General Series 856

Research Data Assembly for Small Watershed Floods Part II

Small Watershed Hydrology Program - Colorado State University

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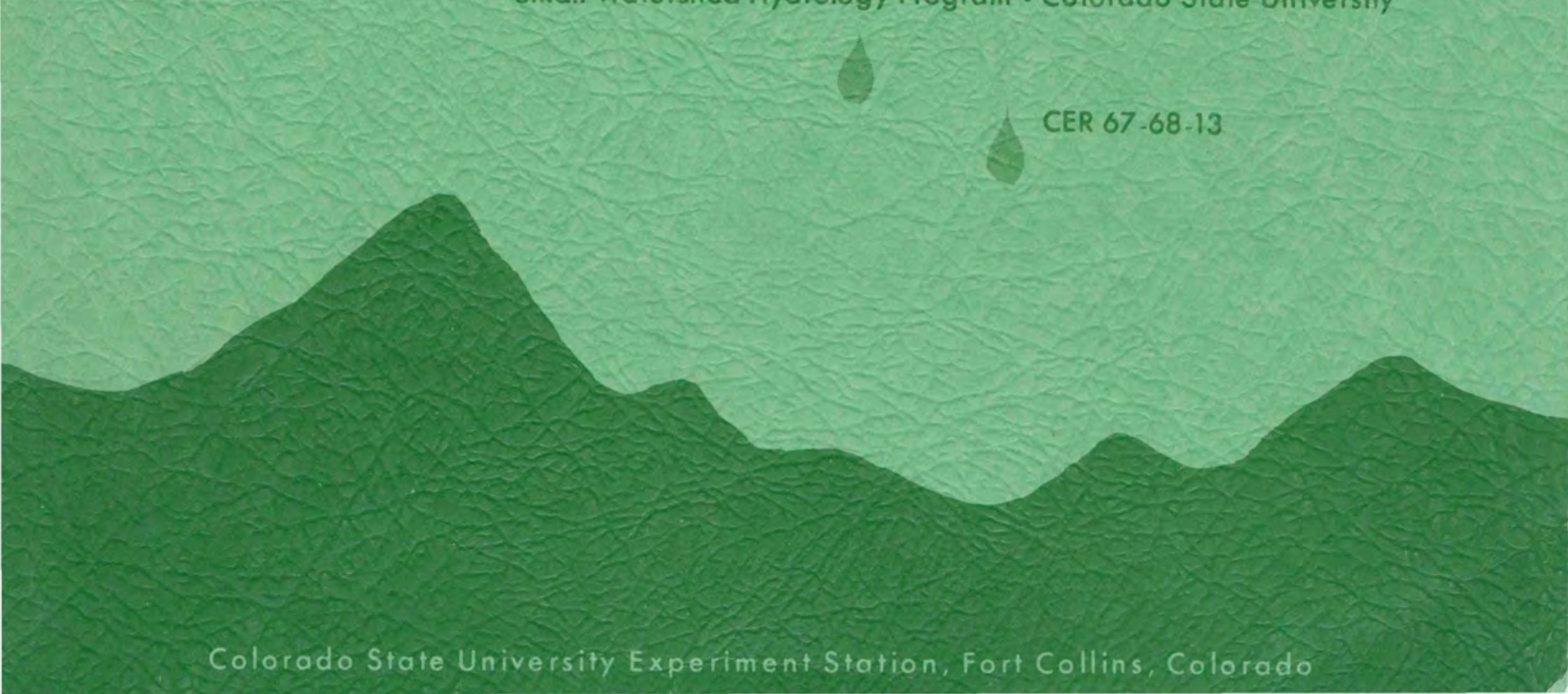

Colorado State University Experiment Station, Fort Collins, Colorado

RESEARCH DATA ASSEMBLY
FOR SMALL WATERSHED FLOODS
PART II

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750 September 1967 CER67-68-13

FOREWORD

This University has been engaged in small watershed research on a diversified basis since September of 1963 when the existing program was initiated. As described in Part I of this series, "Research Data Assembly for Small Watershed Floods" by E. M. Laurenson, E. F. Schulz, and V. M. Yevdjevich, the current program has the following three objectives:

(1) to collect, process, and store, in a form suitable for ready analysis, a large volume of data on floods from small watersheds;
(2) to construct an experimental outdoor facility capable of producing a controlled rainfall and permitting accurate measurement of the runoff response; and
(3) to conduct theoretical studies into the hydrologic processes which regulate the flood hydrograph by means of mathematical models designed to simulate watershed response.

As the first phase of this three-pronged effort, a compilation of high-quality hydrologic data previously recorded by various Federal and state agencies has been assembled. This data pertaining to small watershed floods has been partially processed, punched on data-processing cards, and mounted on magnetic tape for permanent storage and future analyses. The current publication has been prepared in an effort to present specific information about the processing of both flood and physical watershed data.

Generally speaking, the types of data of interest consist of stream discharge obtained from continuous stage records, rainfall from both recording and non-recording gages, and topographic features of watersheds. The types of watersheds investigated can be described as predominantly rural watersheds with areas less than 40 square miles which are drained by natural channels. We propose that ultimately the data from some hundreds of small watersheds, both in the United States and in many overseas countries,will be assembled on magnetic tape.

The basic philosophy of small watershed data collection and an outline of data processing methods were contributed by E. M. Laurenson, E. F. Schulz, and V. M. Yevdjevich in the publication "Research Data Assembly for Small Watershed Floods." Implementation of these basic procedures for data acquisition was undertaken in September 1963 by graduate students R. N. Downer, M. K. Siddiqi, and R. D. Markovic. The supervision of B. M. Reich from September 1964 to September 1966 produced further refinements in the methodology of data processing as well as significant contributions to the small watershed data file. The search for runoff events occurring on small watersheds was continued with the additional assistance of the following graduate students who entered the program during the 1965-66 academic year: Y.B. Ho, D. F. Kibler,

S. Om Kar, A. Voytik, M. E. Ulugur, and L. A. V. Hiemstra. At this time, initial efforts were made to place the existing data file on magnetic tape and to obtain computer analyses of flood frequencies, hyetographs, and hydrographs. Under the guidance of W. U. Garstka from September 1966 to July 1967, a considerable number of flood events were added to the collection and work on a quality control study of physical watershed data was completed. Assistance in the retrieval and analysis of small watershed data from F. C. Bell, visiting professor on leave from the University of New South Wales, during the year commencing June 1966, is gratefully acknowledged. The Small Watershed Project is currently directed by M. E. Holland and it is under his supervision that the present publication has been prepared.

The following theses have been written on the basis of analyses of data in the small watershed compilation:

(1) Mohammed K. Siddiqi, "Rainfall Runoff Volume Relationship for Small Watershed Floods," M.S. Thesis completed August 1966;
(2) Yu Bing Ho, "Evaluation of Runoff Characteristics from Hydrograph Recessions," M.S. Thesis completed June 1967;
(3) Songthara Om Kar, "Hydrograph Rise Times," M.S. Thesis completed June 1967;
(4) Andrew Voytik, "Runoff Predictions from Arid Regions," M.S. Thesis completed June 1967; and
(5) Richard N. Downer, "The Effect of the Time Distribution of Rainfall Intensities on Small Watershed Floods," Ph.D. Dissertation completed September 1967.

The purpose of Colorado State University's effort in developing a large quantity of high quality hydrologic data in the computer-oriented Research Data Assembly Program is to open various areas of hydrologic research for the staff and students at the University. The lack of available data has been a significant block to small watershed hydrology research. It is felt in the Hydrology Program that the investment in the Research Data Assembly Program was justified because of the potential for graduate research studies, thesis work, research by staff members, and research combining students and staff. It is part of the continuing development of hydrology research and graduate program at the University.

The data assembly has been possible because of the cooperation of the many governmental agencies who have made the basic data available. Therefore, it is appropriate that the data file be open to the staff of those agencies who have contributed significantly to the data file. The data are also available to the scientists participating in the research at Colorado State University as visiting professors.

At a later stage in the development of the Small Watershed Data Assembly Program, it is intended to make the file more generally open to hydrologists. When most of the potential watersheds have been brought into the file, there will be at least 2000-3000 storm events included. Such a file would be of great value to all researchers in small watershed hydrology, and efforts will be made to have the data generally available. However, in the present stage of development of the data file, it is felt that the wide availability of access to the file might divert the efforts of the Small Watershed Program and dissipate its effectiveness in further data collection and assembly before the potential of the system is realized.

Colorado State University's Civil Engineering Hydrology Program appreciates the cooperation it has received and welcomes additional cooperation that may hasten the development of the Data Assembly Program to the point that general access is justified.

Vujica Yevjevich
M. E. Holland

ACKNOWLEDGMENTS

Much of the current progress in the small watershed data compilation program would have been impossible without funding from the following agencies:

(1) Colorado State University Experiment Station; and
(2) Bureau of Land Management, U. S. Department of the Interior.

The cooperative efforts of other agencies and institutions in supplying hydrologic data are gratefully acknowledged. For records of rainfall and runoff received, the Small Watershed Project is indebted to the following:

(1) Agricultural Research Service, U. S. Department of Agriculture;
(2) U. S. Geological Survey, U. S. Department of the Interior;
(3) U. S. Forest Service, U. S. Department of Agriculture;
(4) Bureau of Public Roads, U. S. Department of Commerce;
(5) Tennessee Valley Authority;
(6) Soil Conservation Service, U. S. Department of Agriculture;
(7) U. S. Weather Bureau, U. S. Department of Commerce;
(8) Corps of Engineers, U. S. Department of the Army;
(9) California Department of Water Resources;
(10) The Pennsylvania State University, Department of Civil Engineering; and
(11) Bureau of Reclamation, U. S. Department of the Interior.

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Section 1

GENERAL DESCRIPTION OF SMALL WATERSHED DATA COMPILATION PROGRAM

Objectives

The present needs in small watershed hydrology are clearly reflected by the statistics of river-gaging as cited in 1963 by E. V. Giusti ("Distribution of River Basin Area in the Conterminous United States," International Association of Scientific Hydrology, Vol. VIII, No. 3: 20-29, September 1963). Of the 796 river basins in the U.S.A. with areas between 1,000 and 2,500 square miles, 90.5 per cent have been gaged. There are an estimated 42,300 basins within the size range from 20 to 50 square miles of which only 1.9 per cent are gaged. In the 1 to 2 square mile class, containing about 846,000 basins, only 0.007 per cent are gaged. Because large watershed techniques for synthesizing streamflow apply with only rather dismal results to floods on small watersheds, it is apparent that a fuller understanding of small watershed hydrology will require new methods of approach.

In light of the foregoing research needs, a primary objective of the Small Watershed Program was seen as the compilation of a large quantity of data pertaining to rainfall and runoff as it occurs on watersheds in the size range 0.10 to 40.0 square miles. Such an assembly of high quality data would then provide a broad basis for investigations into the nature of small watershed response as it occurs under widely varying hydrologic regimes.

The ultimate objective of the program is the derivation of prediction equations which can be used to forecast various characteristics of the streamflow hydrograph as they vary with changing storm and watershed conditions. The linkage between storm rainfall and resultant flood will be assisted by the many recent advances in statistics, hydrograph synthesis and transmission loss analysis. The success of these innovations is, however, completely dependent upon the quantity and quality of hydrologic data assembled in the initial phase of the program. The clarification of relations existing between complex hydrologic variables can then be attempted with some assurance of success.

Departures from "Research Data Assembly for Small Watershed Floods - Part 1" - Criteria for Watershed Selection

Upon implementation of this data assembly project it became clear that certain criteria set forth in Part 1 of this series (written in 1963 by Laurenson, Schulz, and Yevdjevich) could not be fully met. As experience was acquired in the retrieval of hydrologic data, the need for certain compromises, based on the quantity and quality of available hydrologic records, was indicated. The following paragraphs describe specific changes in the basic policy of data collection.

In order to minimize the influence of artificial regulation of catchment streamflow, it was necessary to exclude a large number of small watersheds whose runoff was clearly affected by contoured crops, terraces, irrigation systems, and drainage channels. Initial efforts in this direction were also aimed at the exclusion of all watersheds having known diversions above the stream gage. However, this restriction proved to be too severe. Therefore, the criterion was lowered to include watersheds whose diversion neither bypassed the stream gage nor appreciably affected the shape of the runoff hydrograph. Small agricultural diversions were generally considered acceptable on the premise that farmers would normally close their head gates during flood stages and the head gates would remain closed during the recession due to a saturation of farmlands during the floods. Naturally, large diversions for agricultural uses, domestic water supplies, and power generation were unacceptable because of their unknown regulatory effects on catchment streamflow. It should be noted that the rejection of small watersheds on the basis of streamflow regulation is a subjective task which becomes highly dependent on streamflow notes and remarks provided by the agency operating the watershed.

The original requirement of available contour maps having sufficient detail to permit determination of physical watershed characteristics also proved too severe. The mid-west and southern sections of the United States, for example, are inadequately covered by topographic mapping. This is particularly true of the sparsely populated regions where the headwaters for many small, unregulated watersheds are located. Consequently, prospective watersheds have been admitted to the sample even though complete map coverage is as yet unavailable.

Further criteria for watershed selection provided that data would be collected only from those watersheds which were predominantly rural in nature. Because the problems of flood estimation in urbanized drainage systems are totally different from those of rural watersheds, this measure was taken as a means of introducing a certain homogeneity in the data and also of setting limits on the task of data compilation. In this regard, it was soon realized that many small watersheds, having rather long records as rural watersheds, are now being steadily advanced upon by expanding urban centers. Certain of these watersheds were included in the data file for the following two reasons: (1) a sufficiently long record as a rural watershed will yield many useful flood events; and (2) the changing land use will make them valuable as pilot watersheds in later studies of the effects of urbanization on flood estimation and control.

The single most difficult criterion to satisfy was the requirement of at least one recording raingage and a sufficient number of nonrecording raingages to give a complete description of the time and areal distribution of rainfall on the watershed. Except in the cases of experimental watersheds, few small watersheds have completely adequate raingage coverage. In order to retain those watersheds with substantial records of continuous streamflow, the recording raingage criterion was modified to include situations where storm totals were the only available rainfall data. This modification greatly enhances the data ensemble from the standpoint of investigations of hydrograph shapes and recession characteristics which do not require explicit knowledge of the rainfall distribution in time.

The intention of the original authors was to store and analyze single-peaked hydrographs which were produced by precipitation in the form of rainfall only, and which were unaffected by retardation of flow along the drainage system. In keeping with this intention, all watersheds in the data assembly have been classified according to their departure from the ideal of a "natural" watershed without extensive overland flow retardations. The classes are ranked and coded in order of desirability as follows:

(1) watersheds exhibiting a well developed drainage pattern with few lakes and swamps (code = 50);
(2) watersheds exhibiting a well developed drainage pattern and small natural lakes on swamps which could provide considerable storage (code = 51);
(3) watersheds with a well-developed pattern of drainage channels but having, in addition to small lakes, many unregulated farm ponds (code = 52);
(4) watersheds having extensive drainage improvements such as canals, terraces, levees, and tile drains (code = 54); and
(5) watersheds with engineering structures designed for flood control and irrigation purposes (code = 57).

Watersheds falling in classes (4) and (5) are excluded from the data assembly program. Those in classes (1) through (3) are retained and their respective codes are recorded on the back of the watershed card which is described in Section 2.

The method of processing streamflow data has been changed only slightly. Hydrograph ordinates are now tabulated in units of inches per hour at irregular time intervals. The change of units from cfs to in/hr was made to facilitate easy comparison of rates of runoff with rates of rainfall. These units, being independent of area, also permit ready comparison of runoff rates among watersheds of different sizes. Tabulation of hydrograph ordinates at irregular intervals was implemented to give better definition to the hydrograph shapes.

The processing of rainfall data has followed the intent of the original authors closely except for the method of storage. The determination of the average hyetograph proved to be very tedious in the case of storms observed at several recording raingages. It was felt the work could be expedited by the combination of these individual mass curves to form an average mass curve of rainfall. The procedures by which the average mass curve and the hyetograph are obtained are explained in Section 3.

Description of Assembled Hydrologic Data

As stated in the foreword, the watersheds of interest are those with non-urban surface characteristics whose runoff is not subject to severe regulation by swamps or lakes nor diversion for irrigation. Of equal importance for purposes of this investigation is the adequacy of the recording raingage network and the availability of topographic maps covering the area concerned.

A watershed meeting the above criteria and having an area between 0.1 and 40 square miles is first assigned a watershed number designating the state and major river basin in which the catchment is situated. The longitude, latitude, and elevation of the streamgage are determined and the appropriate topographic map is obtained. Information pertaining to soil type, surface cover conditions, and geologic formations is then recorded on a keysort card for that watershed. An example of specific data obtained for a watershed is included in Section 5. The dates of continuous operation of the streamgage and raingages are filled in and the mean annual discharge and rainfall are computed from the corresponding records. At this time, the annual peak discharge series is compiled for purposes of determining the return period of specific floods occurring on the watershed. Presently a computer program is used for plotting the observed annual peak flows on Gumbel extremal probability paper and also for fitting the Gumbel and Jenkinson theoretical distribution curves to these points. The probability distributions of rainfall and selected maximum intensities are also determined by plotting on Gumbel paper. It is expected that the distributions of peak discharge and rainfall thus derived will play a significant role in future analyses of floods from small watersheds.

In the next step, physiographic data for each watershed is taken by direct measurements from a topographic quadrangle sheet. This data includes size and shape of the watershed, as well as various relief features occurring within its boundary. Total fall, stream slope, and overland slope are expected to be important factors in governing the rate of runoff and the magnitudes of certain rainfall losses. Drainage density, average watershed width, and watershed compactness are considered as significant physiographic parameters in describing variations in runoff rates and volumes. In addition, engineering descriptions of soil types and geologic structures associated with the watershed are to be utilized in later analyses of runoff data.

It is anticipated that each watershed in the sample will eventually observe a minimum of 10 significant storms which can be included in the small watershed data compilation. Since the ultimate aim of the study is to synthesize relationships between rainfall, runoff, and watershed characteristics, continuous records of storm rainfall and streamflow are of obvious importance. In addition to mass curves of rainfall and streamflow hydrographs, the storm data consists of antecedent moisture and surface cover indices, as well as various measures of infiltration and other losses. As mentioned in the last section, the probabilities of peak discharge and 30, 60, 180 and 360 minute maximum rainfalls are included as parameters in the study.

Both the physical watershed data and the storm event data are taken from maps and station records, respectively, and recorded on keysort data cards, as described in Sections 2 and 3. The keysort cards are then used directly by a keypunch operator to enter this information on data processing cards. The data processing cards are in turn read onto magnetic tape by means of available computer programs. The tape can now be called to duplicate either the entire store of hydrologic data or any selected portion of the ensemble. The entire compilation of small watershed flood data is thus stored in a manner which is completely adaptable to the needs of the research hydrologist.

Arrangement of Assembled Data on Magnetic Tape

In order to facilitate the storage and retrieval of hydrologic data which has been mounted on magnetic tape, all data for a single watershed and a single storm has been broken down into six sections. The sections are shown schematically in the block representation of Figure 1.1. As shown by Figure 1.1, the information pertaining to a single watershed description is stored in the blocks labeled 0000, 1000, 2000, and 3000. The cards in these blocks will have identical serial numbers punched in the first eight columns (with zeroes in columns 9 and 10), since the data of these sections does not change from storm to storm. The flood event data is contained in blocks 4000, 5000, and 6000. The last two digits of the serial number on these cards remain fixed for a single event but vary from storm to storm. This method of watershed and storm identification, which is described in Section 2, is such that the first eight digits of the ten-digit serial number are reserved for the watershed, while the last two digits are assigned to storm events occurring on that watershed. The sketch of Figure 1.1 illustrates the method of storing the data for a second storm on a particular watershed. The API series, rainfall mass curve, and runoff hydrograph for the second event are positioned immediately behind the same data for the preceding storm. In comparison with the preceding event, the 4000, 5000, and 6000 cards for this second event would have the same watershed number in the first eight columns but different digits in the ninth and tenth columns. The simplified numbering scheme presented here has been expanded to include many runoff events occurring on nearly two hundred small watersheds. A brief description of the data contained in the blocks of Figure 1.1 is presented in the following paragraphs.

Watershed name and location (0000 series) - This block of four cards, numbered 0000 through 0004, contains the name, town, state, country, continent, longitude, latitude, elevation of stream gage, watershed area, average annual runoff in cfs, average annual precipitation in inches, name of the operating agency, and the dates of continuous operation of the water-stage recorder.

Watershed description (1000 series)- This block of cards, numbered 1000 up to 1999, will be of sufficient length to give a complete alphameric description of the watershed in terms of its soil types, cover conditions, geology, land use, character of streamflow, type of instrumentation and references to pertinent data.

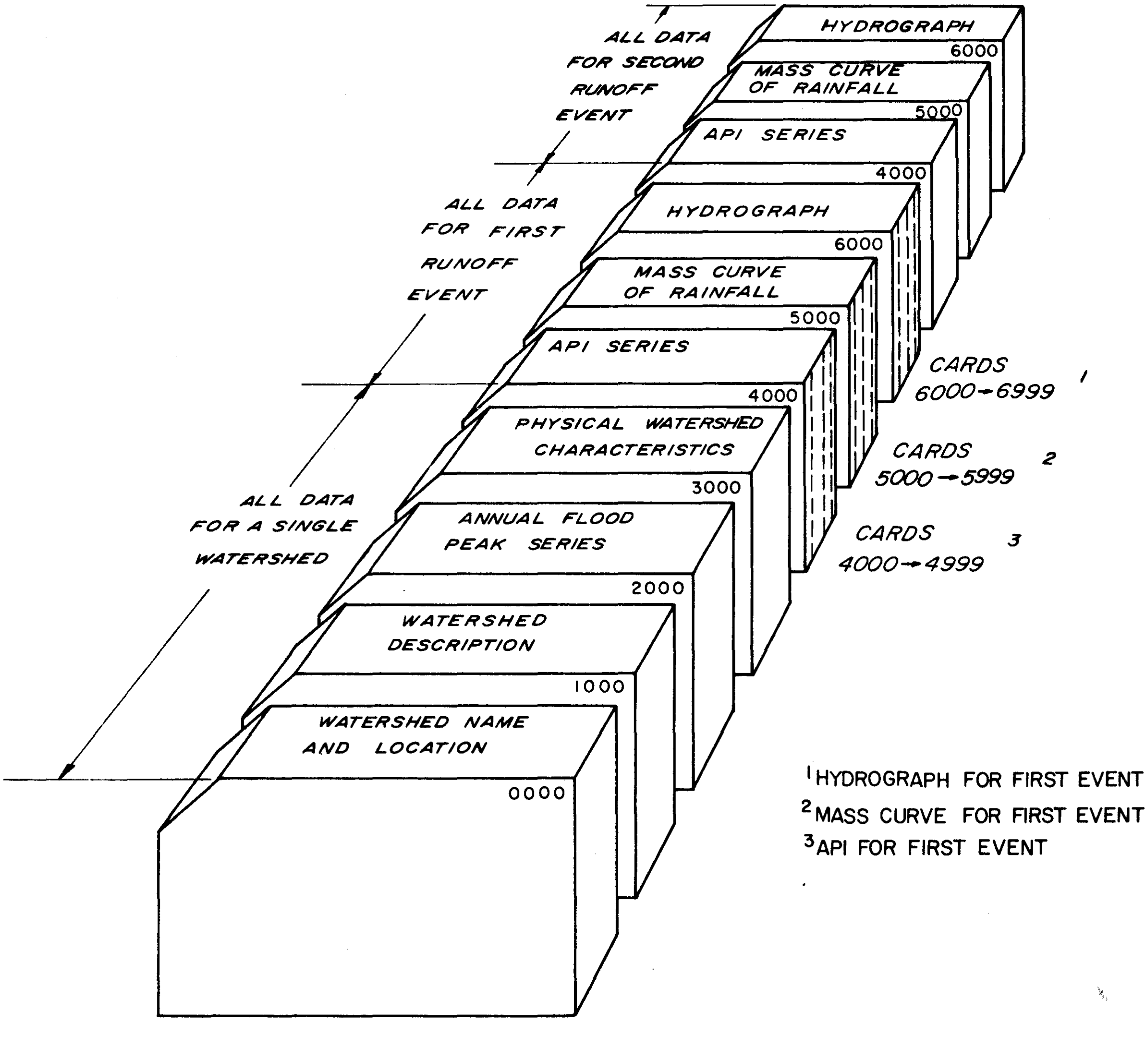


Figure 1.1. Schematic representation of data arrangement for a single watershed with two runoff events

Flood series (2000 series) - The 2000 series contains the dates and peaks of the maximum annual peak discharge series. The peaks are tabulated in whatever units are available from the source agency. The factor for conversion of the peaks to inch per hour units is stored in this block.

Physical watershed characteristics (3000 series) - This block of three cards, numbered 3000 through 3002, contains all watershed parameters computed from a topographic map of the watershed.

API series (4000 series) - The cards in this block contain the antecedent rainfall for each storm event. Antecedent rain falling on the day of the storm and one day before is recorded on a minute by minute basis. Rainfall preceding the commencement of the storm by more than one full day is reported at midnight (2400 hours) for that entire day.

Mass-curve of rainfall (5000 series) - The cards of the 5000 series contain the cumulative rainfall ordinates and corresponding times of break-points in the average mass curve of rainfall determined in Section 3. The first card of the series contains the date and time of storm commencement in addition to the total storm rainfall in inches.

Discharge hydrograph (6000 series) - This block of cards is reserved for selected ordinates of the discharge hydrograph, in inch per hour units, together with the incremental times between these ordinates. The first card in the series contains the date and time of storm commencement, the peak discharge, lag time between beginning of rainfall and beginning of runoff, and the time of rise of the hydrograph.

Section 5 of this report is presented in an effort to provide specific examples of the physical watershed and storm data described in the preceding paragraphs.

Section 2

COMPUTATION OF PHYSICAL CATCHMENT CHARACTERISTICS FOR THE WATERSHED CARD

Description of Symbols for the Watershed Card

Symbol	Definition	Units of Measurement	Decimal Places
A	Area	Square miles	2
c	Contour interval	Feet	0
C	Compactness coefficient	Dimensionless	2
D_d	Drainage density	Miles per sq. mi.	2
F	Form factor	Dimensionless	2
Δh	Difference in elevation	Feet	0
h	Elevation above outlet	Feet	0
H	Total fall	Feet	0
l_i	Length of reach	Miles	2
l_t	Distance from grid intersection to outlet	Miles	2
L	Length of main stream	Miles	2
$\bar{L}$	Average length of two successive contour lines	Miles	2
L_c	Distance to centroid of area	Miles	2
L_{con}	Length of a contour line	Miles	2
L_g	Length of the grid lines within the catchment	Miles	2
L_m	Dimensionless mean travel distance	Dimensionless	2
L_s	Total length of extended streams	Miles	2
L_t	Average travel distance	Miles	2
n	Number of grid intersections		
N_i	Number of intersections of the grid lines with i^{th} contour line		
P	Perimeter of catchment	Miles	2

Section 2 was first written in May 1964. Revisions were made in March 1967.

