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Stochastic Simulation of Daily Rainfall

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STOCHASTIC SIMULATION OF DAILY RAINFALL

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PREFACE

This report is the technical completion report for a research project entitled "Stochastic Simulation of Daily Rainfall". The project was supported in part by funds provided by the United States Department of Interior to the University of Kentucky Water Resources Institute as authorized by the Water Resources Act of 1964, Public Law 88-379, as Office of Water Resources Research Project No. A-045-KY. Partial funding was also provided by the Kentucky Agricultural Experiment Station as a contribution to Southern Regional Research Project S-53 "Factors Affecting Water Yields from Small Watersheds and Shallow Ground Aquifers".

ABSTRACT

The design of many water resources projects requires knowledge of possible long-term rainfall patterns. In this project a stochastic model based on a first order Markov chain was developed to simulate daily rainfall at a point. The model is applicable to any point in Kentucky (and other areas with similar rainfall patterns). The model in its present form is useful in providing rainfall inputs into hydrologic models for designing water supply facilities and other water resources systems.

The model uses historical rainfall data to estimate the Markov transitional probabilities. A separate matrix is estimated for each month of the year. In this report 7 X 7 transitional probability matrices were used.

The model is capable of simulating a daily rainfall record of any length based on the estimated transitional probabilities and frequency distributions of rainfall amounts within each class interval. The simulated data has statistical properties similar to historical data.

DESCRIPTORS:

Hydrology*, Precipitation (Atmospheric), Rainfall*, Stochastic Processes

IDENTIFIERS:

Markov chain

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

CHAPTER I

INTRODUCTION

The design of water resources systems that include the impoundment of water requires relatively long records of rainfall and runoff. In many instances these long records are not available and must be synthesized in some fashion or another. One approach to the generation of streamflow data that is currently very popular is through the use of parametric hydrologic models.

Parametric hydrologic models are a collection of mathematical statements that convert rainfall into streamflow in such a fashion that (hopefully) the generated streamflows are hydrologically similar to what the historical flows would have been. If these parametric models are to be used to generate extremely long traces of streamflow, extremely long records of rainfall are required as a model input. For example a water yield model developed by Haan (1972) requires daily rainfall as input.

Again one frequently finds that long records of rainfall are not available. With this in mind the study reported here was undertaken. The objective of the study was to develop a stochastic model for simulating daily precipitation amounts at a point. It was desired that the model use existing historical rainfall information to estimate model parameters. These parameters could then be used in the model to produce a daily record of simulated rainfall of any length.

It was further required that certain statistical properties of the simulated and historical rainfalls not be significantly different. Such things as the amounts of rainfall as well as the pattern of occurrence of the rainfall were of concern.

CHAPTER II
RESEARCH PROCEDURES

The principal objective of this project was to develop, describe and implement a stochastic model suitable for computer simulation of daily precipitation at any location in Kentucky.

Studies on daily weather patterns in general and especially rainfall have shown that they exhibit both persistence and periodicities (Wiser, 1964). By persistence is meant that the amount of accumulated precipitation on any given day (or simply daily rainfall) is dependent on that of the previous day or days. By periodicities is meant that daily rainfall patterns vary according to time of year but largely recur from year to year. It was these two fundamental characteristics of daily rainfall which guided the development of the model.

Daily rainfall in Kentucky is recorded to the nearest hundredth of an inch, and any accumulation of less than 0.01 inches is called a trace and is recorded as zero. In order to reduce the magnitude of the problem, the non-zero measurements may be grouped into c+1 classes or states, providing an open class for largest rainfall.

Actual depth of rainfall (in.)	Corresponding class limits
$[0, 0.01)$	DRY = trace
$[0.01, n_1)$	1 to n_1-1
$[n_1, n_2)$	n_1 to n_2-1
⋮	⋮
$[n_{c-2}, n_{c-1})$	n_{c-2} to $n_{c-1}-1$
$[n_{c-1}, \infty)$	n_{c-1} to ∞

Let $X_1, X_2, \ldots$ be observations of daily rainfall on successive days, and let $E_{i,j}$ ($i=1,2,\ldots$ and $j=0,1,\ldots,c$) denote the event that X_i belongs to class j. If

$$P(E_{n,j}|E_{n-1,j_{n-1}},\ldots,E_{1,j_1}) = P(E_{n,j}|E_{n-1,j_{n-1}}),$$

then we are dealing with a first order Markov chain with c+1 states. If, in addition, $P(E_{n,j}|E_{n-1,i})$ does not depend on n, then we denote these transition probabilities by p_{ij}, and the Markov chain is said to be stationary. We gather these probabilities together in to a $c+1 \times c+1$ between class transition matrix, (p_{ij}).

For c=1, the problem reduces to the consideration of sequences of dry and wet days. The goodness-of-fit of this model has been studied, among others, by Gabrial and Neuman (1962) and Feyerherm and Bark (1967). Of course, the quality of the fit depends on the climate of the region modeled, but these studies suggest that one might achieve an adequate model by taking c greater than one, then simulating daily rainfall using suitable probability distributions over each class. This is an extension of the approach taken by Khanal and Hamrick (1971) in their study for Bithlo, Florida.

By a season it is meant any set of neighboring days in which the modeling transition probabilities are taken to be constant. The choice of the number, s, and length of seasons should fairly represent whatever periodicities are present within the year. At the same time an undue proliferation of parameters beyond the capacity of the data to estimate them with reasonable accuracy must be avoided. Denoting by superscript k the k^{th} season, the model is expanded to a finite Markov chain with between-class transition matrices stationary within seasons:

$$(p_{ij}^{(k)}) \quad (i,j=0,1,\ldots,c \text{ and } k=1,\ldots,s).$$

That is, one stochastic matrix for each season, in which $p_{ij}^{(k)}$ represents the transition probability, in the k^{th}

season, that tomorrow's rainfall will belong to class j given that it belongs to class i today. One must estimate sc(c+1) transition probabilities since the sum over j of the p_{ij} must be one. Note also that it is an insignificant restriction to employ the same classes for all seasons.

To complete the model, probability distributions must be fit to each class. The assumption is made that the same set of distributions will model each season. Thus c+1 cumulative distribution functions are required

$$F_m(x) \quad (m=0,\ldots,c) \ ,$$

where $F_m(x) = P(\text{rainfall} \le x \mid \text{rainfall belongs to class } m)$.

Practical decisions must be made with respect to the number and length of seasons and classes . In this study seasons were taken to be months, a convenient, intelligible breakdown of the year which represents any significant periodicities which might be present. A coarser grouping into, say, two to six seasons might not sacrifice much modeling detail, at the same time improving the accuracy of parameter estimates. Further study is needed on this point.

After trying as many as 13 classes, c=6 was found to be a reasonable choice in view of the decision to use months as seasons. Experimentation also revealed that class widths increasing as a geometric progression was a viable grouping.

Class Boundaries inches x 100	Class Limits inches × 100
DRY	DRY
[1, 3)	1 - 2
[3, 7)	3 - 6
[7, 15)	7 - 14
[15, 31)	15 - 30
[31, 63)	31 - 62
[63, ∞)	63 - ∞

Note that in the associated computer program, the number and choice of the class boundaries are at the user's option; the only restriction is that c can be no more than 10.

We thus have $s(c+1)^2 = 588$ transition probabilities to represent the year. At the weather stations considered in the present study, 40.5 years of rainfall data were available, or around 15,000 observations per station. Using the method of maximum likelihood, estimates are formed by

$$\hat{p}_{ij}^{(k)} = f_{ij}^{(k)} / \sum_{j=0}^{c} f_{ij}^{(k)} \quad (i,j=0,1,\ldots,c \text{ and } k=1,\ldots,s),$$

where $f_{ij}^{(k)}$ is the historical frequency of transition from class i to class j within season k. Even with so many observations, a few of these estimates appear to be unstable. This is explained by the preponderance of DRY days which occasionally reduced the marginal frequencies (denominators above) to small values which are unsuitable for estimating the transition probabilities between wet classes. However, the difficulty was primarily encounterd for i=1, where rainfall is less than 0.03 inches, and therefore the trouble was not considered to be serious. The trade-off between preserving needed modeling detail and retaining accuracy of parameter estimates would require reconsideration of c and s at those weather stations with 25 or fewer years of record. For these stations, grouping the months (12,1,2), (3,4,5), (6,7,8), and (9,10,11) into four seasons seems to us to be a good possibility.

Several rainfall distributions were tried over the six non-zero classes with the result that a (shifted) exponential distribution

$$\begin{aligned} F_7(x) &= \exp((x-0.63)/\lambda) \quad x \geq 0.63 \text{ inches} \\ &= 0 \text{ elsewhere} \end{aligned}$$

was chosen for class seven, and uniform distributions over classes two through six.

Now if F denotes any cumulative distribution function, then $F^{-1}(U)$, where U is a random variable distributed uniformly over the interval from zero to one, defines a random variable having the distribution of F. The IBM subroutine RANDU was used to simulate U, and by the above transformation, F.

Again, the method of maximum likelihood was used to estimate λ by $\bar{x}-0.63$, where $\bar{x}$ is the sample mean of all rainfalls greater than or equal to 0.63 inches over the period of record.

The FORTRAN program was written for the University of Kentucky IBM 360/65; a brief description follows (for more detailed information, please refer to the accompanying program documentation).

1) Read-in the historical data and compute the parameter estimates (transitional probability matrices and λ's).
2) Call RANDU and, using the appropriate estimated transition matrix, determine the next day's rainfall class (the initial state of the system is chosen to be DRY).
3) Call RANDU and, using the appropriate distribution, determine a simulated rainfall for that day.
4) Repeat steps two and three as often as desired, accumulating and outputing all statistical records of interest.

The approach to the evaluation of the simulation model was basically this: assume a model (here, Markov chain having one dry and six wet states, stationary within months, with rainfall simulated uniformly in classes two through six and exponentially in class seven); construct a simulation program in accordance with that model, estimating the model parameters from historical records; ask whether the simulated and historical records are in tolerable agreement with respect to important characteristics such as monthly and annual rainfall and the distribution of runs of wet and dry days.

Standard statistical tests do not apply to patterns of daily rainfall, since the observations are not independent (we have specifically introduced one-day dependence into the simulated data by assuming the first order Markov chain). Thus the problem of evaluation is approached primarily through descriptive rather than inferential statistics: historical and simulated records are summarized side by side for the reader's inspection and judgment.

The statistics that are presented are from seven weather stations chosen in an effort to reflect rainfall patterns across Kentucky. They include:

Station location	Identification #
Ashland	0254
Bowling Green	0909
Carrollton Lock	1345
Henderson	3762
Hopkinsville	3994
Little Hickman	4825
Pikeville	6353

At each of these stations the forty year record extending from January 1, 1932 to December 31, 1971 was used.

The Kentucky Division of Water recently completed a project of assembling daily climatological data for use in various types of studies. They compiled it in a uniform format and loaded it onto four magnetic tapes stored at the University of Kentucky. They also provide annual updates. Altogether, there are more than 180 weather stations in Kentucky at which data has been collected, but the records are of varying lengths. The data for most stations currently covers the period from July 1, 1948 through June 30, 1972, a period of 24 years. At 25 of these stations, the records for the period January 1, 1932 through June 30, 1948 are also available. All of the data since July 1, 1966 came on magnetic tapes purchased from the Environmental Data Service, National Climatic Center, Asheville, North Carolina, and was thence converted to the standard Form 1009 format, one card per station-day. The 1948-1966 cards were prepared by the United States Weather Bureau, and were stored in the University of Kentucky College of Agriculture; the Department of Agricultural Engineering at the University of Kentucky prepared the 1932-1948 cards, which include only precipitation and temperature data (Form 1009 includes such observations as smoke haze, fog, thunder, hail, 24 hour wind movement, amount of evaporation, etc.). For further information regarding the data, see Griffin (1974).

CHAPTER III
EVALUATION OF MODEL

The amount of rainfall on a given day is correlated with the amount of rainfall on the preceding day. Successive simulated rainfalls generated by a Markov process are also correlated. Because of the nonindependence of rainfall and the nonindependence of simulated rainfall, exact statistical tests to compare their properties are not available. While Kolmogorov tests are other goodness-of-fit tests have been used in the literature, they are not valid for this purpose. We have calculated extensive descriptive statistics which indicate good agreement between simulated and actual rainfall. For each of the seven rainfall stations, the following information is tabulated for both actual and simulated rainfall:

a) Mean and standard deviation of monthly rainfall (Table 6).
b) Average annual number of wet days (Table 7)
c) Maximum daily rainfall by months (Table 8)
d) Runs of wet and dry days for a month with average rainfall (Table 9)
e) Runs of wet and dry days for the wettest month (Table 10)
f) Runs of wet and dry days for the driest month (Table 11).

Inspection of Table 6 reveals that the simulated mean monthly rainfalls are in good agreement with the historical mean monthly rainfall. The average annual rainfall based on the average of the 6 simulations (nearly equivalent to 240 years of simulated rainfall) is always within 1.5 inches of the historical average annual rainfall. One disturbing aspect is that the simulated average rainfall is always greater than the historical average annual rainfall. This bias toward excess rainfall averages 1.08 inches or about 2.5 percent.

Table 6 also shows that the standard deviations of the observed and simulated monthly rainfall are very similar. It is difficult to place a percentage error on the differences.in the standard deviations. Suffice it to say that it appears as though there is no significant difference between the standard deviations of the simulated and historical monthly precipitation.

Table 7 presents a comparison of the average annual number of wet days per year. Clearly the Markov chain model is preserving this property.

Table 8 compares the magnitudes of the largest daily rainfalls during the 40 years of simulated and historical data. Here again the model seems to be doing a reasonably good job. A slight trend toward underestimating the largest rainfall is apparent.

Tables 9, 10 and 11 compare runs of wet and dry days for selected months for each of the seven stations. The three months selected for each station correspond to the wettest and driest months and the month closest to an "average" monthly rainfall. Again these tables show that the model is doing a reasonably good job in simulating daily rainfall.

Table 13 contains the parameter values used in the Markov chain simulations. These parameters consist of the transitional probability matrices and the parameter λ of the shifted exponential. These values are shown so that others working with this type of model will have a basis of comparison.

In addition to the tables contained in this report, the computer program provides other information for the users inspection. For example, the entire record of simulated flows can be printed, punched on cards or put on tape. A table of monthly rainfall by years is generated.

The daily average rainfall by months and years is displayed. The number of days with and without (wet and dry) rainfall for each month of the simulated and historical record is printed. The largest daily rainfall for each month of the record is printed. Finally the frequency of occurrence of runs of wet and dry days for runs of 1 to 31 days is displayed for each month of the simulated and for historical record.

Based on the above comparison it is concluded that the present model is doing a reasonably good job of simulating daily rainfall. It is felt that the use to be made of the simulated data would determine if the simulations are sufficiently representative of historical data.

CHAPTER IV

MODEL VALIDATION WITH SIMULATED RUNOFF

One reason for simulating daily rainfall is to use it as an input into a hydrologic model for simulating streamflow. Thus one test of the validity of the rainfall simulation model is to compare streamflow generated using a hydrologic model along with simulated and historical rainfall.

Haan (1972) has developed and tested a monthly water yield model. The model has been found to accurately simulate streamflow on a monthly basis for watersheds in Kentucky (Haan, 1975). The water yield model is a four-parameter model. Values were assigned to each of the four model parameters at the 7 rainfall stations based on studies of watersheds located near these rainfall stations. Table 1 shows the model parameters that were used. The report by Haan (1972 or 1975) should be consulted for a definition of these terms and an explanation of the water yield model.

The 40 years of historical rainfall data and 5 simulations of 40 years of generated data were used to generate monthly runoff at each of the 7 rainfall stations. Table 2 summarizes the results of these simulations. More detailed information on the resulting simulated streamflow can be found in Table 12 in the appendix of this report.

Table 2 shows that in general the streamflow generated using simulated rainfall exceeds the streamflow generated using historical rainfall. Even though the difference at any particular rainfall station is not significantly different from zero, the fact that the average streamflow from simulated rainfall always exceeds that from historical rainfall indicates a bias toward more streamflow in the case of simulated rainfall.

Table 1. Model Parameters Used in Runoff Generation

Rainfall Station	f_{max}	s_{max}	c	f
254	.67	.054	3.64	.65
909	.53	.080	4.85	.70
1345	.50	.017	4.11	.36
3762	.53	.068	5.33	.23
3994	.58	.080	5.65	.14
4825	.55	.058	3.80	.52
6353	.53	.032	7.50	.53

Table 2. Summary Comparison of Average Annual Streamflow Generated Using Historical and Simulated Rainfall

	Simulation Number						
Station	2	3	4	5	6	Ave	Historical
254	16.14	16.29	16.19	15.83	16.01	16.09	14.92
909	23.93	21.95	23.55	22.60	25.43	23.49	22.30
1345	15.70	16.83	17.25	17.98	16.49	16.85	15.68
3762	13.99	13.84	15.32	13.88	14.61	14.33	13.54
3994	11.60	15.70	12.72	12.35	13.48	13.17	12.32
4825	18.56	18.13	18.71	18.26	17.06	18.15	17.44
6353	16.77	18.12	15.89	17.10	17.17	17.01	15.96

This bias in the generated streamflows of roughly 1 inch in average annual streamflow again indicates that the rainfall simulation model is overestimating daily rainfall.

Whether or not the simulated rainfall could be used to generate streamflows for use in the analysis of a water resources system would depend on the level of accuracy required. It appears that if the generated streamflows must be within 1 inch on an average annual basis of historical streamflow, the present rainfall simulation model would be inadequate. If this degree of accuracy is not required, the rainfall simulator may work very well.

In the design of a water supply reservoir, it is generally the dry months of the year that determine the design reservoir capacity. Table 12 in the appendix shows the simulated average flows by months for the 7 rainfall stations. If this monthly streamflow data is summed for the 3 driest months of the year, the results shown in Table 3 are obtained. This table indicates that the errors in the simulation of rainfall may be occurring during the wetter months having relatively little effect on the design of a water supply reservoir.

Table 3. Total Average Monthly Streamflow (inches) for Driest Three Months of Year

	Based on	
Station	Average of 5 Rainfall Simulations	Historical Rainfall
254	1.26	1.17
909	2.06	1.77
1345	0.69	0.84
3762	0.91	0.95
3994	0.70	0.71
4825	1.26	1.19
6353	1.41	1.24

In order to test this hypothesis the 40 years of run-off generated using the historical rainfall and the 5 simulations of runoff generated using 40 years of simulated rainfall were used to determine the reservoir capacity required to meet a constant annual demand or withdrawal of 5 inches and 10 inces.

The demand was assumed to include all reservoir outflows including evaporation, seepage and spillway discharges for low flow control. Tables 4 and 5 present the results of this analysis.

In general the over estimation of rainfall is again apparent in that smaller reservoirs are required with the simulated rainfall than with the historical rainfall. Two exceptions to this are stations 909 and 4825 where the reservoir based on historical rainfall and based on the average of 5 simulated rainfall records are nearly identical.

It is interesting to note the range on reservoir sizes among the 5 simulations for a given station. For example, for station 3994 the required reservoir capacity to meet a 10 inch demand ranges from 7.5 inches to 15.3 inches. This difference of 7.8 inches of storage required is produced by simulations that vary by only 4.1 inches of annual runoff. This again verifies the need for a long record of streamflow for the reservoir design.

Table 4. Reservoir Capacity (inches) Demand Equal 5 Inches

	Simulation						
Station	2	3	4	5	6	Ave	Historical
254	2.0	2.0	2.0	2.3	2.0	2.06	1.8
909	1.8	1.5	1.0	1.5	2.0	1.56	1.5
1345	2.8	2.8	3.0	3.0	3.3	2.98	4.0
3762	2.5	2.8	3.3	2.3	2.5	2.68	3.3
3994	3.3	2.8	3.5	2.8	3.5	3.18	4.3
4825	2.3	2.0	1.8	1.8	2.3	2.04	2.0
6353	1.8	1.5	1.8	1.3	1.8	1.64	2.0

Table 5. Reservoir Capacity (inches) Demand Equal 10 Inches

Station	Simulation						Historical
	2	3	4	5	6	Ave.	
254	6.0	5.3	5.5	6.3	8.3	6.28	9.0
909	4.0	4.3	3.3	3.8	4.5	3.98	4.0
1345	7.5	8.8	7.8	6.8	7.5	7.68	13.0
3762	14.0	10.3	10.5	8.5	10.0	10.66	12.5
3994	15.3	7.5	12.8	14.3	9.8	11.94	19.0
4825	5.8	6.0	6.3	5.0	5.3	5.68	5.8
6353	9.0	5.5	5.8	8.0	7.3	7.12	11.0

CHAPTER V
SUMMARY AND CONCLUSIONS

A first order Markov chain model was developed and tested on 7 rainfall stations in Kentucky. After some initial experimentation, 7×7 transitional probability matrices were used. A separate transitional probability matrix was used for each month. The class boundaries for the states in the Markov chain were found by using a geometric progression. The distribution of rainfall amounts within a class was taken as uniform with the exception of the last class in which a shifted exponential was used.

Simulated rainfall was compared to actual rainfall in several ways. The results of these comparisons indicate generally satisfactory performance of the model. The model seems to be generating annual rainfalls that exceed historical by about 2.5 percent or 1.08 inches on the average.

A hydrologic model was used to generate streamflow using both the simulated and historical rainfall. The runoff generated using the simulated rainfall averaged about 1 inch more than that generated using the historical rainfall.

The model offers promise as a means of obtaining long records of daily rainfall. Some problems that require further attention are:

1) reducing overestimation of rainfall
2) combining several months to get a smaller number of transitional probability matrices
3) investigate the number of years of historical record required to obtain stable parameter estimates.

