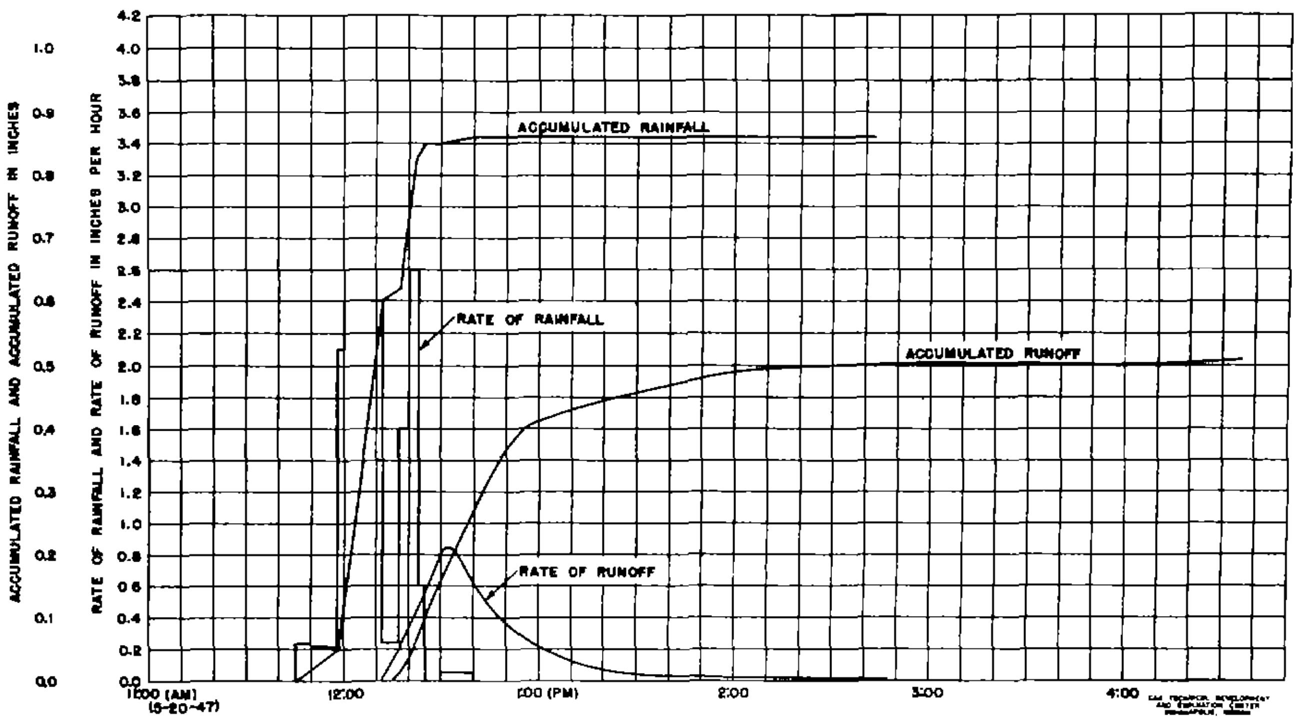

Fig. 9 Rainfall and Runoff Data, Area A, Rome, Georgia

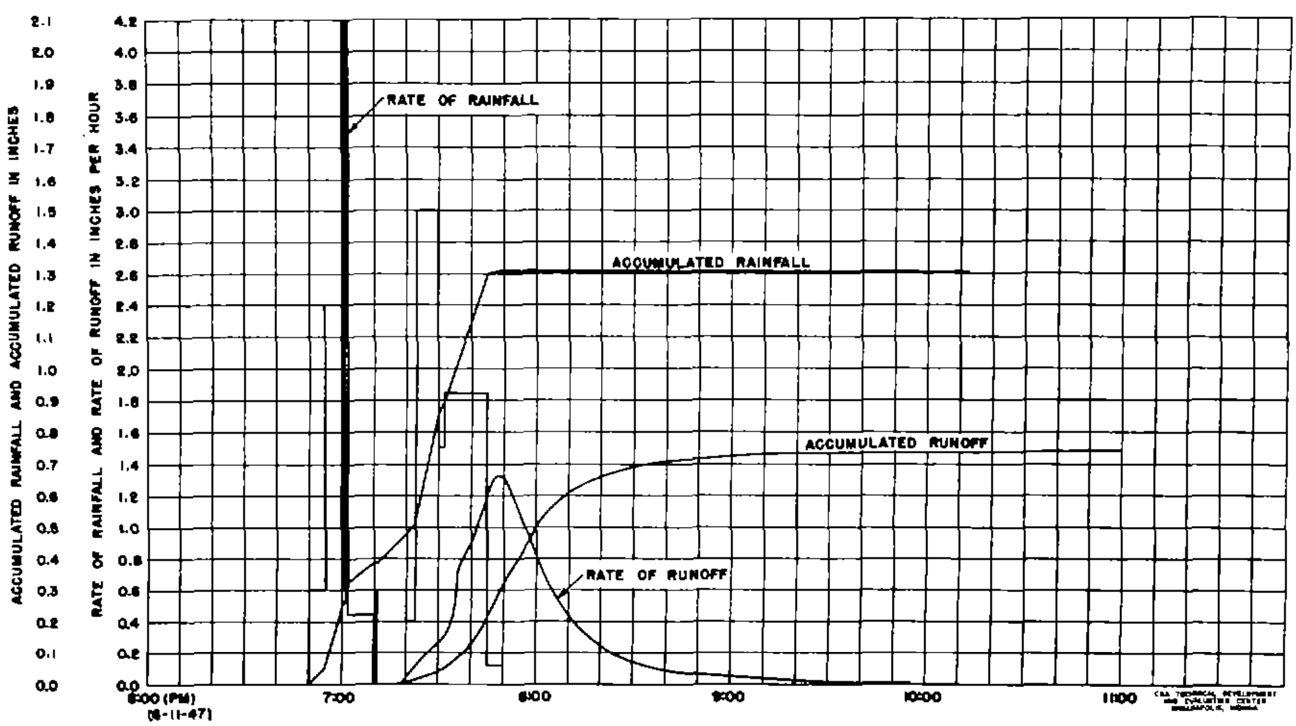

Fig. 10 Rainfall and Runoff Data, Area A, Rome, Georgia

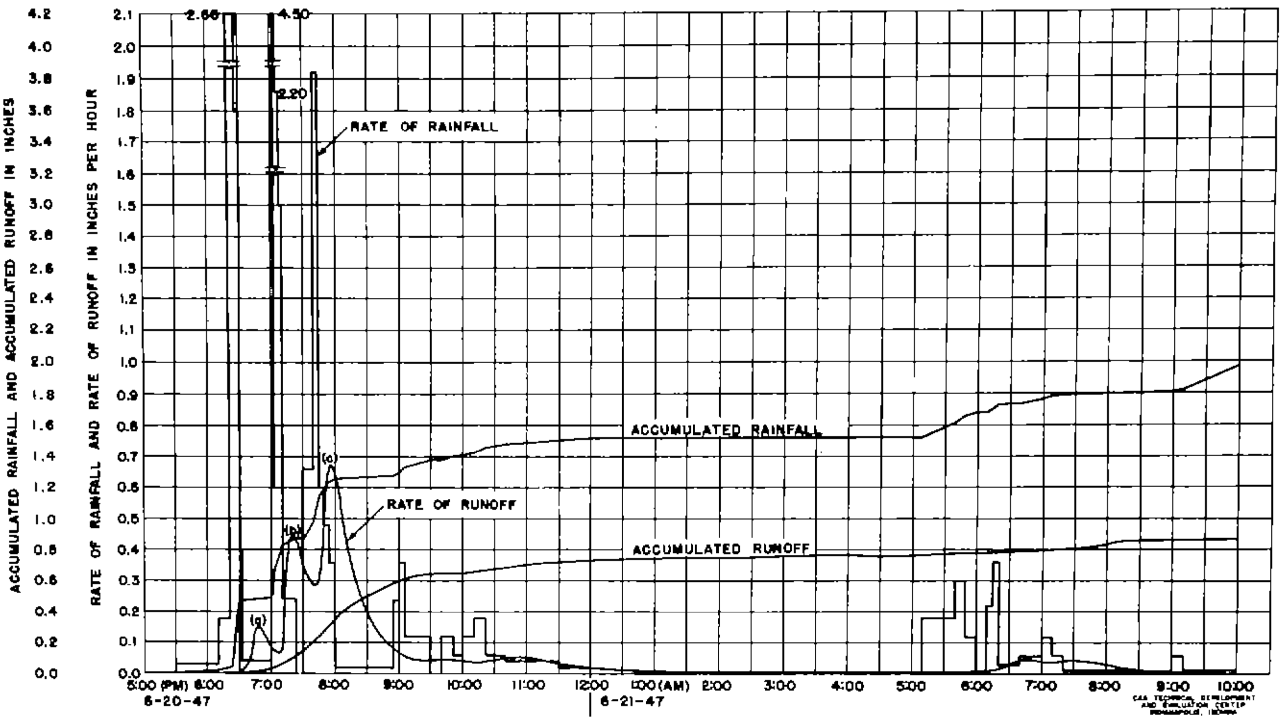

Fig. 11 Rainfall and Runoff Data, Area A, Rome, Georgia