Description of Symbols for the Watershed Card - Continued

Symbol	Definition	Units of Measurement	Decimal Places
P_a	Average annual precipitation	Inches	2
q_a	Areal average discharge	cfs per sq. mi.	3
Q_a	Average discharge	cfs	3
R_1	Overland slope	Feet per mile	0
R_2	Overland slope	Feet per mile	0
R_3	Overland slope	Feet per mile	0
R_4	Overland slope	Feet per mile	0
R_5	Overland slope	Feet per mile	0
R_6	Overland slope	Dimensionless	4
S_1	Stream slope	Feet per mile	0
S_2	Stream slope	Feet per mile	0
S_3	Stream slope	Feet per mile	0
S_4	Stream slope	Feet per mile	0
s_t	Standard deviation	Miles	2
s_d	Dimensionless standard deviation	Dimensionless	2
X	Latitude of gaging station	deg., min., sec.	0
Y	Longitude of gaging station	deg., min., sec.	0
Z	Elevation of gaging station	Feet above MSL	0
Z_i	Average elevation of a reach	Feet above outlet	0

General Catchment Information

As outlined in Section 1, the first step in the processing of physical watershed information is the classification of a prospective watershed according to its streamflow diversions, map coverage, degree of urbanization, raingage network, and overland flow retardations. A code taken from each category of Table 2.1 is assigned to any new watershed as a means of evaluating its overall acceptability for the intended purposes of this data compilation program. The codes selected from Table 2.1 are recorded in the first column on the left half of the reverse side of the watershed card. The right half of this side is taken up with the names and scales of all topographic maps covering the watershed in question. It is emphasized that the primary sources of information for determining the watershed codes are: (1) the topographic map covering the watershed and (2) notes on streamflow regulation made by the agency responsible for the watershed. An inspection of the code numbers recorded on the back of the watershed card will reveal whether the watershed in question meets the criteria for acceptance established in Section 1 of this report.

All data pertaining to physical characteristics of the catchment are to be recorded on the front side of the watershed card, a copy of which is shown in Figure 2.1.

Serial Number

The watershed serial number is a ten digit number which, when read from left to right, is broken down as follows:

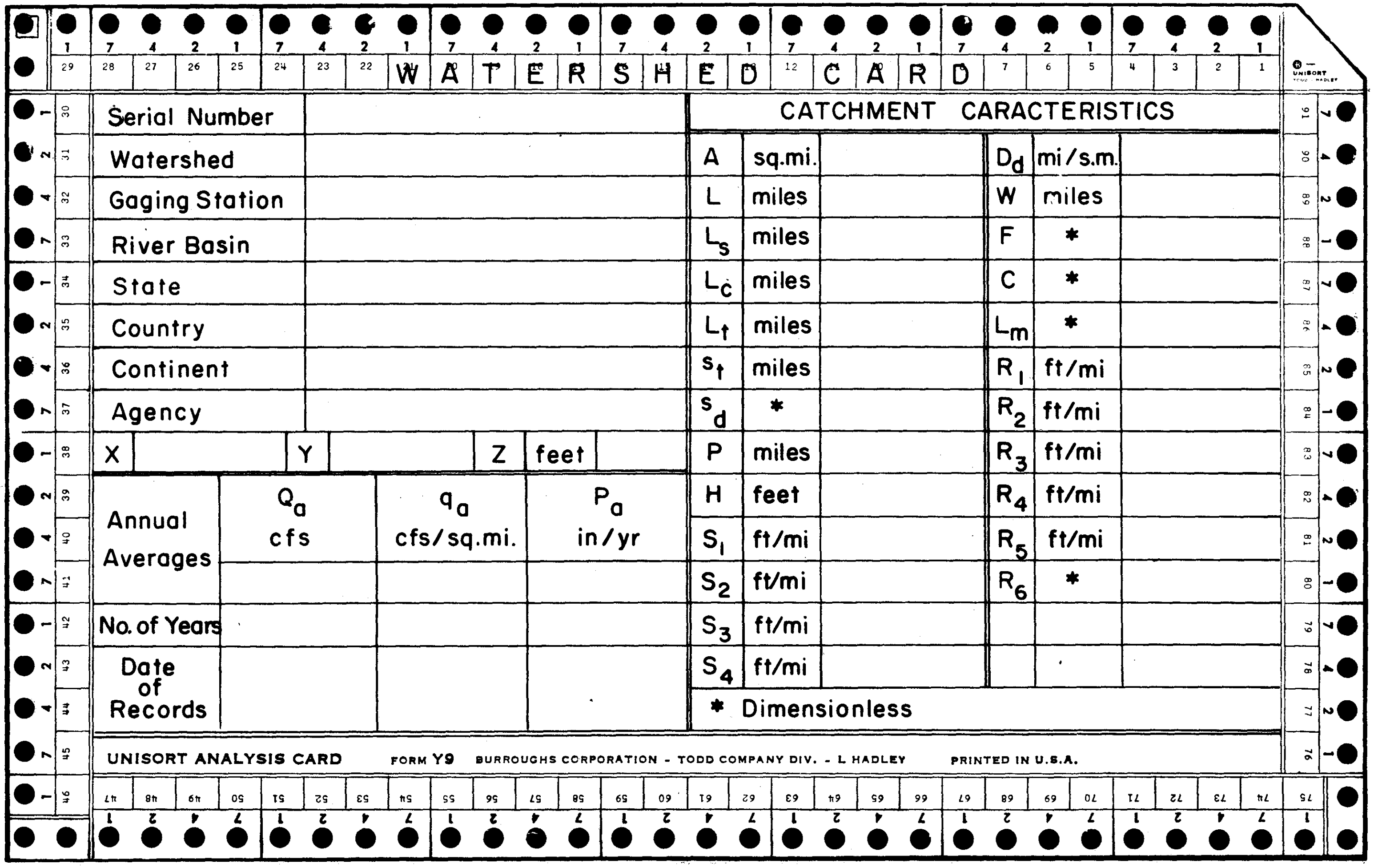
(1) the first digit designates continent with the number one reserved for North America;
(2) the second and third digits represent the number of the state when ranked alphabetically;
(3) the fourth and fifth digits designate the U.S. Geological Survey number for the major river basin in which the watershed is found;
(4) the sixth, seventh, and eighth digits designate the watershed number which is assigned from the Watershed Master List within the major river basin, state and continent in which the watershed is located;
(5) the ninth and tenth digits are reserved for the purpose of identifying the storm events on the watersheds in question, and are always zero on the watershed card.

An illustration of the watershed serial number is shown below:

1	-	43	-	09	-	128	-	00
Continent of North America		State of Texas		USGS river basin number for Rio Grande River		Watershed number 128 in this basin and state		Event number

Table 2.1. Watershed Codes

Code No.	Category
	Diversions
10	No diversions
11	Diversions tolerable - negligible influence on runoff hydrograph
12	Diversions unacceptable - involving large quantites imported or exported
	Maps
20	Complete topographic map coverage
21	Partial map coverage
22	No maps at 7½' or 15' scale available
	Urbanization
30	Insignificant urbanization - rural watershed
31	Urbanized but has substantial record as rural watershed
32	Substantial record as both rural and urban watershed
34	Highly urbanized watershed with no past record of rural conditions
	Raingage Network
40	Several recording gages inside watershed boundary giving complete definition of the mass curve of rainfall
41	Recording gages fall outside watershed but are close enough to give good definition of the mass curve of rainfall on the watershed
42	No recording gages - storm totals obtained by non-recording gages in watershed
44	No recording or non-recording gages near enough
	Overland Flow Retardations
50	Natural watershed exhibiting a well developed drainage with few lakes and swamps
51	Watershed with well developed drainage system but having small natural lakes or swamps
52	Watershed with a well developed drainage system but having, in addition to small lakes, several unregulated farm ponds
54	Watershed having extensive drainage improvements such as canals, terraces, levees, and tile drains
57	Watershed with engineering structures designed for flood control and irrigation purposes



WATERSHED CARD

Serial Number	
Watershed	
Gaging Station	
River Basin	
State	
Country	
Continent	
Agency	

X ______ Y ______ Z feet ______

Annual Averages	Q_a cfs	q_a cfs/sq.mi.	P_a in/yr
No. of Years			
Date of Records			

CATCHMENT CARACTERISTICS

A	sq.mi.		D_d	mi/s.m.	
L	miles		W	miles	
L_s	miles		F	*	
L_c	miles		C	*	
L_t	miles		L_m	*	
s_t	miles		R_1	ft/mi	
s_d	*		R_2	ft/mi	
P	miles		R_3	ft/mi	
H	feet		R_4	ft/mi	
S_1	ft/mi		R_5	ft/mi	
S_2	ft/mi		R_6	*	
S_3	ft/mi				
S_4	ft/mi				

* Dimensionless

UNISORT ANALYSIS CARD FORM Y9 BURROUGHS CORPORATION - TODD COMPANY DIV. - L HADLEY PRINTED IN U.S.A.

Figure 2.1. Front side of the watershed card showing location of catchment characteristics

Watershed

The name of the river, stream or creek. If an experimental watershed, this will probably be a number rather than the name of a stream.

Gaging Station

The name of the town or city at or near the gaging station.

River Basin

This is the major basin to which the river, stream or creek belongs. A major basin is usually several thousand square miles.

Country

Country in which gaging station is located.

Continent

This term is self-explanatory (North America, South America, Europe, Asia, Africa, and Australia).

Records Available

This is the period (day, month and year) during which the gaging station and raingages were in operation.

Latitude, X

This is the latitude of the gaging station in degrees, minutes, and seconds.

Longitude, Y

This is the longitude of the gaging station in degrees, minutes, and seconds.

Elevation, Z

This is the mean sea level elevation of the gaging station in feet.

Average Daily Discharge, Q_a

This is the average daily discharge in cfs based on a long period of observation. Also enter the period in years on which this average discharge is based.

Areal Average Daily Discharge, q_a

q_a equals Q_a divided by the catchment area in square miles.

Average Annual Precipitation, P_a

This is the average annual precipitation in inches per year which falls on or near the catchment. Also enter the period in years on which this average rainfall is based.

Physical Catchment Characteristics

Note on Map Scale

Since all dimensions are to be expressed in feet or miles, it will be advantageous to convert the map scale to feet and miles and draw it on the margin of the map.

Area, A

The area will usually be given, but if not, it will be necessary to delineate the catchment boundary and planimeter the area. Record on the map in some convenient place (e.g. below the name of watershed) the area in square inches and the area in square miles to two decimal places. If the area is given, one needs only record the area in square miles on the map. For the present, areas less than 64 acres (0.1 square mile) and greater than 25,600 acres (100 square miles) will be omitted. Use the dittoed form for "Catchment Area."

Length of Main Stream, L

Extend all marked stream systems up to the watershed boundaries in accordance with the contours. Extension to the watershed boundary is not done for streams which appear to originate in springs or swamps. The main stream is defined as that stream draining the greatest area. Using a paper strip, mark off the total length of the main stream by a series of straight line segments on the strip. The total strip distance equals L when measured by the map scale. At the same time mark and label points where the main stream crosses a contour line. Calculate the distance in miles to two decimal places between successive contours and record on the paper strip. The summation of these distances is the length of the main stream, L. Save the strip of paper for use in plotting the main stream profile, and calculation of slope.

Total Length of Extended Streams, L_s

Using the paper strip method, measure the total length of all extended streams. It is suggested to measure all the tributaries on one side of the main stream and then the other side. L_s is computed as the sum of all tributary distances to the confluence with the main stream plus L.

Length to Centroid of Area, L_c

The centroid of the catchment can be found quickly and easily and with a fairly high degree of accuracy by centering over a map of the watershed a clear plastic overlay having a system of lines drawn on it at 45° angles to form a star-shaped design. L_c is the distance along the main stream from the outlet to a point adjacent to the centroid of area projected to the main stream. This distance can be found most easily by using the paper strip originally used to measure the length of the main stream, L. Determine L_c in miles to two decimal places.

Mean Travel Distance, L_t

The average travel distance is determined by measuring the travel distance to the outlet along the stream system from each intersection of a square grid placed over a map of the catchment. The grid should be oriented in a North-South, East-West orientation. The grid should be of such a size that between 30 and 50 intersections fall within the catchment. It is suggested to number each of the intersections which fall within the catchment to aid in accounting for every intersection. The distances should be measured by the paper strip method and recorded in miles in tabular form so that L_t can easily be determined from $\frac{\sum l_t}{n}$, where $\sum l_t$ is the sum of individual travel distances and n is the number of intersections within the catchment. By noting and recording on the map the distances to key points or stream forks, the measurement of distances to other points can be greatly facilitated. Use Form W-1 as shown in Figure 2.2.

Standard Deviation of Travel Distance, s_t

The standard deviation of the travel distance will be computed as the square root of

$$\{\frac{1}{n} \sum l_t^2 - (\sum l_t)^2\}.$$

This form lends itself to easy computation since the second term is equal to the average travel distance, L_t, squared. The first term $\sum l_t^2$, can be determined on the desk calculator by using accumulative multiply. Use Form W-1 as shown in Figure 2.2.

Perimeter, P

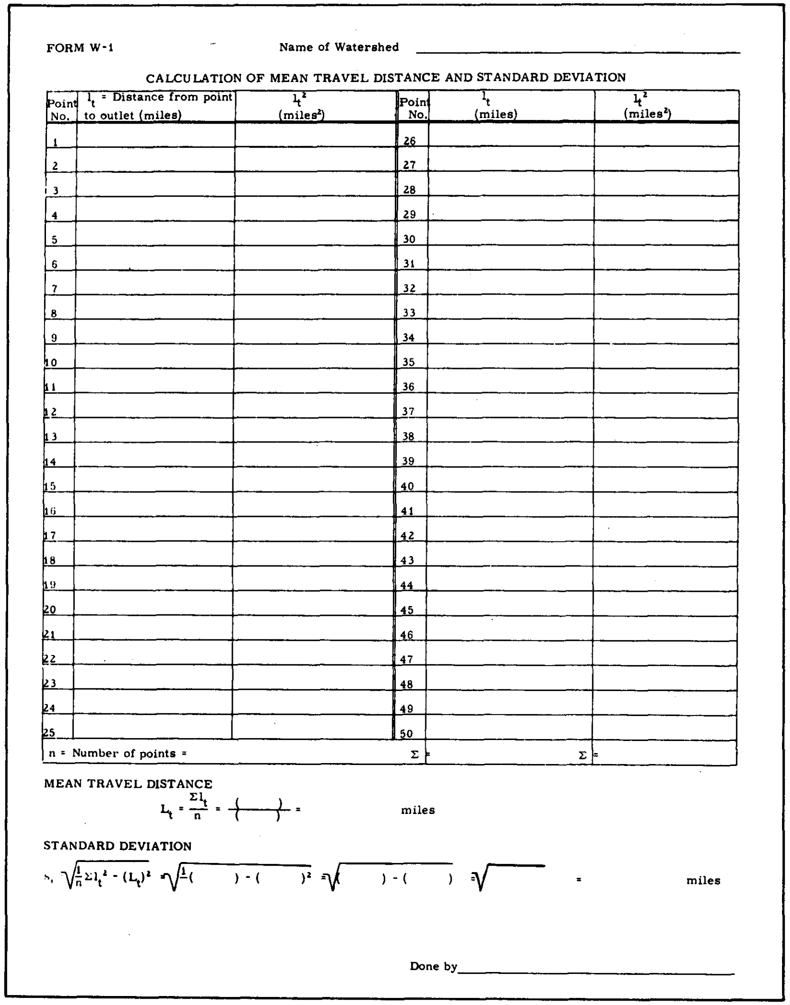
The perimeter is the distance around the catchment measured along the watershed boundary. Using the paper strip method, determine the perimeter in miles to two decimal places by starting at the gage and proceeding around the area and back to the gage to form a closed circuit.

Total Fall, H

Using the strip of paper with the main stream marked off on it as the abscissas, plot a graph of distance vs. elevation along the main stream on 20 x 20 to the inch graph paper. After the profile is plotted, extrapolate each of the ends of the profile. Determine the minimum and maximum elevations of the main stream from these extended slopes. The total fall can now be determined to the nearest foot. Record the distances in miles between successive contour lines on the profile.

Stream Slope, S_1

S_1 is calculated by dividing the total fall, H, by the length of the main stream in miles, L. Calculate to the nearest foot per mile. Use Form W-2 as shown in Figure 2.3.



FORM W-1

Name of Watershed ______________________

CALCULATION OF MEAN TRAVEL DISTANCE AND STANDARD DEVIATION

Point No.	l_t = Distance from point to outlet (miles)	l_t^2 (miles^2)	Point No.	l_t (miles)	l_t^2 (miles^2)
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		
n = Number of points =				Σ =	Σ =

MEAN TRAVEL DISTANCE

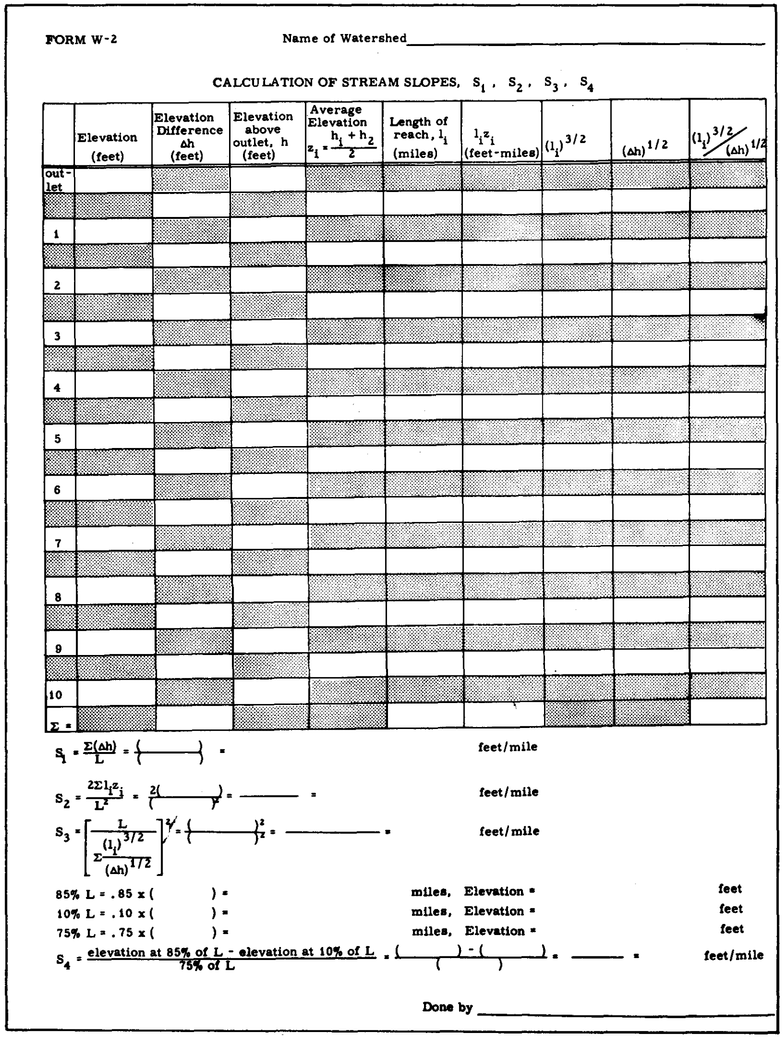
$L_t = \frac{\Sigma l_t}{n} = \frac{(\quad)}{(\quad)} =$ miles

STANDARD DEVIATION

$s_t \sqrt{\frac{1}{n}\Sigma l_t^2 - (L_t)^2} = \sqrt{\frac{1}{}(\quad) - (\quad)^2} = \sqrt{(\quad) - (\quad)} = \sqrt{\quad} =$ miles

Done by ______________________

Figure 2.2. Form W-1



FORM W-2

Name of Watershed ______________________

CALCULATION OF STREAM SLOPES, S_1, S_2, S_3, S_4

	Elevation (feet)	Elevation Difference Δh (feet)	Elevation above outlet, h (feet)	Average Elevation $z_i = \frac{h_i + h_2}{2}$	Length of reach, l_i (miles)	$l_i z_i$ (feet-miles)	$(l_i)^{3/2}$	$(\Delta h)^{1/2}$	$(l_i)^{3/2} / (\Delta h)^{1/2}$
outlet		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
1		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
2		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
3		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
4		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
5		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
6		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
7		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
8		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
9		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
10		▨		▨	▨	▨	▨	▨	▨
Σ =	▨		▨	▨			▨	▨	

$S_1 = \frac{\Sigma(\Delta h)}{L} = \frac{(\quad)}{(\quad)} =$ feet/mile

$S_2 = \frac{2\Sigma l_i z_i}{L^2} = \frac{2(\quad)}{(\quad)^2} = \_\_\_\_ =$ feet/mile

$S_3 = \left[\frac{L}{\Sigma\frac{(l_i)^{3/2}}{(\Delta h)^{1/2}}}\right]^2 = \frac{(\quad)^2}{(\quad)^2} = \_\_\_\_ =$ feet/mile

85% L = .85 x (   ) =   miles, Elevation =   feet

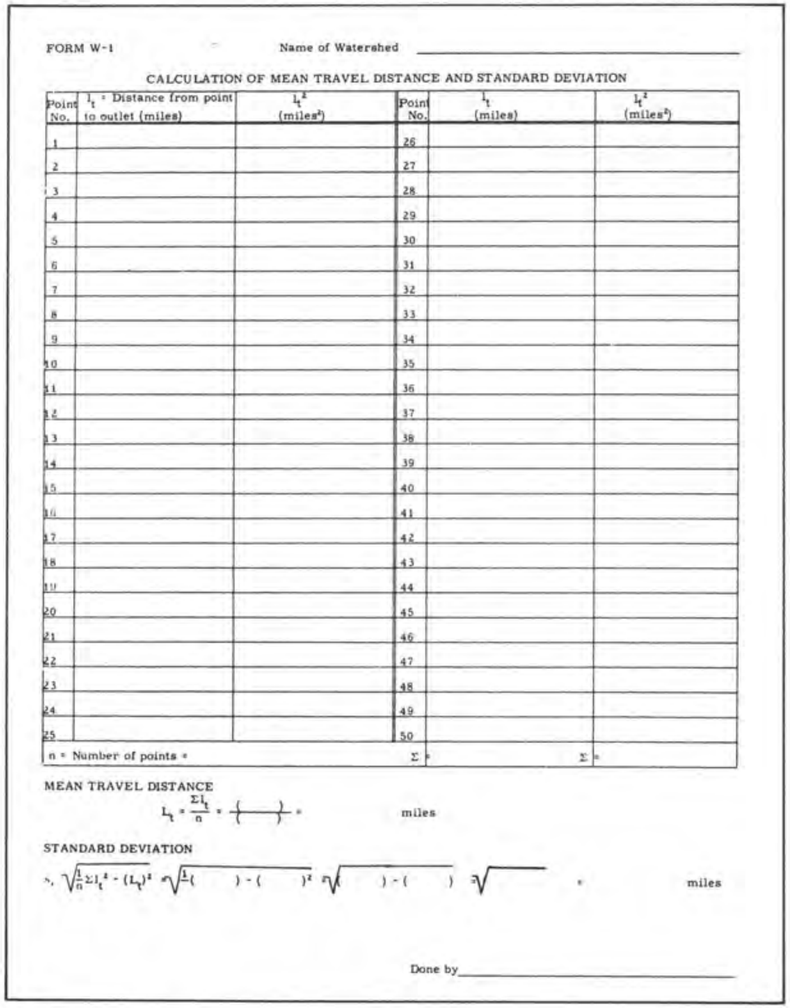
10% L = .10 x (   ) =   miles, Elevation =   feet

75% L = .75 x (   ) =   miles, Elevation =   feet

$S_4 = \frac{\text{elevation at 85\% of L - elevation at 10\% of L}}{\text{75\% of L}} = \frac{(\quad) - (\quad)}{(\quad)} = \_\_\_\_ =$ feet/mile

Done by ______________________

Figure 2.3. Form W-2



FORM W-1 Name of Watershed ____________________

CALCULATION OF MEAN TRAVEL DISTANCE AND STANDARD DEVIATION

Point No.	l_t = Distance from point to outlet (miles)	l_t^2 (miles²)	Point No.	l_t (miles)	l_t^2 (miles²)
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		
n = Number of points =			Σ =		Σ =

MEAN TRAVEL DISTANCE

$L_t = \frac{\Sigma l_t}{n} = \frac{(\quad)}{(\quad)} =$ miles

STANDARD DEVIATION

$s_t = \sqrt{\frac{1}{n}\Sigma l_t^2 - (L_t)^2} = \sqrt{\frac{1}{(\quad)}(\quad) - (\quad)^2} = \sqrt{(\quad) - (\quad)} = \sqrt{\quad} =$ miles

Done by ____________________

Figure 2.2. Form W-1

FORM W-2 Name of Watershed ____________________

CALCULATION OF STREAM SLOPES, S_1, S_2, S_3, S_4

	Elevation (feet)	Elevation Difference Δh (feet)	Elevation above outlet, h (feet)	Average Elevation $z_i = \frac{h_1 + h_2}{2}$	Length of reach, l_i (miles)	$l_i z_i$ (feet-miles)	$(l_i)^{3/2}$	$(\Delta h)^{1/2}$	$(l_i)^{3/2} / (\Delta h)^{1/2}$
outlet		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
1		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
2		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
3		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
4		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
5		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
6		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
7		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
8		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
9		▨		▨	▨	▨	▨	▨	▨
▨	▨		▨						
10		▨		▨	▨	▨	▨	▨	▨
Σ =	▨		▨	▨			▨	▨	

$S_1 = \frac{\Sigma(\Delta h)}{L} = \frac{(\quad)}{(\quad)} =$ feet/mile

$S_2 = \frac{2\Sigma l_i z_i}{L^2} = \frac{2(\quad)}{(\quad)^2} = \_\_\_\_ =$ feet/mile

$S_3 = \left[\frac{L}{\Sigma\frac{(l_i)^{3/2}}{(\Delta h)^{1/2}}}\right]^2 = \frac{(\quad)^2}{(\quad)^2} = \_\_\_\_ =$ feet/mile

85% L = .85 x (   ) = miles, Elevation = feet
10% L = .10 x (   ) = miles, Elevation = feet
75% L = .75 x (   ) = miles, Elevation = feet

$S_4 = \frac{\text{elevation at 85\% of L - elevation at 10\% of L}}{\text{75\% of L}} = \frac{(\quad) - (\quad)}{(\quad)} = \_\_\_\_ =$ feet/mile

Done by ____________________

Figure 2.3. Form W-2

Stream Slope, S_2

$$S_2 = \frac{2\sum l_i z_i}{(\sum l_i)^2} = \frac{2\sum l_i z_i}{L^2} \text{ , feet/mile}$$

where l_i = distance along the main stream between successive contours. The individual l_i can be easily determined from the plotted profile of the main stream or from the paper strip used to measure the length of the main stream. z_i = the average elevation above the outlet for each reach of length, ℓ_i . Use Form W-2 as shown in Figure 2.3.

Stream Slope, S_3

$$S_3 = \left[\frac{L}{\sum\left(\frac{(l_i)^{3/2}}{(\Delta h)^{1/2}}\right)}\right]^2$$

where l_i = length of a reach in miles and Δh = the change in elevation in a reach. Calculate S_3 to the nearest foot per mile. Use Form W-2 as shown in Figure 2.3. For convenience of computations, the 1/2 and 3/2 powers of numbers from 0.01 to 1.00 are listed in Table 2.2.