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APPENDIX A

TABLES COMPARING SIMULATED AND OBSERVED RAINFALL

Table 6. Mean Monthly Rainfall and Standard Deviation of Monthly Rainfall

Mean Monthly Rainfall Station 254

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.43	3.29	3.71	3.53	4.16	3.96	3.52	3.70
Feb	2.94	2.97	3.08	3.03	2.88	2.97	3.04	3.00
Mar	4.16	4.63	3.87	4.47	4.36	4.71	4.40	4.41
Apr	3.39	3.72	4.23	3.80	4.39	2.93	3.45	3.75
May	3.91	4.24	3.84	4.54	3.86	3.88	4.44	4.13
June	3.65	3.51	4.07	3.75	3.62	3.72	4.07	3.79
July	4.37	4.18	4.03	3.82	4.55	4.25	4.12	4.16
Aug	3.43	3.20	3.28	3.44	2.50	3.22	2.47	3.02
Sept	2.76	2.86	2.50	2.97	2.74	2.57	2.57	2.70
Oct	2.02	1.76	2.11	2.36	2.17	2.11	2.16	2.11
Nov	2.76	3.02	3.23	2.62	2.91	2.88	3.22	2.98
Dec	2.86	3.19	3.24	3.44	2.81	3.42	3.05	3.19
Annual	39.68	40.56	41.20	41.78	40.95	40.62	40.51	40.94

Standard Deviation of Monthly Rainfall Station 254

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	2.10	1.31	1.79	1.87	1.95	2.14	1.56	1.77
Feb	1.77	1.40	1.40	1.25	1.52	1.38	1.89	1.47
Mar	1.76	1.60	2.07	1.56	1.77	1.78	2.05	1.81
Apr	1.46	1.80	1.69	1.63	2.05	1.30	1.46	1.66
May	1.88	1.92	2.15	2.35	1.81	1.68	2.24	2.03
June	1.84	1.72	1.80	1.47	1.65	1.78	2.40	1.80
July	1.96	1.90	1.60	1.70	1.88	1.97	1.71	1.79
Aug	1.72	1.55	1.33	1.52	1.09	1.41	1.50	1.40
Sept	1.41	1.93	1.68	1.60	1.58	1.85	1.64	1.71
Oct	1.06	1.40	1.23	1.43	1.44	1.12	1.45	1.35
Nov	1.34	1.58	1.23	1.39	1.41	1.42	1.36	1.40
Dec	1.41	1.52	1.44	1.49	1.53	1.84	1.91	1.62

Table 6. (continued)

Mean Monthly Rainfall Station 909

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	5.14	5.05	5.82	4.61	5.29	4.83	4.98	5.10
Feb	4.07	4.39	4.56	4.07	4.29	3.97	5.16	4.41
Mar	5.32	4.72	5.70	5.14	5.05	5.63	5.85	5.35
Apr	4.23	4.45	4.58	4.11	4.67	4.75	4.70	4.54
May	3.97	4.07	4.29	4.15	4.59	4.41	4.01	4.25
June	4.23	3.95	4.04	4.27	4.16	3.77	3.88	4.02
July	4.24	4.52	4.26	4.37	4.75	3.85	4.49	4.37
Aug	3.52	3.56	3.73	3.56	3.56	3.14	3.83	3.56
Sept	2.94	2.31	3.50	3.03	3.00	3.17	3.11	3.02
Oct	2.42	2.62	2.87	2.62	3.10	2.74	2.78	2.79
Nov	3.50	3.21	2.92	3.60	3.16	4.07	3.73	3.45
Dec	4.22	4.75	3.63	4.11	4.21	3.77	5.09	4.26
Annual	47.78	47.60	49.90	47.64	49.85	48.10	51.60	49.12

Standard Deviation of Monthly Rainfall Station 909

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.95	2.07	2.57	2.25	2.87	2.26	2.86	2.48
Feb	2.39	1.80	2.47	2.24	1.71	1.92	2.90	2.17
Mar	2.31	1.91	2.21	2.12	2.37	1.99	2.83	2.24
Apr	1.59	2.31	2.85	2.18	2.07	2.31	1.86	2.26
May	2.23	1.77	2.10	2.15	2.51	2.26	2.05	2.14
June	2.57	2.03	2.20	2.68	2.15	2.02	2.78	2.31
July	2.32	1.97	2.21	2.49	1.86	1.81	2.08	2.07
Aug	1.65	2.23	2.46	1.73	2.31	2.03	1.91	2.11
Sept	1.66	1.50	2.16	2.41	1.99	2.41	2.15	2.10
Oct	1.28	1.41	1.79	1.40	1.77	1.69	2.11	1.70
Nov	1.71	1.88	1.67	2.08	1.75	1.85	2.19	1.90
Dec	2.13	2.08	2.23	2.36	2.00	1.71	2.66	2.17

Table 6. (continued)

Mean Monthly Rainfall Station 1345

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.45	4.25	3.37	4.17	4.36	3.17	3.45	3.80
Feb	3.04	3.11	3.21	2.79	3.82	3.35	3.29	3.26
Mar	4.45	4.27	4.36	4.53	4.28	4.76	4.72	4.49
Apr	3.71	3.39	3.60	3.47	3.98	3.89	3.28	3.60
May	3.67	3.93	3.47	4.16	4.25	4.57	3.68	4.01
June	3.94	4.23	3.68	3.84	3.65	4.62	4.01	4.01
July	3.75	3.96	3.31	3.37	3.28	3.75	3.36	3.51
Aug	3.25	3.58	3.30	3.05	2.44	3.27	2.93	3.10
Sept	2.69	2.74	2.73	2.42	2.15	2.60	2.40	2.51
Oct	2.25	2.73	2.23	3.13	2.00	2.45	2.31	2.48
Nov	2.94	2.92	3.38	2.98	3.72	3.10	3.36	3.24
Dec	2.67	2.83	3.31	2.86	2.79	3.21	3.43	3.07
Annual	39.81	41.94	39.95	40.76	40.70	42.74	40.22	41.05

Standard Deviation of Monthly Rainfall Station 1345

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	2.74	2.52	2.36	2.24	2.26	1.74	1.75	2.15
Feb	2.07	1.69	2.31	1.56	1.93	1.78	1.78	1.84
Mar	2.88	1.95	2.10	2.72	2.27	1.99	2.51	2.26
Apr	1.87	1.52	1.98	1.65	2.02	1.58	1.98	1.79
May	1.87	2.14	1.23	2.41	2.25	2.07	1.92	2.00
June	2.40	2.12	2.13	1.79	1.92	1.91	1.95	1.97
July	1.56	2.29	1.48	1.55	1.65	2.17	1.54	1.78
Aug	1.79	1.92	1.62	2.10	1.50	1.90	1.90	1.82
Sept	1.56	1.66	1.53	1.56	1.31	1.45	1.73	1.54
Oct	1.34	1.55	1.56	1.87	1.25	1.53	1.60	1.56
Nov	1.60	1.59	1.77	1.61	1.65	1.68	1.71	1.67
Dec	1.37	1.61	1.72	1.52	1.68	1.67	2.06	1.71

Table 6. (continued)

Mean Monthly Rainfall Station 3762

		Simulation No.						
Month	Observed	1	2	3	4	5	6	Ave
Jan	4.35	4.50	3.80	3.65	3.95	4.61	3.78	4.05
Feb	3.46	4.12	3.94	3.79	4.18	3.67	3.63	3.89
Mar	5.22	5.20	4.70	5.22	4.75	5.44	6.47	5.30
Apr	4.40	4.05	4.24	4.79	5.14	4.11	4.56	4.48
May	4.25	4.24	4.22	4.59	4.41	3.90	4.52	4.31
June	3.65	4.19	4.82	3.98	3.82	3.48	3.96	4.04
July	4.00	4.09	4.20	3.99	4.17	4.15	4.38	4.16
Aug	3.15	2.59	3.21	2.75	3.34	2.85	2.31	2.84
Sept	3.19	3.11	3.70	3.58	3.29	3.85	2.98	3.42
Oct	2.70	2.58	2.34	2.78	3.19	3.06	2.96	2.82
Nov	3.33	3.79	3.52	3.16	3.51	2.89	3.39	3.38
Dec	3.50	4.34	4.12	3.89	4.07	3.87	3.57	3.98
Annual	45.20	46.78	46.79	46.17	47.80	45.89	46.51	46.66

Standard Deviation of Monthly Rainfall Station 3762

		Simulation No.						
Month	Observed	1	2	3	4	5	6	Ave
Jan	4.05	2.37	2.33	2.38	1.67	2.35	2.45	2.26
Feb	2.15	1.75	2.65	1.91	2.70	1.72	1.86	2.10
Mar	3.50	2.20	1.60	2.64	2.14	2.46	3.45	2.42
Apr	1.91	2.31	1.89	2.53	2.83	1.86	2.40	2.30
May	2.08	2.62	2.44	2.67	2.25	2.09	2.20	2.38
June	1.90	1.89	2.29	2.04	2.17	1.91	2.48	2.13
July	2.60	1.95	2.10	1.80	2.50	2.46	2.54	2.23
Aug	2.05	1.59	1.85	1.35	1.59	1.64	1.55	1.60
Sept	2.26	2.23	1.91	1.96	2.00	1.90	1.73	1.96
Oct	1.69	1.73	1.33	1.60	2.02	2.17	1.72	1.76
Nov	2.02	2.29	2.21	2.06	1.74	1.14	2.12	1.93
Dec	1.93	2.43	2.57	2.39	2.54	2.19	1.89	2.34

Table 6. (continued)

Mean Monthly Rainfall Station 3994

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	4.85	4.23	4.29	5.19	4.13	4.43	4.51	4.46
Feb	4.01	4.11	4.10	4.94	4.04	4.29	4.52	4.33
Mar	5.21	5.02	5.22	5.15	5.85	5.11	5.15	5.25
Apr	4.26	4.26	4.22	5.10	4.29	5.26	4.61	4.62
May	4.31	5.00	4.59	4.07	4.37	4.48	4.69	4.53
June	4.17	3.86	3.25	4.87	3.96	3.78	4.80	4.09
July	4.02	3.46	3.84	3.94	4.07	3.56	3.86	3.79
Aug	3.43	3.34	3.84	2.70	3.28	3.20	3.17	3.26
Sept	2.97	3.04	2.86	3.57	3.21	2.81	2.96	3.08
Oct	2.55	2.60	2.48	3.36	2.76	3.05	3.83	3.01
Nov	3.79	3.39	3.67	4.33	3.40	3.78	3.40	3.66
Dec	3.94	4.21	4.12	4.86	4.97	3.85	4.31	4.39
Annual	47.52	46.53	46.47	52.08	48.32	47.61	49.84	48.48

Standard Deviation of Monthly Rainfall Station 3994

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.96	2.81	2.16	3.08	2.00	2.38	2.38	2.47
Feb	2.32	2.16	2.24	2.63	2.06	2.04	1.88	2.17
Mar	2.39	2.30	2.38	2.75	2.30	1.92	2.29	2.32
Apr	1.68	2.03	2.09	1.98	1.98	2.59	2.36	2.17
May	2.54	2.42	2.57	2.23	2.68	2.34	1.94	2.36
June	2.40	1.73	1.75	2.49	2.42	2.47	3.07	2.32
July	1.88	1.77	1.91	2.05	2.08	2.12	2.00	1.99
Aug	1.82	2.16	1.71	1.50	1.45	1.75	1.94	1.75
Sept	1.85	1.80	2.17	2.65	2.10	1.82	1.84	2.06
Oct	1.63	1.49	1.61	1.85	1.75	2.18	2.52	1.90
Nov	2.33	1.55	2.10	2.78	2.06	1.88	2.12	2.08
Dec	1.89	2.13	2.76	2.69	2.19	2.00	2.00	2.30

Table 6. (continued)

Mean Monthly Rainfall Station 4825

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	4.37	4.12	4.32	4.74	4.39	4.25	4.29	3.72
Feb	3.67	4.03	3.66	3.74	3.97	3.76	3.26	3.74
Mar	4.71	4.92	4.92	3.93	4.77	4.39	4.56	4.58
Apr	3.87	4.00	4.39	4.27	4.07	4.27	4.15	3.69
May	4.07	3.52	4.19	4.51	4.25	43.6	3.87	4.12
June	4.35	3.78	4.19	3.99	4.38	3.94	4.15	4.07
July	4.81	4.34	4.73	4.93	4.66	4.70	4.91	4.71
Aug	3.81	3.89	3.68	3.11	3.53	3.69	3.03	3.48
Sept	2.96	3.08	3.02	2.85	3.15	2.73	2.83	2.94
Oct	1.94	2.13	1.86	1.68	2.01	2.02	2.00	1.95
Nov	3.17	3.43	3.24	3.39	3.11	3.49	3.12	2.79
Dec	3.40	3.38	3.98	4.12	3.94	4.20	3.98	3.93
Annual	45.12	44.62	46.17	45.26	46.21	45.79	44.14	45.37

Standard Deviation of Monthly Rainfall Station 4825

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	2.98	2.35	2.19	2.92	2.21	2.60	2.68	2.49
Feb	2.33	1.93	1.63	1.81	1.79	1.95	1.52	1.77
Mar	2.15	1.81	2.04	1.78	1.95	1.65	1.96	1.87
Apr	1.81	2.13	2.41	2.05	1.74	2.37	1.81	2.09
May	2.02	1.83	2.35	1.92	2.02	2.07	1.85	2.01
June	2.13	1.73	1.81	2.05	2.50	1.93	2.24	2.04
July	1.96	1.70	2.11	2.05	2.25	1.77	2.25	2.02
Aug	1.90	2.21	1.91	1.87	2.10	1.90	1.74	1.96
Sept	1.50	1.85	1.94	1.97	2.15	2.11	1.72	1.96
Oct	.93	1.22	1.14	1.16	1.45	1.33	1.20	1.25
Nov	1.66	1.87	1.69	1.92	1.49	1.66	1.89	1.75
Dec	1.76	1.85	2.41	2.60	1.60	2.11	1.99	2.09

Table 6. (continued)

Mean Monthly Rainfall Station 6353

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.56	3.78	3.80	3.60	3.78	3.34	3.71	3.67
Feb	3.70	3.92	3.95	3.82	3.74	3.35	4.12	3.82
Mar	4.34	4.39	3.74	4.09	4.24	4.74	4.64	4.31
Apr	3.59	4.12	4.11	3.84	3.70	4.09	3.82	3.95
May	3.91	3.96	3.82	4.36	3.80	4.31	4.62	4.15
June	4.15	4.12	3.76	3.71	3.95	4.01	4.10	3.94
July	5.16	4.26	5.13	5.65	5.50	5.19	4.47	5.03
Aug	3.60	3.81	3.77	4.14	3.44	3.40	2.98	3.59
Sept	3.24	3.52	3.32	3.02	3.02	3.76	3.39	3.34
Oct	2.16	2.28	2.21	2.81	1.90	2.16	1.83	2.20
Nov	2.79	2.61	3.15	3.06	2.83	2.92	3.06	2.94
Dec	3.12	3.20	3.40	3.81	3.42	3.47	3.54	3.47
Annual	43.32	43.98	44.16	45.89	43.32	44.73	44.28	44.39

Standard Deviation of Monthly Rainfall Station 6353

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	1.67	2.12	1.70	1.60	1.74	1.27	1.64	1.68
Feb	1.85	2.12	1.87	1.65	1.90	1.88	1.62	1.84
Mar	2.12	1.48	1.68	1.59	1.80	1.71	1.52	1.63
Apr	1.42	1.56	1.79	1.69	1.73	1.93	1.79	1.75
May	2.05	1.71	2.29	1.81	1.84	1.70	1.83	1.86
June	1.71	1.98	1.51	1.83	1.86	1.90	1.87	1.83
July	2.29	1.65	1.65	2.23	1.83	2.35	2.12	1.97
Aug	2.21	1.59	1.86	1.99	1.68	1.77	1.40	1.72
Sept	1.75	1.63	1.74	1.66	1.51	1.77	1.55	1.64
Oct	1.27	1.49	1.27	1.40	.90	1.19	1.12	1.23
Nov	1.32	1.24	1.46	1.48	1.22	1.52	1.28	1.37
Dec	1.38	1.38	1.67	1.77	1.58	1.44	1.43	1.55

Table 7. Average Annual Number of Wet Days

Station	Simulation No. 1	2	3	4	5	6	Simulation Ave	Historical
254	128	131	131	126	126	127	128	126
909	114	113	111	115	112	115	113	113
1345	101	101	99	101	103	100	101	102
3762	105	103	101	102	101	103	103	102
3994	106	107	112	107	108	111	109	108
4825	100	105	102	103	102	101	102	103
6353	134	133	134	132	133	133	133	133

Table 8. Maximum Daily Rainfall

Maximum Daily Rainfall Station 254

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	2.31	1.99	2.22	2.28	3.49	2.73	3.06	2.63
Feb	2.40	4.01	1.69	2.29	3.06	2.27	3.03	2.73
Mar	2.63	3.25	3.75	2.61	2.97	2.04	3.10	2.95
Apr	2.67	2.71	2.19	2.84	3.14	2.23	2.64	2.63
May	3.21	2.50	3.15	2.93	3.29	2.48	2.64	2.83
June	4.09	3.23	2.81	1.96	2.33	2.49	3.29	2.69
July	3.38	2.72	1.97	1.91	2.33	2.78	2.19	2.32
Aug	3.97	3.22	2.76	2.65	1.83	2.34	1.91	2.45
Sept	2.91	2.79	3.16	1.93	2.44	2.26	2.78	2.56
Oct	1.62	1.57	3.06	2.27	2.65	1.88	4.00	2.57
Nov	2.35	4.22	2.45	2.19	2.12	2.13	2.69	2.63
Dec	2.09	2.20	2.16	2.51	3.86	2.72	2.75	2.70
Annual	4.09	4.22	3.75	2.93	3.86	2.78	4.00	3.59

Maximum Daily Rainfall Station 909

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	4.75	2.50	3.58	3.33	3.96	3.32	2.77	3.24
Feb	3.01	3.12	4.30	4.13	3.27	2.51	3.33	3.44
Mar	4.48	3.02	3.77	3.70	2.71	3.48	3.21	3.32
Apr	4.61	3.43	3.06	3.08	2.87	3.34	3.13	3.15
May	2.98	2.76	3.89	3.64	2.99	2.94	3.61	3.31
June	5.69	3.84	4.26	4.95	3.01	5.36	2.84	4.04
July	3.20	3.23	4.26	4.31	3.19	3.88	3.20	3.68
Aug	2.87	3.13	2.91	2.48	4.83	2.39	3.42	3.19
Sept	3.91	3.09	3.16	2.87	3.71	3.71	3.76	3.38
Oct	2.70	2.89	2.79	3.16	3.77	3.33	2.13	3.01
Nov	3.54	2.69	4.39	4.13	2.92	3.54	3.49	3.53
Dec	4.47	4.42	3.87	2.90	3.54	3.92	3.00	3.61
Annual	5.69	4.42	4.39	4.95	4.83	5.36	3.76	4.62

Table 8. (continued)

Maximum Daily Rainfall Station 1345

		Simulation No.						
Month	Observed	1	2	3	4	5	6	Ave
Jan	2.93	3.67	3.06	2.82	4.28	2.69	2.65	3.20
Feb	3.14	1.99	2.58	2.88	2.82	2.58	2.21	2.51
Mar	3.66	4.02	2.58	3.03	3.05	3.86	4.35	3.48
Apr	2.45	2.86	2.38	2.54	4.12	3.36	2.42	2.95
May	3.85	2.16	2.11	2.79	2.72	7.31	2.67	3.29
June	4.25	3.36	3.41	2.82	3.16	3.15	3.13	3.17
July	2.88	4.12	3.03	3.90	2.87	4.29	2.22	3.41
Aug	5.05	2.28	2.24	2.45	2.47	2.48	3.24	2.53
Sept	3.41	2.75	3.58	1.90	2.36	2.40	3.97	2.83
Oct	3.80	2.57	3.30	2.28	2.53	2.45	2.34	2.58
Nov	3.20	1.94	2.60	2.31	2.65	2.60	3.01	2.52
Dec	2.90	4.11	2.96	2.54	2.53	3.46	4.85	3.41
Annual	5.05	4.12	3.58	3.90	4.28	7.31	4.85	4.67

Maximum Daily Rainfall Station 3762

		Simulation No.						
Month	Observed	1	2	3	4	5	6	Ave
Jan	4.15	3.32	4.82	3.66	3.54	5.19	3.43	3.99
Feb	3.57	2.67	3.38	2.82	5.15	3.25	3.41	3.45
Mar	6.33	3.45	2.79	2.89	2.83	3.93	6.01	3.65
Apr	3.91	3.19	3.58	2.99	4.48	3.06	3.20	3.42
May	3.25	4.63	2.80	4.15	3.67	3.00	4.12	3.73
June	3.06	3.89	3.56	3.15	3.21	3.04	3.09	3.32
July	5.02	3.39	3.26	3.18	3.29	4.35	3.55	3.50
Aug	4.32	2.74	2.82	3.75	3.30	2.72	2.71	3.01
Sept	4.10	3.30	4.00	3.26	2.69	3.20	2.82	3.21
Oct	2.35	2.76	2.87	3.47	3.51	5.39	4.36	3.73
Nov	2.83	2.82	2.68	3.20	2.52	3.19	2.82	2.87
Dec	4.28	3.37	3.58	3.15	4.22	4.09	2.80	3.54
Annual	6.33	4.63	4.82	4.15	5.15	5.39	6.01	5.03

Table 8. (continued)

