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**Interactive Programs for Low-Flow
Frequency Analyses for Use in Regional Studies**

J. R. Hyndman
D. D. Huff

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1213

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INTERACTIVE PROGRAMS FOR LOW-FLOW FREQUENCY ANALYSES
FOR USE IN REGIONAL STUDIES

J. R. Hyndman and D. D. Huff

ENVIRONMENTAL SCIENCES DIVISION
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ABSTRACT

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Seven-day ten-year low-flow values have been used as indices of water availability for regional energy facility siting (Samuels, 1976; Peterson and Sonnichson, 1976). This paper describes an automated system for generating low-flow frequency distributions for United States Geological Survey streamflow gaging sites. Since no single frequency distribution will match the low flow frequencies at all stream gaging stations, it is necessary to examine several possible distributions for each station to determine the most useful one. Four representative low flow frequency distributions, Gumbel's limited distribution of the smallest value, the Pearson Type III, the Log-Pearson Type III, and the Log-Normal distributions, have been chosen for inclusion in an interactive set of programs, named LOFL02. LOFL02 forms one analysis module of the ORNL Water Analysis System (WAS) (Jalbert and Sheperd, 1977), and when used in conjunction with other WAS programs makes frequency analysis viable on a regional scale by facilitating the handling of large amounts of data for large numbers of stations. Care must be taken to ensure the use of consistent data; however, the LOFL02 analyses can themselves act as a screen for inconsistent data sets.

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	iii
LIST OF TABLES	vii
INTRODUCTION	1
DESCRIPTION OF LOW-FLOW FREQUENCY DISTRIBUTION	5
THE EFFECTS OF INCONSISTENT RECORDS ON LOW-FLOW ANALYSES	9
IMPLEMENTATION	12
PROGRAM APPLICATIONS AND DISCUSSION	14
CONCLUSIONS	22
LITERATURE CITED	24
APPENDIX A	27
APPENDIX B	77

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LIST OF TABLES

Table	Page
1 Major characteristics for six gaging stations on four streams in the Tennessee Valley	15
2 Low-flow distribution	17

INTRODUCTION

Seven-day low-flow frequency distributions have been chosen as indices of water availability in regional energy facility siting and assessment studies. These have been selected because they offer standard measures of streamflow with the precision and the flexibility needed for iterative siting and assessment processes. Calculated directly from daily streamflow records, they can provide a reproducible measure of expected flow under critical conditions. Low-flow ranges have been used as suitability and exclusion criteria in siting studies (Samuels, 1976), and expected low flows have been used as indices to the amount of water potentially available for energy purposes (Peterson and Sonnichson, 1976; Harte and El-Gassier, 1978). Subsequent to siting studies, low flows of individual stream reaches have been used to evaluate the resulting environmental impacts (Dobson et al., 1977; Habegger et al., 1977). Seven-day ten-year low flows are among the information elements used for environmental reports for nuclear power plants and geothermal development projects (U.S. Nuclear Regulatory Commission, 1976; U.S. Energy Research and Development Administration, 1977).

The seven-day ten-year flow is not a worst-case low-flow prediction. It represents the lowest average flow expected to occur for one week once in ten years. The figure is useful for large-scale regional studies because it typically represents flow under unusually dry conditions. In impact statements, when a stream's ability to assimilate waste heat or dilute pollutants is being assessed, it is used for the same reason. But if the availability of flow is extremely critical,

more severe conditions must be considered. When a nuclear power plant is being licensed, regulations require the estimation of the probable minimum flow, though no widely accepted standards yet exist for its definition or calculation (Giusti and Meyer, 1977).

Several frequency distributions have been examined for their usefulness in low-flow studies. For example, Matalas (1963) discussed the relative merits of Gumbel's limited distribution of the smallest value, the 3-Parameter Log-Normal distribution, the Pearson Type III distribution, and the Pearson Type V distribution. He found that the Pearson Type III and Gumbel distributions were about equally representative of observed data, and were better than the other two. Riggs (1972) indicates that the Log-Pearson Type III distributions is preferred for use by the United States Geological Survey (USGS). Bobee (1975) has suggested a refinement to the Log-Pearson Type III fitting process and discussed some limitations to the use of this distribution. He concludes from Monte Carlo simulation studies "... that it is generally desirable to get the best possible fitting method". In other words, the test of utility of a particular distribution and fitting procedure is how well it matches data. Sangal and Biswas (1970), in their evaluation of the 3-Parameter Log-Normal distribution, state that there is no standard method of comparing the merits of one distribution with another. However, they conclude that in the central part of the frequency curve, where plotting positions are more reliable, results are quite similar for most distributions.

In view of these earlier findings, we have chosen to use some of the more widely accepted distributions for low-flow frequency analysis

and depend upon a median value to determine which results are applicable in any given case. Gumbel's limited distribution of the smallest value, the Pearson Type III, Log-Pearson Type III, and Log-Normal analyses have been chosen for inclusion in an interactive program, called LOFL02.

LOFL02 forms one analysis module of the ORNL Water Analysis System (WAS) (Jalbert and Shepherd, 1977), a series of interactive programs which can be used to select, retrieve, and analyze streamflow data from the United States Geological Survey DAILY-VALUE water tapes.

One question that arises, in addition to which theoretical distributions to choose, is the choice of which formula to use to determine the plotting position, or the expected cumulative probabilities, of the annual average seven-day low flows calculated from the daily flow data. This is important since the goodness of fit of a particular frequency distribution is often based on how it compares to the plotted data. Matalas (1963) gives two equations for plotting position:

$$P = (n+1-m)/(n+1) \quad (1)$$

and

$$P = [n(3n+1)+2 - m(3n+1)] \cdot [3(n^2-1)]^{-1} , \quad (2)$$

where

P = cumulative probability,

n = number of independent values used in the analysis (i.e., years of record), and

m = the order of the observation, which goes from 1 to n as flow goes from the largest to smallest value.

These are known as the "simple" (Equation 1) and "Thomas" (Equation 2) plotting position equations in WAS. The United States Geological Survey currently uses the "simple" formula shown above for calculating plotting position.

One underlying assumption of all theoretical methods is that the data are consistent, i.e., that the data represent a consistent set of conditions over the entire period. Thus, a stream that is unregulated, or one whose record has covered a period of consistent regulation practices is suitable, but a record that spans the time when one or more reservoirs were built and brought into operation must be considered unsuitable without adjustment. By generating plots of data and theoretical distributions, one can often spot spurious data values such as those produced when a reservoir is being filled and flow is drastically reduced. It is also likely that spurious values will result in significant differences between theoretical distributions and plotted data. For those cases, it is desirable to examine data more closely. The plots generated by the WAS/LOFLO2 system thus serve as a guide for identifying stations where further analysis of the data is warranted.

In the following pages, the probability distribution functions are described in detail. For the reader who is not interested in those details, it is acceptable to skip to the next section which deals with some of the shortcomings and limitations of the methods described here.

DESCRIPTIONS OF LOW-FLOW FREQUENCY DISTRIBUTIONS

Pearson Type III Distribution

The Pearson Type III distribution is a special case of a gamma function (Matalas, 1963), where the probability density function is given as

$$p(x) = \frac{1}{a^{b+1}\Gamma(b+1)} \left(\frac{x-m}{a}\right)^b \left[\exp - \left(\frac{x-m}{a}\right)\right] , \quad (3)$$

where

a, b , and m are parameters of the distribution.

The mean ($\bar{x}$) of the population is given as

$$\bar{x} = m + a(b+1) , \quad (4)$$

the variance (s^2) is

$$s^2 = a^2(b+1) , \quad (5)$$

and the coefficient of skewness (C_s) is

$$C_s = 2/\sqrt{b+1} . \quad (6)$$

The cumulative probabilities are defined by $P(u)$ as

$$P(u) = \frac{1}{\Gamma(b+1)} \int_0^u e^{-u} u^{(b+1)-1} du \quad (7)$$

where

$$u = A(t+A) \quad (8)$$

$$A^2 = b+1 \quad (9)$$

$$t = (x-\bar{x})/s \quad (10)$$

and $2u$ is distributed as chi-square with $2A^2$ degrees of freedom. For positive skewness in the sample population of low flows, one may find the estimated low flow for any recurrence interval. The recurrence interval, T_r , represents the period of time, in years, during which some certain low flow, x , is expected to occur at least once. The following steps are taken to compute the low flow value:

1. Compute the mean, standard deviation, and coefficient of skewness for the sample population.
2. From the computed skewness coefficient C_s and (8) and (9), determine the degrees of freedom, $2A^2$.
3. Letting $P(u) = 1 - (T_r - 1)/T_r$, determine the value of $2u$ from the chi-square distribution.
4. From (8), determine the value of t associated with the skewness and recurrence interval chosen.
5. From (10), compute x , the actual flow associated with the recurrence interval.

(When skewness is negative, the same procedure is used. However,

$P(u) = (T_r - 1)/T_r$ is substituted in step 3.)

It should be noted that when skewness is zero, the Pearson Type III distribution becomes a normal distribution, and provision for this occurrence has been included in the FORTRAN program.

Log-Pearson Type III Distribution

The Log-Pearson Type III (Riggs, 1972) distribution has also been implemented for low flow analysis. It is essentially identical to the method for the standard Pearson Type III analysis, except the raw daily flow data are transformed to their logarithms before determining the mean, standard deviation, and skewness coefficient. The Pearson Type III analysis is applied to the transformed distribution, and the final result is transformed again to flow by taking the anti-log of the result. It should be noted that zero skewness results in fitting a log-normal distribution to the sample data for purposes of determining flows for specific recurrence intervals.

Gumbel's Limited Distribution of the Smallest Value

Gumbel's limited distribution of the smallest value (Gumbel, 1954) has the form

$$p(x) = \frac{\alpha}{\mu - \epsilon} \left(\frac{x - \epsilon}{\mu - \epsilon} \right)^{-1} \exp - \left[\left(\frac{x - \epsilon}{\mu - \epsilon} \right) \right] , \quad (11)$$

where the parameters α , μ , and ϵ represent a scale parameter, the characteristic drought, and the lower limit of flow, respectively. The mean, μ_1 , and the second and third central moments, μ_2 , and μ_3 , are defined by:

$$\mu_1 = \epsilon + (\mu - \epsilon) < (1 + 1/\alpha) , \quad (12)$$

$$\mu_2 = (\mu - \epsilon)^2 [< (1 + 2/\alpha) - <^2 (1 + 1/\alpha)], \text{ and} \quad (13)$$

$$\mu_3 = (\mu - \epsilon)^3 [< (1 + 3/\alpha) - 3 < (1 + 2/\alpha) < (1 + 1/\alpha)] + 2 <^3 (1 + 1/\alpha) . \quad (14)$$

The skewness, G_1 , is defined by:

$$G_1 = \frac{\mu_3}{\mu_2^{3/2}} \quad (15)$$

Cumulative probabilities are expressed as:

$$P(X) = 1 - \exp \left[- \left(\frac{x - \epsilon}{\mu - \epsilon} \right)^\alpha \right] \quad (16)$$

To estimate the low flow expected during a recurrence interval, T_r , from a sample population of low flows, it is necessary to find sample estimates for α , μ , and ϵ . These parameters can be computed from the sample mean, $\bar{x}$, standard deviation, S , and skewness, g_1 , as follows:

1. Skewness is a function of α (equation 15). Gumbel (1954) provides a table showing the values of skewness corresponding to a range of values of α . After the sample estimate of skewness has been computed, the corresponding value of α can be read from the table.
2. By solving equations 12 and 13 simultaneously, and replacing μ_1 and μ_2 by their sample estimates $\bar{x}$ and S ,

$$\mu = \bar{x} + S \left[1 - \left(1 + 1/\alpha \right) \right] \left[<(1+2/\alpha) - <^2 (1+1/\alpha) \right]^{-1/2}, \quad (17)$$

and

$$\epsilon = \bar{x} - S \left[<(1+1/\alpha) \right] \left[<(1+2/\alpha) - <^2 (1+1/\alpha) \right]^{-1/2} \quad (18)$$

3. The cumulative probability of a flow, x , can be expressed as

$$P(x) = \frac{1}{T_r} \quad (19)$$

By letting

$$y = - \ln \left(\frac{T_r - 1}{T_r} \right) , \quad (20)$$

from equation 16

$$\ln y = \alpha [\ln(x-\epsilon) - \ln(\mu-\epsilon)] . \quad (21)$$

The estimated low flows for the desired return periods can be computed from equation 21.

THE EFFECTS OF INCONSISTENT RECORDS ON LOW FLOW ANALYSES

Predicting drought flows by fitting any of the described frequency distributions to observed low flows assumes that the low flows represent samples from a single distribution. If major changes have occurred in a stream system or its watershed during the period of record, the assumption will not be true. When the factors which control streamflow rates have changed, the low-flow records which span the period of change will represent samples from two or more distributions, and using such inconsistent data in the low-flow analyses without some form of correction will lead to unreliable drought flow predictions.

As noted earlier, some major individual inconsistencies in low-flow data can be detected directly by comparing the plotted data and the theoretical distributions. If anomalously low values occur for only a few years as a reservoir is being filled, they will be apparent when the probabilities of the annual average low flows, as determined by

the plotting position equations, are plotted against their values in the theoretical cumulative probability distributions. The probabilities predicted by plotting position, which depend only on the number of other observations in the data set, will generally be much higher than those predicted by the theoretical distributions, where the extremely low flows will be viewed as unlikely events with low probabilities and long recurrence intervals.

In some cases, the results of the low flow analyses indicate the presence of major inconsistencies in the streamflow records not confined to one or even several data points. This is the problem most commonly encountered in using WAS/LOFL02, and usually occurs on regulated streams where one or more dams have been built during the period of record. Following closure of the dam or dams, streamflow regulation so changes the low-flow regimes of the streams that analyses using the distributions previously described are meaningless. Such unreliable analyses are often indicated by predicted low flows and lower limits of flow less than zero. Predicted lower limits of flow greater than recorded low flows can also be caused by the unusual data distributions found in inconsistent records, and indicate use of a theoretical distribution inappropriate for that data.

Other changes which may cause inconsistent records are more subtle and difficult to detect than the closure of dams and subsequent streamflow regulation. The cumulative effects of many gradual changes, such as of agricultural drainage projects, changes in vegetation, road-building, stream channel alterations, and urban development may alter the low-flow characteristics of a drainage basin without causing

extreme or obvious effects in the computed low-flow frequency distributions. Time-series analysis may offer a means of detecting such gradual shifts in low-flow distributions.

Once detected, inconsistencies must be reconciled before valid low-flow analyses can be made. Examples of reconciliation are beyond the scope of this paper, but some possible methods will be discussed. When a distinct break in a streamflow record can be detected and dated, the simplest treatment is to drop one of the inconsistent parts of the record. In the case of a dam, a record which gives invalid predictions when used in its entirety can be broken into pre- and post-operational parts. These can then be used to make separate low-flow predictions for regulated and natural conditions. Unfortunately, this method of handling inconsistent records does reduce the number of observations available for each analysis.

A possible means of treating records made inconsistent by regulation without losing data consists of reconciling the differing parts using streamflow synthesis models. Models such as the Corps of Engineers' Streamflow Synthesis and Reservoir Regulation (SSARR) model offer the possibility of adding the effects of regulation to the unregulated portion of a record, or removing them from the regulated portion. In either case, a consistent record for the entire period is obtained.