Stream Slope, S_4

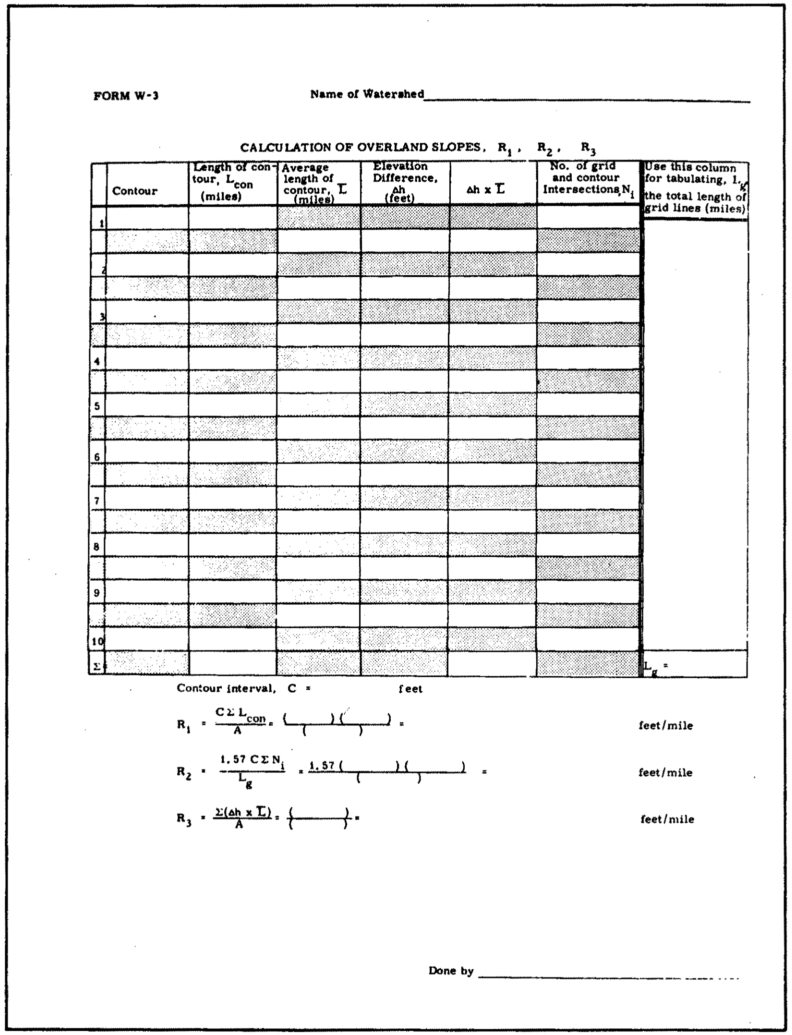
$$S_4 = \frac{\text{elevation at 85\% of L - elevation at 10\% of L}}{\text{75\% of main stream length}}$$

The elevation at 85% and 10% of the stream length can most easily be found by drawing vertical lines on the main stream profile at 85% and 10% of the length and noting the elevation where these lines cut the profile.

Overland Slope, R_1

$$R_1 = \frac{c\sum L_{con}}{A} \text{ feet/mile ,}$$

where c = the contour interval, L_{con} = the length of an individual contour line on a map of the catchment, and A = the catchment area. L_{con} can best be determined by using the paper strip method. Label each strip and mark the length of each contour line on it for later use. Use Form W-3 as shown in Figure 2.4.



FORM W-3 Name of Watershed ____________________

CALCULATION OF OVERLAND SLOPES, R_1, R_2, R_3

	Contour	Length of contour, L_{con} (miles)	Average length of contour, $\bar{L}$ (miles)	Elevation Difference, Δh (feet)	$\Delta h \times \bar{L}$	No. of grid and contour Intersections, N_i	Use this column for tabulating, l_g, the total length of grid lines (miles)
1			▨	▨	▨		
	▨	▨				▨	
2			▨	▨	▨		
	▨	▨				▨	
3			▨	▨	▨		
	▨	▨				▨	
4			▨	▨	▨		
	▨	▨				▨	
5			▨	▨	▨		
	▨	▨				▨	
6			▨	▨	▨		
	▨	▨				▨	
7			▨	▨	▨		
	▨	▨				▨	
8			▨	▨	▨		
	▨	▨				▨	
9			▨	▨	▨		
	▨	▨				▨	
10			▨	▨	▨		
Σ	▨		▨	▨		▨	L_g =

Contour interval, C = feet

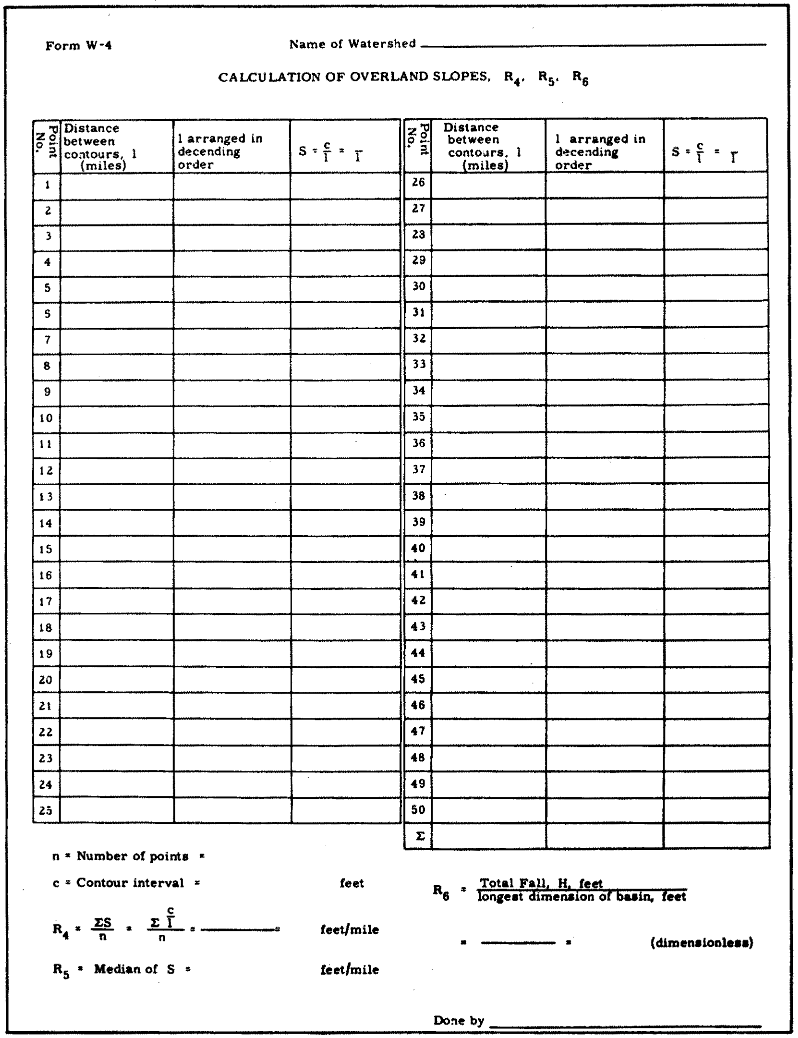
$R_1 = \frac{C \Sigma L_{con}}{A} = \frac{(\quad)(\quad)}{(\quad)} =$ feet/mile

$R_2 = \frac{1.57\, C \Sigma N_i}{L_g} = \frac{1.57(\quad)(\quad)}{(\quad)} =$ feet/mile

$R_3 = \frac{\Sigma(\Delta h \times \bar{L})}{A} = \frac{(\quad)}{(\quad)} =$ feet/mile

Done by ____________________

Figure 2.4. Form W-3



Form W-4 Name of Watershed ____________________

CALCULATION OF OVERLAND SLOPES, R_4, R_5, R_6

Point No.	Distance between contours, l (miles)	l arranged in decending order	$S = \frac{c}{l} = \frac{\quad}{l}$	Point No.	Distance between contours, l (miles)	l arranged in decending order	$S = \frac{c}{l} = \frac{\quad}{l}$
1				26			
2				27			
3				23			
4				29			
5				30			
5				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			
				Σ			

n = Number of points =

c = Contour interval = feet

$R_4 = \frac{\Sigma S}{n} = \frac{\Sigma \frac{c}{l}}{n} = \underline{\qquad} =$ feet/mile

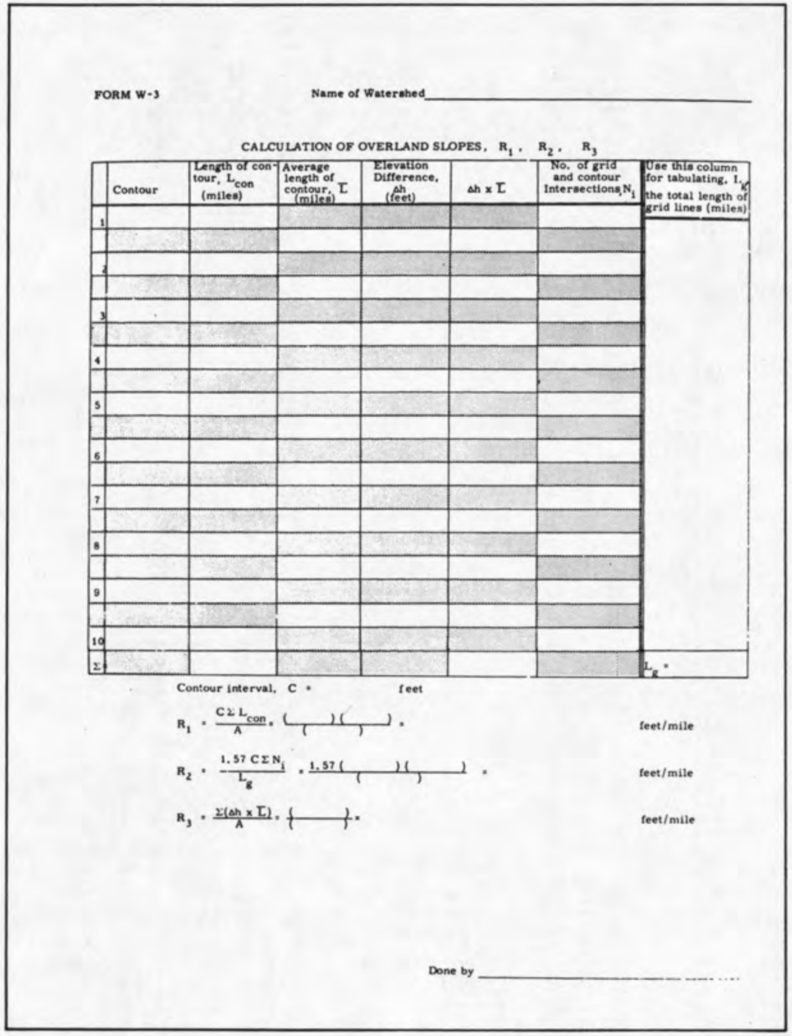
R_5 = Median of S = feet/mile

$R_6 = \frac{\text{Total Fall, H, feet}}{\text{longest dimension of basin, feet}}$

$= \underline{\qquad} =$ (dimensionless)

Done by ____________________

Figure 2.5. Form W-4



FORM W-3 Name of Watershed ______________________

CALCULATION OF OVERLAND SLOPES, R_1, R_2, R_3

	Contour	Length of contour, L_{con} (miles)	Average length of contour, $\bar{L}$ (miles)	Elevation Difference, Δh (feet)	$\Delta h \times \bar{L}$	No. of grid and contour Intersections, N_i	Use this column for tabulating, L_g the total length of grid lines (miles)
1			▨	▨	▨		
	▨	▨				▨	
2			▨	▨	▨		
	▨	▨				▨	
3			▨	▨	▨		
	▨	▨				▨	
4			▨	▨	▨		
	▨	▨				▨	
5			▨	▨	▨		
	▨	▨				▨	
6			▨	▨	▨		
	▨	▨				▨	
7			▨	▨	▨		
	▨	▨				▨	
8			▨	▨	▨		
	▨	▨				▨	
9			▨	▨	▨		
	▨	▨				▨	
10			▨	▨	▨		
Σ	▨		▨	▨		▨	L_g =

Contour interval, C = feet

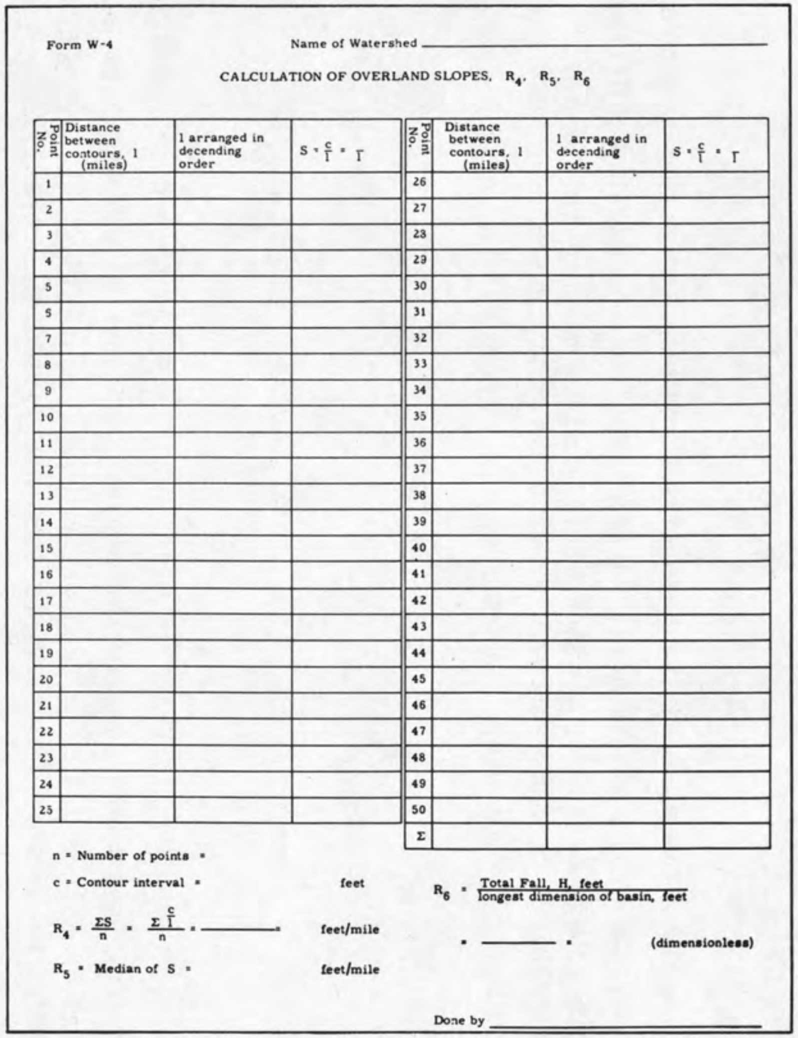
$R_1 = \frac{C \Sigma L_{con}}{A} = \frac{(\quad)(\quad)}{(\quad)} =$ feet/mile

$R_2 = \frac{1.57\, C \Sigma N_i}{L_g} = \frac{1.57(\quad)(\quad)}{(\quad)} =$ feet/mile

$R_3 = \frac{\Sigma(\Delta h \times \bar{L})}{A} = \frac{(\quad)}{(\quad)} =$ feet/mile

Done by ______________________

Figure 2.4. Form W-3



Form W-4 Name of Watershed ______________________

CALCULATION OF OVERLAND SLOPES, R_4, R_5, R_6

Point No.	Distance between contours, l (miles)	l arranged in decending order	$S = \frac{c}{l} = \Gamma$	Point No.	Distance between contours, l (miles)	l arranged in decending order	$S = \frac{c}{l} = \Gamma$
1				26			
2				27			
3				28			
4				29			
5				30			
5				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			
				Σ			

n = Number of points =

c = Contour interval = feet

$R_4 = \frac{\Sigma S}{n} = \frac{\Sigma \frac{c}{l}}{n} = \underline{\qquad} =$ feet/mile

R_5 = Median of S = feet/mile

$R_6 = \frac{\text{Total Fall, H, feet}}{\text{longest dimension of basin, feet}}$

$= \underline{\qquad} =$ (dimensionless)

Done by ______________________

Figure 2.5. Form W-4

Overland Slope, R_2

$$R_2 = \frac{1.57\, c \sum N_i}{L_g} ,$$

where c = the contour interval, N_i = the number of intersections of the grid lines with the i^{th} contour line, and L_g = the total length of grid lines within the catchment measured in both the North-South and East-West directions. L_g can be determined by using the paper strip method. N_i is determined by starting at the catchment boundary and following each contour line and counting the number of times each crosses a grid line. Use Table W-3 as shown in Figure 2.4. Care must be taken not to omit the closed contours representing watershed peaks and depressions.

Overland Slope, R_3

?

$$R_3 = \frac{\sum(\Delta h \times \bar{L})}{A} ,$$

where Δh = the difference in elevation between contours, $\bar{L}$ = the average length of two successive contours, and A = the catchment area. $\bar{L}$ can be calculated from L_{con} found while calculating R_1 . Consider the outlet and extreme boundary point of the watershed as having contour lines of zero length when computing values of $\bar{L}$. Use Form W-3 in Figure 2.4.

Overland Slope, R_4

R_4 is the mean overland slope. The overland slope is calculated by dividing the contour interval by the perpendicular distance between contours at each intersection of the square grid.

$$R_4 = \frac{\sum \frac{c}{l}}{n} , \text{ feet/mile}$$

where c = contour interval, l = the distance between contours at each grid intersection and n = the number of grid intersections for which l was computed. Use Form W-4 as shown in Figure 2.5.

Relief Ratio, R_5

R_5 is the median of the overland slopes computed above. This can be found by arranging the distances between contours in descending order. The median is the distance which evenly splits this descending array, with one half of the distances above it and one half of the distances below it. When the median falls between two distances, the average of those distances is the median. Use Form W-4 as shown in Figure 2.5.

Relief Ratio, R_6

The longest dimension of the basin is the longest distance between two parallel lines touching the boundaries of the catchment.

$$R_6 = \frac{\text{Total Fall, } H}{\text{Longest dimension of the basin}} \text{, dimensionless}$$

Calculate to 4 decimal places. Use Form W-4 as shown in Figure 2.5.

Drainage Density, D_d

The drainage density, D_d , equals the total length of extended streams, L_s , divided by the catchment area, A.

$$D_d = \frac{L_s}{A} \text{, miles/square miles}$$

Average Width of Catchment, W

The average width of the catchment, W , equals the catchment area, A, divided by the length of the main stream, L .

$$W = A/L \text{ , miles}$$

Form Factor, F

The form factor, F , equals the average width of the catchment, W , divided by the length of the main stream, L .

$$F = \frac{W}{L} = \frac{A}{L^2} \text{, dimensionless}$$

Compactness Coefficient, C

The compactness coefficient, C , equals 0.28 times the perimeter, P , divided by the square root of the catchment area, A.

$$C = \frac{0.28\ P}{\sqrt{A}} \text{, dimensionless}$$

Dimensionless Mean Travel Distance, L_m

The dimensionless mean travel distance, L_m , equals the mean travel distance, L_t , divided by the square root of the catchment area, A.

$$L_m = \frac{L_t}{\sqrt{A}} \text{, dimensionless}$$

Dimensionless Standard Deviation, s_d

The dimensionless standard deviation, s_d , equals the standard deviation, s_t , divided by the square root of the catchment area, A.

$$s_d = s_t/\sqrt{A} \text{ , dimensionless}$$

Table 2.2. Powers of Numbers

No.	1/2 Power	3/2 Power
.00	.000	.000
.01	.100	.001
.02	.141	.003
.03	.173	.005
.04	.200	.008
.05	.224	.011
.06	.245	.015
.07	.264	.018
.08	.283	.023
.09	.300	.027
.10	.316	.032
.11	.332	.036
.12	.346	.042
.13	.361	.047
.14	.374	.052
.15	.387	.058
.16	.400	.064
.17	.412	.070
.18	.424	.076
.19	.436	.083
.20	.447	.089
.21	.458	.096
.22	.469	.103
.23	.480	.110
.24	.490	.118
.25	.500	.125
.26	.510	.133
.27	.520	.140
.28	.529	.148
.29	.539	.156
.30	.548	.164
.31	.557	.173
.32	.566	.181
.33	.574	.190
.34	.583	.198
.35	.592	.207
.36	.600	.216
.37	.608	.225
.38	.616	.234
.39	.624	.244
.40	.632	.253
.41	.640	.262
.42	.648	.272
.43	.656	.282
.44	.663	.292
.45	.671	.302
.46	.678	.312
.47	.686	.322
.48	.693	.332
.49	.700	.343
.50	.707	.354
.51	.714	.364
.52	.721	.375
.53	.728	.386
.54	.735	.397
.55	.742	.408
.56	.478	.419
.57	.755	.430
.58	.762	.442
.59	.768	.453
.60	.775	.465
.61	.781	.476
.62	.787	.488
.63	.794	.500
.64	.800	.512
.65	.806	.524
.66	.812	.536
.67	.819	.548
.68	.825	.561
.69	.831	.573
.70	.837	.586
.71	.843	.598
.72	.849	.611
.73	.854	.624
.74	.860	.637
.75	.866	.650
.76	.872	.663
.77	.877	.676
.78	.883	.689
.79	.889	.702
.80	.894	.716
.81	.900	.729
.82	.906	.742
.83	.911	.756
.84	.917	.770
.85	.922	.784
.86	.927	.798
.87	.933	.812
.88	.938	.826
.89	.943	.840
.90	.949	.854
.91	.954	.868
.92	.959	.882
.93	.964	.897
.94	.970	.911
.95	.975	.926
.96	.980	.941
.97	.985	.955
.98	.990	.970
.99	.995	.985
1.00	1.000	1.000

Section 3

REDUCTION OF MASS CURVES, HYDROGRAPHS, AND VARIABLE CATCHMENT CHARACTERISTICS FOR THE FLOOD EVENT CARD

Description of Symbols for the Flood Event Card

Symbol	Definition	Units of Measurement	Decimal Places
a	Interception capacity factor	Inches	2
b	Interception capacity factor	Inches	2
f_1	One hour infiltration for bare soils	in/hr	2
f_2	Cover factor	Dimensionless	1
f_s	Standard infiltration capacity	in/hr	2
h	Height of plants	Feet	2
I_s	Season index	Dimensionless	2
L_i	Initial loss	Inches	2
M	Starting with January No. of the month in which a storm occurs	---	0
n	Interception capacity factor	Dimensionless	2
ϕ	ϕ-Index	in/hr	2
P_i	Antecedent precipitation index	Inches	2
P	Precipitation occurring on i^{th} day	Inches	2
P_Q	Peak discharge probability	---	3
P_s	Average uniform total storm rainfall	Inches	2
Q	Ordinate of hydrograph	in/hr	4
q_p	Peak areal discharge	in/hr	4
Q_p	Peak discharge	cfs	4
Q_i	Initial discharge	in/hr	2
t_j	j^{th} day before the storm	Days	0
T	Overall storm duration	Minutes	0
T_R	Time of rise	Minutes	0
T_L	Lag time	Minutes	0

Section 3 was first written in July 1964. Revisions were made in March 1967.

Description of Symbols for the Flood Event Card - Continued

Symbol	Definition	Units of Measurements	Decimal Places
T_r	Time of recession	Minutes	0
T_s	Duration of the supply period	Minutes	0
V	Volume or runoff	Inches	5

General Instructions for Completing the Flood Event Card

✓Serial Number

The first eight digits will be the same as those on the watershed card for this catchment. The last pair of digits, which designate the event number, will be assigned according to the Master Watershed List.

✓Watershed Name

This item is taken from the watershed card.

✓Gaging Station

This item is taken from the watershed card.

✓Commencement of Storm

Commencement of the storm is determined by the beginning of the average mass curve of rainfall which is described later in this section. The date should be given in the form of month, day and year, i.e., March 10, 1964 = Mar. 10, 1964. The time should be given in the 24-hour system, i.e., 2:14 p.m. = 14:14.

✓Peak Discharge, Q_{p_1}

The peak discharge is the maximum discharge for a given runoff hydrograph, in cfs (see description of q_p).

✓Peak Areal Discharge, q_{p_2}

Peak areal discharge in in/hr is obtained by the following formula:

$$q_p = \frac{Q_p}{645.333 \times A}$$

where Q_p is the peak discharge in cfs and A is the watershed area in square miles. If q_p is already given in inches per hour, the above formula may be inverted to obtain the value of Q_p in cfs.

✓ Equivalent Uniform Depth of Rainfall, P_s

In order to begin filling the event card, it will be necessary to draw an average mass rainfall curve. Before drawing the mass curve, one must know the equivalent uniform depth of rainfall, P_s. P_s can be found by one of three methods:

1. arithmetic average method
2. Thiessen method, and
3. isohyetal method.

(1) P_s is the simple arithmetic average of rainfall at each of the gages. This method will be used if the gages are uniformly distributed and if the variation of the individual gages from the mean is not very great.

(2) In the Thiessen method, P_s is the areal weighted average of the rainfall at each of the gages. This method is preferred.

(3) The isohyetal method might be used for catchments with four or more raingages. P_s is the areal average rainfall, determined by measuring areas between isohyets and computing a weighted average depth of rainfall. However, the Thiessen method yields similar results on small watersheds and is the preferred procedure.

General Instructions for Plotting and Recording Rainfall and Runoff Data

Because the objective of this program is to store a large quantity of rainfall-runoff data on magnetic tape, it is necessary that this data be condensed to a form which is readily adaptable to automatic machine processing. In order to accomplish this task, each mass curve and hydrograph will be reduced to a series of coordinates (rainfall, time or discharge, time) between which the mass curve or discharge hydrograph conforms essentially to a straight line. The assumption of a linear variation in rainfall or runoff between these coordinates, or "break-points" as they are called, affords abbreviation in the computer tabulation and plotting of mass curves and hydrographs. Hence, the plotting procedures are designed to identify the break-points in mass curves and hydrographs. The coordinates of these break-points are then recorded on the flood event card, from which they are in turn transferred to magnetic tape for storage. The procedures for plotting and recording, which are set forth in this section, are thus aimed at the condensation of observed mass curves and hydrographs.

If the period between the commencement of runoff and major part of the recession runoff is more than five hours and the runoff is recorded with a time increment of about five minutes or multiples thereof, use 12 x 20 to the inch graph paper. Mark 1" = 1 hour on 12 divisions to an inch side and use appropriate runoff scale on 20 divisions to an inch side. If above period is within five hours and the runoff is recorded after every minute or so, use 20 x 20 to the inch graph paper. Mark three inches = 1 hour, (1 division = 1 min.). Runoff, if available in cfs units, is to be converted to inches per hour by the formula given for q_p above.

When runoff recedes over a period of several hours, the remaining hydrograph need not be plotted if the time when the final discharge equals the initial discharge is known. This time in 24-hour system and corresponding date should be indicated near the last plotted point of the hydrograph.

If the time when the final runoff equals the initial runoff is not known, the longer end part of the hydrograph should be plotted in a convenient space above the plotted hydrograph, using a smaller time scale (e.g. 1" = 1 hour) and the final point determined by extrapolation of the curve. Beyond a point, however, when the curve assumes a straight line form, plotting is not required and the end time could be determined by ratio method.

For rainfall mass curves, use 20 x 20 to the inch graph paper, 7" x 10" size, or when the period is long, use the 10" x 15" size .

All hydrographs and rainfall mass curves should first be drawn with pencil and when a satisfactory shape is assumed it should be inked in blue. Mark in red (distinctly) those points between which the curve is appreciably straight. The coordinates of these points (time and ordinate) are then transferred to the reverse side of the flood event card as described in a later section.

Labeling of Plotted Mass Curves and Hydrographs

The following information is to be recorded at the top right-hand corner of every graph:

1. name of graph (mass curve or hydrograph);
2. name of watershed;
3. event number;
4. date of the event; and
5. duration of the hydrograph in minutes.

Example - top right corner

Average mass curve of rainfall
Watershed J. Riesel (Waco), Texas
1-43-09-004-04
June 15, 1942
Duration: 554 minutes

The following additional data should be shown in each plot:

1. the time of commencement (in 2400 hour system) of the mass curve or hydrograph beneath the point on the time scale;
2. the date and time of the end of rainfall or runoff;
3. the raingage number on the observed mass curve of rainfall - e.g. R.G. 17; and
4. the scale of the plot along each axis - e.g. 1 division = x minutes, inches, etc.

The Average Mass Curve of Rainfall

Introduction

Because the response of a watershed to a given set of storm conditions is represented by a single curve (the hydrograph), it is desirable to derive a single mass curve of rainfall which is the input function or driving force underlying watershed response. There are many pitfalls associated with any attempt to define an average mass curve of rainfall. The first difficulty is encountered in the failure of the raingage to accurately record point rainfall due to the combined influence of wind action, storm type, and watershed topography. A second source of error is found in the technique by which point estimates of rainfall are converted to a measure of areal rainfall distribution. The variations of rainfall with respect to time and space must necessarily be distorted to some degree by any method of averaging point measurements of rainfall. In spite of these pitfalls, it is believed that certain steps can be taken which will tend to preserve the essential features of rainfall distribution in time as recorded at various points in the watershed.

