STORAGE ANALYSES FOR EPHEMERAL STREAMS IN SEMIARID REGIONS

By Kent C. Glover

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 83-4078

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Cheyenne, Wyoming

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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METRIC CONVERSIONS

The following factors may be used to convert the inch-pound units used in this report to International System (SI) metric units:

Multiply	By	To obtain
acre-foot	1,233	cubic meter
cubic foot per second (CFS)	0.02832	cubic meter per second
cubic foot per second-day (CFS-day)	0.02832	cubic meter per second-day

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ABSTRACT

A model has been developed for determining the probability of a reservoir being unable to provide a specified downstream water supply. By applying the model with a number of assumed storage capacities, the long-term water supply of a stream can be evaluated. Previous methods for determining available water supply using storage analysis of streamflow records have met with limited success in semiarid regions. The shortcomings are due to the failure of the methods to account for zero-flow periods and the high day-to-day variability of discharge of many streams. The reservoir storage model presented in this report is designed to account for these streamflow characteristics. Reservoir inflow, outflow, and evaporation are modeled as varying daily, and values of storage probability are adjusted for zero-flow periods.

INTRODUCTION

A variety of factors commonly are considered in the design of a reservoir storage project. These factors include streamflow characteristics, demand for water, physical characteristics of the reservoir site, reservoir evaporation, economics, flood control, and recreational needs. The U.S. Geological Survey often has the responsibility of providing hydrologic information to water-resource planners for use in reservoir design. The information is presented in terms of probabilities of failing to supply a variety of long-term water demands from reservoir storage. A number of hypothetical reservoirs capacities are considered in the analysis of streamflow records.

The procedure used in reservoir-storage analysis is called probability routing. Langbein (1958) gives a detailed description of probability routing with several examples. The methodology has been successfully applied to streamflow records in humid regions by Riggs and Hardison (1973). Unfortunately, their procedure does not account for zero-flow periods and the high day-to-day variability of discharge of many streams of the western United States. This report describes a model that was developed for use in reservoir-storage analyses in semiarid regions. The behavior of ephemeral and intermittent streams is simulated by accounting for day-to-day variations in streamflow as well as zero-flow periods.

PROBABILITY ROUTING THEORY

The goal of this reservoir-storage analysis is to predict water supply downstream from a reservoir. This is accomplished by calculating reliable probabilities of a reservoir filling to various levels at various times of the year. Risks of failure can then be defined as the probabilities of a reservoir being empty and therefore being unable to meet downstream demand. The model divides the year into time steps of one month and develops a steady-state storage-frequency histogram for the end of each month. The storage-frequency histogram is obtained by first dividing the reservoir into a number of layers. Separate layers are used to describe the empty and spill states of reservoir storage. Klemes (1977) provides criteria that are useful in determining the optimal number of layers. Because of the potential impact on the error of the analysis, careful attention must be paid to selecting a proper number of layers. A discussion of this point is presented in the section, "Discussion of errors" later in this report. A hypothetical storage-frequency histogram for a 15-layer reservoir is shown in figure 1.

The chance of a reservoir being at a particular level at the end of the month, is dependent on the following:

1. The probabilities of the reservoir being at each level at the beginning of the month, and
2. The probabilities of the reservoir changing from each initial level to the level of interest, at the end of the month.

The second probability is called a transition probability.

Because it may be possible for a reservoir to change from any level to any new level, the probabilities of being at each level at the end of month i may be determined from the matrix equation

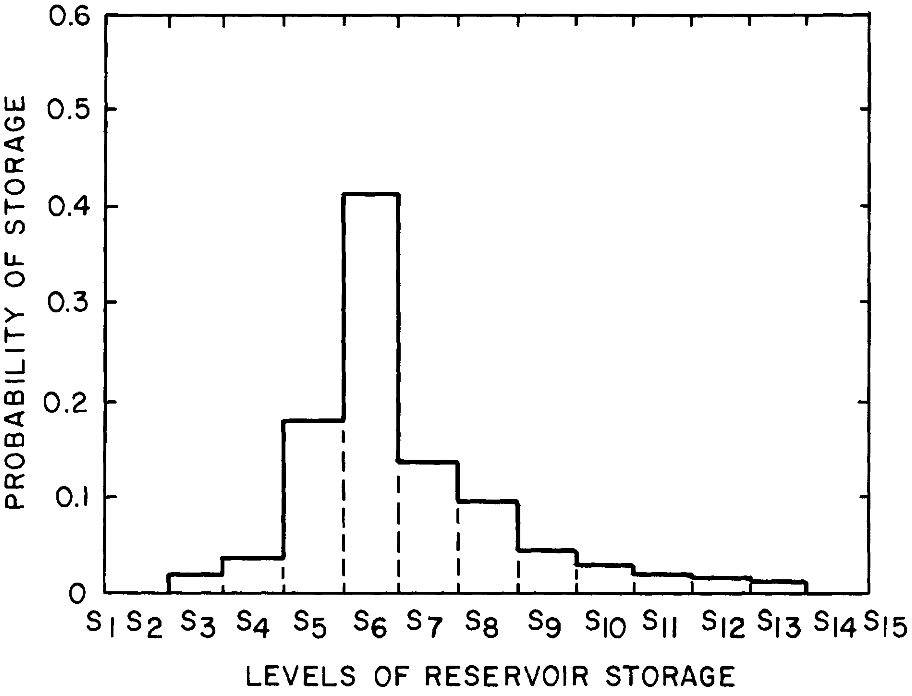

Figure 1.-Hypothetical reservoir storage-frequency histogram including empty (s_1) and spill (s_{15}) states

$$P_i \, s_{i-1} = s_i \qquad (1)$$

where

P_i = matrix of transition probabilities from month i-1 to month i,

s_{i-1} = vector of probabilities of reservoir storage at the beginning of month i, and

s_i = vector of probabilities of reservoir being at storage at the end of of month i.

Equation 1 can be written for each month of the year, producing 12 matrix equations. These equations are linked because the probability vector of reservoir storage obtained at the end of month i is the same as the inital probability vector for month i+1.

The steady-state storage probabilities are eigenvectors of the following system of equations for λ of unity.

$$\begin{aligned} Q_1 \, s_1^* &= \lambda \, s_1^* \\ Q_2 \, s_2^* &= \lambda \, s_2^* \\ Q_3 \, s_3^* &= \lambda \, s_3^* \\ &\cdot \\ &\cdot \\ &\cdot \\ Q_{11} \, s_{11}^* &= \lambda \, s_{11}^* \\ Q_{12} \, s_{12}^* &= \lambda \, s_{12}^* \end{aligned} \qquad (2)$$

where

$Q_i = P_{i+12} \, P_{i+11} \, P_{i+10} \cdots P_{i+2} \, P_{i+1}$,

P_i = matrix of transition probabilities,

s_i^* = steady-state vector of reservoir-storage probabilities,

λ = eigenvalue of Q_i, and

i = month subscript taken module 12.

Equation 2 was obtained from the twelve sets of matrix equation 1 by repeated substitution for s_{i-1}.

Eigenvectors can be determined directly by Gaussian elimination for known eigenvalues, but a more simple iterative-solution technique is used in the program given in Attachment D. Application of a direct solution technique for n reservoir layers would require approximately $12n^3$ calculations to formulate each Q matrix and $2n^3$ to invert each Q matrix. With 12 matrices a total of approximately $168n^3$ calculations would be required. The iterative approach outlined below performs $12n^2$ * ITMAX calculations, where ITMAX is the number of iterations required for convergence. Experience with the program has shown that, for differences in probabilities of less than 0.0001 between iterations, convergence can usually be expected in less than 100 iterations. This indicates that, for most realistic values of n, the iterative technique is more efficient.

The iterative-solution technique begins by solving equation 1 for i=1 with an assumed initial vector of storage probabilities. While it can be shown that any set of initial conditions will converge to the steady-state probability vectors, experience with the solution technique has shown that setting all initial storage probabilities to the value 1/n provides for reasonably rapid convergence under a wide variety of conditions. The solution to equation 1 for i=1 is used as the initial condition for a new solution of the equation with i=2. Solutions are obtained for the remaining 12 months in a similar manner. A second iteration with equation 1 can then begin using the month-ending storage-probability vector for i=12 as the initial probabilities of storage for i=1. Iteration continues by applying equation 1 sequentially until the difference in all probabilities of storage between iterations is less than some tolerance value. The resulting quasi steady-state probabilities of storage for the end of each month define the long-term risks of failure.

Obtaining The Transition Probability Matrix

The matrix of transition probabilities for a particular month defines the chance of reservoir storage changing from any level to any new level. As pointed out in the previous section, a transition probability matrix is required for each month of the year. Details of the method for deriving one transition matrix are given in this section. The method is repeated to obtain matrices for the remaining months of the year.

The general method used to obtain each element of a transition probability matrix is given below.

1. Determine the total monthly inflow required to change reservoir storage from the month-beginning level to the month-ending level associated with the element of the transition probability matrix. The relationship between inflow, initial, and final storage levels is described by an empirical equation obtained by least-squares analysis of conventional flow-routing data. This relationship is described in the following section.
2. Determine the cumulative frequency of the total monthly inflow obtained above by using an appropriate probability density function. The cumulative frequency of inflow is equal to the cumulative transition probability of storage. A discussion of monthly inflow frequency distributions is presented in the following section.
3. After completely filling the cumulative transition probability matrix, neighboring values in each column of initial storage are subtracted to obtain the monthly transition probability matrix.

Conventional reservoir flow routing is used to develop relationships of total monthly inflow, initial storage, and final storage (fig. 2). Daily flows for each month of discharge record are routed through the reservoir by assuming various initial storage levels. The routing equation is:

$$V_i = V_{i-1} + \sum_{j=1}^{m} (I_j - O_j) \qquad (3)$$

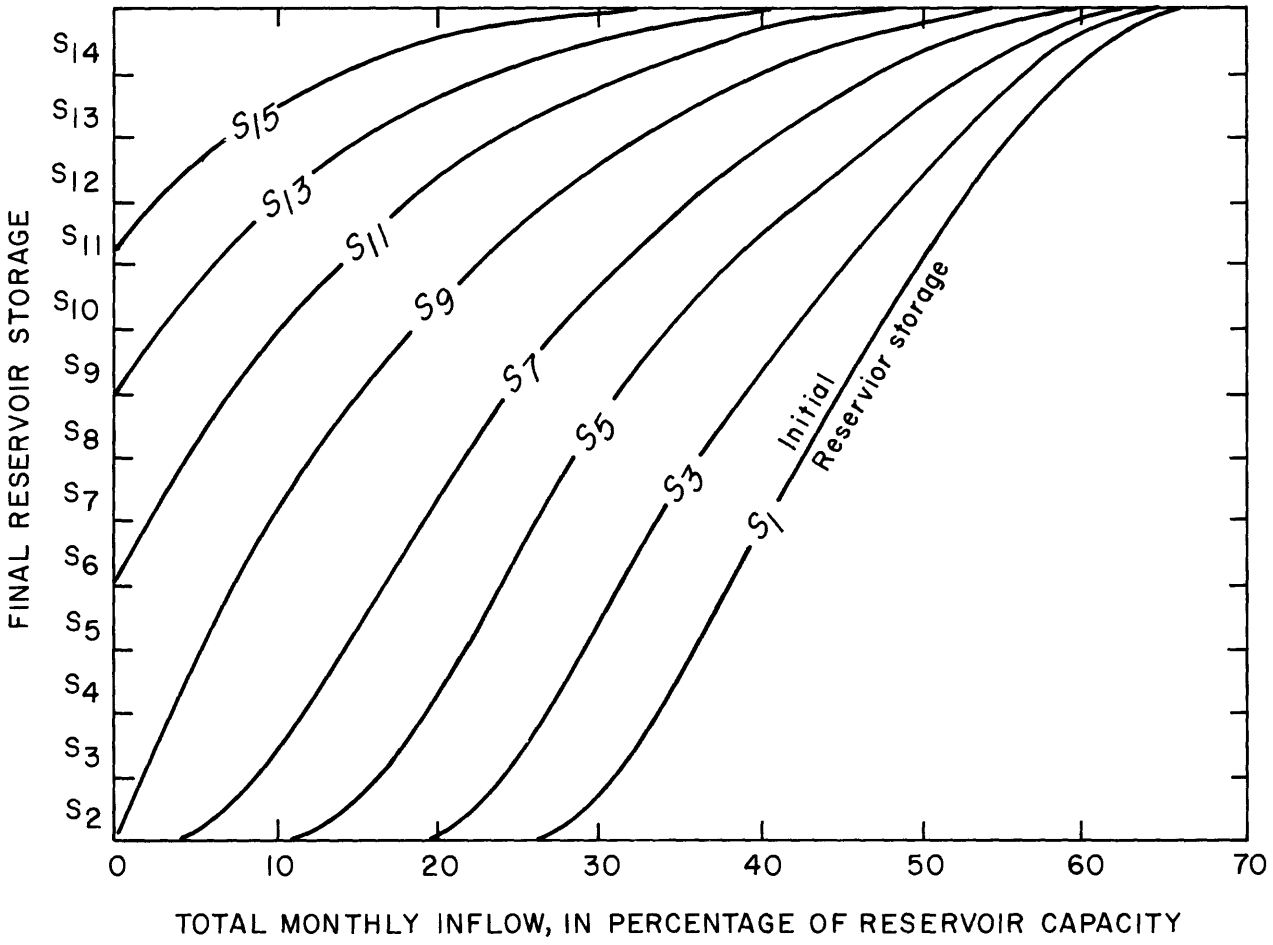

Figure 2.-Hypothetical routing relationships of total monthly inflow and final reservoir storage for various levels of initial reservoir storage

where

V_i = storage at the end of the month,

V_{i-1} = storage at the beginning of the month,

I_j = daily inflow obtained from discharge record,

O_j = sum of daily demand, seepage, and evaporative losses, and

m = number of days in the month.

This equation must be applied under the constraints that storage on any day cannot exceed the capacity of the reservoir and cannot be negative. Because of these constraints and because it is possible for reservoir spillage and deficiencies to occur on a time scale shorter than 1 month, the relationship between total monthly inflow and month-ending storage generally is nonlinear. Therefore, equation 3 is exact only if no spillage or deficiency occurs. At low values of inflow and low values of initial storage, the month-ending storage is zero. Similarly, at high values of inflow and high values of initial storage, the month-ending storage is equal to the reservoir capacity. Between these extremes, the relationship is generally nonlinear.

The nonlinear section of the total monthly inflow-final storage relationship is described for each assumed initial storage level by:

$$\frac{V_i}{C} = 1 - b_0 \exp(-b_1 T^{b_2}) \tag{4}$$

where

V_i = storage at the end of the month,

C = reservoir capacity,

T = total monthly inflow, and

b_0, b_1 and b_2 = coefficients.

This equation was derived empirically after reviewing data plots of total monthly inflow versus final storage for a number of Wyoming streams that drain both mountain and plains watersheds. A least-squares fit of equation 4 to these data produced correlation coefficients that were generally in excess of 0.95. In cases where the correlation coefficient was less than 0.95, the standard error of estimate for month-ending storage indicated that equation 4 was still an accurate representation of the total monthly inflow-final storage relationship.