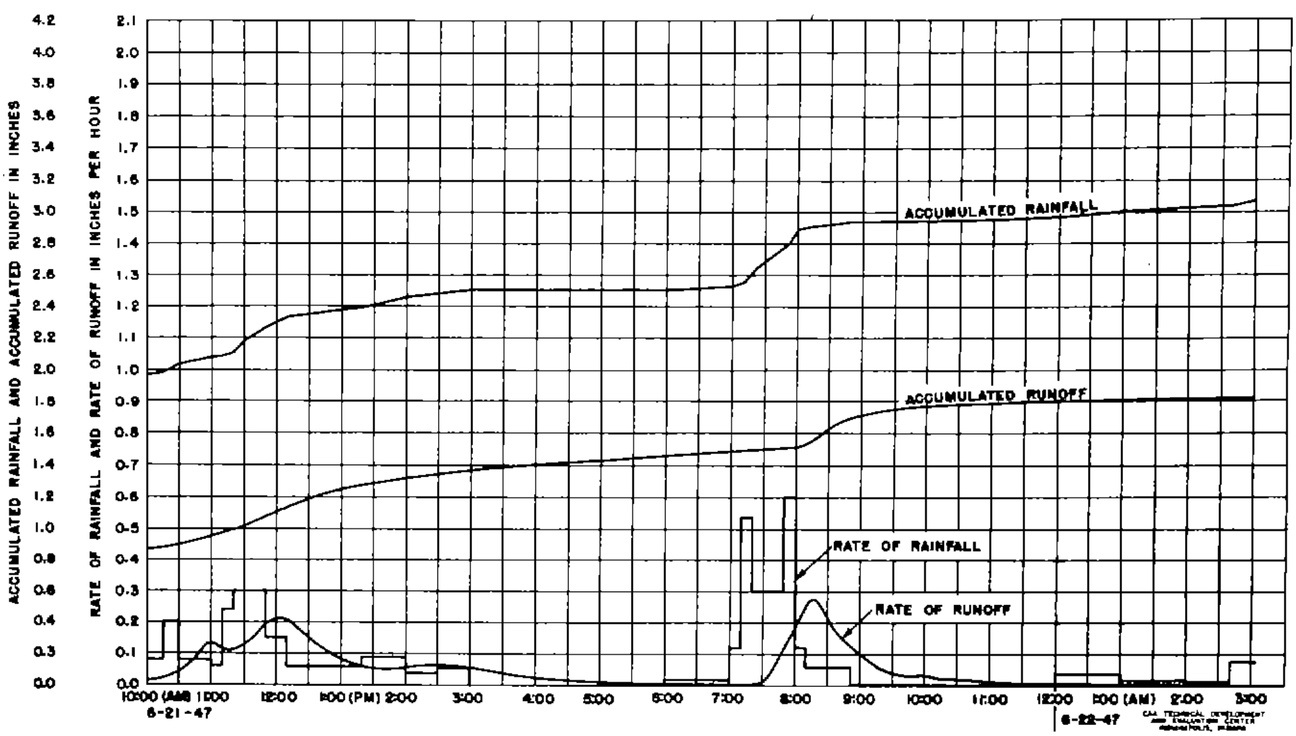

Fig. 12 Rainfall and Runoff Data, Area A, Rome, Georgia

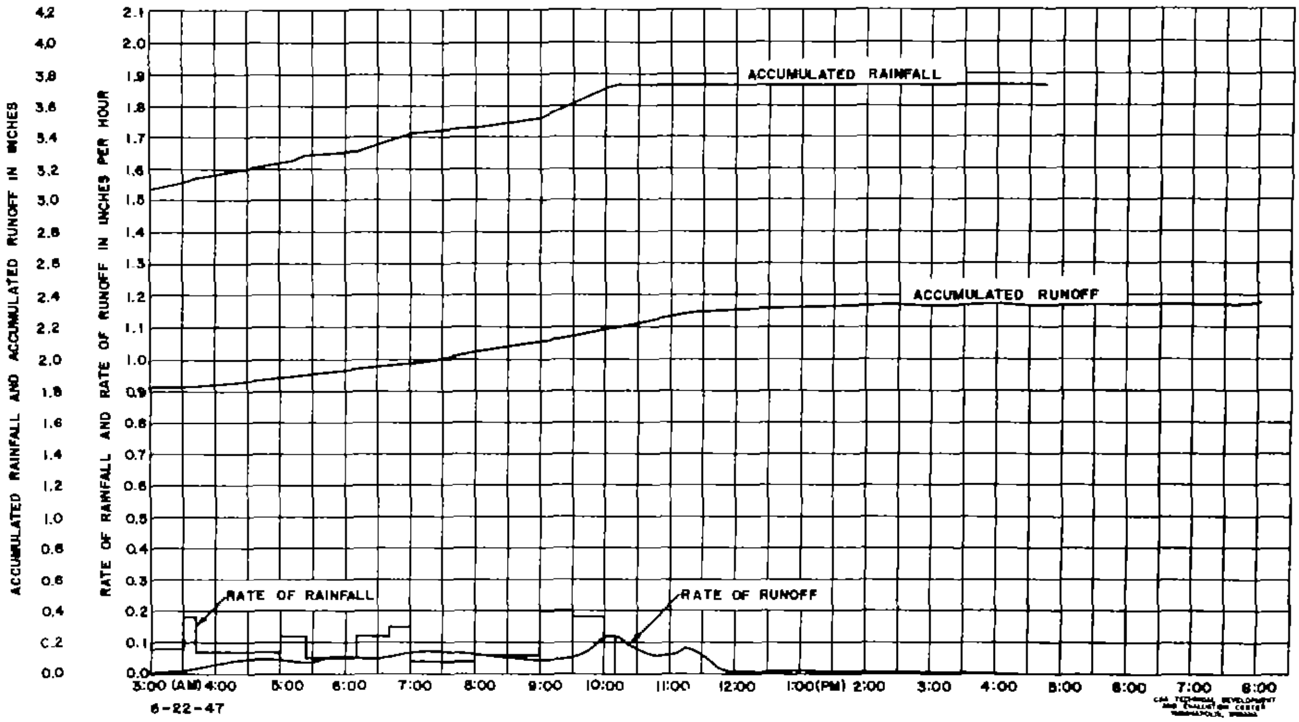

Fig. 13 Rainfall and Runoff Data, Area A, Rome, Georgia

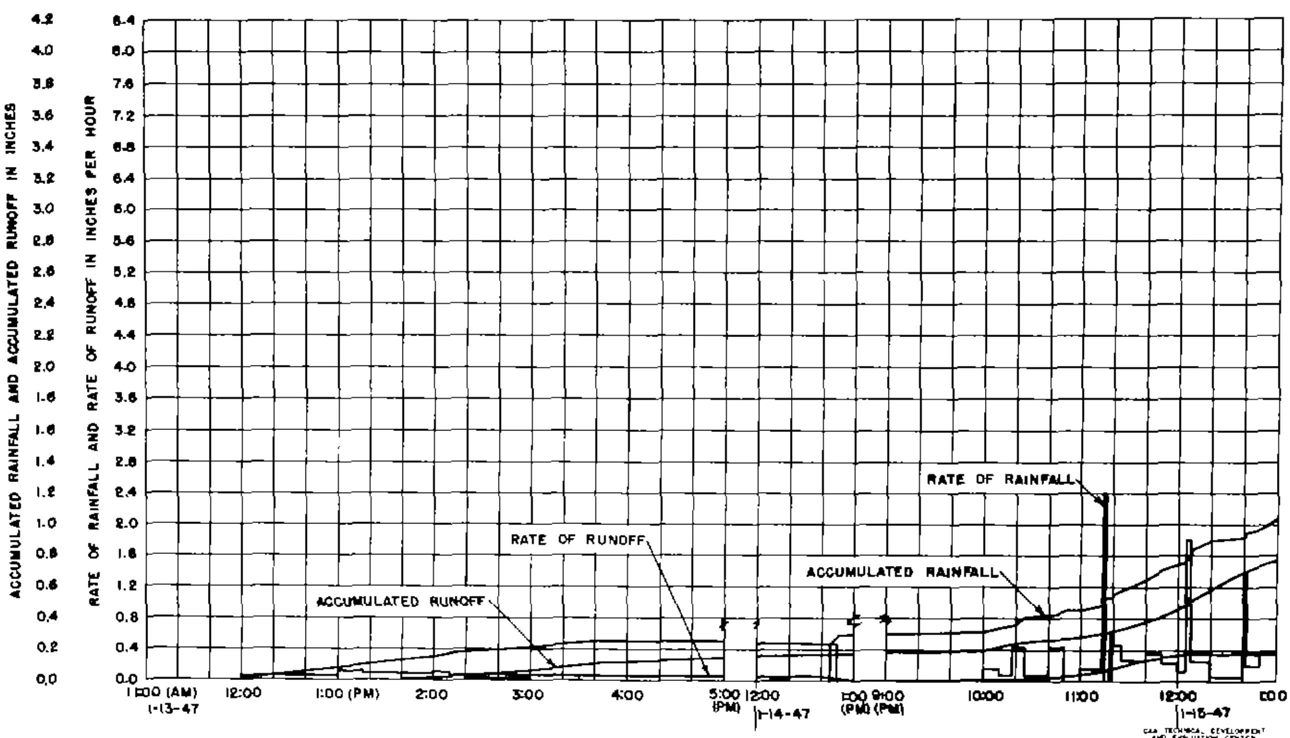