The numerical method of deriving the average mass curve of rainfall is based on the application of the Thiessen weighting factors to ordinates of the mass curves observed at specific gaging stations in the watershed. In the procedure set forth herein, the total Thiessen rainfall is established at the end of the storm and the average mass curve is extended backward in time to the beginning of rainfall. Because of its simplicity and ease of application, the numerical method is currently utilized to derive the average mass curve of rainfall by the Small Watershed Project.

Events with Only One Recording Raingage

The cumulative rainfall in inches and the cumulative time in minutes corresponding to every point in the tabulated mass curve of rainfall are recorded directly in the appropriate columns of the event card.

Events with One Recording Raingage and Other Non-Recording Gages

As in the previous case, the mass curve for precipitation does not need to be plotted. It is necessary to compute the total Thiessen average rainfall by using the recording gage and all non-recording gages on the watershed. An approximate average mass curve may be obtained by multiplying each point of inflection on the observed mass curve by the R ratio where R is defined as:

$$R = \frac{\text{Total Thiessen Average Rainfall}}{\text{Total Rainfall at Recording Raingage}} .$$

This procedure will provide an approximation to the Thiessen weighted mass curve of rainfall.

Events with Several Recording and Non-Recording Raingages

Where both recording and non-recording raingages are available the following procedure is used in drawing the average mass curve of rainfall.

(1) Draw the Thiessen polygon for recording and non-recording raingages and compute the Thiessen factor for <u>each</u> gage.
(2) Compute the total Thiessen weighted rainfall using the weighting factors in (1).
(3) Redraw the Thiessen polygon utilizing only the recording raingages and calculate the corresponding Thiessen weighting factors.
(4) Plot the mass curves of rainfall for all recording gages on a single sheet of graph paper as in Figure 3.1 (20 x 20 to 1 inch paper seems to work well).
(5) Locate the total Thiessen rainfall on this graph at the last break point on the time scale as shown in Figure 3.2.
(6) Draw vertical lines through every point where a change of slope occurs for all mass curves as shown in Figure 3.3. The first point of interest occurs at the end of the storm and is located at vertical F in Figure 3.4.
(7) Compute the Thiessen weighted rainfall ordinate at each vertical by multiplying the observed rainfalls by the corresponding Thiessen factors and summing the individual contributions in the conventional

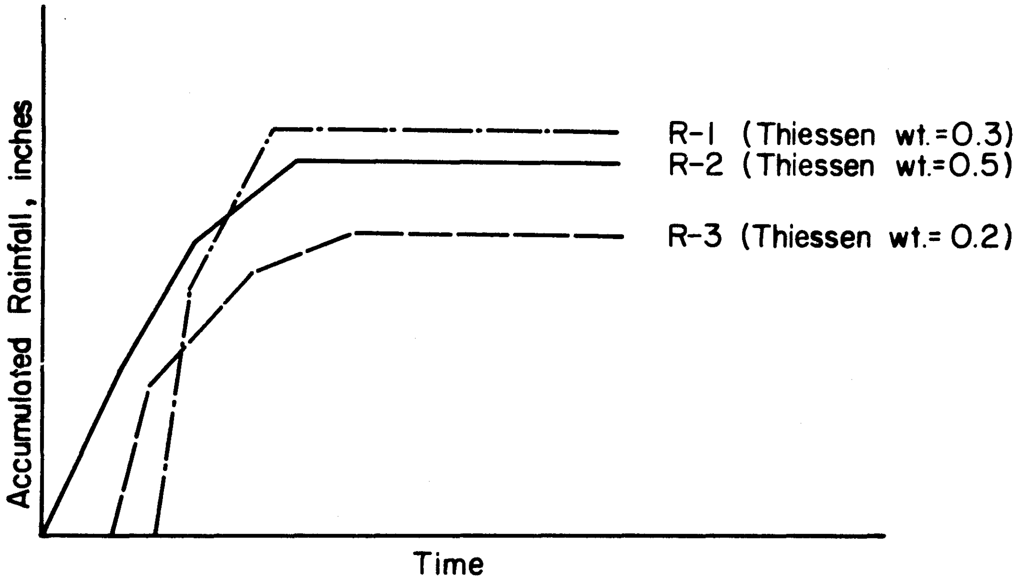


Figure 3.1. Mass curves observed at individual recording gages

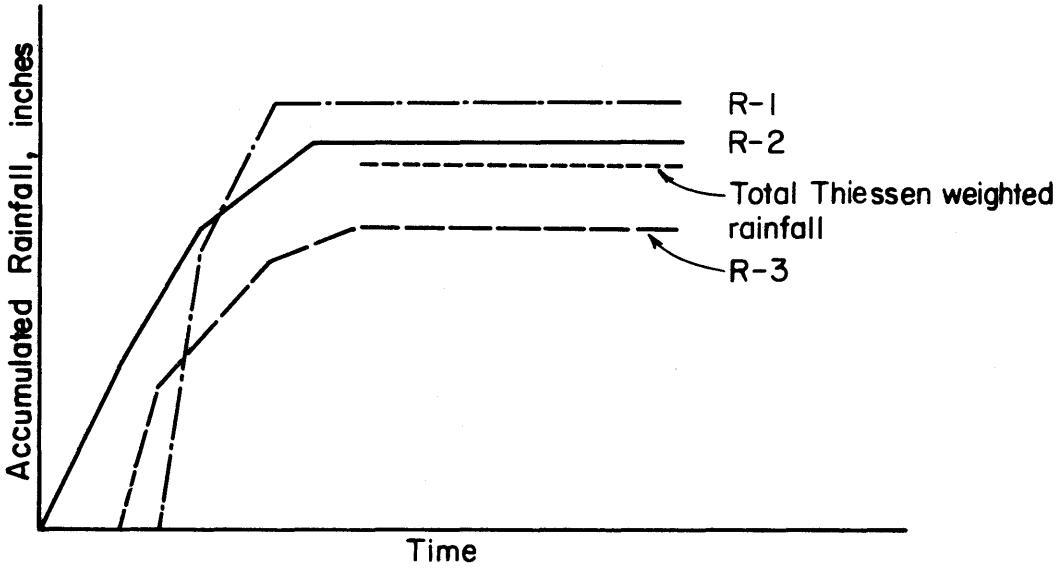


Figure 3.2. Location of total Thiessen weighted rainfall and end-point for average mass curve

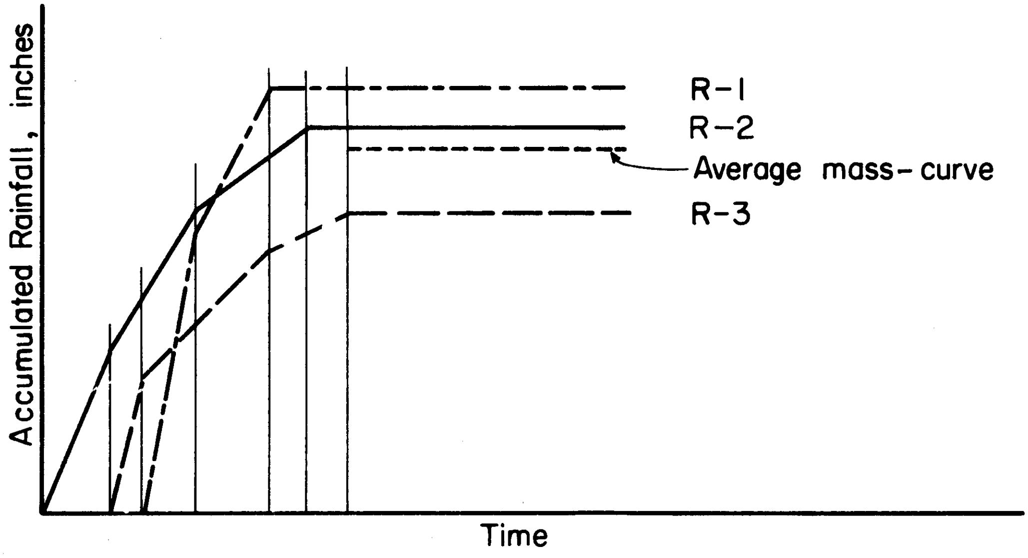


Figure 3.3. Vertical lines drawn at break points of the observed mass curve

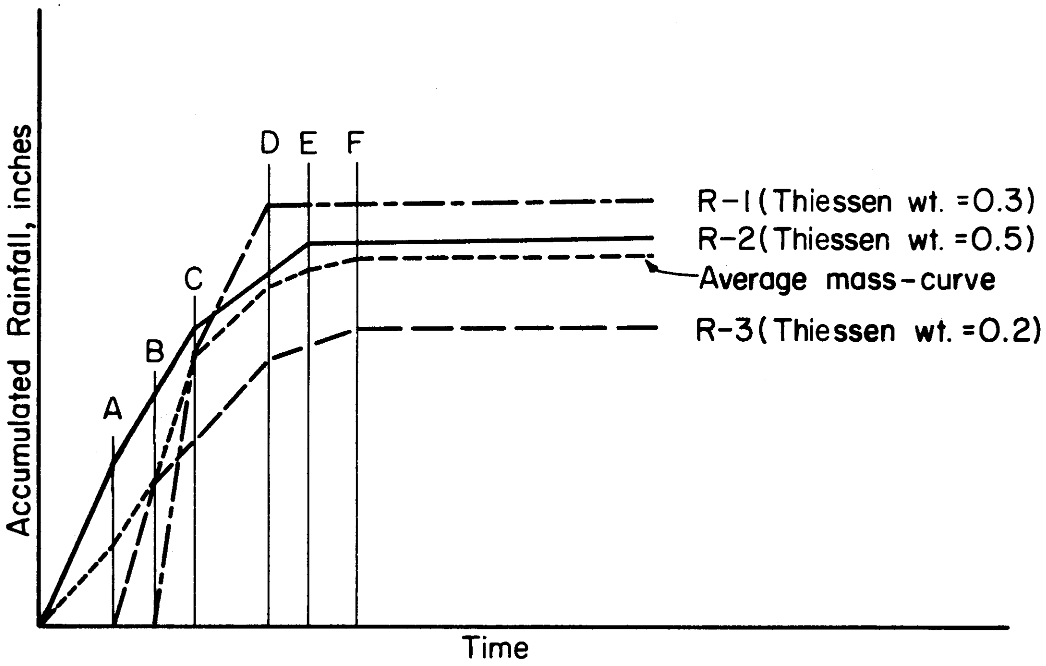


Figure 3.4. Complete average mass curve of rainfall

way. Locate the points of the computed average mass curve on the respective vertical lines. This procedure can be followed backward in time from the end of the storm, as marked by vertical F in Figure 3.4, to the point where the beginning of rainfall is last recorded, as marked by vertical B in Figure 3.4.

(8) At vertical B in Figure 3.4, the Thiessen weights for gages R-2 and R-3 are not recomputed due to the commencement of gage R-1. The original weights for the remaining gages are used to obtain the ordinate of the average mass curve at vertical B. The commencement of gage R-1 at vertical B is treated as though this gage had remained in operation prior to vertical B but was recording zero rainfall for this preceding portion of the storm. In effect, the sum of the Thiessen weights will equal unity at any given point on the average mass curve. The ordinate of the average mass curve at vertical B is then computed as the sum of 0.5 times the R-2 value plus 0.2 times the R-3 value at vertical B. A similar procedure is used at vertical A as described in step (9).

(9) Before proceeding to vertical A in Figure 3.4, a decision must be made regarding the beginning of the average mass curve of rainfall. From the standpoint of analyzing watershed response, the most logical step in defining the beginning of the storm is to select that time when rain was first observed to fall within the boundaries of the watershed. The aim then is to find the gage which first records rainfall during the storm in question and which is so located that the rainfall pattern observed at the gaging site is representative of the rainfall distribution as it actually occurred within the watershed. The index of correlation between station rainfall and watershed areal rainfall is the Thiessen weight for the gage in question. If the Thiessen weight is comparatively high for the gage which first observes rainfall during the storm, then the starting time of this observed mass curve will be taken as the beginning of rain for the average mass curve. In the example of Figure 3.4, raingage R-2 has a Thiessen weight of 0.5 and is the first of three gages to record rainfall. Because its Thiessen factor is large in comparison with those for the other two gages, raingage R-2 will be used to define the commencement of rainfall for the average mass curve. The ordinate of the average mass curve is simply 0.5 times the ordinate of the R-2 mass curve at vertical A since, as set forth in step (8), no readjustment of the Thiessen weights is made. Further break points in the mass curve of gage R-2 would be computed in the same fashion, although in the present case the average mass curve is completed by connecting the point at vertical A to the origin of the R-2 mass curve. The accumulated rainfall in inches and the elapsed time in minutes corresponding to every break point in the average mass curve are now transferred to the event card in the manner described in the part "Recording of an Average Mass Curve on the Event Card."

Notes on Procedure

It is noted that in the event only recording raingages are available, the Thiessen polygon and total Thiessen rainfall will be determined solely on the basis of selected recording raingages. The analyst can proceed directly to step (3) and, thus, simplify the derivation of the average mass curves of rainfall.

A final check of the procedure outlined in steps (7) through (9) is available by consideration of the following requisite features of an average mass curve derived by the numerical method:

1) the average mass curve can lie neither above nor below all of the individual observed curves since it is by definition an average of the individual observations;
2) the general shape of the average mass curve should conform to that indicated by a majority of the observed mass curves;
3) if all individual mass curves pass through a common point, the average mass curve must pass through that point;
4) the starting time of the average mass curve should represent the beginning of rainfall on the watershed and is not an average position derived from all operating gages;
5) the starting time of the average mass curve must be consistent with that of the runoff hydrograph - rainfall must always precede runoff; and
6) the average mass curve can never decrease since it represents a summation curve involving only zero or positive elements.

Summary and Conclusions

Table 3.1 is presented as a summary of the experience accumulated by the Small Watershed Project in deriving the average mass curve of rainfall.

It is concluded that by virtue of its overall simplicity and potential for automatic data processing, the numerical method offers advantages which justify its selection as the means for deriving average mass curves of rainfall for the Small Watershed Project at Colorado State University.

Table 3.1. Advantages and Disadvantages of the Numerical Method of Deriving the Average Mass Curve of Rainfall

Advantages	Disadvantages
a. Simple to use for any number of gages once the Thiessen weights have been computed	a. No allowance for topographic influence - a linear variation of rainfall between stations is assumed
b. No adjustment of weights required during course of a given storm	b. Recorded rainfall intensities are not preserved - average intensities are obtained
c. The beginning of rainfall is established as the time when rain first occurs inside the watershed divide	c. Some judgment required in ascertaining when rainfall first occurred on the watershed
d. Ordinates of the average mass curve are computed independently of one another so that errors do not carry over from one break point computation to the next	d. The duration of rainfall could be over-extended by early and late rainfall bursts
e. Method is readily adapted to automatic data processing	

Plotting of a Hydrograph From Tabular Data

In many cases the hydrograph $Q = f(t)$ is given in tabular form. In such a case the hydrograph is plotted as follows:

(1) select the left bottom corner of the graph paper as origin with the abscissa as the time (t) axis;
(2) convert each discharge to in/hr by the formula

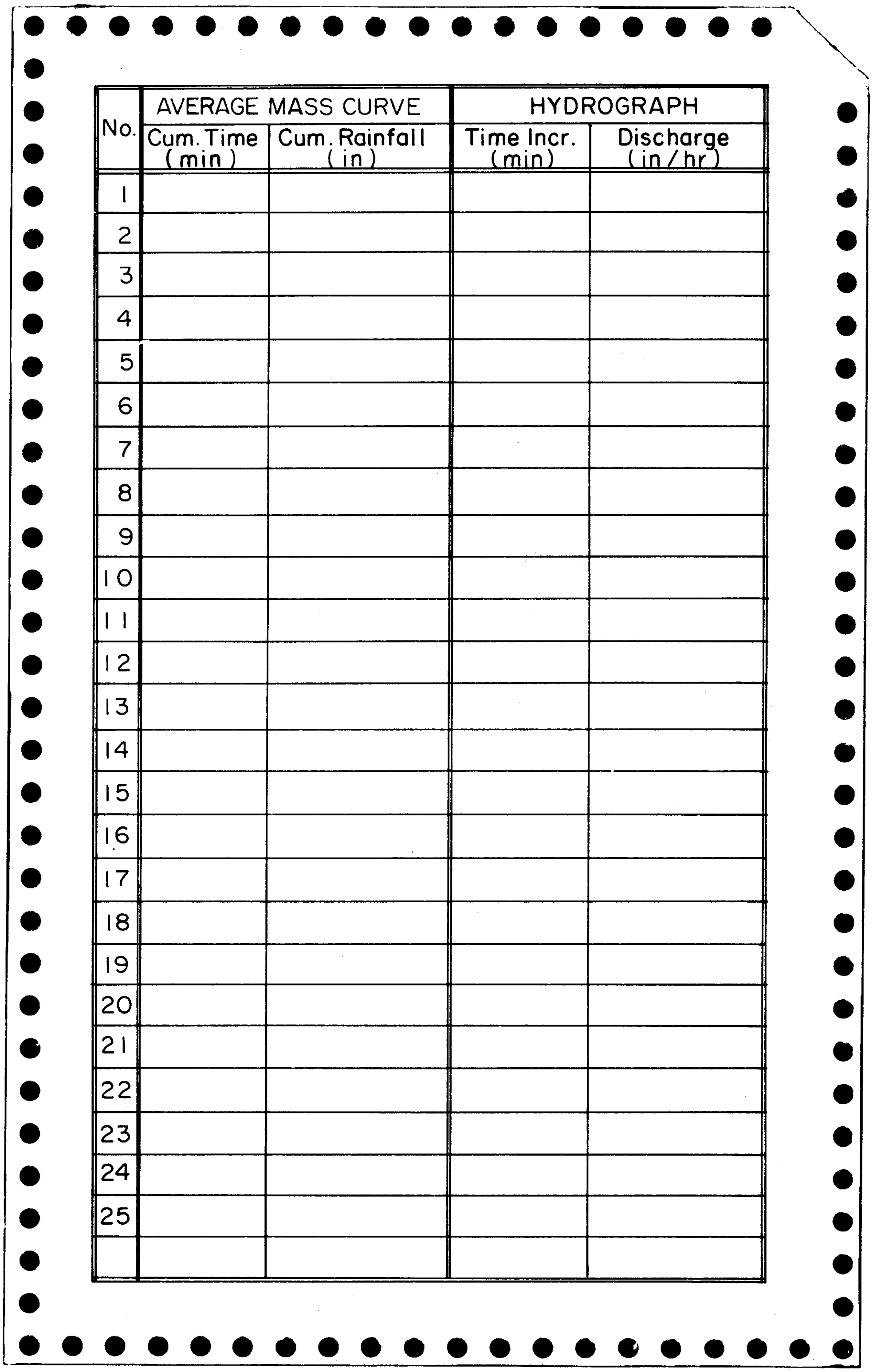
$$Q(\text{in/hr}) = \frac{Q(\text{cfs})}{645.33 \times A}$$

where A is area of the watershed in square miles;
(3) select a reasonable scale for Q on the ordinate axis,
(4) select the time corresponding to the first discharge as "zero" of the time axis;
(5) plot the beginning discharge on the Q axis at $t = 0$.
(6) locate the next time of the table on the t axis;
(7) plot the value of the discharge for the time of step 6;
(8) repeat steps 6 and 7 until all values of the table are plotted; and
(9) as per the General Instructions for Plotting, the final hydrograph should be drawn in ink and the points where a distinct break in slope occurs should be marked in red.

Recording of an Average Mass Curve on the Event Card

The following procedure is used in transferring the coordinates of time and rainfall from the average mass curve to the flood event card. The instructions apply to any available rainfall mass curve -- whether it has been obtained by the numerical averaging procedure or not.

(1) The beginning of rainfall is established from the mass curve which represents the rainfall distribution for the storm in question. This representative mass curve could be the numerically-averaged mass curve or it could be the single mass curve observed on a watershed having only one recording raingage. It is emphasized that the beginning of rainfall must precede the beginning of runoff as defined by the hydrograph.
(2) Figure 3.5 reveals that the left half of the event card is reserved for entries of accumulated time and rainfall taken directly from the representative mass curve. The first column contains the values of total elapsed time measured from the beginning of rainfall in minutes. The second column contains the corresponding ordinates of the mass curve measured in accumulative inches of rainfall. The first entries will be zeros since both the accumulated rainfall and the total elapsed time are zero at the beginning of the storm.
(3) Determine the elapsed time to the first break point or vertical line (established in the averaging procedure) in the rainfall mass curve. Establish the accumulated rainfall at that point and record both entries in their respective columns on the event card.



No.	AVERAGE MASS CURVE		HYDROGRAPH	
	Cum. Time (min)	Cum. Rainfall (in)	Time Incr. (min)	Discharge (in/hr)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

Figure 3.5. Backside of the flood event card showing locations of average mass curve and hydrograph entries

(4) Repeat step (3) for each successive break point in the representative mass curve until the end of the mass curve is reached. At each break point, it is the total elapsed time and corresponding accumulated rainfall which are recorded in the appropriate columns on the event card. The termination of rainfall is indicated where the mass curve assumes a constant value. Small additions or traces of rainfall (0.01 inch or less) occurring after the cessation of the main storm are ignored in establishing the end of rainfall.

(5) A check on the recorded mass curve should now be run by:
   a. determining whether the total elapsed time for the last rainfall ordinate agrees with the measured duration of rainfall;
   b. comparing the last rainfall ordinate with P_s since they should be equal; and
   c. examining all recorded rainfall ordinates to see that none show a decrease in cumulative rainfall.

Recording of a Hydrograph on the Event Card

The following procedure is used in transferring to the event card the coordinates in time and discharge of each point identified in step (9) of the section on hydrograph plotting. The same instructions apply to those hydrographs which were obtained originally in graphical form from the watershed agency. In the latter instance, conversion to in/hr units may be necessary.

(1) The initial time and discharge must first be established by keeping in mind that:
   a. the lowest value of antecedent flow marks the beginning of the hydrograph; and
   b. the beginning of the runoff hydrograph must occur after commencement of rainfall as recorded by the average mass curve of rainfall.

(2) On the reverse side of the event card, which is depicted in Figure 3.5, note that the two right-hand columns are reserved for the time increment and corresponding ordinate of the hydrograph. The first column on the right side of the card contains the time increment in minutes between successive discharge ordinates. The first entry in this column is always zero since no time has elapsed when the very first discharge ordinate is observed. The second column of the right half of the card is reserved for successive discharge ordinates (in in/hr) which are taken directly from the hydrograph plot. The first entry in this column will be the initial discharge, Q_i , which defines the beginning of the hydrograph.

(3) Determine the incremental time in minutes to the next point where a break in slope occurs (should be marked in red) and obtain the corresponding discharge at the end of this interval. The discharge and time interval associated with this hydrograph break point are entered in their respective columns on the back of the flood event card.

(4) Repeat step (3) until the plotted hydrograph has been completely described. The end of the runoff hydrograph is signaled by its return to the initial flow, Q_i , or by the achievement of a constant slope out on the recession limb. Record as many points as necessary in order to adequately describe all major changes in slope found in the

hydrograph. It should be remembered these points will be used to compute the volume or depth of runoff by assuming a straight line variation of flow between successive points. Additional cards can be used whenever the number of break points exceeds 25.

(5) A check on the recorded hydrograph should now be run by:
   a. summing the time increments and comparing with the duration of the hydrograph since they should be equal;
   b. comparing the recorded hydrograph peak with the observed peak; and
   c. examining all recorded discharge ordinates to see that none exceed the peak discharge.

Derivation of an Average Hyetograph

The hyetograph is determined directly from the recorded ordinates of the representative mass curve of rainfall. A computer program has been written to determine the slope of the average mass curve between successive break points or changes in slope. Since these points have been recorded as cumulative rainfall in inches and total elapsed time in minutes, the hyetograph computation becomes:

$$H_i(\text{in/hr}) = \frac{P_i - P_{i-1}}{t_i - t_{i-1}} \times 60 \text{ min/hr}$$

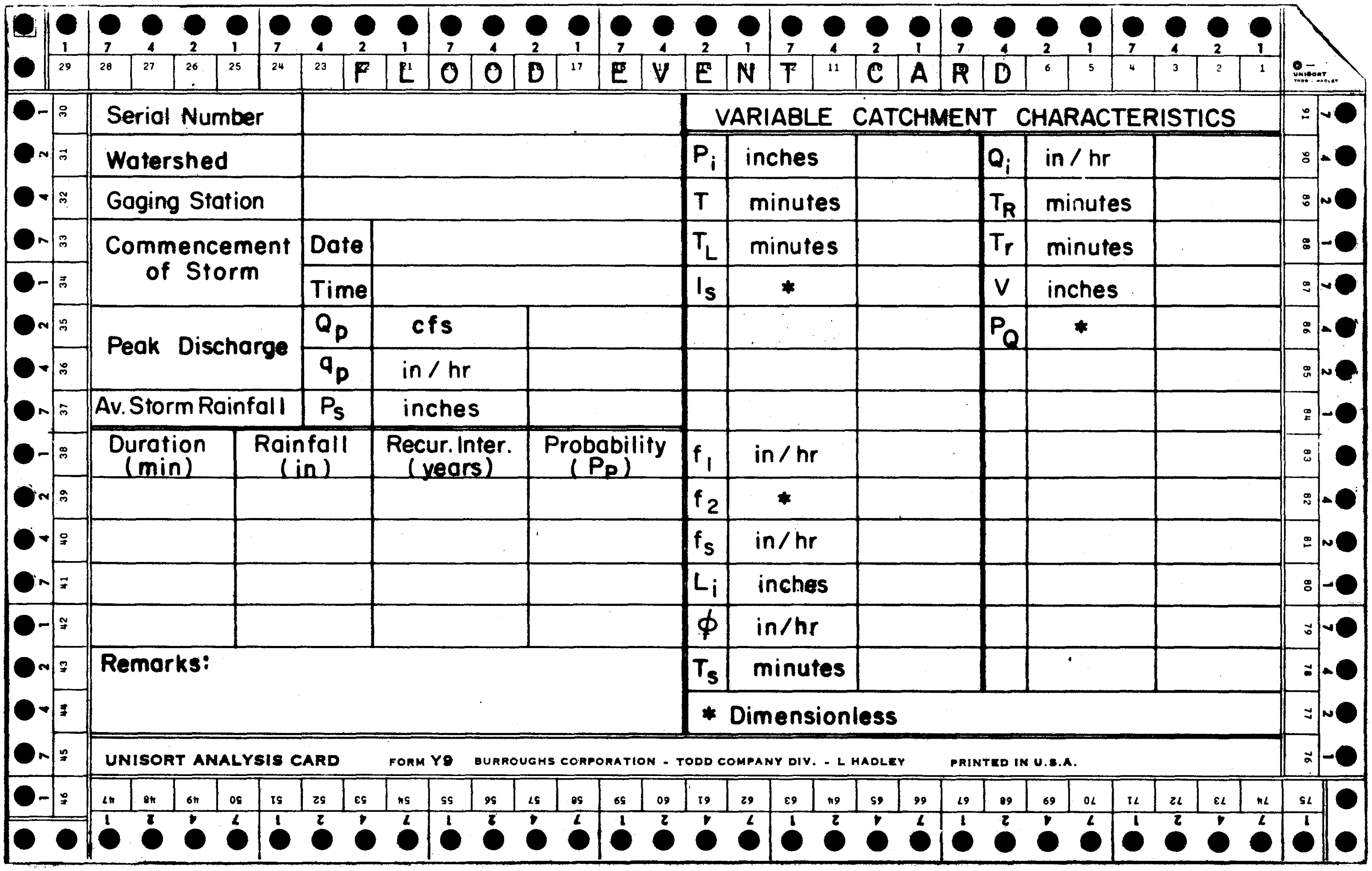
where H_i is the i^{th} value of the hyetograph corresponding to the rainfall increment $(P_i - P_{i-1})$ and time interval $(t_i - t_{i-1})$. The entire mass curve is processed in this way to obtain the complete hyetograph.