Maximum Daily Rainfall Station 3994

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	4.47	5.21	2.46	3.33	3.12	3.88	3.53	3.59
Feb	4.75	3.55	3.35	5.16	2.99	3.02	2.59	3.44
Mar	3.44	2.99	2.94	3.88	3.76	3.76	3.64	3.50
Apr	3.37	3.89	4.33	3.26	4.63	3.66	3.47	3.87
May	3.86	3.00	3.89	3.96	3.28	3.30	4.18	3.60
June	4.22	2.60	3.66	5.34	3.94	2.58	3.85	3.66
July	4.13	2.96	4.21	3.26	3.82	3.78	4.32	3.73
Aug	2.93	3.79	3.25	2.91	3.50	2.90	2.80	3.19
Sept	4.15	2.91	3.13	2.71	2.97	4.51	3.47	3.28
Oct	2.55	2.71	4.11	3.91	2.54	4.16	4.31	3.62
Nov	4.07	2.76	3.76	3.31	3.06	2.60	3.31	3.13
Dec	2.75	2.74	3.88	3.41	3.26	3.56	3.67	3.42
Annual	4.75	5.21	4.33	5.34	4.63	4.51	4.32	4.72

Maximum Daily Rainfall Station 4825

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	3.10	3.44	2.72	3.12	2.83	3.42	3.72	3.21
Feb	2.75	4.42	5.11	2.65	2.43	3.30	2.48	3.40
Mar	3.00	3.19	3.42	4.35	3.10	2.08	3.09	3.21
Apr	2.80	3.03	3.20	4.73	3.03	2.49	2.91	3.23
May	2.65	2.65	2.47	2.48	3.47	3.36	2.65	2.85
June	2.75	2.75	2.82	3.26	3.22	4.32	3.11	3.25
July	3.50	3.54	3.10	3.68	3.94	2.92	3.75	3.49
Aug	2.95	3.17	3.03	2.21	2.53	2.35	2.73	2.67
Sept	2.44	2.47	3.62	2.52	2.82	3.16	3.00	2.93
Oct	1.99	2.18	2.05	2.87	2.95	3.36	2.13	2.59
Nov	2.15	3.11	2.73	2.45	2.66	2.42	3.43	2.80
Dec	2.45	2.27	3.12	4.41	3.19	2.72	3.12	3.14
Annual	3.50	4.42	5.11	4.73	3.94	4.32	3.75	4.38

Table 8. (continued)

Maximum Daily Rainfall Station 6353

Month	Observed	Simulation No. 1	2	3	4	5	6	Ave
Jan	2.05	3.07	2.55	2.80	2.80	2.18	1.90	2.55
Feb	2.67	2.04	2.82	2.07	2.96	2.46	3.08	2.57
Mar	2.76	2.23	2.34	1.95	2.70	2.34	2.99	2.43
Apr	2.94	2.96	2.28	2.21	1.83	2.41	3.50	2.53
May	3.02	2.81	2.79	2.53	2.59	1.98	2.64	2.56
June	3.12	2.51	2.22	3.04	2.12	2.52	4.44	2.81
July	3.41	2.72	3.18	2.61	3.27	2.64	2.79	2.87
Aug	2.43	2.39	2.08	2.84	2.36	1.65	2.32	2.27
Sept	2.83	2.51	1.88	2.41	2.44	3.40	2.80	2.57
Oct	2.20	1.93	2.42	2.26	2.01	1.96	2.06	2.11
Nov	2.20	1.74	2.17	3.28	1.82	2.13	1.95	2.18
Dec	2.76	2.66	2.51	2.33	2.18	2.49	2.73	2.48
Annual	3.41	3.07	3.18	3.28	3.27	3.40	4.44	3.44

Table 9. Runs of Wet and Dry Days for a Month with Average Rainfall

Runs of Dry Days Station 254 (April)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	77	82	97	78	80	74	79	81.7
2	66	56	55	50	60	49	62	55.3
3	35	32	47	40	29	30	32	35.0
4	19	21	20	28	16	31	22	23.0
5	12	18	11	13	18	17	12	14.8
6	13	11	6	13	13	15	12	11.7
7	13	7	7	5	9	7	8	7.2
8	2	6	2	8	5	8	6	5.8
9	1	3	2	1	4	4	1	2.5
10	0	2	1	0	3	2	1	1.5
11	3	0	2	1	0	0	5	1.3
12	1	0	1	0	1	1	0	.5
13	0	2	1	1	0	0	2	1.0
14	0	1	2	0	1	0	1	.8
≥15	2	1	0	2	0	2	1	1.0

Runs of Wet Days Station 254 (April)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	107	111	126	101	117	134	132	120.2
2	71	74	58	73	56	48	53	60.3
3	30	26	29	26	31	29	29	28.3
4	21	17	11	15	15	15	10	13.8
5	8	3	7	9	6	5	7	6.2
6	2	6	10	5	8	3	4	6.0
7	0	1	4	2	1	1	1	1.7
8	0	1	1	0	0	0	2	.7
9	0	0	1	0	1	0	0	.3
10	0	0	0	1	1	0	0	.3
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
≥15	0	0	0	0	0	0	0	0

Table 9. (continued)

Runs of Dry Days Station 909 (May)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	59	81	63	59	60	74	68	67.5
2	57	52	37	39	58	47	46	46.5
3	39	32	37	32	34	42	36	35.5
4	19	21	17	24	23	24	24	22.2
5	14	25	14	19	19	15	19	18.5
6	14	9	13	11	8	11	12	10.6
7	10	9	14	8	14	10	8	10.5
8	5	6	7	11	4	4	11	7.2
9	7	4	5	10	5	3	4	5.2
10	8	2	3	3	3	1	3	2.5
11	1	4	6	3	1	2	0	2.7
12	2	2	0	1	2	4	2	1.8
13	2	0	4	2	0	0	1	1.2
14	0	0	1	0	3	0	1	0.8
≥15	0	3	1	1	2	4	3	2.3

Runs of Wet Days Station 909 (May)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	116	134	109	105	120	116	125	118.2
2	57	54	41	47	63	66	53	54.0
3	28	27	29	28	17	19	28	24.7
4	9	13	16	15	16	17	10	14.5
5	3	4	6	5	3	4	1	3.8
6	2	3	4	4	2	2	2	2.8
7	3	0	0	1	1	3	2	1.2
8	1	0	0	0	2	0	0	0.3
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	1	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 9. (continued)

Runs of Dry Days Station 1345 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	33	42	26	29	34	44	39	35.7
2	28	36	30	30	32	37	24	31.5
3	20	29	33	32	18	30	18	26.7
4	23	24	22	16	14	23	13	18.7
5	14	15	22	16	16	19	15	17.2
6	12	16	12	8	9	10	7	10.3
7	16	13	8	13	6	9	9	9.7
8	13	10	9	5	10	10	8	8.7
9	5	4	4	2	9	6	10	5.8
10	6	8	4	3	5	5	5	5
11	3	5	5	7	5	3	4	4.8
12	1	1	6	6	2	0	3	3.0
13	3	0	4	3	2	4	3	2.7
14	0	0	1	1	4	0	5	1.8
≥15	10	7	7	13	14	9	11	10.2

Runs of Wet Days Station 1345 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	100	128	95	96	111	123	92	107.5
2	48	37	45	38	32	43	37	38.7
3	13	13	11	9	10	20	17	13.3
4	6	6	6	7	1	5	4	4.8
5	0	2	3	3	1	0	1	1.7
6	0	1	1	1	0	0	2	0.8
7	0	1	0	0	0	0	0	0.2
8	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 9. (continued)

Runs of Dry Days Station 3762 (June)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	50	72	52	47	50	51	45	52.8
2	43	49	33	36	37	41	39	39.2
3	19	37	24	25	23	21	28	26.3
4	27	23	28	23	22	28	31	25.8
5	18	14	21	15	13	16	14	15.5
6	11	12	19	13	11	8	12	12.5
7	8	6	10	14	7	6	10	8.8
8	2	6	7	4	5	10	8	6.7
9	10	5	4	2	6	6	6	4.8
10	6	5	3	6	6	5	1	4.3
11	3	3	2	3	3	3	3	2.8
12	2	2	2	2	5	3	1	2.5
13	3	0	1	1	0	1	2	0.8
14	1	0	4	2	3	0	1	1.7
≥15	4	3	1	8	6	8	6	5.3

Runs of Wet Days Station 3762 (June)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	103	127	106	86	104	110	105	106.3
2	52	54	53	57	41	40	48	48.8
3	24	17	31	22	17	18	27	22.0
4	8	12	6	7	8	8	5	7.7
5	1	4	5	3	4	2	3	3.5
6	2	2	0	1	3	3	2	1.8
7	0	3	0	0	3	1	1	1.3
8	1	0	0	1	1	0	0	0.3
9	0	0	0	0	0	1	0	0.2
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 9. (continued)

Runs of Dry Days Station 3994 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	26	33	37	44	34	40	39	37.8
2	33	26	33	36	25	34	37	31.8
3	22	22	18	36	30	31	27	27.3
4	24	16	18	14	12	18	19	16.2
5	21	15	13	21	12	20	20	16.8
6	13	19	12	21	16	12	9	14.8
7	10	14	12	5	13	11	8	10.5
8	11	8	5	8	8	11	9	8.2
9	4	7	9	5	6	3	11	6.8
10	3	5	5	1	3	6	2	3.7
11	1	4	5	5	6	5	2	4.5
12	4	4	6	4	1	3	4	3.7
13	3	2	2	4	4	7	4	3.8
14	1	2	2	1	4	2	1	2.0
≥15	10	8	10	6	9	3	7	7.2

Runs of Wet Days Station 3994 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	95	110	103	126	108	120	110	112.8
2	53	34	39	44	30	36	38	36.8
3	13	12	12	16	10	22	18	15.0
4	6	5	4	3	8	3	8	5.2
5	0	2	1	4	4	3	4	3.0
6	0	2	2	0	4	0	2	1.7
7	0	1	1	0	0	0	0	0.3
8	1	1	0	1	0	0	1	0.5
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 9. (continued)

Runs of Dry Days Station 4825 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	45	44	37	36	59	52	35	43.8
2	30	28	39	35	35	38	35	35.0
3	23	27	31	34	27	24	28	28.5
4	26	22	28	17	14	23	16	20.0
5	21	12	22	14	9	20	28	17.5
6	14	11	13	10	18	15	14	13.5
7	21	5	6	18	11	11	12	10.5
8	12	7	7	5	8	5	11	7.2
9	4	7	5	4	9	10	4	6.5
10	7	8	4	3	7	4	4	5.0
11	3	5	5	9	6	1	5	5.2
12	0	1	4	2	4	6	2	3.2
13	2	5	0	2	2	3	2	2.3
14	2	4	2	1	2	2	2	2.2
≥15	3	8	7	10	5	3	7	6.7

Runs of Wet Days Station 4825 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	118	114	125	127	130	125	116	122.8
2	55	35	35	34	42	48	46	40.7
3	12	13	13	18	16	18	17	15.8
4	1	9	5	3	3	5	1	4.3
5	3	3	0	0	1	1	1	1.0
6	1	0	1	0	0	1	0	0.3
7	0	0	1	0	0	0	0	0.2
8	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 9. (continued)

Runs of Dry Days Station 6353 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	69	72	64	50	59	57	40	57.0
2	35	51	46	55	48	55	34	48.2
3	28	33	30	35	40	30	38	34.3
4	18	22	23	23	21	26	25	23.3
5	22	21	16	18	14	12	22	17.2
6	19	15	19	7	12	9	16	13.0
7	12	9	5	10	14	9	11	9.7
8	5	3	7	5	7	6	8	6.0
9	5	11	5	5	5	5	7	6.3
10	3	0	1	5	1	1	4	2.0
11	3	4	3	5	5	2	1	3.3
12	1	2	3	1	1	5	5	2.8
13	1	0	1	1	2	1	1	1.0
14	1	1	1	1	2	1	1	1.2
≥15	2	1	3	3	1	5	1	2.3

Runs of Wet Days Station 6353 (August)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	105	126	109	106	124	125	119	118.2
2	64	67	60	54	46	49	50	54.3
3	25	24	35	33	16	26	24	26.3
4	9	11	4	8	20	11	10	10.7
5	8	1	5	4	4	3	4	3.5
6	1	2	1	3	2	3	0	1.8
7	2	1	1	0	2	2	0	1.0
8	0	0	1	0	0	1	0	0.3
9	0	0	0	0	0	0	0	0.0
10	0	0	1	1	0	0	0	0.3
11	0	0	0	0	0	0	0	0.0
12	0	0	1	1	0	0	0	0.3
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. Runs of Wet and Dry Days for the Wettest Month

Runs of Dry Days Station 254 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	86	89	81	72	91	91	83	84.5
2	49	53	41	59	60	53	56	53.7
3	33	32	46	32	36	36	43	37.5
4	23	37	23	29	23	22	21	25.8
5	15	15	27	14	20	15	9	16.7
6	15	11	7	12	13	11	13	11.3
7	4	7	10	10	4	10	13	9.0
8	9	3	5	5	6	5	1	4.2
9	8	3	0	8	3	3	5	3.7
10	3	1	1	2	4	2	1	1.8
11	1	3	3	1	0	1	0	1.3
12	4	1	3	1	1	3	2	1.8
13	0	1	0	1	1	2	5	1.7
14	0	1	1	0	2	0	1	0.8
≥15	0	0	2	1	0	1	1	.8

Runs of Wet Days Station 254 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	122	123	124	132	137	135	122	128.8
2	70	65	60	50	51	61	63	58.3
3	27	35	30	30	37	34	30	32.7
4	13	16	12	13	12	13	14	13.3
5	5	4	4	7	3	5	5	4.7
6	2	6	3	4	4	3	3	3.8
7	1	0	1	1	0	0	0	.3
8	0	0	1	0	1	0	0	.3
9	0	0	0	0	0	0	0	.0
10	0	0	0	0	1	0	0	.2
11	0	0	0	0	0	0	0	.0
12	0	0	0	0	0	0	0	.0
13	0	0	0	0	0	0	0	.0
14	0	0	0	0	0	0	0	.0
≥15	0	0	0	0	0	0	0	.0

Table 10. (continued)

Runs of Dry Days Station 909 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	85	92	97	99	90	92	84	92.3
2	61	53	69	64	50	69	62	61.2
3	48	39	33	34	41	38	38	37.2
4	31	23	30	27	24	33	29	27.7
5	16	18	15	15	16	16	20	16.7
6	13	13	9	10	16	13	12	10.5
7	6	7	10	6	11	8	4	7.7
8	6	3	4	7	3	2	4	3.8
9	0	4	1	0	4	2	2	2.2
10	3	3	3	3	1	0	1	1.8
11	0	0	1	2	2	1	4	1.7
12	1	1	0	1	0	0	2	0.7
13	1	0	0	1	1	0	0	0.3
14	0	0	0	0	0	0	0	0.0
≥15	0	1	2	2	1	1	1	1.3

Runs of Wet Days Station 909 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	141	135	129	142	129	142	127	134.0
2	67	60	74	69	65	71	69	68.0
3	22	32	37	34	30	29	29	31.8
4	16	14	12	8	11	18	11	12.3
5	6	5	4	6	5	4	8	5.3
6	2	1	3	3	3	2	1	2.2
7	1	1	0	0	2	1	1	0.8
8	1	1	0	0	1	1	0	0.5
9	0	0	0	0	0	0	1	0.2
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. (continued)

Runs of Dry Days Station 1345 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	68	75	84	67	73	89	69	76.2
2	64	50	53	53	54	54	54	53.
3	37	38	42	37	44	24	37	37.
4	32	31	19	26	23	19	31	24.8
5	15	13	14	19	22	15	15	16.3
6	16	13	14	8	15	13	12	12.5
7	7	15	9	11	7	15	8	10.8
8	7	5	5	11	5	6	5	6.2
9	8	7	5	3	4	10	6	5.8
10	0	2	0	0	3	3	2	1.7
11	1	4	4	5	4	4	4	4.2
12	2	1	4	2	2	1	1	1.8
13	1	0	0	0	1	0	2	0.5
14	0	1	1	0	1	0	2	0.8
≥15	0	0	2	2	0	0	1	0.8

Runs of Wet Days Station 1345 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	138	153	145	125	145	136	149	142.2
2	65	52	56	64	61	54	56	57.2
3	22	23	22	22	20	28	23	23.
4	13	8	12	8	12	12	9	10.2
5	2	3	5	5	2	3	1	3.2
6	1	1	0	2	0	0	0	0.5
7	1	1	0	1	0	2	1	0.8
8	0	0	1	0	0	1	1	0.5
9	0	0	0	1	0	0	0	0.2
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. (continued)

Runs of Dry Days Station 3762 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	73	85	77	92	95	95	91	89.2
2	50	46	54	57	65	57	51	55.0
3	40	38	44	39	30	35	36	37.0
4	35	29	25	25	26	27	29	26.8
5	17	17	23	20	22	19	15	19.3
6	14	8	6	12	5	10	12	8.8
7	11	11	10	11	4	6	6	8.0
8	3	8	8	7	5	5	1	5.7
9	5	1	1	2	5	3	2	2.3
10	3	3	2	3	3	2	3	2.7
11	0	2	0	1	3	3	1	1.7
12	1	0	0	1	1	1	0	0.5
13	1	0	2	0	2	1	2	1.2
14	0	1	0	0	1	1	0	0.5
≥15	1	1	2	0	1	1	3	1.3

Runs of Wet Days Station 3762 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	121	129	131	148	146	147	119	136.7
2	75	49	62	65	62	65	64	61.2
3	26	25	29	22	25	24	31	26.0
4	9	15	12	15	8	13	16	13.2
5	5	11	7	6	2	6	10	7.0
6	2	3	1	0	7	1	2	2.3
7	0	2	2	1	1	1	1	1.3
8	0	1	1	0	0	0	0	0.3
9	0	0	0	0	0	0	1	0.2
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	1	0	0	0	0	1	0.3
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. (continued)

Runs of Dry Days Station 3994 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	81	72	103	82	86	103	85	88.5
2	58	56	63	50	62	61	68	60.0
3	53	37	40	42	40	39	35	38.8
4	27	27	36	27	23	32	21	27.7
5	14	28	14	18	14	21	18	18.8
6	13	9	9	12	12	14	12	11.3
7	9	7	13	8	5	5	4	7.0
8	6	9	1	3	9	3	7	5.3
9	3	4	1	9	2	4	4	4.0
10	0	0	0	2	2	1	3	1.3
11	1	3	2	0	2	1	3	1.8
12	0	1	1	1	1	0	0	0.7
13	0	1	1	1	1	0	1	0.8
14	2	0	0	0	0	0	0	0.0
≥15	0	0	0	2	1	0	0	0.5

Runs of Wet Days Station 3994 (March)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	126	129	163	141	134	156	134	142.8
2	73	64	68	57	59	69	61	63.0
3	24	30	24	22	23	28	34	26.8
4	16	10	9	10	14	11	15	11.5
5	5	4	3	6	7	6	5	5.2
6	3	0	4	3	5	1	1	2.3
7	0	3	2	2	2	1	1	1.8
8	0	0	1	0	0	0	2	0.5
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	1	0	0	0.2
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. (continued)

Runs of Dry Days Station 4825 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	78	77	85	88	65	70	87	77.7
2	54	58	47	42	58	52	55	52.0
3	44	45	34	44	37	28	34	37.0
4	15	29	24	29	18	28	20	24.7
5	17	9	13	26	11	17	10	14.3
6	13	14	16	12	16	13	10	13.5
7	6	15	11	6	14	13	19	13.0
8	9	5	5	1	7	11	6	5.8
9	4	4	8	5	3	4	5	4.8
10	3	0	3	4	5	3	6	3.3
11	3	1	1	1	1	3	3	1.7
12	0	2	1	1	4	2	1	1.8
13	5	2	4	1	3	0	1	1.8
14	1	1	0	1	1	0	0	0.5
≥15	1	1	1	2	1	2	1	1.3

Runs of Wet Days Station 4825 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	136	150	139	162	138	141	137	144.5
2	64	64	59	55	51	55	68	68.7
3	27	19	24	28	26	18	19	22.3
4	6	9	10	4	5	6	7	6.8
5	2	1	3	4	3	6	4	3.5
6	0	0	1	1	2	0	2	1.0
7	0	1	0	0	0	0	1	0.3
8	0	1	0	0	0	1	0	0.3
9	1	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 10. (continued)

Runs of Dry Days Station 6353 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	90	77	97	93	115	84	92	93.0
2	49	48	56	52	66	58	56	56.0
3	49	47	34	31	37	44	38	38.5
4	26	28	28	32	22	32	20	27.0
5	23	17	20	16	13	14	16	16.0
6	5	17	9	9	9	9	11	10.7
7	7	7	5	7	5	5	7	6.0
8	4	6	5	1	3	6	5	4.3
9	3	0	3	5	2	4	2	2.7
10	1	5	2	1	6	1	3	3.0
11	2	0	0	1	0	3	0	0.7
12	1	0	2	2	1	0	2	1.2
13	1	0	0	0	0	0	4	0.7
14	0	1	1	0	1	0	2	0.8
≥15	0	1	0	1	00	1	0	0.5

Runs of Wet Days Station 6353 (July)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	124	141	118	109	142	142	136	131.3
2	70	63	66	70	71	62	57	64.8
3	25	19	34	33	31	22	24	27.2
4	15	17	6	21	15	10	18	14.5
5	8	4	10	8	10	9	4	7.5
6	6	1	9	4	3	3	2	3.7
7	1	2	2	2	1	3	0	1.7
8	0	0	0	2	0	0	0	0.3
9	1	1	1	0	0	1	1	0.7
10	0	1	0	0	0	1	2	0.7
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. Runs of Wet and Dry Days for the Driest Month