Both of these methods for predicting low flows on regulated streams assume that the future operating rules for the reservoirs are known. The first method, constructing flow frequency distributions using only post-regulation data, assumes that the reservoirs will

continue to operate in the future as they have in the past. The streamflow synthesis method can be more flexible. Any set of operating rules can be imposed on the recorded flows, but separate low-flow predictions must be made for each different set. The operating priorities of reservoirs are subject to change and when low flows on regulated streams are predicted using streamflow records, it must be recognized that the predictions will be valid only when the reservoir is operated under the rules which produced the low flows used to compute the predicted distributions. If shifts in low-flow distributions caused by gradual changes in the watersheds being monitored can be detected and quantified by such means as time series analysis, streamflow synthesis models may again provide a means of producing consistent data for the entire period of record.

IMPLEMENTATION

WAS Programs

The ORNL Water Analysis System (WAS), described by Jalbert and Shepherd (1977), is an integrated package of interactive programs for retrieving, translating, and analyzing streamflow data from the USGS DAILY-VALUE water tapes. Modifications which have been made in two of the WAS modules used in low-flow analysis, SELECT and LOFLO, will be described. The SELECT module performs the data retrieval step in WAS and computes annual average seven-day low flows from the daily average flows recorded on the DAILY-VALUE tapes. The LOFLO module, which in its revised form is called LOFLO2, computes and graphs low-flow

frequency distributions from the annual average seven-day low flows computed by SELECT.

The time required to develop low-flow distribution using WAS/LOFL02 is almost independent of the number of stations being analyzed. The WAS data retrieval system permits stations to be chosen by state and county, latitude-longitude frame, or individual USGS station numbers. The interactive LOFL02 module allows the operator the choice of performing the low-flow analyses on all the stations previously chosen, or specifying individual stations. Therefore, low-flow analyses for all gaging stations in a geographical area can be performed without knowing station numbers in advance. This feature makes the programs especially useful and efficient for analyzing the large numbers of stations encountered in large-scale regional studies.

SELECT Program Changes

The original version of SELECT (Jalbert and Shepherd, 1977) did not compute low flows for stations with interrupted records. This meant low-flow frequency distributions could not be found for many stations with continuous records for thirty or more years, because values for two or three months were missing. Therefore, SELECT was changed so that it will process stations with incomplete records, but will compute annual average low flows only for those years in the record for which complete records are available. When an incomplete record is processed, the incompleteness and the number of years for which complete records are available, are noted in the SELECT output. The revised version of SELECT is listed in Appendix A.

LOFLO Program Changes

The original LOFLO module (Jalbert and Shepherd, 1977) computed and plotted seven-day ten-year low flows according to Gumbel's limited distribution of the smallest value, as described earlier. It also computed cumulative probabilities using the simple and Thomas plotting position equations. The LOFLO2 program includes the analyses found in LOFLO, and adds the options for the Pearson Type III, Log-Pearson Type III and Log-Normal distributions. These new distributions were programmed as four new subroutines, LOGDST, NORMT, PRSN3 and PRSNT added to LOFLO. To accomodate the new subroutines and the output from the revised SELECT program, changes were made in the main LOFLO module, and in the PTSTAT and PTREW subroutines. The revised low flow program, LOFLO2, is printed in Appendix A.

PROGRAM APPLICATIONS AND DISCUSSION

The WAS/LOFLO2 system was used to construct seven-day low-flow frequency distributions for six gaging stations on four streams in the Tennessee Valley. Daily flow data for at least forty years were available for every station. The names, USGS station numbers, and major characteristics of the six stations are listed in Table 1. The complete LOFLO2 output is reproduced in Appendix B.

The six stations were chosen to represent a variety of stream sizes and flow conditions. They range from a small, free-running headwater stream to the well-regulated mainstem of a major river. Stations 03524000 (Clinch River at Cleveland, VA), 03528000 (Clinch River at Tazewell, TN), and 03533000 (Clinch River below Norris Dam,

Table 1. Major characteristics for six gaging stations on four streams in the Tennessee Valley

Station Number (yrs flow data)	Station Name	Regulation	Drainage Area (mi ²)	Recorded Average 7-Day Low Flows		
				Maximum	Minimum	Mean
03501000 (51)	Cullasaja R. at Cullasaja, N.C.	Small Impoundment	86.5	146.1	19.7	64.1
03524000 (52)	Clinch R. at Cleveland, VA	None	528.0	172.2	39.5	84.0
03528000 (53)	Clinch R. above Tazewell, TN	None	1474.0	531.4	116.4	225.3
03584500 (56)	Elk R. near Prospect, TN	Dam Multipurpose	1784.0	1027.5	93.5	276.5
03533000 (69)	Clinch R. below Norris Dam, TN	Dam Multipurpose	2913.0	1508.5	5.8	342.5
03571850 (41)	Tenn. River at S. Pittsburg, TN	Dams Multipurpose	22640.0	24000.0	6121.4	15335.3

TN) form a downstream series on the Clinch River. The first two stations are above the dammed portions of the river system. The third is immediately below a large hydroelectric dam. Station 03501000 (Cullasaja River at Cullasaja, NC) is in the mountainous region of North Carolina. Though its drainage area is the smallest of all the examples, there is a dam upstream from the gage at Cullasaja. The 14.4 square miles of drainage area above the dam represent 17% of the total drainage above the gage.

Station 03584500 (Elk River near Prospect, TN) is 123.5 miles below the TVA's Tims Ford Dam, a hydroelectric generating facility. Filling of the reservoir behind Tims Ford Dam began in 1970. Tims Ford replaced the Elk River Dam, an older hydroelectric dam 32 miles upstream which is now in the Tims Ford backwaters. 529 of the 1784 square miles of drainage area (30%) above station 03584500 lie above Tims Ford Dam.

There are four hydroelectric dams with storage reservoirs on the mainstem of the Tennessee River above Station 03571850 (Tennessee River at S. Pittsburgh, TN). The nearest is Nickajack Dam, six miles upstream. Nickajack controls runoff from 96.6% of the 22,640 square miles of drainage basin above the South Pittsburgh station.

The seven-day low-flow frequency distributions predicted by the four types of analyses, and the cumulative probabilities as calculated by the Thomas method (interpolated) are listed in Table 2. The values calculated for Gumbel's $\underline{x}$, the predicted lower limits of flow, are also displayed. Table 2 shows that all the calculated distributions for the Cullasaja (03501000) and two upper Clinch (03524000 and 03528000)

Table 2. Low-Flow Distributions

Station 03501000 (Cullasaja River at Cullasaja, NC)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $\epsilon=27.48$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	85.0	99.8	99.0	98.3	99.4
2.0	58.4	59.4	59.8	60.6	59.8
3.0	49.6	49.9	50.6	51.4	50.8
5.0	42.0	42.6	43.3	43.7	43.5
10.0	35.4	36.7	36.8	36.5	36.8
20.0	24.8	33.2	32.4	31.4	32.0
25.0	19.9	32.4	31.3	30.0	30.8
30.0	19.7	31.9	30.5	28.9	29.8
40.0	19.7	31.1	29.3	27.4	28.5
50.0	19.7	30.6	28.5	26.3	27.4

Station 03524000 (Clinch River at Cleveland, VA)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $\epsilon=37.2$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	121.8	127.2	126.3	125.9	124.4
2.0	75.3	78.7	79.2	78.0	79.3
3.0	62.5	66.9	67.8	67.7	68.6
5.0	58.3	57.7	58.5	59.5	59.7
10.0	49.0	50.0	50.2	52.1	51.5
20.0	43.3	45.4	44.5	46.9	45.6
25.0	39.9	44.3	43.0	45.5	44.0
30.0	39.5	43.5	41.9	44.5	42.8
40.0	39.5	42.5	40.3	43.0	41.1
50.0	39.5	41.8	39.1	41.9	39.7

Table 2 (continued)

Station 03528000 (Clinch River above Tazewell, TN)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $\epsilon=107.9$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	326.2	353.4	351.0	347.0	341.8
2.0	206.8	205.2	206.6	205.9	210.7
3.0	166.4	173.1	175.2	177.2	180.3
5.0	141.5	149.7	151.2	154.7	155.4
10.0	131.7	131.8	131.4	134.8	132.5
20.0	116.7	121.9	119.0	121.1	116.2
25.0	116.4	119.7	115.9	117.5	111.8
30.0	116.4	118.2	113.7	114.8	108.5
40.0	116.4	116.2	110.7	110.9	103.9
50.0	116.4	114.9	108.6	108.1	100.2

Station 03584500 (Elk River near Prospect, TN)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $\epsilon=167.2$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	376.6	461.0	463.9	446.8	433.5
2.0	230.9	224.1	218.0	238.7	252.3
3.0	207.6	195.2	194.4	203.7	211.9
5.0	189.3	179.9	185.2	178.3	179.3
10.0	158.9	171.9	182.2	157.5	150.0
20.0	113.2	169.0	181.6	144.2	129.5
25.0	99.2	168.5	181.5	140.8	124.1
30.0	93.5	168.3	181.5	138.3	120.0
40.0	93.5	167.9	181.5	134.8	114.3
50.0	93.5	167.7	181.5	132.3	109.7

Table 2 (continued)

Station 03533000 (Clinch River below Norris Dam, TN)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $c=-106.5$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	726.7	807.0	797.8	916.0	1006.5
2.0	229.2	275.0	280.2	210.1	189.8
3.0	80.6	155.1	163.3	121.1	110.8
5.0	53.3	65.4	72.1	69.0	66.3
10.0	29.4	-5.1	-5.8	36.3	38.3
20.0	19.6	-45.4	-56.3	20.7	24.3
25.0	15.8	-54.5	-68.9	17.5	21.3
30.0	9.7	-60.8	-78.1	15.3	19.2
40.0	5.8	-69.3	-91.2	12.4	16.5
50.0	5.8	-74.8	-100.1	10.6	14.6

Station 03571850 (Tennessee River at S. Pittsburgh, TN)

Recurrence Interval (Years)	Thomas Method	Gumbel's Method $c=-4407.8$	Pearson Type III	Log- Pearson Type III	Log- Normal
1.1	20397.1	21740.6	21757.4	22395.6	23446.1
2.0	15492.6	15543.2	15465.1	15142.7	14470.0
3.0	12173.0	13342.6	13337.2	12905.4	12385.9
5.0	10279.4	11176.2	11262.0	10899.4	10674.4
10.0	7480.5	8824.8	8990.5	8929.3	9104.8
20.0	6144.3	6903.4	7075.4	7461.7	7989.2
25.0	6121.4	6354.2	6510.9	7063.7	7687.0
30.0	6121.4	5927.2	6064.7	6758.3	7463.0
40.0	6121.4	5290.0	5385.5	6313.6	7145.4
50.0	6121.4	4824.5	4877.3	5995.7	6891.0

stations are very similar. At the ten-year point, the four low-flows computed for each of the three stations differ by only 0.8% (Cullasaja), 4.2% (Clinch at Cleveland) and 2.6% (Clinch above Tazewell). This is consistent with the findings of Matalas (1963), that over the period for which cumulative probabilities could be calculated, the Gumbel and Pearson Type III distributions were nearly coincident and equally representative of the cumulative probabilities.

The Cullasaja station, however, shows an $\underline{\epsilon}$ (Gumbel's predicted lower limit of flow) higher than the lowest recorded low flow, shown in Table 1. Matalas (1963) considers this evidence that the distribution is inappropriate for the data. He finds that, by chance, the one or two largest low flows in a record may deviate considerably from the next lower flows, causing an overestimate of the skewness and consequently an overestimate of the lower limit of flow. The highest low-flow in the Cullasaja record is much larger than the second highest, and might have caused such an overestimation of the predicted lower limit of flow. However, the one recorded low-flow which is below the predicted $\underline{\epsilon}$ is also considerably smaller than the next lowest low-flow. Because there is an impoundment above the gaging station, it is possible flows were artificially low for one year while the impoundment was being filled, creating an apparent inconsistency in the analysis. In either case, only the extremes of the distribution would be affected, and the estimate at the ten-year point, which is often of interest in energy related studies, would be reasonably accurate.

The three remaining stations are all downstream, at varying distances, of large, multipurpose dams and reservoirs. Their low-flow analyses all show greater anomalies than the single unexpectedly low value seen on the Cullasaja. In its 56-year record, Station 03584500 (Elk River near Prospect, TN) has five annual low flows below the ϵ lower limit predicted by the Gumbel's analysis. At the ten-year point, the low flows predicted by the four methods differ from each other by as much as 20%. Gumbel's analyses at Stations 03533000 (Clinch River below Norris Dam) and 03517850 (Tennessee River at S. Pittsburg, TN) show predicted lower limits of flow below zero. Both the Gumbel's and Pearson Type III analyses at 03533000 predicted negative flows for all return of ten years or longer. These clearly unrealistic results indicate that the analyses used are inappropriate and inapplicable to the data.

The flow-regulating dams and reservoirs constructed during the periods of record and located upstream of these three stations are sufficient to explain the irregular results. With regulation, yearly low flows no longer reflect natural variations, but some combination of the needs of flood control, navigation, recreation, and power production. When the low flows produced by regulation are added to a data set which had previously consisted of natural low flows, an inconsistent record and abnormal analyses result.

At stations where results from one or more analyses show anomalies which can be attributed to regulation, none of the predictions should be considered valid, for even if one distribution shows no unusual results, all of them were designed to be used with consistent data, and

predictions based on inconsistent records will be incorrect. In practice, regulation does occur on many stations on major streams, and the unusual LOFL02 results make it easy to detect them among numbers of other stations when all records from an area are being analyzed.

When no obvious inconsistencies are present, our examples agree with the observation of Sangal and Biswas (1970) that the results for most distributions are quite similar in the central part of the frequency curve. Because this central region contains the ten-year point so often of interest in large-scale regional studies, there will usually be no need to choose among the various distribution. If estimates for longer recurrence intervals are wanted, and the predicted flows have begun to differ, the predicted flows must be compared to the recorded flows and their probabilities as calculated by the plotting position equations. However, because there are fewer observations at extremely low flows to base both the predictions and the comparisons upon, as the return periods increase the possible error in all predictions also increases.

CONCLUSIONS

The LOFL02 module, when used as part of the ORNL Water Analysis System (Jalbert and Shepherd, 1977), can generate four different frequency distributions for the stations being examined. The most serious problems encountered in using WAS/LOFL02 to generate low-flow distributions were caused by inconsistent flow data. Though the system was not designed to detect inconsistencies, the results of the analyses indicate their occurrence in the records of most, if not all, regulated

streams. When streamflow records are consistent, all four LOFL02 analyses make similar predictions around the ten-year point that is often of special interest in energy-related studies, and there is no reason to prefer one over the others. When records are inconsistent, the predicted flows often differ greatly and the analyses may show such anomalies as negative predicted flows and predicted lower limits of flow greater than recorded flows. The greatest advantage of having several different analyses in the LOFL02 module is, rather unexpectedly, that it makes the system a screening device for detecting stations where none of the analyses can be considered valid because of reservoir development during the period of recorded flows.

More subtle changes which affect low-flow patterns may not be evident in LOFL02 results. Other techniques, such as time series analysis, should be investigated as a means of detecting gradual shifts in low-flow frequency distributions over time.