Variable Catchment Characteristics

The variable watershed characteristics pertain to those features of the catchment which change from storm to storm, such as soil moisture and cover conditions. These items are recorded on the front side of the flood event card which is shown in Figure 3.6.

✓Antecedent Precipitation Index, P_i

The antecedent precipitation index is, $P_i = \sum_{j=1}^{5} P \times 0.85^{t_j}$ where P is the Thiessen weighted precipitation in inches recorded t_j days before the storm. The number of days before the storm and the precipitation in inches associated with each of those days should be tabulated. Using Form E-1, the antecedent rainfall should be recorded in inches to two decimal places for the 30-day period preceding the storm. The 30-day antecedent rainfall is to be stored on magnetic tape. The 5-day P_i is to be computed in inches to two decimal places and recorded on the flood event card. Rainfall which fell earlier in the same day as the storm commencement should be recorded as occurring on the zero day. Form E-1 is shown in Figure 3.7.



FLOOD EVENT CARD

Serial Number			
Watershed			
Gaging Station			
Commencement of Storm	Date		
	Time		
Peak Discharge	Q_p	cfs	
	q_p	in / hr	
Av. Storm Rainfall	P_s	inches	

Duration (min)	Rainfall (in)	Recur. Inter. (years)	Probability (P_P)

Remarks:

VARIABLE CATCHMENT CHARACTERISTICS

P_i	inches		Q_i	in / hr	
T	minutes		T_R	minutes	
T_L	minutes		T_r	minutes	
I_s	*		V	inches	
			P_Q	*	
f_1	in / hr				
f_2	*				
f_s	in / hr				
L_i	inches				
ϕ	in / hr				
T_s	minutes				

* Dimensionless

UNISORT ANALYSIS CARD FORM Y9 BURROUGHS CORPORATION - TODD COMPANY DIV. - L HADLEY PRINTED IN U.S.A.

Figure 3.6. Frontside of the flood event card showing locations of variable catchment characteristics

FORM E - 1

Event Number ________________

Name of Watershed ________________

CALCULATION OF ANTECEDENT PRECIPITATION INDEX, P_i

Date of Storm ________________

Commencement

Time of Storm ________________

Date	Days before the Storm, t_i	Daily Rainfall (inches)	0.85^{t_i}	0.85^{t_i} x rainfall
	0		1.00	
	1		0.850	
	2		0.723	
	3		0.614	
	4		0.522	
	5		0.444	
	6		5-day P_i : Σ	
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	17			
	18			
	19			
	20			
	21			
	22			
	23			
	24			
	25			
	26			
	27			
	28			
	29			
	30			

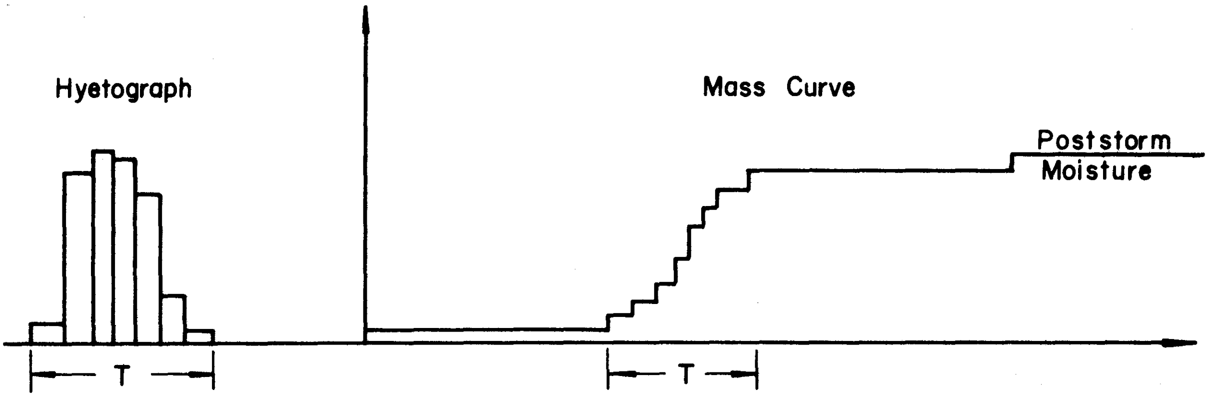
Prepared by: ________________

Date: ________________

Figure 3.7. Form E-1 for antecedent precipitation index.

X Overall Storm Duration, T

The overall storm duration, T , is the duration in minutes of the rainfall. The definition sketch below may be helpful in the determination of T.



If the hyetograph is given, its length of base gives the overall storm duration. If the mass curve is given, the storm duration is the total elapsed time between two essentially horizontal lines occurring immediately before and after the storm. The antecedent and post-storm moisture should be excluded from the determination of storm duration.

✓ Lag Time, T_L (Incorrect term)

The lag time, T_L , is the time in minutes between the start of the rainfall and the start of the runoff. Record to the nearest minute.

✓ Seasonal Index, I_s

The seasonal index, I_s , is calculated from the formula

$$I_s = \frac{\sin\left[\left(\frac{M-10}{6}\right)\pi\right] + 1}{2}$$

where M is the number of the month in which the storm occurs. For catchments in the southern hemisphere, the constant 10 in the equation must be replaced by 4 to give an index of zero in midsummer and unity in midwinter. Values of I_s can be read directly from Table 3.2.

✓ Initial Discharge, Q_i

The initial discharge, or low flow discharge as it is sometimes called is that value of the discharge in the stream at the commencement of the rise of the hydrograph. Q_i should be recorded in inches per hour.

✓ Time of Rise, T_R, time in minutes betw. initial discharge, Q_i, and peak discharge, Q_{pi}.

The initial discharge, or low discharge as it is sometimes called, is that value of the discharge in the stream at the commencement of the rise of the hydrograph. Q_i should be recorded in inches per hour.

Table 3.2. Seasonal Index, I_s

	Season Index	
	Northern Hemisphere	Southern Hemisphere
January	1.00	0.00
February	0.93	0.07
March	0.75	0.25
April	0.50	0.50
May	0.25	0.75
June	0.07	0.93
July	0.00	1.00
August	0.07	0.93
September	0.25	0.75
October	0.50	0.50
November	0.75	0.25
December	0.93	0.07

✗ Time of Recession, T_r

The time of recession, T_r, is the time in minutes from the runoff peak to the point where the runoff is equal to the initial discharge, Q_i. In case runoff does not return to Q_i, T_r should be measured from the peak to the point on the recession limb where the hydrograph has attained a constant slope. Record to the nearest minute.

✓ Volume of Runoff, V, (inches)

This is obtained by the computer as the area beneath the hydrograph. A linear variation of runoff between successive discharge ordinates is assumed and the trapezoidal rule is used in computing incremental areas.

✗ Peak Discharge Probability, P_Q

The peak discharge probability is determined from a flood frequency analysis of the annual peak discharge series. A computer program has been written to fit both the Gumbel double exponential distribution (see E.J. Gumbel, "Statistical Theory of Extreme Values and Some Practical Applications," U.S. National Bureau of Standards Applied Mathematics Serial 22, 1953) and the Jenkinson distribution (see A. F. Jenkinson, "The Frequency Distribution of the Annual Maximum Values of Meteorological Elements," Quarterly J. Royal Meteorological Society, Vol. 81, No. 348, April 1955) to the annual series for each watershed. The output from this program has been plotted by computer on extreme-value probability paper and it is from this plot that P_Q is obtained. Examples of the graphical output from the flood frequency analysis program are contained in Section 5.

One Hour Infiltration Capacity for Bare Soils, f_1

f_1 is a standard infiltration capacity at a time of one hour. It is obtained from Table 3.3 which, together with the accompanying text, is taken directly from the ASCE Hydrology Handbook (1949, pp. 48-51).

Table 3.3. Range in f_1 for various soil groups

Soil Group	Range in f_1 (in. per hr)
High.	0.50 to 1.00
Intermediate. . . .	0.10 to 0.50
Low	0.01 to 0.10

The soil characteristics of the groups given in Table 3.3 are as follows:

High Group

Embraces many sandy soils but also includes open-structured soils of other textures, particularly the most friable of the silt loams.

The higher values of f_1 in the range indicated are ordinarily associated with relatively loose and porous sandy soils. Some soils that appear quite coarse upon casual inspection actually contain considerable portions of fine material. When such soils are subjected to the pelting of raindrops the fine particles tend to block the entrances to the larger pores, forming a thin layer that largely controls the rate of infiltration, making it much lower than would be the case were the drops prevented from striking the soil surface by vegetal cover, humus, or mulch.

The lower values are associated with soils characterized by a low clay content, a high organic matter content, a high degree of aggregation, and relatively small amounts of swelling and shrinking with change in moisture content. (Useful indicators: Easy tillage with absence of clod formation over a wide range of moisture content; little or no tendency for surface crust to form on tilled land after rain; vigorous natural vegetation and good crops when properly managed; and quick disappearance of standing water after rain.)

Intermediate Group

The higher values of f_1 in the range indicated are associated with soils approaching the "high group" in structural and other characteristics.

The lower values are associated with soils approaching the "low group" in structural and other characteristics.

The central values are associated with the loams typical of the better agricultural regions. These typical loams contain considerable clay and much silt, but are rather highly aggregated and, therefore, friable at ordinary moisture contents. (Useful indicators: Fairly easy tillage and little trouble with clod formation at ordinary moisture contents; clods and surface crusts break down readily; little checking or cracking when dry; fairly sticky when wet; and good crops under proper management.)

Low Group

Embraces most clays and clay loams, but also includes soils of other texture that are dense in structure.

The higher values of f_1 in the range indicated are ordinarily associated with the heavy loams. Such loams are characterized by a high clay content, a low degree of aggregation (dense structure), and excessive swelling and shrinking with change in moisture content. (Useful indicators: Cracking of the surface during dry periods - soils that check and crack during dry periods almost always have low infiltration capacities when wet, but it must be kept in mind that, when these soils are extensively and deeply cracked, the initial rainfall during a storm will be infiltrated at a high rate; as soon as the soil becomes wetted, and the cracks are closed by the resultant swelling, the infiltration capacity will decrease rapidly to the low rates associated with these heavy soils; a very narrow range of moisture content in which tillage is possible without excessive formation of long lasting clods; extreme stickiness when wet; a strong tendency for tilled land to crust after rain; usually inferior natural vegetation; and slow disappearance of standing water after rains.)

The lower values are usually associated with the clay soils. These soils are stickier and denser than the heavy loams previously described and are highly plastic when wet.

Cover Factor, f_2

This factor is the ratio of f_1 for a given soil cover to f_1 for the same soil without cover. The cover factor table, Table 3.4, together with the accompanying text, are taken from the ASCE Hydrology Handbook (1949, pp. 48-51). The range in cover factor values represents a real variation due to the influence of soil characteristics, as well as an allowance for error. The adjectives "good", "medium," and "poor" describe only the effect of the cover on infiltration capacity.

The cover characteristics of the groups given in Table 3.4 are as follows:

Forest Cover

Forests increase infiltration capacities by covering the soil surface with a layer of organic matter (humus and litter). If this layer is removed, infiltration will be low in spite of the tree canopy and, if the latter could be removed without affecting the layer, infiltration capacity would continue to be high. Actually, of course, the surface organic material would soon oxidize and disappear if the canopy were removed. From the standpoint of infiltration, "good" forest cover does not mean

Table 3.4. Cover Factors for Various Conditions

Cover[a]		Range in value of cover factor[b]
Type	Condition	
Permanent (forest and grass)	Good Medium Poor	3.0 to 7.5 2.0 to 3.0 1.2 to 1.4
Close growing crops	Good Medium Poor	2.5 to 3.0 1.6 to 2.0 1.1 to 1.3
Row crop	Good Medium Poor	1.3 to 1.5 1.1 to 1.3 1.0 to 1.1

[a] The covers referred to are described in the text.
[b] This factor is the ratio of f_1 for given soil with cover to f_1 for same soil without cover.

just a good stand of timber. Two additional conditions must be met: (a) There must be a good humus layer; and (b) the canopy must produce sufficient litter to maintain this layer.

Where the terms "good," "medium," and "poor" are used in Table 3.4 with respect to forest cover they have the following meanings:

Good -- humus 1 in. or more thick; soil not excessively eroded previously; area not overgrazed.
Medium -- humus 1 in. to ¼ in. thick; soil not excessively eroded previously; area not overgrazed.
Poor -- humus less than ¼ in. thick; soil previously eroded; area grazed too intensively.

Grass Cover

Grasses increase infiltration capacity by affording protection against raindrop impact, by providing a layer of humus and litter, and by changing the character of the soil itself. The infiltration under a grass cover then depends not only on the density and the kind of plants, but also on the length of time the area has been in grass and on the management of the land. The classifications of grass cover follow:

Good -- dense vegetal cover of high quality grass having extensive root systems; area previously in grass for several years; if pasture, properly managed (not overgrazed).
Medium -- vegetal density from 80% to 30% of that on "good" areas with good quality grasses having extensive root systems; area in grass at least two years; if pasture, area well managed (not overgrazed).

Poor -- density of vegetation less than 30% of that on "good" areas; sparse growth of low quality grass; poor management (overgrazed or otherwise abused).

Close Growing Crops

This term refers to cultivated crops like small grains, hay in rotations, and winter cover crops. These are quite effective in increasing infiltration during the time they are flourishing. However, it must be realized that the land is entirely unprotected during the period following tillage, that the protection varies as the plants grow, and that, after harvest, there may be a period when the land is protected only by the stubble. It is obvious from this that the infiltration capacities of such lands vary through a wide range during the year. If runoff is to be calculated for the specific conditions existing at a given time, this variation must be considered. The values in Table 3.4 are for crops at or approaching maturity and the classes are as follows:

Good -- high plant density; soil fertility at high level.
Medium -- density of plants from 80% to 30% of that on "good" areas; soil fertility such that the yield is from 80% to 30% of that on "good" areas.
Poor -- sparse cover, less than 30% of the density on "good" areas; soil fertility such that the yield is less than 30% of that on "Good" areas.

When it is necessary to estimate infiltration capacities during other stages of growth of such crops, the condition closest to that at the time should be used. For example, between the time the land is prepared and the plants reach a height of perhaps 2 in., the area could very well be classed as bare. Again, after the crop is harvested and still in stubble, the land might all be classed as in "poor" close growing crop, or, if the crop were poor, even as "bare" land.

Row Crops

Some protection against the impact of raindrops on the bare soil is provided by such row crops as corn when it approaches maturity. Moreover, the treatment given a soil in growing row crops tends to increase the infiltration capacity over what it would be for bare soil. Fertilizers, cultivation (for example, contour plowing), and rotation of crops are particularly effective in this respect.

As is true for all growing crops, there is a large variation in the condition of row crop land during the year. In the spring the soil is bare, and this is followed by a period in which the plants are too small to provide any great amount of protection. After harvest and during the winter the field will be practically bare unless a cover crop is planted. All these things must be considered in much the same way as suggested for close growing crops.

Infiltration into row crop lands depends, then, not only on the existing cover, but also, in an important measure, on the previous use of the land and on the farming and conservation practices followed. For this reason it is necessary to put this factor on a par with the cover condition:

Good -- a flourishing vegetation; soil fertility high; land in best rotation and all other necessary farming practices followed.

Medium -- vegetation good; soil fertility such that yield is from 80% to 30% of that of "good" areas; land in fair rotation and conservative farming practices followed otherwise.

Poor -- vegetation poor; soil fertility such that yield is less than 30% of "good" areas; row crops grown continuously and poor farming practices followed otherwise.

✓ Standard Infiltration Capacity, f_s

$$f_s = f_1 \cdot f_2$$

Sometimes f_s will be given. If not, it will be calculated from f_1 and f_2 . Record f_s in inches per hour to two decimal places.

✗ Initial Loss, L_i

The initial loss is not computed at the present time due to its resemblance to the ϕ-index.

ϕ-index, ϕ

The ϕ-index is defined as that rate of rainfall above which the rainfall volume equals runoff volume. This index represents the rate at which losses are exerted throughout the course of the storm. ϕ is determined by computer from the rainfall hyetograph and runoff volume.

✗ Duration of the Supply Period, T_s

This will be determined by computer at a later date.

Section 4

QUALITY CONTROL STUDY OF PHYSICAL WATERSHED DATA

Introduction

While the ultimate objective of the small watersheds program at Colorado State University is the derivation of a generalized rainfall-runoff relation, the immediate goal is seen as the assembly of a large quantity of data pertaining to rainfall and runoff from watersheds in the size range 0.1 to 40.0 square miles. Such a compilation of high quality data would then provide a broad basis for investigation into the nature of small watershed response as it occurs under widely varying hydrologic conditions. The success of these future analyses is, therefore, highly dependent upon the quality of hydrologic data assembled in this initial phase of the program. Provided the task of data collection is completed with a desirable measure of accuracy, the clarification of relations existing between complex hydrologic variables can be attempted with some assurance of success.

The purpose of this study was to obtain an estimate of the errors contained in the physical watershed data. This was seen as the final step in the processing of small watershed data, since the flood event data had been checked previously by means of comparison with the records of rainfall and streamflow received from the operating agency. It should be noted that in some cases it was impossible to work up the runoff data directly from the original strip-charts of rainfall and streamflow. In many instances, the flood event data was transcribed from tabulations which were compiled after a partial processing of rainfall and streamflow data by the agency responsible for the watershed operations. This data was then converted to a standard form by means of a computer program and mounted on magnetic tape for storage. As a consequence of this procedure, minor discrepancies between the stored data and the original rainfall and streamflow data, as taken directly from recorder strip charts, may have developed. However, because original recorder traces were not generally available, no attempt was made to check on this potential source of error. A careful review of each storm event has been made by means of a comparison with such records of rainfall and streamflow as were available.

Accordingly, three sources of error influencing the quality of physical watershed data were identified in the following way:

(1) gross errors resulting from transpositions of numbers, misplacing of decimal points, and major errors of computation;
(2) measurement errors associated with the use of planimeters, paper strips, and contour maps; and
(3) raw data errors such as those contained in the contour mapping of the watershed.

This quality control study was made for the dual purpose of identifying the sources of gross errors and estimating the magnitude of measurement errors associated with individual watershed parameters. No attempt has been made to isolate errors in basic data, such as topographic mapping, since this aspect of the problem is considered beyond the scope of the present study.

Procedure

In order to obtain a reliable estimate of errors contained in each watershed parameter, it was decided that a sample of 20 watersheds, selected randomly from the entire collection of 192 complete watersheds (as of January 1967) would be checked in a detailed manner according to the instructions for processing new watersheds. Thus, the watersheds selected for the checking procedure were treated as though they had never been processed. A duplicate set of parameter estimates for each watershed of this random sample was thereby obtained. The error associated with each parameter was defined as the absolute deviation between the first and second computations of a given parameter. This absolute departure was then converted to a percentage error by the expression:

$$\text{Parameter error} = \frac{\text{absolute deviation of two trials}}{\text{average value of the two trials}} \times 100 \text{ .}$$

To insure that the watershed selected at random would not all be taken from the same state (Colorado or California, for example), the total of 192 watersheds was divided into four groups of 48 watersheds each. Every member of a sub-sample was assigned a number from 1 to 48 and a table of random numbers found in the appendix of Li's "Statistical Inference" (Vol. 1, pp. 589-598) was used in selecting five watersheds from each of the four sub-samples. In this way, 20 watersheds were selected for the purposes of the quality control study.

Four students employed by the small watershed hydrology program carried out the task of redoing the 20 selected watersheds in complete detail. The assignment of watersheds to students was attempted on a random basis, although the work was arranged so that no watershed would be checked by the individual who had made the original computations. In this manner, the effects of personal abilities and individual errors of judgment were minimized.

Results of the Study

The primary results of the study were tabulated as the percentage deviations associated with each of the 24 watershed parameters investigated. A summary of these results is presented in Tables 4.1 and 4.2. The array of Table 4.1 was obtained by summing the percentage deviations in a given parameter and dividing this total by the number of watersheds for which the parameter was recomputed - in this case 20. Table 4.2 shows the percentage deviation in parameters arranged in ranking order under selected characteristics of the watershed.

Discussion of Results

As seen in Table 4.1, the average errors range from a minimum of 0.5 percent, for the area, A, to a maximum of 16.0 percent for the overland slope parameter, R_5 . The maximum single deviation encountered was 75 percent in the mean travel distance parameter, L_m . It was apparent that this discrepancy, as well as several others of smaller magnitude, was produced by a simple error of machine computation made after the appropriate measurements had been taken from the topographic map. In order to eliminate possible systematic errors of computation, as indicated by excessive deviations in the results, a careful review of those parameters having errors greater than 50 percent was made. Accordingly, the parameters S_d, C, and L_m were re-examined for all 192 watersheds.

Table 4.1. Average Errors for all Watershed Parameters

Watershed parameter ranked by error		Average Error in percent
A	Area	0.5
P	Perimeter of watershed	1.6
H	Total fall	2.9
L	Length of main stream	3.1
W	Average watershed width	3.4
L_t	Mean travel distance	3.7
L_c	Distance from centroid to outlet	4.2
R_6	Overland slope	4.6
R_1	Overland slope	4.8
F	Watershed form factor	5.2
C	Compactness coefficient	6.3
S_1	Stream slope	6.3
S_4	Stream slope	6.9
S_t	Standard deviations of L_t	7.0
R_3	Overland slope	7.2
D_d	Drainage density	7.5
L_s	Length of extended streams	7.5
S_2	Stream slope	8.1
L_m	Dimensionless travel distance	8.8
R_2	Overland slope	10.0
S_d	Dimensionless S_t	10.7
S_3	Stream slope	11.3
R_4	Overland slope	15.3
R_5	Overland slope	16.0

Total mean error for all parameters = 6.8%.

Table 4.2. Average Errors in Selected Watershed Characteristics

	Watershed Characteristics	Average Error in percent
General physiographic parameters:		
A	Area	0.5
P	Perimeter of watershed	1.6
W	Average Watershed width	3.4
F	Watershed form factor	5.2
C	Compactness coefficient	6.3
Stream length and density parameters:		
L	Length of main stream	3.1
L_s	Length of extended streams	7.5
D_d	Drainage density	7.5
Travel distance parameters:		
L_t	Mean travel distance	3.7
L_c	Distance from centroid to outlet	4.2
S_t	Standard deviation of L_t	7.0
L_m	Dimensionless travel distance	8.8
S_d	Dimensionless S_t	10.7
Overland slope parameters:		
R_6	Overland slope	4.6
R_1	Overland slope	4.8
R_3	Overland slope	7.2
R_2	Overland slope	10.0
R_4	Overland slope	15.3
R_5	Overland slope	16.0
Stream slope parameters:		
H	Total fall	2.9
S_1	Stream slope	6.3
S_4	Stream slope	6.9
S_2	Stream slope	8.1
S_3	Stream slope	11.3

Other watershed parameters presenting significant errors of measurement are the overland slopes, R_4 and R_5. These departures are noteworthy primarily because they represent differences in individual judgment and not the effects of oversight or miscalculation. It is apparent that the various overland slope parameters, R_2 through R_5, are of sufficient complexity as to preclude duplication of results.

The computation of L_s and related parameters offers similar complications. It was found that the length of extended streams is highly dependent upon: (1) the completeness of detail shown in the topographic survey map, and (2) the hydrologic intuition of the analyst. For example, it was noted that whenever maps from two different sources are available for the same watershed, one of them invariably provides better definition of the first order tributary streams than the other. However, there is no assurance that those low order streams were placed at the discretion of the engineering survey and not the cartographic enthusiasm of the draftsman. The other concern is that the analyst himself might reasonably increase the magnitude of the parameter L_s by locating permanent stream courses in steep ravines and gullies which otherwise are shown only as ephemeral streams or even dry washes on the available map. It seems that the source and scale of the topographic map should somehow be specified in conjunction with the measurement of L_s. Naturally the accuracy of the derived parameter, D_d (drainage density), is greatly affected by that of the basic parameter L_s .

For the random sample consisting of 20 watersheds, no errors of measurement greater than 10 percent were encountered in the following parameters:

A	(area of watershed)
L	(Length of main stream)
L_c	(distance from centroid of basin to outlet)
L_t	(mean travel distance)
P	(perimeter of watershed)
H	(total fall in basin)
W	(average watershed width).

With but one or two exceptions, which have been noted previously, the parameters S_d, C, L_m, and F also fell in this category. The stream and overland slopes S_1, S_4, and R_1 nearly met this criterion.

The small error associated with watershed area is no doubt due to the repetitive planimetering technique used in measuring this quantity. According to this method watershed area is established as the result of averaging five successive planimeter trials. The average technique is necessary in view of the fact that the following eight watershed parameters are related in a functional way to area: R_1, R_3, D_d, W, F, C, L_m and S_d . Naturally, measurement errors associated with watershed area will be reflected in the computation of these dependent quantities.

It is noted finally that, in general, the larger measurement errors were associated with the watershed parameters which required rather complex and tedious computations. The overland slopes, R_2 through R_5, and the stream slopes S_2 and S_3 for example, require lengthy calculations and are not readily duplicated in successive measurements. The slope parameters R_1, S_1, and S_4, on the other hand, are easily computed on the basis of simple measurements and consequently contain relatively little error.

Summary and Conclusions

An attempt has been made to estimate the magnitude of errors associated with the measurement of parameters related to the physiographic features of a watershed. The primary sources of error in this particular data acquisition system have been discussed. The aim of this study was to identify gross errors resulting from systematic computational oversight and to estimate the residual errors due mainly to differences of individual judgment.

The results, as presented in Table 4.1, have shown that the mean error for each parameter ranges from a minimum of 0.5 percent to a maximum of 16.0 percent. Due to simple errors of machine computation, however, the actual errors reached as high as 50 percent for four watershed parameters, and as high as 75 percent in the case of a single parameter. Emphasis is placed on the fact that those large errors occurred in derived parameters and not in the basic measurements. Anticipation of gross errors contained in these widely deviating parameters led to a review of the total 192 watersheds. The mean error computed for all parameters and averaged over 20 watersheds is 6.8 percent.

In general, the larger errors are associated with those watershed parameters requiring lengthy computations. In particular, the overland slope parameters, R_2 through R_5, and the stream slopes, S_2 and S_3, offer the greatest complexity of computation and in turn have the least accuracy of measurement. The doubtful validity of these parameters would justify the use of extreme caution in analyzing their effects on future hydrologic studies. In addition, the effects of derived parameters (those which are related functionally to basic watershed measurements) in multiple-regression analyses may be deleterious due to high interactions between parameters.

It is concluded that the overall error and the errors exhibited by each of the individual watershed parameters are not outside the bounds of expected variability in human performance associated with the measurement of hydrologic factors. The reduction of measurement errors in overland slope and stream slope parameters has been identified as an area requiring further investigation.

Section 5

SMALL WATERSHED INVENTORY

This section describes the data in the small watershed flood event file in the following way: first, detailed examples of physical watershed and storm event data are presented; and second, an overall data processing summary is given followed by a list of all processed watersheds and their associated storm events.

The first part of this section is presented in an attempt to illustrate more fully the nature of the data assembled by the Small Watershed Project. It is emphasized that while the data for five selected watersheds has been retrieved from magnetic tape output, the arrangement of this data on the following pages was tailored to the specific needs of this publication. The graphical output which illustrates the flood frequency analysis and the rainfall hyetograph - runoff hydrograph plots was obtained from the computer in the form of 35 mm microfilm. The microfilm was subsequently developed and enlarged for illustrative purposes.