While equation 4 has no physical basis, it does have several useful mathematical properties. As T becomes large, V_i/C approaches 1, implying that reservoir storage will not exceed capacity. As T approaches zero, V_i/C approaches a lower limit of $1-b_0$. The function also is continuous for all positive inflows and the slope of the function is always positive. The values of b_0, b_1, and b_2 are estimated by least-squares analysis.

The program given in Attachment D develops a frequency of inflow equation for each month by assuming the distribution of total-monthly inflow follows either a normal, log-normal, Gumbel, Pearson, or log-Pearson distribution. Monthly streamflow statistics are used to determine the appropriate distribution type. The distribution parameters are estimated from available streamflow record by the method of moments. Logarithmic distribution types are treated by first log-transforming the inflow data.

Zero-flow months are not used to estimate distribution parameters. Instead, probabilities obtained by the distribution function are adjusted by the equation:

$$f' = f(1-N)+N \tag{5}$$

where

f' = adjusted cumulative probability,
f = cumulative probability obtained from the distribution function, and
N = fraction of zero-flow values.

This method of adjusting for zero flow months is similar to the conditional probability adjustment used in flood-peak frequency analysis (Jennings and Benson, 1969).

Procedure Used In The Computer Program

The computer program listed in Attachment D can be summarized in the following way. Conventional flow routing is done on a daily basis for each month of the water year (October 1 - September 30) for user-defined initial storage levels. The routing produces 12 sets of data points relating initial storage, final storage, and total monthly inflow. The relationships are described by equation 4. A cumulative probability of inflow function is developed for each month. Applying the inflow functions to the routing relations produces a transition probability matrix for each month. A system of probability equations is written that describes the final storage probabilities for each month in terms of initial storage probabilities and the monthly transition matrix. This system is solved to give the steady-state storage probabilities at the end of each month. By operating the program with a given set of storage capacities and draft rates, a set of risks of failure are calculated as the probability of an empty reservoir. The user can then construct plots showing storage capacity as a function of draft rate for various risks of failure.

Although the approach to obtaining storage-draft risk of failure given in this report may appear cumbersome, it is considerably more practical than the alternative. The alternative would be to state the shape of the cumulative frequency of storage curve and work backwards to obtain a storage volume. Simply stating the desired risk of failure along with inflow and outflow rates is not sufficient information to determine a unique storage volume. Also, there is no way of insuring that the resulting storage volume would be reasonable from a construction viewpoint.

PRACTICAL CONSIDERATIONS OF USING THE RESERVOIR STORAGE MODEL

Inflow Distribution To Reservoir

Five distribution types for describing total monthly inflow are available to the user within the computer program. These are normal, log-normal, Gumbel, Pearson, and log-Pearson. The user also may allow the program to select an appropriate distribution. The program uses the Riggs and Hardison (1973) criteria for selecting a distribution type. The Pearson and log-Pearson distributions have been added to the criteria to account for streamflow records with large negative skew. The criteria shown in figure 3 are based on untransformed and log-transformed flow statistics. If fewer than 25 nonzero inflow values are available for a month, the criteria restricts the users to normal and log-normal distribution types unless a regional skew coefficient is supplied with the input data. If all inflow values for a month are zero, the storage analysis reduces to a deterministic problem, and the inflow distribution is not needed.

Outflow Distribution From Reservoir

The outflow used in conventional reservoir routing (eq 3) may be varied seasonally within the computer program. Total daily outflow is computed as the sum of releases to meet downstream demand and reservoir evaporation losses. User options are available to link downstream demand to the amount of available storage. This is accomplished in the model through the functions DRY, used when storage is low, and FLOOD, used when storage is high. A wide variety of operational plans can be imagined that would determine downstream demand from the amount of available storage; therefore, the user can change these two functions to meet the particular conditions at a site. User options also are available to limit downstream demand to a specified safe release rate or a minimum flow rate regardless of the release rate computed by functions DRY and FLOOD. By using these options, multipurpose reservoir operation can be simulated. Evaporation is calculated within the model as the product of reservoir-surface area and a user-supplied evaporation rate. The surface area is determined from a user-supplied relationship of area to reservoir volume. The relationship is expressed as a table. The evaporation rate, expressed as depth of water lost per day per unit area is supplied by the user from pan measurements or an empirical technique. For reservoirs with large surface areas, evaporation can be a significant part of the outflow function and should not be ignored.

Reservoir Layering Scheme

The program treats the storage-frequency curve as a discrete function rather than a continuous one. This is accomplished by dividing the reservoir into a user-defined number of layers. Separate layers are used to describe the empty and spill states of reservoir storage. The remaining layers may be designed in either of two ways. One design is to assign an equal storage volume to each layer. The second design allows the user to define the storage volume associated with each layer. The advantage of the second design is that layers of smaller volume can be defined where greater accuracy is needed.

The number of reservoir layers that can be used in a storage analysis is limited by the amount of streamflow record that is available. The proof of this statement is given by analyzing the degrees of freedom associated with a monthly transition probability matrix. Because the parameters of this matrix are estimated for various assumed initial reservoir levels, it is sufficient to examine the degrees of freedom associated with a single column of the transition probability matrix. Equation 4 and a monthly probability-density function of inflow are used in conjunction with the streamflow record to calculate each element of the transition probability matrix. Three parameters are estimated in constructing equation 4. Depending on the distribution type that is selected, two or three parameters are estimated in constructing a

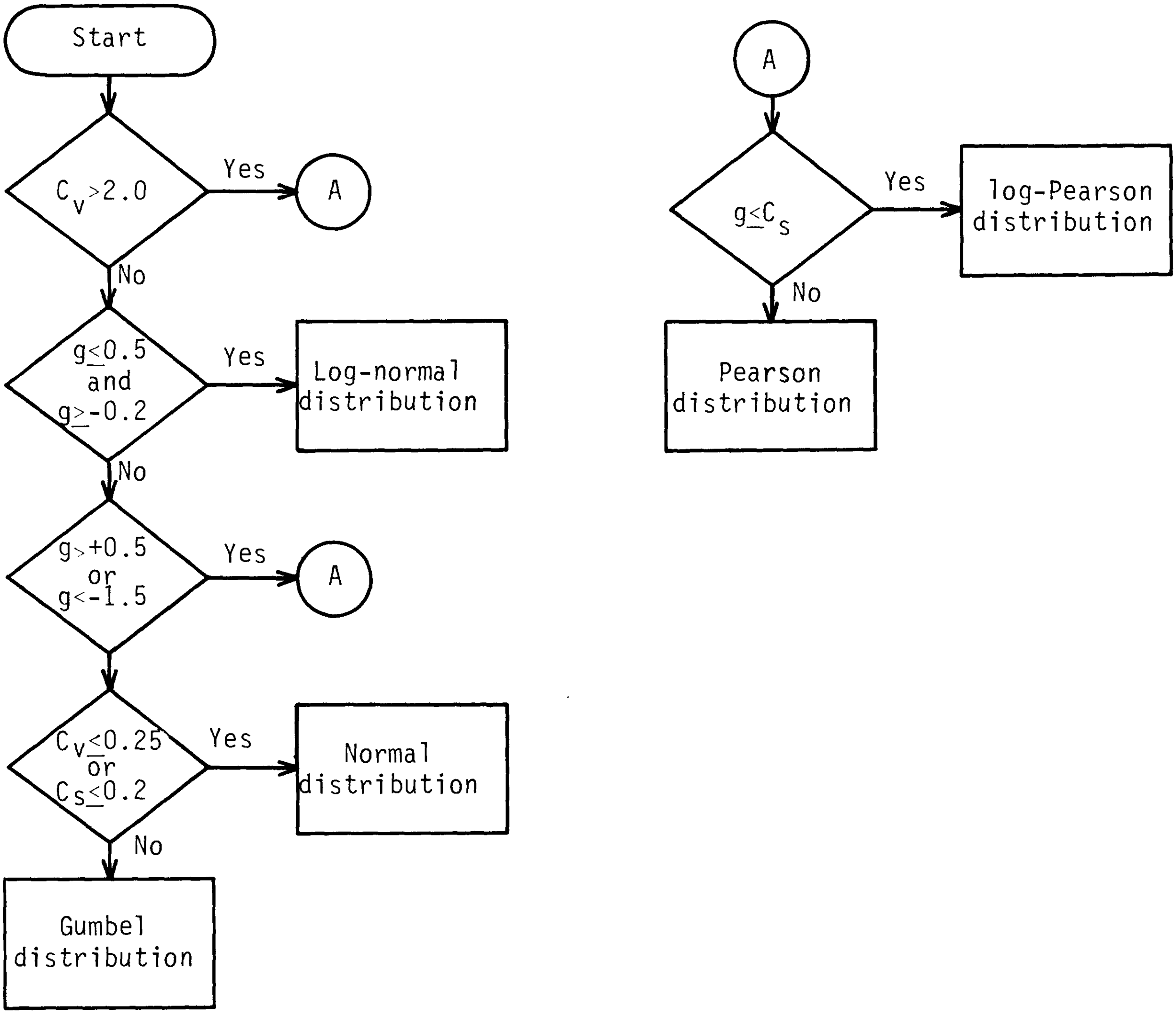

Figure 3.--Criteria for selecting type of distribution. C_v, coefficient of variation; C_s, skew coefficient; and g, skew coefficient of logs

monthly probability density function of inflow. Therefore, a total of seven or eight degrees of freedom are associated with these two equations.

If the transition probabilities are to be estimated from these equations with a minimum of confidence in the results, the number of years of streamflow record must exceed the sum of the number of layers and the degrees of freedom associated with the two equations. For example, if 25 years of data are available for a particular stream and a log-Pearson inflow distribution is used, the maximum number of reservoir layers that can be used in the storage analysis with confidence is 16. Using fewer layers for a given reservoir capacity, in accordance with the criteria of Klemes (1977), will place more degrees of freedom in the error term of the model, and the estimates of transition probabilities should be more accurate.

Discussion of Errors

Errors in a storage-frequency analysis fall into three broad categories: (1) Describing the inflow distribution, (2) describing the model input, and (3) describing the routing relationships. Errors in the model input generally are due to describing inaccurately such factors as reservoir capacity, downstream release rates, or evaporative losses. More detailed preparation of data input is required to minimize this source of error. On the other hand, errors in the routing relationship can be reduced by increasing the number of reservoir layers.

Klemes (1977) suggests that the number of layers used to divide the reservoir storage can have a serious impact on the error of the analysis. This is especially true when using a minimum number of layers with a large reservoir capacity. He presents charts giving the number of layers necessary to obtain risks of failure with an error of less than 0.1 percent for log-normal and normal inflow distributions. Generally, this degree of error is insignificant when compared to typical errors in model inputs. Unfortunately, the charts do not extend beyond a storage ratio of two times the mean annual flow.

The regression equations used to describe routing relations of initial content and final content to total monthly inflow (eq 4) may be a source of significant error. This source of error should always be checked when a user believes the model is not operating properly. The first indication of a problem is when the correlation coefficient and standard error of estimate for the regression equation drop below acceptable limits. Correlation coefficients above 0.9 and standard errors less than the difference between storage levels generally are acceptable.

A possible cause of error in equation 4 is shown in figure 4. The data shown in figure 4 plot as two horizontal patterns connected by a nearly vertical pattern. Because of its exponential form, the regression equation attempts to fit the data at the tails by sacrificing accuracy along the vertical line. Using a larger number of layers will usually eliminate this problem (Klemes, 1977).

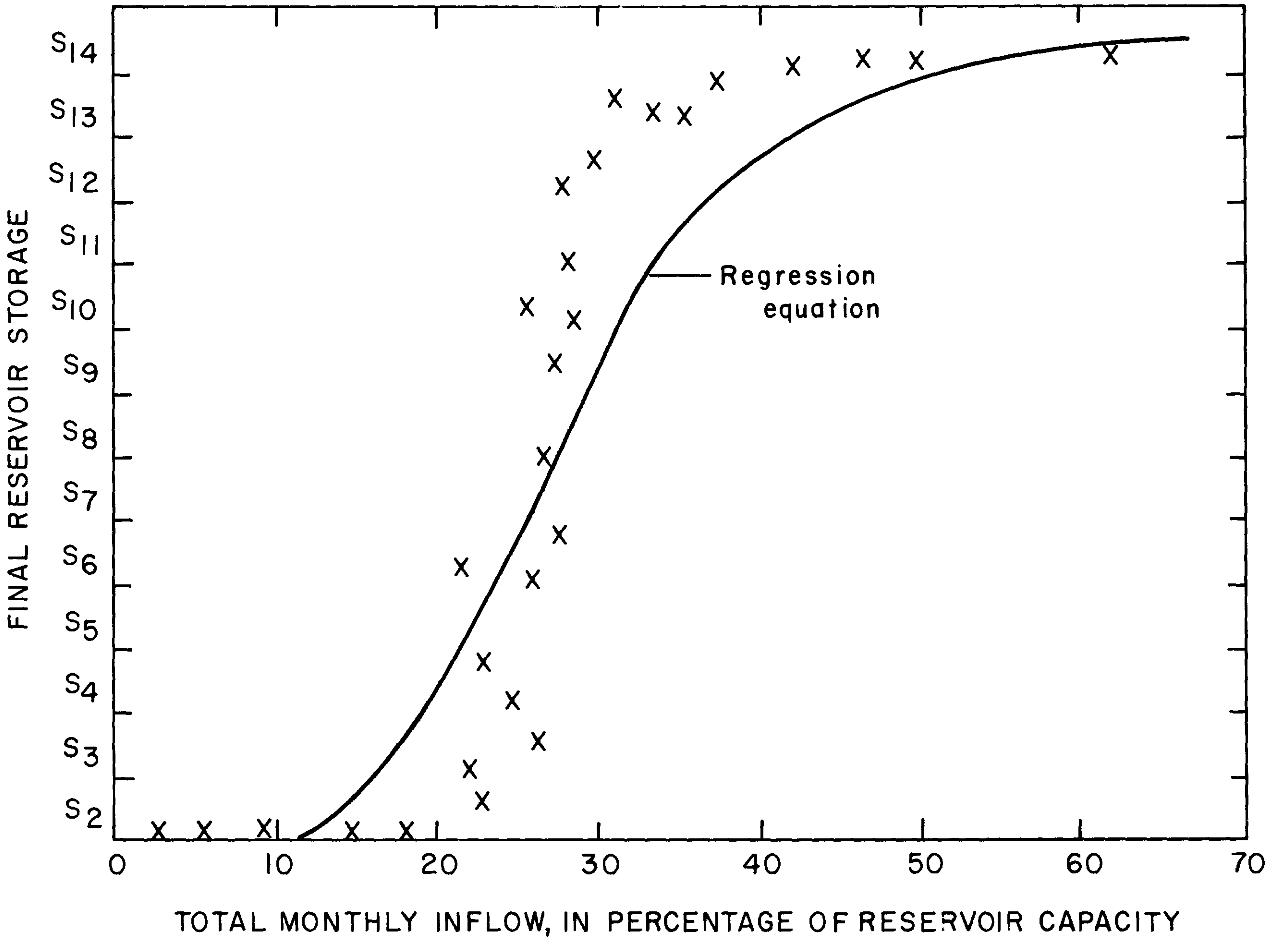

Figure 4.-Hypothetical relationship of total monthly inflow and final reservoir storage for one initial-storage level showing extreme slope of the data

SUMMARY AND CONCLUSIONS

Probability methods for determining available water supply from streamflow have met with limited success in semiarid regions. The shortcomings can be attributed to the failure of the methods to account for zero-flow periods and the high day-to-day variability of discharge of many streams. The reservoir storage model presented in this report is designed to account for these streamflow characteristics. Both reservoir inflow and outflow are modeled as varying daily, and values of storage probability are adjusted for zero-flow periods. By applying the model with a number of assumed storage capacities, the long-term water supply of a stream can be evaluated in a way that is useful to water-resource planners and designers.

