THE BEHAVIOR OF SMALL WATER IMPOUNDMENTS IN SOUTHERN ARIZONA

----A coupled stochastic and deterministic model ----

by

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DEDICATION

両親へ感謝をこめて

To my parents with appreciation

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ABSTRACT

A computer simulation model is presented for evaluating the performance of small water impoundments. A model has been constructed based on the previous work done by Almestad (1983). The model was modified in this study for use in the desert scrub vegetation cover type of southeastern Arizona at Tombstone, Arizona.

Stochastic model of precipitation was used to generate a synthetic time stream of precipitation. A deterministic runoff model was used to determine runoff volume. The SCS method was used for the purpose. Temperature model was used to simulate daily maximum temperature that was used to determine volume of water that evaporates from a pond. A computer program was developed using the temperature, runoff and precipitation model to synthesize the water regimes of ponds for a range of pond geometries, pond sizes, watershed sizes and seepage rates.

Output of the program consists of statistical information for annual spillage, annual retention, and the number of days a pond is dry on an annual and monthly basis.

INTRODUCTION

This study was the second phase of a project begun in 1982 in cooperation with the Arizona Department of Water Resources, the Salt River Project and the U.S. Forest Service. The project was initiated because of the need for information on the effects of small water impoundments on the distribution of the water resources of the state. With an ever increasing demand being made on these limited resources, their equitable apportionment among upstream and downstream users becomes increasingly important.

Most of the water impoundments in the state are for livestock watering, and consequently are small. The exact number of small water impoundments is not known, but there are perhaps thousands of them, and numerous requests have been made to construct many more on public land. Guidelines are needed not only for determining the effects of the impoundments on the distribution of surface water, but also to assist in the adjudication of water rights and to help to design more efficient systems for conserving the water resource in the state.

The project began with a study of water impoundments in the pinyon-juniper cover type on the Beaver Creek Watersheds. Almestad (1983) made the initial analysis in the first phase of the project and developed a system of models, using stochastic simulation that gave the effects of water impoundments on water yield for a large number of combinations of watershed and pond sizes. The results of the analyses were encouraging, but the method has not been tested in other portions of the state.

This study was an extension of the project with the purpose of testing the method under the conditions found in southeast Arizona.

OBJECTIVES

The objectives of the study were:

1. To test and modify where necessary a methodology to assess stock pond performance in the desert vegetation zone in southern Arizona using a coupled stochastic and deterministic computer model developed in the first phase of the project.
2. To produce from the model output tables and nomographs that can be used to assist in the adjudication of surface water rights.

METHOD AND ANALYSIS

The study was made with data collected by the Agricultural Research Service from the Walnut Gulch Experimental Watersheds, located near Tombstone, Arizona. Experimental watershed number 4, with an area of 560 acres, was chosen as the test area. Runoff data collected during the period of 1954 through 1975 were used in the analysis. However, data for 1959 and 1960 were missing from the record.

A five year record of air temperature (1978 to 1983) from Tombstone was analyzed to determine the parameters needed for a submodel of air temperature used in the modeling. Transmission losses in the channels were not considered in the study.

The approach taken in this study required the development of three submodels linked together in a final program. Two of the submodels provided stochastic input of precipitation and temperature. The precipitation submodel provided a stochastic input to a deterministic submodel of runoff, and to determine evaporation from free water surfaces. The three submodels were linked into a final program, PONDY, to yield probabilistic information on the behavior of small water impoundments.

Precipitation Submodel

This submodel provided a daily series of precipitation events for each year of a 200 year simulation. Previous work of Almestad (1983), Duckstein, Fogel and Kisiel (1972);

Duckstein, Fogel and Davis (1975), Hekman (1977) and Fischer (1976) was adapted to conditions found in the Walnut Gulch area. The submodel required six computer programs and manual calculations as shown in Figure 1.

Initial Data Analysis

The initial data were analyzed for daily precipitation amounts and for the interarrival time between precipitation events. For this analysis, the computer programs PPTYK were developed for the Julian-date formatted data of Walnut Gulch by modifying programs PPT and INTER originally written for the month-date formatted data from the Beaver Creek Watersheds (Almestad, 1983). The output of these programs gave the necessary statistical information on means and variances, and calculated the probability density functions (PDF) and cumulative density functions (CDF) for interarrival time and precipitation. Summarized in Table 1 by month for the period of record are: (1) the total number of interarrival days within periods, and (2) the number of precipitation events and total amount of precipitation.

Like-Month Clustering - General Method

In addition to listing statistical information by months, PPTYK and INTYK provide a sequence of student "t" values and the corresponding degrees of freedom for all possible pairings of months. The listing was made to allow the student t-test to be made to determine the statistical significance of pairing like-months.

The clustering of like-months simplifies the model by reducing the number of distributions to be fitted. This grouping is done manually for both precipitation amount and interarrival time by comparing student "t" values for all possible combinations of months.

Distinctive differences between seasonal rainfall types, namely convective types in summer and frontal types in winter, are generally assumed to prevail over most of Arizona. The original model developed by Almestad (1983) was constructed to analyze these seasonal types separately. It was assumed that summer storms occur independently of each other with no more than one event occurring on any given day, although actual convective summer storms in Arizona are characterized by short durations, often less than an hour. A time base of one day was taken because precipitation data are available only on a daily basis. The variables, therefore, for summer type precipitation are simply precipitation amount per event and interarrival time between events.

Frontal type winter precipitation has a more complex structure because storms may persist for several consecutive days. Five random variables were used to describe this structure. They are:

1. number of storm groups per sequence

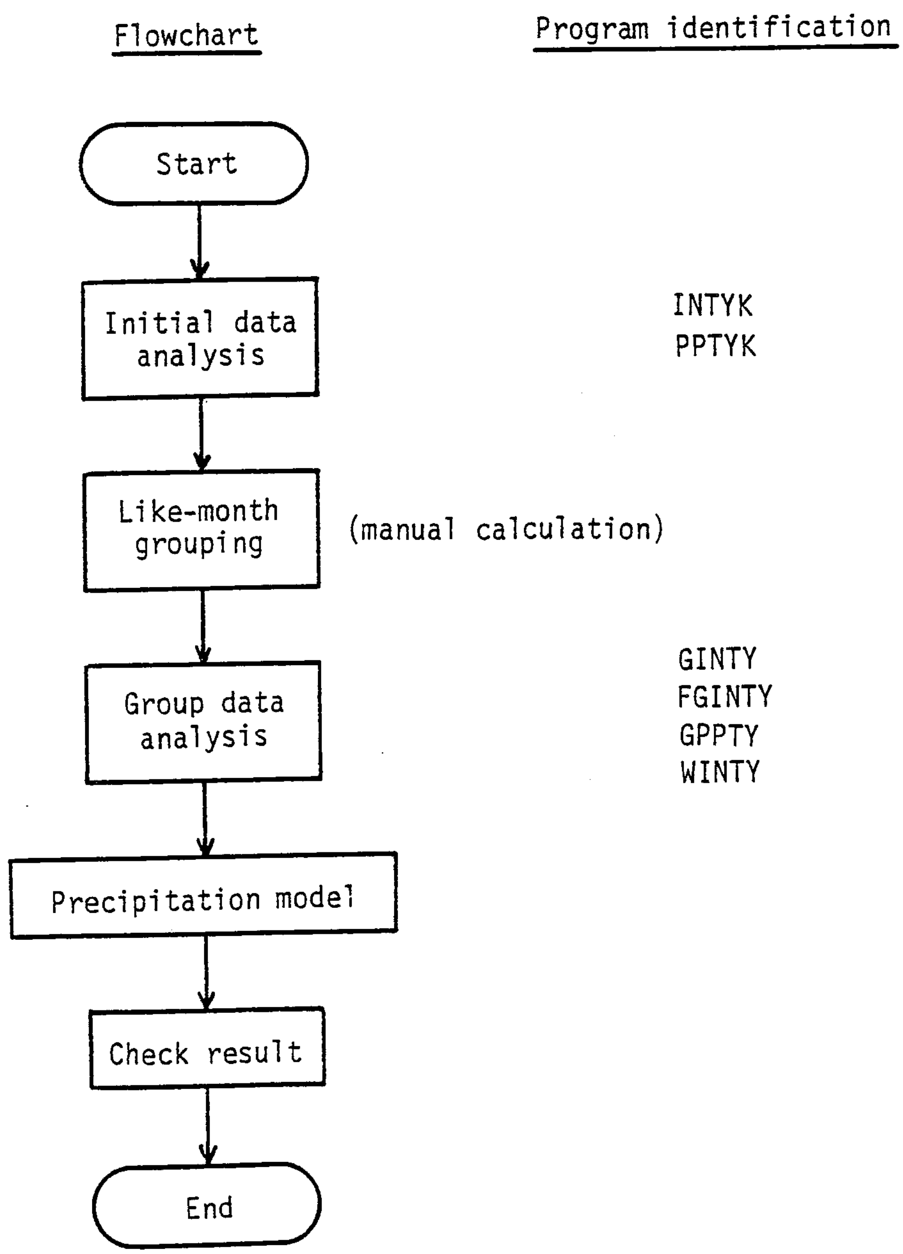


Figure 1. Flowchart and associated computer program for precipitation submodel.

Table 1. Output summary of computer programs for precipitation data analysis (INTYK and PPTYK), using 21 years of record from Walnut Gulch.

Month	Interval days (INTYK) Total number of interarrival days	mean	variance	Precipitation (PPTYK) Total amount	Total number of occurences
Jan.	465	6.94	93.53	10.16	54
Feb.	704	10.35	178.59	7.71	43
Mar.	648	9.00	166.33	10.58	52
Apr.	600	14.63	337.00	2.99	21
May	651	19.15	519.60	1.68	13
Jun.	688	12.98	287.42	6.73	34
Jul.	772	3.06	25.27	109.11	238
Aug.	774	3.26	27.71	69.68	220
Sep.	751	6.53	94.58	29.56	90
Oct.	740	9.19	199.12	14.24	58
Nov.	720	11.43	222.00	9.35	40
Dec.	713	7.43	137.59	13.59	74

2. group duration (in days)

3. precipitation total per storm group

4. number of days between storm groups

5. number of dry days between sequences

A storm group is defined as an individual event or as several consecutive events. A sequence is defined as a lump of groups that occurs with a maximum of three days interarrival time between each group. Consequently, sequences have more than three days between events. This critical three days was determined from an analysis of historic data from Arizona (Hekman, 1977). An example of the components of the winter model is shown in Figure 2. The assumptions made for the winter model are:

1. precipitation is spread evenly over all of the days in each group, and

2. group precipitation is independent of group length.

For the months of winter, a different set of distributions may be used for either precipitation amount or interarrival days, but each set must be described by a single distribution function.

The distribution functions do not have to be the same for all the months of summer, although some of the distributions fitted to the winter data may also fit the data of the summer period. The summer period in this study was defined as the months of April through November. The winter months were December through March.

Like-month Clustering - Walnut Gulch

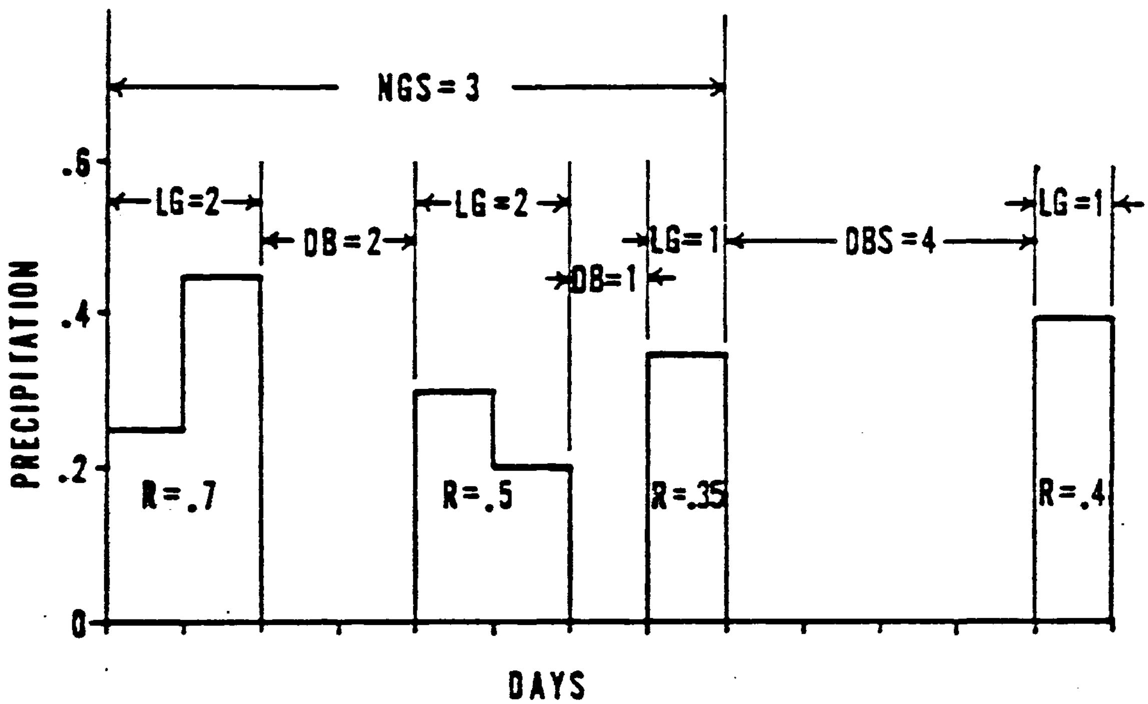
Student "t" test indicated that the same distribution function would adequately define precipitation amount for the winter months of December, January, February, March, as well as the summer months of April, May and June, and that another distribution was required for the summer months of July, August, September, October and November. Interarrival days could be described by the same distribution for the summer months of September, October, November, and the winter months of December, January, February and March. Two other distributions were required for April, May and June, and for July and August. The results of clustering like-months are shown in Figure 3. Like-months are indicated in Figure 3 by the dashed-line boxes, and the clusters of summer and winter periods are indicated by the solid-line boxes.

Group Data Analysis - General Method

In the main structure of the precipitation model, hypothetical distributions are fit to actual data. Three hypothetical distributions were used in previous work by Almestad (1983) and Hekman (1977) that also appeared to describe the statistical behavior of the Walnut Gulch data. They are:

1. Geometric distribution (CDF)

   $Fx(x) = 1 - (1 - P)^x$, where $P = \frac{1}{\bar{X}}$



NGS = Number of Groups per Sequence
LG = Length of Group
DB = Days Between Groups (1-3)
R = Precipitation Total per Group
DBS = Days Between Sequences (>3)

Figure 2. An example of winter precipitation model components.

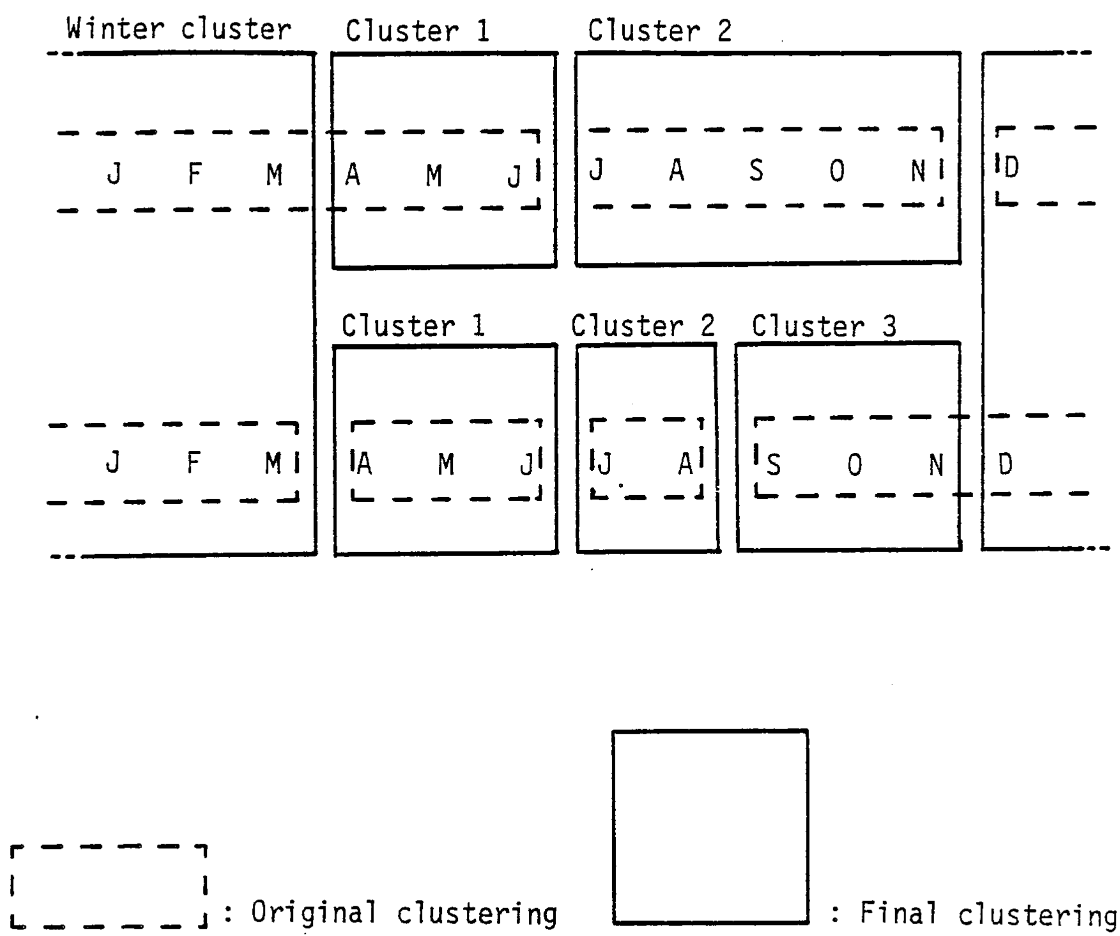


Figure 3. Result of like-month clustering based on 21 years of precipitation record from Walnut Gulch

2. Exponential distribution (CDF)

$$Fx(x) = 1 - e^{-\lambda x}, \quad \text{where} \quad \lambda = \frac{1}{\bar{x}}$$

3. Gamma distribution (PDF)

$$Fx(x) = \frac{\lambda^k x^{k-1} e^{-\lambda x}}{\Gamma(k)}, \quad \text{where} \quad \lambda = \frac{\bar{x}}{s^2}$$

x = either the number of interarrival days or the amount of precipitation per event,

$\bar{x}$ = actual distribution mean,

s^2 = sample variance of actual distribution,

k = shape parameter,

λ = scale parameter, and

$\Gamma(k)$ = gamma function (obtained from a table of K values (Beyer, 1966).