The second part of this section consists of an overall data processing summary and an inventory of watersheds and events which are currently stored on magnetic tape. The overall status of data processing by the Small Watershed Project is summarized by the figures of Table 5.1. While it is felt that much has been accomplished in the past several years, it is apparent that much remains to be done. The figures of Table 5.1 indicate that roughly 70 per cent of all flood events on file have been processed for storage on magnetic tape. However, less than 16 per cent of all presently available watersheds have been entered on magnetic tape. The magnitude of the task of assembling data for small watershed floods and the challenge it presents are both reflected in the figures of Table 5.1.

The tabulation of watersheds and storm events currently stored on magnetic tape is presented in the inventory of Table 5.2. It should be noted that only those watersheds for which the 3000-series data have been assembled are listed in the tabulation. The following symbols are used in identifying the stage of data processing for each watershed listed in the inventory:

C = data processing complete
I = data processing incomplete
Number = number of API series, mass curves,
and hydrographs completed.

These symbols are located in the appropriate columns for each watershed in the listing.

Watershed Description
(0000, 1000, and 3000 Data)

Serial Number: 1-03-06-001-00

Watershed: W-I

Gaging Station: Safford

River Basin: Colorado

State: Arizona

Country: U.S.A.

Continent: N.A.

Stream Gage: Latitude, X = 32°54' 54"
Longitude, Y = 109°49'46"
Elevation, Z = 3210 feet

Annual Averages:

Date of Records
$Q_a = 0.02$ (average discharge, cfs) : 1941 to present
$q_a = 0.03$ (areal average discharge, cfs/sq.mi.): 1941 to present
$P_a = 7.1$ (average annual precipitation, in/yr): 1941 to present

Name of operating agency and agency number for the watershed: Agricultural Research Service, 45.1

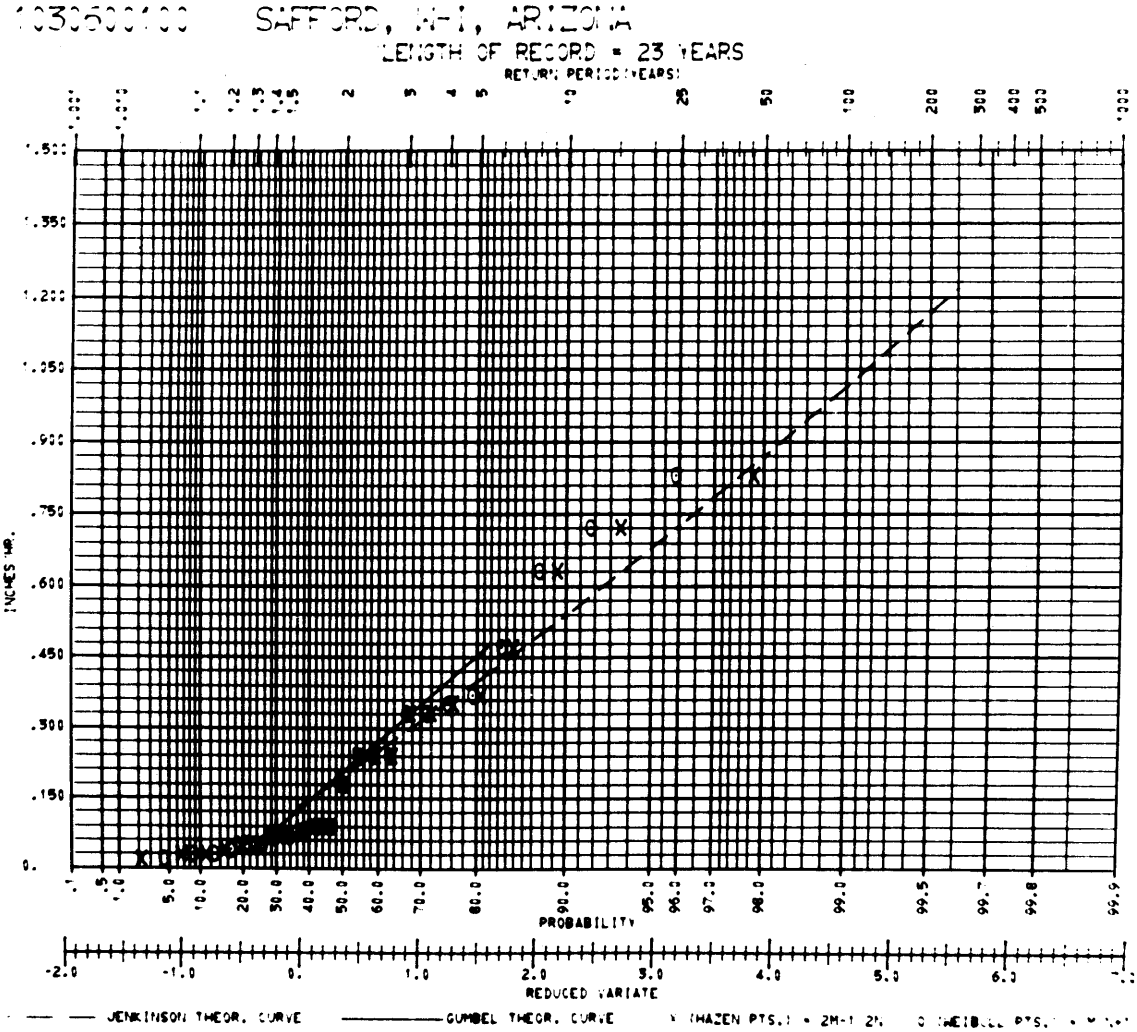
Catchment Characteristics: (3000 Data)
$A = 0.81$ (area, square miles)
$L = 2.70$ (length of main stream, miles)
$L_s = 6.55$ (total length of extended streams, miles)
$L_c = 1.45$ (distance to centroid of area, miles)
$L_t = 1.44$ (average travel distance, miles)
$s_t = 0.73$ (standard deviation, miles)
$s_d = 0.81$ (dimensionless standard deviation, dimensionless)
$P = 5.76$ (perimeter, miles)
$H = 240$ (total fall, feet)
$S_1 = 89$ (stream slope, feet/mile)
$S_2 = 67$ (stream slope, feet/mile)
$S_3 = 73$ (stream slope, feet/mile)
$S_4 = 67$ (stream slope, feet/mile)
$D_d = 8.09$ (drainage density, mile/square mile)
$W = 0.30$ (average width of catchment, miles)
$F = 0.11$ (form factor, dimensionless)
$C = 1.79$ (compactness coefficient, dimensionless)
$L_m = 1.60$ (mean travel distance, dimensionless)
$R_1 = 401$ (overland slope, feet/mile)
$R_2 = 270$ (overland slope, feet/mile)
$R_3 = 395$ (overland slope, feet/mile)
$R_4 = 444$ (overland slope, feet/mile)
$R_5 = 540$ (overland slope, feet/mile)
$R_6 = 0.0205$ (overland slope, dimensionless)

Annual Series of Flood Peaks
(2000 Data)

Watershed No.: 1-03-06-001-00   Watershed: Safford, W-I, Arizona

No.	Date	Peak in/hr	No.	Date	Peak in/hr	No.	Date	Peak in/hr
1	10- 7-39	0.24	9	8-20-47	0.09	17	7-22-55	0.05
2	6-29-40	0.24	10	8- 6-48	0.02	18	7-28-56	0.03
3	4 26-41	0.09	11	9-13-49	0.05	19	7-26-57	0.33
4	9-11-42	0.33	12	7- 7-50	0.18	20	7- 5-58	0.04
5	8-23-43	0.72	13	8- 3-51	0.30	21	8- 3-59	0.24
6	9- 5-44	0.83	14	7- 6-52	0.07	22	7-24-60	0.07
7	8-11-45	0.35	15	7-27-53	0.47	23	8- 7-61	0.63
8	8-30-46	0.08	16	8-22-54	0.37			

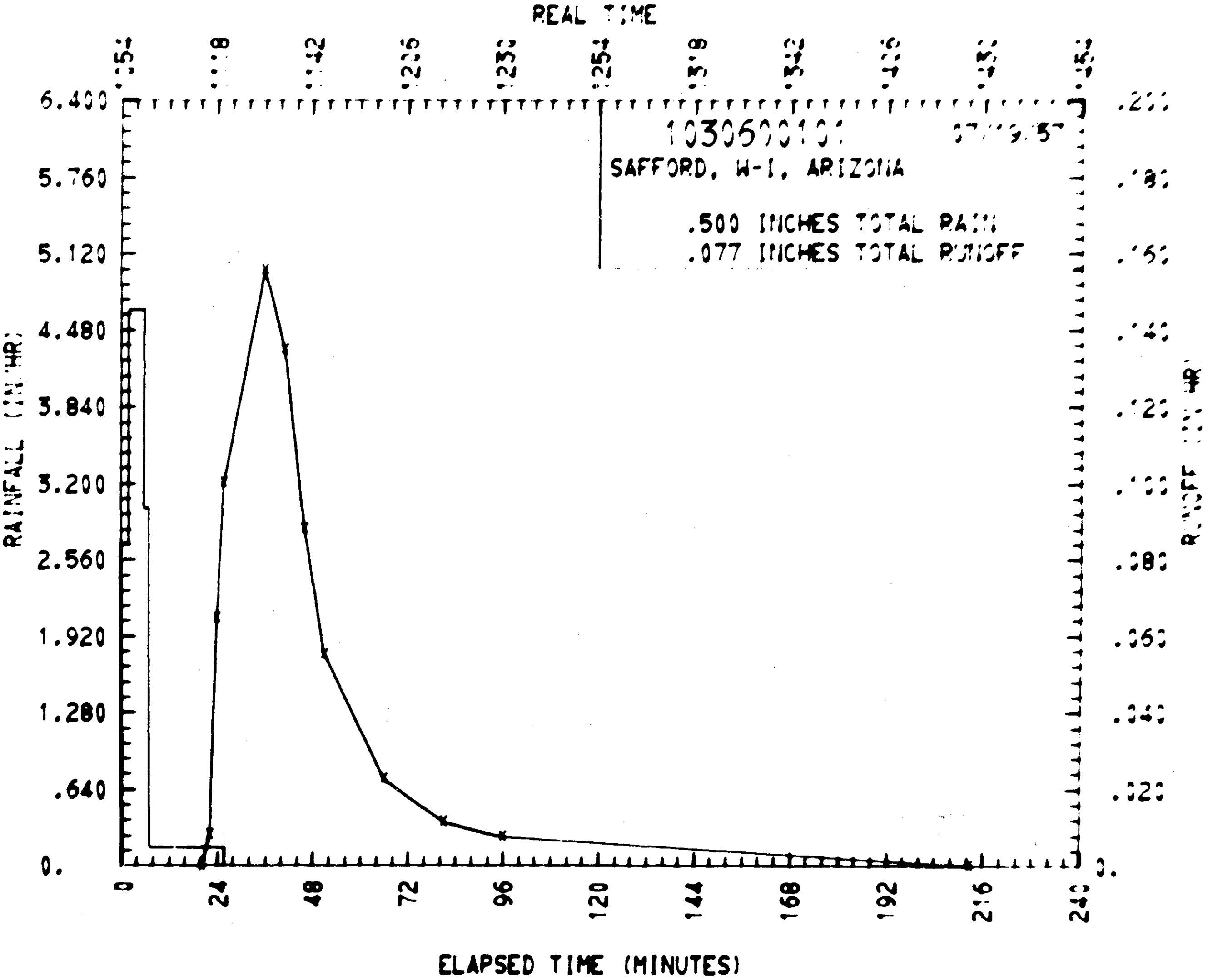
Graphical Analysis of Flood Peaks



Event No.: 1-03-06-001-01 Watershed: Safford, W-I, Arizona

Date of Storm: 7-19-57 Starting Time of Mass Curve: 10:54

API		Mass Curve		Hydrograph	
(4000 Data)		(5000 Data)		(6000 Data)	
Days before	Rainfall inches	Cum. Time minutes	Cum. Rain inches	Time Incr. minutes	Discharge in/hr
1 @ 24:00	0.00	0	0	2	0.0083
2 @ 24:00	0.49	2	0.09	2	0.0646
4 @ 24:00	0.10	6	0.40	2	0.1003
18 @ 24:00	0.09	7	0.45	10	0.1560
		26	0.50	5	0.1347
				5	0.0882
				5	0.0552
				15	0.0225
				15	0.0115
				15	0.0077
				117	0.0000



Watershed Description
(0000, 1000, and 3000 Data)

Serial Number: 1-05-01-001-00

Watershed: Lopez Creek

Gaging Station: Near Smith River

River Basin: Lopez

State: California

Country: U.S.A.

Continent: N.A.

Stream Gage: Latitude, X = 41°57'36"
Longitude, Y = 124°12'08"
Elevation, Z = 35 feet

Annual Averages:

Date of Records
Q_a = 5.49 (average discharge, cfs) : 1961 to present
q_a = 5.90 (areal average discharge, cfs/sq.mi.): 1961 to present
P_a = 89.0 (average annual precipitation, in/yr): 1961 to present

Name of operating agency and agency number for the watershed: California Department of Water Resources (15) and U.S. Geological Survey (11-5330)

Catchment Characteristics: (3000 Data)

A = 0.93 (area, square miles)
L = 3.02 (length of main stream, miles)
L_s = 5.39 (total length of extended streams, miles)
L_c = 1.43 (distance to centroid of area, miles)
L_t = 0.82 (average travel distance, miles)
s_t = 1.12 (standard deviation, miles)
s_d = 1.16 (dimensionless standard deviation, dimensionless)
P = 5.83 (perimeter, miles)
H = 1202 (total fall, feet)
S_1 = 395 (stream slope, feet/mile)
S_2 = 356 (stream slope, feet/mile)
S_3 = 278 (stream slope, feet/mile)
S_4 = 359 (stream slope, feet/mile)
D_d = 5.80 (drainage density, mile/square mile)
W = 0.31 (average width of catchment, miles)
F = 0.10 (form factor, dimensionless)
C = 1.69 (compactness coefficient, dimensionless)
L_m = 0.85 (mean travel distance, dimensionless)
R_1 = 1911 (overland slope, feet/mile)
R_2 = 1746 (overland slope, feet/mile)
R_3 = 1865 (overland slope, feet/mile)
R_4 = 1456 (overland slope, feet/mile)
R_5 = 1333 (overland slope, feet/mile)
R_6 = 0.0910 (overland slope, dimensionless)

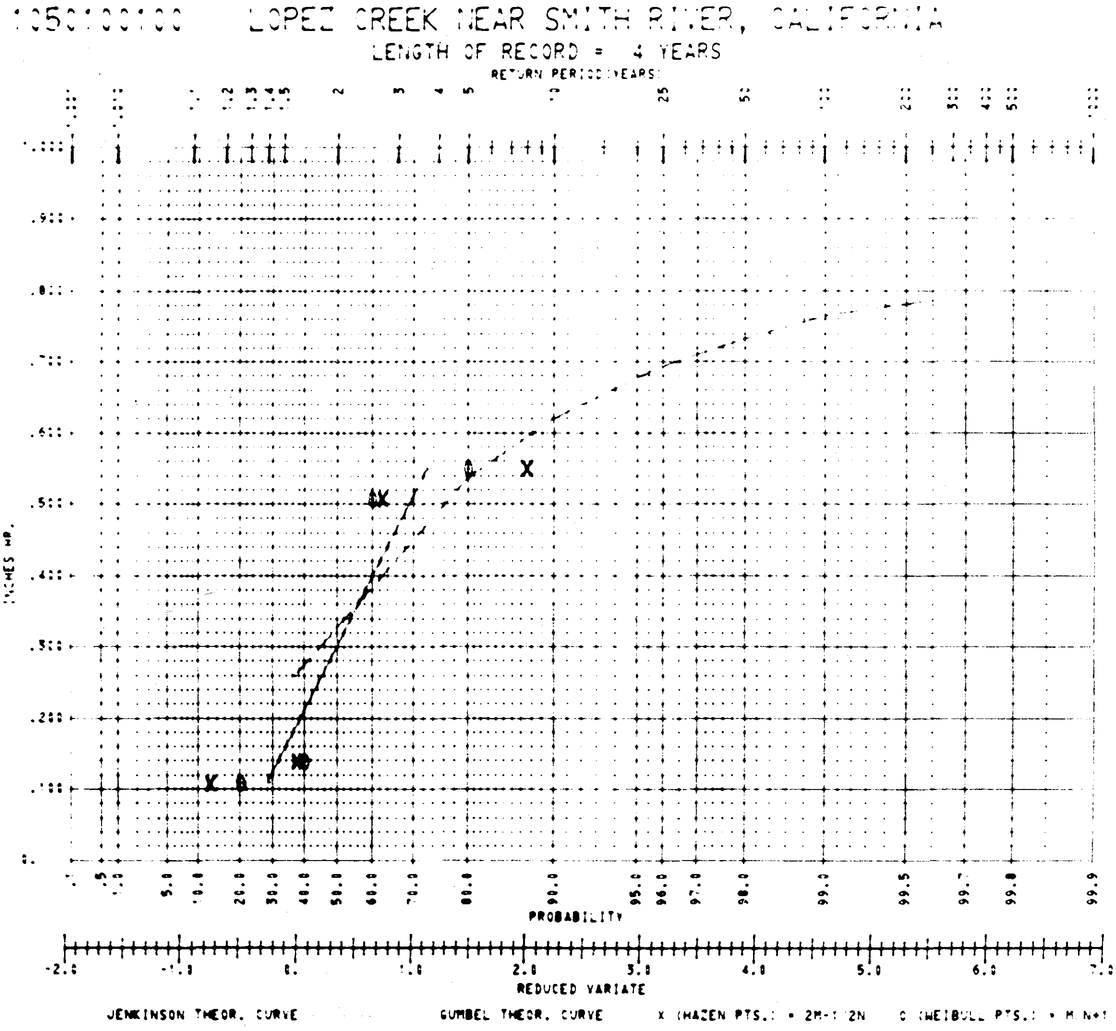
Annual Series of Flood Peaks
(2000 Data)

Watershed No.: 1-05-01-001-00

Watershed: Lopez Creek near Smith River, California

No.	Date	Peak in/hr
1	11-23-61	0.108
2	5- 6-63	0.140
3	1-19-64	0.508
4	12-22-64	0.550

Graphical Analysis of Flood Peaks



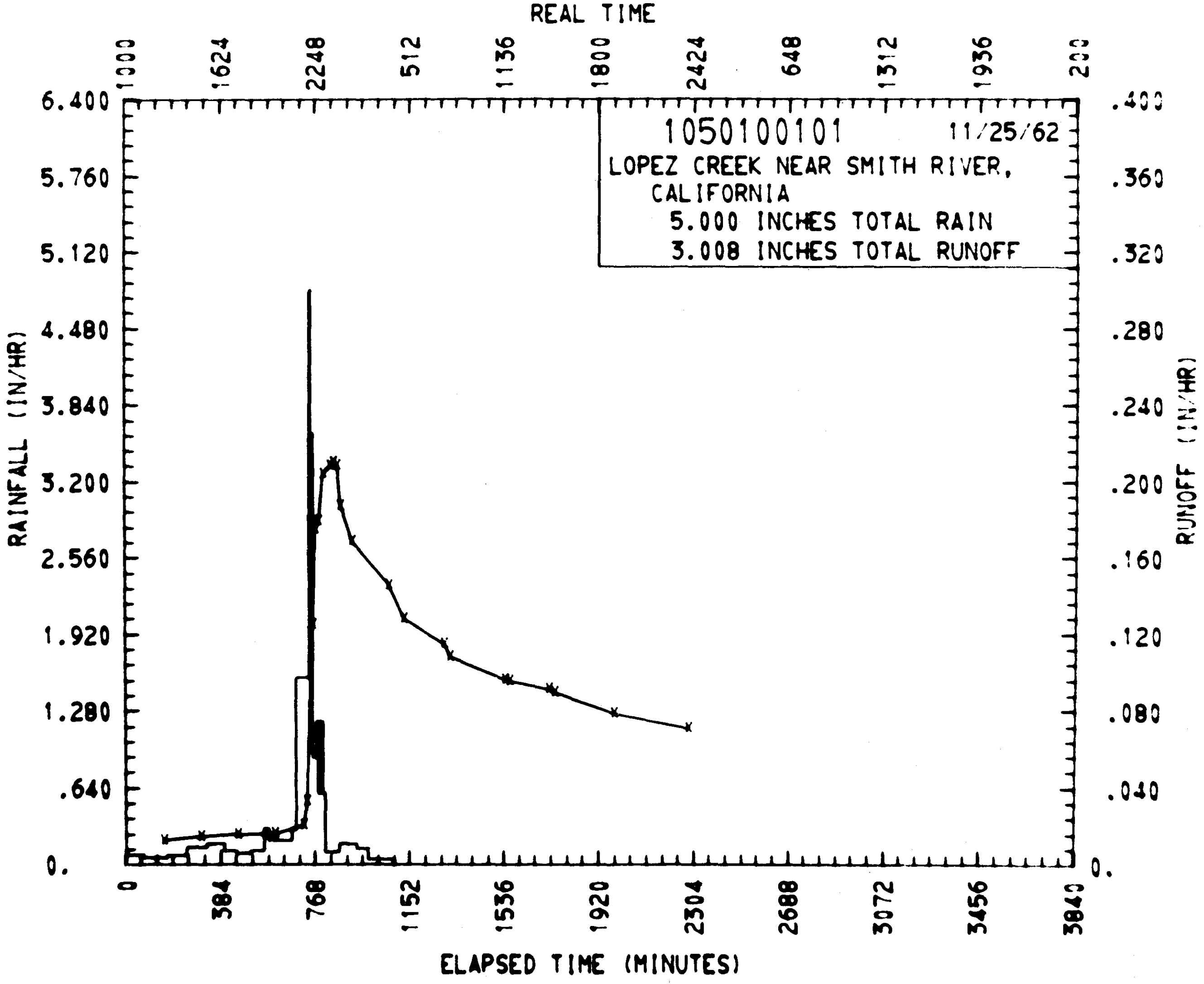
Event: 1-05-01-001-02

Date of Storm: 12-01-62

Watershed: Lopez Creek, near
Smith River, California

Starting Time of Mass Curve: 10:00

API		Mass Curve				Hydrograph	
(4000 Data)		(5000 Data)				(6000 Data)	
Days before	Rainfall inches	Cum.Time minutes	Cum.Rain inches	Cum.Time minutes	Cum.Rain inches	Time Incr. minutes	Discharge in/hr
1 @ 24:00	0.50	0	0.00	1050	2.50	0	0.0200
2 @ 24:00	0.30	60	0.10	1080	2.60	30	0.0225
4 @ 24:00	0.20	190	0.20	1095	2.70	120	0.0267
5 @ 24:00	0.90	480	0.30	1110	2.80	140	0.0283
6 @ 24:00	4.50	495	0.40	1125	2.90	40	0.0350
9 @ 24:00	0.30	510	0.50	1140	3.00	30	0.0433
10 @ 24:00	0.40	540	0.60	1150	3.10	195	0.0733
		580	0.70	1170	3.20	90	0.1000
		600	0.80	1182	3.30	75	0.1667
		630	0.90	1200	3.40	30	0.1667
		675	1.00	1215	3.50	45	0.1834
		720	1.10	1245	3.60	195	0.1700
		780	1.20	1255	3.70	270	0.1467
		795	1.30	1260	3.80	30	0.1467
		825	1.40	1265	3.90	20	0.1667
		835	1.50	1270	4.00	460	0.1250
		840	1.60	1275	4.10	240	0.0900
		850	1.70	1290	4.20	480	0.0668
		885	1.80	1320	4.30		
		915	1.90	1335	4.40		
		930	2.00	1350	4.50		
		960	2.10	1395	4.60		
		975	2.20	1440	4.70		
		1005	2.30	1485	4.80		
		1035	2.40	1560	4.90		


REAL TIME
1000
1624
2248
512
1136
1800
2424
648
1312
1936
200
1050100101
11/25/62
LOPEZ CREEK NEAR SMITH RIVER,
CALIFORNIA
5.000 INCHES TOTAL RAIN
3.008 INCHES TOTAL RUNOFF
RAINFALL (IN/HR)
6.400
5.760
5.120
4.480
3.840
3.200
2.560
1.920
1.280
.640
0.
RUNOFF (IN/HR)
.400
.360
.320
.280
.240
.200
.160
.120
.080
.040
0.
0
384
768
1152
1536
1920
2304
2688
3072
3456
3840
ELAPSED TIME (MINUTES)

Watershed Description
(0000, 1000, and 3000 Data)

Serial Number: 1-06-06-104-00

Watershed: Lower Fool Creek

Gaging Station: At Fraser Experimental Forest

River Basin: Fraser River

State: Colorado

Country: U.S.A.

Continent: N.A.