Fig. 14 Rainfall and Runoff Data, Areas A_1 and A_2, Rome, Georgia

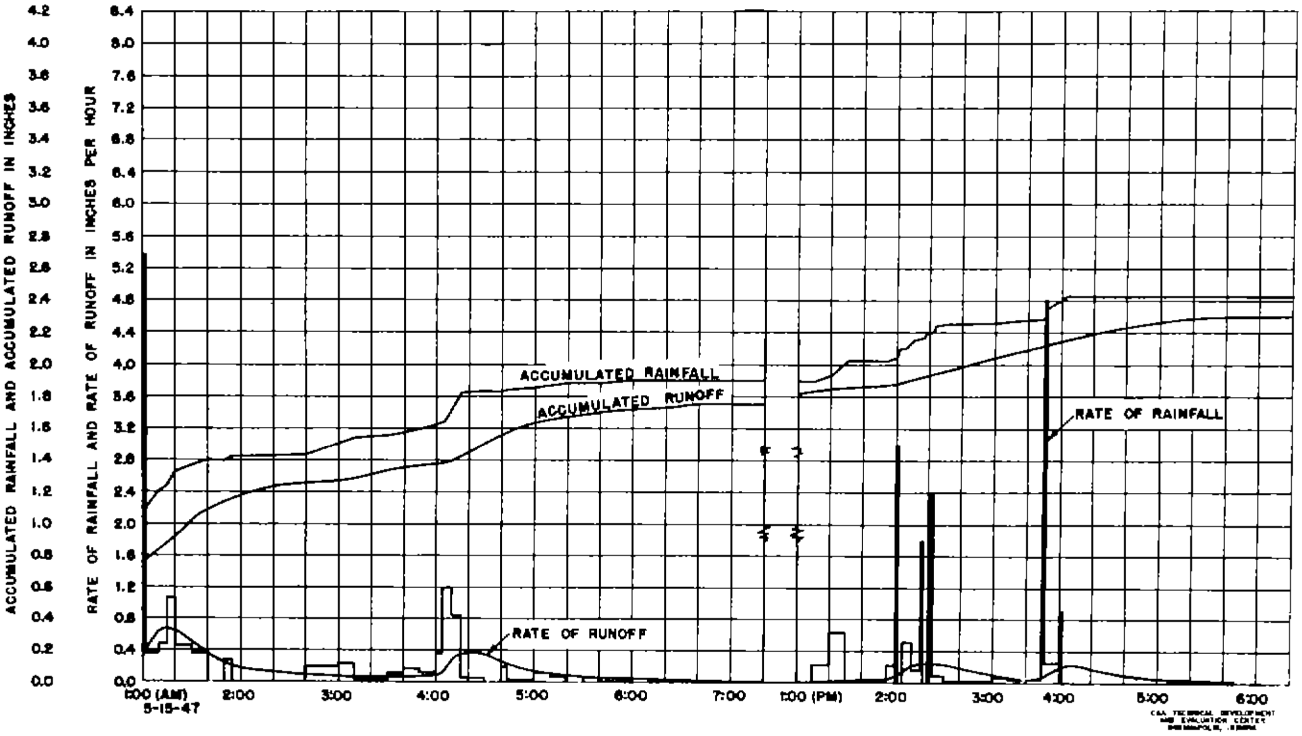

Fig. 15 Rainfall and Runoff Data, Areas A_1 and A_2, Rome, Georgia

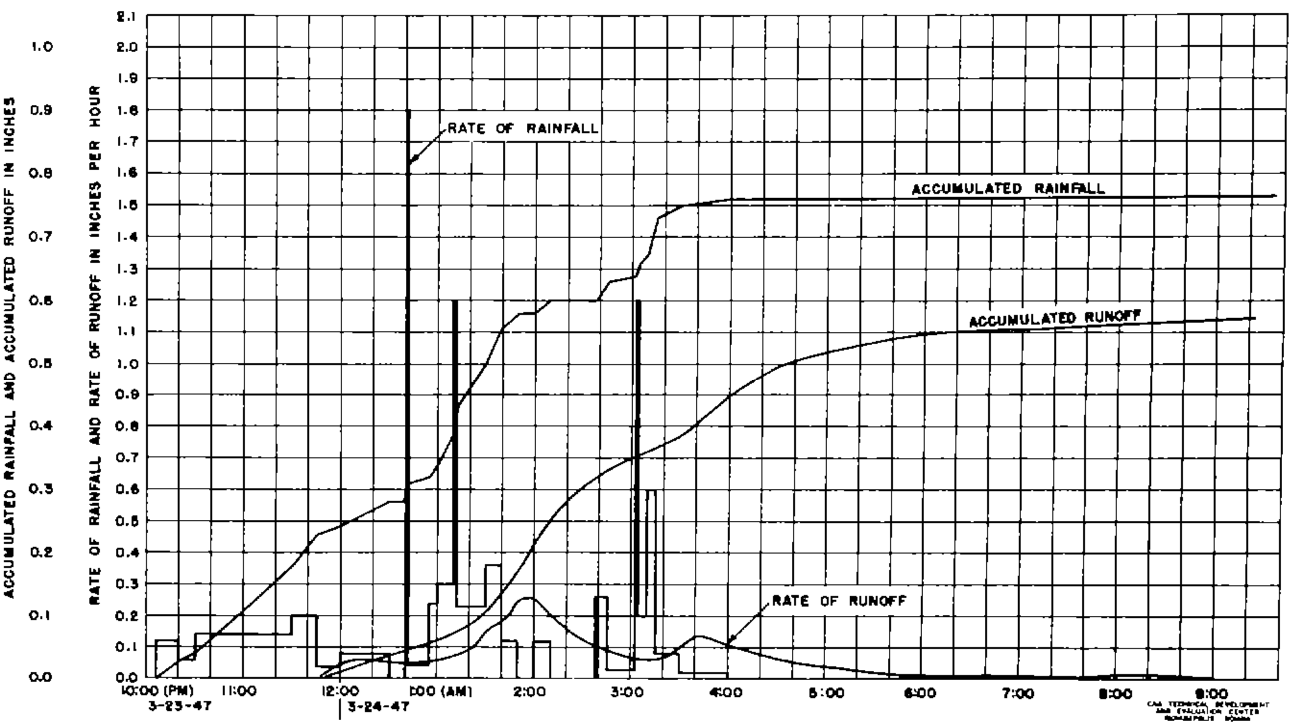

Fig. 16 Rainfall and Runoff Data, Areas A_1 and A_2, Rome, Georgia