Computer programs GPPT, GINT and WINT were written to calculate the actual distributions for each group and to fit PDF and CDF distribution functions to the data.

Group Data Analysis - Walnut Gulch

The programs GPPT, GINT and WINT were modified into GPPTY, GINTY and WINTY for the Walnut Gulch data which were based on Julian date. It was found that the geometric and exponential distributions adequately matched the actual data and that use of the gamma distribution was not necessary.

The Kolomogorov-Smirnov (K-S) test was used to determine the goodness of fit of the hypothetical distributions to the actual distributions. If the calculated K-S value exceeded the K-S tabular value at the 0.05 level of significance, the hypothetical distribution was rejected. In testing the fit of hypothetical distributions to the data for interarrival days, the K-S test indicated nonsignificance for cluster 1 and cluster 3; this was due to the exceptionally high values encountered for interarrival day 1 in these clusters. This problem was overcome by assigning a fixed probability to interarrival day 1, letting interarrival day 2 = interarrival day 1, and fitting in geometric distribution to the remainder of the data beginning at the transformed interarrival day 1. A computer program FGINT was developed to perform this operation for this type of one-day fixed distribution.

Results of the fitting are given in Table 2. All of the K-S tabular values were greater than required for acceptance of fit at the 0.05 significance level including the fixed-exponential distributions developed for interarrival clusters 1 and 3.

Although the K-S test indicated a fit between the hypothetical geometric distribution and actual distribution at a significance level greater than the 0.05 significance level for number of groups per sequence and number of dry days between groups, the difference was small (.045), Furthermore, other distribution functions gave a poor fit. Therefore, the geometric distribution for group duration was

Table 2. Distribution functions and K-S values to fit with actual distribution of twenty-one years precipitation record from Walnut Gulch for each cluster.

Cluster*	Distribution Type	Calculated K-S value		Tabulated K-S value	df
(Precipitation amount per event)					
Cluster 1	Exponential	0.064	<	0.391	11
Cluster 2	Exponential	0.047	<	0.140	100
(Interarrival time)					
Cluster 1	Fixed/Geometric	0.090	<	0.150	80
Cluster 2	Geometric	0.098	<	0.140	100
Cluster 3	Fixed/Geometric	0.093	<	0.140	100
(Winter model)					
Group Duration	Geometric	0.058	<	0.14	100
Number of groups per sequence	Geometric	0.135	<	0.18	55
Number of dry days between group	Geometric	0.125	<	0.17	60
Number of dry days between sequence	Exponential	0.066	<	0.20	45
Precipitation amount per group	Geometric	0.055	<	0.14	100

*See Figure 3 for division of clusters.

accepted. Actual and fitted hypothetical distributions are shown in Figure 4 through 14. The fitted hypothetical distributions shown in the figures were used in the execution of the precipitation submodel.

Operation of the Precipitation Model

The precipitation model was executed, beginning on the first day of the year (January 1) in the following general sequence:

1. Generate and enter a random number into the distribution function for the number of dry days between sequences.

2. Generate and enter a random number into the distribution function for the number of groups in a sequence following the number of dry days.

3. Generate and enter a random number into the distribution function for group duration.

4. Generate and enter a random number into the distribution function for precipitation amount for the group.

5. Divide the precipitation amount determined for the group by the number of days in each group to determine the average daily precipitation.

6. If there is only one group in a sequence repeat step 1; if there is more than one group in a sequence, generate and enter a random number into the distribution function for the number of dry days between groups and return to step 3.

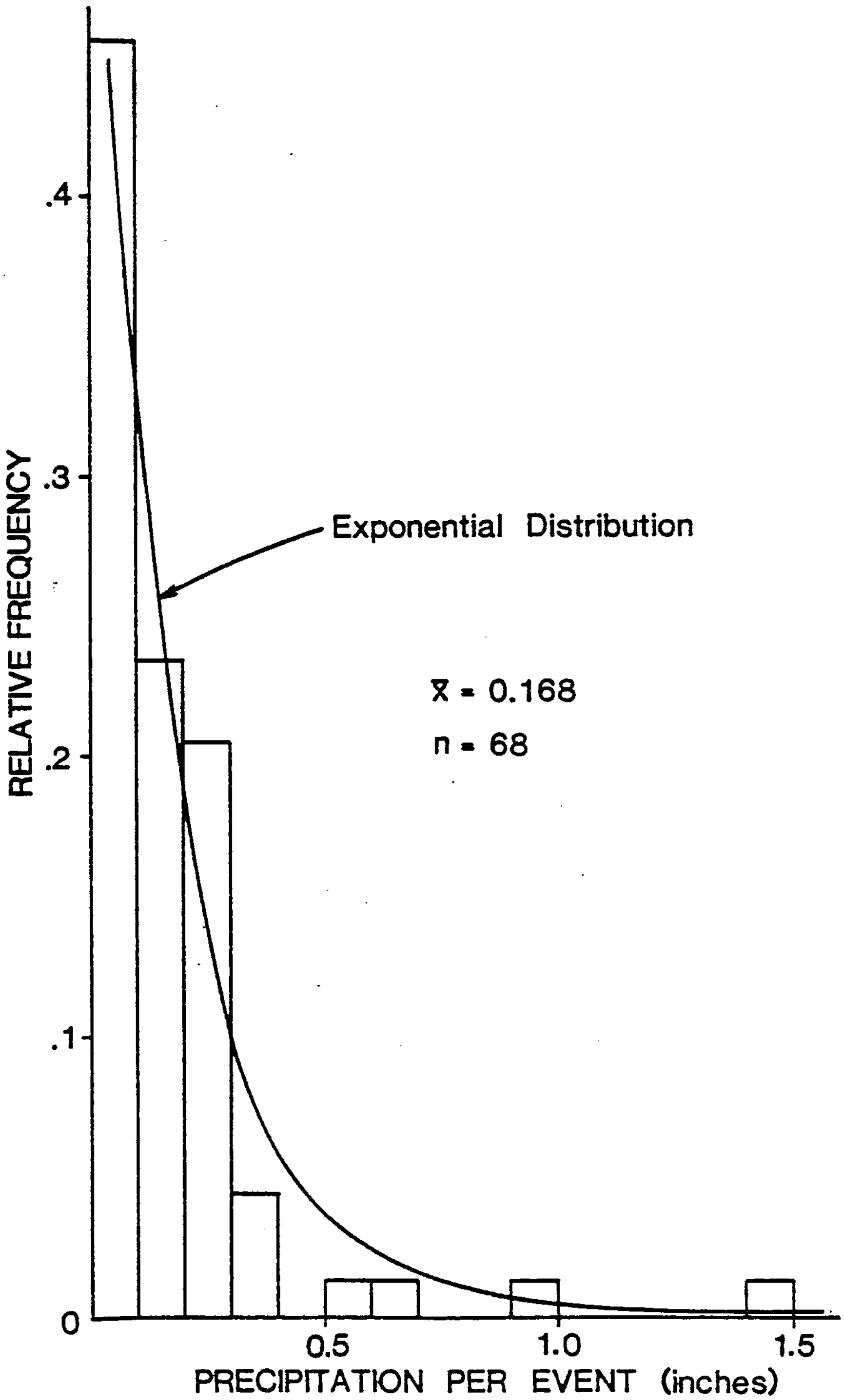


Figure 4. Comparison of actual and hypothetical distribution for precipitation in cluster 1. (April through June)

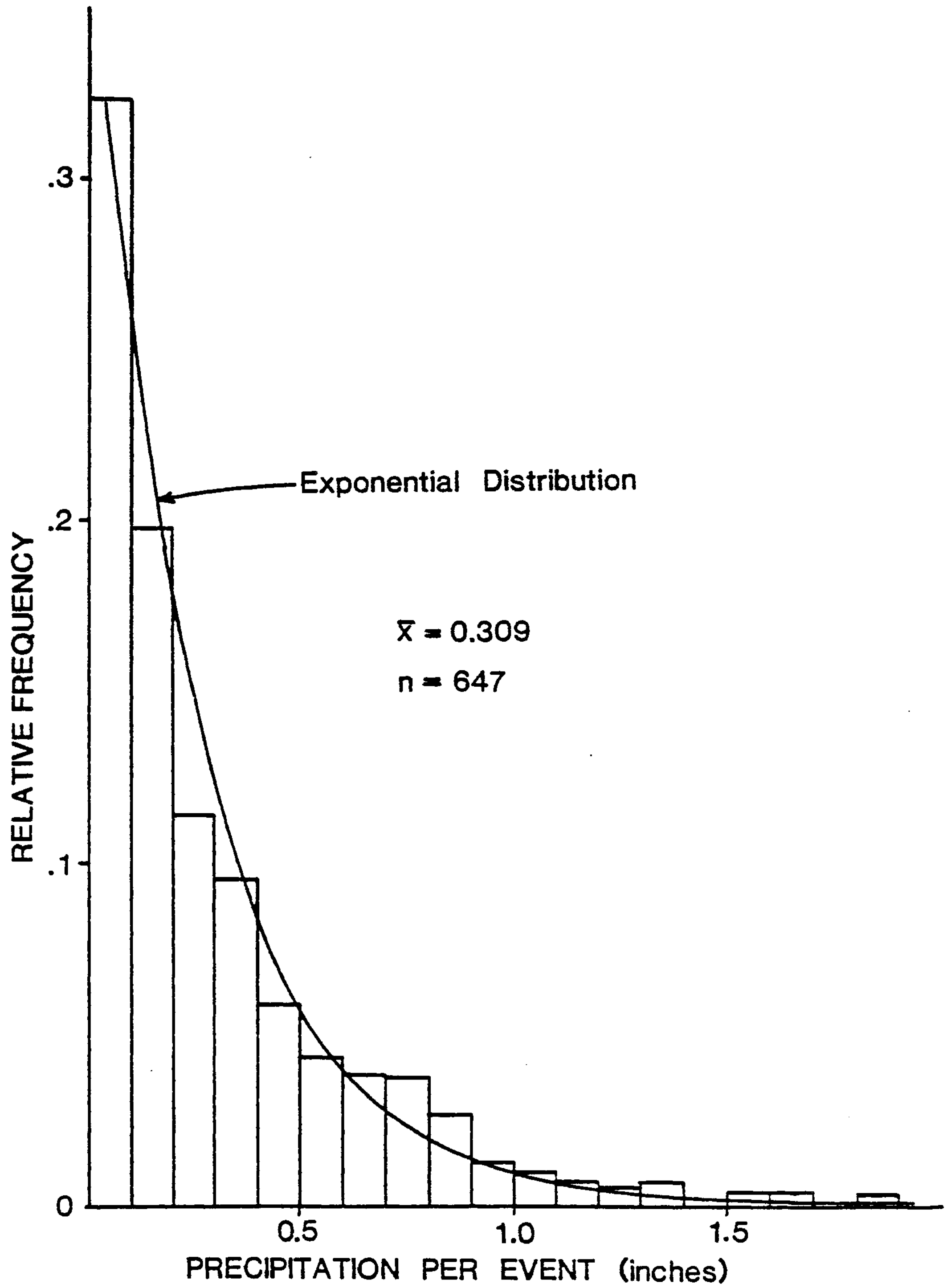


Figure 5. Comparison of actual and hypothetical distribution for precipitation in cluster 2. (July through Nomember)

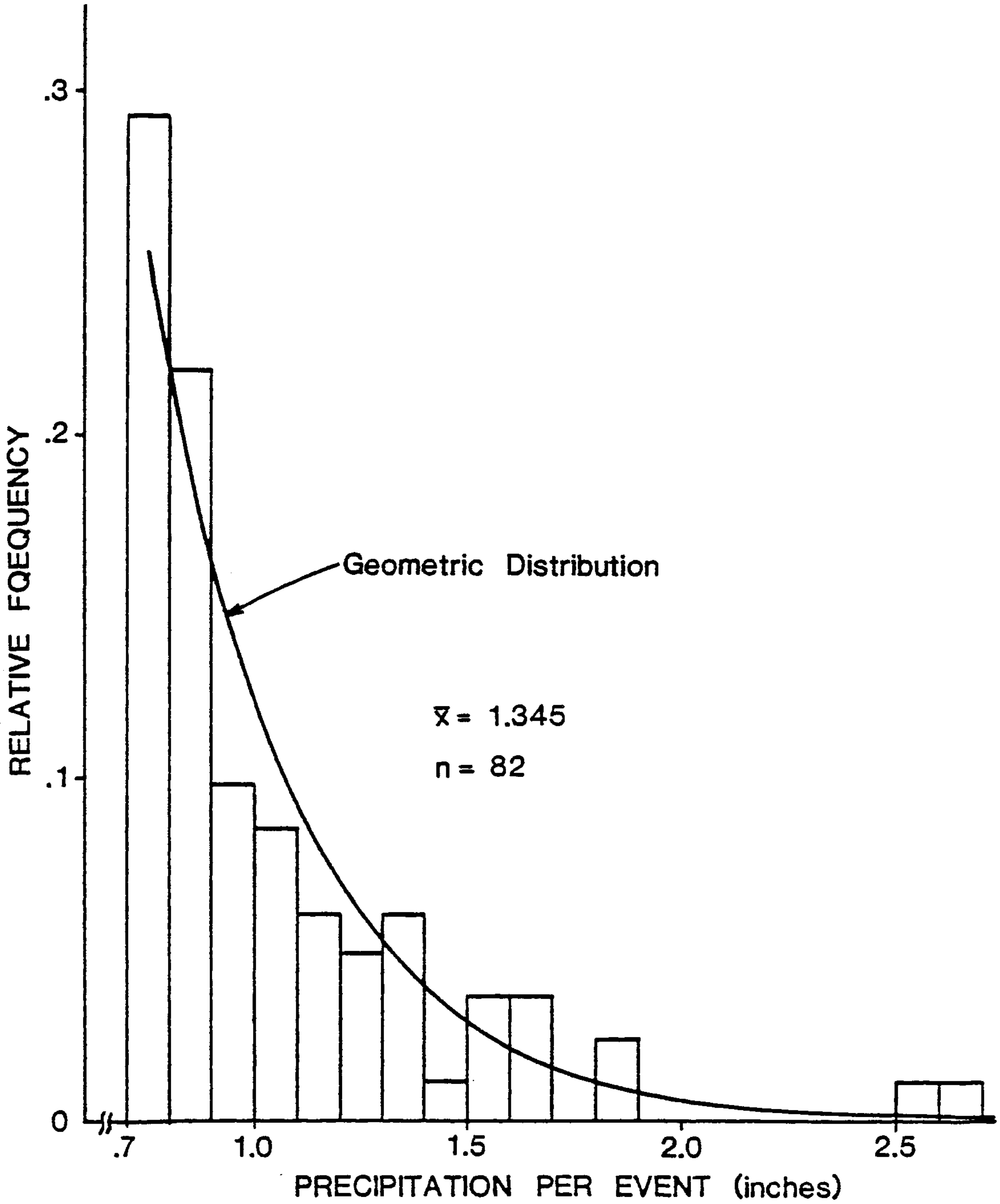


Figure 6. Comparison of actual and hypothetical distribution for precipitation in excess of 0.7 inches in July and August.