Runs of Dry Days Station 254 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	36	41	44	51	50	44	44	45.7
2	33	24	37	37	26	32	34	31.7
3	27	25	26	38	22	33	28	28.7
4	32	25	20	26	26	22	22	23.5
5	25	13	20	15	11	17	16	15.3
6	11	19	12	14	9	10	14	13.0
7	10	10	14	6	12	10	12	10.7
8	10	7	9	6	11	8	11	8.7
9	8	6	11	8	7	3	7	7.0
10	2	8	3	6	11	4	3	5.8
11	1	5	3	0	3	2	4	2.8
12	1	2	2	3	5	7	6	4.2
13	5	2	2	3	1	3	2	2.2
14	0	3	2	1	4	0	2	2.0
≥15	5	6	6	6	3	4	4	4.8

Runs of Wet Days Station 254 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	110	114	130	125	117	131	126	123.8
2	49	36	40	47	45	37	36	40.2
3	19	12	10	18	19	14	20	15.5
4	6	10	2	5	7	3	6	5.3
5	3	2	6	1	0	4	2	2.5
6	0	0	0	3	0	0	0	.5
7	0	1	0	0	1	0	0	.3
8	0	0	1	0	0	0	0	.2
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
≥15	0	0	0	0	0	0	0	0

Table 11. (continued)

Runs of Dry Days Station 909 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	28	46	47	51	52	51	52	49.8
2	29	27	31	27	41	42	38	34.3
3	31	19	26	33	28	20	21	24.5
4	21	23	11	12	21	22	22	18.5
5	22	14	14	21	18	21	13	16.8
6	12	13	12	12	9	17	16	13.2
7	15	9	9	13	11	8	9	9.8
8	7	10	9	8	8	11	6	8.7
9	5	4	4	2	7	7	6	5.0
10	3	5	5	6	7	4	4	5.2
11	0	3	4	5	2	3	4	3.5
12	5	3	7	5	5	2	8	5.0
13	3	6	2	2	1	2	4	2.8
14	1	0	3	1	1	4	2	1.8
≥15	9	10	9	9	6	4	5	7.2

Runs of Wet Days Station 909 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	108	111	105	131	118	137	112	119.
2	43	44	32	35	50	44	44	41.5
3	20	13	26	10	13	14	19	15.8
4	3	3	6	6	9	2	5	5.2
5	0	1	1	1	3	3	2	1.8
6	0	1	0	1	0	0	0	.3
7	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	0.2
9	0	0	0	0	1	0	0	0.2
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. (continued)

Runs of Dry Days Station 1345 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	29	33	25	32	26	37	39	32.0
2	25	27	36	35	22	28	35	30.5
3	23	26	25	21	22	17	25	22.7
4	24	17	18	20	14	18	14	16.8
5	20	13	17	19	9	8	14	13.3
6	10	16	6	16	16	14	14	13.7
7	11	17	10	8	11	7	10	10.5
8	10	12	9	12	11	14	7	10.8
9	4	5	5	7	9	4	9	6.5
10	3	3	5	2	7	4	2	3.8
11	1	4	11	4	3	7	4	5.5
12	3	1	1	0	4	2	2	1.7
13	2	3	4	1	5	1	3	2.8
14	0	2	1	4	4	2	2	2.5
≥15	15	9	10	9	9	12	12	10.2

Runs of Wet Days Station 1345 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	99	103	102	93	99	94	98	98.2
2	43	37	33	44	41	36	45	39.8
3	11	10	15	19	9	9	10	12.0
4	5	9	4	8	4	4	6	5.8
5	2	2	1	3	1	4	2	2.2
6	0	0	0	0	0	3	0	0.5
7	0	1	0	0	0	0	1	0.3
8	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. (continued)

Runs of Dry Days Station 3762 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	19	30	21	39	24	40	27	30.2
2	29	26	33	20	37	30	29	29.2
3	20	19	19	24	21	18	13	19.0
4	30	16	20	13	31	13	15	18.0
5	13	16	13	21	14	17	14	15.8
6	20	9	14	17	12	17	15	14.0
7	10	15	12	9	10	8	15	11.5
8	11	11	7	9	8	8	10	8.8
9	5	9	8	3	9	9	9	7.8
10	2	4	3	5	6	3	5	4.3
11	0	4	6	3	5	8	1	4.5
12	4	3	3	2	2	1	3	2.2
13	3	1	4	1	1	0	6	2.2
14	1	4	2	3	3	2	3	2.8
≥15	11	12	12	14	8	13	9	11.3

Runs of Wet Days Station 3762 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	99	101	105	109	102	107	86	101.7
2	48	27	29	36	31	35	43	33.5
3	9	12	9	10	23	13	14	13.5
4	3	4	6	7	4	5	9	5.8
5	2	1	1	1	2	0	1	1.0
6	0	0	0	0	0	1	0	0.2
7	0	0	0	0	0	0	0	0.0
8	0	0	0	0	1	0	0	0.2
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	00	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. (continued)

Runs of Dry Days Station 3994 (December)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	48	52	58	61	72	58	60	60.2
2	62	41	53	46	45	33	44	43.7
3	33	38	34	38	27	36	54	37.8
4	26	29	32	27	16	25	27	26.0
5	16	14	18	10	23	22	12	16.5
6	13	11	11	17	13	13	11	12.7
7	10	14	15	7	14	8	8	11.0
8	11	7	4	6	9	11	4	618
9	4	3	1	9	5	4	5	4.5
10	2	2	3	3	4	3	5	3.3
11	0	2	3	4	3	3	4	3.2
12	0	3	2	1	0	2	2	1.7
13	1	2	0	2	1	2	1	1.3
14	1	1	2	0	1	1	0	0.8
≥15	5	3	3	1	0	2	3	2.0

Runs of Wet Days Station 3994 (December)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	104	117	134	118	108	105	129	118.5
2	71	50	58	50	47	63	46	52.3
3	24	25	19	31	31	23	23	25.3
4	4	14	13	10	19	11	13	13.3
5	3	6	1	10	7	3	3	5.0
6	1	1	2	1	2	2	1	1.5
7	2	0	0	0	1	0	2	0.5
8	1	1	1	0	0	1	0	0.5
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. (continued)

Runs of Dry Days Station 4825 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	35	28	25	28	31	30	35	29.5
2	20	20	24	24	23	32	31	25.7
3	25	25	26	15	18	29	20	22.2
4	24	17	18	19	11	23	21	18.2
5	15	8	12	9	14	22	7	12.0
6	8	17	15	10	8	12	12	12.3
7	8	9	10	9	9	8	9	9.0
8	12	8	14	7	15	7	9	10.0
9	8	6	5	8	6	2	6	5.5
10	1	5	6	3	7	3	5	4.8
11	5	6	6	6	3	4	5	5.0
12	3	3	1	4	2	7	3	3.3
13	3	3	5	5	4	3	2	3.7
14	3	3	3	2	6	3	3	3.3
≥15	12	14	9	17	12	11	13	12.7

Runs of Wet Days Station 4825 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	104	109	112	97	103	133	116	111.7
2	39	26	37	32	27	30	33	30.8
3	7	10	6	6	9	6	8	7.5
4	4	2	0	1	2	2	3	1.7
5	0	1	0	0	3	0	1	0.8
6	0	1	0	0	1	0	0	0.3
7	0	0	0	0	0	0	0	0.0
8	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	0	0	0	0	0	0	0.0
12	0	0	0	0	0	0	0	0.0
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 11. (continued)

Runs of Dry Days Station 6353 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	46	46	33	50	32	46	39	41.0
2	24	33	31	37	41	36	47	37.5
3	26	30	26	35	27	20	18	26.0
4	30	27	22	18	18	17	20	20.3
5	21	11	22	20	13	12	21	16.5
6	14	15	17	20	17	17	9	15.8
7	10	6	10	8	10	10	11	9.2
8	5	5	12	8	7	6	8	7.7
9	6	5	7	5	10	9	7	7.2
10	4	4	5	5	6	5	6	5.2
11	1	3	2	2	5	5	4	3.5
12	2	5	2	2	1	5	3	3.0
13	3	4	3	2	1	5	3	3.0
14	3	3	1	3	2	3	2	2.3
≥15	6	6	5	1	6	4	6	4.7

Runs of Wet Days Station 6353 (October)

Run Length (Days)	Observed	Simulation No. 1	2	3	4	5	6	Ave
1	96	113	105	108	99	107	121	108.8
2	55	36	41	51	47	43	35	42.2
3	21	18	17	24	19	15	21	19.0
4	7	8	9	7	4	11	7	7.7
5	3	4	1	3	4	2	2	2.7
6	0	1	2	1	1	1	0	1.0
7	1	1	0	0	0	0	0	0.2
8	0	0	0	2	1	0	0	0.5
9	0	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0	0.0
11	0	1	0	0	0	0	0	0.2
12	0	0	0	0	1	0	0	0.2
13	0	0	0	0	0	0	0	0.0
14	0	0	0	0	0	0	0	0.0
≥15	0	0	0	0	0	0	0	0.0

Table 12. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

Kentucky #254. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	2.73	2.50	2.78	2.92	2.32	2.65	2.21
Feb	2.11	2.08	2.10	2.20	2.26	2.15	2.11
Mar	2.74	3.27	3.13	3.33	3.20	3.13	2.90
Apr	2.27	2.11	2.47	1.53	1.66	2.01	1.82
May	1.39	1.73	1.33	1.13	1.77	1.47	1.33
June	0.96	0.78	0.89	0.85	1.03	0.90	0.79
July	0.58	0.57	0.71	0.61	0.63	0.62	0.76
Aug	0.42	0.38	0.33	0.38	0.33	0.37	0.54
Sept	0.37	0.31	0.26	0.39	0.29	0.32	0.36
Oct	0.35	0.38	0.31	0.34	0.37	0.35	0.31
Nov	0.65	0.62	0.55	0.52	0.61	0.59	0.50
Dec	1.59	1.58	1.34	1.62	1.54	1.53	1.28
Sum	16.14	16.30	16.19	15.83	16.01	16.09	14.92

Kentucky #909. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	4.14	3.31	3.90	3.44	3.72	3.70	3.81
Feb	3.62	3.16	3.30	3.06	4.17	3.46	3.18
Mar	4.32	3.71	3.88	4.23	4.58	4.14	3.92
Apr	2.87	2.51	2.74	2.92	2.85	2.78	2.48
May	1.77	1.71	2.11	1.97	1.76	1.87	1.76
June	1.20	1.32	1.25	1.25	1.15	1.23	1.42
July	1.03	1.06	1.10	0.82	1.03	1.01	0.94
Aug	0.71	0.72	0.80	0.57	0.79	0.72	0.71
Sept	0.73	0.68	0.62	0.61	0.65	0.66	0.58
Oct	0.80	0.62	0.72	0.59	0.66	0.68	0.48
Nov	0.94	0.99	0.96	1.06	1.10	1.01	0.85
Dec	1.80	2.16	2.13	2.08	2.97	2.23	2.17
Sum	23.93	21.95	23.55	22.60	25.43	23.49	22.30

Table 12 Continued.

Kentucky #1345. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	2.75	3.35	3.42	2.40	2.71	2.92	2.61
Feb	2.64	2.25	3.21	2.72	2.69	2.70	2.37
Mar	3.38	3.59	3.37	3.85	3.76	3.59	3.44
Apr	1.93	1.72	2.22	2.06	1.73	1.93	2.02
May	0.66	1.57	1.58	1.75	0.99	1.31	1.15
June	0.77	0.66	0.62	1.09	0.64	0.76	0.87
July	0.25	0.34	0.27	0.63	0.40	0.38	0.47
Aug	0.23	0.31	0.15	0.26	0.32	0.25	0.41
Sept	0.18	0.21	0.11	0.24	0.20	0.19	0.24
Oct	0.24	0.46	0.12	0.22	0.21	0.25	0.19
Nov	0.79	0.82	0.61	0.86	0.77	0.77	0.56
Dec	1.90	1.55	1.57	1.91	2.07	1.80	1.35
Sum	15.70	16.83	17.25	17.98	16.49	16.85	15.68

Kentucky #3762. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	1.87	1.72	2.03	2.46	1.92	2.00	2.34
Feb	2.25	1.83	2.45	1.96	1.78	2.06	1.72
Mar	2.41	3.05	2.54	3.28	4.15	3.08	2.99
Apr	1.70	2.09	2.43	1.56	2.00	1.96	1.86
May	1.21	1.41	1.44	0.89	1.14	1.22	1.12
June	0.92	0.62	0.65	0.49	0.82	0.70	0.45
July	0.55	0.44	0.58	0.49	0.54	0.52	0.59
Aug	0.38	0.26	0.27	0.24	0.25	0.28	0.39
Sept	0.39	0.27	0.32	0.34	0.19	0.30	0.32
Oct	0.25	0.27	0.40	0.47	0.26	0.33	0.25
Nov	0.62	0.49	0.55	0.53	0.53	0.54	0.49
Dec	1.44	1.41	1.65	1.18	1.03	1.34	1.02
Sum	13.99	13.84	15.32	13.88	14.61	14.33	13.54

Table 12 Continued.

Kentucky #3994. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	1.73	2.92	1.81	1.96	2.04	2.09	2.30
Feb	1.96	2.72	1.98	2.01	2.31	2.20	1.95
Mar	2.42	2.75	3.09	2.41	2.66	2.67	2.50
Apr	1.51	1.73	1.49	2.12	1.50	1.67	1.38
May	1.01	0.86	0.92	1.03	1.00	0.97	1.09
June	0.41	0.85	0.57	0.53	1.05	0.68	0.50
July	0.28	0.40	0.42	0.37	0.32	0.35	0.37
Aug	0.19	0.16	0.21	0.20	0.19	0.19	0.28
Sept	0.18	0.31	0.22	0.15	0.18	0.21	0.28
Oct	0.20	0.34	0.20	0.30	0.47	0.30	0.15
Nov	0.43	0.87	0.41	0.31	0.43	0.49	0.51
Dec	1.27	1.79	1.42	0.97	1.33	1.36	1.00
Sum	11.60	15.70	12.72	12.35	13.48	13.17	12.32

Kentucky #4825. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	2.92	3.31	3.12	2.99	3.02	3.07	2.96
Feb	2.65	2.73	2.98	2.73	2.28	2.67	2.66
Mar	3.43	2.53	3.31	2.97	3.13	3.07	3.26
Apr	2.31	2.41	2.08	2.22	2.18	2.24	1.93
May	1.56	1.41	1.53	1.67	1.19	1.47	1.36
June	0.89	0.93	1.12	0.78	0.94	0.93	0.99
July	0.80	0.76	0.76	0.65	0.82	0.76	0.92
Aug	0.58	0.43	0.51	0.58	0.41	0.50	0.52
Sept	0.39	0.44	0.51	0.39	0.39	0.42	0.35
Oct	0.32	0.31	0.38	0.34	0.31	0.33	0.32
Nov	0.60	0.67	0.68	0.73	0.69	0.67	0.62
Dec	2.10	2.21	1.74	2.21	1.71	1.99	1.56
Sum	18.56	18.13	18.71	18.26	17.06	18.15	17.44

Table 12 Continued.

Kentucky #6353. Comparisons Between Runoff Generated Using Historical and Simulated Rainfall.

	Simulation Number 2	3	4	5	6	Sim Ave	Historical
Jan	2.38	2.35	2.30	1.97	2.16	2.23	2.09
Feb	3.07	2.88	2.70	2.52	3.11	2.86	2.60
Mar	2.65	3.01	3.06	3.54	3.45	3.14	3.30
Apr	2.16	2.04	1.98	2.38	2.08	2.13	1.82
May	1.42	1.64	1.24	1.44	1.67	1.48	1.36
June	0.70	0.84	0.84	0.99	1.02	0.88	0.95
July	0.82	0.91	0.95	0.93	0.98	0.92	1.00
Aug	0.45	0.84	0.50	0.47	0.41	0.53	0.68
Sept	0.52	0.41	0.38	0.54	0.44	0.46	0.47
Oct	0.39	0.50	0.30	0.42	0.29	0.38	0.31
Nov	0.70	0.80	0.34	0.52	0.49	0.57	0.45
Dec	1.49	1.90	1.29	1.36	1.08	1.42	1.02
Sum	16.77	18.12	15.89	17.10	17.17	17.01	15.96

APPENDIX B

MODEL PARAMETERS

Table 13. Transition Probability Matrices.

Station	λ	Sum of Rainfalls $\geq$ 0.63 in.	Total Number Rainfalls $\geq$ 0.63 in.
254	.4552	792.22	730
909	.5572	1218.02	1026
1345	.5136	922.90	807
3762	.5818	1166.93	963
3994	.5915	1234.89	1011
4825	.4833	1075.41	966
6353	.4131	893.91	857

State boundaries (inches) are:

0 .01 .03 .07 .15 .31 .63 ∞

all intervals are closed on the left and open on the right.

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 254

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.680	0.048	0.058	0.071	0.055	0.051	0.036	722
2	0.608	0.108	0.054	0.068	0.054	0.054	0.054	74
3	0.530	0.120	0.096	0.072	0.084	0.048	0.048	83
4	0.563	0.103	0.080	0.080	0.080	0.069	0.023	87
5	0.488	0.024	0.095	0.048	0.143	0.131	0.071	84
6	0.372	0.116	0.081	0.070	0.058	0.163	0.140	86
7	0.359	0.031	0.109	0.141	0.078	0.109	0.172	64

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.661	0.048	0.060	0.059	0.072	0.069	0.030	663
2	0.589	0.082	0.055	0.082	0.055	0.110	0.027	73
3	0.621	0.030	0.061	0.076	0.076	0.091	0.045	66
4	0.480	0.120	0.107	0.080	0.080	0.040	0.093	75
5	0.528	0.101	0.045	0.101	0.101	0.101	0.022	89
6	0.443	0.101	0.076	0.101	0.139	0.076	0.063	79
7	0.489	0.067	0.089	0.022	0.111	0.089	0.133	45

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.632	0.035	0.053	0.076	0.076	0.087	0.041	682
2	0.629	0.113	0.113	0.016	0.016	0.081	0.032	62
3	0.589	0.063	0.074	0.074	0.063	0.053	0.084	95
4	0.435	0.059	0.118	0.094	0.082	0.106	0.106	85
5	0.486	0.101	0.073	0.046	0.174	0.055	0.064	109
6	0.433	0.041	0.155	0.082	0.113	0.082	0.093	97
7	0.357	0.057	0.157	0.071	0.143	0.100	0.114	70

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.685	0.041	0.044	0.060	0.070	0.057	0.043	702
2	0.625	0.036	0.071	0.036	0.089	0.071	0.071	56
3	0.486	0.057	0.086	0.129	0.086	0.114	0.043	70
4	0.478	0.076	0.054	0.174	0.054	0.087	0.076	92
5	0.531	0.061	0.082	0.092	0.133	0.071	0.031	98
6	0.444	0.086	0.074	0.086	0.123	0.099	0.086	81
7	0.344	0.033	0.148	0.148	0.131	0.082	0.115	61

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.720	0.024	0.045	0.054	0.067	0.059	0.031	706
2	0.489	0.067	0.156	0.111	0.089	0.044	0.044	45
3	0.486	0.056	0.069	0.069	0.153	0.083	0.083	72
4	0.452	0.022	0.054	0.161	0.118	0.118	0.075	93
5	0.429	0.018	0.054	0.107	0.152	0.134	0.107	112
6	0.394	0.058	0.106	0.115	0.096	0.163	0.067	104
7	0.324	0.132	0.059	0.074	0.103	0.162	0.147	68

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.724	0.023	0.039	0.053	0.051	0.054	0.056	779
2	0.629	0.057	0.114	0.057	0.086	0.029	0.029	35
3	0.519	0.056	0.074	0.056	0.093	0.074	0.130	54
4	0.569	0.056	0.056	0.111	0.042	0.069	0.097	72
5	0.671	0.014	0.043	0.014	0.086	0.114	0.057	70
6	0.481	0.074	0.074	0.086	0.099	0.160	0.025	81
7	0.507	0.043	0.072	0.101	0.058	0.130	0.087	69

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.707	0.026	0.035	0.044	0.065	0.068	0.055	779
2	0.463	0.024	0.073	0.073	0.122	0.146	0.098	41
3	0.635	0.058	0.058	0.019	0.038	0.115	0.077	52
4	0.467	0.067	0.033	0.083	0.150	0.100	0.100	60
5	0.573	0.073	0.024	0.024	0.085	0.122	0.098	82
6	0.538	0.038	0.096	0.087	0.067	0.067	0.106	104
7	0.476	0.037	0.098	0.061	0.073	0.171	0.085	82

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.778	0.024	0.051	0.018	0.037	0.057	0.036	842
2	0.512	0.024	0.024	0.122	0.146	0.049	0.122	41
3	0.536	0.058	0.043	0.058	0.058	0.159	0.087	69
4	0.667	0.061	0.0	0.061	0.091	0.121	0.0	33
5	0.527	0.054	0.108	0.027	0.108	0.122	0.054	74
6	0.518	0.035	0.118	0.024	0.118	0.094	0.094	85
7	0.536	0.071	0.071	0.018	0.179	0.054	0.071	56

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.812	0.028	0.032	0.036	0.025	0.034	0.033	872
2	0.686	0.086	0.029	0.029	0.029	0.029	0.114	35
3	0.592	0.020	0.102	0.102	0.020	0.041	0.122	49
4	0.654	0.038	0.019	0.019	0.096	0.115	0.058	52
5	0.650	0.050	0.075	0.075	0.025	0.025	0.100	40
6	0.582	0.0	0.109	0.073	0.036	0.109	0.091	55
7	0.351	0.070	0.070	0.088	0.105	0.175	0.140	57

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.806	0.022	0.034	0.038	0.046	0.032	0.022	906
2	0.714	0.057	0.086	0.086	0.029	0.029	0.0	35
3	0.604	0.038	0.038	0.094	0.094	0.038	0.094	53
4	0.632	0.035	0.088	0.088	0.035	0.035	0.088	57
5	0.582	0.075	0.090	0.060	0.104	0.075	0.015	67
6	0.605	0.070	0.047	0.093	0.047	0.070	0.070	43
7	0.487	0.077	0.103	0.026	0.205	0.026	0.077	39