Since low-flow predictions are often needed on regulated streams, it would be useful to correct the data problems detected by LOFL02 analyses. The simplest means appears to be removing flows recorded prior to regulation and attempting LOFL02 analysis on the remaining record. Because it would be advantageous to use, rather than discard, the years of pre-regulation data, we intend to investigate the use of reservoir regulation models for generating consistent streamflow records.

LITERATURE CITED

- Bobee, B. 1975. The Log Pearson Type III distribution and its application in hydrology. Water Resources Research 11(5):681-689.
- Dobson, J. E., A. D. Shepherd, R. G. Palmer, and S. Chiu. 1977. A nationwide assessment of water quality impacts of the National Energy Plan. Volume 1: Summary and Conclusions. ORNL/TM-6098 (IRNL/OEPA-3). Oak Ridge National Laboratory, Oak Ridge, TN. 117 pp.
- Giusti, E. V., and E. L. Meyer. 1977. Water Consumption by Nuclear Power Plants and Some Hydrological Implications. Geological Survey Circular 745, U.S. Geological Survey, Arlington, VA 22202. 14 pp.
- Gumbel, E. J. 1954. Statistical theory of droughts. Proc. Am. Soc. Civil Engrs., Vol. 80, Separate No. 439. 17 pp.
- Habegger, L. J., A. J. Dvorok, and L. J. Hoover. 1977. A preliminary assessment of the health and environmental effects of coal utilization in the Midwest. Volume 1. Argonne National Laboratory, Argonne, IL (Draft).
- Harte, J., and Mohamed El-Gassier. 1978. Water and Energy. Science 199(4329):623-634.
- Jalbert, J. S., and A. D. Shepherd. 1977. A system for regional analysis of water availability. ORNL/NUREG/TM-82. Oak Ridge National Laboratory, Oak Ridge, TN. 97 pp.
- Matalas, N. C. 1963. Probability distribution of low-flows. Geological Survey Professional Paper 434-A. United States Government Printing Office, Washington, DC. 27 pp.

- Peterson, D. E., and J. C. Sonnichsen. 1976. Assessment of requirements for dry towers. HEDL-TME-76-82. Hanford Engineering Development Laboratory, Richland, WA. 256 pp.
- Riggs, H. C. 1972. Low-flow investigations: Chapter B1 of techniques of water resources investigations of the United States Geological Survey. United States Government Printing Office, Washington, DC. 18 pp.
- Samuels, G. 1976. Assessment of water resources for nuclear energy centers. ORNL-5097. Oak Ridge National Laboratory, Oak Ridge, TN. 99 pp.
- Sangal, B. P., and A. K. Biswas. 1970. The 3-parameter log-normal distribution and its applications in hydrology. Water Resources Research 6(2):505-515.
- U.S. Energy Research and Development Administration. 1977. Guidelines to the preparation of environmental reports for geothermal development projects. Division of Geothermal Energy. ERHQ-0001. 70 pp.
- U.S. Nuclear Regulatory Commission. 1976. Preparation of environmental reports for nuclear power plants. Reg. Guide 4.2, Rev. 2. NUREG-0099. 108 pp.
- Viessman, W., Jr., T. E. Harbaugh, and J. W. Knapp. 1972. Introduction to Hydrology. Intext Educational Publishers, NY. 415 pp.

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APPENDIX A

SELECT and LOFL02 Programs

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/*
/* THIS PROGRAM SCANS THE DAILY VALUES TAPE AND EXTRACTS
/* THE DATA FOR STATIONS THAT HAVE BEEN SELECTED BY THE
/* PDP-10 PROGRAM SEARCH. ONLY THE DATA FOR STREAMFLOW
/* IS PROCESSED. ALL OTHER TYPES OF INFORMATION ARE IGNORED.
/* THE PROGRAM PERFORMS THE FOLLOWING FUNCTIONS:
/* 1. TRANSFORMS THE DATA FROM MONTHLY MATRIX FORM
/* TO A SINGLE YEARLY VECTOR FORM WITH THE START
/* OF THE YEAR OCCURRING OCT #1.
/*
/* 2. CREATES A TABLE CONTAINING THE DATES OF THE WATER
/* YEARS WHICH ARE REPRESENTED IN THE DATA.
/*
/* 3. CREATES A TABLE INDICATING THE POSITION IN THE
/* FINAL OUTPUT LIST FOR THE START OF A GIVEN YEAR'S
/* DATA.
/*
/* 4. CREATES A TABLE OF THE NUMBER OF DAYS IN EACH YEAR'S
/* WORTH OF DATA
/*
/* 5. COMPUTES A TABLE OF THE ABSOLUTE LOFLOW DURING THE
/* YEAR. ALSO INCLUDED ARE 7-DAY AND 14-DAY LOWS. THESE
/* ARE INCLUDED ONLY FOR CONTIGUOUS SETS OF DATA
/* FOR 2 OR MORE YEARS.
/*
/* 6. COMPUTES FLOW LEVELS FOR A PREDETERMINED LIST OF
/* RECURRENCE LEVELS
/*
/* 7. COMPUTES AND PRINTS MONTHLY AVERAGE FLOWS FOR EACH
/* FULL MONTH'S WORTH OF DATA
/*
/* 8. PRINTS YEARLY HIGH AND LOW FLOWS
/*
/* 9. PRINTS YEARLY AVERAGE FLOWS
/*
/* 10. PRINTS HISTORICAL HIGH, LOW AND MEAN FLOWS
/*
/* 11. CREATES AN EBCDIC OUTPUT TAPE WITH THE DATA FOR
/* ALL COMPUTATIONS ABOVE. THIS TAPE MAY BE SENT TO
/* THE PDP-10 FOR FURTHER PROCESSING.
/*
/*****
1 /*****
/*
/* FORMAT OF THE OUTPUT TAPE:
/* THE FIRST 1000 BYTES CONTAIN THE FOLLOWING INFORMATION
/*
/* RECORD #1 IDENTIFICATION RECORD
/*
/* BYTE POSITION IDENTIFICATION
/* 1 - 8 DOWN STREAM ORDER NUMBER
/* 9 - 21 LATITUDE-LONGITUDE OR BLANK
/* 22 - 23 FIPS STATE CODE
/* 24 - 25 FIPS DISTRICT CODE
/* 26 - 28 FIPS COUNTY CODE
/* 29 - 30 SITE CODE
/* 31 - 78 STATION NAME
/* 79 - 87 DRAINAGE AREA PIC 9(7).9
/* 88 - 90 NUMBER OF YEARS IN THIS DATA
/*

```



```

/*          91 - 95          TOTAL NUMBER OF DAILY FLOWS          */
/*          96              IS 1 IF DAILY DATA IS ON TAPE        */
/*                          IS 0 IF NOT ON TAPE                     */
/*          97 -100          THE DAY OF YEAR USED FOR              */
/*                          THE WET SEASON                          */
/*                                                                */
/*          RECORD #2: WATER YEARS(STORED ON TAPE AS 4            */
/*                          BYTES 101 TO 500                      */
/*          BYTE POSITION      IDENTIFICATION                      */
/*          1 - 4             FIRST WATER YEAR                   */
/*          5 - 8             SECOND WATER YEAR                  */
/*          9 - 12           THIRD WATER YEAR                    */
/*                          ETC.                                   */
/*          397 -400         HUNDREDTH WATER YEAR                */
/*                                                                */
/*          RECORD #3: NUMBER OF DAYS(STORED ON TAPE AS           */
/*                          BYTES 501 TO 900                      */
/*          BYTE POSITION      IDENTIFICATION                      */
/*          1 - 4             NUMBER OF DAYS IN 1ST WATER YEAR   */
/*          5 - 8             NUMBER OF DAYS IN SECOND           */
/*                          ETC.                                   */
/*          397 -400         NUMBER IN HUNDREDTH YEAR            */
/*                                                                */
/*          RECORD #4: FLOWS AT FIXED RECURRENCE FREQUENCIES     */
/*                          BYTES 901 TO 1000                    */
/*                                                                */
/*          BYTE POSITION      IDENTIFICATION                      */
/*          1 - 10           FLOW EXCEEDED 99% OF THE TIME      */
/*          11 - 20          FLOW EXCEEDED 95% OF THE TIME      */
/*                          ETC.                                   */
/*          99 -100         FLOW EXCEEDED 70% OF THE TIME       */
/*                                                                */
/* ***** */
/* ***** */
/*          EACH OF THESE RECORDS IS 1000 BYTES LONG              */
/*                                                                */
/*          RECORD #5: LOW FLOWS (7 DAY)(STORED ON TAPE AS 10     */
/*                          CONSECUTIVE RECORDS                   */
/*          BYTE POSITION      IDENTIFICATION                      */
/*          1 - 10           LOW FLOW YEAR #1  PIC 9(9)V9        */
/*          11 - 20          LOW FLOW YEAR #2                    */
/*                          ETC.                                   */
/*          991 -1000       LOW FLOW YEAR #100                  */
/*                                                                */
/*          RECORD #6: LOW FLOWS (14 DAY)                          */
/*          SAME LAYOUT AS RECORD #4.                              */
/*                                                                */
/*          RECORD #7: LOW FLOWS (ABSOLUTE)                       */
/*          SAME LAYOUT AS RECORD #4.                              */
/*                                                                */
/*          RECORD #8: RECURRENCE FLOWS                          */
/*          BYTE POSITION      IDENTIFICATION                      */
/*          1 - 10           RESOLUTION (IN CFS) OF CALC.        */
/*          11 - 20          FLOW EXCEEDED 99% TIME              */
/*          21 - 30          TABLE OF FREQUENCIES IN PROC.      */
/*                          ETC.                                   */
/*          91 - 100        SHOULD BE CONSULTED FOR ALL         */
/*                          PIC 9(10)V                             */

```

```

/*
/*      RECORD #9: DAILY VALUES
/*      EACH DAY FOR WHICH DATA IS AVAILABLE HAS A SINGLE
/*      ENTRY IN THIS RECORD. EACH ENTRY IS 10 POSITIONS
/*      LONG WITH AN ASSUMED DECIMAL POINT TO THE LEFT OF
/*      THE LAST DIGIT.
/*
/*

```

```

/*****

```

```

1 DECLARE
1 DAILY_VALUES_RECORD BASED(BASE_DAILY),
  02 DELETE_CODE          CHAR(1),
  02 STATION_ID,
    03 FILLER              CHAR(7),
    03 DOWN_STREAM_NUMBER  CHAR(8),
  02 XSEC_LOCATOR          FLOAT(6),
  02 DEPTH_LOCATOR          FLOAT(6),
  02 PARAMETER_CODE        FIXED BIN(31),
  02 WATER_YEAR            FIXED BIN(15),
  02 STATISTIC_CODE        FIXED BIN(15),
  02 NO_VALUE_INDICATOR    FLOAT(6),
  02 DAILY_VALUES(12,31)  FLOAT(6),
  02 STATE_CODE            FIXED BIN(15),
  02 DISTRICT_CODE        FIXED BIN(15),
  02 STATION_NAME          CHAR(48),
  02 DRAINAGE_AREA         FLOAT(6),
  02 PROCESS_DATE         FIXED BIN(31),
  02 RESERVED              CHAR(52);

```

```

1 DECLARE
01 HEADER_RECORD BASED(BASE_HEADER),
  02 FILLER                CHAR(2),
  02 STATION_IDENT_NO,
    03 WELL_INFO           CHAR(7),
    03 ORDER_NUMBER        CHAR(8),
  02 LAT_LONG_SEQ,
    03 LATLONG             CHAR(13),
    03 SEQ                 CHAR(2),
  02 DRAINAGE_AREA         FLOAT(6),
  02 CODES,
    03 STATE               CHAR(2),
    03 DISTRICT            CHAR(2),
    03 COUNTY              CHAR(3),
    03 SITE                CHAR(2),
  02 STATION_NAME          CHAR(48),
  02 RESERVED_1            CHAR(2),
  02 AQUIFER_TYPE          CHAR(1),
  02 HYDROLOGIC_UNIT       FIXED BIN(31),
  02 CONTRIB_DRAIN_AREA    FLOAT(6),
  02 GAGE_DATUM            FIXED DEC(7,2),
  02 WELL_DEPTH            FLOAT(6),
  02 GEOLOGIC_UNIT         CHAR(8),
  02 RESERVED_2            CHAR(12);

```

```

1 DECLARE
01 IDENTIFICATION_RECORD,
  02 DOWN_STREAM_ORDER_NUMBER  CHAR(8),
  02 LATLON                    CHAR(13),
  02 CODES,
    03 STATE                   CHAR(2),
    03 DISTRICT                CHAR(2),

```

```

03 COUNTY
03 SITE
02 NAME
02 DRAINAGE
02 NUMBER_OF_YEARS
02 LAST_DAILY
02 DETAIL_INDICATOR
02 WET_DAY_VALUE
02 WATER_YEARS(100)
02 NUMBER_OF_DAYS(100)
02 FLW_RECOUR(10)
- DECLARE
01 RECORD_2,
02 POSITION(100)
02 FILLER
- DECLARE
01 RECORD_5,
02 LOW_FLOWS_1(100)
- DECLARE
01 RECORD_6,
02 LOW_FLOWS_7(100)
- DECLARE
01 RECORD_7,
02 LOW_FLOWS_30(100)
- DECLARE
01 RECORD_9,
02 DAILY_FLOW(100)
1 DECLARE
HEADER RECORD INPUT,
DAILY RECORD INPUT,
RESULT RECORD OUTPUT;
DECLARE
NUMBER
BASE_DAILY
BASE_HEADER
FLOWS(-32767:32767)
END_OF_HEADER_FILE
END_OF_DAILY_FILE
END_OF_REQUEST
STATION
WATER_FLOW
DATA_TO_BE_PRINTED
DRAIN_AREA
ABSMAX
ABSMIN
ABSSUM
BINS(0:1001)
FRACTION(9)

TOT_RECS
INCHES_OF_TAPE
CONTINUOUS_RECORD
DETAIL_TO_BE_TAPED
FLOW_POINTER
DIV
MISSING_POINTER
START_GAP(0:1200)

CHAR(3),
CHAR(2),
CHAR(48),
CHAR(9),
CHAR(3),
CHAR(5),
CHAR(1),
CHAR(4),
CHAR(4),
CHAR(4),
CHAR(10);

CHAR(6),
CHAR(400) INITIAL((400)' ');

CHAR(10);

CHAR(10);

CHAR(10);

CHAR(10); /* EDITED OUT . */

FIXED BIN(31),
POINTER,
POINTER,
FLOAT(6),
BIT(1) INITIAL('0'),
BIT(1) INITIAL('0'),
BIT(1) INITIAL('0'),
CHAR(8),
FIXED BIN(31) INITIAL (00060),
BIT(1) INITIAL('1'),
FLOAT(6),
FLOAT(6),
FLOAT(6),
FLOAT(6),
FIXED BIN(15),
FLOAT(6) INITIAL(.99,.95,
.92,.90,.85,.80,.75,.70,
.50),
FIXED BIN(31) INITIAL(0),
FLOAT(6),
BIT(1),
BIT(1),
FIXED BIN(31),
FIXED BIN(31),
FIXED BIN(31),
FIXED BIN(31),

```