A comparison of the reservoir storage model with other techniques of estimating risks of failure is not included in this report. Such an examination is outside the scope of the current study but should be undertaken before selecting a method as best for widespread application to ephemeral streams. One approach that might be taken in such a study would be to construct a long-term synthetic discharge record, using autoregressive techniques, for a variety of streams throughout the semiarid regions of the United States. The records could be be routed through hypothetical reservoirs of assumed properties, and the resultant risks of failure could be determined. The probability routing model then could be used to analyze the historic streamflow records for risks of failure and compared to the synthetic hydrograph results. The ability of the probability model to reproduce results of a mass curve or similar analysis would not be adequate verification of the model because previously used techniques have not provided satisfactory results for most ephemeral streams.

Until a comparison of methods is undertaken, the probability model should be used with care. The model can, however, be expected to give more accurate results than the probability routing model of Riggs and Hardison (1973) because of the ability to account for day-to-day fluctuations in stream inflow and no-flow periods.

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ATTACHMENT A - PROGRAM DESCRIPTION

Main Program

The main program is used to control the sequence of computations by calling the appropriate subroutines. A generalized flow chart of the main program is shown in figure 5.

Subroutine DATAIN

This subroutine is called to read data and contains two entry points, DATA1 and DATA2. The first entry point reads streamflow record from data set 1 and stores the information in a direct-access data file for later use by the program. The streamflow record is used in computing inflow-distribution parameters and during conventional flow routing. Because the program generally is run with several different storage capacities and outflow options, the inflow-data set is accessed repeatedly. Placing the inflow data in a direct-access file reduces access time and computer costs significantly. The program reads inflow data from data set 1 in the monthly character format as described by Hutchison (1975). This format, which is compatible with the U.S. Geological Survey WATSTORE system, is given in table 1.

The outflow data and options are read by entry DATA2. Instructions for the preparation of these data are given in Attachment B. Data may be input in any consistent set of units. For example, if the inflow record is read in cubic feet per second-day, then all outflow rates and storage variables must also be read in cubic feet per second-day.

Subroutine MOMENT

The method of moments is used to estimate monthly inflow-distribution parameters. Subroutine MOMENTS computes the required moments as well as other monthly statistics. If a log-transformed distribution is requested, all statistics are based on logarithms of monthly inflow. Statistics are computed on the basis of all nonzero flow values. The statistics printed for each month are requested distribution type, number of months of record, mean, standard deviation, skew, kurtosis, lowest nonzero monthly flow, and number of zero-flow months. This information is useful in determining if the inflow-distribution type was properly selected.

Subroutine INDIST

Five distribution types are available to the user for describing total monthly inflow. The selection of an appropriate distribution type is made through the input data. INDIST contains entry points for estimating parameters of the Gumbel and Pearson distributions. There also are entry points for evaluating the Gumbel, Pearson, or normal distributions for given values of monthly inflow. Subroutine MULLER is called by INDIST when estimating Gumbel distribution parameters. MULLER is a parabolic approximation technique used to estimate the parameter of the Gumbel distribution. Muller's method is described by Conte and deBoor (1972).

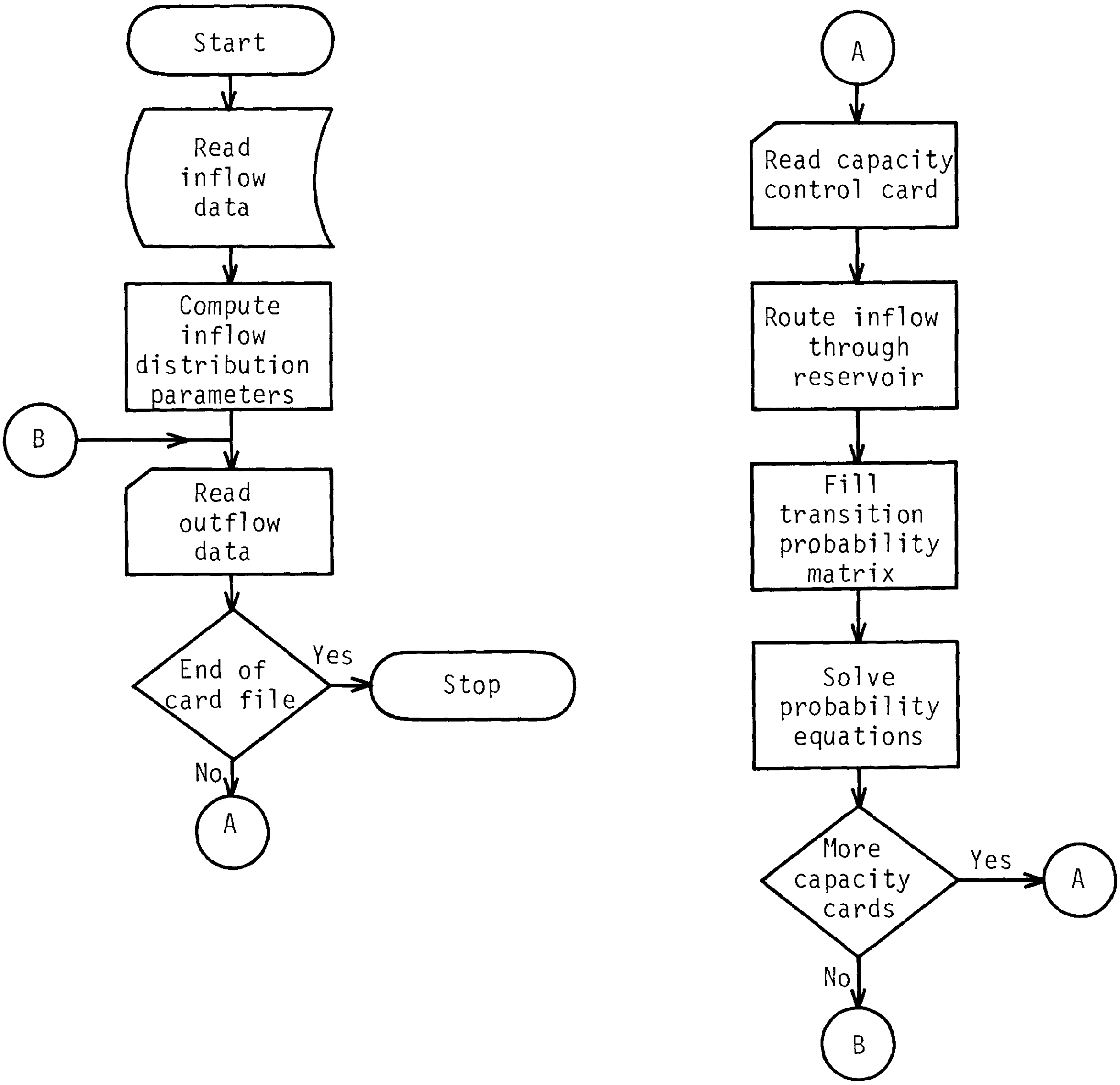

Figure 5.--Generalized flow chart of the main program

Table 1.--Format of streamflow data

Byte position	Format	Variable	Description
43-46	I4	IYR	Calendar year
47-48	I2	MO	Month number
61-277	31A7	VALUE	Array of 31 daily numbers. Decimal point is included. A blank field indicates no value is stored.

Subroutine ROUTE

This routine performs the conventional flow routing and computes the least-squares estimates of parameters in equation 4. In addition to downstream draft and reservoir-evaporation losses, ROUTE adjusts daily outflow to reflect the current storage level. If adjustment due to a high storage level is required, the FLOOD function is called. If low storage adjustments are needed DRY is called. It is important that the user change these functions to reflect conditions at a particular reservoir site.

Subroutine SETUP

This subroutine fills the transition probability matrix for each month of the water year. A monthly inflow corresponding to each change in reservoir storage is obtained by evaluating the appropriate regression equations. The cumulative probability of inflow is obtained by calling the entry point of INDIST for the appropriate inflow-distribution type. Neighboring elements in each initial content column of the resultant cumulative matrix are subtracted to give the transition probability matrix.

Subroutine SOLVE

The storage-frequency distributions are obtained by this subroutine. Uniform estimates of the initial storage probabilities are used to begin the procedure. Solutions are obtained sequentially for month-ending storage probabilities until the change in monthly storage probabilities from year to year is within a user-supplied error tolerance. Convergence of this iterative procedure is usually rapid. Results are printed after convergence is obtained.

Recommended Job-Control Language

The program uses five data sets for input and output. The use of each is described in table 2.

The following job-control language may be used when running the program on the U.S. Geological Survey computer system in Reston, Va. The program in this example is assumed to have been compiled with the load module stored on SYS1.LOADLIB. Daily inflow data are stored on nine-track magnetic tape.

```
// JOB card
/*SETUP    tape#/9
// EXEC FORTRUN,PROG=xxxx,REGION=282K
//FT01F001 DD DSN=name,DISP=(OLD,KEEP),
// UNIT=2400,VOL=SER=tape#,
// LABEL=(1,SL,,IN,RETPD=30),
// SPACE=(CYL,(10,1),RLSE),
// DCB=(RECFM=FB,LRECL=408,BLKSIZE=8160)
//FT09F001 DD DSN=&&WORK,DISP=(,DELETE),
// UNIT=SYSDK,SPACE=(TRK,(1,1),
// DCB=(RECFM=F,LRECL=217,BLKSIZE=217)
//SYSIN DD *
  Data Deck
/*
```

Table 2.--Data sets used by the computer program

Data set	Record length	Description
1	408	Daily inflow data
2	316	Direct-access data set for temporary storage of the daily inflow data
5	80	Input data described in Appendix B
6	133	Output file
9	217	Direct-access work file

ATTACHMENT B - DATA DECK INSTRUCTIONS

Type I: Title and Inflow Distribution Options

This group of cards is read once per program run.

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1	1-80	20A4	TITLE	Any title the user wishes to print
2	1-2	I1,1X	INDIST(1)	Inflow-distribution type for January; =0 if letting the program select a distribution type, =1 if normal, =2 if log-normal, =3 if Gumbel, =4 if Pearson, =5 if log-Pearson
	3-4	I2	INDIST(2)	Inflow-distribution type for February.
	5-6	I2	INDIST(3)	Inflow-distribution type for March.
	7-8	I2	INDIST(4)	Inflow-distribution type for April.
	9-10	I1,1X	INDIST(5)	Inflow-distribution type for May.
	11-12	I1,1X	INDIST(6)	Inflow-distribution type for June.
	13-14	I2	INDIST(7)	Inflow-distribution type for July.
	15-16	I2	INDIST(8)	Inflow-distribution type for August.
	17-18	I2	INDIST(9)	Inflow-distribution type for September.
	19-20	I1,1X	INDIST(10)	Inflow-distribution type for October.
	21-22	I2	INDIST(11)	Inflow-distribution type for November.
	23-24	I2	INDIST(12)	Inflow-distribution type for December.

Type II: Outflow Data

This group of cards is used to read reservoir draft rates, evaporation rates, upper and lower storage limits for normal reservoir releases, and maximum draft rate for safe releases. Each type II data set is preceded by an outflow-control card and function coefficients card. As many type II data sets as required by the user may be coded in a single program run. Each type II data set is separated by type III cards. Outflow must be coded in the same units as the inflow data. The outflow-control card is described below.

COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1-10	G10.0	CDRAFT	Constant draft used throughout the year. If blank an array of daily draft rates will be read.
11-20	G10.0	CET	Constant evaporation rate used throughout the year. If blank, an array of daily evaporation rates will be read. If negative, evaporation will not be considered.
21-30	G10.0	CUPSTOR	Constant upper storage limit. Above this value, reservoir draft will be determined by the FLOOD function. If blank, an array of daily upper limits will be read. If negative, the upper storage limit will not be considered.
31-40	G10.0	CLOSTOR	Constant lower storage limit. Below this value, reservoir draft will be determined by the DRY

COLUMNS	FORMAT	VARIABLE	DESCRIPTION
			function. If blank, an array of daily lower limits will be read. If negative, the lower limit will not be considered.
41-50	G10.0	CUPDFT	Constant maximum draft rate for safe release. Reservoir releases above this value will not be allowed unless reservoir storage is at capacity. If blank, an array of daily draft rates for safe release will be read. If negative, the option will not be used. This option generally is used in conjunction with the CUPSTOR option.
51-60	I10	MAXCAP	Number of type III cards used with this type II data set. One probability routing will be done for each type III card.

The function coefficients card is required with every type II data set, even if the upper and lower storage limit options are not used. The description of this card is given below.

COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1-10	G10.0	A	Coefficients that are passed to function DRY.
11-20	G10.0	B	
21-30	G10.0	C	Coefficients that are passed to function FLOOD.
31-40	G10.0	D	

The user is encouraged to define the DRY and FLOOD functions according to site-specific criteria. For this reason, no physical significance is attached to the function coefficients in this documentation. The program listing in Attachment D does not use these coefficients. The functions DRY and FLOOD simply return the value of downstream demand given to them.

If evaporation is to be considered, the program will attempt to read entries for an area-volume table. This is accomplished by first reading an integer in columns 1 to 10 of a new card into variable NAV. This variable indicates the number of area-volume entries that will be read. One hundred or fewer entries may be read. If NAV is less than or equal to 1, no area-volume entries will be read. Values of area and volume are read one pair per card, using the following format:

COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1-10	G-10.0	area	Surface area of reservoir
11-20	G-10.0	volume	Volume of reservoir storage

These cards must be arranged from smallest to largest reservoir volume, and the first card must correspond to zero storage.

If any of the variables on the outflow-control card except MAXCAP are left blank, the program will attempt to read an array of 366 daily values for the appropriate option. Each array is coded with eight values per card in an 8G10.0 format, beginning with January 1. Coded in this manner, one array is contained on 46 cards. If an array is not needed, there is no need to include 46 blank cards in the input stream. When included, the order of array data is given below.