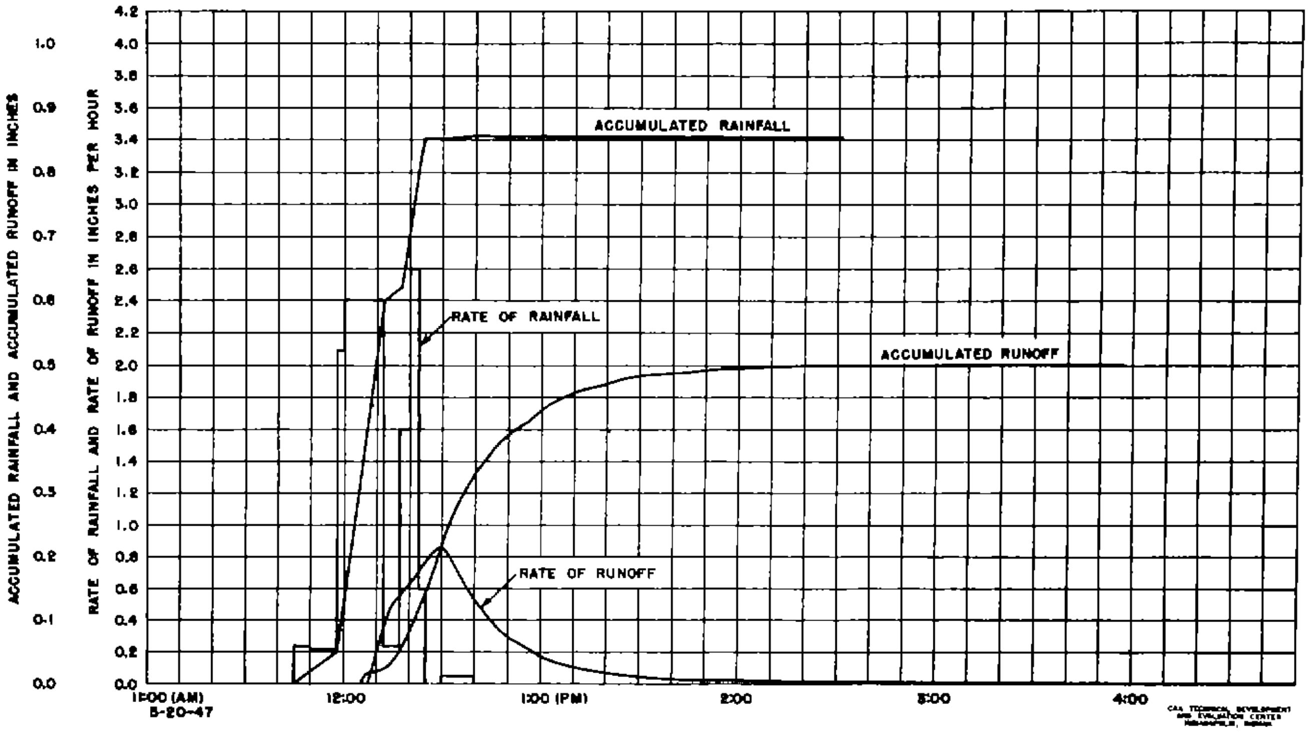

Fig. 17 Rainfall and Runoff Data, Areas A_1 and A_2, Rome, Georgia

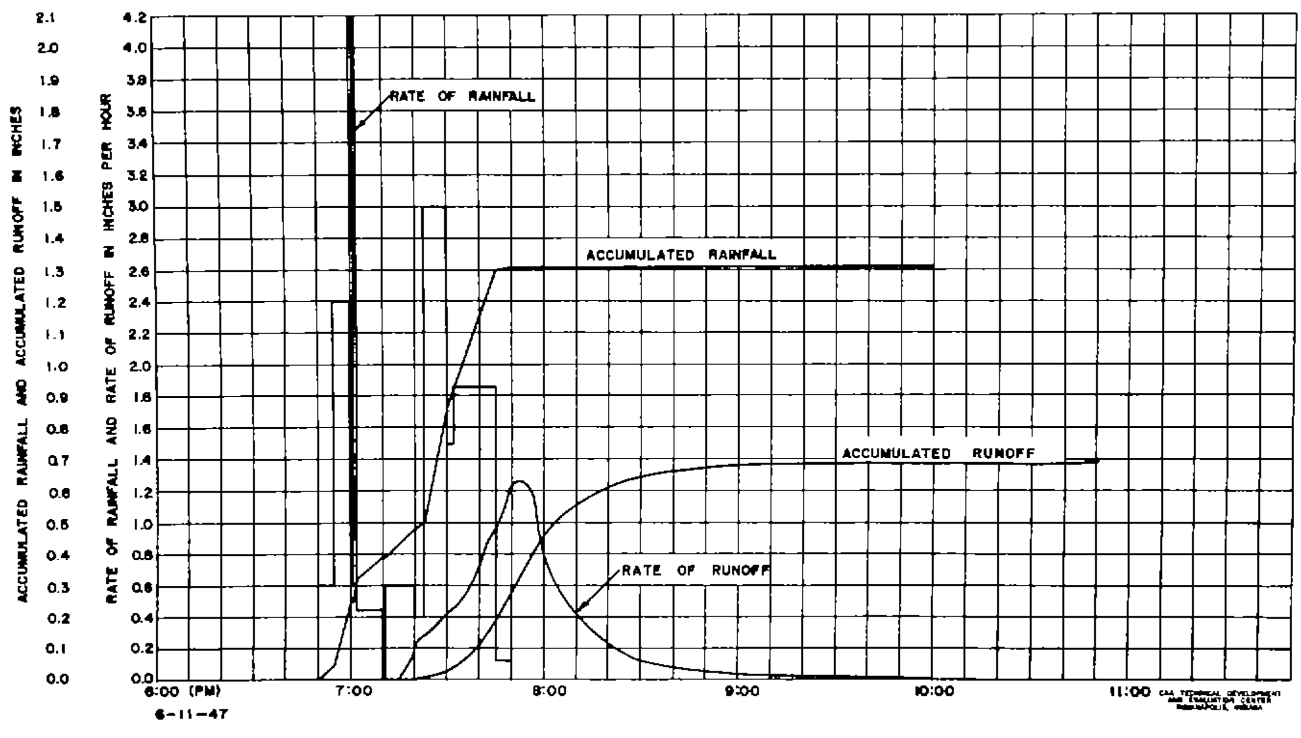

Fig. 18 Rainfall and Runoff Data, Areas A_1 and A_2, Rome, Georgia

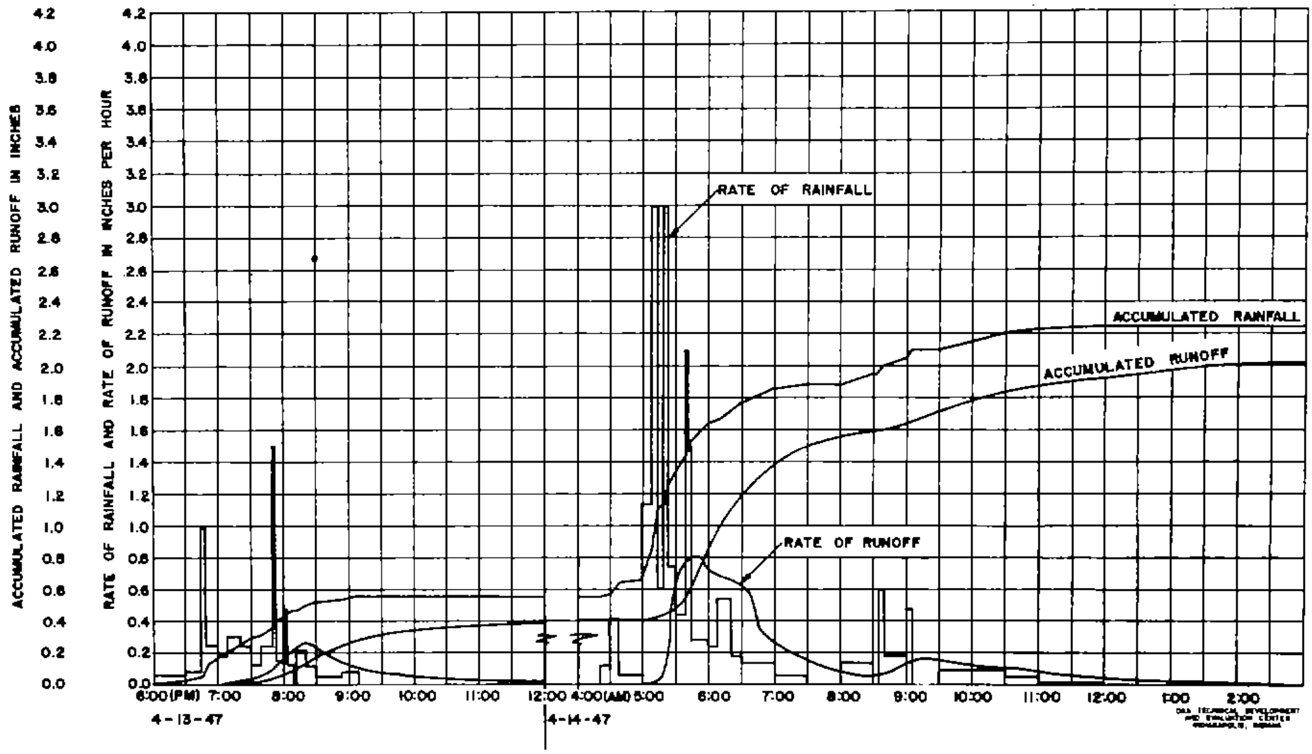

Fig. 19 Rainfall and Runoff Data, Area B, Rome, Georgia