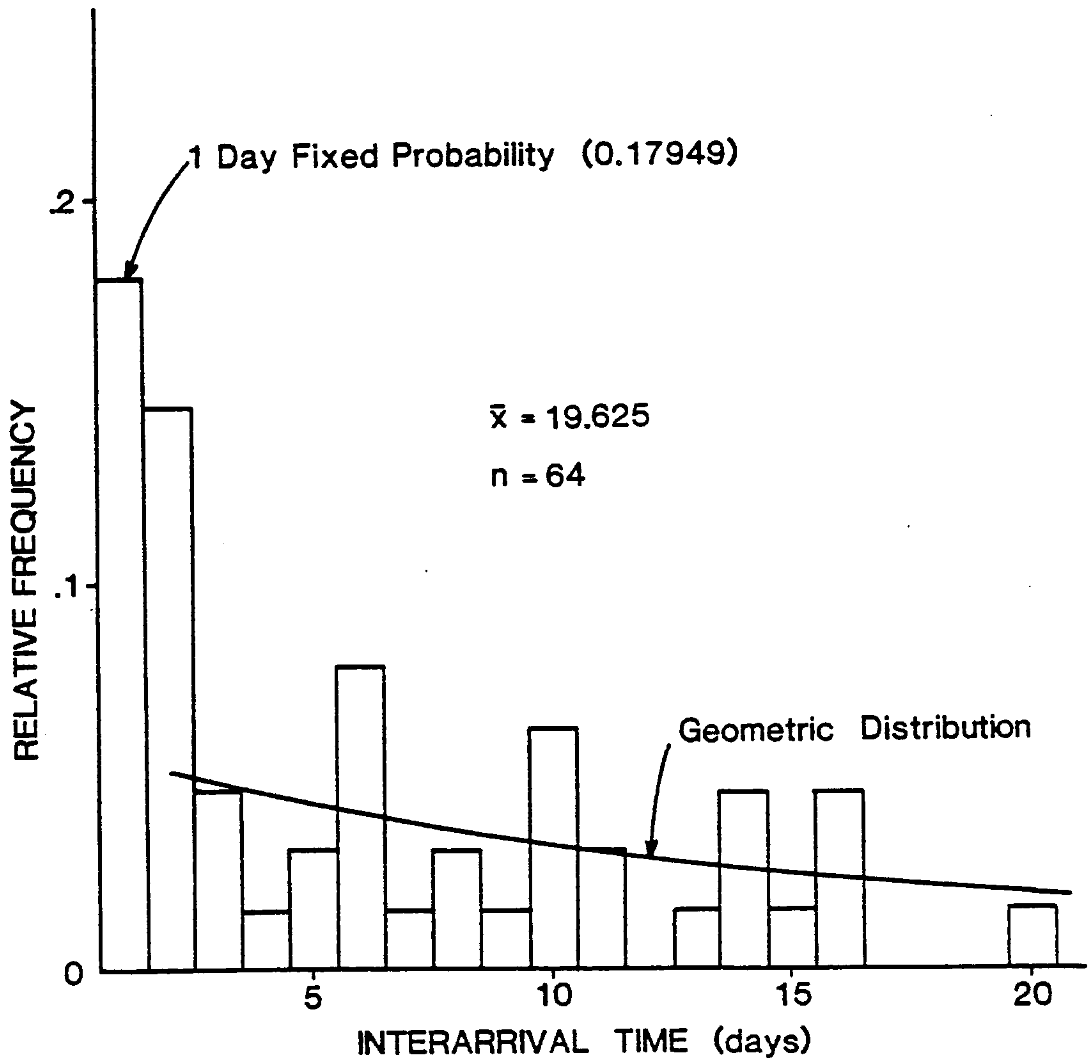


Figure 7. Comparison of actual and hypothetical distribution for interarrival time in cluster 1. (April through June)

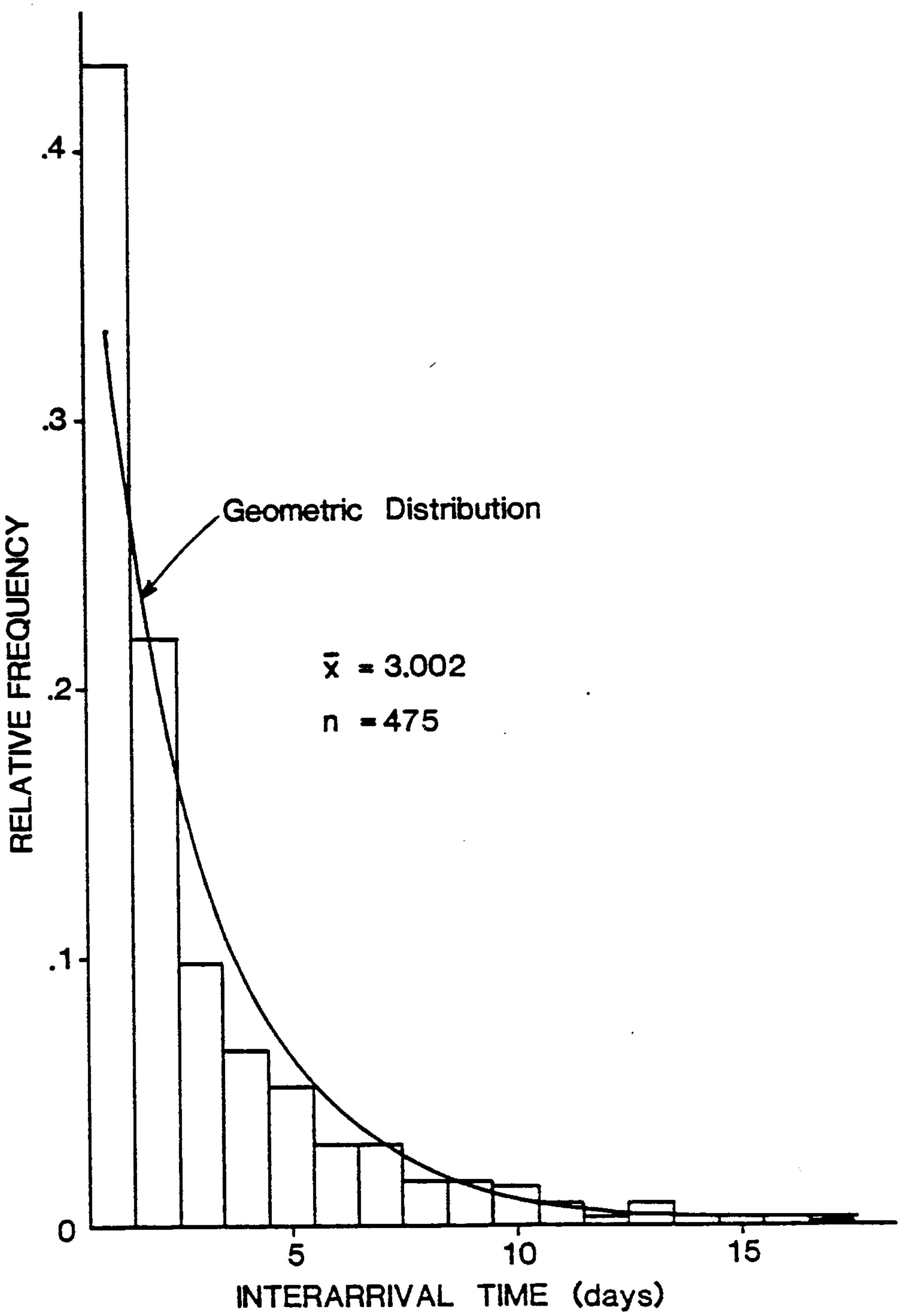


Figure 8. Comparison of actual and hypothetical distribution for interarrival time in cluster 2. (July and August)

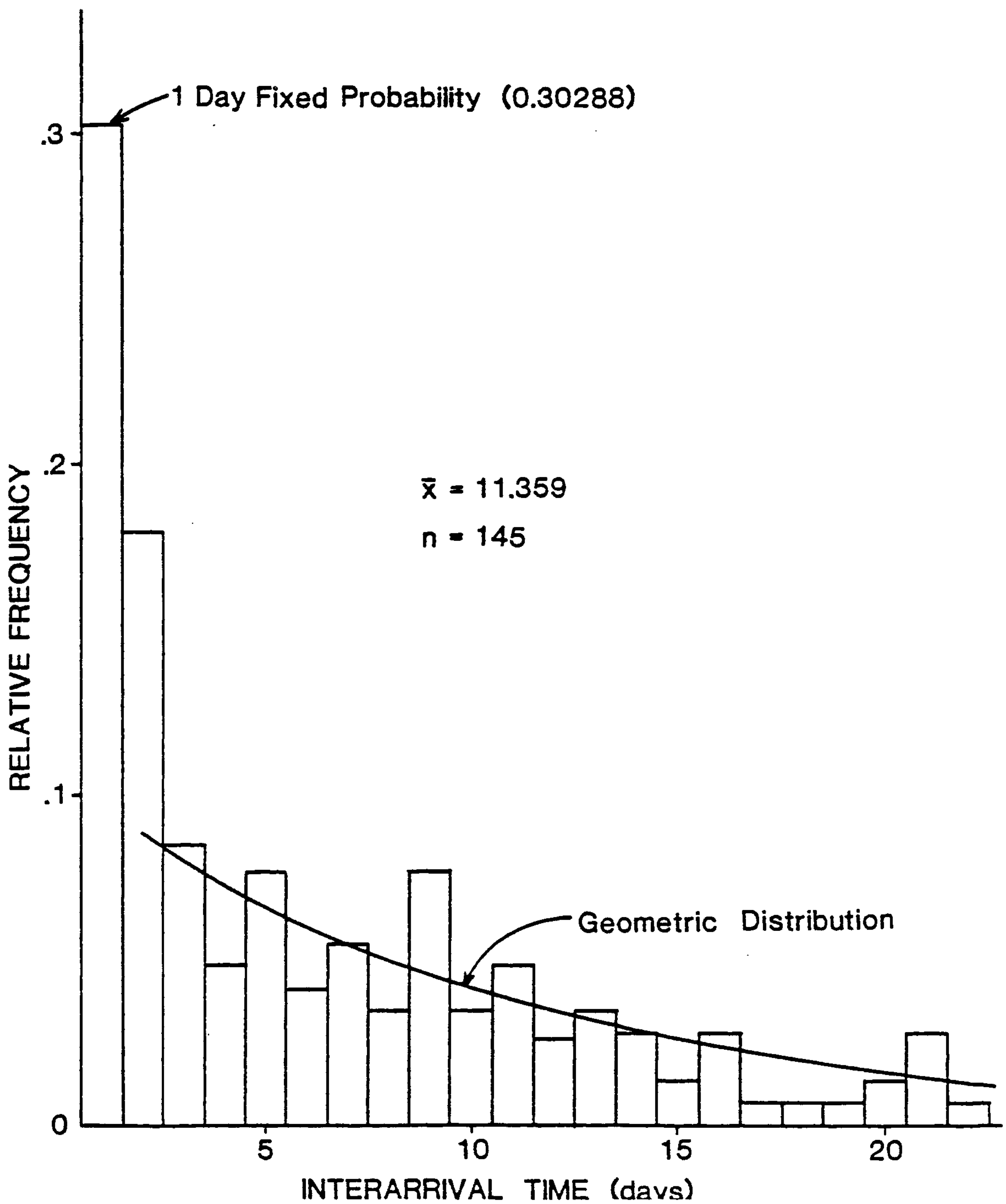


Figure 9. Comparison of actual and hypothetical distribution for interarrival time in cluster 3. (September through Nomember)

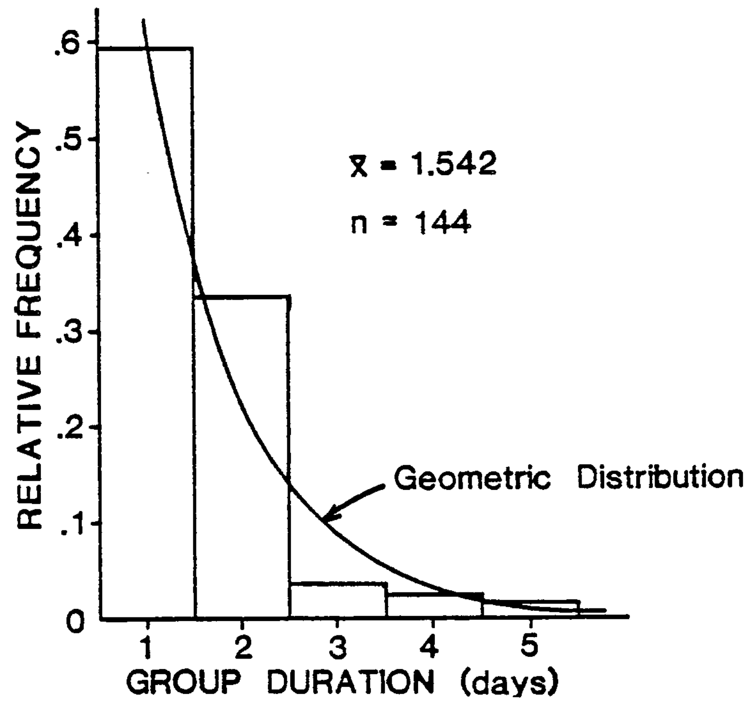


Figure 10. Comparison of actual and hypothetical distribution for group duration in winter cluster.

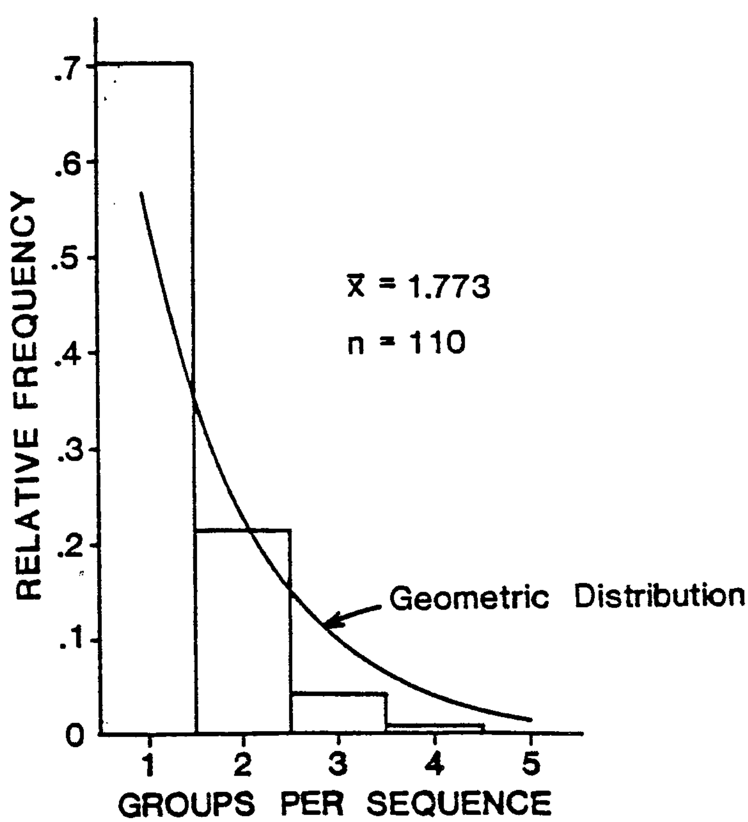


Figure 11. Comparison of actual and hypothetical distribution for number of groups per sequence in winter cluster.

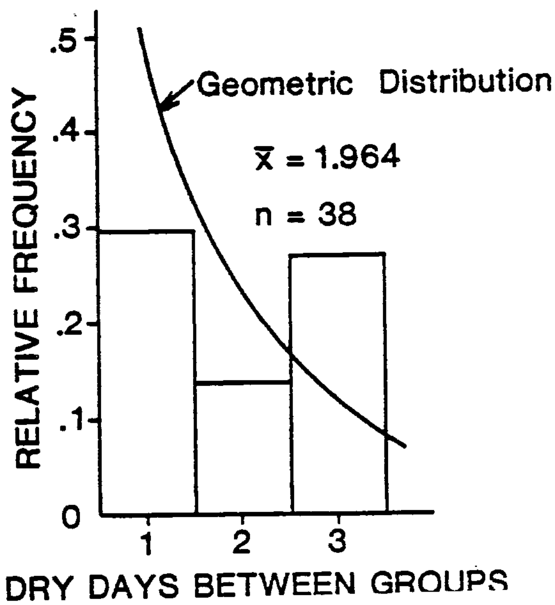


Figure 12. Comparison of actual and hypothetical distribution for dry days between groups in winter cluster.