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.720	0.042	0.071	0.040	0.044	0.053	0.030	742
2	0.603	0.103	0.132	0.015	0.015	0.074	0.059	68
3	0.505	0.053	0.105	0.063	0.126	0.095	0.053	95
4	0.651	0.063	0.063	0.063	0.032	0.095	0.032	63
5	0.371	0.143	0.071	0.143	0.114	0.057	0.100	70
6	0.507	0.082	0.082	0.151	0.055	0.082	0.041	73
7	0.469	0.143	0.102	0.061	0.102	0.082	0.041	49

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.691	0.050	0.051	0.070	0.057	0.053	0.029	761
2	0.587	0.107	0.053	0.067	0.133	0.027	0.027	75
3	0.672	0.030	0.045	0.045	0.090	0.075	0.045	67
4	0.600	0.071	0.047	0.059	0.071	0.094	0.059	85
5	0.477	0.116	0.023	0.116	0.105	0.116	0.047	86
6	0.403	0.065	0.091	0.104	0.143	0.091	0.104	77
7	0.367	0.102	0.143	0.061	0.061	0.143	0.122	49

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 909

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.704	0.043	0.036	0.042	0.053	0.061	0.061	770
2	0.642	0.094	0.0	0.057	0.113	0.038	0.057	53
3	0.563	0.021	0.104	0.083	0.083	0.042	0.104	48
4	0.621	0.034	0.017	0.086	0.069	0.034	0.138	58
5	0.610	0.049	0.049	0.037	0.073	0.098	0.085	82
6	0.420	0.049	0.074	0.049	0.160	0.148	0.099	81
7	0.435	0.046	0.056	0.056	0.083	0.056	0.269	108

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.684	0.045	0.049	0.045	0.064	0.059	0.055	692
2	0.577	0.038	0.077	0.058	0.0	0.077	0.173	52
3	0.633	0.017	0.050	0.067	0.017	0.100	0.117	60
4	0.552	0.052	0.086	0.052	0.086	0.069	0.103	58
5	0.578	0.031	0.094	0.047	0.031	0.078	0.141	64
6	0.538	0.141	0.051	0.051	0.064	0.064	0.090	78
7	0.477	0.035	0.047	0.081	0.093	0.151	0.116	86

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.673	0.028	0.035	0.045	0.065	0.070	0.084	753
2	0.553	0.026	0.053	0.079	0.026	0.105	0.158	38
3	0.627	0.068	0.034	0.034	0.102	0.051	0.085	59
4	0.667	0.050	0.050	0.067	0.017	0.083	0.067	60
5	0.570	0.023	0.093	0.058	0.058	0.093	0.105	86
6	0.521	0.042	0.094	0.052	0.083	0.115	0.094	96
7	0.407	0.028	0.093	0.065	0.148	0.093	0.167	108

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.720	0.029	0.029	0.043	0.064	0.060	0.055	750
2	0.512	0.070	0.140	0.047	0.093	0.093	0.047	43
3	0.660	0.057	0.038	0.019	0.094	0.038	0.094	53
4	0.578	0.016	0.016	0.031	0.078	0.125	0.156	64
5	0.477	0.035	0.093	0.093	0.128	0.070	0.105	86
6	0.468	0.104	0.104	0.065	0.091	0.052	0.117	77
7	0.437	0.023	0.080	0.138	0.092	0.126	0.103	87

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.744	0.021	0.036	0.037	0.046	0.065	0.050	802
2	0.611	0.028	0.083	0.028	0.028	0.139	0.083	36
3	0.569	0.039	0.059	0.078	0.059	0.098	0.098	51
4	0.508	0.032	0.063	0.111	0.063	0.127	0.095	63
5	0.536	0.029	0.043	0.145	0.116	0.130	0.0	69
6	0.464	0.062	0.041	0.062	0.113	0.113	0.144	97
7	0.561	0.073	0.061	0.061	0.061	0.061	0.122	82

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.783	0.025	0.020	0.030	0.052	0.037	0.053	807
2	0.488	0.049	0.073	0.049	0.098	0.146	0.098	41
3	0.595	0.027	0.027	0.054	0.108	0.081	0.108	37
4	0.500	0.125	0.100	0.0	0.175	0.050	0.050	40
5	0.551	0.064	0.013	0.090	0.077	0.115	0.090	78
6	0.600	0.057	0.043	0.029	0.057	0.100	0.114	70
7	0.448	0.023	0.069	0.034	0.138	0.103	0.184	87

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.742	0.019	0.034	0.025	0.051	0.060	0.069	831
2	0.667	0.0	0.100	0.0	0.067	0.133	0.033	30
3	0.481	0.056	0.093	0.074	0.185	0.056	0.056	54
4	0.651	0.047	0.093	0.023	0.070	0.093	0.023	43
5	0.688	0.013	0.039	0.039	0.052	0.065	0.104	77
6	0.524	0.073	0.061	0.024	0.122	0.110	0.085	82
7	0.518	0.036	0.072	0.169	0.036	0.084	0.084	83

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.780	0.028	0.024	0.039	0.040	0.036	0.052	879
2	0.600	0.029	0.086	0.086	0.086	0.086	0.029	35
3	0.628	0.023	0.047	0.023	0.163	0.070	0.047	43
4	0.630	0.056	0.019	0.056	0.037	0.056	0.148	54
5	0.578	0.031	0.109	0.094	0.063	0.016	0.109	64
6	0.620	0.040	0.060	0.060	0.040	0.120	0.060	50
7	0.613	0.013	0.093	0.013	0.120	0.027	0.120	75

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.834	0.027	0.029	0.023	0.036	0.017	0.034	883
2	0.600	0.075	0.025	0.050	0.050	0.050	0.150	40
3	0.622	0.054	0.054	0.081	0.054	0.027	0.108	37
4	0.634	0.024	0.024	0.073	0.073	0.073	0.098	41
5	0.442	0.096	0.038	0.096	0.058	0.154	0.115	52
6	0.622	0.067	0.0	0.067	0.111	0.067	0.067	45
7	0.419	0.048	0.065	0.097	0.081	0.145	0.145	62

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.826	0.028	0.025	0.023	0.028	0.042	0.026	948
2	0.641	0.128	0.0	0.051	0.051	0.026	0.103	39
3	0.600	0.029	0.057	0.0	0.086	0.086	0.143	35
4	0.667	0.056	0.083	0.028	0.028	0.083	0.056	36
5	0.643	0.0	0.024	0.119	0.071	0.071	0.071	42
6	0.667	0.018	0.070	0.070	0.053	0.053	0.070	57
7	0.581	0.093	0.023	0.047	0.047	0.140	0.070	43

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.769	0.013	0.036	0.038	0.032	0.058	0.053	832
2	0.667	0.100	0.0	0.067	0.033	0.067	0.067	30
3	0.625	0.042	0.063	0.042	0.083	0.021	0.125	48
4	0.588	0.039	0.098	0.098	0.020	0.137	0.020	51
5	0.444	0.067	0.089	0.089	0.044	0.156	0.111	45
6	0.675	0.078	0.052	0.065	0.039	0.026	0.065	77
7	0.610	0.026	0.039	0.026	0.078	0.078	0.143	77

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.715	0.041	0.045	0.042	0.046	0.056	0.056	807
2	0.569	0.103	0.086	0.052	0.017	0.086	0.086	58
3	0.607	0.071	0.036	0.089	0.071	0.089	0.036	56
4	0.648	0.037	0.0	0.037	0.093	0.056	0.130	54
5	0.591	0.030	0.061	0.061	0.106	0.045	0.106	66
6	0.500	0.118	0.079	0.079	0.039	0.039	0.145	76
7	0.458	0.036	0.072	0.048	0.133	0.133	0.120	83

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 1345

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.737	0.015	0.052	0.053	0.057	0.050	0.037	814
2	0.640	0.120	0.120	0.0	0.040	0.080	0.0	25
3	0.680	0.040	0.133	0.040	0.027	0.040	0.040	75
4	0.591	0.030	0.121	0.061	0.091	0.030	0.076	66
5	0.541	0.041	0.041	0.108	0.054	0.122	0.095	74
6	0.521	0.014	0.042	0.042	0.113	0.141	0.127	71
7	0.440	0.013	0.093	0.040	0.120	0.093	0.200	75

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.738	0.012	0.048	0.046	0.060	0.054	0.043	766
2	0.333	0.056	0.222	0.222	0.056	0.056	0.056	18
3	0.644	0.051	0.068	0.068	0.068	0.068	0.034	59
4	0.661	0.018	0.107	0.054	0.054	0.036	0.071	56
5	0.638	0.014	0.058	0.043	0.043	0.145	0.058	69
6	0.667	0.0	0.030	0.061	0.061	0.045	0.136	66
7	0.500	0.018	0.089	0.071	0.161	0.054	0.107	56

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.714	0.016	0.034	0.047	0.062	0.065	0.062	803
2	0.636	0.091	0.045	0.045	0.136	0.045	0.0	22
3	0.612	0.0	0.102	0.041	0.082	0.082	0.082	49
4	0.606	0.0	0.015	0.136	0.076	0.106	0.061	66
5	0.611	0.022	0.056	0.033	0.167	0.044	0.067	90
6	0.558	0.047	0.070	0.116	0.047	0.116	0.047	86
7	0.512	0.012	0.036	0.024	0.107	0.095	0.214	84

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.722	0.013	0.037	0.046	0.058	0.076	0.048	788
2	0.680	0.0	0.040	0.080	0.0	0.080	0.120	25
3	0.710	0.0	0.065	0.097	0.048	0.032	0.048	62
4	0.579	0.070	0.140	0.035	0.070	0.035	0.070	57
5	0.562	0.041	0.137	0.068	0.082	0.082	0.027	73
6	0.540	0.034	0.057	0.057	0.126	0.080	0.103	87
7	0.485	0.044	0.044	0.088	0.074	0.118	0.147	68

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.760	0.005	0.029	0.043	0.056	0.070	0.037	818
2	0.667	0.067	0.0	0.0	0.133	0.067	0.067	15
3	0.591	0.023	0.023	0.068	0.068	0.091	0.136	44
4	0.549	0.014	0.056	0.127	0.113	0.042	0.099	71
5	0.534	0.068	0.034	0.091	0.068	0.148	0.057	88
6	0.551	0.0	0.041	0.051	0.173	0.082	0.102	98
7	0.348	0.030	0.076	0.167	0.121	0.167	0.091	66

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.759	0.011	0.025	0.034	0.062	0.052	0.057	805
2	0.750	0.0	0.0	0.125	0.0	0.063	0.063	16
3	0.674	0.047	0.047	0.070	0.047	0.047	0.070	43
4	0.583	0.017	0.083	0.067	0.083	0.117	0.050	60
5	0.602	0.0	0.060	0.060	0.133	0.060	0.084	83
6	0.486	0.028	0.083	0.097	0.083	0.111	0.111	72
7	0.444	0.037	0.049	0.136	0.086	0.074	0.173	81

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.776	0.008	0.024	0.039	0.049	0.046	0.057	890
2	0.818	0.182	0.0	0.0	0.0	0.0	0.0	11
3	0.719	0.031	0.0	0.094	0.031	0.031	0.094	32
4	0.569	0.0	0.069	0.103	0.069	0.138	0.052	58
5	0.687	0.0	0.045	0.075	0.090	0.075	0.030	67
6	0.606	0.015	0.061	0.045	0.061	0.076	0.136	66
7	0.618	0.013	0.039	0.092	0.092	0.066	0.079	76

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.836	0.005	0.015	0.028	0.037	0.039	0.040	950
2	0.600	0.0	0.100	0.0	0.100	0.100	0.100	10
3	0.704	0.037	0.074	0.037	0.0	0.111	0.037	27
4	0.659	0.0	0.073	0.049	0.0	0.049	0.171	41
5	0.583	0.042	0.042	0.125	0.042	0.063	0.104	48
6	0.638	0.017	0.017	0.052	0.069	0.121	0.086	58
7	0.621	0.015	0.045	0.030	0.076	0.076	0.136	66

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.840	0.010	0.022	0.025	0.033	0.031	0.040	918
2	0.563	0.063	0.0	0.0	0.188	0.125	0.063	16
3	0.568	0.081	0.081	0.027	0.081	0.0	0.162	37
4	0.559	0.0	0.118	0.088	0.147	0.029	0.059	34
5	0.692	0.0	0.038	0.038	0.077	0.038	0.115	52
6	0.683	0.024	0.073	0.049	0.024	0.098	0.049	41
7	0.597	0.032	0.081	0.032	0.081	0.065	0.113	62

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.842	0.011	0.019	0.030	0.037	0.027	0.033	964
2	0.615	0.077	0.0	0.154	0.154	0.0	0.0	13
3	0.730	0.0	0.108	0.054	0.054	0.027	0.027	37
4	0.721	0.023	0.070	0.023	0.093	0.023	0.047	43
5	0.556	0.019	0.056	0.093	0.130	0.111	0.037	54
6	0.600	0.0	0.125	0.0	0.0	0.125	0.150	40
7	0.571	0.020	0.122	0.061	0.122	0.041	0.061	49

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.775	0.007	0.031	0.042	0.047	0.060	0.039	817
2	0.500	0.0	0.167	0.111	0.056	0.111	0.056	18
3	0.696	0.018	0.054	0.071	0.054	0.071	0.036	56
4	0.681	0.043	0.072	0.087	0.029	0.058	0.029	69
5	0.456	0.035	0.105	0.053	0.070	0.211	0.070	57
6	0.535	0.047	0.093	0.128	0.035	0.081	0.081	86
7	0.439	0.018	0.105	0.158	0.070	0.105	0.105	57

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.766	0.014	0.052	0.042	0.057	0.045	0.024	865
2	0.636	0.045	0.091	0.0	0.0	0.136	0.091	22
3	0.667	0.058	0.101	0.014	0.014	0.072	0.072	69
4	0.618	0.036	0.055	0.127	0.055	0.091	0.018	55
5	0.597	0.0	0.045	0.104	0.075	0.104	0.075	67
6	0.486	0.028	0.097	0.028	0.097	0.111	0.153	72
7	0.520	0.040	0.080	0.040	0.080	0.140	0.100	50

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 3762

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.774	0.025	0.033	0.035	0.056	0.037	0.040	840
2	0.628	0.116	0.070	0.140	0.0	0.023	0.023	43
3	0.640	0.020	0.060	0.060	0.060	0.080	0.080	50
4	0.696	0.107	0.036	0.054	0.036	0.0	0.071	56
5	0.471	0.043	0.057	0.029	0.086	0.086	0.229	70
6	0.596	0.019	0.038	0.077	0.058	0.058	0.154	52
7	0.404	0.034	0.056	0.090	0.112	0.079	0.225	89

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.732	0.019	0.027	0.051	0.064	0.063	0.044	747
2	0.750	0.071	0.036	0.0	0.0	0.071	0.071	28
3	0.632	0.053	0.053	0.053	0.026	0.105	0.079	38
4	0.648	0.028	0.042	0.113	0.042	0.070	0.056	71
5	0.597	0.032	0.065	0.081	0.048	0.113	0.065	62
6	0.513	0.037	0.100	0.088	0.037	0.100	0.125	80
7	0.438	0.047	0.031	0.125	0.109	0.141	0.109	64

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.711	0.020	0.037	0.047	0.054	0.057	0.074	793
2	0.649	0.108	0.054	0.081	0.054	0.027	0.027	37
3	0.614	0.035	0.070	0.018	0.053	0.070	0.140	57
4	0.603	0.034	0.069	0.034	0.086	0.069	0.103	58
5	0.548	0.096	0.027	0.055	0.110	0.082	0.082	73
6	0.592	0.039	0.079	0.053	0.053	0.066	0.118	76
7	0.415	0.038	0.094	0.057	0.075	0.113	0.208	106

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.707	0.019	0.049	0.042	0.057	0.068	0.058	754
2	0.586	0.034	0.103	0.034	0.138	0.069	0.034	29
3	0.710	0.029	0.029	0.058	0.043	0.043	0.087	69
4	0.433	0.083	0.083	0.117	0.083	0.083	0.117	60
5	0.623	0.026	0.091	0.039	0.026	0.117	0.078	77
6	0.512	0.023	0.081	0.070	0.093	0.070	0.151	86
7	0.459	0.035	0.071	0.094	0.094	0.082	0.165	85

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.759	0.021	0.028	0.037	0.054	0.056	0.045	819
2	0.704	0.037	0.037	0.0	0.074	0.037	0.111	27
3	0.622	0.022	0.067	0.044	0.089	0.067	0.089	45
4	0.481	0.056	0.093	0.056	0.074	0.130	0.111	54
5	0.533	0.027	0.067	0.067	0.080	0.120	0.107	75
6	0.511	0.034	0.057	0.057	0.091	0.102	0.148	88
7	0.500	0.033	0.033	0.087	0.065	0.120	0.163	92

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.789	0.010	0.025	0.031	0.046	0.049	0.050	833
2	0.526	0.0	0.105	0.0	0.105	0.105	0.158	19
3	0.634	0.0	0.073	0.024	0.146	0.049	0.073	41
4	0.640	0.040	0.060	0.040	0.040	0.100	0.080	50
5	0.517	0.017	0.083	0.067	0.067	0.117	0.133	60
6	0.506	0.026	0.013	0.117	0.065	0.143	0.130	77
7	0.550	0.063	0.088	0.075	0.037	0.100	0.088	80

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.772	0.012	0.025	0.036	0.054	0.044	0.056	882
2	0.722	0.056	0.0	0.0	0.0	0.0	0.222	18
3	0.559	0.029	0.088	0.118	0.059	0.088	0.059	34
4	0.709	0.018	0.018	0.055	0.109	0.073	0.018	55
5	0.638	0.014	0.072	0.058	0.029	0.116	0.072	69
6	0.682	0.015	0.030	0.091	0.0	0.076	0.106	66
7	0.579	0.039	0.013	0.066	0.118	0.053	0.132	76

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.820	0.013	0.021	0.032	0.035	0.040	0.039	947
2	0.533	0.0	0.067	0.133	0.067	0.067	0.133	15
3	0.848	0.0	0.030	0.0	0.061	0.0	0.061	33
4	0.778	0.022	0.0	0.0	0.067	0.022	0.111	45
5	0.698	0.0	0.057	0.038	0.038	0.075	0.094	53
6	0.617	0.0	0.064	0.128	0.085	0.043	0.064	47
7	0.550	0.017	0.117	0.083	0.133	0.033	0.067	60

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.829	0.010	0.019	0.028	0.034	0.037	0.043	902
2	0.500	0.0	0.0	0.300	0.0	0.100	0.100	10
3	0.654	0.0	0.038	0.115	0.038	0.038	0.115	26
4	0.538	0.019	0.019	0.115	0.058	0.115	0.135	52
5	0.640	0.020	0.040	0.080	0.140	0.0	0.080	50
6	0.612	0.020	0.041	0.102	0.061	0.061	0.102	49
7	0.606	0.0	0.042	0.056	0.056	0.070	0.169	71

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.843	0.009	0.025	0.027	0.025	0.035	0.036	970
2	0.714	0.0	0.0	0.071	0.071	0.143	0.0	14
3	0.531	0.031	0.094	0.0	0.063	0.125	0.156	32
4	0.703	0.0	0.027	0.027	0.081	0.054	0.108	37
5	0.705	0.045	0.0	0.091	0.045	0.0	0.114	44
6	0.622	0.0	0.067	0.022	0.133	0.067	0.089	45
7	0.603	0.017	0.034	0.069	0.121	0.052	0.103	58

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.775	0.014	0.030	0.048	0.038	0.048	0.047	836
2	0.731	0.0	0.038	0.0	0.077	0.115	0.038	26
3	0.628	0.047	0.0	0.093	0.047	0.070	0.116	43
4	0.684	0.018	0.018	0.018	0.088	0.088	0.088	57
5	0.537	0.056	0.093	0.056	0.056	0.093	0.111	54
6	0.507	0.070	0.099	0.070	0.099	0.070	0.085	71
7	0.658	0.027	0.041	0.068	0.014	0.055	0.137	73

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.763	0.033	0.031	0.031	0.045	0.046	0.052	849
2	0.681	0.021	0.064	0.106	0.0	0.064	0.064	47
3	0.578	0.044	0.044	0.044	0.044	0.133	0.111	45
4	0.560	0.060	0.100	0.0	0.080	0.060	0.140	50
5	0.567	0.083	0.050	0.083	0.083	0.067	0.067	60
6	0.486	0.086	0.071	0.029	0.071	0.157	0.100	70
7	0.494	0.051	0.038	0.101	0.089	0.101	0.127	79

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 3994

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.747	0.025	0.034	0.045	0.044	0.048	0.057	814
2	0.500	0.088	0.059	0.088	0.118	0.118	0.029	34
3	0.674	0.065	0.065	0.065	0.022	0.022	0.087	46
4	0.763	0.017	0.017	0.017	0.034	0.085	0.068	59
5	0.576	0.030	0.061	0.045	0.061	0.091	0.136	66
6	0.512	0.049	0.061	0.049	0.110	0.110	0.110	82
7	0.384	0.010	0.020	0.081	0.081	0.172	0.253	99

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.731	0.008	0.036	0.055	0.050	0.055	0.064	740
2	0.500	0.111	0.111	0.056	0.0	0.056	0.167	18
3	0.638	0.021	0.064	0.021	0.085	0.149	0.021	47
4	0.563	0.016	0.047	0.094	0.078	0.078	0.125	64
5	0.565	0.065	0.016	0.065	0.129	0.081	0.081	62
6	0.542	0.028	0.097	0.083	0.069	0.083	0.097	72
7	0.540	0.023	0.046	0.057	0.057	0.057	0.218	87