ARRAY	DESCRIPTION
DRAFT	Daily draft rates
ET	Daily evaporation rates
UPSTOR	Daily upper limit for normal release
LOSTOR	Daily lower limit for normal release
SAFDFT	Daily maximum draft rate for safe releases

Type III: Reservoir-Storage Data

The number of type III data sets that follow each set of type II data is determined by MAXCAP on the outflow-control card. The probability-routing procedure is repeated for each type III data set. Storage capacity must be coded in the same units as the inflow data. The description of the first type III card is given below.

COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1-10	F10.0	CAPAC	Reservoir storage capacity
11-20	I10	NSTATE	Number of storage layers. A maximum of 50 layers can be defined.
21-30	I10	ITMAX	Maximum number of iterations allowed to solve the probability equations.
31-40	F10.0	PTOL	Error criteria for closure. Used in iterative solution to probability quations.
41-50	I10	IDATA	Code "1" to obtain an extended printout of the least-squares analysis.
51-60	I10	ISPDF	Code "1" to obtain a tabulation of the number of days when reservoir draft could not be met or when reservoir spillage occured during conventional reservoir routing.

If NSTATE is 0, 1, or 2, an additional set of cards is included. These cards indicate the volumes of user-defined storage layers. The volumes are expressed as a percentage of reservoir capacity. The first and last layers correspond to empty and spill states and must be coded as 0.0 and 1.0. The description of the additional cards is given below.

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1	1-3	I3	NSTATE	Number of storage layers that will be read.
2	1-8	F8.3	SI(1)	Storage layers to be used in the analysis, expressed as a percentage of reservoir capacity. Ten layers are coded per card. Cards are read in this format until NSTATE layers have been read.
	9-16	F8.3	SI(2)	
	17-24	F8.3	SI(3)	
	25-32	F8.3	SI(4)	
	33-40	F8.3	SI(5)	
	41-48	F8.3	SI(6)	
	49-56	F8.3	SI(7)	
	57-64	F8.3	SI(8)	
	65-72	F8.3	SI(9)	
	73-80	F8.3	SI(10)	

ATTACHMENT C - EXAMPLE PROBLEM

This example demonstrates the use of the reservoir storage program to estimate the risks of failure to supply a specified outflow for three storage capacities. The discharge record used as inflow is from the U.S. Geological Survey streamflow-gaging station 06386500, Cheyenne River near Riverview, Wyo., for the period 1948-74. All analyses use a constant outflow of 40.8 cubic feet per second. The storage capacities and number of reservoir layers used are given in table 3.

Line printer output from the program includes a summary of inflow data, a summary of the least-squares analysis used in conventional flow routing for each month, the transition probability matrix for each month, and the cumulative frequence of storage at the end of each month. Examples of these outputs are given in tables 4-7.

The risks of failure to supply a constant outflow of 40.8 cubic feet per second with a storage capacity of 10,710 acre-feet can be read directly from table 7 as the probability of 0.0 storage. This information along with the risks of failure with storage capacities of 42,140 acre-feet, 84,280 acre-feet, and 126,420 acre-feet are plotted in figure 6. As would be expected, increasing the storage capacity decreases the risk of failure. However, the most noticeable feature of the graph are the extremely high risks of failure during the winter months for even the largest storage capacity. The high risks illustrate why reservoirs in semiarid regions must be designed with storage capacities several times larger than the mean annual inflow. High risks of failure are particularly common when downstream demand is held constant. If demand were assumed to decrease during winter months, the risks of failure during this period also probably would decrease. The risks of failure show some oscillatory behavior during the months of July to October. This may be caused by numerical dispersion as a result of using too few reservoir layers. A more thorough analysis of this discharge record would include increasing the number of reservoir layers as suggested by Klemes (1977). The analysis could also be refined by using an autoregressive technique to generate a longer period of streamflow record. These refinements are considered to be outside the scope of the current study.

The analysis presented in this example problem should not be considered complete. The end result of an analysis should be a graph showing storage capacity as a function of draft rate for various risks of failure. To accomplish this, the computer program must be run with several additional draft rates and storage capacities. The resulting risks of failure could then be used to produce a set of graphs for critical periods throughout the water year.

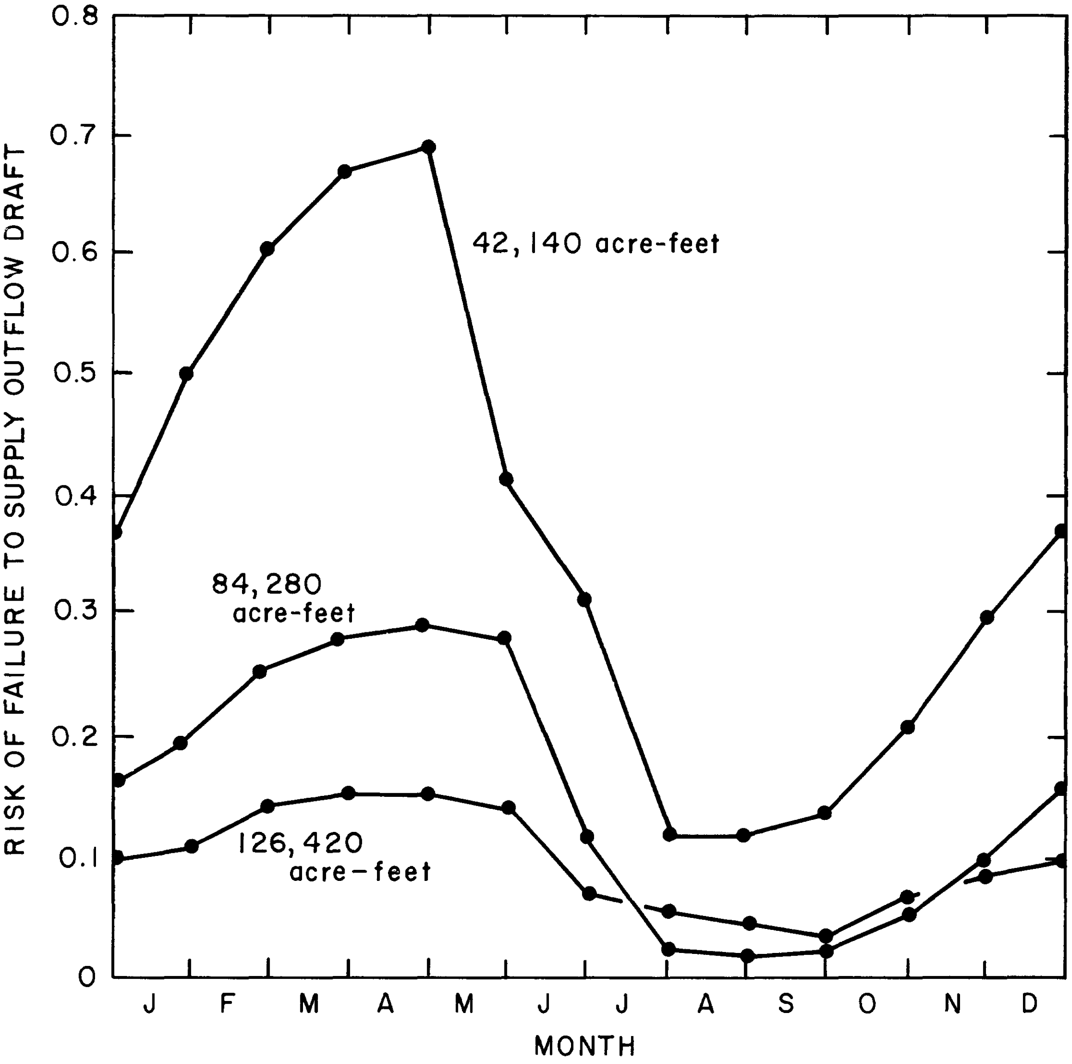

Figure 6.-Risks of failure to supply outflow draft during the year at Cheyenne River near Riverview, Wyo., for three storage capacities and a constant draft of 40.8 cubic feet per second

Table 3.--Storage capacities and number of reservoir layers used in the example problem

Storage capacity		
Acre-feet	Ratio to mean annual inflow	Reservoir layers of equal volume
42,140	1.0	12
84,280	2.0	22
126,420	3.0	32

Table 4.--Summary of inflow data for example problem

[INFLOW DATA: FOR STATION NUMBER 06386500; INFLOW RECORD: 312 MONTHS, 1948-74; DISTRIBUTION: 1, NORMAL; 2, LOG-NORMAL; 3, GUMBEL; 4, PEARSON; 5, LOG-PEARSON]

	STATISTICS OF TOTAL-MONTHLY FLOW FOR MONTHS THAT HAD FLOW											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
MONTH NUMBER	1	2	3	4	5	6	7	8	9	10	11	12
DISTRIBUTION	1	1	1	1	5	3	3	1	1	1	1	1
NUMBER OF MONTHS	26.0	26.0	26.0	26.0	*26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
MEAN (CFS-DAYS)	558.	.106E+04	676.	.120E+04	*2.99	.722E+04	.377E+04	.175E+04	.153E+04	201.	95.2	50.5
STANDARD DEVIATION (CFS-DAYS)	.116E+04	.116E+04	842.	.320E+04	*4.62	.859E+04	.550E+04	.273E+04	.287E+04	332.	204.	68.8
SKEW	2.23	.865	1.53	4.23	*1.32	2.17	2.07	3.08	2.14	1.54	2.77	1.95
KURTOSIS	4.98	-.231	1.04	18.8	*-1.35	5.76	3.86	11.4	3.44	.949	7.75	4.04
LOW NON-ZERO FLOW (CFS-DAYS)	1.50	19.4	1.40	.300	*.447	20.1	38.2	4.50	1.40	.900	1.00	1.00
NUMBER OF ZERO-FLOW MONTHS	21.0	14.0	6.00	4.00	1.00	1.00	.0	2.00	11.0	16.0	18.0	20.0

* LOG_{10} UNITS

Table 5.--Output for least squares analysis during July in example problem

[REGRESSION EQUATION: LOG (1-END OF MONTH STORAGE/CAPACITY) = LOG(BO)+B1*T**B2; UNIT OF EQUATION IS DIMENSIONLESS; CFS-DAYS, CUBIC FOOT PER SECOND × DAY]

INITIAL STORAGE (CFS-DAYS)	CORRELATION COEFFICIENT (DIMENSIONLESS)	ESTIMATED INFLOW (CFS-DAYS)	STANDARD ERROR STORAGE (CFS-DAYS)	LOG(BO) (DIMENSIONLESS)	B1 (1/CFS-DAYS)	B2 (DIMENSIONLESS)	LOW LIMIT (CFS-DAYS)	HIGH LIMIT (CFS-DAYS)
0.	0.997	6132.	0.	-.432935E+12	-.355133E+13	3	2438.	2438.
1062.	.991	8927.	0.	-.609937E+16	-.500282E+17	4	2438.	2438.
3186.	.994	2717.	0.	-.204688E+08	-.141586E+09	2	2860.	2862.
5311.	.989	7074.	0.	-.626823E+16	-.196627E+17	4	5799.	5799.
7435.	.994	2072.	0.	-.338316E+08	-.853618E+08	2	6951.	6953.
9559.	.984	1848.	0.	-.358012E+08	-.649088E+08	2	9006.	9008.
11684.	.996	1312.	0.	-.317101E+08	-.436113E+08	2	10976.	10979.
13808.	.994	191.	0.	-.511834E+04	-.593268E+04	1	12336.	17579.
15932.	.996	890.	0.	-.220305E+08	-.178696E+08	2	15052.	15054.
18057.	.793	2767.	1.	-.129168E+11	-.121651E+11	3	13897.	13897.
20181.	.826	934.	2.	-.390283E+03	-.482571E+03	1	12501.	21243.
21243.	.787	1022.	2.	-.707801E+03	-.499486E+03	1	16473.	21243.

Table 6.--Transition matrix for January in example problem

[CFS-DAYS, CUBIC FOOT PER SECOND × DAY]

INITIAL STORAGE (CFS-DAYS)	FINAL STORAGE (CFS-DAYS)											
	0.	1062.	3186.	5311.	7435.	9559.	11684.	13808.	15932.	18057.	20181.	21243.
0.	1.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1062.	1.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3186.	0.0	0.8801	0.1073	0.0126	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5311.	0.0	0.0	0.8800	0.1073	0.0127	0.0000	0.0	0.0	0.0	0.0	0.0	0.0
7435.	0.0	0.0	0.0	0.8799	0.1073	0.0128	0.0000	0.0	0.0	0.0	0.0	0.0
9559.	0.0	0.0	0.0	0.0	0.8797	0.1074	0.0129	0.0000	0.0	0.0	0.0	0.0
11684.	0.0	0.0	0.0	0.0	0.0	0.8795	0.1074	0.0131	0.0000	0.0	0.0	0.0
13808.	0.0	0.0	0.0	0.0	0.0	0.0	0.8792	0.1075	0.0134	0.0	0.0	0.0
15932.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8786	0.1075	0.0139	0.0	0.0
18057.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8774	0.1070	0.0156	0.0
20181.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8846	0.1111	0.0043
21243.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9959	0.0041

Table 7.--Frequency of indicated storage or less for example problem with a capacity of 10,170 acre-feet

[CFS-DAYS, CUBIC FOOT PER SECOND × DAY]

STORAGE (CFS-DAYS)	PROBABILITY DURING MONTH NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
0.0	0.7160	0.8208	0.8661	0.8380	0.7856	0.3141	0.1550	0.2386	0.1144	0.2939	0.4363	0.5842
.106E+04	.8208	.8889	.9161	.9263	.8081	.8506	.8532	.2386	.4056	.4363	.5842	.7160
.319E+04	.8982	.9370	.9526	.9609	.9075	.8838	.8842	.8842	.5737	.6037	.7232	.8214
.531E+04	.9434	.9657	.9750	.9806	.9625	.8888	.9066	.9066	.7464	.7517	.8342	.8985
.744E+04	.9694	.9828	.9889	.9919	.9840	.9112	.9320	.9320	.8749	.8539	.9069	.9436
.956E+04	.9850	.9939	.9963	.9974	.9950	.9320	.9598	.9598	.9411	.9196	.9484	.9694
.117E+05	.9954	.9987	.9991	.9994	.9987	.9773	.9746	.9758	.9643	.9553	.9722	.9850
.138E+05	.9993	.9998	.9998	.9999	.9997	.9999	.9771	.9765	.9751	.9763	.9867	.9954
.159E+05	1.0000	1.0000	1.0000	1.0000	.9999	1.0000	.9807	.9873	.9830	.9881	.9959	.9993
.181E+05	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.9873	.9944	.9910	.9978	.9995	1.0000
.202E+05	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
SPILL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