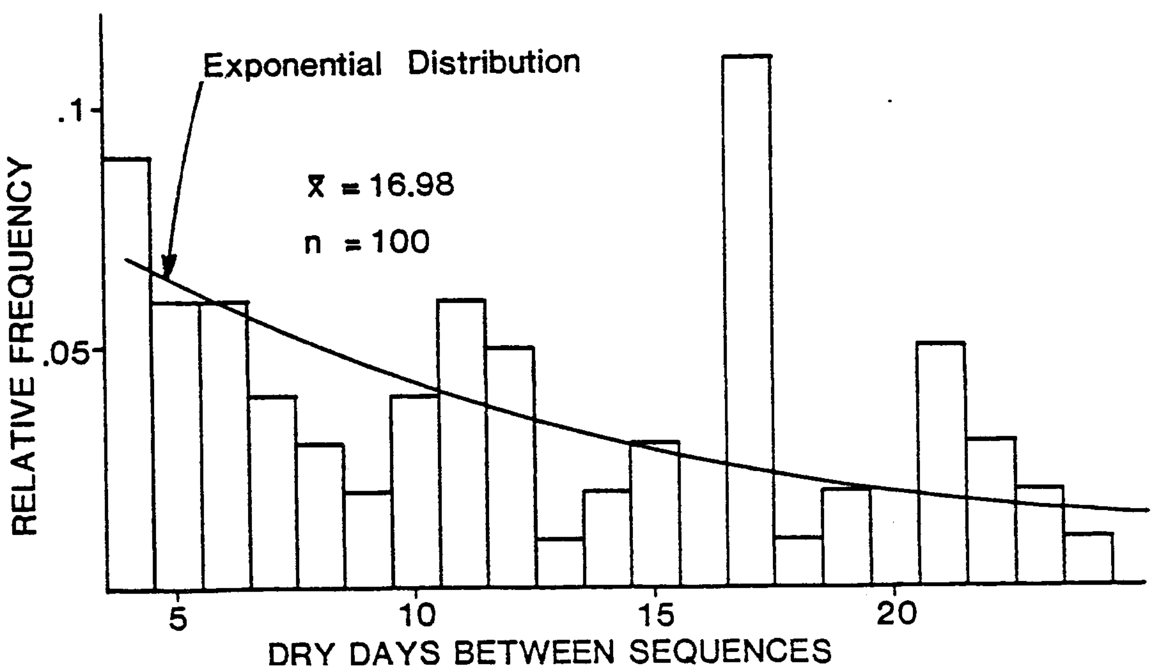


Figure 13. Comparison of actual and hypothetical distribution for dry days between sequences in winter cluster.

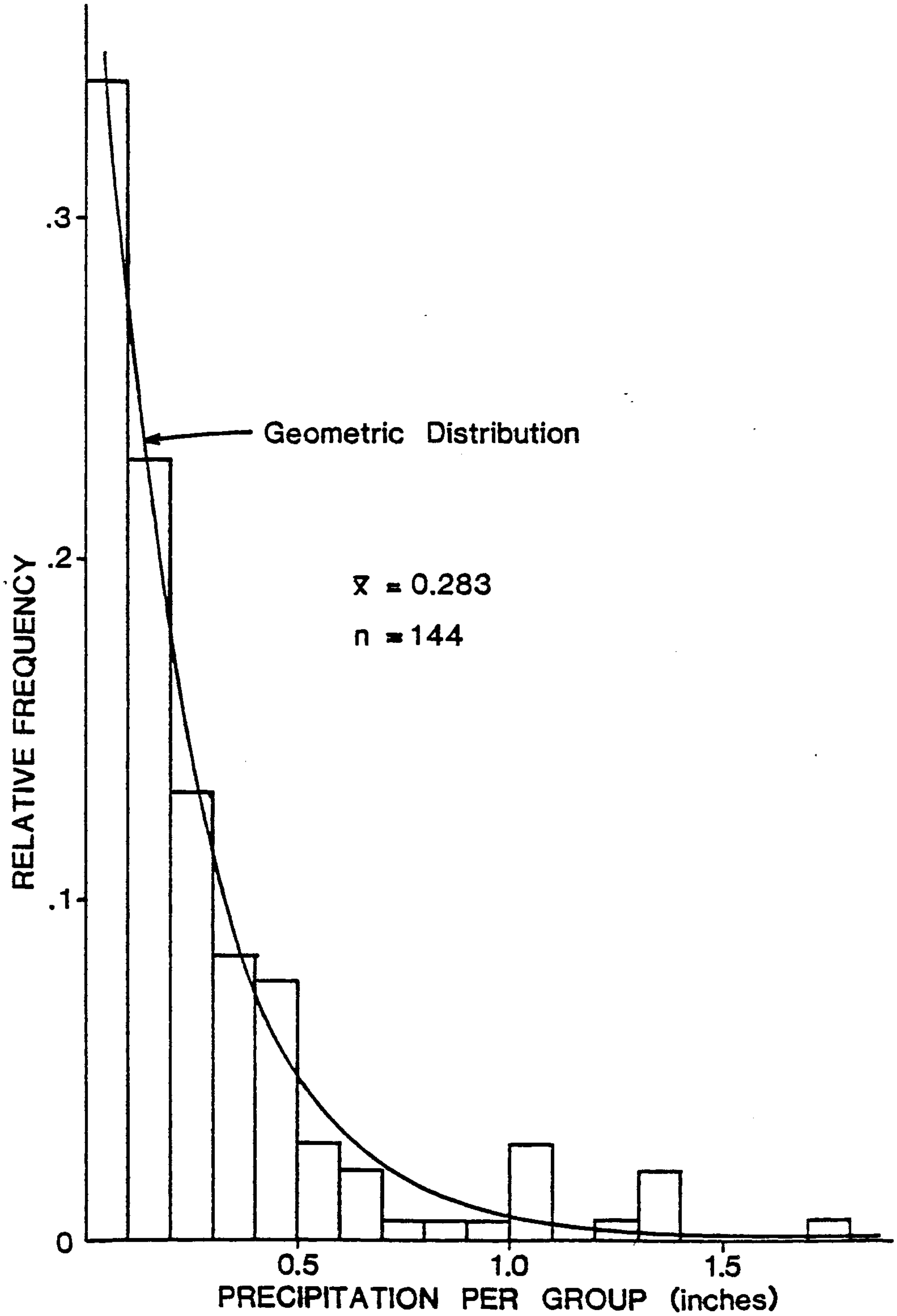


Figure 14. Comparison of actual and hypothetical distribution for precipitation in winter cluster.

(Note) Whenever the date is advanced, it must be checked to determine if it exceeds the last day of the winter cluster, go to the summer type:

7. Generate and enter a random number into the distribution function for interarrival day.

8. Generate and enter a random number into the distribution functions for precipitation amount.

9. Return to step 7 and repeat through step 9 until December 1 is reached.

(Note) Whenever the date is advanced, it must be checked to determine if it exceeds the last day of either one of the clusters. If the last day is exceeded, the distribution function for the following cluster is used.

Results of simulation

Precipitation was simulated for a period of 200 years. Averages obtained from the simulation were compared with those of the twenty-year historical record. (See Table 3, columns 1, 3, 4 and 5.) Differences between the average annual precipitation simulated and the actual was only 0.6 inches. (See Table 3, columns 1 and 3.) There was a difference of twenty-two days in interarrival times.

These differences were not believed to be great considering the wide variation in both precipitation amount and interarrival times between years of the historical record. However, precipitation amount was underestimated in the simulation for the critical months of July and August when over 95 percent of the runoff occurs in the area. Therefore, in order to better tune the model, the frequency distribution for these two months was separated into two distributions, one to be used for precipitation amounts less than 0.7 inches (see Figure 5) and the other for precipitation amounts less than 0.7 inches (see Figure 6). An additional 200 year simulation was made with improved results for July and August. (See Table 3, columns 1, 2 and 3.) A comparison of like-month clusters with actual data using the separated distribution is given in Table 4.

An analysis made by Long (1983) indicated that storm size and storm movement were not greatly different, on the average, between summer and winter. Long (1983) found the radius of an average storm for both seasons to be on the order of 1.2 miles with a standard deviation of 0.85 miles. Therefore, as a test, the summer model was run throughout the entire year without resort to the winter model. The results of this simulation when compared by cluster with the historical data were seemingly good (Table 5). The simulated inter-arrival times using the summer model alone were somewhat closer to the historical values than were those simulated with the combined summer-winter model. However, precipitation amounts were under estimated for the July-November cluster and over estimated for the December-March cluster.

Table 3. Comparison of 200 years simulation with 20 years actual rainfall data of Walnut Gulch by month

Month	Average Rainfall (inches/month) Simulated w/o separation of distribution (1)	Simulated w/separation of distribution (2)	Actual (3)	Average Interarrival Days (days/week) Simulated (4)	Actual (5)
Jan.	.41	.43	.49	7.7	6.9
Feb.	.41	.44	.37	8.6	10.4
Mar.	.48	.50	.50	8.9	9.0
Apr.	.30	.25	.14	10.4	14.6
May	.31	.26	.08	10.7	19.2
Jun.	.32	.35	.32	10.8	12.9
Jul.	3.27	3.64	3.66	2.7	3.1
Aug.	3.59	3.57	3.32	2.6	3.2
Sep.	.96	1.07	1.41	7.1	6.5
Oct.	1.07	.95	.68	7.2	9.2
Nov.	1.06	.77	.45	6.9	11.4
Dec.	.56	.40	.65	8.1	7.4
Total:	12.7	12.6	12.1	91.7	113.8

Table 4. Comparison by like-month clusters of simulated and actual precipitation using a separated distribution for July and August.

	Averaged precipitation per month (inches)	
Cluster	Simulated	Actual
December through March	1.8	2.1
April through June	0.9	0.6
July through November	10.0	10.0

	Averaged interarrival time per event (days)	
Cluster	Simulated	Actual
December through March	8.3	8.4
April through June	10.6	15.6
July through August	2.7	3.2
September through November	7.1	9.0

Table 5. Comparison by like-month clusters of simulated and actual precipitation using the summer model throughout the year.

	Averaged precipitation per month (inches)	
Cluster	Simulated	Actual
December through March	3.2	2.1
April through June	0.8	0.6
July through November	8.7	10.0

	Average interarrival time per event (days)	
Cluster	Simulated	Actual
December through March	9.4	8.4
April through June	16.7	15.6
July through August	3.9	3.2
September through November	7.7	9.0

Because of the underestimates in precipitation amount for July and August, and because the summer-winter model is more acceptable, at least in a conceptual sense, it was decided to use the summer-winter model adjusted by the separated distribution for July and August to simulate runoff.

Runoff Submodel

The Soil Conservation Service (SCS) method was used to estimate runoff because it is widely used and is a relatively simple method that can be extended to ungaged watersheds. The SCS method is essentially an equation which estimates a value of runoff, given the amount of rainfall and a curve number based on watershed characteristics. However, the model is very sensitive to variations in the curve number.

Previous work by Almestad (1983) indicated that runoff from the Beaver Creek watersheds as determined by the SCS method, was an inverse function of the amount of precipitation. It was found that a quadratic equation fitted to the curve numbers calculated for each rainfall even described the relationship. This relationship was used to provide a correction factor to the curve number based on storm size. In addition, it was necessary that snowmelt and soil moisture be taken into account for the Beaver Creek area. Snow is very rare in the Walnut Gulch area and therefore, was not considered in the present study.

Initially, it was thought that runoff as estimated by the SCS method might be a function of rainfall storm size, as was found by Almestad (1983) for the Beaver Creek Watershed data and by Hawkins (1979) for other locations in the west. Accordingly, curve numbers were calculated for all runoff events of record and regressed against rainfall amount with the following equation:

$$CN = 99.15 + 5.705\ (AM\ 3) - 37.61\ (PPT) + 12.23\ (PPT^2)$$

where

CN: curve number

AM3: the cumulative precipitation for the 3 days prior to a runoff event

PPT: precipitation amount

Correlation was poor ($R^2 = .25$). Nevertheless, a simulation of runoff was conducted, using the equation to vary the curve number with rainfall amount. Use of the equation overestimated the runoff from large storms. The large overestimation was due to the preponderance of small storms. Therefore, the correction for storm size was not used in this study.

A constant curve number of 84 was subsequently used in converting the simulated rainfall to runoff. The Agricultural Research Service had previously assigned a curve number of 85 to the watershed. However, data from additional rainfall-runoff events enabled a more accurate curve number of 84 to be derived.

Predictions made with the SCS method were compared with actual measurements of runoff without considering antecedent conditions (Table 6, columns 1 and 3). Because of the low rainfall in the Walnut Gulch watersheds during the cooler months January to July and October to December, antecedent conditions had no apparent effect on runoff. However, during the months of July and August, when over 95 percent of the runoff occurs, the SCS method underestimated runoff, particularly for the month of July.

Analysis of the data indicated that storms of one inch or more which occurred within two days prior to a runoff event had a noticeable effect on the size of the event. Accordingly, a curve number of 96 (antecendent moisture class III for a curve number of 84) was used. Predictions were improved for the critical months of July and August (Table 6, columns 2 and 3). It should also be pointed out that very large flumes are used on the Walnut Gulch experimental watersheds. Consequently, the low flows, which predominate, may not be measured with a very high degree of precision.

An additional comparison was made between the measured runoff and runoff simulated with the models (Table 6, columns 3 and 4). For this comparison the first 20 years of simulation was used. Simulation made for another 20 year period would not be the same. Nevertheless, the simulated annual runoff, using a curve number of 84 with antecedent conditions, was only 0.27 inch greater than the measured

Table 6. Comparison of Runoff Calculated by the SCS Method with Measured Runoff for 9 years of Record (60 Runoff Events) of Walnut Gulch by Month (unit = inches)

	SCS Method (using actual rainfall data)		Actual	SCS Method (using simulated rainfall data for 200 yrs.)
Month	w/o antecedent conditions	w/antecedent conditions		
	(inches/month)			
	(1)	(2)	(3)	(4)
Jan.	.01	.01	0	.01
Feb.	.01	.01	0	.01
Mar.	.01	.01	0	.01
Apr.	0	0	0	0
May	0	0	0	0
Jun.	.03	.03	0	.01
Jul.	.36	.46	.59	.49
Aug.	.31	.37	.33	.50
Sep.	.09	.11	.02	.08
Oct.	.04	.04	0	.06
Nov.	.02	.02	0	.04
Dec.	.03	.03	0	.01
Total	.91	1.09	0.94	1.22

runoff. Much of this difference was due to runoff predicted by the SCS method for the cooler months when little or no runoff actually occurred. The total measured runoff for the critical months of July, August and September was .94 inches as compared with the simulated amount of 1.07 inches.

Temperature Submodel

A stochastic air temperature model based on a model developed previously by Hekman (1976) was designed by Almestad (1983) to simulate maximum daily temperature for use in the Beaver Creek watershed area. The model was used for the Beaver Creek area to estimate: (1) the form of precipitation either rain or snow, (2) the timing and amount of snowmelt, (3) the soil moisture index in the winter runoff model, and (4) the amount of evaporative loss from the stock pond surfaces.

The factors related to snow were not pertinent to this study. However, since water loss from stock ponds by evaporation is particularly high at the lower elevations of southeastern Arizona, the temperature model was needed to estimate these losses.

The temperature submodel is based on a simple form of an autoregressive moving average model (ARMA) known as a first order Markov process. The function used is:

$$\bar{T} = \bar{T}_{year} + AMP \times \cos\,[2\,\pi(i - i\ peak)/365] \qquad (1)$$

where

T_i = mean daily maximum temp. in day i

$\bar{T}$ year = mean annual temperature

AMP = amplitude of temperature rise above long term mean

i = day of year

i peak = day of year in which the long term daily mean temp. is highest.

The second component of the Markov process reflects the influence of the previous days temperature on the present day. This influence is calculated using a weighting factor that is a statistically calculated lag-one serial correlation. The third component of the Markov process is the random component that accounts for the skew in the daily maximum temperature.

The variables used to determine the distribution of maximum temp. are: (1) amplitude of the temperature rise above the long term mean, (2) peak day of the year, and (3) serial correlation value for lag-one.

The principle steps in the temperature model are:

a) the mean maximum temp. for day i is determined with the equation 1.

b) A normal 10.1 random number is generated

c) A normal 10.1 random number is transformed into a gamma distributed random number

d) The max. temp. for day i is derived

e) The temp. value is stored and the process begins again.

Data Analysis

To obtain the necessary variables from the actual data, computer programs MAXTM and CORR2 were written by Almestad (1983) for amplitude of peak day and for the serial correlation coefficient, respectively. The daily maximum temperatures at Walnut Gulch for the years 1978 through 1982 were used in the two programs, and the following values were obtained:

amplitude = 18.28

peak day = 200 (July 19)

Serial correlation coefficient (R) = .64

These values were used in the temperature model to simulate 200 years of record. The simulation gave an annual mean daily maximum temperature of 76.35° F., as compared with a 5-year historical mean of 76.34° F. Because of the close agreement, modification of the model was not necessary for application to the conditions of the Walnut Gulch area.

Stock Pond Submodel

The submodels of precipitation, temperature and runoff were coupled together into a computer program called PONDS for the original work with data from the Beaver Creek watersheds. In the present study, the same program was used with the new parameters for estimating evaporation.

Evaporation

As with the PONDS program, a method developed by Cooley (1970) was used to estimate monthly evaporation rates. By this method, a value is read from a generalized graph of monthly evaporation. This value is then multiplied by an adjusting factor found on an isolines map of the area.

Regression analyses were made on the mean daily evaporation for each month versus the mean monthly maximum temperature for the period January through June and for the period July through December. Regression analysis were also made to determine the relationship between the average monthly evaporation for each month and the mean monthly maximum temperature. The parameters derived were used in the program (see Table 7). The name of the POND program was modified to PONDY to reflect this change in regression parameters. A complete listing of the FORTRAN IV program is found in Appendix A.