```

LOW_FLOWS_14(100)          CHAR(10),
NO_YEARS_DATA              FIXED BIN(31),
END_GAP(0:1200)           FIXED BIN(31);
1  /*******
/*
/*      MAIN PROCEEDURE TO EXTRACT DATA FROM
/*      THE DAILY VALUES TAPES
/*
/*
/*
*****
/*
INITIALIZE:
OPEN FILE(HEADER) SEQUENTIAL RECORD INPUT;
OPEN FILE(DAILY) SEQUENTIAL RECORD INPUT;
OPEN FILE(RESULT) SEQUENTIAL RECORD OUTPUT;
ON ENDFILE(SYSIN) END_OF_REQUEST='1';
READ FILE(DAILY) SET(BASE_DAILY);
READ FILE(HEADER) SET(BASE_HEADER);
GET EDIT(I,J) (F(1),F(1)) SKIP;      /*THE FIRST CARD CONTAINS */
PUT SKIP LIST(I,J);
IF(I=0) THEN DATA_TO_BE_PRINTED='0';/*TWO SWITCHES WHICH ALLOW */
ELSE DATA_TO_BE_PRINTED='1';/*THE SYSTEM TO TURN OFF THE*/
IF(J=0) THEN DETAIL_TO_BE_TAPED='0';/*PRINTING OF THE DAILY VALU*/
ELSE DETAIL_TO_BE_TAPED='1';/*ON THE OUTPUT TAPE */
GET EDIT(STATION) (A(8)) SKIP;
MAJOR_LOOP:
DO WHILE (END_OF_REQUEST);
DO WHILE (STATION > ORDER_NUMBER);      /*GET HEADER FILE REC */
READ FILE(HEADER) SET(BASE_HEADER); /*FOR THIS STATION */
END;
IF (STATION = ORDER_NUMBER)
THEN
PUT SKIP(5) EDIT (STATION, 'NOT FOUND IN HEADER FILE')
(X(3),A(8),X(2),A(24));
ELSE DO;
DO WHILE(STATION>DOWN_STREAM_NUMBER);
READ FILE(DAILY) SET(BASE_DAILY);
END;
DO WHILE
((STATION=DOWN_STREAM_NUMBER)&(PARAMETER_CODE= WATER_FLOW));
READ FILE(DAILY) SET(BASE_DAILY);
END;
IF (STATION = DOWN_STREAM_NUMBER)
THEN
PUT SKIP(5) EDIT (STATION, 'HAS NO DAILY_VALUES RECORDS ')
(X(3),A(8),X(2),A(29));
ELSE DO;      /*PROCESS FIRST RECORD FOR */
CALL NEW_STATION; /*THIS STATION THEN DO ALL */
CALL PROCESS_YEAR; /*THE OTHER FLOW RECORDS */
READ FILE(DAILY) SET(BASE_DAILY);
DO WHILE (STATION = DOWN_STREAM_NUMBER);
IF (PARAMETER_CODE = WATER_FLOW) THEN
CALL PROCESS_YEAR;
READ FILE(DAILY) SET(BASE_DAILY);
END;
CALL FLOW_FREQUENCY;
CALL PROCESS_FINAL; /*ALL FLOWS DONE FOR STA NOW */
CALL OUTPUT_DATA; /*DO LAST DETAILS AND OUTPUT */
END;      /*RESULTS FOR THIS STATION */

```

```

      END;
      GET EDIT(STATION) (A(8)) SKIP;
    END;
1 FINAL_ACTIONS:
  CLOSE FILE(HEADER),FILE(DAILY),FILE(RESULT);
  PUT SKIP(10) LIST('ALL DATA IN INPUT FILE EXHAUSTED');
  PUT SKIP EDIT('TOTAL NUMBER OF LOGICAL RECORDS =',TOT_RECS)
    (A(33),F(7));
  INCHES_OF_TAPE=(TOT_RECS/4+1)*5.7;
  PUT SKIP EDIT(INCHES_OF_TAPE,' INCHES OR ',
    INCHES_OF_TAPE/12+1,' FEET OF TAPE USED')
    (F(7,1),A(11),F(4),A(18));

  STOP;
1 /*****
  /*
  /* PROCEDURES DEFINED ARE:
  /* 1.NEW_STATION  INITIALIZES ALL DATA AREAS TO ACCEPT A
  /*                  NEW STATION. ALSO BUILDS I.D. RECORD
  /*
  /*
  /* 2.PROCESS_YEAR  COMPUTES AND PRINTS MONTHLY AVERAGES AND
  /*                  INSERTS YEARLY VALUES INTO TABLES
  /*
  /*
  /* 3.PROCESS_FINAL  COMPLETES ALL CALCULATIONS ON THE DATA
  /*                  IN CORE AND FINISHES THE OUTPUT TABLES
  /*
  /*
  /* 4.LOW_FLOWS      COMPUTES N DAY LOW FLOWS AND STORES
  /*                  ALL RESULTS IN PASSED ARGUMENTS
  /*
  /*
  /* 5.OUTPUT_DATA    WRITES ALL DATA ONTO THE OUTPUT FILE
  /*                  RECORDS 1 THROUGH 7 ARE WRITTEN IMMEDIATELY
  /*                  MULTIPLE RECORD 8'S ARE CREATED
  /*                  TO HOLD ALL FLOW DATA. DECIMAL POINTS ARE
  /*                  EDITED OUT IN ORDER TO INCREASE PACKING
  /*                  DENSITY OF DATA. THE OUTPUT FORMAT IS
  /*                  9(7)V9.
  /*
  /* 6. FLOW_FREQUENCY PREPARES A TABLE OF FLOWS WHICH ARE
  /*                  EXCEEDED GIVEN FRACTIONS OF THE TIME
  /*
  /*
  /*
  /* *****/
1 NEW_STATION: PROCEDURE;
  FLOW_POINTER=-32768;
  MISSING_POINTER=0;
  NUMBER=0;
  DOWN_STREAM_ORDER_NUMBER=ORDER_NUMBER; /* SET UP THE IDENTIFICATION
  LATLON=LATLONG; /* RECORD FROM INPUT FILES*/
  IDENTIFICATION_RECORD.CODES=HEADER_RECORD.CODES;
  NAME=HEADER_RECORD.STATION_NAME;
  DRAIN_AREA=HEADER_RECORD.DRAINAGE_AREA;
  IF(DRAIN_AREA=0) THEN
    DRAIN_AREA=DAILY_VALUES_RECORD.DRAINAGE_AREA;
  IF(DRAIN_AREA<0) THEN DRAIN_AREA=0;
  PUT STRING(DRAINAGE) EDIT(DRAIN_AREA) (P'99999999V9');
  WATER_YEARS(*)='0000';
  NUMBER_OF_DAYS(*)='0000';
  POSITION(*)='00000';
  LOW_FLOWS_1(*)='999999999';
  LOW_FLOWS_7(*)='999999999';

```

```

LOW_FLOWS_14(*)='999999999';
LOW_FLOWS_30(*)='999999999';
FLOW_RECOUR(*)='0000000000';
IF(DATA_TO_BE_PRINTED) THEN DO;
  PUT PAGE EDIT(ORDER_NUMBER,NAME,LATLONG)
    (A(8),X(3),A(48),X(12),A(13));
  PUT SKIP EDIT('DRAINAGE AREA = ',DRAIN_AREA,'CODES = ',
    IDENTIFICATION_RECORD.CODES)
    (A(16),F(9,1),X(5),A(7),A(2),X(1),A(2),X(1),
    A(3),X(1),A(2));
  PUT SKIP EDIT('YEAR','OCT','NOV','DEC','JAN','FEB','MAR',
    'APR','MAY','JUN','JUL','AUG','SEP')
    (A(4),X(2),(12)(X(2),A(3),X(3)));
  PUT EDIT('DAYS','AVERAG','MAX','MIN')
    (X(3),A(3),X(3),A(6),X(5),A(3),X(5),A(3));
END;
ABSMAX=0;
ABSMIN=1.0E30;
ABSSUM=0;
CONTINUOUS_RECORD='1';
IF(DETAIL_TO_BE_TAPED) THEN DETAIL_INDICATOR='1';
ELSE DETAIL_INDICATOR='0';

END NEW_STATION;
1 PROCESS_YEAR: PROCEDURE;
  DECLARE MIN/
    MAX
    TOTAL
    DAYS
    NO_DAYS_MONTH(12)
    INITIAL(31,28,31,30,31,30,31,31,30,31,30,31);
  IF(DATA_TO_BE_PRINTED) THEN
    PUT SKIP EDIT(WATER_YEAR) (F(4));
  TOTAL=0;
  DAYS=0;
  MAX=0;
  MIN=1.0E30;
  DO I=10 TO 12, 1 TO 9;
    SUM=0;
    N=0;
    DO J=1 TO 31;
      IF(DAILY_VALUES(I,J)~NO_VALUE_INDICATOR) THEN DO;
        SUM =SUM + DAILY_VALUES(I,J);
        N= N + 1;
        FLOW_POINTER=FLOW_POINTER+1;
        FLOWS(FLOW_POINTER) = DAILY_VALUES(I,J);
        IF (MAX < DAILY_VALUES(I,J)) THEN MAX=DAILY_VALUES(I,J);
        IF (MIN > DAILY_VALUES(I,J)) THEN MIN=DAILY_VALUES(I,J);
      END;
    END;
  END;
  IF(N >=NO_DAYS_MONTH(I))
    THEN DO;
    IF(DATA_TO_BE_PRINTED) THEN PUT EDIT(SUM/N) (F(8,1));
    END;
    ELSE DO;
    IF(DATA_TO_BE_PRINTED)
      THEN PUT EDIT('*** ') (X(4),A(4));
    MISSING_POINTER=MISSING_POINTER+1;
    START_GAP(MISSING_POINTER)=FLOW_POINTER+1-N;
  
```

```

        END_GAP(MISSING_POINTER)=FLOW_POINTER+1;
    END;
    DAYS=DAYS+N;
    TOTAL=TOTAL + SUM;
END;
IF(DATA_TO_BE_PRINTED)
    THEN PUT EDIT(DAYS,TOTAL/DAYS,MAX,MIN) (X(2),F(3),F(9,1),
                                                F(10,1),F(8,1));

NUMBER=NUMBER+1;
PUT STRING(NUMBER_OF_DAYS(NUMBER)) EDIT(DAYS) (P'9999');
PUT STRING(POSITION(NUMBER)) EDIT(FLOW_POINTER) (P'S999999');
PUT STRING(WATER_YEARS(NUMBER)) EDIT(WATER_YEAR) (P'9999');
IF(MAX>ABSMAX) THEN ABSMAX=MAX;
IF(MIN<ABSMIN) THEN ABSMIN=MIN;
ABSSUM=ABSSUM+TOTAL;
END PROCESS_YEAR;
1PROCESS_FINAL: PROCEDURE;
DECLARE
    SUM                                FLOAT(6) INITIAL(0);
    MIN                                FLOAT(6) INITIAL(999999);
    DAY                                FIXED BIN(31);
    ONE                                FIXED BIN(31) INITIAL(1);
    SEVEN                              FIXED BIN(31) INITIAL(7);
    FOURTEEN                          FIXED BIN(31) INITIAL(14);
    THIRTY                            FIXED BIN(31) INITIAL(30);
    YEAR                                FIXED BIN(31);
    LONG_DUR                          FIXED BIN(31);
    IS                                 FIXED BIN(15);
    DIFF                              FIXED BIN(31);
    START_POINTER                     FIXED BIN(31);
    END_POINTER                       FIXED BIN(15);
    YEAR_DAY                          FIXED BIN(31);
    NOT_ENOUGH_DATA                   FIXED BIN(15) INITIAL(0);
    NOT_ENOUGH_DATA=0;
    IF(MISSING_POINTER=0) THEN DO;
        START_POINTER=-32767;
        END_POINTER=FLOW_POINTER;
    END;
    ELSE DO;
        MISSING_POINTER=MISSING_POINTER+1;
        START_GAP(MISSING_POINTER)=FLOW_POINTER;
        END_GAP(MISSING_POINTER)=FLOW_POINTER;
        LONG_DUR=0;
        IF(START_GAP(1)>-32767) THEN DO;
            END_GAP(0)=-32767; IS=1; END;
        ELSE IS=2;
        DO I=IS TO MISSING_POINTER;
            DIFF=START_GAP(I)-END_GAP(I-1);
            IF(DIFF>LONG_DUR) THEN DO;
                LONG_DUR=DIFF;
                START_POINTER=END_GAP(I-1);
                END_POINTER=START_GAP(I);
            END;
        END;
        IF(ABS(LONG_DUR)<730) THEN NOT_ENOUGH_DATA=1;
    END;
    IF(NOT_ENOUGH_DATA=1) THEN DO;
        DO I=START_POINTER TO START_POINTER+6;

```

```

SUM=SUM+FLOWS(I);
END;
DO I=START_POINTER+7 TO END_POINTER;
  IF(MIN>SUM) THEN DO;
    MIN=SUM;DAY=I;END;
  SUM=SUM-FLOWS(I-7)+FLOWS(I);
END;
I=1;
DO WHILE(POSITION(I)<DAY);
  I=I+1;
END;
DAY=DAY-POSITION(I)+NUMBER_OF_DAYS(I);
YEAR_DAY=DAY+182;
IF(YEAR_DAY>365) THEN YEAR_DAY=YEAR_DAY-365;
CALL LOW_FLOWS(LOW_FLOWS_1,ONE,DAY,YEAR_DAY);
CALL LOW_FLOWS(LOW_FLOWS_7,SEVEN,DAY,YEAR_DAY);
CALL LOW_FLOWS(LOW_FLOWS_14,FOURTEEN,DAY,YEAR_DAY);
CALL LOW_FLOWS(LOW_FLOWS_30,THIRTY,DAY,YEAR_DAY);
PUT STRING(WET_DAY_VALUE) EDIT(YEAR_DAY) (P'9999');
PUT STRING(NUMBER_OF_YEARS) EDIT(NUMBER) (P'999');
PUT STRING(LAST_DAILY) EDIT(POSITION(NUMBER)) (P'999999');
END;
ELSE DO;
  PUT SKIP(2) LIST
  ('NOT ENOUGH DATA TO COMPUTE THE WET DAY VALUE');
  PUT SKIP(2);
  WET_DAY_VALUE='0000';
  CONTINUOUS_RECORD='0';
END;
END PROCESS_FINAL;
LOW_FLOWS: PROCEDURE(OUTPUT_ARRAY,NDAYS,START_DAY,YEAR_DAY);
  DECLARE
    OUTPUT_ARRAY(100)          CHAR(10),
    NDAYS                      FIXED BIN(31),
    START_DAY                  FIXED BIN(31),
    START_YEAR                  FIXED BIN(31),
    SUM                        FLOAT(6) INITIAL(0),
    BASE_DAY                   FIXED BIN(31),
    LOW                        FLOAT(6),
    IDAY                       FIXED BIN(31) INITIAL(-32877),
    YEAR_DAY                   FIXED BIN(31),
    START_SUM                   FIXED BIN(31),
    END_SUM                     FIXED BIN(31),
    NO_DATA                     FIXED BIN(31) INITIAL(9999999999);
    M=1;
    NO_YEARS_DATA=0;
  DO I= 2 TO NUMBER;
    NOT_ENOUGH_DATA=0;
    IF(MISSING_POINTER=0) THEN DO;
      START_SUM=POSITION(I)-YEAR_DAY-NUMBER_OF_DAYS(I);
      END_SUM=START_SUM+NUMBER_OF_DAYS(I)-NDAYS;
    END;
    ELSE DO;
      BASE_DAY=POSITION(I)-START_DAY-NUMBER_OF_DAYS(I);
      DO WHILE(END_GAP(M)<BASE_DAY);
        M=M+1;END;
      IF(START_GAP(M)<BASE_DAY) THEN NOT_ENOUGH_DATA=1;
      IF(NUMBER_OF_DAYS(I)<200) THEN NOT_ENOUGH_DATA=1;

```