ATTACHMENT D - PROGRAM LISTING

```
      COMMON P(50,50,12),B0(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM,LOFLO,NOFLO,AREAG,LOQ
C
      DEFINE FILE 2 (1200,316,E,IR)
      DEFINE FILE 9 (1,217,E,JR)
C
C     READ INFLOW DATA AND COMPUTE INFLOW DISTRIBUTIONS
C
      CALL DATA1
C
C     CHECK INDIST FOR 0 VALUES
C
      DO 300 I=1,12
      IF (INDIST(MO).LE.0) GO TO 301
300   CONTINUE
      GO TO 203
C
C     INITIALIZE AND READ INFLOW DATA. COMPUTE SUMMATIONS.
C
301   IR=1
      DO 302 I=1,12
      N(I)=0.0
      M1(I)=0.0
      M2(I)=0.0
      G1(I)=0.0
      C1(I)=0.0
      C2(I)=0.0
      C3(I)=0.0
302   CONTINUE
303   IF (IR.GT.IRMAX) GO TO 305
      READ (2'IR,30) IYR,MO,INFLOW
30    FORMAT (I4,I2,31G10.3)
      IF (MO.LE.0.OR.MO.GT.12) GO TO 303
      SUM=0.0
      DO 304 I=1,31
      IF (INFLOW(I).LT.0.0) GO TO 308
      SUM=SUM+INFLOW(I)
304   CONTINUE
308   IF (SUM.LE.0.0) GO TO 303
      N(MO)=N(MO)+1.0
      SUML=ALOG10(SUM)
      M1(MO)=M1(MO)+SUM
      M2(MO)=M2(MO)+SUM*SUM
      G1(MO)=G1(MO)+SUM**3
      C1(MO)=C1(MO)+SUML
      C2(MO)=C2(MO)+SUML*SUML
```

```
      C3(MO)=C3(MO)+SUML**3
      GO TO 303
C
C     COMPUTE STATISTICS FOR CRITERIA
C
305   DO 311 I=1,12
      IF (INDIST(I).GT.0) GO TO 311
      OBS=N(I)
      IF (OBS.GT.2.0) GO TO 312
      INDIST(I)=1
      GO TO 311
312   G1(I)=OBS*OBS*G1(I)-3.0*OBS*M1(I)*M2(I)+2.0*M1(I)**3
      C3(I)=OBS*OBS*C3(I)-3.0*OBS*C1(I)*C2(I)+2.0*C1(I)**3
      M2(I)=SQRT(ABS((M2(I)-M1(I)**2/OBS)/(OBS-1.0)))
      C2(I)=SQRT(ABS((C2(I)-C1(I)**2/OBS)/(OBS-1.0)))
      M1(I)=M1(I)/OBS
      G1(I)=G1(I)/(OBS*(OBS-1.0)*(OBS-2.0)*M2(I)**3)
      C3(I)=C3(I)/(OBS*(OBS-1.0)*(OBS-2.0)*C2(I)**3)
C
C     DISTRIBUTION CRITERIA
C
      IF (OBS.GE.25.0) GO TO 313
      INDIST(I)=1
      GO TO 311
313   CV=M2(I)/M1(I)
      IF (CV.GT.2.0) GO TO 307
      IF (C3(I).GT.0.5.OR.C3(I).LT.-0.2) GO TO 306
      INDIST(I)=2
      GO TO 311
306   IF (C3(I).GT.-0.2.OR.C3(I).LT.-1.5) GO TO 307
      INDIST(I)=3
      IF (CV.LE.0.25.OR.G1(I).LE.0.2) INDIST(I)=1
      GO TO 311
307   INDIST(I)=4
      IF (ABS(C3(I)).LT.ABS(G1(I))) INDIST(I)=5
311   CONTINUE
203   CALL MOMENT
      DO 100 MO=1,12
      K=INDIST(MO)
      GO TO (100,100,200,201,201),K
200   CALL GUMEST
      IF (C1(MO).GT.0.0) GO TO 202
      WRITE (6,22) MO
22    FORMAT ('0INFLOW DISTRIBUTION TYPE FOR MONTH NUMBER ',I2,' CHANGED
     $ TO NORMAL'/6X,'PARAMETER ESTIMATES FOR GUMBEL DISTRIBUTION ARE ',
     $'UNREALISTIC')
      INDIST(MO)=1
      GO TO 100
201   CALL PEREST
202   WRITE (6,20) MO,C1(MO),C2(MO),C3(MO)
20    FORMAT ('0INFLOW DISTRIBUTION PARAMETERS FOR MONTH NUMBER ',I2,
     $' --- C1=',G10.3,', C2=',G10.3,', C3=',G10.3)
      IF (INDIST(MO).LE.3) GO TO 100
      IF (C3(MO).LE.56.0) GO TO 100
```

```
      IF (INDIST(MO).EQ.4) INDIST(MO)=1
      IF (INDIST(MO).EQ.5) INDIST(MO)=2
      WRITE (6,21) MO
21    FORMAT ('0INFLOW DISTRIBUTION TYPE FOR MONTH # ',I2,' CHANGED TO N
     $ORMAL OR LOG NORMAL'/6X,'PARAMETER ESTIMATES FOR PEARSON OR LOG-PE
     $ARSON DISTRIBUTION ARE UNREALISTIC')
100   CONTINUE
C
C     READ OUTFLOW DATA
C
103   CALL DATA2
      ICAP=1
C
C     READ PROBLEM CONTROL CARD
C
C     CAPAC=CAPACITY     NSTATE=# OF LAYERS     ITMAX=MAXIMUM # OF ITERATIONS
C     TO BE ALLOWED IN SOLVING THE PROBABILITY EQUATIONS     PTOL=ERROR
C     TOLERANCE ON PROBABILITIES
C
101   READ (5,10,END=999) CAPAC,NSTATE,ITMAX,PTOL,IDATA,ISPDF
10    FORMAT (F10.0,7X,I3,6X,I4,F10.0,8X,I2,8X,I2)
      WRITE (6,11) CAPAC,NSTATE,ITMAX,PTOL
11    FORMAT ('1***** CONTROL CARD PARAMETERS FOR THIS PROBLEM ****'/
     $        '0CAPACITY = ',F10.0/' # OF LAYERS = ',I3/' ITMAX = ',I4/
     $        ' PTOL = ',F10.5//)
C
C     DETERMINE INITIAL AND FINAL STORAGE VECTORS
C
      IF (NSTATE.GE.3) GO TO 498
      IF (NSTATE.LE.-3) GO TO 400
      READ (5,12) NSTATE,(SI(I),I=1,NSTATE)
12    FORMAT (I3/10F8.3)
      DO 404 I=1,NSTATE
      SI(I)=SI(I)*CAPAC
404   CONTINUE
      NM1=NSTATE-1
      NM2=NM1-1
      SF(1)=SI(1)
      SF(NM1)=SI(NSTATE)
      DO 401 I=2,NM2
      J=I+1
      SF(I)=(SI(I)+SI(J))/2.0
401   CONTINUE
400   NSTATE=IABS(NSTATE)
      ND2=(NSTATE-2)/2
      TMP=ALOG(CAPAC/2.0)/FLOAT(ND2)
      NM1=NSTATE-1
      SF(1)=0.0
      SF(NM1)=CAPAC
      SI(1)=0.0
      SI(NSTATE)=CAPAC
      DO 402 I=1,ND2
      DIST=EXP(TMP*FLOAT(I))
      IP1=I+1
```

```
      SF(IP1)=DIST
      J=NM1-I
      SF(J)=CAPAC-DIST
402   CONTINUE
      DO 403 I=2,NM1
      SI(I)=(SF(I)+SF(I-1))/2.0
403   CONTINUE
      GO TO 499
498   SI(1)=0.0
      SF(1)=0.0
      NM1=NSTATE-1
      DO 102 I=2,NM1
      SF(I)=FLOAT(I-1)*CAPAC/FLOAT(NSTATE-2)
      SI(I)=(SF(I)+SF(I-1))/2.0
102   CONTINUE
      SI(NSTATE)=CAPAC
C
C     ROUTE FLOW THROUGH THE RESERVOIR,SETUP PROBABILITY EQUATIONS AND
C     SOLVE THEM.
C
499   CALL ROUTE(IDATA,ISPDF)
      CALL SETUP
      CALL SOLVE
      ICAP=ICAP+1
      IF (ICAP.LE.MAXCAP) GO TO 101
      GO TO 103
999   STOP
      END
      SUBROUTINE DATAIN
C
      COMMON P(50,50,12),B0(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM,LOFLO,NOFLO,AREAG,LOQ
C
      DOUBLE PRECISION VALUE(31),BLANK,FILL
      INTEGER LIST(12),TITLE(20),ID(4)
C
      DATA FILL/'-99999.'/,LIST/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA BLANK/'        '/
C
      ENTRY DATA1
C
C
C     READ DAILY VALUES OF INFLOW IN MONTHLY FORMAT (UNIT 1). INTERPOLATE
C     MISSING VALUES AND STORE ON RANDOM ACCESS FILE (UNIT 2)
C
      IR=1
      READ (1,30) ID,IYR,MO,(VALUE(I),I=1,31)
      IYR1=IYR
```

```
      GO TO 200
 30   FORMAT (8X,3A4,A3,19X,I4,I2,12X,31A7)
100   READ(1,10,END=120) IYR,MO,(VALUE(I),I=1,31)
10    FORMAT (42X,I4,I2,12X,31A7)
C
C
200   DO 101 I=1,31
      IF (VALUE(I).EQ.BLANK) VALUE(I)=FILL
101   CONTINUE
C
C     CONVERT VALUE FROM AN ALPHA FIELD TO A NUMERIC FIELD
C
      WRITE (9'1,11) (VALUE(I),I=1,31)
      READ (9'1,12) (INFLOW(I),I=1,31)
11    FORMAT (31A7)
12    FORMAT (31F7.0)
C
C     INTERPOLATE
C
      DO 103 K=1,31
      IF (INFLOW(K).LT.0.0) GO TO 103
      DO 102 J=1,K
      INFLOW(J)=INFLOW(K)
102   CONTINUE
      J=K
      I=K
      GO TO 105
103   CONTINUE
C
C     NO FLOW MEASURED DURING THE MONTH.
C
      GO TO 100
C
105   J=J+1
      IF (J.GT.LIST(MO)) GO TO 107
      IF (INFLOW(J).LT.0.0) GO TO 105
      DO 106 K=I,J
      INFLOW(K)=INFLOW(I)+(INFLOW(J)-INFLOW(I))*FLOAT(K-I)/FLOAT(J-I)
106   CONTINUE
      I=J
      GO TO 105
C
C     FINISH UP THE MONTH
C
107   IF (MO.EQ.2.AND.MOD(IYR,4).EQ.0) GO TO 104
      J=LIST(MO)
      GO TO 109
104   IF (J.EQ.29) GO TO 105
      J=29
109   DO 108 K=I,J
      INFLOW(K)=INFLOW(I)
108   CONTINUE
C
C     WRITE MONTHS INFLOW TO RANDOM FILE
```

```
C
      IRMAX=IR
      WRITE (2'IR,13) IYR,MO,INFLOW
13    FORMAT (I4,I2,31G10.3)
      GO TO 100
C
C     READ THE TITLE CARD AND MONTHLY INFLOW DISTRIBUTION CARDS
C
120   READ (5,14) TITLE
14    FORMAT (20A4)
C
C     A DIFFERENT INFLOW DISTRIBUTION TYPE IS ALLOWED FOR EACH MONTH.
C     1=NORMAL     2=LOG-NORMAL     3=GUMBEL TYPE III (WEIBULL)
C     4=PEARSON TYPE III     5=LOG-PEARSON TYPE III
C     0 OR BLANK = PROGRAM WILL SELECT THE APPROPRIATE DISTRIBUTION
C
C
      READ (5,15) (INDIST(I),I=1,12)
15    FORMAT (12I2)
C
      WRITE (6,17) TITLE,ID
17    FORMAT ('1',26X,20A4/'0',42X,'INFLOW DATA FOR STATION NUMBER ',
     $        3A4,A3/)
      WRITE (6,18) IRMAX,IYR1,IYR
18    FORMAT ('0',44X,I4,' MONTHS OF INFLOW RECORD, ',I4,' TO ',I4//)
      RETURN
C
      ENTRY DATA2
C
C     READ OUTFLOW CONTROL CARD,DAILY DRAFT RATE,DAILY ET RATE,UPPER
C     AND LOWER STORAGE LIMITS,AND SAFE DRAFT. ARRAYS ARE ENTERED BY
C     CALENDAR YEAR.
C
C     OUTFLOW CONTROL CARD:

C     CDRAFT=CONSTANT DRAFT (IF BLANK, DAILY DRAFT RATES ARE READ)
C     CET=CONSTANT ET RATE (IF BLANK,---;IF NEGATIVE ET IS NOT USED)
C     CUPSTR=CONSTANT UPPER STORAGE LIMIT FOR NORMAL RELEASES (IF BLANK
C            OR NEGATIVE,---)
C     CLOSTR=CONSTANT LOWER STORAGE LIMIT FOR NORMAL RELEASES(IF BLANK
C            OR NEGATIVE,---)
C     CUPDFT=CONSTANT UPPER FLOW LIMIT FOR SAFE RELEASES (IF BLANK
C            OR NEGATIVE,---)
C
      WRITE (6,31)
31    FORMAT ('***** NEW SET OF OUTFLOW DATA *****')
      READ (5,16,END=999) CDRAFT,CET,CUPSTR,CLOSTR,CUPDFT,MAXCAP
16    FORMAT (8G10.0)
C
C     COEFFICIENTS FOR FLOOD AND DRY FUNCTIONS. A AND B ARE PASSED
C     TO DRY. C AND D ARE PASSED TO FLOOD. IF NOT NEEDED INSERT A BLANK CARD.
C
      READ (5,16) A,B,C,D
C
```

```
C     READ AREA-VOLUME TABLE
C
      IF (CET.LT.0) GO TO 124
      READ (5,30) NAV
30    FORMAT (I10)
      IF (NAV.LE.1) GO TO 124
      READ (5,31) (AREA (K), VOLUME (K), K=1, NAV)
31    FORMAT (2G10.0)
      IF (CET.GT.0.0) GO TO 125
C
C     DAILY DRAFT ARRAY
C
124   DO 121 I=1,366
      DRAFT(I)=CDRAFT
121   CONTINUE
      IF (CDRAFT.GT.0.0) GO TO 122
      READ (5,16) DRAFT
C
C     ET ARRAY
C
122   DO 123 I=1,366
      ET(I)=0.0
      IF (CET.GT.0.0) ET(I)=CET
123   CONTINUE
      IF (CET.NE.0.0) GO TO 125