Stream Gage: Latitude, X = 39°53'27"
Longitude, Y = 105°52'02"
Elevation, Z = 9600 feet

Annual Averages:

Date of Records
Q_a = 1.07 (average discharge, cfs) : 1940 to present
q_a = 0.97 (areal average discharge, cfs/sq.mi.): 1940 to present
P_a = 24.0 (average annual precipitation, in/yr): 1940 to present

Name of operating agency and agency number for the watershed: U.S. Forest Service

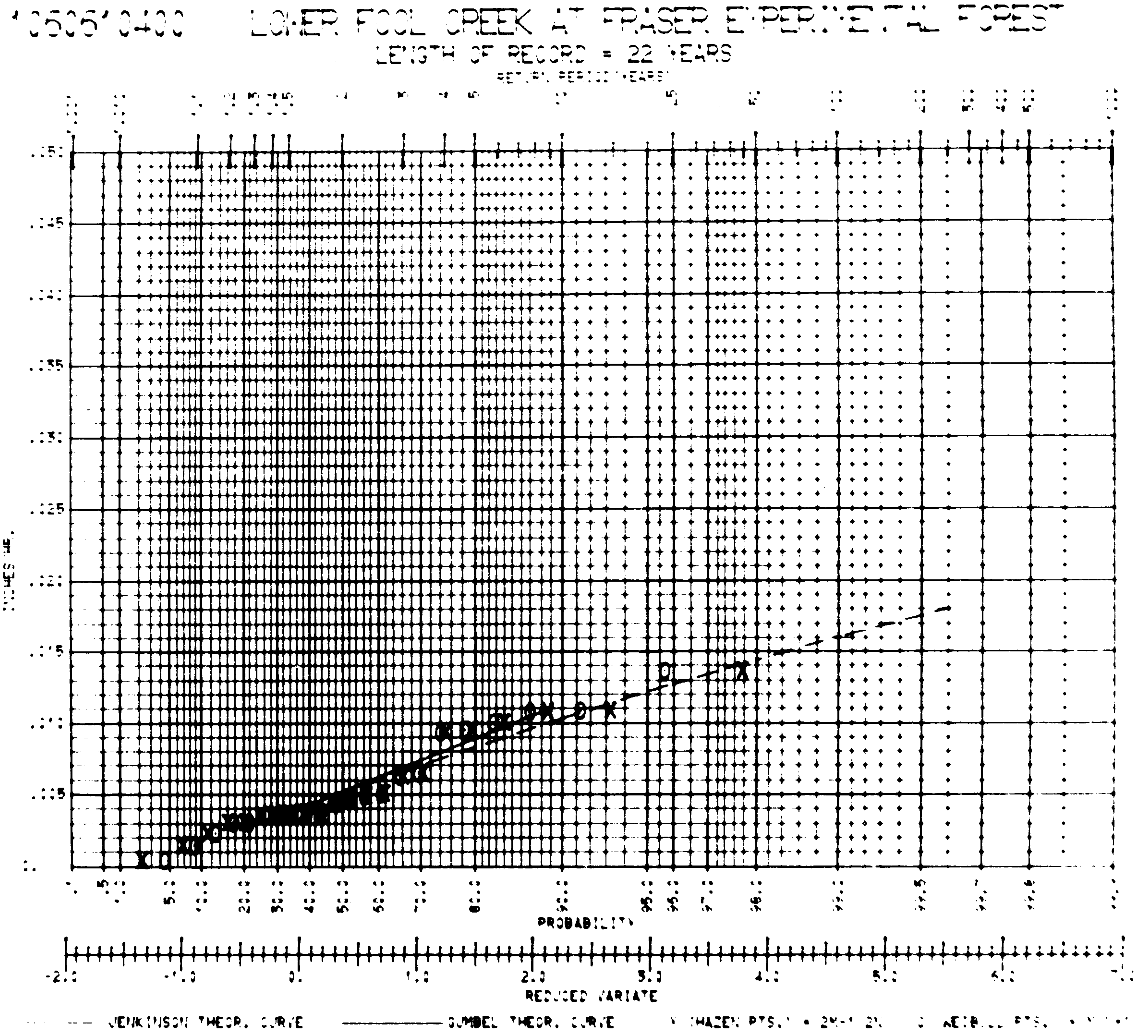
Catchment Characteristics: (3000 Data)
A = 1.12 (area, square miles)
L = 2.38 (length of main stream, miles)
L_s = 2.38 (total length of extended streams, miles)
L_c = 1.02 (distance to centroid of area, miles)
L_t = 1.19 (average travel distance, miles)
s_t = 0.64 (standard deviation, miles)
s_d = 0.60 (dimensionless standard deviation, dimensionless)
P = 5.33 (perimeter, miles)
H = 1965 (total fall, feet)
S_1 = 826 (stream slope, feet/mile)
S_2 = 781 (stream slope, feet/mile)
S_3 = 990 (stream slope, feet/mile)
S_4 = 934 (stream slope, feet/mile)
D_d = 2.13 (drainage density, mile/square mile)
W = 0.47 (average width of catchment, miles)
F = 0.20 (form factor, dimensionless)
C = 1.41 (compactness coefficient, dimensionless)
L_m = 1.12 (mean travel distance, dimensionless)
R_1 = 1370 (overland slope, feet/mile)
R_2 = 1376 (overland slope, feet/mile)
R_3 = 1358 (overland slope, feet/mile)
R_4 = 1292 (overland slope, feet/mile)
R_5 = 1250 (overland slope, feet/mile)
R_6 = 0.1565 (overland slope, dimensionless)

Annual Series of Flood Peaks
(2000 Data)

Watershed No.: 1-06-06-104-00 Watershed: Lower Fool Creek at Fraser
Experimental Forest, Colorado

No.	Date	Peak in/hr	No.	Date	Peak in/hr	No.	Date	Peak in/hr
1	7-16-40	0.004	9	6-19-48	0.006	17	7-17-57	0.009
2	6-24-41	0.010	10	9-20-50	0.001	18	7-14-58	0.002
3	7-17-42	0.005	11	7-20-51	0.003	19	7-30-59	0.003
4	6-29-43	0.011	12	7-24-52	0.000	20	7- 1-62	0.014
5	6-28-44	0.006	13	7-10-53	0.005	21	8- 5-63	0.005
6	8- 7-45	0.004	14	7-13-54	0.003	22	8-30-64	0.004
7	7-13-46	0.004	15	7-23-55	0.009			
8	7-15-47	0.011	16	7-30-56	0.004			

Graphical Analysis of Flood Peaks



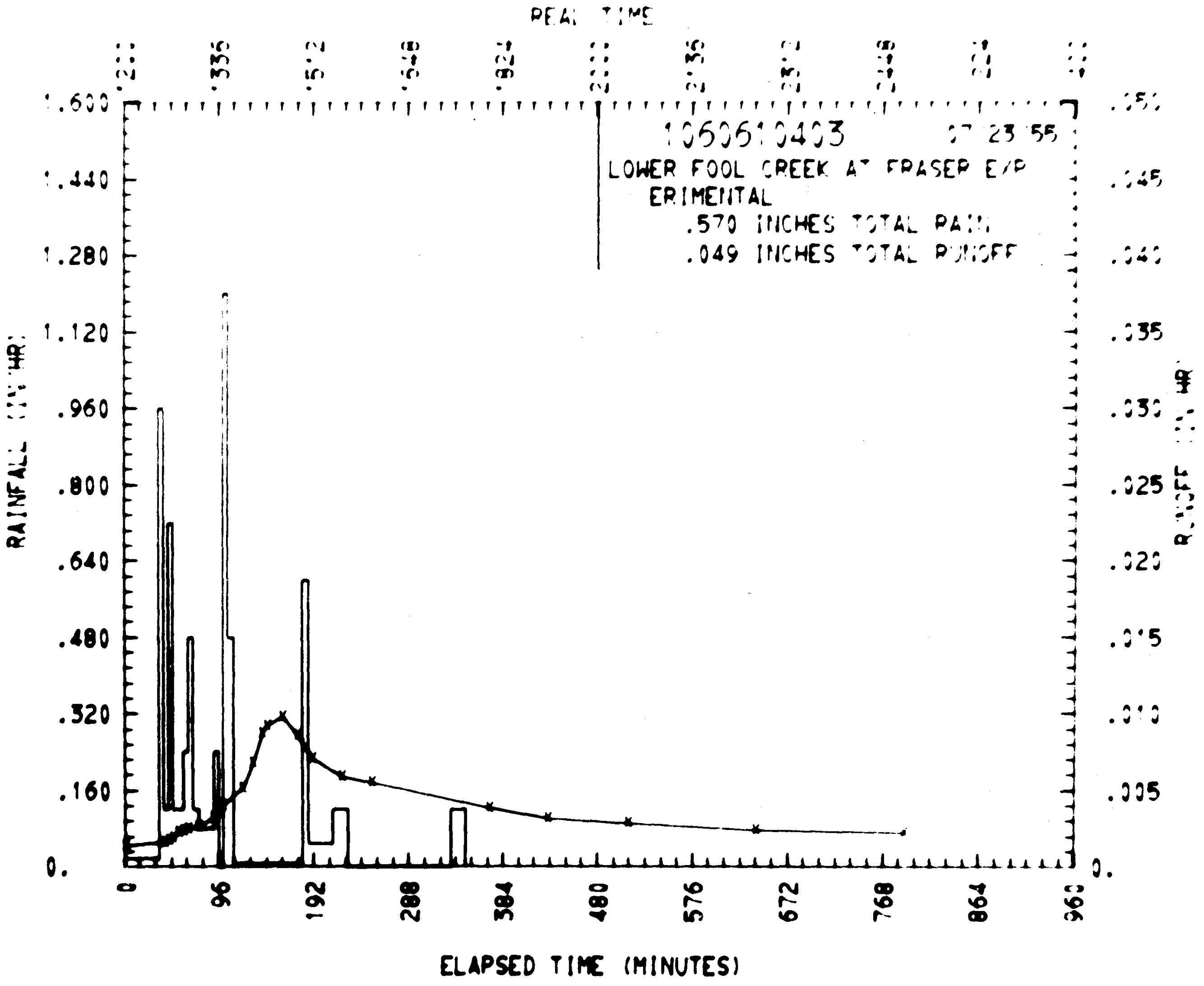
Event No.: 1-06-06-104-03

Date of Storm: 7-15-47

Watershed: Lower Fool Creek at Fraser
Experimental Forest, Colorado

Starting Time of Mass Curve: 12:00

API		Mass Curve		Hydrograph	
(4000 Data)		(5000 Data)		(6000 Data)	
Days before	Rainfall inches	Cum. Time minutes	Cum. Rain inches	Time Incr. minutes	Discharge in/hr
1 @ 24:00	0.00	0	0.00	0	0.0014
3 @ 24:00	0.01	35	0.01	40	0.0016
6 @ 24:00	0.06	40	0.09	5	0.0017
7 @ 24:00	0.02	45	0.10	5	0.0019
8 @ 24:00	0.05	50	0.16	5	0.0023
11 @ 24:00	0.01	55	0.17	5	0.0024
15 @ 24:00	0.01	60	0.18	5	0.0025
16 @ 24:00	0.01	65	0.20	10	0.0027
17 @ 24:00	0.02	70	0.24	15	0.0033
19 @ 24:00	1.03	75	0.25	10	0.0040
		90	0.27	20	0.0051
		95	0.29	10	0.0068
		100	0.29	10	0.0087
		105	0.39	5	0.0092
		110	0.43	15	0.0098
		180	0.44	15	0.0086
		185	0.49	15	0.0071
		210	0.51	30	0.0059
		225	0.54	120	0.0038
		330	0.54	60	0.0032
		345	0.57	80	0.0029
				130	0.0025
				150	0.0023

REAL TIME
.335
1060610403
23 55
LOWER FOOL CREEK AT FRASER EXP
ERIMENTAL
.570 INCHES TOTAL RAIN
.049 INCHES TOTAL RUNOFF
RAINFALL (IN/HR)
1.600
1.440
1.280
1.120
.960
.800
.640
.480
.320
.160
0.
RUNOFF (IN/HR)
.050
.045
.040
.035
.030
.025
.020
.015
.010
.005
0.
0
96
192
288
384
480
576
672
768
864
960
ELAPSED TIME (MINUTES)

Watershed Description
(0000, 1000, and 3000 Data)

Serial Number: 1-09-16-001-00

Watershed: W-3

Gaging Station: Vero Beach

River Basin: Taylor Creek

State: Florida

Country: U.S.A.

Continent: N.A.

Stream Gage: Latitude, X = $27^{o}23'36''$
Longitude, Y = $80^{o}53'42''$
Elevation, Z = 29 feet

Annual Averages:

			Date of Records
Q_a	= 18.69	(average discharge, cfs)	: 1955 to present
q_a	= 1.20	(areal average discharge, cfs/sq.mi.)	: 1955 to present
P_a	= 50.5	(average annual precipitation, in/yr)	: 1955 to present

Name of operating agency and agency number for the watershed: Agricultural Research Service (8.3)

Catchment Characteristics: (3000 Data)

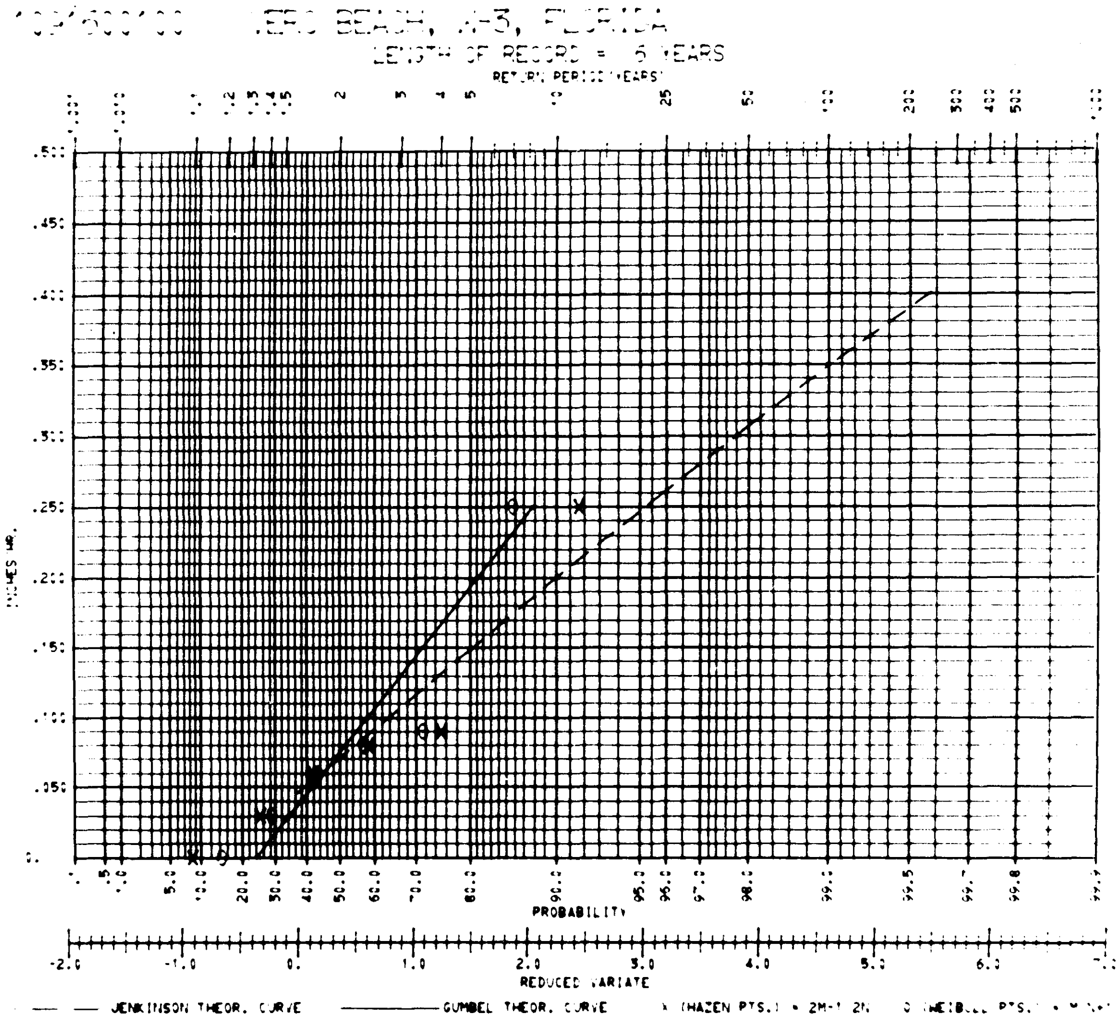
A = 15.60 (area, square miles)
L = 7.20 (length of main stream, miles)
L_s = 20.80 (total length of extended streams, miles
L_c = 3.30 (distance to centroid of area, miles)
L_t = 3.77 (average travel distance, miles)
s_t = 1.73 (standard deviation, miles)
s_d = 0.44 (dimensionless standard deviation, dimensionless)
P = 20.00 (perimeter, miles)
H = 37 (total fall, feet)
S_1 = 5 (stream slope, feet/mile)
S_2 = 6 (stream slope, feet/mile)
S_3 = 4 (stream slope, feet/mile)
S_4 = 6 (stream slope, feet/mile)
D_d = 1.33 (drainage density, mile/square mile)
W = 2.17 (average width of catchment, miles)
F = 0.30 (form factor, dimensionless)
C = 1.42 (compactness coefficient, dimensionless)
L_m = 0.95 (mean travel distance, dimensionless)
R_1 = 17 (overland slope, feet/mile)
R_2 = 17 (overland slope, feet/mile)
R_3 = 16 (overland slope, feet/mile)
R_4 = 10 (overland slope, feet/mile)
R_5 = 7 (overland slope, feet/mile)
R_6 = 0.0011 (overland slope, dimensionless)

Annual Series of Flood Peaks
(2000 Data)

Watershed No.: 1-09-16-001-00 Watershed: Vero Beach, W-3, Florida

No.	Date	Peak in/hr
1	10-15-56	0.25
2	9-17-57	0.06
3	1-24-58	0.03
4	6-18-59	0.09
5	3-18-60	0.08
6	6-12-61	0.00

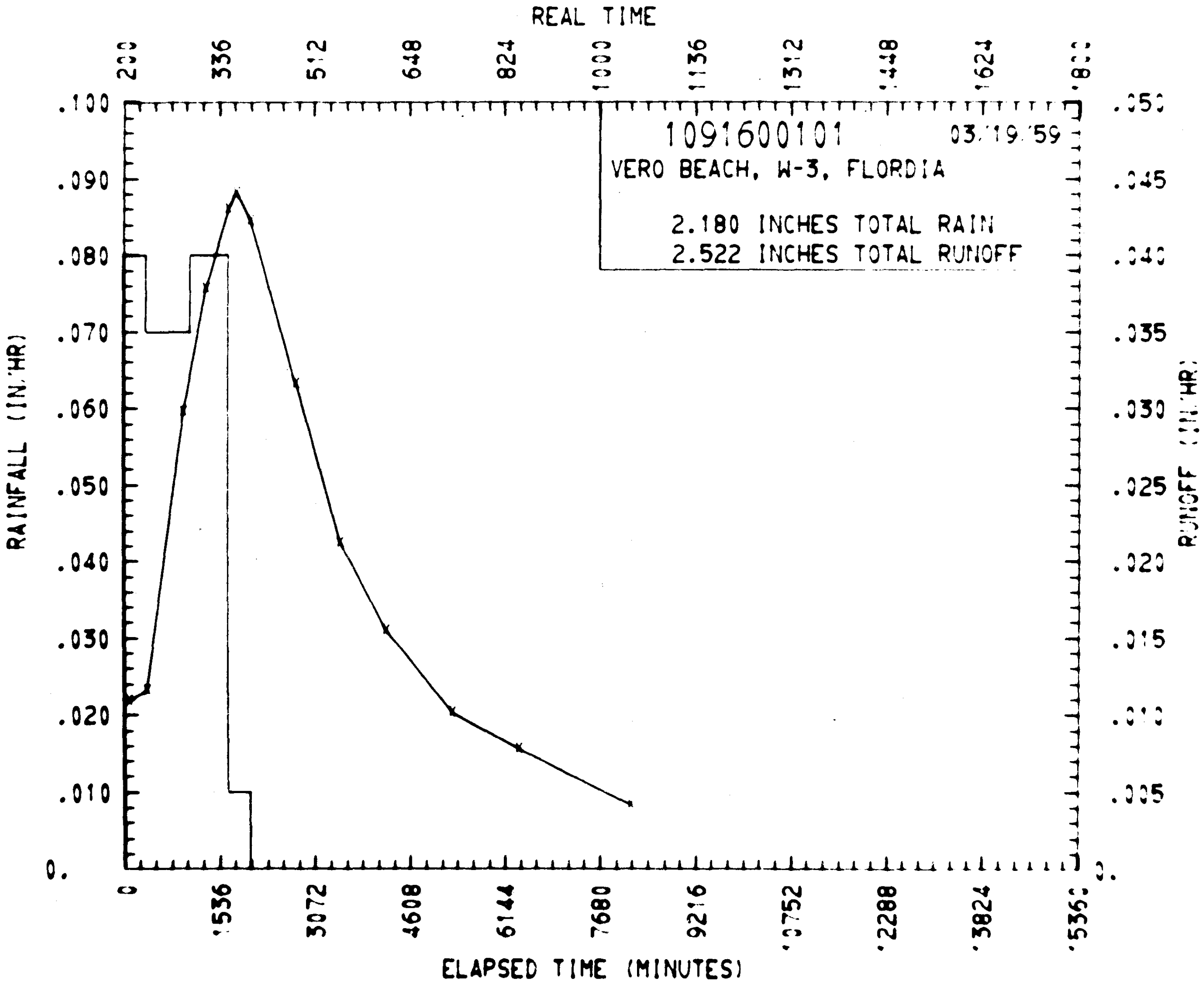
Graphical Analysis of Flood Peaks



Event No.; 1-09-16-001-01 Watershed: Vero Beach, W-3, Florida

Date of Storm: 3-19-59 Starting Time of Mass Curve: 2:00

API (4000 Data)		Mass Curve (5000 Data)		Hydrograph (6000 Data)	
Days before	Rainfall inches	Cum. Time minutes	Cum. Rain inches	Time Incr. minutes	Discharge in/hr
1 @ 00:00	0.00	0	0.00	0	0.0109
1 @ 04:00	0.32	360	0.48	300	0.0116
1 @ 12:00	0.80	1080	1.32	600	0.0298
1 @ 18:00	0.92	1680	2.12	480	0.0378
2 @ 00:00	0.00	2040	2.18	480	0.0430
2 @ 06:00	0.48			120	0.0441
2 @ 22:00	0.48			240	0.0423
2 @ 24:00	0.64			720	0.0316
3 @ 16:00	0.00			720	0.0212
3 @ 20:00	0.68			720	0.0155
3 @ 22:00	0.86			1080	0.0102
3 @ 24:00	0.86			1080	0.0078
7 @ 24:00	0.72			480	0.0042
10 @ 24:00	0.11				
11 @ 24:00	0.16				
13 @ 24:00	0.02				
18 @ 24:00	0.58				
19 @ 24:00	1.10				
20 @ 24:00	0.39				
30 @ 24:00	0.04				


REAL TIME
200
336
512
648
824
1000
1136
1312
1448
1624
1800
1091600101
03/19/59
VERO BEACH, W-3, FLORDIA
2.180 INCHES TOTAL RAIN
2.522 INCHES TOTAL RUNOFF
RAINFALL (IN/HR)
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
0.
RUNOFF (IN/HR)
.050
.045
.040
.035
.030
.025
.020
.015
.010
.005
0.
0
1536
3072
4608
6144
7680
9216
10752
12288
13824
15360
ELAPSED TIME (MINUTES)

Watershed Description
(0000, 1000, and 3000 Data)

Serial Number: 1-42-15-002-00

Watershed: Chestuee Creek

Gaging Station: At Zion Hill

River Basin: Tennessee Valley

State: Tennessee

Country: U.S.A.

Continent: N.A.

Stream Gage: Latitude, $X = 35°24'$
Longitude, $Y = 84°24'$
Elevation, $Z = 779$ feet

Annual Averages:

			Date of Records
Q_a	= 59.20	(average discharge, cfs)	: 1944 to 1961
q_a	= 1.57	(areal average discharge, cfs/sq.mi.)	: 1944 to 1961
P_a	= 51.6	(average annual precipitation, in/yr)	: 1944 to 1961

Name of operating agency and agency number for the watershed: Tennessee Valley Authority

Catchment Characteristics: (3000 Data)

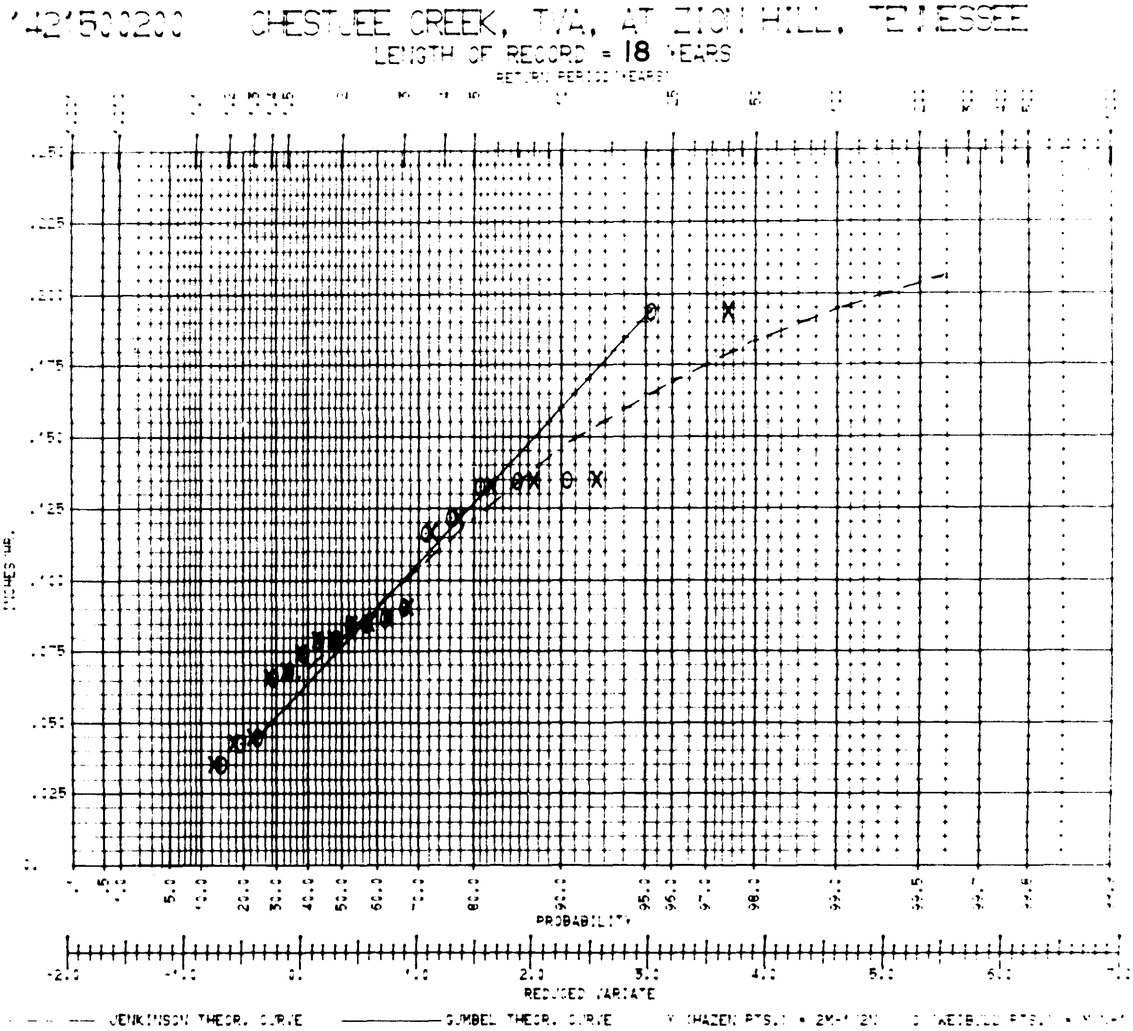
$A = 37.74$ (area, square miles)
$L = 15.99$ (length of main stream, miles)
$L_s = 102.96$ (total length of extended streams, miles)
$L_c = 8.31$ (distance to centroid of area, miles)
$L_t = 9.35$ (average travel distance, miles)
$s_t = 3.77$ (standard deviation, miles)
$s_d = 0.61$ (dimensionless standard deviation, dimensionless)
$P = 40.18$ (perimeter, miles)
$H = 221$ (total fall, feet)
$s_1 = 14$ (stream slope, feet/mile)
$s_2 = 9$ (stream slope, feet/mile)
$s_3 = 9$ (stream slope, feet/mile)
$s_4 = 9$ (stream slope, feet/mile)
$D_d = 2.73$ (drainage density, mile/square mile)
$W = 2.36$ (average width of catchment, miles)
$F = 0.15$ (form factor, dimensionless)
$C = 1.83$ (compactness coefficient, dimensionless)
$L_m = 1.52$ (mean travel distance, dimensionless)
$R_1 = 294$ (overland slope, feet/mile)
$R_2 = 265$ (overland slope, feet/mile)
$R_3 = 274$ (overland slope, feet/mile)
$R_4 = 520$ (overland slope, feet/mile)
$R_5 = 400$ (overland slope, feet/mile)
$R_6 = 0.0031$ (overland slope, dimensionless)

Annual Series of Flood Peaks
(2000 Data)

Watershed No.: 1-42-15-002-00 Watershed: Chestuee Creek at Zion Hill, Tennessee

No.	Date	Peak in/hr	No.	Date	Peak in/hr	No.	Date	Peak in/hr
1	2-18-44	0.07	7	3-13-50	0.08	13	4-16-56	0.08
2	2-17-45	0.04	8	3-29-51	0.13	14	1-31-57	0.09
3	1- 7-46	0.19	9	1-10-52	0.07	15	11-18-57	0.12
4	1-20-47	0.14	10	2-21-53	0.04	16	3-27-59	0.13
5	2-12-48	0.08	11	1-21-54	0.09	17	11-28-59	0.04
6	11-28-49	0.12	12	4- 6-55	0.07	18	2-23-61	0.08

Graphical Analysis of Flood Peaks



Event No.: 1-42-15-002-03

Watershed: Chestuee Creek at Zion Hill,
Tennessee
Starting Time of Mass Curve: 9:00