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.684	0.025	0.033	0.054	0.062	0.077	0.066	763
2	0.500	0.053	0.026	0.079	0.105	0.132	0.105	38
3	0.714	0.024	0.048	0.048	0.048	0.0	0.119	42
4	0.530	0.076	0.045	0.076	0.030	0.091	0.152	66
5	0.545	0.011	0.023	0.091	0.091	0.125	0.114	88
6	0.520	0.060	0.060	0.040	0.120	0.120	0.080	100
7	0.476	0.049	0.029	0.039	0.126	0.097	0.184	103

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.702	0.012	0.032	0.049	0.063	0.068	0.074	748
2	0.704	0.037	0.074	0.037	0.037	0.0	0.111	27
3	0.500	0.054	0.089	0.089	0.107	0.107	0.054	56
4	0.472	0.042	0.111	0.111	0.125	0.042	0.097	72
5	0.649	0.032	0.074	0.074	0.085	0.043	0.043	94
6	0.519	0.051	0.063	0.076	0.114	0.063	0.114	79
7	0.464	0.036	0.071	0.071	0.119	0.167	0.071	84

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.751	0.016	0.034	0.039	0.052	0.049	0.058	812
2	0.600	0.0	0.033	0.133	0.100	0.067	0.067	30
3	0.680	0.020	0.040	0.040	0.120	0.040	0.060	50
4	0.621	0.045	0.030	0.045	0.076	0.045	0.136	66
5	0.558	0.023	0.012	0.081	0.128	0.081	0.116	86
6	0.594	0.031	0.016	0.109	0.047	0.078	0.125	64
7	0.326	0.098	0.141	0.098	0.163	0.065	0.109	92

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.775	0.016	0.028	0.035	0.039	0.043	0.063	819
2	0.739	0.043	0.0	0.043	0.087	0.0	0.087	23
3	0.625	0.021	0.042	0.083	0.083	0.063	0.083	48
4	0.636	0.055	0.073	0.073	0.018	0.055	0.091	55
5	0.563	0.0	0.094	0.063	0.141	0.047	0.094	64
6	0.403	0.075	0.075	0.075	0.119	0.179	0.075	67
7	0.488	0.024	0.083	0.095	0.060	0.107	0.143	84

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.757	0.020	0.020	0.031	0.058	0.052	0.063	863
2	0.680	0.040	0.080	0.040	0.0	0.040	0.120	25
3	0.714	0.0	0.095	0.024	0.048	0.048	0.071	42
4	0.673	0.020	0.041	0.122	0.041	0.061	0.041	49
5	0.634	0.014	0.056	0.085	0.070	0.056	0.085	71
6	0.639	0.0	0.083	0.056	0.111	0.069	0.042	72
7	0.462	0.064	0.090	0.051	0.090	0.154	0.090	78

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.801	0.016	0.032	0.028	0.047	0.038	0.039	901
2	0.579	0.053	0.105	0.053	0.053	0.105	0.053	19
3	0.659	0.023	0.045	0.045	0.045	0.068	0.114	44
4	0.571	0.048	0.048	0.024	0.071	0.119	0.119	42
5	0.683	0.0	0.032	0.079	0.063	0.0	0.143	63
6	0.593	0.0	0.068	0.068	0.085	0.068	0.119	59
7	0.597	0.014	0.056	0.056	0.069	0.111	0.097	72

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.825	0.018	0.030	0.026	0.036	0.032	0.033	873
2	0.833	0.0	0.042	0.083	0.042	0.0	0.0	24
3	0.571	0.0	0.061	0.102	0.061	0.102	0.102	49
4	0.545	0.0	0.045	0.114	0.091	0.114	0.091	44
5	0.561	0.053	0.070	0.035	0.035	0.123	0.123	57
6	0.415	0.057	0.094	0.057	0.132	0.094	0.151	53
7	0.450	0.050	0.167	0.033	0.133	0.033	0.133	60

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.830	0.022	0.018	0.030	0.029	0.038	0.033	942
2	0.667	0.030	0.061	0.091	0.0	0.061	0.091	33
3	0.600	0.100	0.033	0.0	0.133	0.033	0.100	30
4	0.565	0.065	0.043	0.087	0.109	0.065	0.065	46
5	0.667	0.021	0.042	0.104	0.063	0.042	0.063	48
6	0.673	0.058	0.058	0.038	0.038	0.077	0.058	52
7	0.429	0.061	0.082	0.041	0.163	0.102	0.122	49

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.779	0.018	0.021	0.042	0.038	0.046	0.056	840
2	0.643	0.0	0.071	0.036	0.107	0.071	0.071	28
3	0.600	0.057	0.0	0.114	0.057	0.086	0.086	35
4	0.679	0.071	0.071	0.054	0.018	0.054	0.054	56
5	0.566	0.038	0.151	0.075	0.038	0.038	0.094	53
6	0.611	0.042	0.042	0.014	0.083	0.125	0.083	72
7	0.553	0.039	0.026	0.118	0.053	0.092	0.118	76

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.755	0.022	0.035	0.045	0.035	0.048	0.061	836
2	0.619	0.095	0.071	0.0	0.071	0.048	0.095	42
3	0.635	0.048	0.111	0.048	0.048	0.032	0.079	63
4	0.600	0.036	0.091	0.091	0.073	0.055	0.055	55
5	0.608	0.098	0.039	0.039	0.0	0.098	0.118	51
6	0.524	0.095	0.079	0.048	0.079	0.063	0.111	63
7	0.378	0.056	0.144	0.044	0.111	0.089	0.178	90

Table 13 Continued.

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 4825

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.726	0.004	0.043	0.050	0.072	0.049	0.056	797
2	0.857	0.143	0.0	0.0	0.0	0.0	0.0	7
3	0.695	0.0	0.051	0.051	0.051	0.068	0.085	59
4	0.662	0.026	0.078	0.065	0.078	0.039	0.052	77
5	0.567	0.0	0.056	0.078	0.133	0.078	0.089	90
6	0.563	0.014	0.056	0.113	0.099	0.056	0.099	71
7	0.354	0.0	0.071	0.111	0.091	0.111	0.263	99

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.719	0.0	0.030	0.058	0.070	0.075	0.048	744
2	1.000	0.0	0.0	0.0	0.0	0.0	0.0	2
3	0.674	0.0	0.093	0.047	0.093	0.047	0.047	43
4	0.633	0.0	0.067	0.033	0.117	0.083	0.067	60
5	0.607	0.011	0.045	0.067	0.124	0.067	0.079	89
6	0.575	0.0	0.037	0.063	0.063	0.088	0.175	80
7	0.542	0.0	0.069	0.056	0.097	0.083	0.153	72

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.695	0.002	0.033	0.051	0.073	0.078	0.067	807
2	0.500	0.0	0.0	0.500	0.0	0.0	0.0	4
3	0.651	0.0	0.023	0.047	0.070	0.140	0.070	43
4	0.614	0.0	0.029	0.057	0.071	0.157	0.071	70
5	0.511	0.023	0.034	0.091	0.114	0.125	0.102	88
6	0.713	0.010	0.069	0.059	0.059	0.040	0.050	101
7	0.586	0.0	0.046	0.057	0.046	0.080	0.184	87

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.734	0.002	0.027	0.050	0.079	0.061	0.046	802
2	0.500	0.0	0.0	0.0	0.0	0.500	0.0	2
3	0.556	0.0	0.028	0.111	0.139	0.083	0.083	36
4	0.646	0.0	0.046	0.062	0.077	0.092	0.077	65
5	0.670	0.0	0.021	0.072	0.072	0.052	0.113	97
6	0.500	0.0	0.050	0.050	0.113	0.150	0.138	80
7	0.564	0.0	0.051	0.038	0.154	0.077	0.115	78

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.752	0.0	0.021	0.054	0.062	0.059	0.052	828
2	0.600	0.0	0.0	0.200	0.0	0.0	0.200	5
3	0.679	0.036	0.0	0.143	0.071	0.071	0.0	28
4	0.583	0.014	0.056	0.028	0.139	0.069	0.111	72
5	0.573	0.029	0.019	0.068	0.126	0.107	0.078	103
6	0.646	0.0	0.061	0.049	0.110	0.073	0.061	82
7	0.439	0.0	0.024	0.098	0.146	0.098	0.195	82

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.755	0.005	0.019	0.027	0.064	0.059	0.071	828
2	0.571	0.286	0.0	0.143	0.0	0.0	0.0	7
3	0.542	0.0	0.0	0.083	0.167	0.0	0.208	24
4	0.489	0.0	0.044	0.067	0.178	0.022	0.200	45
5	0.621	0.0	0.034	0.069	0.138	0.057	0.080	87
6	0.711	0.0	0.013	0.026	0.105	0.092	0.053	76
7	0.538	0.011	0.032	0.097	0.075	0.161	0.086	93

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.725	0.004	0.021	0.046	0.062	0.069	0.074	826
2	0.500	0.0	0.0	0.167	0.167	0.0	0.167	6
3	0.690	0.0	0.069	0.069	0.034	0.0	0.138	29
4	0.609	0.016	0.047	0.047	0.094	0.094	0.094	64
5	0.560	0.0	0.036	0.107	0.095	0.071	0.131	84
6	0.578	0.022	0.022	0.089	0.111	0.100	0.078	90
7	0.604	0.0	0.040	0.040	0.089	0.119	0.109	101

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.806	0.0	0.022	0.026	0.049	0.039	0.058	916
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
3	0.714	0.0	0.071	0.0	0.107	0.036	0.071	28
4	0.703	0.0	0.0	0.027	0.027	0.135	0.108	37
5	0.662	0.0	0.046	0.031	0.031	0.169	0.062	65
6	0.594	0.0	0.029	0.072	0.087	0.101	0.116	69
7	0.647	0.0	0.012	0.047	0.094	0.047	0.153	85

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.856	0.003	0.014	0.021	0.034	0.037	0.035	919
2	0.500	0.0	0.250	0.250	0.0	0.0	0.0	4
3	0.500	0.0	0.036	0.071	0.143	0.071	0.179	28
4	0.697	0.0	0.061	0.030	0.121	0.061	0.030	33
5	0.686	0.0	0.020	0.059	0.039	0.059	0.137	51
6	0.534	0.0	0.052	0.052	0.052	0.155	0.155	58
7	0.463	0.015	0.119	0.060	0.090	0.104	0.149	67

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.850	0.003	0.015	0.033	0.040	0.030	0.028	987
2	0.500	0.0	0.0	0.0	0.250	0.250	0.0	4
3	0.739	0.0	0.0	0.174	0.043	0.0	0.043	23
4	0.612	0.0	0.041	0.122	0.143	0.020	0.061	49
5	0.689	0.016	0.049	0.049	0.098	0.082	0.016	61
6	0.718	0.0	0.051	0.051	0.077	0.0	0.103	39
7	0.784	0.0	0.027	0.054	0.081	0.027	0.027	37

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.775	0.001	0.026	0.044	0.066	0.046	0.041	846
2	0.333	0.0	0.333	0.0	0.333	0.0	0.0	3
3	0.576	0.0	0.0	0.152	0.121	0.061	0.091	33
4	0.639	0.033	0.049	0.066	0.082	0.066	0.066	61
5	0.588	0.0	0.088	0.088	0.063	0.088	0.088	80
6	0.697	0.0	0.015	0.045	0.076	0.030	0.136	66
7	0.620	0.0	0.028	0.070	0.085	0.085	0.113	71

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.754	0.002	0.037	0.047	0.067	0.052	0.041	854
2	0.600	0.0	0.400	0.0	0.0	0.0	0.0	5
3	0.569	0.039	0.118	0.020	0.098	0.118	0.039	51
4	0.651	0.0	0.048	0.079	0.095	0.079	0.048	63
5	0.580	0.011	0.045	0.068	0.125	0.091	0.080	88
6	0.622	0.0	0.027	0.108	0.041	0.081	0.122	74
7	0.492	0.0	0.046	0.062	0.123	0.092	0.185	65

ESTIMATED TRANSITION PROBABILITY MATRICES

Station 6353

JAN

	1	2	3	4	5	6	7	SUMFREQ
1	0.668	0.040	0.043	0.069	0.076	0.069	0.036	699
2	0.567	0.104	0.090	0.090	0.045	0.090	0.015	67
3	0.500	0.013	0.141	0.128	0.090	0.051	0.077	78
4	0.510	0.080	0.130	0.100	0.070	0.040	0.070	100
5	0.475	0.099	0.050	0.089	0.109	0.089	0.089	101
6	0.402	0.098	0.109	0.087	0.120	0.109	0.076	92
7	0.365	0.063	0.032	0.127	0.190	0.111	0.111	63

FEB

	1	2	3	4	5	6	7	SUMFREQ
1	0.634	0.041	0.056	0.083	0.066	0.073	0.047	640
2	0.565	0.0	0.174	0.087	0.043	0.043	0.087	46
3	0.595	0.054	0.122	0.027	0.095	0.041	0.068	74
4	0.620	0.043	0.033	0.054	0.098	0.109	0.043	92
5	0.443	0.045	0.091	0.114	0.091	0.102	0.114	88
6	0.474	0.051	0.064	0.115	0.064	0.141	0.090	78
7	0.333	0.069	0.083	0.153	0.139	0.042	0.181	72

MAR

	1	2	3	4	5	6	7	SUMFREQ
1	0.648	0.040	0.030	0.070	0.095	0.074	0.044	705
2	0.577	0.058	0.058	0.038	0.096	0.115	0.058	52
3	0.588	0.044	0.074	0.044	0.059	0.103	0.088	68
4	0.432	0.057	0.102	0.091	0.080	0.148	0.091	88
5	0.491	0.019	0.130	0.074	0.093	0.102	0.093	108
6	0.416	0.050	0.069	0.129	0.119	0.119	0.099	101
7	0.577	0.064	0.064	0.051	0.090	0.038	0.115	78

APR

	1	2	3	4	5	6	7	SUMFREQ
1	0.678	0.030	0.041	0.071	0.062	0.068	0.050	705
2	0.650	0.0	0.025	0.100	0.075	0.050	0.100	40
3	0.610	0.034	0.085	0.085	0.051	0.085	0.051	59
4	0.563	0.073	0.063	0.052	0.104	0.083	0.063	96
5	0.521	0.052	0.063	0.083	0.167	0.094	0.021	96
6	0.404	0.032	0.085	0.149	0.085	0.117	0.128	94
7	0.400	0.043	0.071	0.100	0.114	0.157	0.114	70

Table 13 Continued.

MAY

	1	2	3	4	5	6	7	SUMFREQ
1	0.694	0.029	0.046	0.055	0.081	0.053	0.041	713
2	0.519	0.096	0.019	0.077	0.115	0.135	0.038	52
3	0.486	0.097	0.056	0.097	0.139	0.042	0.083	72
4	0.590	0.051	0.077	0.051	0.038	0.103	0.090	78
5	0.482	0.055	0.109	0.082	0.082	0.127	0.064	110
6	0.367	0.020	0.061	0.092	0.143	0.173	0.143	98
7	0.403	0.078	0.104	0.039	0.117	0.130	0.130	77

JUN

	1	2	3	4	5	6	7	SUMFREQ
1	0.698	0.029	0.034	0.060	0.066	0.067	0.046	732
2	0.575	0.050	0.025	0.050	0.100	0.150	0.050	40
3	0.519	0.154	0.038	0.0	0.096	0.077	0.115	52
4	0.466	0.041	0.068	0.082	0.137	0.082	0.123	73
5	0.535	0.035	0.093	0.128	0.070	0.058	0.081	86
6	0.573	0.010	0.063	0.031	0.021	0.156	0.146	96
7	0.444	0.012	0.074	0.062	0.136	0.148	0.123	81

JUL

	1	2	3	4	5	6	7	SUMFREQ
1	0.672	0.025	0.037	0.061	0.065	0.069	0.072	726
2	0.600	0.029	0.057	0.029	0.0	0.200	0.086	35
3	0.541	0.049	0.033	0.098	0.082	0.098	0.098	61
4	0.575	0.0	0.041	0.068	0.068	0.123	0.123	73
5	0.461	0.045	0.090	0.101	0.079	0.090	0.135	89
6	0.447	0.029	0.097	0.049	0.097	0.078	0.204	103
7	0.442	0.053	0.088	0.097	0.097	0.133	0.088	113

AUG

	1	2	3	4	5	6	7	SUMFREQ
1	0.757	0.042	0.042	0.035	0.033	0.048	0.042	808
2	0.612	0.020	0.020	0.122	0.061	0.082	0.082	49
3	0.527	0.036	0.036	0.055	0.127	0.109	0.109	55
4	0.550	0.067	0.117	0.033	0.067	0.067	0.100	60
5	0.486	0.029	0.057	0.086	0.100	0.186	0.057	70
6	0.488	0.036	0.083	0.107	0.071	0.095	0.119	84
7	0.473	0.027	0.054	0.068	0.149	0.095	0.135	74

Table 13 Continued.

SEP

	1	2	3	4	5	6	7	SUMFREQ
1	0.794	0.020	0.024	0.035	0.052	0.035	0.040	851
2	0.593	0.0	0.074	0.037	0.111	0.074	0.111	27
3	0.585	0.073	0.049	0.073	0.049	0.073	0.098	41
4	0.609	0.043	0.065	0.043	0.087	0.130	0.022	46
5	0.526	0.013	0.053	0.105	0.105	0.066	0.132	76
6	0.526	0.018	0.053	0.053	0.105	0.140	0.105	57
7	0.484	0.032	0.081	0.065	0.129	0.113	0.097	62

OCT

	1	2	3	4	5	6	7	SUMFREQ
1	0.806	0.021	0.032	0.046	0.035	0.040	0.019	893
2	0.559	0.0	0.059	0.118	0.088	0.059	0.118	34
3	0.532	0.043	0.043	0.128	0.128	0.043	0.085	47
4	0.635	0.027	0.095	0.081	0.081	0.054	0.027	74
5	0.621	0.069	0.052	0.034	0.103	0.069	0.052	58
6	0.429	0.071	0.107	0.143	0.089	0.089	0.071	56
7	0.526	0.053	0.053	0.184	0.079	0.026	0.079	38

NOV

	1	2	3	4	5	6	7	SUMFREQ
1	0.720	0.046	0.049	0.046	0.056	0.056	0.027	753
2	0.577	0.019	0.077	0.058	0.115	0.077	0.077	52
3	0.608	0.054	0.068	0.095	0.081	0.081	0.014	74
4	0.529	0.059	0.074	0.088	0.103	0.118	0.029	68
5	0.550	0.037	0.113	0.050	0.113	0.113	0.025	80
6	0.533	0.022	0.122	0.133	0.067	0.100	0.022	90
7	0.349	0.093	0.070	0.070	0.093	0.163	0.163	43

DEC

	1	2	3	4	5	6	7	SUMFREQ
1	0.690	0.044	0.060	0.053	0.056	0.057	0.039	749
2	0.634	0.085	0.070	0.085	0.028	0.056	0.042	71
3	0.512	0.119	0.060	0.071	0.083	0.060	0.095	84
4	0.575	0.075	0.037	0.075	0.063	0.088	0.088	80
5	0.416	0.104	0.117	0.091	0.078	0.143	0.052	77
6	0.449	0.051	0.103	0.128	0.115	0.051	0.103	78
7	0.377	0.082	0.131	0.131	0.131	0.098	0.049	61

APPENDIX C

COMPUTER PROGRAM DOCUMENTATION

Part I Program Information

Part II Usage Information

PART I - PROGRAM INFORMATION

The programs were written by Donald F. Linton and revised and run by David C. Jordan, Student Research Assistants in the Department of Statistics at the University of Kentucky, in consultation with the Principal Investigators and James O. Street, Student Research Assistant.

Using historical daily rainfall records the principal program generates arbitrarily long sequences of simulated daily rainfall data in accordance with a Markov chain model. Other programs are capable of calculating various statistics for both the historical and simulated data.

Rainfall data, measured in hundredths of an inch, is grouped in c+1 classes,

Class	Class limits (hundredths of inches)
0	DRY
1	1 to n_1-1
2	n_1 to n_2-1
.	.
.	.
.	.
c-1	n_{c-2} to n_{c-1}
c	n_{c-1} to ∞

Let $f_{ij}^{(k)}$ = the historical frequency of transition from class i to class j for month k (k=1,...,12). A transition from class i to class j occurs if rainfall belongs to class i on a given day and to class j on the following day. Then $\hat{p}_{ij}^{(k)} = f_{ij}^{(k)} / \sum_{j=0}^{c} f_{ij}^{(k)}$ estimates the transition probability from state i to state j for month k. Let $F_m(x) = P(\text{rainfall} \leq x \mid \text{rainfall belongs to class } m)$, $m=0,\ldots,c$.

U is defined as a random variable uniformly distributed over the interval from zero to one. $F_m^{-1}(U)$ is then a random variable with distribution F_m. U is generated using the subroutine, RANDU, part of the IBM System/360 Scientific Subroutine Package.

The user chooses the number of classes, c+1, and a five digit odd integer (seed) with which to initialize RANDU.

For $m=1,\ldots,c-1$,

$$F_m(x) = (x - n_{m-1})/(n_m - n_{m-1}),\ n_{m-1} \leq x < n_m$$

$$= 0,\ x < n_{m-1}$$

$$= 1,\ x \geq n_m$$

and

$$F_c(x) = 1 - e^{-(x-n_{c-1})/\lambda},\ x \geq n_{c-1}$$

$$= 0,\ x < n_{c-1},$$

where $\lambda = \bar{x} - n_{c-1}$ with $\bar{x}$ being the average of all (historical) rainfalls greater than or equal to n_{c-1}.