      READ (5,16) ET
C
C     UPPER STORAGE ARRAY
C
125   DO 126 I=1,366
      UPSTOR(I)=CUPSTR
126   CONTINUE
      IF (CUPSTR.NE.0.0) GO TO 127
      READ (5,16) UPSTOR
C
C     LOWER STORAGE ARRAY
C
127   DO 128 I=1,366
      LOSTOR(I)=CLOSTR
128   CONTINUE
      IF (CLOSTR.NE.0.0) GO TO 129
      READ (5,16) LOSTOR
C
C     SAFE DRAFT ARRAY
C
129   DO 130 I=1,366
      SAFDFT(I)=CUPDFT
130   CONTINUE
      IF (CUPDFT.NE.0.0) GO TO 131
      READ (5,16) SAFDFT
C
C     PRINT OUT INPUT DATA
C
131   IF (CDRAFT.NE.0.0) GO TO 132
```

```
      WRITE (6,19)
19    FORMAT ('0',52X,'NORMAL DRAFT RATES'/)
      WRITE (6,20) DRAFT
20    FORMAT (10(2X,F10.2))
      GO TO 133
132   WRITE (6,21) CDRAFT
21    FORMAT ('ONORMAL DRAFT RATE = ',F10.2)
133   IF (CET.EQ.0.0) GO TO 134
      IF (CET.LT.0.0) GO TO 135
      WRITE (6,22)
22    FORMAT ('1',53X,'EVAPORATION RATES'/)
      WRITE (6,20) ET
      GO TO 135
134   WRITE (6,23) CET
23    FORMAT ('OEVAPORATION RATE = ',F10.2)
135   IF (CUPSTR.EQ.0.0) GO TO 136
      IF (CUPSTR.LT.0.0) GO TO 137
      WRITE (6,24)
24    FORMAT ('1',40X,'UPPER STORAGE LIMIT FOR NORMAL RELEASES'/)
      WRITE (6,20) UPSTOR
      GO TO 137
136   WRITE (6,25) CUPSTR
25    FORMAT ('OUPPER STORAGE LIMIT FOR NORMAL RELEASES = ',F10.2)
137   IF (CLOSTR.EQ.0.0) GO TO 138
      IF (CLOSTR.LT.0.0) GO TO 139
      WRITE (6,26)
26    FORMAT ('1',40X,'LOWER STORAGE LIMIT FOR NORMAL RELEASES'/)
      WRITE (6,20) LOSTOR
      GO TO 139
138   WRITE (6,27) CLOSTR
27    FORMAT ('OLOWER STORAGE LIMIT FOR NORMAL RELEASES = ',F10.2)
139   IF (CUPDFT.EQ.0.0) GO TO 140
      IF (CUPDFT.LT.0.0) GO TO 141
      WRITE (6,28)
28    FORMAT ('1',47X,'UPPER LIMIT OF SAFE RELEASES'/)
      WRITE (6,20) SAFDFT
      GO TO 141
140   WRITE (6,29) CUPDFT
29    FORMAT ('OUPPER LIMIT OF SAFE RELEASES = ',F10.2)
C
141   RETURN
999   STOP
      END
      SUBROUTINE MOMENT
C
C     METHOD OF MOMENTS IS USED TO ESTIMATE PARAMETERS OF FREQUENCY
C     DISTRIBUTIONS OF MONTHLY FLOWS. TO DO THIS THE FIRST FOUR MOMENTS
C     OF MONTHLY FLOWS ARE NEEDED. IF A LOG DISTRIBUTION
C     IS USED, LOG TRANSFORM THE DATA.
C
      COMMON P(50,50,12),B0(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
```

```
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM
      REAL LOFLO,LOQ,NOFLO,HIFLO(12),M2SAV(12),G1SAV(12)
C
      DO 100 I=1,12
      N(I)=0.0
      M1(I)=0.0
      M2(I)=0.0
      G1(I)=0.0
      G2(I)=0.0
      LOFLO(I)=9999999.
      NOFLO(I)=0.0
      HIFLO(I)=-1.0
100   CONTINUE
C
C     READ INFLOW DATA AND CALCULATE THE MEAN
      IR=1
101   IF (IR.GT.IRMAX) GO TO 103
      READ (2'IR,10) IYR,MO,INFLOW
10    FORMAT (I4,I2,31G10.3)
      IF (MO.LE.12.AND.MO.GT.0) GO TO 203
      WRITE (6,14) IYR,MO
14    FORMAT ('0WARNING - INVALID MONTH ENCOUNTERED ON DISCHARGE FILE FO
     $R ',I4/11X,'THE DATA WILL BE IGNORED')
      GO TO 101
203   N(MO)=N(MO)+1.0
      SUM=0.0
      DO 102 I=1,31
      IF (INFLOW(I).LT.0.0) GO TO 201
      SUM=SUM+INFLOW(I)
102   CONTINUE
201   IF (SUM.GT.0.0) GO TO 301
      NOFLO(MO)=NOFLO(MO)+1.0
      GO TO 101
301   IF (INDIST(MO).EQ.2.OR.INDIST(MO).GE.5) SUM=ALOG10(SUM)
      M1(MO)=M1(MO)+SUM
      IF (SUM.LT.LOFLO(MO)) LOFLO(MO)=SUM
      IF (SUM.GT.HIFLO(MO)) HIFLO(MO)=SUM
      GO TO 101
103   DO 104 I=1,12
      IF (N(I).GT.3.0) GO TO 302
      WRITE (6,15) I
15    FORMAT ('0***** ERROR - INSUFFICIENT DATA DURING MONTH NUMBER ',
     $I2/16X,'PROGRAM EXECUTION ABORTED !')
      STOP
302   IF (N(I)-NOFLO(I).GT.3.0) GO TO 204
      IF (N(I)-NOFLO(I).EQ.0.0) GO TO 104
      IF (INDIST(I).GE.5) INDIST(I)=2
      IF (INDIST(I).EQ.3) INDIST(I)=1
      IF (INDIST(I).EQ.4) INDIST(I)=1
      IF (N(I)-NOFLO(I).GT.1.0) GO TO 204
      M1(I)=M1(I)/2.0
```

```
      GO TO 104
204   M1(I)=M1(I)/(N(I)-NOFLO(I))
104   CONTINUE
C
C     READ INFLOW DATA AND CALCULATE THE 2,3 AND 4 MOMENTS
C
      IR=1
105   IF (IR.GT.IRMAX) GO TO 107
      READ (2'IR,10) IYR,MO,INFLOW
      IF (MO.GT.12.OR.MO.LE.0) GO TO 105
      IF (M1(MO).EQ.0.0) GO TO 105
      SUM=0.0
      DO 106 I=1,31
      IF (INFLOW(I).LT.0.0) GO TO 109
      SUM=SUM+INFLOW(I)
106   CONTINUE
109   IF (SUM.EQ.0.0) GO TO 105
      IF (INDIST(MO).EQ.2.OR.INDIST(MO).GE.5) SUM=ALOG(SUM)
202   M2(MO)=M2(MO)+(SUM-M1(MO))**2
      G1(MO)=G1(MO)+(SUM-M1(MO))**3
      G2(MO)=G2(MO)+(SUM-M1(MO))**4
      GO TO 105
C
C     STANDARD DEVIATION,SKEWNESS AND KURTOSIS
C
107   DO 108 I=1,12
      TMPN=N(I)-NOFLO(I)
      IF (M1(I).EQ.0.0) GO TO 108
      M2SAV(I)=M2(I)-(HIFLO(I)-M1(MO))**2
      G1SAV(I)=G1(I)-(HIFLO(I)-M1(MO))**3
      IF (TMPN.GT.1.0) GO TO 303
      M2(I)=(ABS(M2(I)))**0.5
      G1(I)=0.0
      G2(I)=0.0
      GO TO 108
303   M2(I)=(ABS(M2(I)/(TMPN-1.0)))**0.5
      IF (TMPN.GT.3.0) GO TO 304
      G1(I)=0.0
      G2(I)=0.0
      GO TO 108
304   G1(I)=G1(I)/TMPN
      G2(I)=G2(I)/TMPN
      G1(I)=TMPN*TMPN*G1(I)/((TMPN-1.0)*(TMPN-2.0)*M2(I)**3)
      G2(I)=TMPN*TMPN*(TMPN+1.0)*G2(I)
      G2(I)=G2(I)/((TMPN-1.0)*(TMPN-2.0)*(TMPN-3.0)*M2(I)**4)
      G2(I)=G2(I)-3.0*(TMPN-1.0)**2/((TMPN-2.0)*(TMPN-3.0))
C
C     PRINT OUT MEAN, STD.DEV., SKEW AND KURTOSIS
C
      WRITE (6,11)
11    FORMAT ('0',49X,'STATISTICS OF TOTAL-MONTHLY FLOW'/'0',15X,'BY ',
     $'ROWS (MONTH NUMBER, DISTRIBUTION, NUMBER OF MONTHS, MEAN IN CF',
     $'S-DAYS, DEVIATION IN CFS-DAYS,'/25X,'SKEW, KURTOSIS, LOW FLOW',
     $' IN CFS-DAYS, NUMBER OF NO-FLOW MONTHS)'/'0',10X,'JAN',7X,'FEB',
```

```
     $7X,'MAR',7X,'APR',7X,'MAY',7X,'JUN',7X,'JUL',7X,'AUG',7X,'SEP',
     $7X,'OCT',7X,'NOV',7X,'DEC'/'0',11X,'1',9X,'2',9X,'3',9X,'4',9X,
     $'5',9X,'6',9X,'7',9X,'8',9X,'9',8X,'10',8X,'11',8X,'12')
      WRITE (6,12) INDIST
12    FORMAT (3X,12(9X,I1))
      WRITE (6,13)N,M1,M2,G1,G2,LOFLO,NOFLO
13    FORMAT (7X,12(G10.3)/7X,12(G10.3)/7X,12(G10.3)/7X,12(G10.3)/
     $7X,12(G10.3)/7X,12(G10.3)/7X,12(G10.3))
      WRITE (6,17)
17    FORMAT ('0',49X,'DISTRIBUTION NUMBER'/59X,'1',9X,'NORMAL'/59X,'2',
     $9X,'LOG-NORMAL'/59X,'3',9X,'GUMBEL'/59X,'4',9X,'PEARSON'/59X,'5',
     $9X,'LOG-PEARSON')
C
C     TEST FOR HIGH OUTLIERS
C
C     DO 305 I=1,12
C     IF (N(I)-NOFLO(I).LE.4.0) GO TO 305
C     Z=ABS((HIFLO(I)-M1(I))/M2(I))
C     TMPN=2.5+1.2*ALOG10((N(I)-NOFLO(I))/2.718283)
C     IF (INDIST(I).GE.3)TMPN=TMPN-TMPN*0.4*G1(I)
C     IF (Z.LE.TMPN) GO TO 305
C
C     ADJUST STATISTICS FOR HIGH OUTLIER
C
C     WRITE (6,16) I
C16   FORMAT ('0 HIGH OUTLIER FOUND FOR MONTH #',I2)
C     TMP=N(I)-NOFLO(I)
C     N(I)=N(I)-1.0
C     NOFLO(I)=NOFLO(I)-1.0
C     OBS=N(I)-NOFLO(I)
C     M1(I)=(M1(I)*TMPN-HIFLO(I))/OBS
C     M2(I)=(ABS(M2SAV(I)/(OBS-1.0)))**0.5
C     G1(I)=OBS*G1SAV(I)/((OBS-1.0)*(OBS-2.0)*M2(I)**3)
C     IF (AREAG(I).GE.99.0) GO TO 305
C     IF (N(I)-NOFLO(I).GE.100.0) GO TO 305
C     IF (N(I)-NOFLO(I).GE.25.0) GO TO 306
C     G1(I)=AREAG(I)
C     GO TO 305
C306  G1(I)=(OBS-25.0)*G1(I)/75.0+(1.0-(OBS-25.0)/75.0)*AREAG(I)
305   CONTINUE
      RETURN
      END
      SUBROUTINE INDIST
C
      EXTERNAL ALPHA
C
      COMMON P(50,50,12),B0(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM
```

```
      REAL LOFLO,LOQ,NOFLO
      COMPLEX RTS
C
C     ENTRY NORMAL AND GUMBEL RETURN THE CUMULATIVE PROBABILITY FOR
C     A GIVEN INFLOW
C
      ENTRY NORMAL (Q,FQ)
C
C     USING A POLYNOMIAL APPROXIMATION
C
      U=(Q-M1(MO))/M2(MO)
      IF (U.LE.5.0) GO TO 100
      FQ=1.0
      RETURN
100   IF (U.GE.-5.0) GO TO 110
      FQ=0.0
      RETURN
110   IUFLG=0
      IF (U.GT.0.0) IUFLG=1
      U=ABS(U)
      T=1.0/(1.0+0.33267*U)
      U=0.3989423/2.718282**(U**2/2.0)
      FQ=U*(0.4361836*T- .1201676*T**2+0.9372980*T**3)
      IF (IUFLG.EQ.1) FQ=1.0-FQ
      RETURN
C
      ENTRY GUMBEL (Q,FQ)
C
      FQ=(Q-C3(MO))/(C2(MO)-C3(MO))
      IF (FQ.GT.0.0) GO TO 201
206   FQ=0.0
      RETURN
201   FQ=1.0-FQ**C1(MO)
      IF (FQ.LT.1.0E-06) GO TO 205
      IF (FQ.GT.46.0517) GO TO 206
      FQ=EXP(-FQ)
      RETURN
205   FQ=1.0
      RETURN
C
      ENTRY GUMEST
C
C     FIND ESTIMATES FOR GUMBEL COEFFICIENTS. SEE MATALAS (1963) PP434-A PAGE A4
C     FOR EQUATIONS.
C     C1=A     C2=U     C3=E
C
      RTS=1.01
      SKEW=G1(MO)
      CALL MULLER (RTS,100,ALPHA,.TRUE.,SKEW)
      C1(MO)=RTS
      IF (C1(MO).GT.0.0) GO TO 207
      C1(MO)=0.0
      C2(MO)=0.0
      C3(MO)=0.0
```

```
      RETURN
207   DO 204 I=1,2
      X=1.0+FLOAT(I)/C1(MO)
      IF (X.LT.1.0) GO TO 202
      IF (I.EQ.1) GM1=GAMMA(X)
      IF (I.EQ.2) GM2=GAMMA(X)
      GO TO 204
202   NFAC=IABS(IFIX(X))+1
      DEN=0.0
      TMP=TMP+1.0
203   CONTINUE
      X=X+FLOAT(NFAC)
      IF (I.EQ.1) GM1=GAMMA(X)/DEN
      IF (I.EQ.2) GM2=GAMMA(X)/DEN
204   CONTINUE
      C2(MO)=M1(MO)+M2(MO)*(1.0-GM1)/(GM2-GM1**2)**0.5
      C3(MO)=M1(MO)-M2(MO)*GM1/(GM2-GM1**2)**0.5
      RETURN
C
      ENTRY PEREST
C
C     FIND ESTIMATES FOR PEARSON PARAMETERS
C

C     C1=M     C2=A     C3=B
C
      C3(MO)=(2.0/G1(MO))**2-1.0
      IF (G1(MO).LT.0.0) C3(MO)=6.0/G2(MO)-1.0
      C1(MO)=M1(MO)-M2(MO)*SQRT(C3(MO)+1)