Program variables and output

The output of both the POND and PONDY programs include:

1. mean annual spill with standard deviation
2. mean annual retention with standard deviation and median
3. mean annual retention as a percent of runoff
4. fill factor
5. mean annual number of dry days with standard deviation

Table 7. Parameters and coefficient of determination for evaporation based on 5-years temperature record from Walnut Gulch.

Average daily evaporation	R^2
January through June	
coefficient b = 0.0064	0.95
constant a = -0.2903	
July through December	
coefficient b = 0.0066	0.96
constant a = -0.3414	
Average monthly evaporation	
January through June	
coefficient b = 0.1948	0.94
constant a = -8.7164	
July through December	
coefficient b = 0.2012	0.95
constant a = -10.4267	

6. the number of dry days expected for each month of the year.

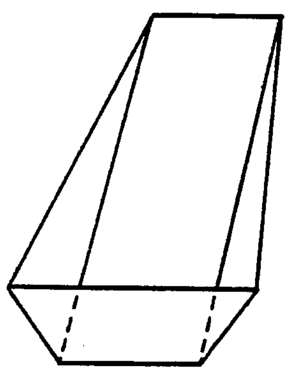
This output is developed for two pond geometries, three seepage rates, six watershed sizes, and nine pond sizes for a total of 324 combinations (see Figure 15).

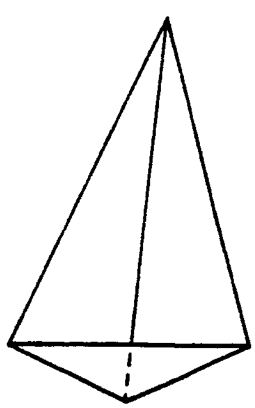
The two stock pond shapes were triangular and trapezoidal, as shown in Figure 13. The method of determining the dimensions for these geometries is outlined by Almestad (1983).

Seepage rates of 0.0, 0.02 and 0.05 feet/day were assumed. Due to a lack of measurement data, these values were used to include the possible range of seepage rates that might be found in the area. It was assumed that seepage occurred only in a vertical direction and that the use of a constant value for seepage rate was suitable for the entire simulation period.

The watershed sizes examined were: 50, 100, 200, 300, 400, and 1000 acres. The pond sizes used were 0.25, 0.50, 0.75, 1.0, 2.0, 3.0, 4.0, 5.0, and 10.0 acre feet. The ratios of pond length to widths and the angles of the side slopes were kept constant for these volumes, and only the depths were varied. The standard pond was taken to be 5 feet deep with a volume of one acre-foot.

Pond geometry	Seepage rate (feet/day)	Watershed size (acre)	Pond size (acre-feet)
Trapezoidal	0.00	50	0.25
	0.02	100	0.50
	0.05	200	0.75
		300	1.00
		400	2.00
		1000	3.00
			4.00
			5.00
Triangular			10.00





Total combination = 2 x 3 x 6 x 9

= 324

Figure 15. Combination of pond geometry, seepage rate, watershed size and pond size.

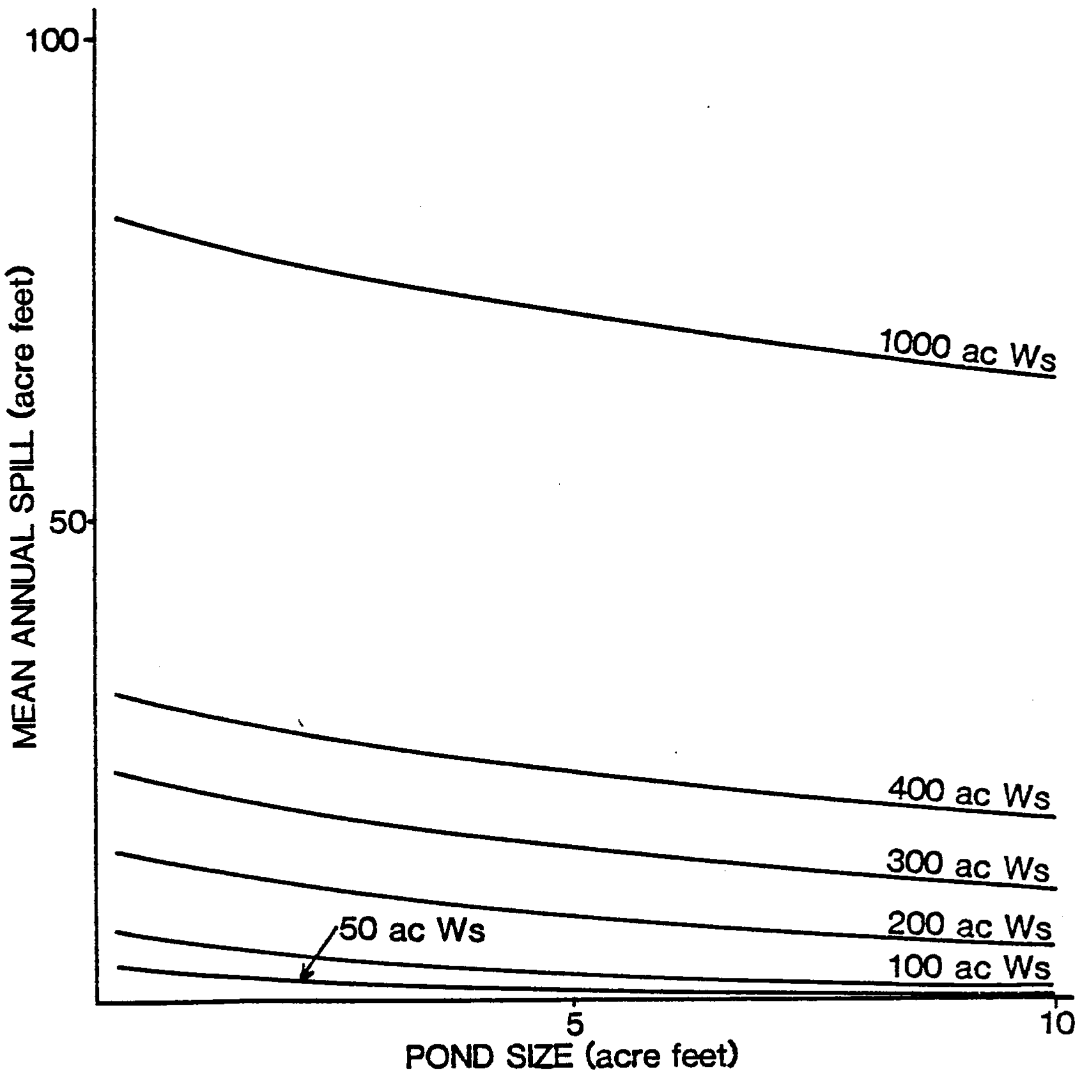


Figure 16. Mean annual spillage for triangular pond with a seepage rate of 0.02 feet per day based on 200 years simulation for Walnut Gulch.

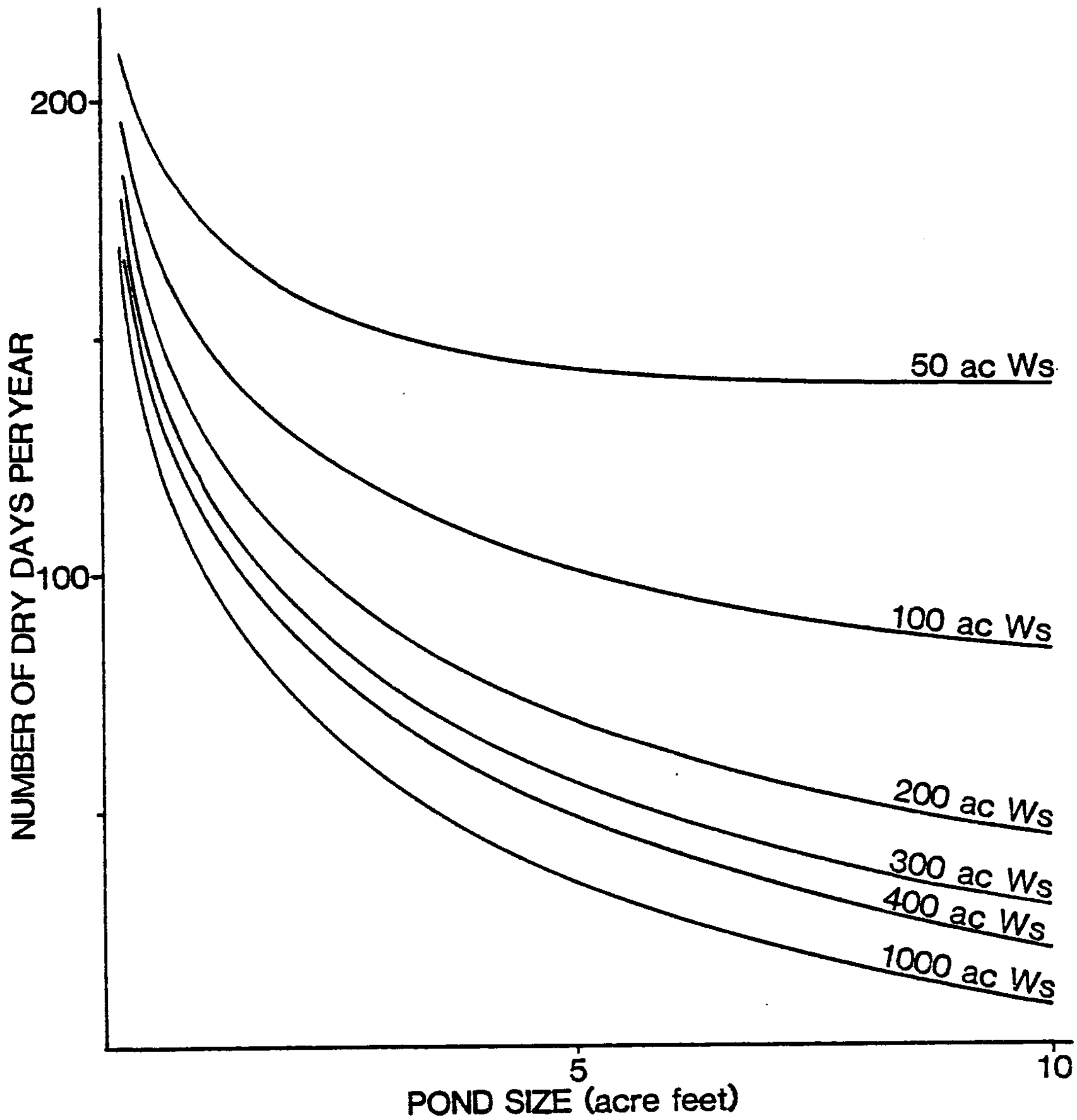


Figure 17. Number of dry days per year for triangular pond with a seepage rate of 0.02 feet per day based on 200 years simulation for Walnut Gulch.

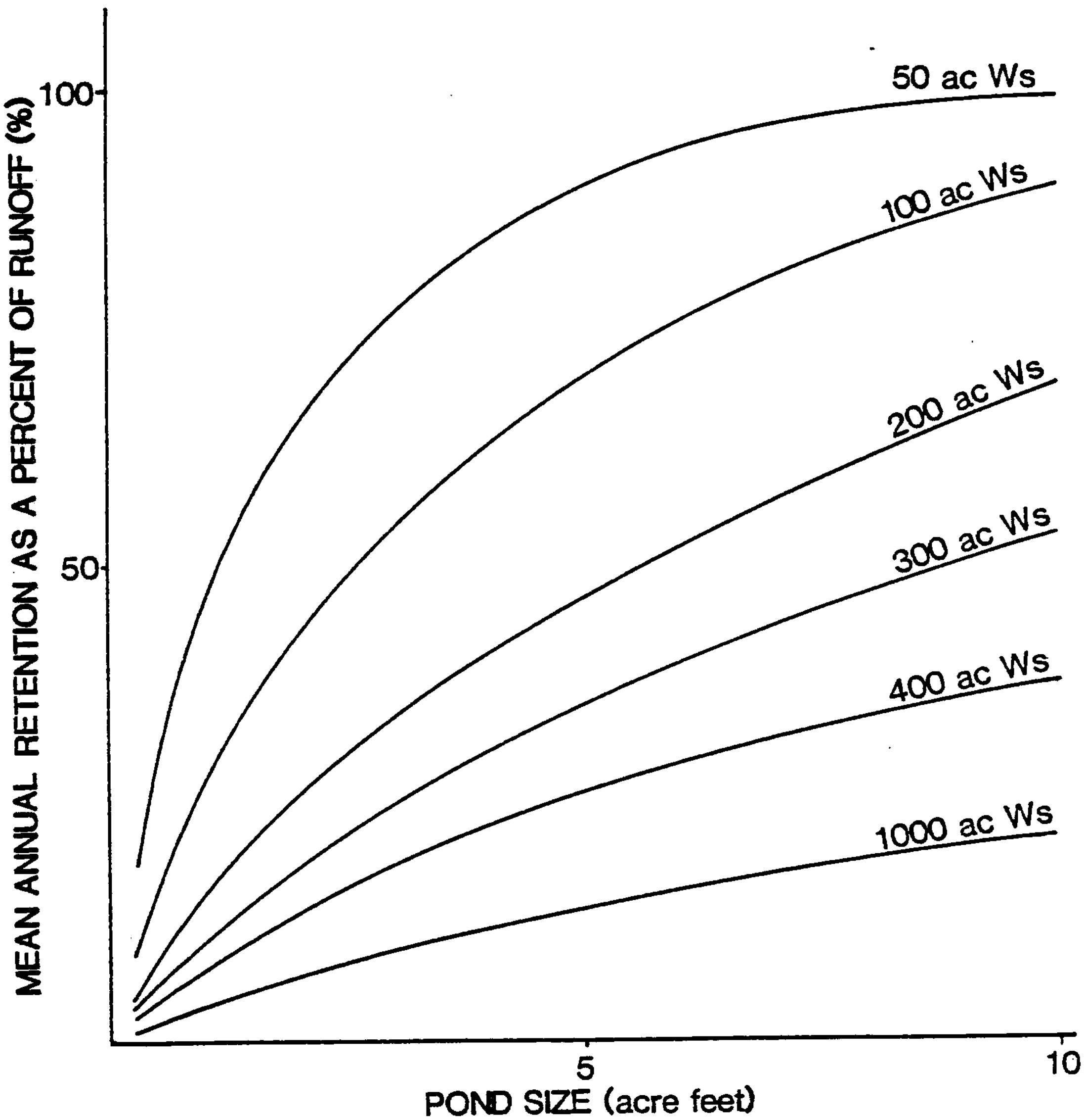


Figure 18. Mean annual retention as a percent of runoff for triangular pond with a seepage rate of 0.02 feet per day based on 200 years simulation for Walnut Gulch.

Livestock Use

The water consumption by cattle was believed to be low because of the strict grazing controls on the watershed. However, this component of loss was included in the program for completeness. The same assumptions made on livestock use in the Beaver Creek study (Almestad 1983) were employed in this study.

SUMMARY OF RESULTS

The output tables of the synthesis programs, which are the results of this study, are contained in an appendix on file in the School of Renewable Natural Resources. For the given watershed sizes pond capacities, seepage rates, and pond geometries, the following are given in each of the output tables:

1. Mean annual spill - The average annual amount of water spilled from the pond during the 200 year simulation. This quantity is given in watershed inches, cubic feet and acre feet. The standard deviation is given in acre feet and watershed inches. Confidence limits may be calcultaed by:

$$\bar{x} \pm t_{.05} \sqrt{S / n}$$

where: $\bar{x}$ = mean

$t_{.05}$ = student t at the 95 percent confidence level

s = standard deviation

n = number of years simulated

The confidence limits for the examples given in tables 8, 9, and 10 are, 12.51 $\pm$ 1.55, 10.89 $\pm$ .09 and 9.86 $\pm$ 1.43 acre-feet respectively.

2. Mean annual retention - The mean annual amount of water withheld by the pond from the downstream channel(s). This was calculated by subtracting the total spill per year

from the total annual runoff. The calculations are given in watershed inches and acre feet, and confidence limits may be calculated as above. For the three examples given, the confidence limits are 3.99 ± 0.16, 5.61 ± 0.26 and 6.64 ± 0.34 acre feet respectively.

3. Median of Retention - The median quantity of water retained by the pond over the 200 year simulation period. For all cases, the median of retention was very close to the average retention which indicates the absence of skew in the distribution of annual values.