To illustrate the generation of a typical daily rainfall value, assume that the process is in state i during month k. RANDU is called to produce a pseudo-random number U in (0,1). The program determines the following day's state by finding i' such that

$$\sum_{j=0}^{i'-1} \hat{p}_{ij}^{(k)} \leq U < \sum_{j=0}^{i'} \hat{p}_{ij}^{(k)},$$

where the left hand sum is taken to be zero for $i'=0$. RANDU is called a second time to produce u'. A simulated daily rainfall is then generated by computing $F_i^{-1}(u')$.

The model described above is a natural extension of the rather successful modeling of wet/dry days using a Markov chain presented in Gabrial and Neumann (1962), as well as the simulation work of Khanal and Hamrick (1971), which also employed a Markov model. Experimentation with historical data from the Ashland, Kentucky, weather station in an effort to balance modeling detail with stability of parameter estimation led to the choice of seven states and of transition probabilities stationary within months.

Before using the model, one should check to see if there is sufficient data available to estimate 12 $c(c+1)$ transition probabilities.

For definition of the statistical terminology the reader is referred to Karlin (1966).

PART II - USAGE INFORMATION

There are several programs used in the study. We begin with a brief description of each of them.

WXCOPY copies and condenses selected station rainfall information from the master tapes onto a user tape. WXHISTRY is available for computing some descriptive statistics summarizing the actual rainfall data. This step is not essential to the simulation procedure. For each station, WXTPM estimates the transition probability matrices and the scale parameter in the shifted exponential distribution from the actual rainfall data. This information is stored on magnetic tape for use by WXSIM which generates simulated rainfall data and computes descriptive statistics summarizing these data. The generated data are stored on magnetic tape for use as input data to hydrologic or other models. The subroutine SUMSTA prints the descriptive statistics computed by WXHISTRY and WXSIM. Meanwhile the subroutine FRQRUN computes and prints frequencies of runs of wet (rainfall $\geq$ one hundredth inch) and dry days. See Figure 1 for a schematic relationship of these programs.

We now define some technical terms used in the detailed description. An EXCP is one (1) physical record read from or written on a disk or tape data set. Rainfall refers to precipitation as defined by the United States Weather Bureau. Wet refers to recorded (or simulated) rainfalls greater than or equal to one hundredth of an inch. Dry refers to recorded (or simulated) rainfalls of zero.

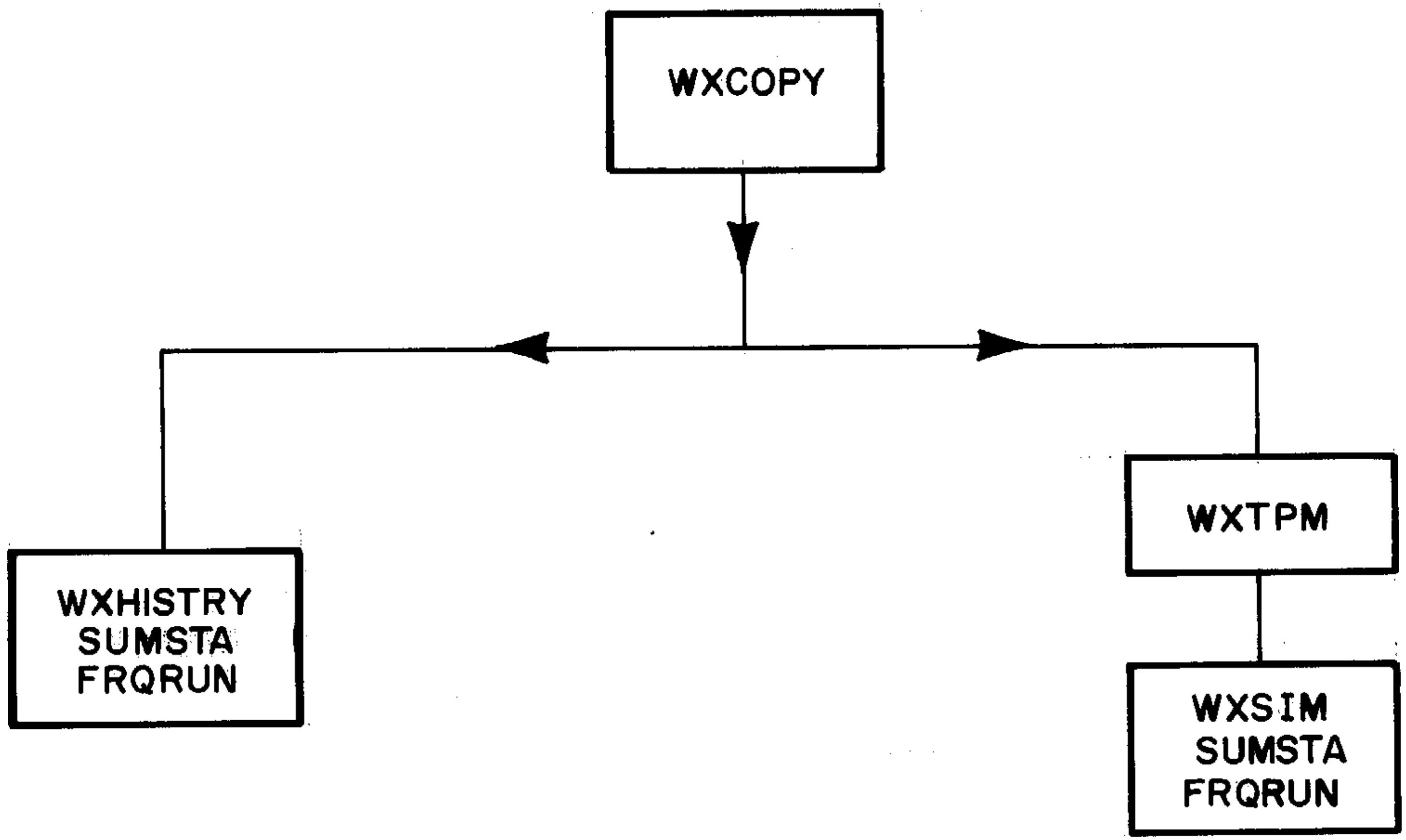

Figure 1. Schematic of Program Control.

The Rainfall Simulation programs are written in FORTRAN IV for use on an IBM 360 or 370 computer. As presently written, these programs require less than 134 K core. At least two magnetic tape drives are required.

The major input requirement is data similar to that on the Kentucky Department of Natural Resources, Division of Water, Climatological Tapes. Generally each program requires one input data card for each station whose data are to be acted upon. WXTPM and WXSIM also require an input data card containing general information applying to each station being processed.

WXCOPY uses data from the Kentucky Department of Natural Resources, Division of Water, Climatological Tapes as input. A description of the tapes' formats and contents is given in Griffin (1972). Essentially these tapes contain historical daily rainfall data.

WXHISTRY uses data from the output tape created by WXCOPY as input. The description of program output from WXCOPY should be consulted for format and contents information. WXTPM also uses data from the output tape created by WXCOPY as input.

WXSIM uses data from the output tape created by WXTPM as input. See the description of program output from WXTPM for format and contents information.

All data card entries must be right justified. WXCOPY uses one data card for each weather station whose data are to be copied and condensed onto another tape for later use as input to other programs.

Columns	Variable	Description
1-5	ISTATN	Station number of a station whose data are to be copied
6-10	INTPE	Logical unit number of the tape drive which is being assigned to the tape containing the station being copied
11-15	IMØNTH	Last month and year of data to be
16-20	IYEAR	copied for this station; the programs will copy all data for the station beginning with the first month available and ending with the month and year as specified by the user.

Any number of stations may be copied in one run of WXCOPY provided the input cards are arranged such that the first data card contains the smallest station number whose data are to be copied, the second card contains the next smallest station number, etc.

WXHISTRY requires one data card for each station whose historical (actual) rainfall data are to be summarized.

Columns	Variable	Description
1-5	ISTATN	Station number of station whose historical data are to be summarized. This number must be the number of a station whose data were previously copied using WXCOPY.

6-10	LIST	1 if a listing of the actual rainfall for each day is to be printed, 0 or blank otherwise
11-15	IYRS	Number of years of data from this station which are to be summarized.

Any number of the stations available on the input tape may be summarized in one run of WXHISTRY provided the input cards are arranged such that the first data card contains the smallest station number whose data are to be summarized, the second card contains the next smallest station number, etc.

WXTPM first requires one data card to define the number of states in the hypothesized Markov chains and to define the states as to amount of rainfall.

STATE CARD

Columns	Variable	Description
1-5	NS	Number of states desired in the Markov chains; must have $2 \leq NS \leq 11$
6-10	BND	Equal to 0
11-15 16-20 . . . 61-65	BND	The upper bounds, in hundredths of inches, on the rainfalls in the successive states. Note: the program assumes the intervals are closed on the left and open on the right.

Additionally one data card is required for each station whose estimated transition probability matrices are desired.

STATION CARDS

Columns	Variable	Description
1-5	ISTATN	Station number of station whose estimated transition probability matrices are to be estimated. This number must be the number of a station whose data were previously copied using WXCOPY.
6-10	IYRS	Number of years of data from this station which are to be used in the estimation procedure; if more years are available than are requested, the more recent years are not used.

Any number of the stations available on the input tape may be processed in one run of WXTPM provided the station cards are arranged such that the first data card contains the smallest station number whose data are to be processed, the second card contains the next smallest station number whose data are to be processed, etc.

WXSIM first requires one data card containing general program information.

SEED CARD

Columns	Variable	Description
1-10	IX	"Seed" for the random number generator RANDU
11-15	NSTATN	Number of stations having estimated transition probability matrices on the input tape

Also one data card is required for each set of data at each station to be generated by the rainfall simulation routine.

SIMULATION CARDS

Columns	Variable	Description
1-5	LIST	1 if simulated rainfall for each day is to be listed; 0 otherwise.
6-10	IWRITE	1 if simulated rainfall for each day is to be saved on output tape; 0 otherwise.
11-15	IYRS	Number of years of data to be generated by the simulator
16-20	NYR	First year for which data are to be simulated.

Any number of data sets may be generated by the simulator in one run of WXSIM. The first simulation card causes a set to be created for the first station on the input tape, the second card causes a set to be created for the second station on the tape, etc. When one set has been created for each station on the input tape, the next simulation card causes another set to be created for the first station on the input tape, etc.

The output from WXCOPY consists of a list of stations whose data were copied and a data tape containing pertinent rainfall data for the user requested stations. This tape has fixed length blocked records, logical record length of 124 bytes, and blocksize of 5952 bytes (48 logical records).

Within a block there are 24 station-months of data. Each station-month consists of two logical records as shown below:

IDENTIFICATION RECORD (first record)

BYTES	Description
1-4	Station number
5-8	Year
9-10	Month
11-12	Number of days in month
13-124	Blank

RAINFALL RECORD (second record)

1-4	Rainfall in hundredths of inches for day 1 of the month
5-8	Rainfall in hundredths of inches for day 2 of the month
.	.
.	.
.	.
(4x-3)-4x	Rainfall in hundredths of inches for day x of the month, $1 \leq x \leq$ number of days in month.

Program output from WXHISTRY consists of a set of descriptive statistics summarizing the historical rainfall for each station requested. Optionally it may include a listing of the actual rainfall (in hundredths of inches) for each day at any station. The portion of the output designated SS(MT) refers to the corrected sum of squares of monthly rainfall totals, viz., for month $i = \sum_{j=1}^{IYRS} (T_{ij} - T_{i\cdot})^2$ where T_{ij} is rainfall for month i in year j and $T_{i\cdot} = \sum_{j=1}^{IYRS} T_{ij}/IYRS$, for any i = 1, 2, ..., 12.

Program output from WXTPM for each station processed consists of an estimated transition probability matrix for each month and a maximum likelihood estimate of λ from $F(x) = 1-\exp[-(x-a)/\lambda]$ where a is the lower boundary of state NS. Also, these estimates are written onto tape for later use by WXSIM. This tape has variable spanned (Unformatted) records, logical record length of 92 bytes, and blocksize of 7500 bytes. The number of records for each station depends on the number of states specified during the input (NS). The first record, though, always contains:

Variable	Description
LAMBDA	$\hat{\lambda}_{MLE}$
STANUM	Station number
NS	Number of states in the Markov chain
BND	See input data description for WXTPM

One record for each row of each month's transition probability matrix is written onto tape. These records contain only the estimated transition probabilities for the particular rows.

Program output from WXSIM consists of a set of descriptive statistics (same as in WXHISTRY) summarizing the generated simulated rainfall for each data set created. Optionally it may include a listing of the simulated rainfall (in hundredths of inches) for each day of any created data set. Also these generated data sets may optionally be written onto tape for later use as input data for other models. This tape has fixed length blocked records, logical record length of 133 bytes, and blocksize of 7980 bytes (60 logical records). Each logical record contains one month of simulated rainfall data formatted as follows:

Bytes	Description
1-5	Station number
6-7	Year - 1900
8-9	Month
10-13	Simulated rainfall for day 1
.	.
.	.
.	.
130-133	Simulated rainfall for day 31

The user should specify "ring-out" for input tapes and "ring-in" for output tapes.

WXHISTRY and WXTPM generate the following error message:

** DATA NØT FØUND FØR STATION XXXX

This message indicates either that no data could be found for station number XXXX or that the amount of data found is less than the amount requested. User should modify the request by changing the station number or the amount (in years) of data requested.

MX and MY refer to the logical unit number of the line printer and card reader, respectively, in each program. Variables in WXCOPY include:

Variable	Description
MT	Logical unit number of tape drive to which output tape is assigned
ISTATN, INTPE, IMØNTH, IYEAR	See input data description for WXCOPY

STANUM	Station number	Refer to an identification record being read from input tape
YEAR	Year	
MØNTH	Month	
MISC	Number of days in month	
X	Rainfall in hundredths of inches	

Variables in WXHISTRY include:

Variable	Description
MT	Logical unit number of tape drive to which input tape is assigned
ISTATN	See input data description for WXHISTRY
LIST	
IYRS	
ICALL	Equals 1 indicating the headings for historical data are to be printed
SMØNTH	Data array used to print the names of the months
IHDG	Data arrays used to print headings
HDNG	
MXRFLY	Maximum rainfall in each year
MXRFLM	Maximum rainfall in each month of each year
NRD	Number of days with rainfall ≥ 1 hundredth inch in each month of each year.
STANUM	Refer to an identification record being read from the input tape
YEAR	
MØNTH	
ND	Number of days in each month
X	Rainfalls for each day in a month-temporary

RAIN	Rainfalls for each day in each month of each year
RTØTAL	Total rainfall in each month of each year
DLYAVG	Daily average rainfall in each month of each year
NDWØR	Number of days with no rainfall in each month of each year
TØTAL	Total historical rainfall
NYR	First year of data being summarized
YRSUM	Total rainfall in each year
DLYAVE	Daily average rainfall in each year
NRDY	Total number of wet days in each year
NDWØRY	Total number of dry days in each year
MØSUM	Total rainfall in each month taken over all the years being summarized
SSMT	Corrected sum of squares of monthly rainfall totals for each month
XI, TEMP, SUM, ISUM2, ISUM3, ISUM4, NDJ, ISUM	Temporary variables

Variables in WXTPM include:

Variable	Description
MT	Logical unit number of tape drive to which input tape is being assigned
MZ	Logical unit number of tape drive to which output tape is being assigned
NS BND ISTATN IYRS	} See input data description for WXTPM
STANUM YEAR MØNTH NDJ	Station number Year Month Number of days in month } Refer to an identification record being read from input tape
F	For each month contains number of transitions from state i to state j, for all i, j = 1,2, ..., NS
RAIN	Rainfalls for each day in a month
ICT	Number of rainfalls $\geq$ lower bound of state NS
ISUM	Sum of these rainfalls $\geq$ lower bound of state NS
STATE	States corresponding to rainfalls for each day in a month
NDJI	Number of days in month minus one
LAMBDA	See program output for WXTPM
NSI	Number of states plus one
SUMF	For each month, contains number times state i was visited for all i = 1, 2, ..., NS

ESTP	For each month, contains estimated probability of nest going to state j given we are in state i, for all i, j = 1, 2, ..., NS
SMØNTH	Data array used to print the names of the months
M, IRAIN, SUM	Temporary variables

Variables used in WXSIM include:

Variable	Description
MP	Logical unit number of tape drive to which the output tape is being assigned
MZ	Logical unit number of tape drive to which the input tape is being assigned
IX, NSTATN, LIST, IWRITE, IYRS, NYR	See input data description for WXSIM
CUMP	For each month, contains estimated distribution function of next going to state j given we are in state i, for all i, j = 1, 2, ..., NS
ESTP	For each month, contains estimated probability of next going to state j given we are in state i, for all i, j = 1, 2, ..., NS

LAMBDA STANUM NS BND	See program output for WXTPM
IY CFL	See description of RANDU, IBM Scientific Subroutine package
ICALL	Equals 2 indicating the headings for simulated data are to be printed
ISTATN YEAR IYR YFL NDJ ISTATE ISUM5 NDD LØØP	Temporary variables

All other variables have the same meaning as in WXHISTRY except that the rainfalls referred to are now simulated rainfalls.

Variables used in SUMSTA include:

Variable	Description
ISSMT YEAR	Temporary variables
ITITLE TITLE	Data arrays used to print headings

All other variables used have the same meaning as they do in WXHISTRY and WXSIM

Variables used in FRQRUN include:

Variable	Description
LGRUN	Equals 31, the maximum days in any month
IFRQD	For each month, contains number of occurrences of runs of dry days of length 1, 2, ..., 31
IFRQW	For each month, contains number of occurrences of runs of wet days of length 1, 2, ..., 31
NDJ, IWET, IDRY, IYR	Temporary variables
ITITLE, TITLE	Data arrays used to print headings

All other variables used have the same meaning as they do in WXHISTRY and WXSIM.

To copy 40 years of data for each of seven (7) "random" stations required 3 minutes CPU time and 3625 EXCP's when performed by WXCOPY. Printed output amounted to 200 lines. WXHISTRY summarized 40 years of historical rainfall data for each of seven stations and incurred costs of 1.25 minutes CPU time and 300 EXCP's. Approximately 6000 lines were printed when the list option was not used. An additional 1600 lines of output is created when listing 40 years of daily rainfall data for one station. To estimate the required parameters for each of seven stations, WXTPM required 1.20 minutes CPU time and 260 EXCP's. Printed output consisted of 1500 lines. Note: 40 years of historical data was used to estimate the parameters for each station. WXSIM generated

40 years of daily rainfall data for each of seven stations and used 1.75 minutes CPU time and 260 EXCP's. Approximately 6700 lines were printed when the list option was suppressed. Note: All printed line estimates include program listing and Job Control Language information.

Changing statement numbers 1020, 1030, and 1050 in WXCOPY could be necessary to accommodate alterations of the input tape format.

If WXHISTRY is to summarize more than 40 years of data for one station (IYRS > 40), one needs to appropriately increase the dimensions of all variables presently having 40 in their dimension specifications. If WXSIM is to generate more than 40 years of data for one station (IYRS > 40), one needs to appropriately increase the dimensions of all variables presently having 40 in their dimension specifications. The values of MX, MY, MZ, MP, MT, ie, logical unit numbers of line printer, card reader, input tapes, and output tapes may need changing for different systems.