      C2(MO)=M2(MO)/SQRT(C3(MO)+1.0)
      RETURN
C
      ENTRY PERSON (Q,FQ)
C
      FQ=0.0
      A2=(ABS(C3(MO)+1.0))**0.5
      U=A2*((Q-M1(MO))/M2(MO)+A2)
      A2=A2*A2
      FACT=U**A2*EXP(-U)/(A2*GAMMA(A2))
      FQ=1.0
      ITER=1
301   DEN=1.0
      DO 302 I=1,ITER
      DEN=DEN*(A2+FLOAT(ITER))
302   CONTINUE
      TERM=U**ITER/DEN
      FQ=FQ+TERM
      IF (ABS(TERM).LT.PTOL/FACT) GO TO 303
      ITER=ITER+1
      GO TO 301
303   FQ=FACT*FQ
      RETURN
      END
      SUBROUTINE MULLER (RTS,MAXIT,FN,FNREAL,SKEW)
```

```
C
C     FINDS A PARABOLIC APPROXIMATION TO A ROOT OF THE EQUATION FN=0
C
      COMPLEX RT,H,DELFPR,FRTDEF,LAMBDA,DELF,DFPRLM,NUM,DEN,G,SQR,FRT
      COMPLEX FRTPRV,RTS
      LOGICAL FNREAL
C
      ICNTRT=0
72    EPS1=1.E-05
      EPS2=1.E-05
      KOUNT=0
C
C     COMPUTE FIRST ESTIMATES FOR ROOT: RTS+.5, RTS-.5, RTS
C
1     H=0.2
      RT=RTS+H
      ASSIGN 10 TO NN
      GO TO 70
10    DELFPR=FRTDEF
      RT=RTS-H
      ASSIGN 20 TO NN
      GO TO 70
20    FRTPRV=FRTDEF
      DELFPR=FRTPRV-DELFPR
      RT=RTS
      ASSIGN 30 TO NN
      GO TO 70
30    ASSIGN 80 TO NN
      LAMBDA=-0.5
C
C     COMPUTE NEXT ESTIMATE FOR ROOT
C
40    DELF=FRTDEF-FRTPRV
      DFPRLM=DELFPR*LAMBDA
      NUM=-FRTDEF*(1.0+LAMBDA)*2.0
      G=(1.0+LAMBDA*2.0)*DELF-LAMBDA*DFPRLM
      SQR=G*G+2.0*NUM*LAMBDA*(DELF-DFPRLM)
      IF (FNREAL.AND.REAL(SQR).LT.0.0) SQR=0.0
      SQR=CSQRT(SQR)
      DEN=G+SQR
      IF (REAL(G)*REAL(SQR)+AIMAG(G)*AIMAG(SQR).LT.0.0) DEN=G-SQR
      IF (CABS(DEN).EQ.0.0) DEN=1.0
      LAMBDA=NUM/DEN
      FRTPRV=FRTDEF
      DELFPR=DELF
      H=H*LAMBDA
      RT=RT+H
      IF (KOUNT.GT.MAXIT) GO TO 100
C
70    KOUNT=KOUNT+1
      IF (REAL(RT).GT.0.054) GO TO 71
      IF (ICNTRT.EQ.0) GO TO 73
      RTS=0.0
      RETURN
```

```
73    RTS=2.15
      ICNTRT=1
      GO TO 72
71    CALL FN(RT,FRT,SKEW)
      FRTDEF=FRT
      GO TO NN,(10,20,30,80)
C
C     CHECK FOR CONVERGENCE
C
80    IF (CABS(H).LT.EPS1*CABS(RT)) GO TO 100
      IF (AMAX1(CABS(FRT),CABS(FRTDEF)).LT.EPS2) GO TO 100
C
C     CHECK FOR DIVERGENCE
C
      IF (CABS(FRTDEF).LT.10.0*CABS(FRTPRV)) GO TO 40
      H=H/2.0
      LAMBDA=LAMBDA/2.0
      RT=RT-H
      GO TO 70
100   RTS=RT
      RETURN
      END
      SUBROUTINE ALPHA(U,FU,SKEW)
C
C     COMPUTES F(A) FOR A GIVEN ALPHA. (SEE MATALAS, 1963, PP434-A PAGE A4 EQ.17)
C
      COMPLEX U,FU
      REAL X,FX,NUM
C
C     FIND GAMMA FUNCTION BY TRANSFORMING NUMBER TO
C     NUMBER BETWEEN 1 AND 2 WITH RECURRENCE FORMULA
C
      X=REAL(U)
      DO 110 I=1,3
      DEN=1.0
      X=1.0+FLOAT(I)/REAL(U)
C     NUMBER GREATER THAN 2.0
98    IF (X.LT.2.0) GO TO 99
      DEN=DEN/X
      X=X-1.0
      GO TO 98
99    IF (X.GT.1.0) GO TO 101
C     NUMBER LESS THAN 1.0
100   DEN=DEN*X
      X=X+1.0
      IF (X.LT.1.0) GO TO 100
101   X=GAMMA(X)/DEN
      IF (I.EQ.1) GM1=X
      IF (I.EQ.2) GM2=X
      IF (I.EQ.3) GM3=X
110   CONTINUE
      DEN=(GM2-GM1*GM1)**1.5
      NUM=GM3-3.0*GM2*GM1+2.0*GM1**3
      FX=NUM/DEN-SKEW
```

```
      FU=FX
      RETURN
      END
      SUBROUTINE ROUTE(IDATA,ISPDF)
C
C     THIS SUBROUTINE DEVELOPS ROUTING EQUATIONS FOR EACH MONTH
C
      COMMON P(50,50,12),BO(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL HOLD(50)
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM,LOQ
      REAL LOFLO,NOFLO
      INTEGER DAY,CALEND(12)
      INTEGER ISPILL(50),MPTY(50)
      REAL SUMX1(5,50,12),SUMX2(5,50,12),SUMY1(50,12),SUMY2(50,12)
      REAL SUMXY(5,50,12),XTRAN(5),R(5)
C
      DATA CALEND/1,32,61,92,122,153,183,214,245,275,306,336/
C
C     INITIALIZE
C
      DO 200 MO=1,12
      DO 200 J=1,50
      SUMY1(J,MO)=0.0
      SUMY2(J,MO)=0.0
      LOQ(J,MO)=1.E20
      HIQ(J,MO)=-1.0
      NOCNT(J,MO)=0
      LON(J,MO)=0
      DO 200 I=1,5
      SUMX1(I,J,MO)=0.0
      SUMX2(I,J,MO)=0.0
      SUMXY(I,J,MO)=0.0
200   CONTINUE
C
C     DETERMINE LOWER LIMIT OF ROUTING EQUATION FOR EACH MONTH AND
C     INITIAL CONTENT. THIS IS DONE BY ROUTING A MONTH OF NO
C     FLOW THROUGH THE RESERVOIR.THE RESULTING FINAL STORAGE IS
C     KEPT AS LOWLIM.
C
      DO 408 MO=1,12
      DO 408 I=1,NSTATE
      DS=SI(I)
      JSTRT=CALEND(MO)
      IF (MO.NE.12) JEND=CALEND(MO+1)-1
      IF (MO.EQ.12) JEND=366
      DO 407 J=JSTRT,JEND
      IF (CLOSTR.LT.0.0.OR.DS.GE.LOSTOR(J)) GO TO 402
      OUTFLO=DRY(A,B,DS,0.0,J)
```

```
      GO TO 404
402   IF (CUPSTR.LT.0.0.OR.DS.LE.UPSTOR(J)) GO TO 403
      OUTFLO=FLOOD(C,D,DS,0.0,J)
      GO TO 404
403   OUTFLO=DRAFT(J)
404   IF (CUPDFT.LT.0.0.OR.OUTFLO.LE.SAFDFT(J)) GO TO 405
      OUTFLO=SAFDFT(J)
405   OUTFLO=OUTFLO+ET(J)
      DS=DS-OUTFLO
      IF (DS.LE.CAPAC) GO TO 406
      DS=CAPAC
406   IF (DS.GE.0.0) GO TO 407
      DS=0.0
407   CONTINUE
      LOWLIM(I,MO)=DS
408   CONTINUE
C
C     DETERMINE HIQ (HIGHEST INFLOW WITH STORAGE LESS THAN CAPACITY) AND
C     LOQ (LOWEST INFLOW WITH STORAGE GREATER THAN ZERO). TABULATE SPILLAGE
C     AND DEFICIENCY WITHIN EACH MONTH.
C
      IF (ISPDF.GE.1) WRITE (6,60)
60    FORMAT ('0',35X,'----- NUMBER OF DAYS DURING EACH MONTH WITH DEFIC
     $IENCY -----'/36X,'-----    AND SPILLAGE FOR VARIOUS INITIAL CONTEN
     $TS     -----')
      IR=1
600   IF (IR.GT.IRMAX) GO TO 699
      DO 620 I=1,NSTATE
      ISPILL(I)=0
      MPTY(I)=0
620   CONTINUE
      READ (2'IR,10) IYR,MO,INFLOW
      IF (MO.GT.12.OR.MO.LE.0) GO TO 600
      DO 611 I=1,NSTATE
      DS=SI(I)
      SUM=0.0
      DO 607 J=1,31
      IF (INFLOW(J).LT.0.0) GO TO 608
      Q=INFLOW(J)
      DAY=CALEND(MO)+J-1
      IF (CLOSTR.LT.0.0.OR.DS.GE.LOSTOR(DAY)) GO TO 602
      OUTFLO=DRY(A,B,DS,Q,DAY)
      GO TO 604
602   IF (CUPSTR.LT.0.0.OR.DS.LE.UPSTOR(DAY)) GO TO 603
      OUTFLO=FLOOD(C,D,DS,Q,DAY)
      GO TO 604
603   OUTFLO=DRAFT(DAY)
604   IF (CUPDFT.LT.0.0.OR.OUTFLO.LE.SAFDFT(DAY)) GO TO 605
      OUTFLO=SAFDFT(DAY)
605   OUTFLO=OUTFLO+ET(DAY)
      DS=DS+INFLOW(J)-OUTFLO
      SUM=SUM+INFLOW(J)
      IF (DS.LE.CAPAC) GO TO 606
      DS=CAPAC
```

```
      ISPILL(I)=ISPILL(I)+1
606   IF (DS.GE.0.0) GO TO 607
      DS=0.0
      MPTY(I)=MPTY(I)+1
607   CONTINUE
608   IF (DS.LT.CAPAC.AND.SUM.GT.HIQ(I,MO)) HIQ(I,MO)=SUM
      IF (DS.GT.0.0.AND.SUM.LT.LOQ(I,MO)) LOQ(I,MO)=SUM
611   CONTINUE
      IF (ISPDF.LE.0) GO TO 600
      WRITE (6,61) MO,IYR,SUM
61    FORMAT ('0MONTH #',I2,' YEAR ',I4,' TOTAL INFLOW ',G11.4/'0',
     $4(' STORAGE   SPILL  EMPTY',7X))
      WRITE (6,62)(SI(I),ISPILL(I),MPTY(I),I=1,NSTATE)
62    FORMAT (4(1X,G10.3,2X,I3,4X,I3,7X))
      GO TO 600
C
699   IR=1
      IF (IDATA.GE.1) WRITE (8,70) (SI(I),I=1,NSTATE)
70    FORMAT ('1DATA POINTS FOR REGRESSION ANALYSIS (STORAGE = ****** IN
     $DICATES DATA POINT IS NOT USED)'/53X,'INITIAL STORAGE CONTENT'/
     $1X,'MO TOTAL INFLOW',8(3X,G10.3)/15X,8(3X,G10.3))
100   IF (IR.GT.IRMAX) GO TO 112
C
C     READ INFLOW FOR ONE MONTH
C
      READ (2'IR,10) IYR,MO,INFLOW
10    FORMAT (I4,I2,31G10.3)
      IF (MO.GT.12.OR.MO.LE.0) GO TO 100
C
      DO 111 I=1,NSTATE
      DS=SI(I)
      SUM=0.0
      DO 107 J=1,31
      IF (INFLOW(J).LT.0.0) GO TO 108
      Q=INFLOW(J)
      DAY=CALEND(MO)+J-1
C
C     CHECK TO SEE IF STORAGE AT END OF PREVIOUS DAY IS BELOW THE LOWER
C     LIMIT. IF TRUE AND OPTION IS IN USE CALL DRY TO CALCULATE DRAFT.
C
      IF (CLOSTR.LT.0.0.OR.DS.GE.LOSTOR(DAY)) GO TO 102
      OUTFLO=DRY(A,B,DS,Q,DAY)
      GO TO 104
C
C     CHECK STORAGE AGAINST UPPER LIMIT.
C
102   IF (CUPSTR.LT.0.0.OR.DS.LE.UPSTOR(DAY)) GO TO 103
      OUTFLO=FLOOD(C,D,DS,Q,DAY)
      GO TO 104
C
C     STORAGE LEVEL IS OK, SET OUTFLO TO NORMAL RELEASE
C
103   OUTFLO=DRAFT(DAY)
C
```

```
C     CHECK OUTFLOW AGAINST THE SAFE DRAFT
C
104   IF (CUPDFT.LT.0.0.OR.OUTFLO.LE.SAFDFT(DAY)) GO TO 220
      OUTFLO=SAFDFT(DAY)
C
C     COMPUTE SURFACE AREA ON PREVIOUS DAY
C
220   DSA=1.0
      IF (NAV.LE.1) GO TO 105
          DO 221 K=2,NAV
          IF (DS.GT.VOLUME(K)) GO TO 221
          KM1=K-1
          DSA=AREA(KM1)+(AREA(K)-AREA(KM1))*(DS-VOLUME(KM1))/
         $    (VOLUME(K)-VOLUME(KM1))
      GO TO 105
221   CONTINUE
      DSA=AREA(NAV)
C
C     ADD ET LOSS TO OUTFLOW
C
105   OUTFLO=OUTFLO+ET(DAY)*DSA
C
C     COMPUTE STORAGE AT DAY'S END.SUM INFLOW.
C
      DS=DS+INFLOW(J)-OUTFLO
      SUM=SUM+INFLOW(J)
      IF (DS.LE.CAPAC) GO TO 106
      DS=CAPAC
C
106   IF (DS.GE.0.0) GO TO 107
      DS=0.0
107   CONTINUE
C
C     MONTH'S ROUTING IS COMPLETE. CHECK INFLOW AGAINST LOQ AND
C     HIQ. COMPUTE STORAGE TRANSFORM.
C
108   CONTINUE
      HOLD(I)=1.E20
      IF (M1(MO).NE.0.0) GO TO 301
      SUMY1(I,MO)=SUMY1(I,MO)+DS
      GO TO 110
301   IF (SUM.LE.HIQ(I,MO)) GO TO 304
      NOCNT(I,MO)=NOCNT(I,MO)+1
      GO TO 110
304   IF (SUM.GE.LOQ(I,MO).AND.SUM.GT.0.0) GO TO 305
      LON(I,MO)=LON(I,MO)+1
      NOCNT(I,MO)=NOCNT(I,MO)+1
      GO TO 110
305   Y=ALOG(1.00001-DS/CAPAC)
      HOLD(I)=Y
C
C     TRANSFORM TOTAL MONTHLY INFLOW
C
      DO 109 J=1,5
```

```
      XTRAN(J)=SUM**J
109   CONTINUE
C
C     COMPUTE SUMMATIONS
C
      SUMY1(I,MO)=SUMY1(I,MO)+Y