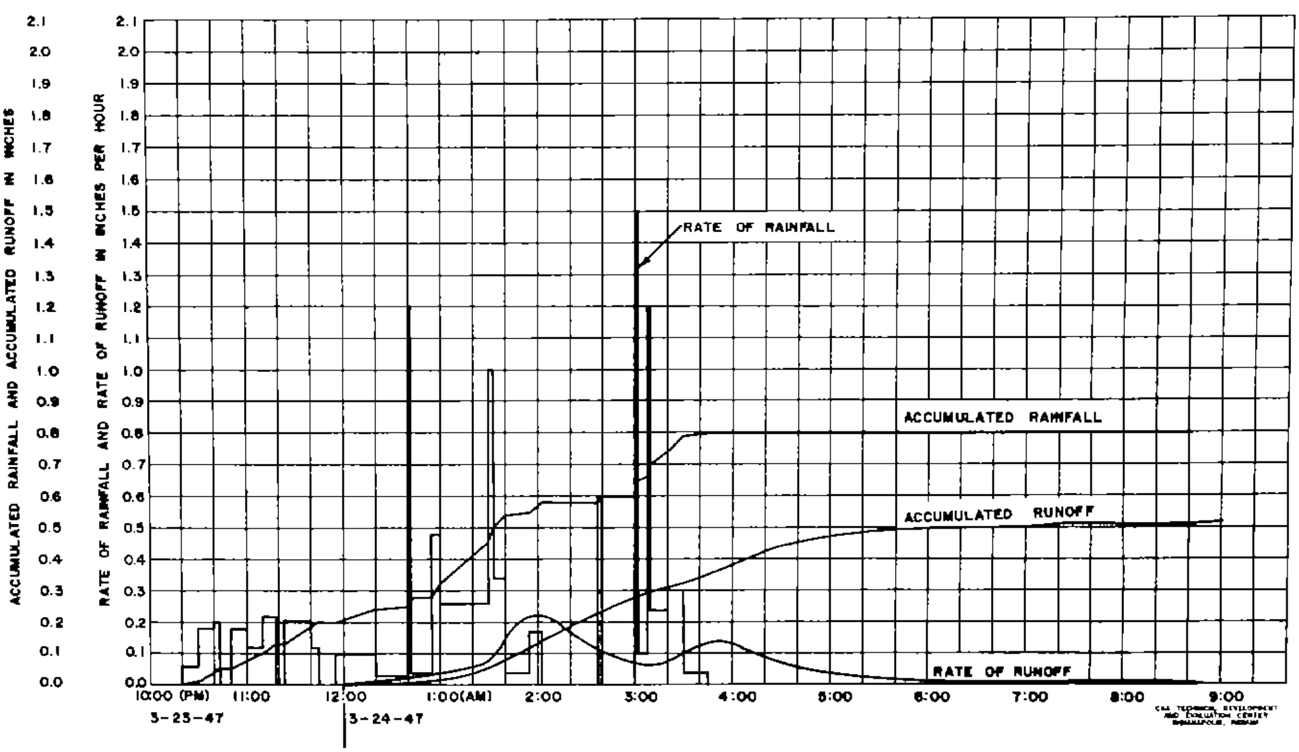

Fig. 20 Rainfall and Runoff Data, Area D, Rome, Georgia

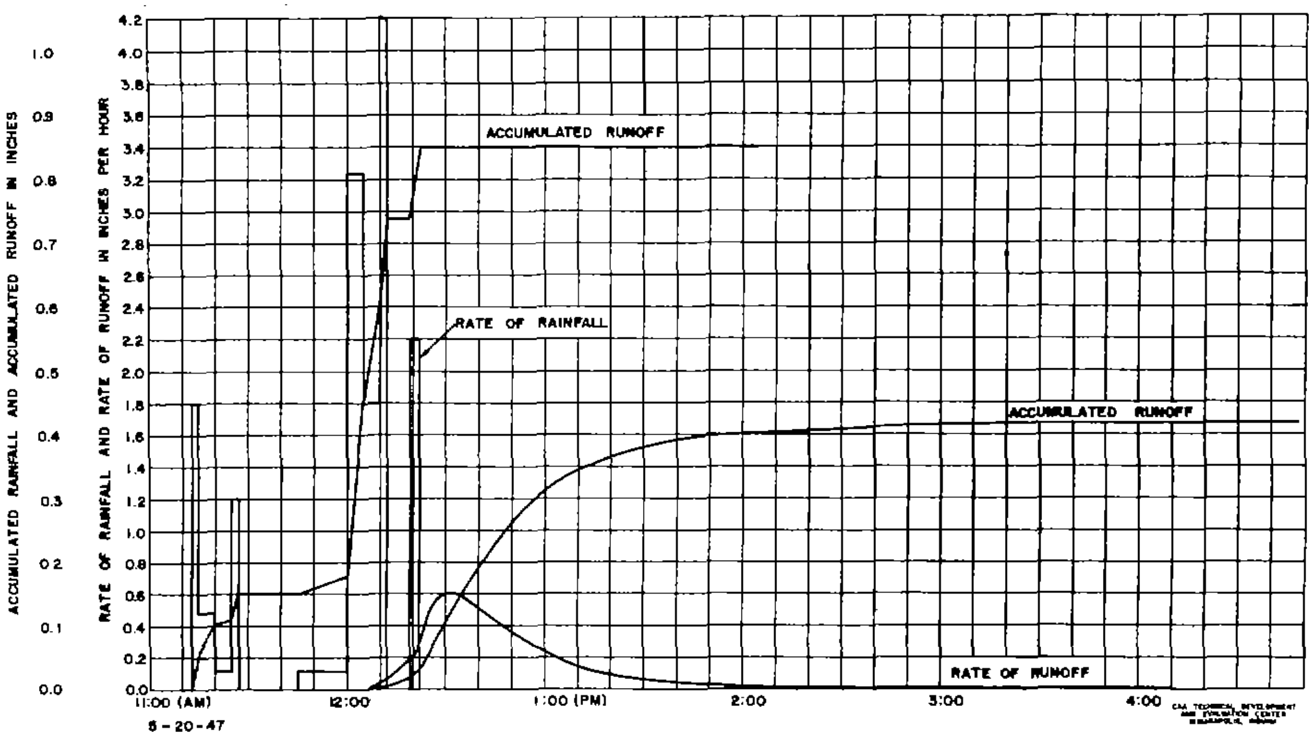

Fig. 21 Rainfall and Runoff Data, Area D, Rome, Georgia

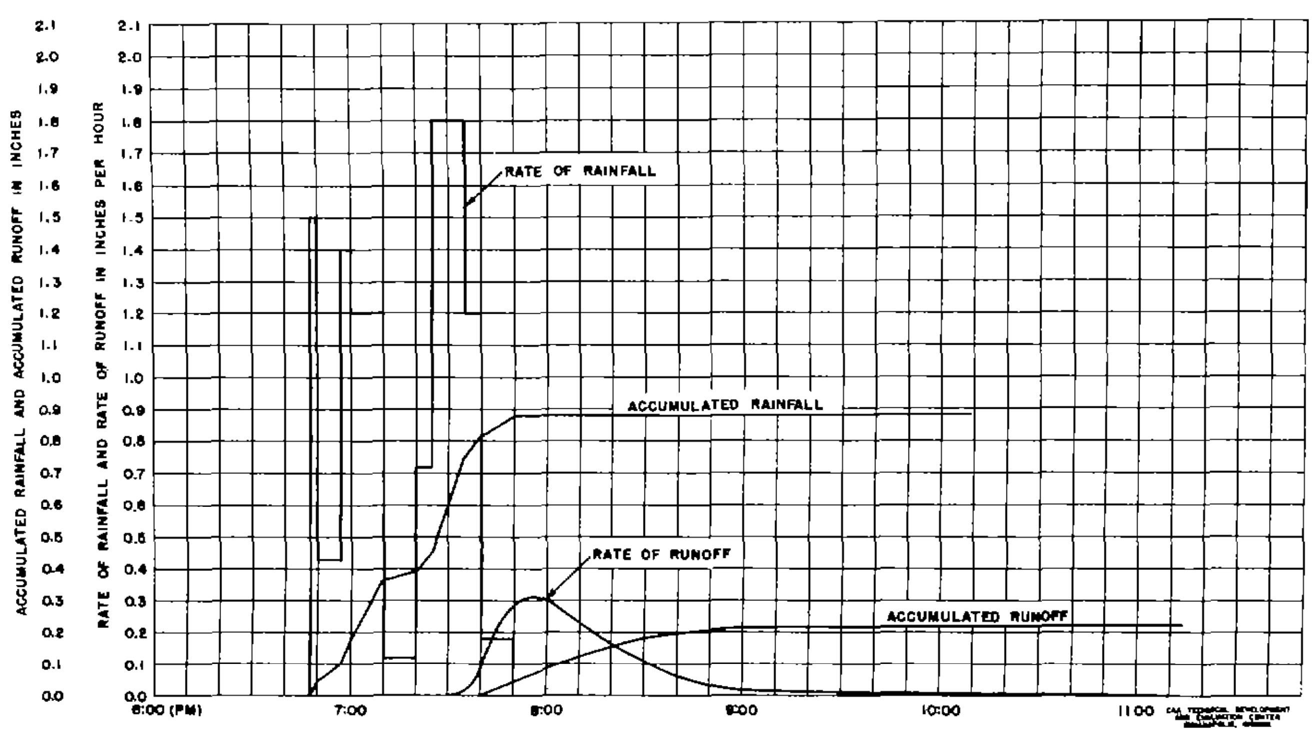