APPENDIX D

COMPUTER PROGRAM LISTINGS

```
C     WXCOPY
C
      DIMENSION X(31)
      INTEGER STANUM,YEAR
      MY=5
      MX=6
      MT=8
      WRITE(MX,1000)
 1000 FORMAT(1H1,'STATIONS COPIED BY WXCOPY INCLUDE')
   10 READ(MY,1010,END=60) ISTATN,INTPE,IYEAR,IMONTH
 1010 FORMAT(4I5)
      GO TO 30
   20 READ(INTPE,1020)
 1020 FORMAT(30(/))
   30 READ(INTPE,1030) STANUM,YEAR,MONTH,MISC
 1030 FORMAT(3X,I4,2X,I4,I2,A2,9X)
      IF(STANUM .NE. ISTATN) GO TO 20
      WRITE(MT,1040) STANUM,YEAR,MONTH,MISC
 1040 FORMAT(2I4,I2,A2)
      DO 40 I=1,31
   40 READ(INTPE,1050) X(I)
 1050 FORMAT(10X,A4,12X)
      WRITE(MT,1060) X
 1060 FORMAT(31A4)
      IF(YEAR .EQ.  IYEAR .AND. MONTH .EQ. IMONTH) GO TO 50
      GO TO 30
   50 WRITE(MX,1070) ISTATN,MONTH,YEAR
 1070 FORMAT(' STATION',I5,'  ALL DATA THRU',I3,'/',I4)
      GO TO 10
   60 CALL EXIT
      END
```

```
C      WXHISTRY
C
       IMPLICIT INTEGER*2(I-N)
       REAL*8 SSMT(12),HDNG(3),TOTAL,DLYAVG(40,12),SUM,TEMP
       REAL MOSUM(12)
       INTEGER*2 STANUM,YEAR,X(31),RAIN(40,12,31),X1(28)
       INTEGER IHDG(3),MX,MY,MT
       DIMENSION RTOTAL(40,12),                DLYAVE(40),YRSUM(40),
      -SMONTH(12),ND(12),NRD(40,12),NDWOR(40,12),NRDY(40),NDWORY(40),
      -IFRQW(31),IFRQD(31),MXRFLM(40,12),MXRFLY(40)
       COMMON/STAT/   DLYAVG,RTOTAL,YRSUM,MOSUM,TOTAL,SSMT,DLYAVE,
      -NRD,NRDY,NDWOR,NDWORY,MXRFLM,MXRFLY
       COMMON/FRQRNS/ND,IFRQD,IFRQW,RAIN
       COMMON IYRS,ISTATN,ICALL,NYR
       EQUIVALENCE (X(1),X1(1))
       DATA MX,MY,MT/6,5,8/
       DATA SMONTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
      -'OCT','NOV','DEC'/
       DATA HDNG/'YR TOTAL','  YR AVG','WHOLE YR'/
       DATA IHDG/'/W  ','/WO ','    '/
       CALL ERRSET(215,256,-1,1)
       ICALL=1
   10  READ(MY,1000,END=160) ISTATN,LIST,IYRS
 1000  FORMAT(3I5)
       DO 20 I=1,IYRS
       MXRFLY(I)=0
       DO 20 J=1,12
       MXRFLM(I,J)=0
   20  NRD(I,J)=0
       DO 90 I=1,IYRS
       IF(LIST .NE. 0) WRITE(MX,1010) ISTATN
 1010  FORMAT('1',35X,'HISTORICAL RAINFALL AT STATION',I5)
       DO 70 J=1,12
   30  READ(MT,1020) STANUM,YEAR,MONTH,ND(J)
 1020  FORMAT(2I4,2I2)
       IF(ISTATN .EQ. STANUM) GO TO 40
       READ(MT,1040) X1
       IF(STANUM .GT. ISTATN) GO TO 150
       GO TO 30
   40  IF(LIST .NE. 0) WRITE(MX,1030) SMONTH(J),YEAR
 1030  FORMAT('0',48X,A3,3X,I4)
       IF(I .EQ. 1) NYR=YEAR
       NDJ=ND(J)
       READ(MT,1040) (X(K),K=1,NDJ)
 1040  FORMAT(31I4)
       IF(LIST .NE. 0) WRITE(MX,1050) (X(M),M=1,NDJ)
 1050  FORMAT('0',7I7,5X,7I7)
       DO 50 K=1,NDJ
       RAIN(I,J,K)=X(K)
       IF(X(K) .GT. 0) NRD(I,J)=NRD(I,J)+1
       IF(X(K) .GT. MXRFLM(I,J)) MXRFLM(I,J)=X(K)
   50  CONTINUE
       ISUM=0
       DO 60 K=1,NDJ
```

```
   60 ISUM=ISUM+X(K)
      RTOTAL(I,J)=ISUM
      SUM=ISUM
      DLYAVG(I,J)=SUM/NDJ
      NDWOR(I,J)=NDJ-NRD(I,J)
      IF(MXRFLM(I,J) .GT. MXRFLY(I)) MXRFLY(I)=MXRFLM(I,J)
   70 CONTINUE
      SUM=0.
      ISUM2=0
      ISUM3=0
      ISUM4=0
      DO 80 L=1,12
      SUM=SUM+RTOTAL(I,L)
      ISUM2=ISUM2+ND(L)
      ISUM3=ISUM3+NRD(I,L)
   80 ISUM4=ISUM4+NDWOR(I,L)
      YRSUM(I)=SUM
      DLYAVE(I)=YRSUM(I)/ISUM2
      NRDY(I)=ISUM3
   90 NDWORY(I)=ISUM4
      TOTAL=0.
      DO 100 I=1,IYRS
  100 TOTAL=TOTAL+YRSUM(I)
      DO 120 J=1,12
      SUM=0.
      DO 110 I=1,IYRS
  110 SUM=SUM+RTOTAL(I,J)
  120 MOSUM(J)=SUM
      DO 140 J=1,12
      SUM=0.
      TEMP=MOSUM(J)
      DO 130 I=1,IYRS
  130 SUM=SUM+RTOTAL(I,J)**2
  140 SSMT(J)=SUM-TEMP**2/IYRS
                          WRITE(MX,1060) STANUM
 1060 FORMAT('1',42X,'HISTORICAL RAINFALL AT STATION',I5)
      CALL SUMSTA(HDNG,IHDG,SMONTH)
      CALL FRQRUN
      GO TO 10
  150 WRITE(MX,1070) ISTATN
 1070 FORMAT(1H0,'** DATA NOT FOUND FOR STATION',I5)
      BACKSPACE MT
      BACKSPACE MT
      GO TO 10
  160 CALL EXIT
      END
```

```
C       WXTPM
C
        IMPLICIT REAL*8(A-H,O-Z)
        INTEGER*2 STATE(31),F(12,11,11),SUMF(12,11),RAIN(31),BND(12),NS
        INTEGER*2 IRAIN(28)
        INTEGER STANUM,YEAR
        REAL*8 LAMBDA
        DIMENSION ESTP(12,11,11),SMONTH(12)
        EQUIVALENCE (RAIN(1),IRAIN(1))
        DATA SMONTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
       -'OCT','NOV','DEC'/
        CALL ERRSET(215,256,-1,1)
        MY=5
        MX=6
        MT=8
        MZ=9
        READ(MY,1000) NS,BND
 1000   FORMAT(13I5)
   10   DO 20 K=1,11
        DO 20 J=1,11
        DO 20 I=1,12
   20   F(I,J,K)=0
        READ(MY,1000,END=160) ISTATN,IYRS
        ISUM=0
        ICT=0
        DO 80 I=1,IYRS
        DO 80 J=1,12
   30   READ(MT,1010) STANUM,YEAR,MONTH,NDJ
 1010   FORMAT(2I4,2I2)
        IF(ISTATN .EQ. STANUM) GO TO 40
        READ(MT,1020) IRAIN
        IF(STANUM .GT. ISTATN) GO TO 150
        GO TO 30
   40   READ(MT,1020) (RAIN(K),K=1,NDJ)
 1020   FORMAT(31I4)
        DO 60 K=1,NDJ
        DO 50 II=1,NS
        IF(RAIN(K) .GE. BND(II) .AND. RAIN(K) .LT. BND(II+1)) STATE(K)=II
   50   CONTINUE
        IF(RAIN(K) .LT. BND(NS)) GO TO 60
        ISUM=ISUM+RAIN(K)
        ICT=ICT+1
   60   CONTINUE
        NDJ1=NDJ-1
        DO 70 K=1,NDJ1
   70   F(J,STATE(K),STATE(K+1))=F(J,STATE(K),STATE(K+1))+1
   80   CONTINUE
        SUM=ISUM
        LAMBDA=SUM/ICT-BND(NS)
        WRITE(MX,1030) BND(NS),BND(NS),ISUM,ICT
 1030   FORMAT(1H1,'F(X) = 1 - EXP(('  ,I3,'-X)/LAMBDA)'//,' SUM OF RAINFALL
       -S GE ',I3,' =',I8,5X,'TOTAL SUCH RAINFALLS =',I6)
        WRITE(MX,1040) LAMBDA,STANUM
 1040   FORMAT(' MLE OF LAMBDA FROM F(X) =',F8.2, 5X,'STATION NUMBER IS',
```

```
     -I5,///)
      NS1=NS+1
      WRITE(MX,1050)
 1050 FORMAT(8X,'STATE BOUNDARIES ARE :')
      WRITE(MX,1060) (BND(II),II=1,NS1)
 1060 FORMAT(10X,12I7)
      WRITE(MX,1070)
 1070 FORMAT(8X,'NOTE :  INTERVALS ARE CLOSED ON THE LEFT, OPEN ON THE R
     -IGHT'/,16X,'BOUNDARIES ARE GIVEN IN HUNDREDTHS OF AN INCH',///)
      WRITE(MZ) LAMBDA,STANUM,NS,BND
      DO 120 J=1,12
      DO 120 K=1,NS
      M=0
      DO 90 L=1,NS
   90 M=M+F(J,K,L)
      SUMF(J,K)=M
      SUM=SUMF(J,K)
      DO 110 L=1,NS
      IF(SUMF(J,K) .EQ. 0) GO TO 100
      ESTP(J,K,L)=F(J,K,L)/SUM
      GO TO 110
  100 ESTP(J,K,L)=0.
  110 CONTINUE
  120 CONTINUE
      WRITE(MX,1080)
 1080 FORMAT(29X,'ESTIMATED TRANSITION PROBABILITY MATRICES',//)
      DO 140 J=1,12
      WRITE(MX,1090) SMONTH(J)
 1090 FORMAT(47X,A5,/)
      WRITE(MX,1100) (I,I=1,NS)
 1100 FORMAT(T99,'SUMFREQ',T11,11I8,/)
      DO 130 K=1,NS
      WRITE(MX,1110) SUMF(J,K),K,(ESTP(J,K,L),L=1,NS)
 1110 FORMAT(T99,I5,T9,I2,2X,11F8.3)
  130 WRITE(MZ) (ESTP(J,K,L),L=1,NS)
  140 WRITE(MX,1120)
 1120 FORMAT(1X,//)
      GO TO 10
  150 WRITE(MX,1130) ISTATN
 1130 FORMAT(1H0,'** DATA NOT FOUND FOR STATION',I5)
      BACKSPACE MT
      BACKSPACE MT
      GO TO 10
  160 CALL EXIT
      END
```

```
C      WXSIM
C
       IMPLICIT INTEGER*2(I-N)
       REAL*8 SSMT(12),HDNG(3),TOTAL,DLYAVG(40,12),YFL,CUMP(12,11,12),
      -ESTP(11),X(31),SUM,TEMP,LAMBDA
       REAL MOSUM(12)
       INTEGER*2         YEAR,BND(12),RAIN(40,12,31)
       INTEGER IHDG(3),MX,MY,MP,IX,IY,STANUM,MZ
       DIMENSION RTOTAL(40,12),DLYAVE(40),YRSUM(40),SMONTH(12),ND(12),
      -NRD(40,12),NDWOR(40,12),NRDY(40),NDWORY(40),IFRQW(31),IFRQD(31),
      -MXRFLM(40,12),MXRFLY(40),NDD(12)
       COMMON/STAT/DLYAVG,RTOTAL,YRSUM,MOSUM,TOTAL,SSMT,DLYAVE,NRD,NRDY,
      -NDWOR,NDWORY,MXRFLM,MXRFLY
       COMMON/FRQRNS/NDD,IFRQD,IFRQW,RAIN
       COMMON IYRS,ISTATN,ICALL,NYR
       DATA HDNG/'YR TOTAL','  YR AVG','WHOLE YR'/
       DATA IHDG/'/W  ','/WO ','    '/
       DATA MX,MY,MP,MZ/6,5,10,9/
       DATA SMONTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
      -'OCT','NOV','DEC'/
       DATA ND/31,28,31,30,31,30,31,31,30,31,30,31/
       ICALL=2
       LOOP=0
       READ(MY,1000) IX,NSTATN
  1000 FORMAT(I10,I5)
    10 READ(MY,1010,END=210) LIST,IWRITE,IYRS,NYR
  1010 FORMAT(4I5)
       LOOP=LOOP+1
       DO 20 I=1,IYRS
       MXRFLY(I)=0
       DO 20 J=1,12
       NRD(I,J)=0
    20 MXRFLM(I,J)=0
       READ(MZ) LAMBDA,STANUM,NS,BND
       LAMBDA=LAMBDA/100.D0
       DO 30 I=1,12
       MOSUM(I)=0.
       DO 30 J=1,NS
       READ(MZ) (ESTP(K),K=1,NS)
       CUMP(I,J,1)=0.
       DO 30 K=1,NS
    30 CUMP(I,J,K+1)=CUMP(I,J,K)+ESTP(K)
       K=1
       DO 170 I=1,IYRS
       YRSUM(I)=0.
       IF(LIST .NE. 0) WRITE(MX,1020) STANUM
  1020 FORMAT('1',36X,'SIMULATED RAINFALL AT STATION',I5)
       YEAR=NYR+I-1
       IYR=YEAR-1900
       IF(YEAR-(YEAR/4)*4) 40,50,40
    40 ND(2)=28
       GO TO 60
    50 ND(2)=29
    60 DO 150 J=1,12
```

```
      IF(LIST .NE. 0) WRITE(MX,1030) SMONTH(J),YEAR
 1030 FORMAT('0',48X,A3,3X,I4)
      NDJ=ND(J)
      DO 130 M=1,NDJ
      CALL RANDU(IX,IY,CFL)
      YFL=CFL
      IX=IY
      DO 70 N=1,NS
      IF(YFL .LT. CUMP(J,K,N+1)) GO TO 80
   70 CONTINUE
      ISTATE=NS
      GO TO 90
   80 ISTATE=N
      IF(ISTATE .EQ. 1) GO TO 110
   90 CALL RANDU(IX,IY,CFL)
      YFL=CFL
      IX=IY
      IF(ISTATE .NE. NS) GO TO 100
      X(M)=100.D0*(BND(NS)/100.D0-DLOG(YFL)*LAMBDA)
      GO TO 120
  100 X(M)=(BND(ISTATE+1)-BND(ISTATE))*YFL+BND(ISTATE)
      GO TO 120
  110 X(M)=0.
  120 RAIN(I,J,M)=X(M)
      IF(X(M)-RAIN(I,J,M) .GT. .5)   RAIN(I,J,M)=RAIN(I,J,M)+1
      MOSUM(J)=MOSUM(J)+X(M)
      YRSUM(I)=YRSUM(I)+X(M)
      IF(X(M) .GT. 0.) NRD(I,J)=NRD(I,J)+1
      IF(X(M)-MXRFLM(I,J) .GT. 0.) MXRFLM(I,J)=X(M)
  130 K=ISTATE
      IF(LIST .NE. 0) WRITE(MX,1040) (X(M),M=1,NDJ)
 1040 FORMAT('0',7F7.2,5X,7F7.2)
      IF(IWRITE .NE. 0) WRITE(MP,1050) STANUM,IYR,J,(RAIN(I,J,M),M=1,NDJ
     1)
 1050 FORMAT(I5,2I2,31I4)
      SUM=0.
      DO 140 N=1,NDJ
  140 SUM=SUM+X(N)
      DLYAVG(I,J)= SUM /ND(J)
      RTOTAL(I,J)=SUM
      NDWOR(I,J)=ND(J)-NRD(I,J)
      IF(MXRFLM(I,J) .GT. MXRFLY(I)) MXRFLY(I)=MXRFLM(I,J)
  150 CONTINUE
      ISUM2=0
      ISUM3=0
      ISUM5=0
      DO 160 N=1,12
      NDD(N)=ND(N)
      ISUM2=ISUM2+ND(N)
  160 ISUM3=ISUM3+NRD(I,N)
      DLYAVE(I)=YRSUM(I)/ISUM2
      NRDY(I)=ISUM3
      NDWORY(I)=ISUM2-ISUM3
  170 CONTINUE
```

```
      TOTAL=0.
      DO 180 I=1,IYRS
  180 TOTAL=TOTAL+YRSUM(I)
      DO 200 J=1,12
      TEMP=MOSUM(J)
      SUM=0.
      DO 190 I=1,40
  190 SUM=SUM+RTOTAL(I,J)**2
  200 SSMT(J)=SUM-TEMP**2/IYRS
      ISTATN=STANUM
                          WRITE(MX,1020) STANUM
      CALL SUMSTA(HDNG,IHDG,SMONTH)
      CALL FRQRUN
      IF(LOOP .NE. NSTATN)  GO TO 10
      REWIND MZ
      LOOP=0
      GO TO 10
  210 CALL EXIT
      END
```

```
      SUBROUTINE SUMSTA(HDNG,IHDG,SMONTH)
      IMPLICIT INTEGER*2(I-N)
      REAL*8 SSMT(12),HDNG(3),DLYAVG(40,12),TOTAL,TITLE(2),TEMP
      REAL MOSUM(12)
      INTEGER YEAR,IHDG(3),MX,ISSMT(12)
      DIMENSION     RTOTAL(40,12),YRSUM(40),DLYAVE(40),SMONTH(12),
     -NRD(40,12),NRDY(40),NDWOR(40,12),NDWORY(40),MXRFLM(40,12),
     -MXRFLY(40),ITITLE(2)
      COMMON/STAT/   DLYAVG,RTOTAL,YRSUM,MOSUM,TOTAL,SSMT,DLYAVE,
     -NRD,NRDY,NDWOR,NDWORY,MXRFLM,MXRFLY
      COMMON IYRS,ISTATN,ICALL,NYR
      DATA TITLE/'HISTORIC',' SIMULAT'/
      DATA ITITLE/'AL','ED'/
      MX=6
      WRITE(MX,1000)
 1000 FORMAT('0',50X,'MONTH BY YEAR TOTALS',//)
      WRITE(MX,1010) HDNG(1)
 1010 FORMAT(17X,'JAN',5X,'FEB',5X,'MAR',5X,'APR',5X,'MAY',5X,'JUN',5X,
     -'JUL',5X,'AUG',5X,'SEP',5X,'OCT',5X,'NOV',5X,'DEC',4X,A8,/)
      DO 10 I=1,IYRS
      YEAR=NYR+I-1
   10 WRITE(MX,1020) YEAR,(RTOTAL(I,J),J=1,12),YRSUM(I)
 1020 FORMAT(4X,I4,4X,12F8.2,2X,F10.2)
      WRITE(MX,1030) MOSUM,TOTAL
 1030 FORMAT('0',' MO. TOTAL',2X,12(F7.1,1X),F11.1)
      DO 20 J=1,12
      ISSMT(J)=SSMT(J)
      TEMP=SSMT(J)-ISSMT(J)
      IF(           TEMP .GT. .5D0) ISSMT(J)=ISSMT(J)+1
   20 MOSUM(J)=MOSUM(J)/IYRS
      WRITE(MX,1040) MOSUM,ISSMT
 1040 FORMAT(2X,'MONTH AV.',1X,12F8.2,/,2X,'SS(MT)',4X,12I8)
      WRITE(MX,1050) TITLE(ICALL),ITITLE(ICALL),ISTATN
 1050 FORMAT('1',42X,A8,A2,' RAINFALL AT STATION',I5)
      WRITE(MX,1060)
 1060 FORMAT('0',44X,'DAILY AVERAGE BY MONTH BY YEAR',//)
      WRITE(MX,1010) HDNG(2)
      DO 30 I=1,IYRS
      YEAR=NYR+I-1
   30 WRITE(MX,1020) YEAR,(DLYAVG(I,J),J=1,12),DLYAVE(I)
      WRITE(MX,1050) TITLE(ICALL),ITITLE(ICALL),ISTATN
      WRITE(MX,1070)
 1070 FORMAT('0',39X,'NUMBER DAYS WITH/WO RAIN BY MONTH BY YEAR',//)
      WRITE(MX,1010) HDNG(1)
      DO 40 I=1,IYRS
      YEAR=NYR+I-1
      WRITE(MX,1080)
 1080 FORMAT(' ')
      WRITE(MX,1090) YEAR,IHDG(1),(NRD(I,J),J=1,12),NRDY(I)
   40 WRITE(MX,1090) YEAR,IHDG(2),(NDWOR(I,J),J=1,12),NDWORY(I)
 1090 FORMAT(4X,I4,A4,12I8,2X,I10)
      WRITE(MX,1050) TITLE(ICALL),ITITLE(ICALL),ISTATN
      WRITE(MX,1100)
 1100 FORMAT('0',43X,'LARGEST RAINFALL BY MONTH BY YEAR',//)
```

```
      WRITE(MX,1010) HDNG(3)
      DO 50 I=1,IYRS
      YEAR=NYR+I-1
   50 WRITE(MX,1090) YEAR,IHDG(3),(MXRFLM(I,J),J=1,12),MXRFLY(I)
      RETURN
      END
```

```
      SUBROUTINE FRQRUN
      IMPLICIT INTEGER*2(I-N)
      REAL*8 TITLE(2)
      INTEGER*2 RAIN(40,12,31)
      INTEGER MX
      DIMENSION ND(12),IFRQD(31),IFRQW(31),SMONTH(12),ITITLE(2)
      COMMON/FRQRNS/ND,IFRQD,IFRQW,RAIN
      COMMON IYRS,ISTATN,ICALL,NYR
      DATA TITLE/'HISTORIC',' SIMULAT'/
      DATA ITITLE/'AL','ED'/
      DATA MX,LGRUN/6,31/
      DATA SMONTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
     -'OCT','NOV','DEC'/
      DO 90 J=1,12
      NDJ=ND(J)
      DO 10 I=1,LGRUN
      IFRQD(I)=0
   10 IFRQW(I)=0
      WRITE(MX,1000) TITLE(ICALL),ITITLE(ICALL),ISTATN
 1000 FORMAT('1',42X,A8,A2,' RAINFALL AT STATION',I5)
      DO 70 I=1,IYRS
      IWET=0
      IDRY=0
      IF(J .NE. 2) GO TO 40
      IYR=NYR+I-1
      IF(IYR-(IYR/4)*4) 30,20,30
   20 NDJ=29
      GO TO 40
   30 NDJ=28
   40 DO 60 K=1,NDJ
      IF(RAIN(I,J,K) .GT. 0)  GO TO 50
      IF(IWET .GT. 0) IFRQW(IWET)=IFRQW(IWET)+1
      IDRY=IDRY+1
      IWET=0
      GO TO 60
   50 IF(IDRY .GT. 0) IFRQD(IDRY)=IFRQD(IDRY)+1
      IWET=IWET+1
      IDRY=0
   60 CONTINUE
      IF(IWET .GT. 0) IFRQW(IWET)=IFRQW(IWET)+1
      IF(IDRY .GT. 0) IFRQD(IDRY)=IFRQD(IDRY)+1
   70 CONTINUE
      IF(J .EQ. 2) NDJ=29
      WRITE(MX,1010) SMONTH(J),IYRS
 1010 FORMAT(///,50X,A3,//,52X,'FREQUENCY (',I3,' YEARS)',/,30X,'LENGTH
     -OF RUN',13X,'WET',7X,'DRY',/)
      DO 80 I=1,NDJ
   80 WRITE(MX,1020) I,IFRQW(I),IFRQD(I)
 1020 FORMAT(36X,I2,18X,I3,7X,I3)
   90 CONTINUE
      RETURN
      END
```