Table 8. An example of output table of 3.0 acre feet pond in 200 acres watershed with a seepage rate of 0.00 ft/day.

```
POND SIZE =  3.00 ACRE FEET     MAXIMUM DEPTH =   7.21 FEET

MEAN ANNUAL SPILL =    .7504 INCHES        544809.0 CUBIC FEET      12.507 ACRE FEET
STANDARD DEVIATION OF SPILL =     .672 INCHES        11.199 ACRE FEET

MEAN ANNUAL RETENTION =    .2393 INCHES        173748.2 CUBIC FEET        3.989 ACRE FEET
STANDARD DEVIATION OF RETENTION =     .0683 INCHES        1.138 ACRE FEET
MEDIAN OF RETENTION =    .2382 INCHES        3.970 ACRE FEET
MEAN ANNUAL RETENTION AS A PERCENT OF RUNOFF =  24.180
FILL FACTOR =     1.33

M3AN ANNUAL NUMBER OF DRY DAYS =    4.755          STANDARD DEVIATION =  25.651
```

MONTHLY DRY DAYS DISTRIBUTIONS

MONTH	DRY DAY MEAN	NUMBER OF YEARS IN EACH DRY DAY CLASS 0	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27
JANUARY	.465	196	1	0	0	0	0	0	0	0	0
FEBRUARY	.620	196	0	0	0	0	0	0	0	0	0
MARCH	.635	195	1	0	0	0	0	0	0	0	0
APRIL	.710	195	0	0	0	0	0	0	0	0	0
MAY	.810	194	0	0	1	0	0	0	0	0	0
JUNE	.900	191	2	0	0	1	0	1	0	0	0
JULY	.320	193	3	1	1	0	0	0	1	0	1
AUGUST	.055	198	1	0	1	0	0	0	0	0	0
SEPTEMBER	0.000	200	0	0	0	0	0	0	0	0	0
OCTOBER	0.000	200	0	0	0	0	0	0	0	0	0
NOVEMBER	0.000	200	0	0	0	0	0	0	0	0	0
DECEMBER	.230	197	0	0	1	1	0	0	0	0	0

Table 9. An example of output table of 3.0 acre feet pond in 200 acres watershed with a seepage rate of 0.02 ft/day.

POND SIZE = 3.00 ACRE FEET MAXIMUM DEPTH = 7.21 FEET

MEAN ANNUAL SPILL = .6534 INCHES 474344.6 CUBIC FEET 10.889 ACRE FEET
STANDARD DEVIATION OF SPILL = .646 INCHES 10.760 ACRE FEET

MEAN ANNUAL RETENTION = .3364 INCHES 244212.7 CUBIC FEET 5.606 ACRE FEET
STANDARD DEVIATION OF RETENTION = .1117 INCHES 1.861 ACRE FEET
MEDIAN OF RETENTION = .3243 INCHES 5.405 ACRE FEET
MEAN ANNUAL RETENTION AS A PERCENT OF RUNOFF = 33.987
FILL FACTOR = 1.87

MEAN ANNUAL NUMBER OF DRY DAYS = 90.610 STANDARD DEVIATION = 64.199

MONTHLY DRY DAYS DISTRIBUTIONS

MONTH	DRY DAY MEAN	NUMBER OF YEARS IN EACH DRY DAY CLASS: 0	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27
JANUARY	6.425	130	4	7	3	11	4	9	3	5	3
FEBRUARY	10.540	114	5	4	3	3	3	1	4	4	6
MARCH	13.350	95	2	3	2	4	8	6	4	3	3
APRIL	14.035	84	6	3	5	3	0	5	1	3	3
MAY	17.830	62	5	6	4	6	4	2	4	2	5
JUNE	18.645	55	6	2	8	1	5	4	2	4	7
JULY	5.545	96	27	17	13	10	13	5	5	2	4
AUGUST	.875	179	5	4	4	3	2	2	1	0	0
SEPTEMBER	.105	195	3	0	1	1	0	0	0	0	0
OCTOBER	.405	193	2	1	1	0	1	0	1	0	0
NOVEMBER	.755	192	1	1	1	0	0	1	0	0	0
DECEMBER	1.995	177	1	5	2	4	0	0	0	2	2

Table 10. An example of output table of 3.0 acre feet pond in 200 acres watershed with a seepage rate of 0.05 ft/day.

```
POND SIZE =  3.00 ACRE FEET      MAXIMUM DEPTH =   7.21 FEET

MEAN ANNUAL SPILL =    .5917 INCHES        429546.5 CUBIC FEET       9.861 ACRE FEET
STANDARD DEVIATION OF SPILL =     .621 INCHES       10.344 ACRE FEET

MEAN ANNUAL RETENTION =    .3981 INCHES        289010.7 CUBIC FEET       6.635 ACRE FEET
STANDARD DEVIATION OF RETENTION =    .1454 INCHES        2.424 ACRE FEET
MEDIAN OF RETENTION =    .3906 INCHES        6.511 ACRE FEET
MEAN ANNUAL RETENTION AS A PERCENT OF RUNOFF =  40.221
FILL FACTOR =     2.21

MEAN ANNUAL NUMBER OF DRY DAYS = 167.405          STANDARD DEVIATION =  53.000
```

MONTHLY DRY DAYS DISTRIBUTIONS

MONTH	DRY DAY MEAN	NUMBER OF YEARS IN EACH DRY DAY CLASS: 0	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27
JANUARY	18.035	45	9	4	10	4	9	7	8	8	6
FEBRUARY	22.270	31	4	4	4	5	5	7	5	7	13
MARCH	23.250	28	1	3	6	5	3	5	10	7	5
APRIL	21.515	30	4	7	2	5	1	3	2	6	5
MAY	24.430	19	3	5	4	5	6	8	5	3	2
JUNE	24.155	19	10	2	3	1	4	3	2	5	7
JULY	7.795	68	29	23	17	9	13	11	4	6	6
AUGUST	1.485	169	6	7	6	5	3	0	1	1	1
SEPTEMBER	.800	186	4	2	1	0	2	3	0	1	0
OCTOBER	1.925	168	8	4	5	3	2	1	2	1	3
NOVEMBER	7.180	109	8	10	13	10	8	8	5	2	8
DECEMBER	14.135	77	8	7	8	5	6	7	2	3	5

Table 11. Mean Annual Spillage for Triangular Pond with a Seepage Rate of .02 inches/day based on 200 years Simulation for Walnut Gulch.

Pond size (acre-feet)	Watershed size (acre)					
	50	100	200	300	400	1000
		------- (acre-feet) --------				
0.25	3.3	7.3	15.5	23.7	31.9	81.3
0.5	2.8	6.7	14.8	23.0	31.2	80.5
0.75	2.5	6.3	14.2	22.4	30.5	79.8
1.0	2.2	5.9	13.8	21.8	30.0	79.2
2.0	1.4	4.6	12.1	20.1	28.0	76.9
3.0	0.8	3.7	10.8	18.6	26.4	75.0
4.0	0.5	2.9	9.7	17.2	24.9	73.2
5.0	0.3	2.3	8.7	16.0	23.6	71.5
10.0	0.0	.7	5.1	11.3	18.3	64.5

Table 12. Number of Dry Days per year for Triangular Pond with a Seepage Rate of .02 inches/day based on 200 years simulation for Walnut Gulch.

Pond size (acre-feet)	Watershed size (acre)					
	50	100	200	300	400	1000
	---------(days) --------					
0.25	210	196	184	179	176	168
0.50	192	171	157	150	145	139
0.75	182	159	141	133	128	116
1.0	175	151	131	122	166	104
2.0	160	130	106	94	88	74
3.0	151	117	90	77	70	56
4.0	146	107	78	65	58	43
5.0	143	100	69	51	49	34
10.00	140	83	44	31	23	12

Table 13. Mean Annual Retention as a percentage of Runoff for Triangular Pond with a Seepage Rate of .02 inches/day based on 200 years simulation for Walnut Gulch.

Pond size (acre-feet)	Watershed sizes (acre)					
	50	100	200	300	400	1000
	---------- (%) ---------					
0.25	19	10	5	4	3	1
0.5	30	17	9	6	5	2
0.75	38	23	13	9	7	3
1.0	45	28	16	11	9	3
2.0	66	43	26	18	14	6
3.0	79	54	33	25	19	9
4.0	87	63	40	30	24	11
5.0	91	71	46	35	28	13
10.0	99	90	69	53	44	21

CONCLUSIONS

This study was part of a larger project dealing with the problems of adjudicating surface water rights in Arizona. Although the results of this study may be used for this purpose in the desert scrub vegetation zone of southern Arizona, they are limited by several factors which were not considered. These factors include the lack of actual data on seepage rates from ponds, the problems associated with the spatial distribution of rainfall, and water lost by transmission through the stream channels. In this study, a range of seepage rates were used, which were believed to include those that might be found in the field. This is presently being investigated in another aspect of the larger project. Uniform rainfall over a watershed was assumed in this study. Thus, the methods developed should not be applied to watersheds much larger than one square mile. Furthermore, transmission losses in the channels of larger watersheds may also give rise to errors. These problems are also being studied in the larger project.

Ultimately the results of this study will be incorporated into a regional model that will better account for seepage, as well as the spatial distribution of rainfall and channel transmission losses.