Fig. 22 Rainfall and Runoff Data, Area D, Rome, Georgia

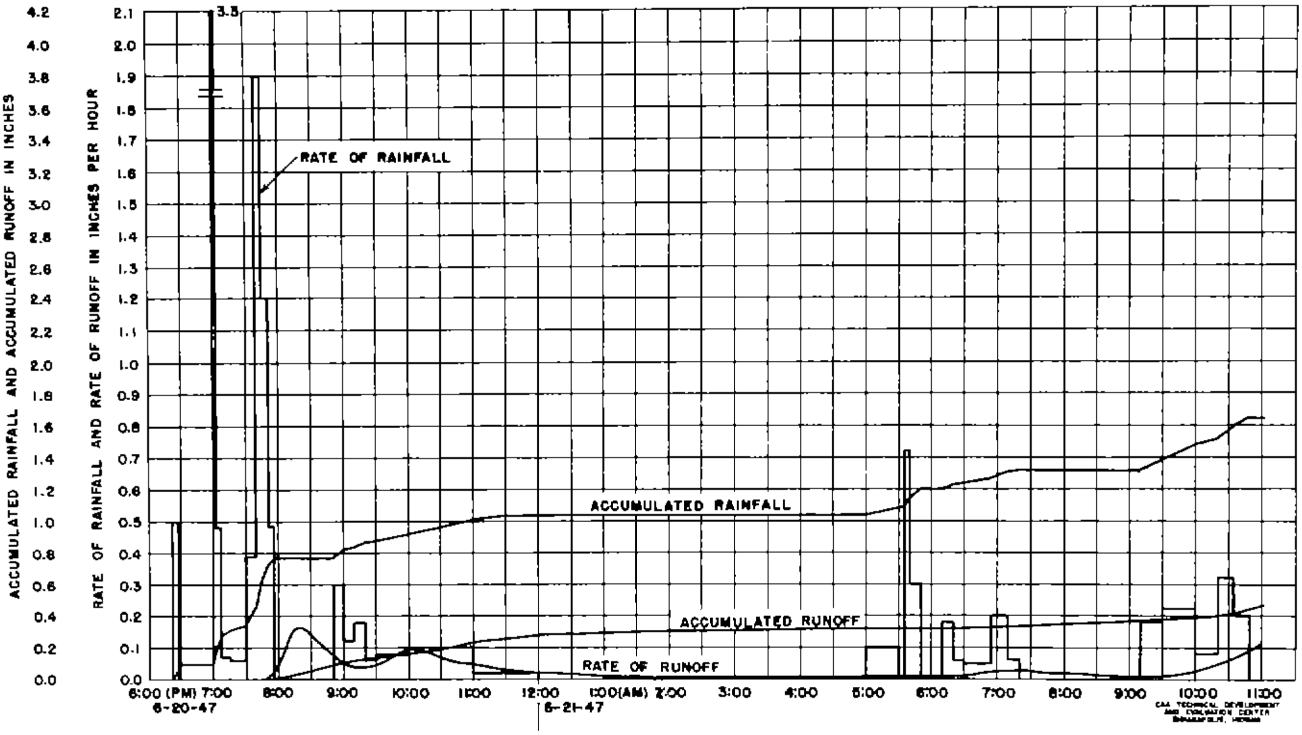

Fig. 23 Rainfall and Runoff Data, Area D, Rome, Georgia

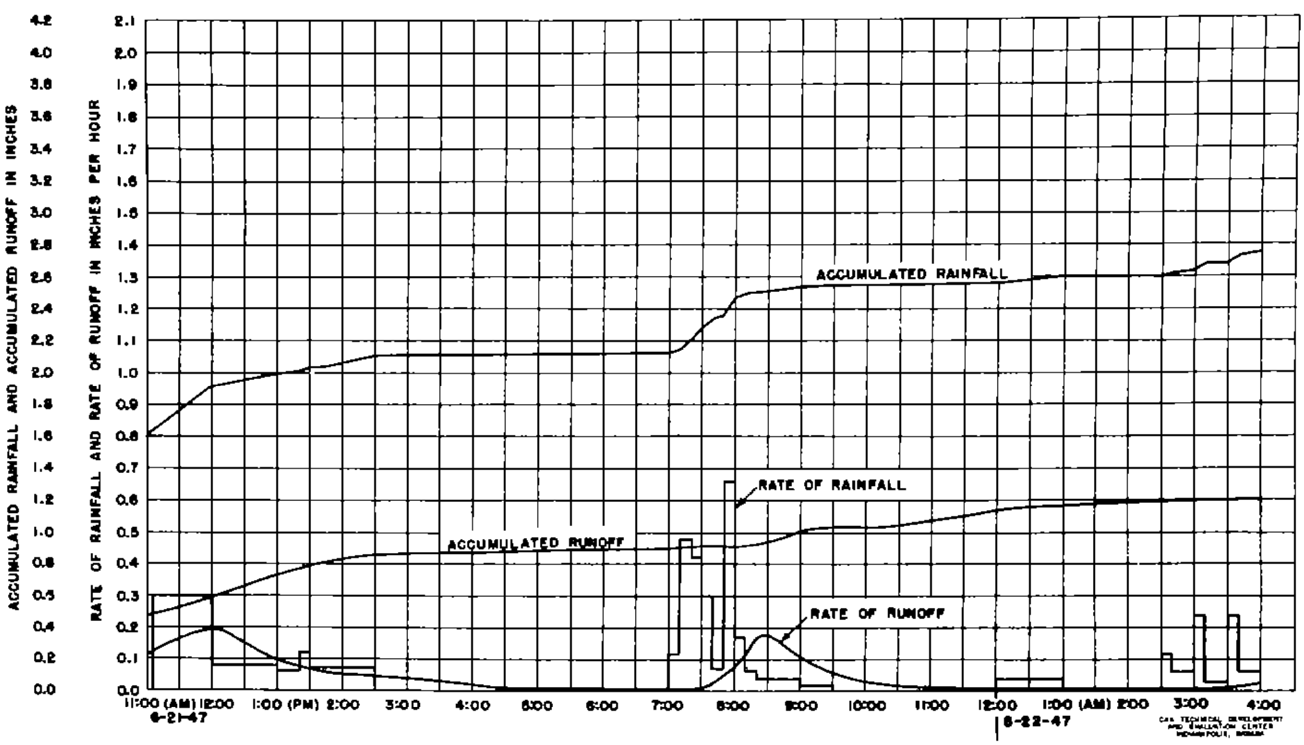

Fig. 24 Rainfall and Runoff Data, Area D, Rome, Georgia

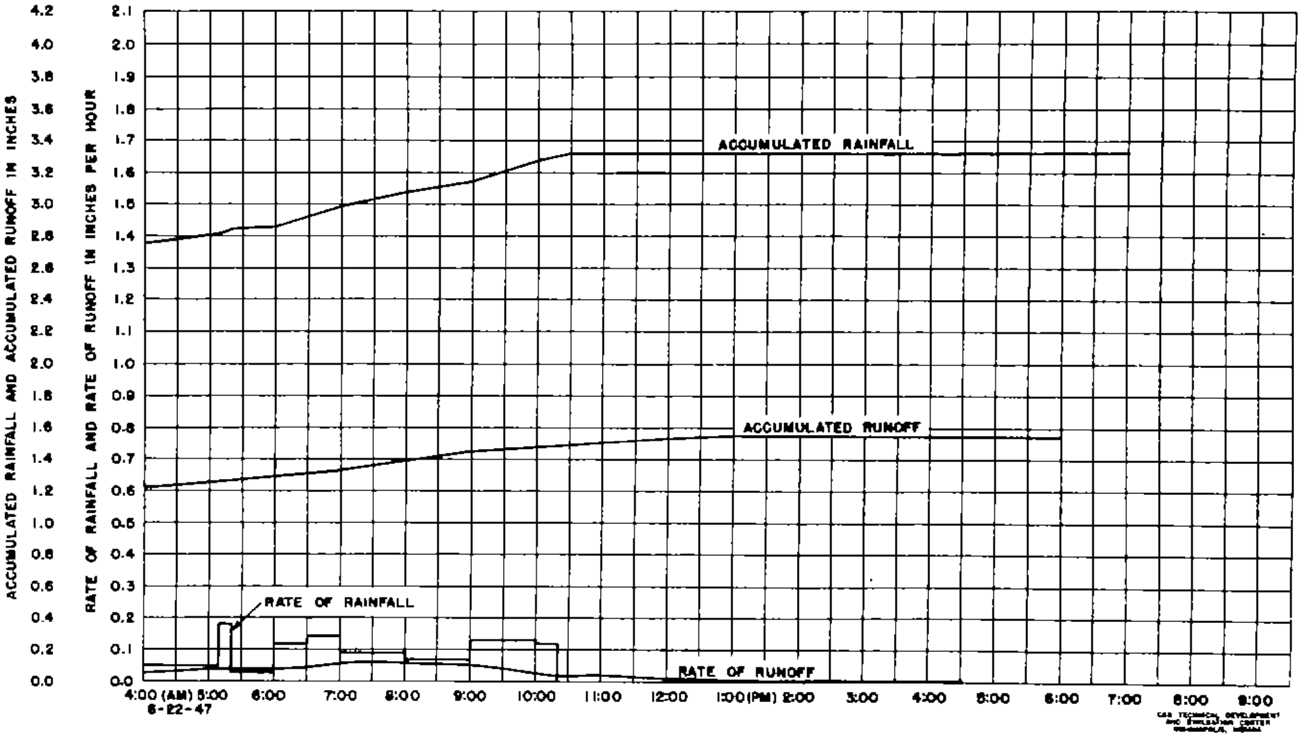