API (4000 Data)		Mass Curve (5000 Data)		Hydrograph (6000 Data)	
Days before	Rainfall inches	Cum. Time minutes	Cum. Rain inches	Time Incr. minutes	Discharge in/hr
1 @ 24:00	0.00	0	0	0	0.0000
5 @ 24:00	0.10	60	0.08	140	0.0016
6 @ 24:00	0.01	180	0.13	130	0.0064
11 @ 24:00	0.01	220	0.21	90	0.0116
12 @ 24:00	0.24	240	0.23	120	0.0194
15 @ 24:00	0.47	300	0.39	60	0.0282
18 @ 24:00	0.05	450	0.54	30	0.0362
21 @ 24:00	0.51	480	0.66	30	0.0582
23 @ 24:00	0.15	500	0.66	60	0.1002
25 @ 24:00	0.08	540	0.78	30	0.1196
26 @ 24:00	0.27	600	0.79	30	0.1268
		740	0.80	30	0.1294
		800	0.87	30	0.1272
		810	0.96	60	0.1142
		830	1.06	200	0.0482
		860	1.47	40	0.0396
		880	1.60	60	0.0316
		890	1.71	120	0.0212
		900	1.98	60	0.0176
		920	2.15	180	0.0112
		950	2.19	240	0.0072
		1000	2.52	240	0.0052
		1040	2.96	1080	0.0031
		1600	2.98	1080	0.0028
				1080	0.0016

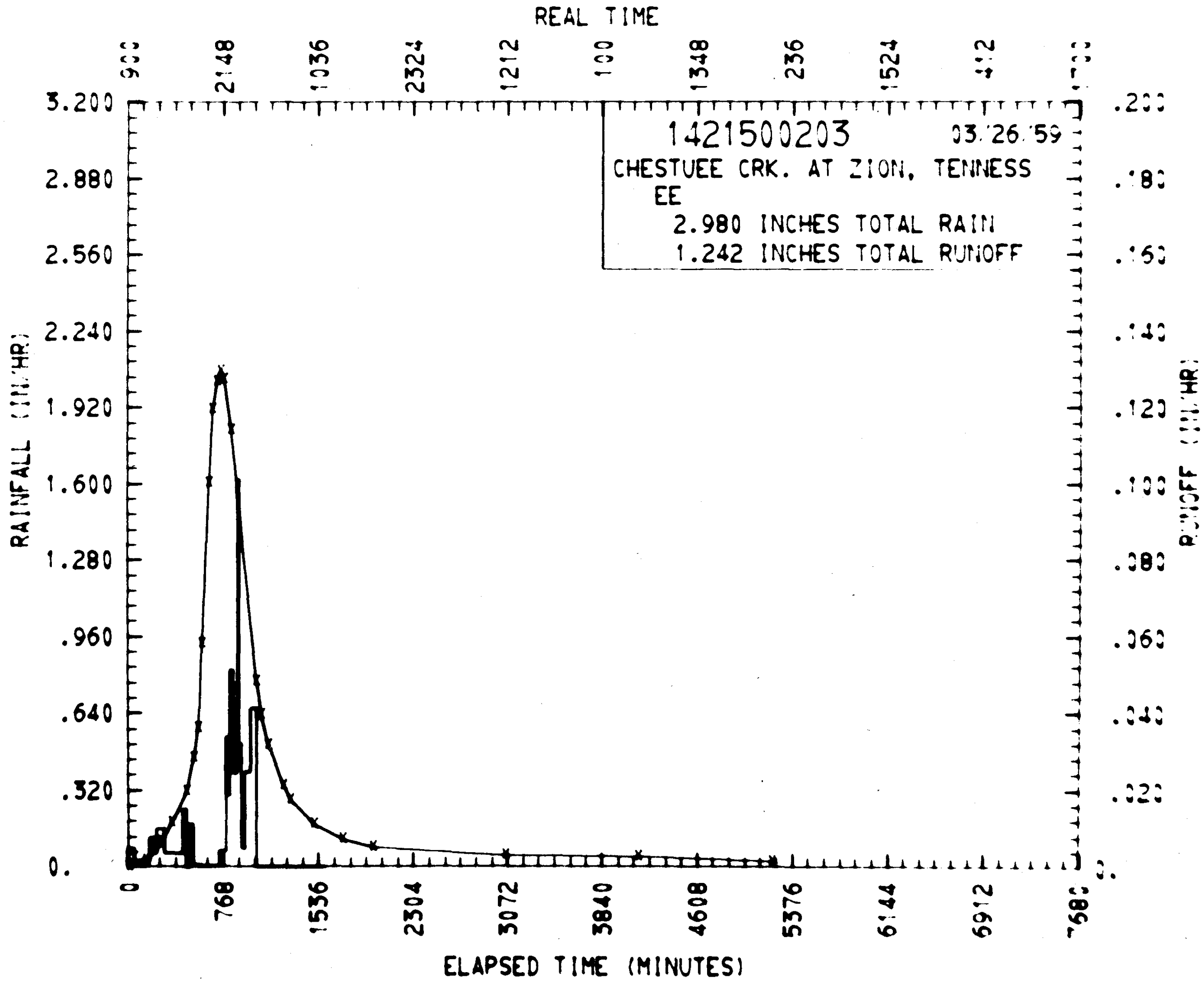

REAL TIME
900
2148
1036
2324
1212
100
1348
236
1524
412
1700
1421500203
03/26/59
CHESTUEE CRK. AT ZION, TENNESSEE
2.980 INCHES TOTAL RAIN
1.242 INCHES TOTAL RUNOFF
RAINFALL (IN/HR)
3.200
2.880
2.560
2.240
1.920
1.600
1.280
.960
.640
.320
0.
RUNOFF (IN/HR)
.200
.180
.160
.140
.120
.100
.080
.060
.040
.020
0.
0
768
1536
2304
3072
3840
4608
5376
6144
6912
7680
ELAPSED TIME (MINUTES)

Table 5.1. Small Watershed Program Summary of Data Processing

Summary of Watershed (W/S) Data					Summary of Storm Events			
Date of Entry	No. of W/S Not Completed	No. of W/S Completed Not on Tape	No. of W/S Now on Tape	Total No. W/S	No. of Events Not Completed	No. of Events Completed Not on Tape	No. of Events Now on Tape	Total No. Events
10/ 1/64	34	37	0	71	100	37	0	137
10/ 1/65	1000	100	0	1100	100	300	0	400
9/16/66	1020	50	115	1185	146	0	426	572
12/22/66	1020	77	115	1212	246	125	426	797
1/3/67	1027	77	115	1219	357	125	426	898
8/1/67	1072	0	195	1267	282	0	616	898

Table 5.2. Watershed Data Inventory

No.	Station No.	Name and Location	Area sq. mi.	2000 data	3000 data	4000 data	5000 data	6000 data
1	1-03-06-001	Safford, W-I, Arizona	0.81	C	C	5	10	10
2	1-03-06-002	Safford, W-II, Arizona	1.07	C	C	7	12	12
3	1-03-06-003	Tombstone, W-3, Arizona	3.47	C	C	4	7	7
4	1-03-06-004	Tombstone, W-4, Arizona	0.88	C	C	6	10	10
5	1-03-06-005	Tombstone, W-5, Arizona	8.61	C	C	2	9	9
6	1-03-06-006	Safford, W-5, Arizona	1.13	C	C	6	10	10
7	1-03-06-015	Bear Creek near Tucson, Arizona	16.30	I	C	0	0	0
8	1-03-06-017	Sabino Creek near Tucson, Arizona	35.50	I	C	0	0	0
9	1-03-06-018	Safford, W-4, Arizona	1.19	I	C	0	6	6
10	1-03-06-019	Tombstone, W-2, Walnut Creek, Ariz.	43.19	I	C	0	6	6
11	1-05-01-001	Lopez Creek near Smith River, Calif.	0.93	C	C	6	10	10
12	1-05-02-001	Sebastopol, W-1, California	0.13	C	C	0	0	0
13	1-05-02-002	Green Valley Creek near Corralitos, California	7.05	C	C	5	5	5
14	1-05-02-003	East Fork Russian River Tributary nr. Potter Valley, Calif.	0.15	C	C	0	0	0
15	1-05-02-004	Honda Barranca nr. Somis, California	2.57	C	C	0	0	0
16	1-05-02-005	Ti Creek near Somesbar, Calif.	9.46	C	C	6	6	6
17	1-05-02-006	Dunn Creek nr. Rockport, Calif.	1.88	C	C	5	5	5
18	1-05-02-007	Cow Creek near San Ardo, California	4.80	C	C	4	4	4
19	1-05-02-008	Rat Creek near Lucia, California	0.82	C	C	1	1	1

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq. mi.	2000 data	3000 data	4000 data	5000 data	6000 data
20	1-05-02-009	North Fork Matilija Creek at Matilija Hot Springs, Calif.	15.67	I	C	0	0	0
21	1-05-02-011	Coyote Creek near Oak View, Calif.	13.20	I	C	0	0	0
22	1-05-02-014	Cachuma Creek near Santa Ynez, Calif.	23.80	I	C	0	0	0
23	1-05-02-015	Canada Honoa Creek near Lompoc, Calif.	3.09	I	C	0	0	0
24	1-05-02-016	Jacoby Creek near Freshwater, Calif.	6.07	I	C	0	0	0
25	1-05-02-018	Purisima Creek near Half Moon Bay, California	4.83	I	C	0	0	0
26	1-05-02-019	Miller Creek near Live Oak Springs, California	0.97	I	C	0	0	0
27	1-05-02-022	Short Creek near Covelo, California	15.20	I	C	0	0	0
28	1-05-02-023	West Branch Soquel Creek near Soquel, California	12.10	I	C	0	0	0
29	1-05-02-024	Zayante Creek at Zayante, California	11.10	I	C	0	0	0
30	1-05-02-055	Wolfskill, W-01, at San Dimas Exp. Forest, California	2.39	C	C	0	0	0
31	1-05-02-056	Fern, W-02, at San Dimas Exp. Forest, California	2.14	C	C	0	0	0
32	1-05-02-057	Upper East Fork, W-03, at San Dimas Exp. Forest, Calif.	2.14	C	C	0	0	0
33	1-05-02-058	East Fork, W-04 at San Dimas Exp. Forest, California	5.48	C	C	0	0	0
34	1-05-02-059	North Fork, W-05 at San Dimas Exp. Forest, California	4.23	I	C	0	0	0

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
35	1-05-02-062	Bell, W-08, at San Dimas Exp. Forest, California	1.36	C	C	0	0	0
36	1-05-02-063	Volfe, W-09, at San Dimas Exp. Forest, California	1.16	C	C	0	0	0
37	1-05-02-064	Monroe, W-10, at San Dimas Exp. Forest, California	1.37	C	C	0	0	0
38	1-05-02-067	Cholame Creek Tributary nr. Cholame, California	9.26	I	C	0	0	0
39	1-05-03-001	Highland Creek nr. Highland Creek Dam, California	11.90	C	C	7	9	9
40	1-05-03-005	Capell Creek Tributary nr. Wooden Valley, California	0.87	C	C	4	4	4
41	1-05-03-007	Shingle Creek nr. Shingletown, Calif.	3.25	C	C	2	6	6
42	1-05-03-008	Little Panoche Creek Tributary No. 1 nr. Panoche, California	0.33	C	C	0	0	0
43	1-05-03-009	Cascade Creek nr. Pinecrest, California	4.97	C	C	3	3	3
44	1-05-03-010	Bear Creek Tributary nr. Wilber Springs, California	4.50	C	C	5	5	5
45	1-05-03-016	Packsaddle Canyon Creek nr. Fairview, California	4.05	I	C	0	0	0
46	1-05-03-018	Redwood Creek at Redwood City, Calif.	9.81	I	C	0	0	0
47	1-05-05-001	Beacon Creek at Helendale, Calif.	0.72	C	C	0	0	0
48	1-05-05-002	Buckhorn Creek nr. Valyermo, California	0.48	C	C	2	2	2
49	1-05-05-006	Alder Creek near Truckee, California	7.36	I	C	0	0	0

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq. mi.	2000 data	3000 data	4000 data	5000 data	6000 data
50	1-05-05-027	Wildrose Creek nr. Wildrose Station, California	23.70	I	C	0	0	0
51	1-05-05-028	China Spring Creek nr. Mountain Pass, California	0.94	I	C	0	0	0
52	1-05-06-007	Cottonwood Wash nr. Cottonwood Spring, California	0.71	I	C	0	0	0
53	1-06-06-002	Meadow Creek near Tabernash, Colorado	7.73	C	C	0	0	0
54	1-06-06-104	Lower Fool Creek at Fraser Exp. Forest, Colorado	1.12	C	C	3	3	3
55	1-06-06-105	East St. Louis Creek at Fraser Ex. Forest Colorado	3.10	C	C	5	5	5
56	1-06-06-135	Badger Wash 2-A nr. Mack Mesa County, Colorado	0.17	I	C	0	0	0
57	1-06-06-136	Badger Wash 2-B nr. Mack Mesa Co., Colorado	0.16	I	C	0	0	0
58	1-06-08-004	Lower Missouri Gulch Manitou Exp. Forest, Colorado	7.19	C	C	0	3	3
59	1-09-16-001	Vero Beach, W-3, (Taylor Creek nr. Basinger), Florida	15.60	C	C	4	4	4
60	1-12-04-001	Emmett, W-2, Idaho	0.11	C	C	3	3	3
61	1-12-04-003	Moscow, W-1, Idaho	0.23	C	C	2	2	2
62	1-12-04-004	Moscow, W-2, Idaho	0.28	C	C	3	3	3
63	1-12-04-016	Clear Creek near Naf, Idaho	20.20	C	C	0	0	0
64	1-12-04-021	Robie Creek near Arrowrock, Idaho	15.80	C	C	0	0	0
65	1-12-04-024	Macks Creek near Boise, Idaho	12.49	I	C	0	0	0

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
66	1-12-04-025	Salmon Creek near Boise, Idaho	13.62	I	C	0	0	0
67	1-13-11-003	Monticello, IA, Illinois	0.13	C	C	5	5	5
68	1-13-14-001	Lake Glendale Inlet nr. Dixon Springs, Ill.	1.04	I	C	0	0	0
69	1-15-11-001	Ralston Creek at Iowa City, Iowa	3.01	C	C	5	5	5
70	1-18-08-001	Little Sandy Creek at Kisatchie, La.	21.46	I	C	0	0	0
71	1-20-18-001	Northwest Branch Anacostia River nr. Colesville, Maryland	21.14	I	C	0	0	0
72	1-24-12-001	Oxford, W-4, Mississippi	3.13	C	C	4	4	4
73	1-24-12-002	Oxford, W-5, Mississippi	1.77	C	C	4	4	4
74	1-24-12-003	Oxford, W-10, Mississippi	8.64	C	C	5	5	5
75	1-24-12-004	Oxford, W-12, Mississippi	35.63	C	C	5	5	5
76	1-24-12-005	Oxford, W-19, Mississippi	0.38	C	C	5	5	5
77	1-24-12-006	Oxford, W-24, Mississippi	0.80	C	C	3	3	3
78	1-24-12-007	Oxford, W-28, Mississippi	1.69	C	C	5	5	5
79	1-24-12-009	Oxford, W-32, Mississippi	31.26	C	C	5	5	5
80	1-24-12-010	Oxford, W-35, Mississippi	11.57	C	C	5	5	5
81	1-24-12-019	Oxford, W-35A, Mississippi	1.70	C	C	1	1	1
82	1-24-12-020	Oxford, W-17A, Mississippi	5.21	C	C	1	1	1
83	1-24-12-021	Oxford, W-17, Mississippi	54.36	I	C	0	0	0
84	1-27-07-001	Hastings, W-3, Nebraska	0.74	C	C	6	6	6

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
85	1-27-07-002	Hastings, W-5, Nebraska	0.64	C	C	5	5	5
86	1-27-07-003	Hastings, W-8, Nebraska	3.26	C	C	6	6	6
87	1-27-07-004	Hastings, W-11, Nebraska	5.45	C	C	2	2	2
88	1-31-06-001	Mexican Springs, W-2, New Mexico	0.95	C	C	0	4	4
89	1-31-06-002	Mexican Springs, W-6, New Mexico	8.76	C	C	0	2	2
90	1-31-06-003	Mexican Springs, W-8, New Mexico	33.00	C	C	0	3	3
91	1-31-09-001	Albuquerque, W-1, New Mexico	0.15	C	C	4	14	14
92	1-31-09-002	Albuquerque, W-3 (1939-56), New Mexico	0.29	C	C	1	1	1
93	1-31-09-003	Albuquerque, W-3 (after 1956), New Mexico	0.26	C	C	3	6	6
94	1-31-09-004	Santa Fe, W-1, New Mexico	0.22	C	C	4	4	4
95	1-31-09-005	Three Rivers nr. Three Rivers, New Mexico	6.81	I	C	0	0	0
96	1-31-09-006	Indian Creek near Three Rivers, New Mexico	6.76	I	C	0	1	1
97	1-31-09-033	Santa Fe River nr. Santa Fe, New Mex.	18.20	C	C	0	0	0
98	1-31-09-041	Cornfield Wash No. 6A nr. Cuba, New Mexico	2.18	I	C	0	0	0
99	1-31-09-042	Cornfield Wash No. 7A nr. Cuba, New Mexico	0.51	I	C	0	0	0
100	1-31-09-043	Cornfield Wash No. 3 nr. Cuba, New Mexico	0.25	I	C	0	0	0
101	1-31-09-044	Cornfield Wash No. 4 nr. Cuba, New Mex.	1.18	I	C	0	0	0

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
102	1-31-09-045	Cornfield Wash No. 5 nr. Cuba, New Mexico	1.04	I	C	0	0	0
103	1-31-09-046	Cornfield Wash No. 6 nr. Cuba, New Mexico	2.77	I	C	0	0	0
104	1-31-09-047	Cornfield Wash No. 7 nr. Cuba, New Mexico	1.07	I	C	0	0	0
105	1-31-09-048	Cornfield Wash No. 10 nr. Cuba, New Mexico	3.05	I	C	0	0	0
106	1-31-09-051	Cornfield Wash No. 30 nr. Cuba, New Mexico	0.33	I	C	0	0	0
107	1-31-09-052	Cornfield Wash No. 15 nr. Cuba, New Mexico	1.04	C	C	0	0	0
108	1-31-09-053	Cornfield Wash No. 16 nr. Cuba, New Mexico	0.56	I	C	0	0	0
109	1-31-09-054	Cornfield Wash No. 17 nr. Cuba, New Mexico	0.59	I	C	0	0	0
110	1-31-09-055	Cornfield Wash No. 10A nr. Cuba, New Mexico	2.01	I	C	0	0	0
111	1-33-15-001	Parker Branch, TVA, nr. Leicester, North Carolina	1.50	I	C	0	0	0
112	1-33-15-010	Coweeta Exp. Forest, W-8, North Carolina	2.94	I	C	0	0	0
113	1-33-15-011	Coweeta Exp. Forest, W-14, North Carolina	0.24	I	C	0	0	0
114	1-33-15-012	Coweeta Exp. Forest, W-28, North Carolina	0.55	I	C	0	0	0
115	1-33-15-013	Coweeta, W-36, North Carolina	0.18	I	C	0	0	0
116	1-35-14-001	Hamilton, W-1, Ohio	0.17	C	C	3	3	3

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
117	1-35-14-002	Coshocton, 5, Ohio	0.55	C	C	5	5	5
118	1-35-14-003	Coshocton, 10, Ohio	0.19	C	C	3	3	3
119	1-35-14-004	Coshocton, 92, Ohio	1.44	C	C	4	4	4
120	1-35-14-005	Coshocton, 94, Ohio	2.38	C	C	5	3	3
121	1-35-14-006	Coshocton, 95, Ohio	4.30	C	C	5	5	5
122	1-35-14-007	Coshocton, 97, Ohio	7.16	C	C	7	7	7
123	1-35-14-008	Coshocton, 183, Ohio	0.12	C	C	8	8	8
124	1-35-14-009	Coshocton, 196, Ohio	0.47	C	C	9	9	9
125	1-35-14-010	Coshocton, 994, Ohio	2.73	C	C	4	4	4
126	1-35-14-032	Coshocton, 177, Ohio	0.12	C	C	6	6	6
127	1-36-08-001	Stillwater, W-3, Oklahoma	0.14	C	C	8	8	8
128	1-36-08-002	Stillwater, W-4, Oklahoma	0.32	C	C	6	6	6
129	1-36-08-003	Guthrie, W-6, Oklahoma	0.15	C	C	4	4	4
130	1-36-08-008	Sandstone Creek above structure No. 16A nr. Cheyenne, Okla.	8.78	I	C	6	6	6
131	1-36-08-009	Sandstone Creek above Structure No. 16, near Cheyenne, Okla.	10.52	I	C	10	10	10
132	1-36-08-010	Sandstone Creek above Structure No. 14 near Cheyenne, Okla.	1.02	I	C	4	1	1
133	1-36-08-011	Sandstone Creek above Structure No. 17 near Cheyenne, Okla.	11.13	I	C	10	10	10
134	1-36-08-012	Sandstone Creek above Structure No. 10A near Elk City, Okla.	2.87	I	C	8	8	8
135	1-36-08-013	Sandstone Creek above Structure No. 6 near Elk City, Oklahoma	6.46	I	C	3	3	3

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
136	1-36-08-014	Sandstone Creek above Structure No. 5 near Elk City, Oklahoma	3.89	I	C	3	3	3
137	1-36-08-015	Sandstone Creek above Structure No. 3 near Elk City, Oklahoma	0.62	I	C	6	6	6
138	1-36-08-016	Sandstone Creek above Structure No. 9 near Elk City, Oklahoma	3.50	I	C	6	6	6
139	1-36-08-017	Sandstone Creek above Structure No. 22 near Cheyenne, Okla.	2.25	I	C	3	0	0
140	1-36-08-018	Sandstone Creek above Structure No. 1 near Cheyenne, Okla.	5.33	I	C	2	0	0
141	1-38-18-001	Evitts Creek near Centerville, Pa.	30.63	I	C	3	3	3
142	1-38-18-017	Shaver Creek at University Park, Pennsylvania	3.75	I	C	0	0	0
143	1-41-07-009	Newell, W-12, South Dakota	0.14	I	C	0	0	0
144	1-42-15-001	White Hollow, TVA, near Sharps Chapel, Tennessee	2.76	I	C	0	0	0
145	1-42-15-002	Chestuee Creek, TVA, at Zion Hill, Tenn.	37.80	I	C	0	0	0
146	1-42-15-003	Chestuee Creek, TVA, above Englewood, Tennessee	14.84	I	C	0	0	0
147	1-42-15-004	Little Chestuee Creek, TVA, below Wilson Sta., Tenn.	8.19	I	C	0	0	0
148	1-42-15-005	Cane Creek, TVA, near Shady Hill, Tennessee	16.70	I	C	0	0	0

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
149	1-42-15-006	Harmon Creek, TVA, near Lexington, Tennessee	6.87	I	C	0	0	0
150	1-42-15-012	Turtletown Creek at Turtletown, Tenn.	26.90	I	C	0	0	0
151	1-42-15-017	North Fork Citico Creek nr. Tellico Plains, Tennessee	7.07	I	C	0	1	1
152	1-43-08-001	Vega, W-2, Texas	0.15	C	C	5	5	5
153	1-43-09-001	Riesel, C, (Waco), Texas	0.90	C	C	6	6	6
154	1-43-09-002	Riesel, D, (Waco), Texas	1.74	I	C	8	8	8
155	1-43-09-003	Riesel, G, (Waco), Texas	6.84	C	C	2	2	2
156	1-43-09-004	Riesel, J, (Waco), Texas	9.16	C	C	4	4	6
157	1-43-09-005	Riesel, W-1, (Waco), Texas	0.28	I	C	5	5	5
158	1-43-09-006	Riesel, W-2, (Waco), Texas	0.20	C	C	5	5	5
159	1-43-09-007	Riesel, Y, (Waco), Texas	0.48	C	C	6	6	6
160	1-43-09-008	Riesel, Y-2, (Waco), Texas	0.21	C	C	6	6	6
161	1-43-09-009	Riesel, Y-4, (Waco), Texas	0.12	I	C	6	6	6
162	1-43-09-010	Deep Creek Sub-watershed No. 8 nr. Mercury, Texas	4.32	C	C	0	4	4
163	1-43-09-023	Calaveras Crk Sub-watershed No. L nr. Elmendorf, Texas	7.01	C	C	5	4	4
164	1-43-09-024	Escondido Crk Sub-watershed No. 1 nr. Kenedy, Texas	3.39	C	C	0	8	8
165	1-43-09-025	Escondido Crk Sub-watershed No. 11 (Dry Escondido Crk) nr. Kenedy, Texas	8.43	C	C	7	7	7

Table 5.2 Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq.mi.	2000 data	3000 data	4000 data	5000 data	6000 data
166	1-43-09-027	Honey Creek Subwatershed No. 11 nr. McKinney, Tex.	2.14	I	C	12	7	7
167	1-43-09-028	Honey Creek Subwatershed No. 12 nr. McKinney, Tex.	1.26	I	C	15	8	8
168	1-43-09-030	Mukewater Subwatershed No. 9 nr. Trickham, Tex.	4.02	I	C	14	5	5
169	1-43-09-031	Dry Prong Deep Crk nr. Mercury, Texas	8.31	C	C	0	0	0
170	1-44-05-002	Dove Creek near Park Valley, Utah	35.00	C	C	0	0	0
171	1-44-05-010	Holmes Creek near Kaysville, Utah	2.49	C	C	0	0	0
172	1-44-05-011	Ricks Creek above Diversions near Centerville, Utah	2.35	C	C	0	0	0
173	1-44-05-023	Vernon Creek nr. Vernon, Utah	25.00	C	C	0	0	0
174	1-44-05-044	Stone Creek near Bountiful, Utah	4.48	C	C	0	0	0
175	1-44-05-045	Mill Creek at Muller Park near Bountiful, Utah	8.79	C	C	0	0	0
176	1-44-06-023	Kanarra Creek at Kanarraville, Utah	10.00	C	C	0	2	2
177	1-45-17-001	North Danville, W-1, Vermont	16.58	C	C	2	2	2
178	1-45-17-002	North Danville, W-2, Vermont	0.23	C	C	2	2	2
179	1-46-18-001	Bell Creek, W-1, Staunton (at Saint Pauls Chapel), Virginia	0.61	C	C	1	1	1
180	1-46-18-002	Chub Run, W-1, Blacksburg, Virginia	3.16	C	C	1	1	1
181	1-46-18-003	Chestnut Branch, W-1, Blacksburg, Virginia	1.65	C	C	2	2	2

Table 5.2. Watershed Data Inventory - Cont'd.

No.	Station No.	Name and Location	Area sq. mi.	2000 data	3000 data	4000 data	5000 data	6000 data
182	1-46-18-004	Brush Creek, W-1, Blacksburg, Virginia	1.40	C	C	2	2	2
183	1-46-18-005	Crab Creek, W-1, Blacksburg, Virginia	1.23	C	C	2	2	2
184	1-46-18-006	Fosters Creek, W-1, Blacksburg, Virginia	0.61	C	C	2	2	2
185	1-46-18-007	Little Winns Creek, W-1, Blacksburg, Virginia	2.30	C	C	4	4	4
186	1-46-18-008	Pony Mountain Branch, W-1, Blacksburg, Virginia	0.30	C	C	4	4	4
187	1-46-18-009	Powells Creek, W-1, Blacksburg, Virginia	0.28	C	C	4	4	4
188	1-46-18-010	Rocky Run Branch, W-1, Blacksburg, Va.	0.87	C	C	4	4	4
189	1-46-18-011	Thorne Creek, W-1, Blacksburg, Virginia	4.77	C	C	1	1	1
190	1-47-04-001	Pullman, G.S.I., Washington	0.11	C	C	3	3	3
191	1-49-11-001	Fennimore, W-1, Wisconsin	0.52	C	C	5	5	5
192	1-49-11-002	Fennimore, W-4, Wisconsin	0.27	C	C	6	6	6
193	1-49-11-003	Colby, W-1, Wisconsin	0.54	C	C	3	3	3
194	1-50-06-021	New Fork River nr. Cora, Wyoming	36.20	C	C	0	0	0
195	1-50-07-001	Douglas Creek above Keystone, Wyoming	22.10	C	C	0	0	0

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