APPENDIX A

THE LIST OF COMPUTER PROGRAM, PONDY

```
FTN7X
*FILES 1,1
      PROGRAM PONDY,,150
C     THIS PROGRAM DETERMINES STOCK POND PERFORMANCE BY SIMULATING WATERSHED
C     RAINFALL/RUNOFF FOR ANY NUMBER OF YEARS AND ROUTING THE RUNOFF THROUGH
C     THE STOCK POND. AS PRESENTLY SET UP, THIS PROGRAM SIMULATES 6 WATER-
C     SHEDS AND 9 STOCK PONDS FOR 200 YEARS. THIS PROGRAM IS A COUPLED
C     STOCHASTIC/DETERMINISTIC MODEL. OUTPUT GIVES STATISTICS ON RETENTION,
C     SPILLAGE, AND THE NUMBER OF DRY DAYS. IF DESIRED, OUTPUT CAN ALSO BE
C     WRITTEN TO A TAPE. RAINFALL IS SIMULATED BY USING TWO DIFFERENT TYPE
C     MODELS (ONE FOR SUMMER CONVECTIVE STORM, OTHER FOR WINTER FRONTAL STORM).
C     RUNOFF IS SIMURATED BY USING S.C.S. METHOD WITH ANTECEDENT MOISTURE
C     CONDITION. THIS MODEL WAS WRITTEN BY C. ALMESTAD AND MODIFIED BY
C     Y. KIYOSE.

C     **********   LIST OF VARIABLES TO INITIALIZE    *****************
C              PRECIPITATION MODEL PARAMETERS
C     IDCDSP(CLUSTER #)= IDENTIFICATION CODE FOR SUMMER PPT DISTRIBUTION
C                           1:EXPONENTIAL
C                           2:FIXED/EXP.
C                           3:GEOMETRIC
C                           4:FIXED/GEO.
C     IDCDSI(CLUSTER #)= ID. CODE FOR SUMMER INTERARRIVAL TIME
C
C     MGEWLG=    M   GE   W   LG
C     MGEWGS=    M   EX   +   GS
C     MGEWDG=    M   +    +   DG
C     MEXWDS=    M   +    +   DS
C     MGEWPT=    M   +    +   PT
C                +   +    +   +
C                M:MEAN VALUE
C                    +    +   +
C                    GE:GEOMETRIC DISTRIBUTION
C                    EX:EXPONENTIAL DISTRIBUTION
C                         +   +
C                         W:WINTER PRECIP. MODEL
C                             +
C                             LG:LENTH OF GROUP
C                             GS:GROUPS PER SEQUENCE
C                             DG:DRY DAYS BETWEEN GROUPS
C                             DS:DRY DAYS BETWEEN SEQUENCES
C                             PT:PRECIPITATION AMOUNT
C
C     MEXSP(CLUSTER #)=       M   EX   S   P
C     MGESI(CLUSTER #)=       M   GE   S   I
C     FGESI(CLUSTER #)=       F   GE   S   I
C                             +   +    +   +
C                             M:MEAN VALUE
C                             F:FIXED PROBABILITY
C                                 +    +   +
C                                 EX:EXPONENTIAL DISTRIBUTION
C                                 GE:GEOMETRIC DISTRIBUTION
C                                      +   +
C                                      S:SUMMER PRICIP. MODEL
C                                          +
C                                          P:PRECIPITATION AMOUNT
C                                          I:INTERARRIVAL TIME
C
C              OUTPUT VARIABLES
C     LP=         LINE PRINTER LOGICAL UNIT NUMBER
C     LTAPE=      MAG. TAPE LOGICAL UNIT NUMBER
C     LPRN1=      WRITE OUT DAILY TEMP. VALUES
C     LPRN2=      WRITE OUT DAILY PRECIP. VALUES
C     LPRN3=      WRITE OUT DAILY RUNOFF VALUES
C     LPRN4=      WRITE OUT DAILY STAGE, SPILL, AND STORAGE
C     LPRN5=      WRITE OUT DAILY AVAILABLE MOISTURE
C     LPRN6=      WRITE OUT ANNUAL WINTER/SUMMER RUNOFF
C           (FOR LPRN1-LPRN6, NUMBER = NUMBER OF YEARS TO WRITE OUT)
C     LPRN7=      WRITE OUT ANNUAL SPILL, DRY DAYS, AND RETENTION
C     LPRN8=      WRITE TO TAPE YEARLY SPILL, DRY DAYS, AND RETENTION
C           (FOR LPRN7&LPRN8, 0 = DO NOT WRITE)
C
C     NYEARS=     NUMBER OF YEARS TO SIMULATE
C     NPONDS=     NUMBER OF PONDS TO SIMULATE
C     NACRE=      NUMBER OF WATERSHED SIZES TO SIMULATE
C              TEMPERATURE MODEL PARAMETERS
C     TAVE=       MEAN ANNUAL MAXIMUM TEMPERATURE
C     AMP=        AMPLITUDE OF COSINE FUNCTION
```

```
C     PEAK=      PEAK TEMP. DAY OF YEAR
C     TMAX=      INITIAL STARTING MAXIMUM TEMPERATURE
C     R=         LAG ONE SERIAL CORRELATION
C     SKEW=      SKEW OF THE DAILY TEMPERATURES ABOUT THE DAILY MEAN
C     STDEV( )=ARRAY OF MONTHLY AVERAGE STANDARD DEVIATIONS OF MAXIMUM
C                TEMPS. ABOUT DAILY MEAN
C              PRECIPITATION TYPE PARAMETERS
C     STEMP=     DAILY MAXIMUM TEMPERATURE BELOW WHICH SNOW OCCURS
C     RTEMP=     DAILY MAXIMUM TEMPERATURE ABOVE WHICH RAIN OCCURS
C              EVAPORATION REGRESSION EQUATION COEFFICIENTS
C     EM1A=      CONSTANT FOR MONTHLY EQUATION (JAN.1-JUNE 30)
C     EM1B=      TEMP. COEFF. FOR MONTHLY EQN. (JAN. 1-JUNE 30)
C     EM2A=      CONSTANT FOR MONTHLY EQN. (JULY 1-DEC. 31)
C     EM2B=      TEMP. COEFF. FOR MONTHLY EQN. (JULY 1-DEC. 31)
C     ED1A=      CONSTANT FOR DAILY EQN. (JAN. 1-JUNE 30)
C     ED1B=      TEMP. COEFF. FOR DAILY EWN. (JAN. 1-JUNE 30)
C     ED2A=      CONSTANT FOR DAILY EQN. (JULY 1-DEC. 31)
C     ED2B=      TEMP. COEFF. FOR DAILY EQN. (JULY 1-DEC. 31)
C              STOCK POND PARAMETERS
C     PTYPE=     CODE FOR POND GEOMETRY (1=TRIANGULAR,4=TRAPEZOIDAL)
C     SRATE=     SEEPAGE RATE
C     U( )=      AREA FACTORS (CONSTANTS) FOR PONDS
C     V( )=      VOLUME FACTORS (CONSTANTS) FOR PONDS
C     W( )=      MAXIMUM DEPTHS FOR EACH POND
C     PSIZE( )=POND SIZES IN ACRE FEET
C     ACRE( )= ACREAGES OF WATERSHEDS TO BE SIMULATED
C              LIVESTOCK PARAMETERS
C     COWS=      NUMBER OF LIVESTOCK USING POND
C     DRINK=     DAILY CONSUMPTION OF WATER BY LIVESTOCK (GALLONS)
C     NFD1=      FIRST DAY OF FIRST GRAZING PERIOD
C     NLD1=      LAST DAY OF FIRST GRAZING PERIOD
C     NFD2=      FIRST DAY OF SECOND GRAZING PERIOD
C     NLD2=      LAST DAY OF SECOND GRAZING PERIOD
C   ***********************************************************************

      DIMENSION JDSPST(5),JDSPEN(5),JDSIST(5),JDSIEN(5),
     +           IDCDSP(5),IDCDSI(5)

      REAL MGEWLG,MGEWGS,MGEWDG,MEXWDS,MGEWPT
      REAL MEXSP(5),MGESP(5),FEXSI(5),MEXSI(5),MGESI(5),FGESI(5)

      REAL PPT(3,600),M(10),RAIN(366),TRAIN2(200)
      REAL STDEV(12),TEMP(366),SPILL2(200,9),NDRY(200,9)

      REAL ACRE(6),AMOIST(182),Q(366),TQQ(200)
      REAL ALPHA(36),U(9),V(9),STLAST(9),HLAST(9)
      REAL PSIZE(9),W(9),SPL(200),PGEU(6)
      REAL RET(200)
      INTEGER MDRY(12,9),IMDRY(12),ICDRY(12,9,12)
      INTEGER DBG,PEAK
      INTEGER PTYPE
      COMMON/OUT/TEMP,RAIN,AMOIST,Q,NUM2,ILEAP,LP
      DATA ALPHA/4HJANU,4HARY ,4H    ,4HFEBR,4HUARY,4H    ,4HMARC,
     +4HH   ,4H    ,4HAPRI,4HL   ,4H    ,4HMAY ,4H    ,4H    ,4HJUNE,
     +4H    ,4H    ,4HJULY,4H    ,4H    ,4HAUGU,4HST  ,4H    ,4HSEPT,
     +4HEMBE,4HR   ,4HOCTO,4HBER ,4H    ,4HNOVE,4HMBER,4H    ,4HDECE,
     +4HMBER,4H    /

      DATA STDEV/7.3445,8.4054,8.2434,7.1166,7.0554,6.5621,
     +           6.2545,4.5423,5.7809,8.4622,9.2330,8.7635/

      DATA PGEO/4HTRIA,4HNGUL,4HAR  ,4HTRAP,4HEZOI,4HDAL /

      DATA W/3.1498026,3.9685026,4.5428015,5.0,6.2996052,7.2112479,
     +7.9370053,8.5498797,10.772173/
      DATA PSIZE/0.25,0.5,0.75,1.,2.,3.,4.,5.,10./
      DATA ACRE/50.,100.,200.,300.,400.,1000./

      OPEN(45,FILE='@PSAVE',STATUS='NEW')

      DO 111 I=1,9
        U(I)=1045.4375
        V(I)=348.48
  111 CONTINUE

      LTAPE=8
```

```
      LPRN1=0
      LPRN2=0
      LPRN3=0
      LPRN4=0
      LPRN5=0
      LPRN6=0
      LPRN7=0
      LPRN8=0

C***ICH. 1 FOR PRINTING EACH PPT & RO (AFTER YR. 4)
      ICHECK=0

C*** IECYR =1 FOR PRINTING EACH YR. SIMU. SUMMARRY


      NPOND=9
      NACRE=6
C TEMPERATURE PARAMETERS (ALSO STDDEV DATA STATEMENT ABOVE)
      TAVE=76.3454
      AMP=18.282
      PEAK=200
      TMAX=60.14

      R=0.640
      SKEW=-0.348


C  WINTER MODEL CALIBRATION PARAMETERS
      SMI=17.96
      DEPLET=0.0000327
      ICALIB=0
C  SUMMER CURVE NUMBER QUADRATIC REGRESSION COEFFICIENTS
      B0=98.265125
      B1=-22.630338
      B2=6.8136245
C  EVAPORATION REGRESSION EQUATION COEFFICIENTS
      EM1A=-8.716409709
      EM1B=0.194798708
      EM2A=-10.42664959
      EM2B=0.201238694
      ED1A=-0.290344934
      ED1B=0.006444847
      ED2A=-0.341412516
      ED2B=0.006568046

C*******CHANGE FOR EACH RUN***************************************
      NYEARS=200
      IECYR=0
      LP=45
C  POND PARAMETERS  (ALSO DATA STATEMENTS U,V,W, AND PSIZE ABOVE)
      PTYPE=4
      SRATE=0.02

C  LIVESTOCK PARAMETERS
      COWS=31.00
      DRINK=10.0
      NFD1=152
      NLD1=212
      NFD2=213
      NLD2=151
C
C********** NEW VARIABLES FOR PPT MODEL **********
C           (INITIALIZE VARIABLES)

      IDCDSP(1)=1
      IDCDSP(2)=1
      IDCDSI(1)=4
      IDCDSI(2)=3
      IDCDSI(3)=4

      MGEWLG=1.542
      MGEWGS=1.773
      MGEWDG=1.974
      MEXWDS=16.980
      MGEWPT=0.287

      MEXSP(1)=0.168
      MEXSP(2)=0.309
```

```
      MGESI(1)=19.625
      FGESI(1)=0.17949
      MGESI(2)=3.002
      FGESI(3)=0.30288
      MGESI(3)=11.359

C  END VARIABLE INITIALIZATION

      SS=SQRT(1.-(R**2))
      SK=(1.-R**3)*SKEW/((1.-R*R)**1.5)
      COWVOL=COWS*DRINK/7.48

C  START SIMULATION ************************************************
C   START OF LOOP FOR EACH WATERSHED SIZE
      DO 4000 KKKK=1,NACRE
      WRITE(LP,50) ACRE(KKKK),NYEARS,SRATE
   50 FORMAT(/////," ",/,1X,20("*"),3X,"STOCK POND SIMULATION FOR ",
     +I5," ACRE WATERSHED",3X,20("*"),//,10X,"NUMBER OF YEARS SIMULATED
     += ",I4,/,10X,"SEEPAGE RATE = ",F5.3," FEET/DAY")

      IXX=PTYPE+1
      IXX2=PTYPE+2
      WRITE(LP,55) PGEO(PTYPE),PGEO(IXX),PGEO(IXX2)
   55 FORMAT(10X,"POND TYPE = ",3(A4))

      I1=0
      I2=2309
      TLAST=TMAX

      DO 75 LL=1,NPOND
      DO 65 N=1,12
      MDRY(N,LL)=0
      DO 60 I=1,12
      ICDRY(N,LL,I)=0
   60 CONTINUE
   65 CONTINUE

      DO 70 J=1,NYEARS
      SPILL2(J,LL)=0.0000
      NDRY(J,LL)=0.0000
   70 CONTINUE

      STLAST(LL)=0.0000
      HLAST(LL)=0.0000
   75 CONTINUE

      DO 80 I=1,NYEARS
      TQQ(I)=0.0000
      TRAIN2(I)=0.0000

   80 CONTINUE
      LDAY=0
      TTOT2=0
      PAVE=0.000
      LCOUNT=0
      NYEAR=NYEARS+1

      ATVOL=0.0

C START OF ANNUAL LOOP   ********************************************
      DO 3000 JJJJ=1,NYEAR


      JXXX=JJJJ-1
      SM=SMI
      DSNOW=0.0000
      TEV=0.00000
      DSNO=0.0000
      QQ=0.00000
      TQ1=0.0000
      TQ2=0.0000
      TQ3=0.0000
      WRAIN=0.0000
      SRAIN=0.0000
      TRAIN=0.0000
      JDAY=0
```

```
      DO 90 I=1,366
      RAIN(I)=0.00
      TEMP(I)=0.00
      Q(I)=0.0000
   90 CONTINUE
      DO 100 I=1,182
      AMOIST(I)=0.000
  100 CONTINUE
C LEAP YEAR DETERMINATION
      ILEAP=0
      LCOUNT=LCOUNT+1
      IF(LCOUNT.EQ.4) ILEAP=1
      IF(LCOUNT.EQ.4) LCOUNT=0

      N1=30
      N2=61
      N3=92
      N4=120+ILEAP
      N5=151+ILEAP
      N6=181+ILEAP
      N7=212+ILEAP
      N8=242+ILEAP
      N9=273+ILEAP
      N10=304+ILEAP
      N11=334+ILEAP
      N12=365+ILEAP

C******* INITIALIZE THE JULIAN DATE FOR EACH GROUP (START & END) **********

      JDWST=335+ILEAP
      JDWEN=90+ILEAP
      JDYEN=365+1

      JDSPST(1)=91+ILEAP
      JDSPEN(1)=181+ILEAP
      JDSPST(2)=182+ILEAP
      JDSPEN(2)=334+ILEAP
      JDSIST(1)=91+ILEAP
      JDSIEN(1)=181+ILEAP
      JDSIST(2)=182+ILEAP
      JDSIEN(2)=243+ILEAP
      JDSIST(3)=244+ILEAP
      JDSIEN(3)=334+ILEAP

C  TEMPERATURE MODEL ******************************************
      TTOT=0.000
      DO 120 JJ=1,JDYEN
      IF(JJ.LE.61) J=304+JJ+ILEAP
      IF(JJ.GT.61) J=JJ-61
      TMEAN=TAVE+AMP*COS(6.2831853*(J-PEAK)/(365.+ILEAP))
      IF(J.LE.31) STD=STDEV(1)
      IF(J.GT.31.AND.J.LE.59+ILEAP) STD=STDEV(2)
      IF(J.GT.59+ILEAP.AND.J.LE.90+ILEAP) STD=STDEV(3)
      IF(J.GT.90+ILEAP.AND.J.LE.120+ILEAP) STD=STDEV(4)
      IF(J.GT.120+ILEAP.AND.J.LE.151+ILEAP) STD=STDEV(5)
      IF(J.GT.151+ILEAP.AND.J.LE.181+ILEAP) STD=STDEV(6)
      IF(J.GT.181+ILEAP.AND.J.LE.212+ILEAP) STD=STDEV(7)
      IF(J.GT.212+ILEAP.AND.J.LE.243+ILEAP) STD=STDEV(8)
      IF(J.GT.243+ILEAP.AND.J.LE.273+ILEAP) STD=STDEV(9)
      IF(J.GT.273+ILEAP.AND.J.LE.304+ILEAP) STD=STDEV(10)
      IF(J.GT.304+ILEAP.AND.J.LE.334+ILEAP) STD=STDEV(11)
      IF(J.GT.334+ILEAP.AND.J.LE.365+ILEAP) STD=STDEV(12)
      XX=0.

      DO 110 I=1,12
      CALL RANDM(I1,I2,X)

      XX=XX+X
  110 CONTINUE
      XNORM=XX-6.
      XGAMA=(2/SK)*((1.+((SK*XNORM)/6)-(SK**2/36))**3)-2/SK
      TEMP(JJ)=TMEAN+((TLAST-TMEAN)*R)+(XGAMA*STD*SS)
      TTOT=TTOT+TEMP(JJ)
      TLAST=TEMP(JJ)
  120 CONTINUE

      IF(JJJJ.EQ.1) GO TO 200
```

```
      AVTEMP=TTOT/JDYEN
      TTOT2=TTOT2+AVTEMP
C   WRITE OUT DAILY TEMPERATURE VALUES
      IF(LPRN1.EQ.0) GO TO 135
      IF(JXXX.GT.LPRN1) GO TO 200
      WRITE(LP,130) JXXX
  130 FORMAT(//,10X,30("*"),3X,"MAXIMUM TEMPERATURES YEAR  ",I3,3X,
     +30("*"),/)
      NUM2=1
      CALL OUTPT

  135 IF(IECYR.EQ.0) GO TO 200

      WRITE(LP,136) JJJJ
  136 FORMAT(//,5X,"*** ANNUAL SUMMARY FOR YR. ",I3," ***")

      WRITE(LP,140) AVTEMP
  140 FORMAT(/,10X,"ANNUAL AVERAGE MAXIMUM TEMP. = ",F6.2,/)

C    WINTER PRECIPITATION    *************************************
C
C      DETERMINE THE NUMBER OF DAYS BETWEEN SEQUENCES (B)
  200 CALL RANDM(I1,I2,X)

      NINT=INT(ALOG(1-X)*(-MEXWDS)+1.0)+3
C***** SKIP GEO. *****
      GO TO 202

      P=1./MGEWDS
      NINT=INT((ALOG(1-X))/(ALOG(1-P))+1.0)+3

  202 JDAY=JDAY+NINT


  205 IF(JDAY.GT.JDWEN.AND.JDAY.LE.JDWST) GO TO 250
      IF(JDAY.GT.JDYEN) GO TO 400

C   DETERMINE THE NUMBER OF GROUPS PER SEQUENCE (ANO)

      CALL RANDM(I1,I2,X)
      P=1./MGEWGS


      NGRPS=INT((ALOG(1.-X))/(ALOG(1.-P))+1.0)