Fig. 25 Rainfall and Runoff Data, Area D, Rome, Georgia

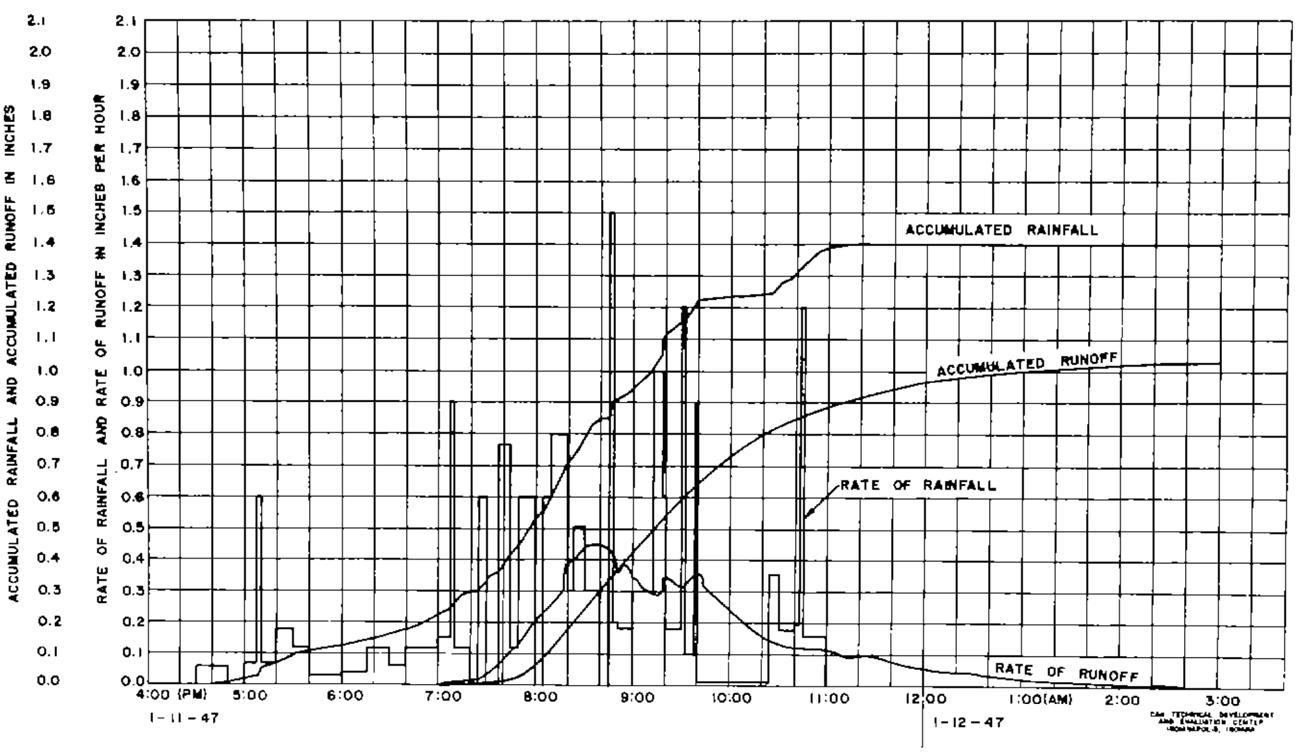

Fig. 26 Rainfall and Runoff Data, Area E, Rome, Georgia

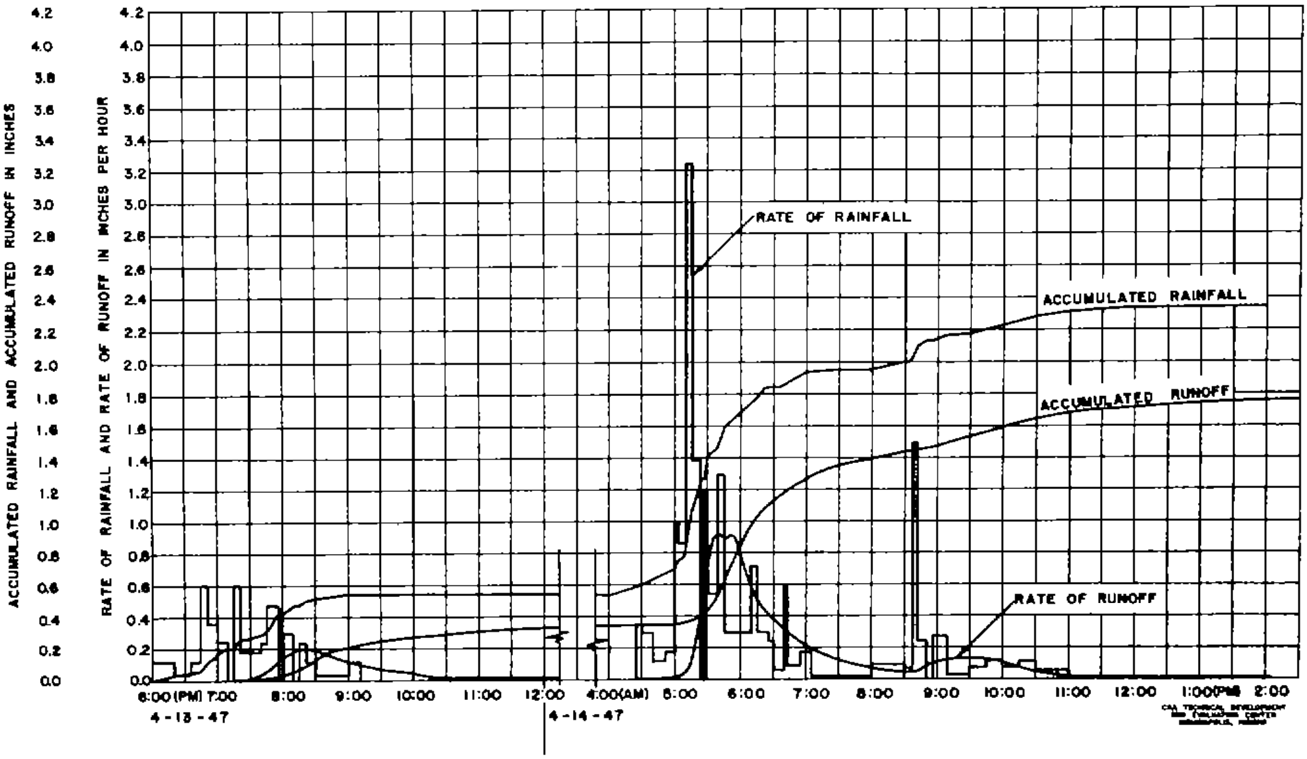

Fig. 27 Rainfall and Runoff Data, Area E, Rome, Georgia