      SUMY2(I,MO)=SUMY2(I,MO)+Y*Y
      DO 110 J=1,5
      SUMX1(J,I,MO)=SUMX1(J,I,MO)+XTRAN(J)
      SUMX2(J,I,MO)=SUMX2(J,I,MO)+XTRAN(J)*XTRAN(J)
      SUMXY(J,I,MO)=SUMXY(J,I,MO)+XTRAN(J)*Y
110   CONTINUE
111   CONTINUE
      IF (IDATA.GE.1) WRITE (8,71) MO,SUM,(HOLD(I),I=1,NSTATE)
71    FORMAT (1X,I2,G12.5,8(3X,F10.2)/15X,8(3X,F10.2))
      GO TO 100
C
C     ALL INFLOW DATA HAS BEEN READ AND LEAST SQUARES SUMMATIONS HAVE BEEN
C     MADE. NOW COMPUTE CORRELATIONS.
C
112   DO 116 MO=1,12
      WRITE (6,11) MO
11    FORMAT ('1',41X,'***** ROUTING ANALYSIS FOR MONTH NUMBER ',I2,
     $        ' *****'/)
      IF (M1(MO).NE.0.0) GO TO 303
C
C     ROUTINE FOR MONTHS OF NO FLOW
C
      WRITE (6,31)
31    FORMAT('0',30X,'NO FLOW HAS BEEN RECORDED DURING THIS MONTH'/
     $       '0',43X,'INITIAL'/44X,'CONTENT',3X,'DELTA S'/)
      DO 302 I=1,NSTATE
      B0(I,MO)=LOWLIM(I,MO)
      WRITE (6,32) SI(I),B0(I,MO)
32    FORMAT (41X,G10.3,2X,G10.3)
302   CONTINUE
      GO TO 116
303   WRITE (6,12)
12    FORMAT ('0',30X,'REGRESSION EQUATION : INITIAL STORAGE/CAPACITY',
     $'=1.0-B0*EXP(-B1*I**B2)'/'0',
     $4X,'  INITIAL     CORRELATION   ESTIMATED STANDARD ERROR'/
     $5X,'  STORAGE     COEFFICIENT       INFLOW     STORAGE         ',
     $'LN(B0)',10X,'-B1',13X,'B2',8X,'LOW LIMIT   HIGH LIMIT'/5X,
     $'(FT**3/S-D) (DIMENSIONLESS) (FT**3/S-D) (FT**3/S-D) (DIMENSION',
     $'LESS) (1/FT**3/S-D) (DIMENSIONLESS) (FT**3/S-D) (FT**3/S-D)'/)
      DO 115 I=1,NSTATE
      OBS=N(MO)-FLOAT(NOCNT(I,MO))
      IF (OBS.GE.2.0) GO TO 501
C
C     SET FLAG IN IPOWER IF INSUFFICIENT DATA FOR REGRESSION
C
      ITERM=0
      IPOWER(I,MO)=0
      B0(I,MO)=0.0
```

```
      B1(I,MO)=0.0
      RTEST=0.0
      GO TO 502
C
501   DO 113 J=1,5
      DEN=(ABS((OBS*SUMX2(J,I,MO)-SUMX1(J,I,MO)**2)*(OBS*
     $    SUMY2(I,MO)-SUMY1(I,MO)**2)))**0.5
      R(J)=(OBS*SUMXY(J,I,MO)-SUMX1(J,I,MO)*SUMY1(I,MO))/DEN
113   CONTINUE
C
C     DETERMINE X TERM WITH THE STRONGEST CORRELATION TO Y
C
      IPOWER(I,MO)=0
      RTEST=0.0
      ITERM=0
      STDEI=0.0
      STDES=0.0
      DO 114 J=1,5
      RTEMP=ABS(R(J))
      IF (RTEMP.GT.1.0000) GO TO 114
      IF (RTEST.GE.RTEMP) GO TO 114
      RTEST=RTEMP
      ITERM=J
114   CONTINUE
      IF (ITERM.GT.0) GO TO 214
      ITERM=ISAVE
      B1(I,MO)=B1SAVE
      STDEI=0.0
      STDES=0.0
      GO TO 215
C
C     COMPUTE BETA COEFFICIENTS AND STANDARD ERROR OF INFLOW
C
214   DEN=OBS*SUMY2(I,MO)-SUMY1(I,MO)**2
      B1(I,MO)=(OBS*SUMXY(ITERM,I,MO)-SUMX1(ITERM,I,MO)*SUMY1(I,MO))
     $        /DEN
      STDES=(OBS*SUMY2(I,MO)-SUMY1(I,MO)*SUMY1(I,MO))/OBS/(OBS-1.0)
      STDEI=(OBS*SUMX2(ITERM,I,MO)-SUMX1(ITERM,I,MO)**2)/OBS/(OBS-1.0)
      STDES=(STDES*(1.0-RTEST*RTEST))**0.5
      STDEI=(STDEI*(1.0-RTEST*RTEST))**0.5
      STDEI=STDEI**(1.0/FLOAT(ITERM))
215   BO(I,MO)=SUMX1(ITERM,I,MO)/OBS-B1(I,MO)*SUMY1(I,MO)/OBS
      B1SAVE=B1(I,MO)
      ISAVE=ITERM
      IPOWER(I,MO)=ITERM
C
C     OBTAIN LOW AND HIGH STORAGE LIMITS OF REGRESSION EQUATION
C
      LOQ(I,MO)=CAPAC*(1.00001-EXP((LOQ(I,MO)-BO(I,MO))/B1(I,MO)))
      HIQ(I,MO)=CAPAC*(1.00001-EXP((HIQ(I,MO)-BO(I,MO))/B1(I,MO)))
      IF (OBS.GT.2.0) GO TO 502
      STDEI=0.0
      STDES=0.0
C
```

```
C     PRINT OUT RESULTS
C
502   WRITE (6,13) SI(I),RTEST,STDEI,STDES,BO(I,MO),B1(I,MO),ITERM,
     $LOQ(I,MO),HIQ(I,MO)
13    FORMAT (5X,F11.0,6X,F5.3,5X,2(1X,F11.0),2(3X,E12.6),8X,I1,7X,
     $2(1X,F11.0))
115   CONTINUE
116   CONTINUE
      RETURN
      END
      FUNCTION DRY(A,B,DS,Q,DAY)
C
C     RETURNS A DRAFT WHEN STORAGE IS MINIMAL
C
      INTEGER DAY
C
      DRY=A*DS**B
      RETURN
      END
      FUNCTION FLOOD (C,D,DS,Q,DAY)
C
C     RETURNS A DRAFT WHEN STORAGE IS EXCESSIVE
C
      INTEGER DAY
C
      FLOOD=Q
      RETURN
      END
      SUBROUTINE SETUP
C
C     THIS SUBROUTINE FILLS THE TRANSITION PROBABILITY MATRIX.
C
      COMMON P(50,50,12),BO(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM
      REAL LOFLO,LOQ,NOFLO
C
      NM1=NSTATE-1
      DO 110 MO=1,12
      DO 108 I=1,NSTATE
      DO 105 J=1,NM1
C
C     NO FLOW MONTH
C
      IF (M1(MO).NE.0.0) GO TO 201
      DS=SF(J)-SI(I)
      FQ=0.0
      IF (DS.GE.BO(I,MO)) FQ=1.0
      GO TO 202
```

```
C
C     FINAL STORAGE BELOW LOWER LIMIT
C
201   IF (SF(J).GE.LOWLIM(I,MO)) GO TO 303
      P(J,I,MO)=0.0
      GO TO 105
C
C     NO REGRESSION EQUATION
C
303   IF (IPOWER(I,MO).GT.0) GO TO 203
      FQ=1.0
      IF (J.LE.NM1) FQ=FLOAT(LON(I,MO))/(N(MO)-NOFLO(MO))
      GO TO 202
C
C     CHECK SF FROM REGRESSION AGAINST HIQ AND LOQ.
C
203   IF (SF(J).LE.HIQ(I,MO)) GO TO 305
      IF (NOCNT(I,MO)-LON(I,MO).LE.0) GO TO 205
C     FQ=1.0-FLOAT(NOCNT(I,MO)-LON(I,MO))/(N(MO)-NOFLO(MO)-
C    $   FLOAT(NOCNT(I,MO)))
      FQ=1.0
      GO TO 103
305   IF (SF(J).GE.LOQ(I,MO)) GO TO 205
      IF (LON(I,MO).LE.0) GO TO 205
      FQ=FLOAT(LON(I,MO))/(N(MO)-NOFLO(MO))
      GO TO 103
C
C     COMPUTE CHANGE IN STORAGE AND CORRESPONDING INFLOW
C
205   Q=B0(I,MO)+B1(I,MO)*ALOG(1.00001-SF(J)/CAPAC)
C
C     CHECK FOR Q=0.0
C
      IF (Q.GT.0.0) GO TO 301
      FQ=NOFLO(MO)/N(MO)
      GO TO 204
301   Q=Q**(1.0/FLOAT(IPOWER(I,MO)))
C
C     LOG TRANSFORM Q IF NEEDED AND OBTAIN THE CUMULATIVE PROBABILITY
C
307   K=INDIST(MO)
      IF (K.EQ.2.OR.K.GE.5) Q=ALOG10(Q)
      GO TO (101,101,102,302,302),K
101   CALL NORMAL(Q,FQ)
      GO TO 103
102   CALL GUMBEL(Q,FQ)
      GO TO 103
302   CALL PERSON (Q,FQ)
103   IF (FQ.LT.0.0) FQ=0.0
      IF (FQ.GT.1.0) FQ=1.0
C
C     ADJUST PROBABILITY FOR ZERO FLOW VALUES
C
      IF (NOFLO(MO).EQ.0.0) GO TO 202
```

```
      TMP =NOFLO(MO)/N(MO)
      FQ=FQ*(1-TMP)+TMP
C
202   IF (J.EQ.1) GO TO 204
      IF (FQ.LT.P(J-1,I,MO)) FQ=P(J-1,I,MO)
204   P(J,I,MO)=FQ
      IF (FQ.LE.0.99999) GO TO 105
      DO 104 K=J,NSTATE
      P(K,I,MO)=1.0
104   CONTINUE
      GO TO 106
105   CONTINUE
C
C     SUBTRACT NEIGHBORING ELEMENTS IN THE INITIAL CONTENT COLUMN.
C
106   P(NSTATE,I,MO)=1.0
      PLAST=P(1,I,MO)
      DO 107 K=2,NSTATE
      PNEXT=P(K,I,MO)
      P(K,I,MO)=PNEXT-PLAST
      PLAST=PNEXT
107   CONTINUE
C
C     END OF INITIAL CONTENT LOOP
C
108   CONTINUE
C
C     PRINT OUT TRANSITION MATRIX
C
      WRITE (6,10) MO,(SI(J),J=1,NSTATE)
10    FORMAT ('1',35X,'***** TRANSITION PROBABILITY MATRIX FOR MONTH ',
     $'NUMBER ',I2,
     $' *****',/'0',50X,'FINAL STORAGE'/'   INITIAL',42X,'(FT**3/S-D)'/
     $'   STORAGE'/' (FT**3/S-D)',
     $12(1X,F9.0)/11X,12(1X,F9.0)//)
      DO 109 I=1,NSTATE
      WRITE (6,11) SI(I),(P(J,I,MO),J=1,NSTATE)
11    FORMAT (1X,F9.0,2X,12(3X,F7.4)/11X,12(3X,F7.4)//)
109   CONTINUE
C
C     END OF LOOP FOR MONTH
C
110   CONTINUE
      RETURN
      END
      SUBROUTINE SOLVE
C
C     THIS SUBROUTINE OBTAINS THE SIMPLE STORAGE FREQUENCY DISTRIBUTION
C     FOR EACH MONTH BY TRIAL AND ERROR.
C
      COMMON P(50,50,12),B0(50,12),B1(50,12),LOWLIM(50,12),
     $LOQ(50,12),HIQ(50,12),DRAFT(366),AREA(100),VOLUME(100),
     $ET(366),UPSTOR(366),LOFLO(12),NOFLO(12),AREAG(12),G2(12),
     $LOSTOR(366),SAFDFT(366),SF(50),SI(50),INFLOW(31),M1(12),M2(12),
```

```
     $G1(12),N(12),C1(12),C2(12),C3(12),CAPAC,CLOSTR,CUPDFT,CUPSTR,PTOL,
     $A,B,C,D,IPOWER(50,12),NOCNT(50,12),LON(50,12),INDIST(12),IRMAX,
     $ITMAX,IYR,MO,NSTATE,IR,MAXCAP,NAV
      REAL INFLOW,LOSTOR,M1,M2,N,LOWLIM
      REAL POLD(50,12),PNEW(50,12)
      REAL LOFLO,LOQ,NOFLO
C
      DO 100 MO=1,12
      DO 100 I=1,NSTATE
      POLD(I,MO)=1.0/FLOAT(NSTATE)
      PNEW(I,MO)=POLD(I,MO)
100   CONTINUE
C
C     BEGIN ITERATIVE LOOP
C
      DO 107 K=1,ITMAX
C
C     BEGIN MONTHLY LOOP
C
      DO 103 MO=1,12
      MOP1=MO+1
      IF (MO.EQ.12)MOP1=1
C
      DO 102 J=1,NSTATE
      ANS=0.0
      DO 101 I=1,NSTATE
      ANS=ANS+P(J,I,MO)*PNEW(I,MO)
101   CONTINUE
      PNEW(J,MOP1)=ANS
102   CONTINUE
103   CONTINUE
C
C     CHECK FOR CONVERGENCE
C
      DO 104 MO=1,12
      DO 104 J=1,NSTATE
      IF (ABS(PNEW(J,MO)-POLD(J,MO)).GT.PTOL) GO TO 105
104   CONTINUE
      GO TO 108
105   DO 106 MO=1,12
      DO 106 J=1,NSTATE
      POLD(J,MO)=PNEW(J,MO)
106   CONTINUE
107   CONTINUE
      WRITE (6,13) ITMAX
13    FORMAT ('0***** WARNING SOLUTION DOES NOT CONVERGE IN ',I4,
     $' ITERATIONS'//)
C
C     COMPUTE CUMULATIVE FREQUENCY
C
108   DO 109 MO=1,12
      POLD(1,MO)=PNEW(1,MO)
      DO 109 J=2,NSTATE
      POLD(J,MO)=POLD(J-1,MO)+PNEW(J,MO)
```

```
109   CONTINUE
C
C     PRINT OUT SOLUTION
C
      WRITE (6,10)
10    FORMAT ('1',29X,'***** CUMULATIVE STORAGE FREQUENCY CURVES FOR TH
     $E END OF EACH MONTH *****'/'0',60X,'PROBABILITY DURING MONTH NUMBE
     $R')
      WRITE (6,11) (J,J=1,12)
11    FORMAT (6X,'STORAGE'/4X,'(FT**3/S-D)',6X,I2,11(8X,I2)/)
      NM1=NSTATE-1
      DO 110 I=1,NM1
      WRITE(6,12) SI(I),(POLD(I,MO),MO=1,12)
12    FORMAT (3X,G10.3,12(3X,F7.4))
110   CONTINUE
      WRITE(6,14) (POLD(NSTATE,MO),MO=1,12)
14    FORMAT (5X,'SPILL',3X,12(3X,F7.4))
      RETURN
      END
```

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