```

START_SUM=MAX(END_GAP(M-1),BASE_DAY-182);
END_SUM=MIN(START_GAP(M),BASE_DAY+182);
END_SUM=END_SUM-NDAYS;
IF(START_SUM>BASE_DAY-100 ) THEN NOT_ENOUGH_DATA=1;
IF(END_SUM<BASE_DAY+100) THEN NOT_ENOUGH_DATA=1;
END;
IF(NOT_ENOUGH_DATA=0) THEN DO;
  NO_YEARS_DATA=NO_YEARS_DATA+1;
  SUM=0;
  DO J= 0 TO      NDAYS-1;
    SUM = SUM + FLOWS(J+START_SUM);
  END;
  LOW = 1.0E30;
  DO J =START_SUM TO END_SUM;
    IF(LOW > SUM) THEN DO; IF(J >IDAY+100)
                          THEN DO;LOW =SUM;JDAY=J;
    END;
  END;
  SUM = SUM-FLOWS(J)+FLOWS(J+NDAYS);
END;
IDAY=JDAY;
/*SET THE DAY OF LOW FLOW */
/*THE LAST YEAR TO FORCE */
/*LOW FLOWS NEXT SEASON */
PUT STRING (OUTPUT_ARRAY(1)) EDIT(LOW/NDAYS) (P'999999999V9');
END;
ELSE DO;
  PUT STRING(OUTPUT_ARRAY(1)) EDIT(NO_DATA) (P'999999999V9');
END;
END;
END LOW_FLOWS;
1OUTPUT_DATA: PROCEDURE;
IF(DATA_TO_BE_PRINTED) THEN DO;
  PUT SKIP(2) EDIT('MAXIMUM FLOW:',ABSMAX,'MINIMUM FLOW:',ABSMIN)
    (A(13),F(10,1),X(3),A(14),F(10,1));
  DIV=FLOW_POINTER+32768;
  PUT EDIT('OVERALL AVERAGE:',ABS(ABSSUM/DIV))
    (X(3),A(16),F(10,1));
  IF(CONTINUOUS_RECORD) THEN DO;
    PUT SKIP EDIT(' NUMBER OF YEARS WITH ENOUGH DATA FOR LOW FLOW',
      'CALCULATIONS IS',NO_YEARS_DATA)
      (A(50),A(16),F(7,0));
    PUT SKIP(2) LIST('LOW FLOWS:');
    PUT SKIP LIST('      1-DAY','      7-DAY',
      '      14-DAY','      30-DAY');
    DO I=1 TO NUMBER;
      PUT SKIP EDIT(LOW_FLOWS_1(I),LOW_FLOWS_7(I),
        LOW_FLOWS_14(I),LOW_FLOWS_30(I))
        ((3)(P'ZZZZZZZZ9.9',X(10)));
    END;
  END;
  PUT SKIP(2) LIST('FLOW RECURRENCE:');
  PUT SKIP LIST('FRACTION','FLOW');
  DO I=2 TO 10;
    PUT SKIP EDIT(FRACTION(I-1),FLOW_RECOUR(I))
      (F(3,2),X(15),P'ZZZZZZZZ9.9');
  END;
END;
WRITE FILE(RESULT) FROM(IDENTIFICATION_RECORD);

```

```

WRITE FILE(RESULT) FROM(RECORD_5);
WRITE FILE(RESULT) FROM(RECORD_6);
WRITE FILE(RESULT) FROM(RECORD_7);
NO_RECS=4;
IF(DETAIL_TO_BE_TAPED) THEN DO;
  I=(32767+FLOW_POINTER)/100;          /*GET THE NUMBER OF FULL */
  J=-32767;                             /*BLOCKS OF DATA TO WRITE */
  DO II=1 TO I;                          /*BUILD 1 RECORD OF DATA */
    DO K = 1 TO 100;
      PUT STRING(DAILY_FLOW(K)) EDIT(FLOWS(J)) (P'999999999V9');
      J=J+1;
    END;
    WRITE FILE(RESULT) FROM(RECORD_9);
  END;
  K=1;                                  /*NOW DO THE LAST BLOCK */
  DO I= J TO FLOW_POINTER;
    PUT STRING(DAILY_FLOW(K)) EDIT(FLOWS(I)) (P'999999999V9');
    K=K+1;
  END;
  DO I=K,100;                           /*FILL REMAING BLOCK WITH ZERO*/
    DAILY_FLOW(I)='0000000000';
  END;
  WRITE FILE(RESULT) FROM(RECORD_9); /*WRITE LAST RECORD */
  NO_RECS = 4+ FLOW_POINTER/100 +1;
END;
TOT_RECS=TOT_RECS+NO_RECS;
PUT SKIP(2) LIST('NUMBER OF OUTPUT TAPE RECORDS = ');
PUT EDIT (NO_RECS) (F(4));              /*REPORT # TAPE RECORDS */
END OUTPUT_DATA;
1 FLOW_FREQUENCY: PROCEDURE;
  DECLARE
    FLOW_VALUE          FLOAT(6),
    INCREMENT           FLOAT(6);
  BINS(*)=0;
  INCREMENT=ABSMAX/2000;
  PUT STRING(FLOW_RECOUR(1)) EDIT(INCREMENT) (P'999999999V999');
  DO I=-32767 TO FLOW_POINTER;          /******
    L=(FLOWS(I)-ABSMIN)/INCREMENT; /* GET THE DISTRIBUTION OF */
    IF(L > 1000) THEN L=1000;          /* THE OBSERVED FLOWS FOR THE*/
    BINS(L)=BINS(L)+1;                 /* STATION */
  END;                                  /******
  DO I=1000 TO 0 BY -1;                 /*AND GENERATE THE CUMULATIVE*/
    BINS(I)=BINS(I)+BINS(I+1);          /*RECURRENCE FUNCTION */
  FND;                                  /******
  J=0;
  DO I= 1 TO 9;
    DO WHILE((BINS(J)>FRACTION(I)*(FLOW_POINTER+32767))&(J<1001));
      J=J+1;
    END;
    FLOW_VALUE=ABSMIN+J*INCREMENT;
    PUT STRING(FLOW_RECOUR(I+1)) EDIT (FLOW_VALUE) (P'999999999V9');
  END;
  END FLOW_FREQUENCY;
1 END DAILY_SELECT;

```

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LOFLOW PROGRAM

PURPOSE:

THIS PROGRAM SERVES AS THE MAINLINE PROGRAM THAT DRIVES THE
LOW FLOW ANALYSIS SUBSYSTEM.

MODES:

THE OPTIONS THAT ARE AVAILABLE ARE--

1. CUMULATIVE FREQUENCY ANALYSIS
 BIAS PROVIDED BY SIMPLE STATISTICS
 BIAS PROVIDED BY THOMAS' INTERPOLATION
2. GUMBEL'S DISTRIBUTION

PRESENTATION OF RESULTS:

THE FOLLOWING MODES FOR PRESENTING RESULTS MAY BE USED.

ONCE A MODE HAS BEEN CHOSEN IT IS USED FOR ALL ANALYSES

1. STATISTICAL PARAMETERS TYPED ON TTY
2. STATISTICAL PARAMETERS WRITTEN ON THE LOG FILE
3. FLOWS AT DIFFERENT RECURRENCE INTERVALS WRITTEN ON TTY
4. FLOWS AT DIFFERENT RECURRENCE INTERVALS WRITTEN ON LOG FILE
5. TTY PLOT MADE OVER THE OBSERVED RANGE OF THE DATA
6. CALCOMP PLOT MADE OVER THE OBSERVED RANGE OF THE DATA

STATIONS USED:

THERE ARE TWO BASIC MODES FOR SELECTING THE STATIONS THAT ARE
TO BE USED IN THE ANALYSIS

1. ANALYSIS FOR A SELECTED LIST OF STATIONS
2. ANALYSIS FOR ALL STATIONS IN THE DATASET

ASSUMPTIONS:

THE INPUT DATA IS ALWAYS IN THE FORMAT GENERATED BY THE DAILY
SELECT PROGRAM WITH RECORDS AS COMPACTED BY THIS SYSTEM.

COMMENTS:

THREE LOW FLOWS ARE IMBEDDED IN THE INPUT DATA. AT PRESENT THIS
PROGRAM CAN PROCESS ONLY THE 7 DAY FLOWS. THIS MAY BE CHANGED
BY A SIMPLE MODIF. TO THE SUBROUTINE FINDST.

SUBROUTINES CALLED:

FINDST, CUMPRO, GUMPRO,
PTSTAT, PTRECU, TTYPLO, CALCOM, STORIT

.....
.....
.....

* COMMON DEFINITIONS

.....

COMMON GUMPAR/XMEAN, STDDEV, REDMON, XKURT, ALPHA, EPSLON, UDROUT, ERROR/

DESCRIPTION:

XMEAN = DOUBLE PRECISION IS MEAN OF THE INPUT DATA
STDDEV = DOUBLE PRECISION STANDARD DEVIATION OF THE INPUT DATA

```

C      REDMOM = DOUBLE PRECISION  SKEWNESS OF THE INPUT DATA
C      XKURT  = DOUBLE PRECISION  KURTOSIS OF THE INPUT DATA
C      ALPH   = SINGLE PRECISION  GUMBEL'S ALPHA
C      EPSLON = SINGLE PRECISION  GUMBEL'S EPSILON
C      UDKOUT = SINGLE PRECISION  GUMBEL'S U
C      ERROR  = LOGICAL VARIABLE  SET TO TRUE IF THE SKEWNESS IS
C                                  LESS THAN -1.081272 OR IF THE
C                                  SKEWNESS IS GREATER THAN 190.0
C
C      .....
C
C      COMMON /CUMPAR/FLO(4,10)
C      FLO IS A MATRIX CONTAINING FLOWS PREDICTED BY THE SIMPLE
C      CUMULATIVE STATISTICS FOR THE RECURRENCE INTERVALS STORED IN THE
C      COMMON AREA RECOUR. THE FIRST INDEX SELECTS THE DISTRIBUTION
C      METHOD:
C          1 = ACTUAL OBSERVED FLOW
C          2 = INTERPOLATED FLOW
C          3 = ACTUAL THOMAS OBSERVED
C          4 = INTERPOLATED THOMAS FLOW
C      THE SECOND INDEX SELECTS WHICH OF THE 10 INTERVALS WAS USED
C
C      .....
C
C      COMMON /RECOUR/TR(10)
C      THIS IS ESTABLISHED BY THE BLOCK DATA SUBROUTINE. IT CONTAINS
C      10 VALUES THAT ARE USED AS THE STANDARD RECURRENCE
C      INTERVALS THROUGHOUT THE SYSTEM
C
C      .....
C
C      INTEGER Y, ISTATN(100,8)
C      LOGICAL ALL, ANALYS(10), TYPE, PRINT, FOUND, REPORT(10)
C      COMMON /RECOUR/TR(10)
C      COMMON FLOWS(100), ASCII(78)
C      DATA ALL, ANALYS, TYPE, PRINT, FOUND, REPORT/24*.FALSE./
C      DATA Y/'Y'/
C
C      THIS SECTION ALLOWS THE USER TO SELECT HIS MENU
C
400  CONTINUE
      TYPE 10
10  FORMAT(' PROGRAM TO ANALIZE STATIONS BY LOW FLOW CRITERIA',/,
1    ' DO YOU WISH TO ANALIZE ALL STATIONS IN THE INPUT FILE?')
      ACCEPT 20, INPUT
20  FORMAT(A1)
      IF(INPUT.EQ.Y) ALL=.TRUE.
      IF(ALL) GO TO 80
      TYPE 30
30  FORMAT(' HOW MANY STATIONS DO YOU WISH TO SELECT (2 DIGITS)?')
      ACCEPT 40, NSTAS
40  FORMAT(I2)
      TYPE 50
50  FORMAT(' TYPE STATION NUMBERS AS 8 DIGIT ENTRIES - ONE PER LINE')
      DO 70 I=1, NSTAS
      ACCEPT 60, (ISTATN(I,J), J=1,8)
60  FORMAT(8A1)

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```

70 CONTINUE.
80 TYPE 90
90 FORMAT(' THE FOLLOWING ANALYSES ARE AVAILABLE:',/,
1      ' 1.CUMULATIVE PROBABILITY',/,
2      ' 2.GUMBELS THREE PARAMETER DISTRIBUTION',/,
3      ' 3.PEARSON TYPE III DISTRIBUTION',/,
4      ' 4.LOG-PEARSON TYPE III DISTRIBUTION',/,
5      ' 5.LOG-NORMAL DISTRIBUTION')
      TYPE 100
100 FORMAT(/, ' TYPE DIGITS REPRESENTING THE DESIRED ANALYSES',/,
1      ' (ONE PER LINE)', ' 0 TERMINATES THE LIST',/)
110 ACCEPT 120,I
120 FORMAT(I1)
      IF(I.EQ.0)GO TO 130
      ANALYS(I)=.TRUE.
      GO TO 110
130 TYPE 140
140 FORMAT(' DO YOU WISH OUTPUT DIRECTED TO YOUR TERMINAL?')
      ACCEPT 20,INPUT
      IF(INPUT.EQ.Y)TYPE=,TRUE.
      TYPE 150
150 FORMAT(' DO YOU WISH OUTPUT DIRECTED TO A LOG FILE?')
      ACCEPT 20,INPUT
      IF(INPUT.EQ.Y)PRINT=,TRUE.
      TYPE 160
160 FORMAT(' THE FOLLOWING REPORTS MAY BE SELECTED',/,
1      ' 1. PRINT STATISTICS BY DISTRIBUTION',/,
2      ' 2. PRINT RECURRENCE TABLES',/,
3      ' 3. PRINT TTY PLOTS',/,
4      ' 4. GENERATE CALCOMP PLOTTER FILES',/,
5      ' 5. STORE STATION PARAMETERS AND NAME IN SAVE FILE')
      TYPE 170
170 FORMAT(/, ' ENTER SELECTIONS, 0 TERMINATES THE LIST')
180 ACCEPT 120,INPUT
      IF(INPUT.EQ.0)GO TO 300
      REPORT(INPUT)=.TRUE.
      GO TO 180