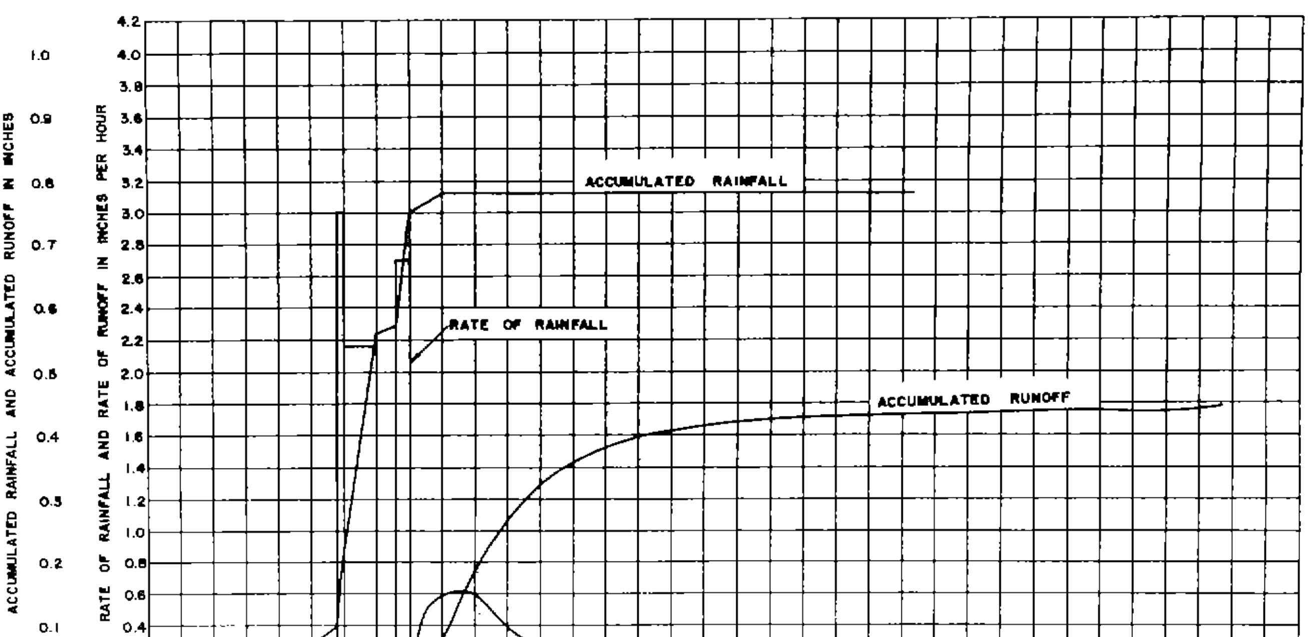

Fig. 28 Rainfall and Runoff Data, Area E, Rome, Georgia

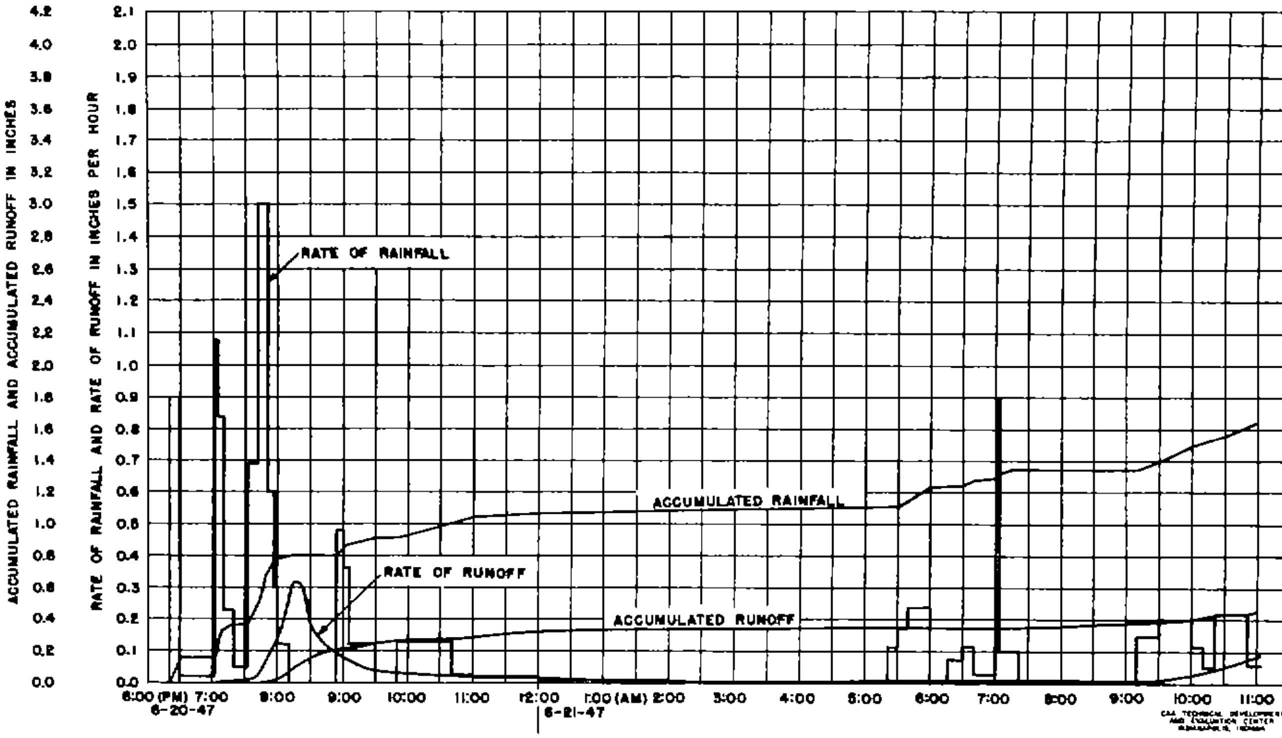

Fig. 29 Rainfall and Runoff Data, Area E, Rome, Georgia

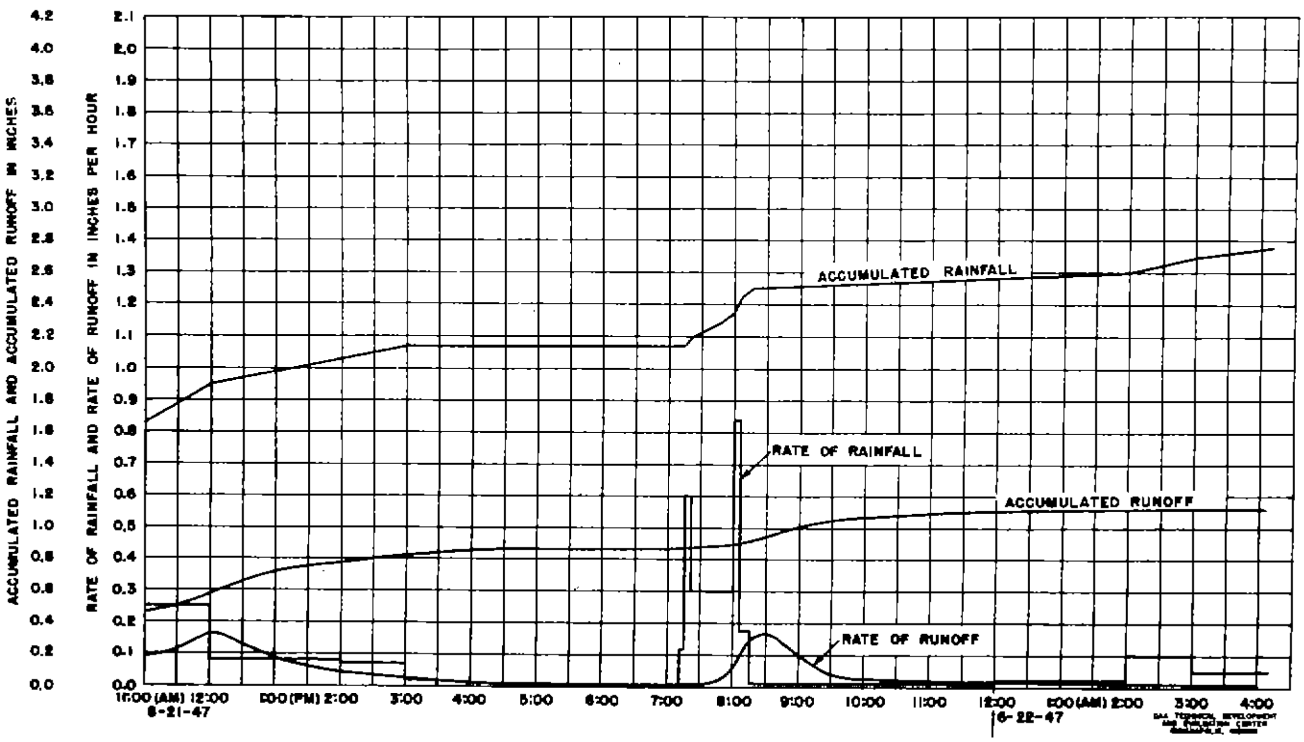

Fig. 30 Rainfall and Runoff Data, Area E, Rome, Georgia