C   DETERMINE RAIN/GROUP,DRY DAYS BETWEEN GROUPS,NUMBER OF DAYS/GROUP

      JJ=1
      I=1

      DO 220 JJ=1,NGRPS
      CALL RANDM(I1,I2,X)

C   LENGTH OF GROUP

      P=1./MGEWLG
      LG=INT((ALOG(1-X))/(ALOG(1-P))+1.0)


C   PRECIP. PER GROUP

      CALL RANDM(I1,I2,X)
      P=1.0/(MGEWPT*10.0)
      PRECIP=(ALOG(1-X))/(ALOG(1-P))/10.0
      RPT=PRECIP/LG


         DO 210 I=1,LG
              JDAY=JDAY+1
```

```
          IF(JDAY.GT.JDYEN) GO TO 400

          RAIN(JDAY)=RPT

  210 CONTINUE

      IF(JDAY.GT.JDWEN.AND.JDAY.LT.JDWST) GO TO 230
      IF(JJ.EQ.NGRPS) GO TO 230

      CALL RANDM(I1,I2,X)
      P=1./MGEWDG
C   DAYS BETWEEN GROUPS
      DBG=INT((ALOG(1-X))/(ALOG(1-P))+0.5)
      IF(DBG.EQ.0) DBG=1
      IF(DBG.GT.3) DBG=3
  216 JDAY=JDAY+DBG
  220 CONTINUE
  230 IF(JDAY.LT.JDWEN.OR.JDAY.GE.JDWST) GO TO 200
      IF(JDAY.GT.JDYEN) GO TO 400
C    ******** SUMMER PPT *********************
  250 IIN=1
      JPT=1
      JDAY=JDWEN+1

C***** FOR INTERVAL ******
  300 CALL RANDM(I1,I2,X)

      IF(IDCDSI(IIN).EQ.2) GO TO 310
      IF(IDCDSI(IIN).EQ.4) GO TO 290
C** (GEO.) **
          P=1.0/MGESI(IIN)

          NINT=INT((ALOG(1-X))/(ALOG(1-P))+1.0)
      GO TO 312
C** (FIX./GEO.) **
  290     IF(X.GT.FGESI(IIN)) GO TO 291
          NINT=1
          GO TO 312
  291     P=1.0/MGESI(IIN)

          NINT=INT((ALOG(1-X))/(ALOG(1-P))+1.5)
          GO TO 312
C** (FIX./EXP.) **
  310     IF(X.GT.FEXSI(IIN)) GO TO 311
          NINT=1
          GO TO 312
  311     XTR=(X-FEXSI(IIN))/(1.0-FEXSI(IIN))

          NINT=INT((ALOG(1-XTR))*(-MEXSI(IIN))+1.5)
  312 JDAY=JDAY+NINT
```

```
      IF(JDAY.LT.JDWST) GO TO 333
         JDAY=JDWST
         GO TO 200

  333 IF(JDAY.LE.JDS1EN(IIN)) GO TO 313
         IIN=IIN+1
         JDAY=JDSIST(IIN)

  313 IF(JDAY.LE.JDSPEN(JPT)) GO TO 314
         JPT=JPT+1

C***** PPT. *****

  314 CALL RANDM(I1,I2,X)


      IF(IDCDSP(JPT).EQ.1) GO TO 315

C** (GEO.) **
          P=1.0/(MGESP(JPT)*10.0)
          PRECIP=(ALOG(1-X)/(ALOG(1-P))/10.0)

      GO TO 316

C** (EXP.) **
  315  IF(JDAY.GE.182.AND.JDAY.LE.243) GO TO 320
          PRECIP=(ALOG(1-X)*(-MEXSP(JPT)))
       GO TO 316

C***** SEPARATE PPT).7 FOR 7,8 *****
  320     IF(X.GT.0.87326) GO TO 330
            PRECIP=(ALOG(1-X)*(-MEXSP(JPT)))
       GO TO 316

  330     XCONV=(X-0.87326)/0.12674
          SPECIM=0.4421

            P=1.0/(SPECIM*10.0)
              PRECIP=(ALOG(1.0-XCONV)/(ALOG(1.0-P))/10.0)+0.7
C           PRECIP=(ALOG(1.0-XCONV))*(-(SPECM))+0.7

  316 RAIN(JDAY)=PRECIP

      GO TO 300


C  ANNUAL PRECIPITATION SUMMATION ****************************************
  400 IF(JJJJ.EQ.1) GO TO 450
      DO 410 I=1,JDYEN
      IF(I.LE.JDWEN.OR.I.GE.JDWST) WRAIN=WRAIN+RAIN(I)
      IF(I.GT.JDWEN) SRAIN=SRAIN+RAIN(I)
  410 CONTINUE
      TRAIN=WRAIN+SRAIN
      PAVE=TRAIN+PAVE
      TRAIN2(JXXX)=TRAIN

C  WRITE OUT YEARLY PRECIPITATION RECORD  *************************
      IF(LPRN2.EQ.0) GO TO 430
      IF(JXXX.GT.LPRN2) GO TO 450

      WRITE(LP,420) JXXX
  420 FORMAT(10X,30("*"),3X,"PRECIPITATION YEAR  ",I3,3X,30("*"),/)
      NUM2=2
      CALL OUTPT

  430 IF(IECYR.EQ.0) GO TO 450

      WRITE(LP,440) WRAIN,SRAIN,TRAIN
  440 FORMAT(1X,5X,"TOTAL WINTER PRECIP. = ",F5.2,15X,"SUMMER RAIN = "
     +,F5.2,15X,"ANNUAL TOTAL = ",F5.2)
```

```
C  WATERSHED RUNOFF MODELS ********************************************
C   WINTER  ******************

C  SUMMER RUNOFF *********************************************
 450 NST=1
     NEN=JDYEN
     DO 540 I=NST,NEN
     IF(RAIN(I).EQ.0.0000) GO TO 540

     IF(ICHECK.EQ.0) GO TO 541

     IF(JJJJ.LE.3) GO TO 541
      WRITE(6,990) I,RAIN(I)
 990  FORMAT(5X,"RAIN  "I3,3X,F7.5)

 541 IF(I.LT.3) GO TO 540
     IPR=I-1
     IWP=I-2
     IF(RAIN(IPR).GE.(1.0)) GO TO 11
     IF(RAIN(IWP).GE.(1.0)) GO TO 11

     CN=84.0
     GO TO 12

  11 CN=96.0

  12 S=(1000./CN)-10.
     IF((RAIN(I)-0.2*S).LE.0.0000) GO TO 540
     Q(I)=((RAIN(I)-0.2*S)**2)/(RAIN(I)+0.8*S)
     IF(I.LE.90.OR.I.GE.335) TQ1=TQ1+Q(I)
     IF(I.GT.90.AND.I.LT.335) TQ2=TQ2+Q(I)
     TQ3=TQ1+TQ2

     IF(ICHECK.EQ.0) GO TO 540

     IF(JJJJ.LE.3) GO TO 540
     WRITE(6,991) Q(I),CN,TQ3
 991 FORMAT(10X,F7.5,3X,I3,3X,F8.5)

 540 CONTINUE

C  WRITE OUT RUNOFF, AVAILABLE MOISTURE, AND ANNUAL RUNOFF SUMMARY *****
     IF(JJJJ.EQ.1) GO TO 600
     TQQ(JXXX)=TQ1+TQ2
     IF(LPRN5.EQ.0) GO TO 560
     IF(JXXX.GT.LPRN5) GO TO 560
     WRITE(LP,550) JXXX
 550 FORMAT(/,10X,30("*"),3X,"DAILY AVAILABLE MOISTURE YEAR ",I3,3X,
    +30("*"),/)
     NUM2=5
     CALL OUTPT
 560 IF(LPRN3.EQ.0) GO TO 580
     IF(JXXX.GT.LPRN3) GO TO 580
     WRITE(LP,570) JXXX
 570 FORMAT(/,10X,30("*"),3X,"DAILY RUNOFF YEAR ",I3,3X,30("*"),/)
     NUM2=3
     CALL OUTPT
 580 IF(LPRN6.EQ.0.AND.IECYR.EQ.0) GO TO 600
     WRITE(LP,590) TQ1,TQ2,TQQ(JXXX)
 590 FORMAT(1X,/,5X,"TOTAL WINTER RUNOFF = ",F6.2,15X,"SUMMER RUNOFF
    += ",F6.2,15X,"TOTAL = ",F6.2)

C  STOCK POND ROUTING **************************************************
 600 DO 700 LL=1,NPOND
     C=U(LL)
     D=V(LL)
     DO 610 I=1,12
     IMDRY(I)=0
 610 CONTINUE
     PVOL=D*(W(LL)**3)
     DO 670 I=1,JDYEN
     IF(I.EQ.1) STORE=STLAST(LL)
     IF(I.EQ.1) H=HLAST(LL)
     PT=0.00000

     VOL=(Q(I)/12.)*ACRE(KKKK)*43560.+((PT+RAIN(I))/12.)*C*(H**2)
```

```
      EVAP=ED2A+ED2B*TEMP(I)
      IF(I.LE.61.OR.I.GT.N8) EVAP=ED1A+ED1B*TEMP(I)
      IF(EVAP.LT.0.) EVAP=0.000
      EVOL=(EVAP/12.)*C*(H**2)
      SEEP=SRATE*C*(H**2)
      STOCK=0.0000
      IF(I.GE.NFD1.AND.I.LE.NLD1) STOCK=COWVOL
      IF(I.GE.NFD2.OR.I.LE.NLD2) STOCK=COWVOL

      DEFICT=PVOL-STORE
          IF(DEFICT.LT.0.0) DEFICT=0.0
C         IF(DEFICT.LT.0.0000) PAUSE 1111
C         IF(EVOL.LT.0.0000)   PAUSE 2222
C         IF(SEEP.LT.0.0000)   PAUSE 3333
C         IF(STOCK.LT.0.0000)  PAUSE 4444
      SPILL=VOL-DEFICT-EVOL-SEEP-STOCK
      IF(SPILL.LT.0.) SPILL=0.000000
C       VOLQ=(Q(I)/12.)*ACRE(KKKK)*43560.
C        IF(SPILL.GT.VOLQ) VOL=VOLQ
C        IF(SPILL.GT.VOLQ) SPILL=VOL-DEFICT-EVOL-SEEP-STOCK
C        IF(SPILL.LT.0.) SPILL=0.000000

      STORE=VOL-EVOL-SEEP+STORE-SPILL-STOCK
      IF(STORE.GT.0.) GO TO 620
      STORE=0.
      H=0.
      GO TO 630
  620 H=(STORE/D)**(1./3.)
  630 IF(I.EQ.N12) STLAST(LL)=STORE
      IF(I.EQ.N12) HLAST(LL)=H
      IF(JJJJ.EQ.1) GO TO 670
C  SUMMARIES OF STOCK POND ROUTING  ******************************
      SPILL2(JXXX,LL)=SPILL2(JXXX,LL)+SPILL
      IF(STORE.NE.0.) GO TO 640
      NDRY(JXXX,LL)=NDRY(JXXX,LL)+1.
      IF(I.LE.N1) IMDRY(1)=IMDRY(1)+1
      IF(I.GT.N1.AND.I.LE.N2) IMDRY(2)=IMDRY(2)+1
      IF(I.GT.N2.AND.I.LE.N3) IMDRY(3)=IMDRY(3)+1
      IF(I.GT.N3.AND.I.LE.N4) IMDRY(4)=IMDRY(4)+1
      IF(I.GT.N4.AND.I.LE.N5) IMDRY(5)=IMDRY(5)+1
      IF(I.GT.N5.AND.I.LE.N6) IMDRY(6)=IMDRY(6)+1
      IF(I.GT.N6.AND.I.LE.N7) IMDRY(7)=IMDRY(7)+1
      IF(I.GT.N7.AND.I.LE.N8) IMDRY(8)=IMDRY(8)+1
      IF(I.GT.N8.AND.I.LE.N9) IMDRY(9)=IMDRY(9)+1
      IF(I.GT.N9.AND.I.LE.N10) IMDRY(10)=IMDRY(10)+1
      IF(I.GT.N10.AND.I.LE.N11) IMDRY(11)=IMDRY(11)+1
      IF(I.GT.N11.AND.I.LE.N12) IMDRY(12)=IMDRY(12)+1
  640 IF(LPRN4.EQ.0) GO TO 670
      IF(JXXX.GT.LPRN4) GO TO 670
      IF(I.EQ.1) WRITE(LP,650)
  650 FORMAT(/,2X,"DAY",3X,"STAGE",7X,"SPILLAGE",5X,"RETENTION",/)
      WRITE(LP,660) I,H,SPILL,STORE
  660 FORMAT(2X,I3,2X,F7.4,2(2X,F11.2))
  670 CONTINUE
      IF(JJJJ.EQ.1) GO TO 700
      DO 690 N=1,12
      MDRY(N,LL)=MDRY(N,LL)+IMDRY(N)
      IXX=1
      DO 680 I=2,12
      IXX2=IXX+3
      IF(IMDRY(N).GE.IXX.AND.IMDRY(N).LT.IXX2)
     +ICDRY(N,LL,I)=ICDRY(N,LL,I)+1
      IXX=IXX2
  680 CONTINUE
      IF(IMDRY(N).EQ.0) ICDRY(N,LL,1)=ICDRY(N,LL,1)+1
  690 CONTINUE

  700 CONTINUE
C   WRITE SIMULATION PROGRESS TO MONITOR
      WRITE(1,710) JXXX,ACRE(KKKK)
  710 FORMAT(5X,"YEAR ",I3," SIMULATED",8X,F8.1," ACRE WATERSHED")
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```
3000 CONTINUE

C   CALCULATION OF TEMPERATURE, PRECIPITATION, AND RUNOFF STATISTICS *********
      TOTAL=0.0000
      AA=0.0000
      AAA=0.0000
  720 AVE2=PAVE/NYEARS
      DO 730 I=1,NYEARS
      TOTAL=TOTAL+TQQ(I)
  730 CONTINUE
      AVE=TOTAL/NYEARS
      AVE1=(AVE/12.)*43560.*ACRE(KKKK)
      DO 740 I=1,NYEARS
      AA=AA+(TQQ(I)-AVE)**2
      AAA=AAA+((TRAIN2(I)-AVE2)**2)
  740 CONTINUE
      STD=SQRT(AAA/(NYEARS-1.))
      WRITE(LP,750) NYEARS,AVE2,STD
  750 FORMAT(///,10X,I4," YEAR MEAN YEARLY PRECIPITATION = ",F5.2,
     +1X,"INCHES",2X,"STANDARD DEVIATION = ",F6.3,1X,"INCHES",/)
      STD=SQRT(AA/(NYEARS-1.))
      AVE1A=AVE1/43560.
      WRITE(LP,760) AVE,AVE1A,STD
  760 FORMAT(10X,"MEAN RUNOFF = ",F5.2," INCHES",5X,F7.3," ACRE FEET",
     +5X,"STANDARD DEVIATION = ",F6.3," INCHES")
      AVE3=TTOT2/NYEARS
      WRITE(LP,770) NYEARS,AVE3
  770 FORMAT(/,10X,I4," YEAR MEAN MAXIMUM TEMPERATURE = ",F6.2,/)
      IF(ICALIB.EQ.1) GO TO 930

C   CALCULATION OF STOCK POND STATISTICS ********************************
      DO 920 LL=1,NPOND

      SPILL3=0.0000
      DRYDAY=0.0000
      WRITE(LP,780) PSIZE(LL),W(LL)
  780 FORMAT(/," ",/,10X,"POND SIZE = ",F5.2," ACRE FEET",5X,"MAXIMUM DE
     +PTH = ",F6.2,1X,"FEET",/)
      DO 790 I=1,NYEARS
      SPILL3=SPILL3+SPILL2(I,LL)
      DRYDAY=DRYDAY+NDRY(I,LL)
      SPL(I)=(SPILL2(I,LL)/(43560.*ACRE(KKKK)))*12.
  790 CONTINUE
      AVE4=((SPILL3/NYEARS)/(ACRE(KKKK)*43560.))*12.
      AVE5=SPILL3/NYEARS
      AVE5A=AVE5/43560.
      AVE6=DRYDAY/FLOAT(NYEARS)
      AVE8=AVE1-AVE5
      AVE9=(AVE8/(43560.*ACRE(KKKK)))*12.
      AVE10=AVE8/43560.
      AVE7=(AVE9/AVE)*100.
      FFACT=AVE8/(V(LL)*(W(LL)**3))
      AA=0.0000
      AAA=0.0000
      AAAA=0.0000
      DO 800 I=1,NYEARS
      AA=AA+(SPL(I)-AVE4)**2
      AAA=AAA+((TQQ(I)-SPL(I))-AVE9)**2
      AAAA=AAAA+(NDRY(I,LL)-AVE6)**2
  800 CONTINUE
      STDSPL=SQRT(AA/(NYEARS-1.))
      STDSAF=(STDSPL/12.)*ACRE(KKKK)
      STDRET=SQRT(AAA/(NYEARS-1.))
      STDRAF=(STDRET/12.)*ACRE(KKKK)
      STDDRY=SQRT(AAAA/(NYEARS-1.))

C   WRITE OUT ANNUAL SPILLAGE, DRY DAYS, AND RETENTION ON LINE PRINTER OR TAPE
      IF(LPRN7.EQ.0) GO TO 820
      WRITE(LP,810)
  810 FORMAT(15X,"SPILLAGE",3X,"NUMBER OF DRY DAYS",3X,"WATER RETAINED")
  820 DO 860 I=1,NYEARS
      RET(I)=TQQ(I)-SPL(I)
      IF(LPRN7.EQ.0) GO TO 840
      WRITE(LP,830) SPL(I),NDRY(I,LL),RET(I)
  830 FORMAT(15X,F7.4,10X,I3,15X,F8.5)
  840 IF(LPRN8.EQ.0) GO TO 860
      WRITE(LTAPE,850) SPL(I),NDRY(I,LL),RET(I)
  850 FORMAT(F8.5,5X,I3,5X,F8.5)
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  860 CONTINUE
C   RETENTION MEDIAN CALCULATION
      NY=NYEARS-1
      DO 880 I=1,NY
      J=I+1
      DO 870 I1=J,NYEARS
      IF(RET(I).GE.RET(II)) GO TO 870
      TMPR=RET(I)
      RET(I)=RET(II)
      RET(II)=TMPR
  870 CONTINUE
  880 CONTINUE
      RTMED1=(RET(NYEARS/2)+RET(NYEARS/2+1))/2
      RTMED2=(RTMED1/12.)*ACRE(KKKK)
C   WRITE OUT RESULTS   ***********************************************
      WRITE(LP,890) AVE4,AVES,AVESA,STDSPL,STDSAF,AVE9,AVE8,AVE10,
     +STDRET,STDRAF,RTMED1,RTMED2,AVE7,FFACT,AVE6,STDDRY
  890 FORMAT(10X,"MEAN ANNUAL SPILL = ",F7.4," INCHES",5X,F10.1," CUBIC
     +FEET",5X,F7.3," ACRE FEET",/,10X,"STANDARD DEVIATION OF SPILL = "
     +,F7.3," INCHES",5X,F7.3," ACRE FEET",//,10X,"MEAN ANNUAL RETENTION
     + = ",F7.4," INCHES",5X,F10.1," CUBIC FEET",5X,F7.3," ACRE FEET",
     +/,10X,"STANDARD DEVIATION OF RETENTION = ",F7.4," INCHES",5X,F7.3,
     +" ACRE FEET",/,10X,"MEDIAN OF RETENTION = ",F7.4," INCHES",5X,
     +F7.3," ACRE FEET",/,10X,"MEAN ANNUAL RETENTION AS A PERCENT OF RUN
     +OFF = ",F7.3,/,10X,"FILL FACTOR = "F7.2,//,10X,"MEAN ANNUAL NUMBER
     + OF DRY DAYS = ",F7.3,10X,"STANDARD DEVIATION = ",F7.3,//,
     +40X,"MONTHLY DRY DAYS DISTRIBUTIONS",/,17X,"MONTH",6X,"DRY DAY",
     +20X,"NUMBER OF YEARS IN EACH DRY DAY CLASS",/,29X,"MEAN",6X,
     +"0",4X,"1-3",3X,"4-6",3X,"7-9",2X,"10-12",1X,"13-15",1X,"16-18",
     +1X,"19-21",1X,"22-24",1X,"25-27",1X,"28-30",3X,"31")

      IXX=1
      IXX2=3
      DO 910 I=1,12
      MO=I
      DM=FLOAT(MDRY(MO,LL))/NYEARS
      WRITE(LP,900) (ALPHA(JJ),JJ=IXX,IXX2),DM,(ICDRY(MO,LL,N),N=1,12)
  900 FORMAT(15X,3A4,1X,F6.3,4X,I3,11(3X,I3))
      IXX=IXX+3
      IXX2=IXX2+3
  910 CONTINUE
  920 CONTINUE
 4000 CONTINUE
C   ******************  END OF PROGRAM  ********************************
  930 CONTINUE
      CLOSE(45)
      STOP
      END
      BLOCK DATA
      COMMON/OUT/TEMP(366),RAIN(366),AMOIST(182),Q(366),NUM2,
     +ILEAP,LP
      END
      SUBROUTINE OUTPT
C   SUBROUTINE WRITES OUT DAILY PRECIPITATION, TEMPERATURE, AVAILABLE
C   MOISTURE, AND RUNOFF
      REAL TEMP(366),RAIN(366),AMOIST(182),Q(366),CC(366)
      COMMON/OUT/TEMP,RAIN,AMOIST,Q,NUM2,ILEAP,LP
      J=365+ILEAP
      IF(NUM2.GT.4) J=181+ILEAP
      DO 10 I=1,J
      IF(NUM2.EQ.1) CC(I)=TEMP(I)
      IF(NUM2.EQ.2) CC(I)=RAIN(I)
      IF(NUM2.EQ.3) CC(I)=Q(I)
      IF(NUM2.EQ.5) CC(I)=AMOIST(I)
   10 CONTINUE
      LL=0
      L=0
      K=12
      IF(NUM2.GT.4) K=6
      DO 70 I=1,K
      GO TO (50,20,20,60,20,50,20,50,20,20,50,20),I
   20 L=LL+1
      LL=LL+31
   30 WRITE(LP,40) (CC(KK),KK=L,LL)
```

```
40 FORMAT(1X,16(F6.2,1X,"I"),/,9X,15(F6.2,1X,"I"))
   GO TO 70
50 L=LL+1
   LL=LL+30
   GO TO 30
60 L=LL+1
   LL=LL+28+ILEAP
   GO TO 30
70 CONTINUE
   RETURN
   END
```

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