C
C   THE PROGRAM DESCRIPTION IS NOW COMPLETE.
C   NOW PROCESS EACH STATION AND PERFORM THE APPROPRIATE ANALYSES
C   UPON IT.
C
300 CALL FINDST(ASCII,FLOWS,NSTAS,NYEARS,FOUND,ALL,ISTATN)
      IF(.NOT.FOUND)GO TO 310
      IF(ANALYS(1))CALL CUMPRO(FLOWS,NYEARS)
      IF(ANALYS(2))CALL GUMPRO(FLOWS,NYEARS)
      IF(ANALYS(3))CALL PRSN3(FLOWS,NYEARS)
      IF(ANALYS(4))CALL LOGDST(FLOWS,NYEARS,.TRUE.)
      IF(ANALYS(5))CALL LOGDST(FLOWS,NYEARS,.FALSE.)
C   SORT THE DATA INTO DESCENDING ORDER IF NOT DONE SO
C   ALREADY. THIS IS NEEDED FOR MOST REPORTS
      IF(.NOT.ANALYS(1))CALL SORT(FLOWS,NYEARS,.FALSE.)
      IF(.NOT.TYPE)GO TO 305
      M=-1
      IF(REPORT(1))CALL PTSTAT(FLOWS,NYEARS,ANALYS,ASCII,M)
      IF(REPORT(2))CALL PTRECU(FLOWS,NYEARS,ANALYS,M)
      IF(REPORT(3))CALL TYPLO(FLOWS,NYEARS,ANALYS,M)
305 IF(.NOT.PRINT)GO TO 307

```

```

      M=10
      IF(REPORT(1)) CALL PTSTAT(FLOWS,NYEARS,ANALYS,ASCII,M)
      IF(REPORT(2)) CALL PTRECU(FLOWS,NYEARS,ANALYS,M)
      IF(REPORT(3)) CALL TYPLO(FLOWS,NYEARS,ANALYS,M)
307  CONTINUE
      IF(REPORT(4)) CALL CALCOM(FLOWS,NYEARS,ANALYS)
      IF(REPORT(5)) CALL STORIT(ANALYS,ASCII)
      GO TO 300
310  TYPE 320
320  FORMAT(' STATION NOT FOUND OR NORMAL TERMINATION')
      TYPE 401
401  FORMAT(' DO YOU WISH TO REPROCESS STATIONS BEFORE EXITING?')
      ACCEPT 402,NAGAIN
402  FORMAT(A1)
      IF(NAGAIN.NE.'Y') GO TO 403
      END FILE (20)
      TYPE=.FALSE.
      PRINT=.FALSE.
      DO 404 KK=1,10
      ANALYS(KK)=.FALSE.
404  REPORT(KK)=.FALSE.
C    IT IS NECESSARY TO RE-INITIALIZE THE OUTPUT OPTIONS FOR RE-RUN
      GO TO 400
403  CONTINUE
      STOP
      END

C
C .....
C
C BLOCK DATA SUBROUTINE
C
C PURPOSE:
C   TO INITIALIZE SOME COMMON AREAS
C
C .....
C
C BLOCK DATA
C DIMENSION TR(10)
C COMMON /RECOUR/TR
C DATA TR/1.1,2.0,3.0,5.0,10.0,20.0,25.0,30.0,40.0,50.0/
C END

C
C .....
C
C CALCOM(D,N,ANALYS)
C
C PURPOSE:
C   TO GENERATE CALCOPM PLOTS FO THE CUMULATIVE PROBABILITY
C   FUNCTIONS OF THE GUMBEL AND THOMAS DISTRIBUTIONS
C
C ASSUMPTIONS:
C   THE INPUT FLOW DATA IS IN ARRAY D, SORTED IN DESCENDING ORDER
C   WITH N ACTIVE ELEMENTS. THE SUBROUTINE GUMBEL HAS BEEN CALLED
C   TO COMPUTE THE PARAMETERS OF THE GUMBEL DISTRIBUTION.
C
C CALLED ROUTINES:
C   THIS PROGRAM MAKES USE OF THE INTRIGUE II SUBROUTINE PLOTTING
C   LIBRARY, AVAILABLE AT ORNL.

```

```

C
C
C
.....
SUBROUTINE CALCOM(D,N,ANALYS)
  DIMENSION D(N)
  LOGICAL ANALYS(10),ERRORG
  DIMENSION V(100),A(7)
  DOUBLE PRECISION XMEAN,STDDEV,REDMOM,XKURT
  COMMON /GUMPAR/XMEAN,STDDEV,REDMOM,XKURT,ALPH,EPSLON,UDROUT,ERRORG
  COMMON /CRPA/ICRT,IPAPER

C
C
C
  INITIALIZE THE PROGRAM

  ICRT=1
  IPAPER=1
  A(7)=5.
  MAX=D(1)
  I=1
10 IF(MAX/10**I.LT.10)GO TO 20
  I=I+1
  GO TO 10
20 I=I-1
  MULT=10**I
  DELX=FLOAT((MAX/MULT + 1)*MULT)/10.
  CALL SEMLOG(3,0,0,0,DELX,10,-7,0,2,A)

C
C
C
  NOW LETTER THE AXES

  CALL LETTER(0,20,20HCUM PROB. VS LOWFLOW,A)
  CALL LETTER(1,9,9HFLOW(CFS),A)
  CALL LETTER(2,22,22HCUMULATIVE PROBABILITY,A)

C
C
C
  NOW COMPUTE THE CUMULATIVE PROBABILITY VIA THOMAS
  METHOD AND PLOT JUST THE POINTS

  DO 30 I=1,N
  PROB=FLOAT((3*N+1)*(N-I)+2)/FLOAT(3*(N*N-1))
  IF(PROB.LE.0)GO TO 35
  CALL POINT(I,D(I),PROB,0,0,0,0,0,1,A)
30 CONTINUE
35 CALL SUBTLE(26,26H.....THOMAS' SIMPLE PROB ,4,0,0,5,A)

C
C
C
  NOW PLOT THE GUMBEL DISTRIBUTION. 100 POINTS ARE PLOTTED
  IF THE RESULTANT GRAPH IS NOT SMOOTH ENOUGH THIS
  NUMBER CAN BE RAISED

C
40 IF(.NOT.ANALYS(2))GO TO 60
  IF(ERRORG)GO TO 60
  FLOW=EPSLON
  DELTA=(1.1*D(1)-XSTART)/100.
  DO 50 I=1,100
  FLOW=FLOW+DELTA
  PROB=1.0-EXP(-((FLOW-EPSLON)/(UDROUT-EPSLON))**ALPH)
50 CALL CURVE(I,FLOW,PROB,1,A)
  CALL SUBTLE(26,26H----GUMBEL'S DISTRIBUTION,4,25,0,5,A)
60 CONTINUE

C
C
  NOW TERMINATE THE PLOT

```

```

C      CALL ADVANC(A)
C      RETURN
C      END
C
C .....
C
C      SUBROUTINE CUMPRO(D,N)
C
C      PURPOSE:
C      THE FUNCTION OF THIS ROUTINE IS TO REPORT THE CUMULATIVE
C      PROBABILITY RECURRENCE FREQUENCY OF LOW FLOWS.
C      THE PROBABILITIES ARE EVALUATED
C      ON THE BASIS  $(N+1-M)/(N+1)$ , WHICH IS THE EXPECTED
C      CUMULATIVE PROBABILITY OF THE MTH ORDER VALUE. THESE
C      ARE SCANNED AND REPORTED FOR RECURRENCE INTERVALS DEFINED IN
C      DATA STATEMENT TR. THE VALUES OBTAINED ARE THE ACTUALLY
C      OBSERVED CLOSEST VALUES. NEXT THE INTERPOLATED RESULTS
C      ARE PRESENTED. THESE ARE OBTAINED AS ABOVE, BUT ARE INTERPOLA-
C      BETWEEN OBSERVED VALUES. FINALLY A CUMULATIVE PROBABILITY
C      FUNCTION DUE TO H.A. THOMAS IS USED. REFER TO USGS PROFESSIONAL
C      PAPER 434-A BY NICHOLAS C. MATALAS "PROBABILITY DISTRIBUTION
C      OF LOW FLOWS"
C
C      CALLED SUBROUTINES:
C      SORT,FIND
C
C .....
C
C      SUBROUTINE CUMPRO(D,N)
C      DIMENSION D(N)
C      DIMENSION TR(10),FLO(4,10)
C      LOGICAL ASCEND
C      COMMON /RECOUR/TR
C      COMMON /CUMPAR/FLO
C      DATA ASCEND/.TRUE./
C
C      SORT THE INPUT INTO DESCENDING ORDER
C
C      CALL SORT(D,N,.NOT.ASCEND)
C
C      NOW EVALUATE THE FLOWS FOR THE SIMPLE RECURRENCE METHOD
C
C      DO 10 I=1,10
C      P=1.0/TR(I)
C      AM=FLOAT(N+1)-P*FLOAT(N+1)
C
C      EVALUATE ROUNDED AND INTERPOLATED VALUES
C
C      CALL FIND(D,N,AM,TRUNK,AINTER)
C      FLO(1,I)=TRUNK
C      FLO(2,I)=AINTER
C
C      DO THE SAME FOR THOMAS' CUMULATIVE PROBABILITY
C
C      AM=FLOAT(N+2)-3.0*P*FLOAT(N*N-1)/FLOAT(3*N+1)
C      CALL FIND(D,N,AM,TRUNK,AINTER)

```



```

      FLO(3,I)=TRUNK
      FLU(4,I)=AINTER
10  CONTINUE
      RETURN
      END

```

```

C
C .....
C
C      SUBROUTINE FIND(D,N,AM,TRUNK,AINTER)
C
C      PURPOSE:
C          TO USE AM AS AN INDEX INTO THE ARRAY D TO FIND A VALUE
C          FOR TRUNK AND TO INTERPOLATE A VALUE FOR AINTER
C
C .....
C

```

```

C      SUBROUTINE FIND(D,N,AM,TRUNK,AINTER)
C      DIMENSION D(N)
C      IF(AM.LE.1.0) GO TO 10
C      K=INT(AM)
C      IF(K.GE.N)GO TO 20
C      TRUNK=D(K)
C      DIFF=AM-FLOAT(K)
C      AINTER=D(K)-DIFF*(D(K)-D(K+1))
C      RETURN
C
C      HANDLE THE CASE OF POINTING BEFORE THE START OF THE ARRAY
C
10  TRUNK=D(1)
    AINTER=D(1)
C
C      HANDLE THE CASE OF POINTING AFTER THE END OF THE ARRAY
C
20  AINTER=D(N)
    TRUNK=D(N)
    RETURN
    END

```

```

C
C .....
C
C      SUBROUTINE SORT
C
C      PURPOSE:
C
C          THE PURPOSE OF THIS SUBROUTINE IS TO SORT AN ARRAY
C          OF NUMBERS INTO ASCENDING OR DESCENDING ORDER.
C
C      ARGUMENTS:
C
C          D=INPUT ARRAY.  THE DATA IS SORTED IN PLACE
C          N=UPPER LIMIT OF THE DATA TO BE SORTED BY THIS ROUTINE
C          ASCEND=LOGICAL VARIABLE DEFINING THE ORDER OF THE SORT
C                  .TRUE.=ASCENDING SORT
C                  .FALSE.=DESCENDING SORT
C
C      ALGORITHM:
C

```

C THE ALGORITHM USED IS SHELL'S DIMINISHING INCREMENT SORT
 C AS DESCRIBED IN KNUTH'S "ART OF COMPUTER PROGRAMMING" VOL3
 C
 C

C SUBROUTINE SORT(D,N,ASCEND)
 C DIMENSION D(N)
 C LOGICAL ASCEND
 C IF(N.LE.1)GO TO 60

C COMPUTE THE DIMINISHING INCREMENT
 C

C M=1
 10 M=3*M+1
 IF(M.LT.N)GO TO 10
 M=(M-1)/3
 M=(M-1)/3
 IF(M.LT.1)M=1

C THE OUTER LOOP
 C

20 J=M+1

C SORT THIS ELEMENT DOWN
 C

DO 50 K=J,N
 L=K-M
 D1=D(K)
 30 IF(.NOT.ASCEND)GO TO 32
 IF(D1.GT.D(L))GO TO 40
 GO TO 34
 32 IF(D1.LT.D(L))GO TO 40
 34 CONTINUE
 D(L+M)=D(L)
 L=L-M
 IF(L.GT.0)GO TO 30
 40 D(L+M)=D1
 50 CONTINUE

C DIMINISH THE INCREMENT
 C

M=(M-1)/3
 IF(M.GT.0)GO TO 20

C SORT NOW COMPLETED
 C

60 RETURN
 END

C
 C SUBROUTINE GUMPRO
 C

C PURPOSE:

C TO FIT A SET OF LOW FLOW DATA TO A PROBABILITY
 C DISTRIBUTION DUE TO GUMBEL. SEE USGS PROFESSIONAL PAPER
 C 434-A BY NICHOLAS C. MATLAS "PROBABILITY OF LOW FLOWS"
 C

C AUTHOR:

C THE PRINCIPLE AUTHOR OF THIS SUBROUTINE IS DALE HUFF.
 C THE PRESENT FORM OF THE ROUTINE WAS CREATED
 C BY J.JALBERT FROM FILES SUPPLIED BY JANET HYNOMAN.

C COMMENTS:

C THIS ROUTINE TYPES CUT RECURRENCE INTERVALS AT PRE-
 C ESTABLISHED POINTS DEFINED BY THE DATA STATEMENT TR//.
 C ADDITIONALLY, SOME OF THE PARAMETERS OF THE FITTED DISTRIBUTION
 C AND THE SOURCE DATA ARE ALSO PRESENTED.

C CALLED SUBROUTINES:

C THIS ROUTINE CALLS YLAG,DGAMMA,FLOSTA
 C
 C

C SUBROUTINE GUMPRO(D,N)

C LOGICAL ERROR

C DIMENSION D(N)

C DOUBLE PRECISION ALPHA(100),GAMA(99),ALFAPM(11),GAMAPM(11),ALPRM(
 C *5),GMPRM(5),REDMM,ALRECP, GIA, GSQ, G2A,
 C *XMEAN, STDEV,XKURT,DGAMMA

C DEFINE THE COMMON AREAS

C COMMON /RECOUR/TR

C COMMON /GUMPAR/XMEAN, STDEV, REDMM, XKURT, ALPH, EPSLON, UDROUT, ERROR

C DEFINE TABLES

C DATA ALPRM/1.000,2.000,3.000,4.000,5.000/,GMPRM/2.000,6.61876100,1
 C *9.58485900,60.09173300,190.11324000/
 C DATA ALFAPM/1.000,1.100,1.200,1.300,1.400,1.500,1.600,1.700,1.800,
 C *1.900,2.000/,GAMAPM/2.000,2.30934800,2.64003500,2.99614600,3.38201
 C *300,3.80231100,4.26214200,4.76712400,5.32347800,5.93811800,6.61876
 C *100/
 C DATA ALPHA/.0100,.0200,.0300,.0400,.0500,.0600,.0700,.0800,.0900,.
 C *1000,.1100,.1200,.1300,.1400,.1500,.1600,.1700,.1800,.1900,.2000,.
 C *2100,.2200,.2300,.2400,.2500,.2600,.2700,.2800,.2900,.3000,.3100,.
 C *3200,.3300,.3400,.3500,.3600,.3700,.3800,.3900,.4000,.4100,.4200,.
 C *4300,.4400,.4500,.4600,.4700,.4800,.4900,.5000,.5100,.5200,.5300,.
 C *5400,.5500,.5600,.5700,.5800,.5900,.6000,.6100,.6200,.6300,.6400,.
 C *6500,.6600,.6700,.6800,.6900,.7000,.7100,.7200,.7300,.7400,.7500,.
 C *7600,.7700,.7800,.7900,.8000,.8100,.8200,.8300,.8400,.8500,.8600,.
 C *8700,.8800,.8900,.9000,.9100,.9200,.9300,.9400,.9500,.9600,.9700,.
 C *9800,.9900,1.0000/
 C DATA GAMA/-1.08127200,-1.20485300,-.97070200,-.91845
 C *900,-.86796700,-.77174000,-.72577200,-.68110200,-.63763700,-.59529
 C *600,-.55400200,-.51368700,-.47428700,-.43574300,-.39800200,-.36101
 C *200,-.32472900,-.28910800,-.25411000,-.21969700,-.18583500,-.15249
 C *000,-.11963400,-.08723700,-.05527200,-.02371500
 C *,.00745800,.03827000,
 C *.06874200,.09889300,.12874300,.15830800,.18760600,.21665300,.24546
 C *500,.27445500,.30243700,.33062500,.35863200,.38646800,.41414700,.4
 C *4167800,.46907200,.49634000,.52349100,.55053500,.57748100,.6043360
 C *0,.63111100,.65781200,.68444800,.71102600,.73755300,.76403800,.790

```

*486D0,.816904D0,.843299D0,.869677D0,.896045D0,.922408D0,.948772D0,
*.975143D0,1.001527D0,1.027929D0,1.054354D0,1.080808D0,1.107296D0,1
*.133822D0,1.160393D0,1.187012D0,1.213685D0,1.240415D0,1.267209D0,1
*.294070D0,1.321004D0,1.348013D0,1.375104D0,1.402280D0,1.429545D0,1
*.456904D0,1.484362D0,1.511921D0,1.539587D0,1.567363D0,1.595254D0,1
*.623264D0,1.651396D0,1.679655D0,1.708045D0,1.736570D0,1.765232D0,1
*.794038D0,1.822990D0,1.852093D0,1.881350D0,1.910765D0,1.940343D0,1
*.970086D0,2.000000D0/

C      CALL FLOSTA(D,N,XMEAN,STDEV,REDMOM,XKURT)
      ERROR =.FALSE.

C
      IF (REDMOM + 1.081272) 200, 1, 1
1      IF (REDMOM - 2.000) 2, 3, 4
4      IF (REDMOM - 6.618761D0) 5, 5, 6
2      ALRECP = YLAG(REDMOM, GAMA, ALPHA, 0, 2, 100, IEX)
      GO TO 7
3      ALRECP = 1.0000
      GO TO 7
5      ALRECP = YLAG(REDMOM, GAMAPM, ALFAPM, 0, 2, 11, IEX)
      GO TO 7
6      IF (REDMOM.GT.190.000) GO TO 200
      ALRECP = YLAG(REDMOM, GMPRM, ALPRM, 0, 2, 5, IEX)

C
7      ALPH = 1.0/ALRECP
      GIA = DGAMMA(1.0 + ALRECP)
      GSQ = GIA**2
      G2A = DGAMMA(1.0 + (2*ALRECP))

C
      UDROUT = XMEAN + STDEV*((1.0-GIA)*((1.0/(G2A - GSQ))**0.5)
      EPSLON = XMEAN - STDEV*GIA*((1.0 / (G2A - GSQ))**0.5)

C
      RETURN

C
C      ERROR EXIT FROM THE SUBROUTINE
C
200  TYPE 120, REDMOM
      ERROR = .TRUE.
400  FORMAT (10F5.0)
110  FORMAT(' ALPHA   =',F11.4,/,
1      ' REDMOM    =',F11.4,/,
2      ' EPSILON   =',F11.4,/,
3      ' U         =',F11.4)
120  FORMAT (1X,'THE REDUCED MOMENT IS',1X,G15.6,2X,'AND IS OUTSIDE THE
      *RANGE OF THE TABLE')
130  FORMAT (1X,'RETURN PERIOD IS',2X,F5.2,2X,'FLOW IS',1X,F10.2)
1000 ERROR=.TRUE.
      ALPH=0.0
      EPSLON=0.0
      UDROUT=0.0
      RETURN
      END

C
C      .....
C
C      DOUBLE PRECISION FUNCTION YLAG(XI,C,Y,IND1,N1,IMAX,IEX)
C
C      PROGRAM AUTHORS  A.A. BROOKS AND E.C.LONG,

```

C COMPUTING TECHNOLOGY CENTER, UNION CARBIDE CORP., NUCLEAR DIV.,
 C OAK RIDGE, TENN.

C LAGRANGIAN INTERPOLATION
 C XI IS INTERPOLATED ENTRY INTO X-ARRAY
 C N IS THE ORDER OF LAGRANGIAN INTERPOLATION
 C Y IS ARRAY FROM WHICH YLAG IS OBTAINED BY INTERPOLATION
 C IND IS THE MIN-I FOR X(I).GT.XI
 C IF IND=0, X-ARRAY WILL BE SEARCHED
 C IMAX IS MAX INDEX OF X- AND Y-ARRAYS
 C EXTRAPOLATION CAN OCCUR, IEX=-1 OR +1

C
 C

```

      DOUBLE PRECISION FUNCTION YLAG(XI,X,Y,IND1,N1,IMAX,IEX)
      DIMENSION X(1),Y(1)
      DOUBLE PRECISION P,D,S,XD,XI,X,Y
      IND=IND1
      N=N1
      IEX=0
      IF(N.LE.IMAX) GO TO 10
      N=IMAX
      IEX=N
10  IF(IND.GT.0) GO TO 40
      DO 20 J=1,IMAX
        IF(XI-X(J)) 30,130,20
20  CONTINUE
      IEX=1
      GO TO 70
30  IND=J
40  IF(IND.GT.1) GO TO 50
      IEX=-1
50  INL=(IND-(N+1))/2
      IF(INL.GT.0) GO TO 60
      INL=1
60  INU=INL+N-1
      IF(INU.LE.IMAX) GO TO 80
70  INL=IMAX-N+1
      INU=IMAX
80  S=0.
      P=1.
      DO 110 J=INL,INU
        P=P*(XI-X(J))
      D=1.
      DO 100 I=INL,INU
        IF(I.NE.J) GO TO 90
        XU=XI
      GO TO 100
90  XD=X(J)
100 D=D*(XD-X(I))
110 S=S+Y(J)/D
      YLAG=S*P
120 RETURN
130 YLAG=Y(J)
      GO TO 120
      END

```

C
 C

```

C
C      SUBROUTINE FLOSTA
C
C      .....
C
C      SUBROUTINE FLOSTA(D,I,MEAN,STDEEV,SKEW,KURT)
C
C      PROGRAM TO COMPUTE THE MEAN, SKEWNESS AND STD DEV
C      OF A TABLE OF NUMBERS
C
C      DOUBLE PRECISION MEAN,MOM2,MOM3,MOM4,KURT,DIFF,DIFFA,SUM,STDEEV,
+ SKEW
C      DIMENSION D(I)
C
C      ACCUMULATE TO THE MEAN
C
C      SUM=0.0
C      DO 50 K=1,I
50  SUM=SUM+D(K)
C      MEAN=SUM/FLOAT(I)
C
C      COMPUTE THE MOMENTS
C
C      MOM2=0.0
C      MOM3=0.0
C      MOM4=0.0
C      DO 60 K=1,I
C      DIFF=D(K)-MEAN
C      DIFFA=DIFF*DIFF
C      MOM2=MOM2+DIFFA
C      DIFFA=DIFF*DIFF
C      MOM3=MOM3+DIFFA
C      DIFFA=DIFF*DIFF
C      MOM4=MOM4+DIFFA
60  CONTINUE
C      STDEEV=DSQRT(MOM2/DFLOAT(I-1))
C      SKEW=(DFLOAT(I)/DFLOAT((I-1)*(I-2)))*MOM3/STDEEV**3
C      KURT=(DFLOAT(I*(I+1))/DFLOAT((I-1)*(I-2)*(I-3)))*MOM4/STDEEV**4
C      KURT=KURT-3.0*DFLOAT((I-1)*(I-1))/DFLOAT((I-2)*(I-3))
C      RETURN
C      END
C
C      .....
C
C      DOUBLE PRECISION FUNCTION DGAMMA(XX)
C
C      PURPOSE:
C
C      COMPUTES THE GAMMA FUNCTION FOR A GIVEN ARGUMENT
C
C      USAGE:
C
C      DVAR=DGAMMA(XX)
C
C      DESCRIPTION OF THE PARAMETERS:
C
C      XX IS THE ARGUMENT OF THE GAMMA FUNCTION
C

```

```

C      REMARKS:
C
C      AN ERROR CODE IS PRODUCED UPON ENCOUNTERING UNUSUAL
C      CIRCUMSTANCES. THESE ARE:
C      ERROR=1  XX IS WITHIN .000001 OF BEING A NEGATIVE INTEGER
C      ERROR=2  XX GT 57, AND THE FUNCTION OVERFLOWS AND IS SET TO
C                1.0E+38
C
C      METHOD:
C      THE RECURSION RELATION AND POLYNOMIAL APPROXIMATION
C      BY C. HASTINGS JR. 'APPROXIMATIONS FOR DIGITAL COMPUTERS'
C      PRICETON UNIVERSITY PRESS 1955.
C
C      ERROR:
C      QUOTED ERROR OF THE ALGORITHM IS LT. 2.0EXP(-7)
C
C      .....
C
C      DOUBLE PRECISION FUNCTION DGAMMA(XX)
C      DOUBLE PRECISION GX,X,GY,Y,ERR
C      IF(XX-57.0016,6,6)
C 4  TYPE 3
C      DGAMMA=1.7D38
C      RETURN
C 5  FORMAT(' DGAMMA-ERROR=2')
C 6  X=XX
C      ERR=1.0D-06
C      GX=1.0D0
C      IF(X-2.0D0)50,50,15
C 10 IF(X-2.0D0)110,110,15
C 15 X=X-1.0D0
C      GX=GX*X
C      GO TO 10
C 50 IF(X-1.0D0)60,120,110
C
C      SEE IF X IS NEAR NEGATIVE INTEGER OR ZERO
C
C 60 IF(X-ERR)62,62,80
C 62 Y=DFLOAT(IDINT(X))-X
C      IF(DABS(Y)-ERR)130,130,64
C 64 IF(1.0D0-Y-ERR)130,130,70
C
C      X NOT NEAR A NEGATIVE INTEGER OR ZERO
C
C 70 IF(X-1.0D0)80,80,110
C 80 GX=GX/X
C      X=X+1.0D0
C      GO TO 70
C 110 Y=X-1.0D0
C      GY=1.0D0+Y*(-0.577191652D0+Y*(0.988205891D0+Y*(-0.897056937D0
C      *+Y*(0.918206857D0+Y*(-0.756704078D0+Y*(0.482199394D0+Y*
C      *-0.193527818D0+Y*(0.035868343))))))
C      DGAMMA=GX*GY
C      RETURN
C 120 DGAMMA=GX
C      RETURN
C 130 TYPE 140
C 140 FORMAT(' DGAMMA-ERROR=1')

```

```

      DGAMMA=0.000
      RETURN
      END
C
C .....
C
C SUBROUTINE LOGDST
C .....
C
C SUBROUTINE LOGDST(D,N,FLAG)
C
C THIS SUBROUTINE OPERATES ON THE LOGS OF THE FLOW DATA
C
C REAL NT,LT
C LOGICAL FLAG
C DIMENSION D(N),Q(100)
C DOUBLE PRECISION LMEAN,LSTDEV,LSKEW,LKURT,NMEAN,NSTDEV,PMEAN,PSTDE
C *V,PSKEW
C
C DEFINE THE COMMON AREAS
C COMMON /LPNPAR/PMEAN,PSTDEV,PSKEW,LT(10)
C COMMON /NORPAR/NMEAN,NSTDEV,NT(10)
C
C DO 1 I=1,N
C   Q(I) = D(I)
C   IF(Q(I).LT.0.1E-10) Q(I)=0.1E-10
1  Q(I) = ALOG(Q(I))
C
C DETERMINE STATISTICS OF LOG DATA
C
C CALL FLOSTA(Q,N,LMEAN,LSTDEV,LSKEW,LKURT)
C
C CHECK FOR LOG-NORMAL OPTION
C IF(FLAG)GO TO 2
C
C FOLLOWING IMPLIES THE LOG NORMAL OPTION
C CALL NORMT(NT)
C NMEAN = LMEAN
C NSTDEV = LSTDEV
C RETURN
C
C FOLLOWING IMPLIES LOG-PEARSON OPTION
C CHECK SKEWNESS
C
C 2 IF(ABS(LSKEW).GT.0.01) CALL PRSNT(LSKEW,LT)
C   IF(ABS(LSKEW).LE.0.01) CALL NORMT(NT)
C   PMEAN = LMEAN
C   PSTDEV = LSTDEV
C   PSKEW = LSKEW
C   RETURN
C   END
C
C SUBROUTINE MDCH (CS,DF,P,IER)
C
C-MDCH-----S-----LIBRARY 1-----
C

```

```

MDCH0010
MDCH0020
MDCH0030
MDCH0040

```



```

C FUNCTION - CHI-SQUARED PROBABILITY - NON-INTEGER DEGREES MDCH0050
C OF FREEDOM MDCH0060
C USAGE - CALL MDCH (CS,DF,P,IER) MDCH0070
C PARAMETERS CS - INPUT VALUE FOR WHICH THE PROBABILITY IS MDCH0080
C COMPUTED. CS MUST BE GREATER THAN OR EQUAL MDCH0090
C TO ZERO. MDCH0100
C DF - INPUT VALUE CONTAINING NUMBER OF DEGREES OF MDCH0110
C FREEDOM OF THE CHI-SQUARED DISTRIBUTION. DF MDCH0120
C MUST BE GREATER THAN OR EQUAL TO .5 AND MDCH0130
C LESS THAN OR EQUAL TO 200,000. MDCH0140
C P - OUTPUT VALUE CONTAINING PROBABILITY MDCH0150
C IER - ERROR PARAMETER. MDCH0160
C TERMINAL ERROR=128*N. MDCH0170
C N = 1 INDICATES THAT CS OR DF WAS MDCH0180
C SPECIFIED INCORRECTLY. MDCH0190
C WARNING ERROR=32*N. MDCH0200
C N = 2 INDICATES THAT THE NORMAL PDF WOULD MDCH0210
C HAVE PRODUCED AN UNDERFLOW. MDCH0220
C PRECISION - SINGLE MDCH0230
C REQD. IMSL ROUTINES - UERTST MDCH0240
C LANGUAGE. - FORTRAN MDCH0250
C ----- MDCH0260
C LATEST REVISION - JULY 26,1973 MDCH0270
C SUBROUTINE MDCH (CS,DF,P,IER) MDCH0280
C MDCH0290
C REAL*8 A,Z,DGAM,EPS,W,W1,B,Z1 MDCH0300
C DATA RINFM/"377777777777/ MDCH0310
C FUNC(W,A,Z)=W*DEXP(A*DLOG(Z)-Z) MDCH0320
C TEST FOR INVALID INPUT VALUES MDCH0330
C IF (DF .GE. .5 .AND. DF .LE. 2.E5 .AND. CS .GE. 0.0) GO TO 5 MDCH0340
C IER=129 MDCH0350
C P=RINFM MDCH0360
C GO TO 9000 MDCH0370
C 5 IER=0 MDCH0380
C SET P=0. IF CS IS LESS THAN OR MDCH0390
C EQUAL TO 10.**(-12) MDCH0400
C IF (CS .GT. 1.E-12) GO TO 15 MDCH0410
C 10 P=0.0 MDCH0420
C GO TO 9005 MDCH0430
C 15 IF (DF .LE. 100.) GO TO 20 MDCH0440
C USE NORMAL DISTRIBUTION APPROXIMATION MDCH0450
C FOR LARGE DEGREES OF FREEDOM MDCH0460
C X=SQRT(CS+CS)-SQRT(DF+DF-1.) MDCH0480
C IF (X .GT. 5.0) GO TO 50 MDCH0470
C IF (X .LT. -18.8125) GO TO 55 MDCH0490
C XP= X * .7071068 MDCH0500
C IFLAG = 1
C IF (XP.LT.0.0) IFLAG=-1
C IF(IFLAG.LT.0) XP = -XP
C THE ERF FUNCTION IS ONLY GOOD FOR POSITIVE VALUES OF XP
C CALL ERF(XP,XPR)
C IF (IFLAG.LT.0) XPR = -XPR
C USE SYMMETRY OF THE NORMAL DISTRIBUTION TO GET XPR FOR -XP.
C P = 0.5*(1.+XPR)
C WHEN SKEW IS NEGATIVE, THE NORMAL APPROXIMATION VALUES FOR
C P WILL BE REVERSED FOR + AND - VALUES OF T. THUS ON RETURN
C TO THE CALLING PROGRAM, ONE SHOULD CHECK SKEW AND

```

```

C      MAKE AN ADJUSTMENT IF NECESSARY.
      GO TO 9005
C
C      INITIALIZATION FOR CALCULATION USING INCOMPLETE GAMMA FUNCTION
C
20 IF (CS .GT. 200.) GO TO 50
   EPS=1.D-6
   A=5.D-1*DF
   Z=5.D-1*CS
   DGAM=DGAMMA(A)
   W=DMAX1(.5D0*A,13.0D0)
   IF (Z .GE. W) GO TO 35
   IF (DF .GT. 25. .AND. CS .LT. 2.) GO TO 10
C      CALCULATE USING EQUATION NO. 6.5.29
   W=1.D0/(DGAM*A)
   W1=W
   DO 25 I=1,100
     B=I
     W1=W1*Z/(A+B)
     IF (W1 .LE. EPS*W) GO TO 30
     W=W+W1
25  CONTINUE
30 P=FUNC(W,A,Z)
   GO TO 9005
C      CALCULATE USING EQUATION NO. 6.5.32
35 Z1=1.D0/Z
   B=A-1.0D0
   W1=B*Z1
   W=1.0D0+W1
   DO 40 I=2,100
     B=B-1.0D0
     W1=W1*B*Z1
     IF (W1 .LE. EPS*W) GO TO 45
     W=W+W1
40  CONTINUE
45 W=Z1*FUNC(W,A,Z)
   P=1.D0-W/DGAM
   GO TO 9005
50 P=1.0
   GO TO 9005
C      WARNING ERROR - UNDERFLOW WOULD HAVE OCCURRED
C
55 P=0.0
   IER=34
9000 CONTINUE
   CALL UERTST (IER,'MDCH ')
9005 RETURN
   END
C      SUBROUTINE UERTST (IER,NAME)
C
C-----LIBRARY 1-----
C
C      FUNCTION          - ERROR MESSAGE GENERATION
C      USAGE             - CALL UERTST(IER,NAME)
C      PARAMETERS      IER - ERROR PARAMETER. TYPE + N WHERE
C                        TYPE= 128 IMPLIES TERMINAL ERROR
C                        64 IMPLIES WARNING WITH FIX
C                        32 IMPLIES WARNING
C                        N   = ERROR CODE RELEVANT TO CALLING ROUTINE

```

```

MDCH0520
MDCH0530
MDCH0540
MDCH0550
MDCH0560
MDCH0570
MDCH0580
MDCH0590
MDCH0600
MDCH0610
MDCH0620
MDCH0630
MDCH0640
MDCH0650
MDCH0660
MDCH0670
MDCH0680
MDCH0690
MDCH0700
MDCH0710
MDCH0720
MDCH0730
MDCH0740
MDCH0750
MDCH0760
MDCH0770
MDCH0780
MDCH0790
MDCH0800
MDCH0810
MDCH0820
MDCH0830
MDCH0840
MDCH0850
MDCH0860
MDCH0870
MDCH0880
MDCH0890
MDCH0900
MDCH0910
MDCH0920
MDCH0930
MDCH0940
MDCH0950
MDCH0960
MDCH0970
UERT0010
UERT0020
UERT0030
UERT0040
UERT0050
UERT0060
UERT0070
UERT0080
UERT0090
UERT0100
UERT0110

```

C	NAME	- INPUT VECTOR CONTAINING THE NAME OF THE	UERT0120
C		CALLING ROUTINE AS A SIX CHARACTER LITERAL	UERT0130
C		STRING.	UERT0140
C	LANGUAGE	- FORTRAN	UERT0150
C	-----		UERT0160
C	LATEST REVISION	- JANUARY 18, 1974	UERT0170
C			UERT0180
C	SUBROUTINE UERTST(IER,NAME)		UERT0190
	DIMENSION	ITYP(5,4),IBIT(4)	UERT0200
	INTEGER*2	NAME(3)	UERT0210
	INTEGER	WARN,WARF,TERM,PRINTR	UERT0220
	EQUIVALENCE	(IBIT(1),WARN),(IBIT(2),WARF),(IBIT(3),TERM)	UERT0230
	DATA	ITYP	UERT0240
		/'WARN','ING ',' ',' ',' ',' '	UERT0250
	*	'WARN','ING(',' ','WITH',' FIX',' ')	UERT0260
	*	'TERM','INAL',' ',' ',' ',' '	UERT0270
	*	'NON-','DEFI','NED ',' ',' '	UERT0280
	*	IBIT	UERT0290
		/ 32,64,128,0/	UERT0300
	DATA	PRINTR	UERT0310
		/ 6/	UERT0320
	IER2=IER		UERT0330
	IF (IER2 .GE. WARN) GO TO 5		UERT0340
		NON-DEFINED	UERT0350
	IER1=4		UERT0360
	GO TO 20		UERT0370
5	IF (IER2 .LT. TERM) GO TO 10		UERT0380
		TERMINAL	UERT0390
	IER1=3		UERT0400
	GO TO 20		UERT0410
10	IF (IER2 .LT. WARF) GO TO 15		UERT0420
		WARNING(WITH FIX)	UERT0430
	IER1=2		UERT0440
	GO TO 20		UERT0450
		WARNING	UERT0460
15	IER1=1		UERT0470
		EXTRACT 'N'	UERT0480
20	IER2=IER2-IBIT(IER1)		UERT0490
		PRINT ERROR MESSAGE	UERT0500
	WRITE (PRINTR,25) (ITYP(I,IER1),I=1,5),NAME,IER2,IER		UERT0510
25	FORMAT(' *** I M S L(UERTST) *** ',5A4,4X,3A2,4X,I2,		UERT0520
	* ' (IER = ',I3,')')		UERT0530
	RETURN		
	END		
			
	SUBROUTINE MERFCI(P,X,IER)		
	PURPOSE:		
	TO COMPUTE THE INVERSE COMPLIMENTED ERROR FUNCTION		
	METHOD:		
	THE RELATION ERFC(X)=1-ERF(X) SO THAT		
	INVERFC(P)=INVERF(1.0-P).		
	THIS ROUTINE MERELY RELAYS THE CALL ON TO MERFI		
	WITH THE PROPER CHANGE OF ARGUMENTS		
	COMMENTS:		
	THIS ROUTINE IS CONSTRUCTED TO EMULATE THE ONE WITH THE		

C SAME NAME IN THE IMSL SUBROUTINE LIBRARY. ALL
C INEFFICIENCIES ARE DUELY RECOGNIZED.

C AUTHOR:
C J.S.JALBERT

C DATE:
C JUNE 26, 1976

C
C
C SUBROUTINE MERFCI(P,X,IER)
C CALL MERFI(1.0-P,X,IER)
C RETURN
C END

C
C
C SUBROUTINE MERFI(P,X,IER)

C PURPOSE:
C COMPUTES THE INVERSE ERROR FUNCTION

C ARGUMENTS:

C P = INPUT VALUE MUST BE IN RANGE $-1.0 \leq P \leq 1.0$
C X = INVERSE ERROR FUNCTION OF P $X = \text{INVERF}(P)$
C IER = ERROR INDICATOR, VALUES RETURNED ARE:
C 0 = NO ERROR
C 129 = ARGUMENT OUTSIDE SPECIFIED RANGE.
C (ROUTINE RETURNS A VALUE OF PLUS OR MINUS
C INFINITY, DEPENDING ON THE SIGN OF P)

C COMMENTS:

C THE ALGORITHM USED HERE IS TAKEN FROM THE IMSL PACKAGE. IT
C WAS ORIGINALLY CREATED AT THE UNIVERSITY OF CHICAGO. FOR A
C COMPLETE DISCUSSION OF THE METHOD SEE "A SINGLE PRECISION
C INVERSE ERROR FUNCTION SUBROUTINE" COMPUTATION CENTER,
C THE UNIVERSITY OF CHICAGO, CHICAGO ILL.

C METHOD:

C THE BASIC INTERVAL (0,1) IS DIVIDED INTO 4 SEGMENTS. IN EACH
C SEGMENT $\text{INVERF}(P)$ IS APPROXIMATED BY A MINIMAX RATIONAL FUNCTION.
C THE APPROXIMATION FOR THE FINAL THREE SEGMENTS, COMPRISING
C THE INTERVAL (0.85,1) ARE FUNCTIONS OF THE TRANSFORMED
C VARIABLE $W = \sqrt{-\ln(1-P^2)}$, WHERE P IS THE ARGUMENT TO THE
C ROUTINE. THIS TRANSFORMATION IMPROVES THE EFFICIENCY AND
C STABILITY OF THE APPROXIMATION.

C REFERENCES:

C IMSL LIBRARY DOCUMENTATION
C HART, F.J. ET. AL. "COMPUTER APPROXIMATIONS" WILEY(1968)
C STRECKO, A.J. "ON THE CALCULATION OF THE INVERSE ERROR FUNCTION"
C MATHEMATICS OF COMPUTATION, 22(101) 1968

C ACCURACY:

C THE ACCURACY OF THIS IMPLEMENTATION IS PROBABLY NO WORSE THAN
C $1.0E-06$ AND THE RMS ERROR IS PROBABLY $< 4.0E-07$.

AUTHOR:
J.S. JALBERT

DATE:
JUNE 26, 1976

.....
SUBROUTINE MERFI(P,X,IER)
DOUBLE PRECISION COEF(21),RESULT,ARG,T(21)
DIMENSION R(4,3),Q(3,3)

DATA COEF/.992885376618949D0,
1 .120467516143104D0,
2 .016078199342099D0,
3 .007686704437162D0,
4 .000499634730235D0,
5 .000098898218599D0,
6 .000020391812763D0,
7 .000004327271617D0,
8 .000000938081412D0,
9 .000000206734720D0,
A .000000046159699D0,
B .000000010416679D0,
C .000000002371500D0,
D .000000000543928D0,
E .000000000125548D0,
F .000000000029138D0,
G .000000000006794D0,
H .000000000001591D0,
I .000000000000374D0,
J .000000000000088D0,
K .000000000000020D0/
DATA AINFIN/"67777777777777/
DATA R/-.1146665896,-.1314774423,-.2368201033,+.05073974908,
1 -.05668422809,.3937020912,-.3166501041,+.06208962947,
2 -.0001851159136,-.002028152042,-.1498384437,+.01078638579/
DATA Q/-44.27976939,+.21.98546225,-7.586102703,
1 -6.266785861,+.4.666262710,-2.962883238,
2 +.09952975065,+.2511732887,-.06888300851/

COMMENCE THE CALCULATION, FIRST CHECK FOR SMALL ARGUMENTS
Y=ABS(P)
IER=0
IF(Y.GT. 3.0E-04)GO TO 10

FOR SMALL ARGUMENTS ONLY, JUST MULTIPLY BY SQRT(PI)/2

X= Y* 0.886226926
GO TO 60

NOW CHECK TO SEE IF LESS THAN .85

10 IF(Y.GT.0.85) GO TO 20

COMPUTE THE TCHYBYCHEFF POLYNOMIALS
THIS PART OF THE ALGORITHM IS DIRECTLY FROM
STRECKOCK'S PAPER. IT WAS NOT POSSIBLE TO
REPRODUCE THE IMSL ROUTINE IN THIS INTERVAL

```

C      ARG=P
      ARG=ARG*ARG/0.32D0-1.0D0
      T(1)=1.0D0
      T(2)=ARG
      DO 200 I=3,21
        T(I)=2.0D0*ARG*T(I-1)-T(I-2)
200    CONTINUE
      RESULT=0.0D0
      DO 300 I=1,21
        M=22-I
300    RESULT=T(M)*COEF(M)+RESULT
      RESULT=RESULT*DBLE(P)
      X=RESULT
      GO TO 60

C
C      ARGUMENT > 0.85, COMPUTE A,B TO PRESERVE ACCURACY
C
20    A=1.0-Y
      IF(A.LT.0.0)GO TO 70
      B=Y
      W=SQRT(-ALOG(A+A*B))

C
C      NOW TEST W AND PARTITION THE INTERVAL FURTHER
C
      IF(W.GE.4.0)GO TO 40
      IF(W.GE.2.5)GO TO 30

C
C      THIS SECTION FOR W<2.5
C
      FR0=W
      FR2=W
      M=1
      GO TO 50

C
C      THIS SECTION FOR 2.5<=W<4.0
C
30    FR0=W
      FR2=W
      M=2
      GO TO 50

C
C      THIS SECTION IS FOR W>=4.0
C
40    FR0=W
      FR2=1.0/W
      M=3
50    X=FR0+FR0*(R(1,M)+(FR2*(R(2,M)+FR2*(R(3,M)+FR2*R(4,M)))) /
1      (Q(1,M)+FR2*(Q(2,M)+FR2*(Q(3,M)+FR2)))
60    X=SIGN(X,P)
      RETURN

C
C      THE ARGUMENT IS OUT OF BOUNDS, SO POST THE ERROR CONDITION
C      AND SET THE RESULT TO INFINITY
C
70    IER=129
      X=AINFIN
      GO TO 60

```

```

C      END
C      SUBROUTINE MDCHI (P,DF,X,IER)
C
C-----S-----LIBRARY 1-----
C
C      FUNCTION          - INVERSE CHI-SQUARED PROBABILITY DISTRIBUTION
C                        FUNCTION
C      USAGE             - CALL MDCHI (P,DF,X,IER)
C      PARAMETERS        P      - INPUT PROBABILITY IN THE EXCLUSIVE RANGE
C                        (0,1)
C                        DF      - INPUT VALUE CONTAINING NUMBER OF DEGREES OF
C                        FREEDOM. DF MUST BE IN THE EXCLUSIVE RANGE
C                        (.5,200000.)
C                        X        - OUTPUT CHI-SQUARED VALUE, SUCH THAT A RANDOM
C                        VARIABLE, DISTRIBUTED AS CHI-SQUARED WITH
C                        DF DEGREES OF FREEDOM, WILL BE LESS THAN OR
C                        EQUAL TO X WITH PROBABILITY P.
C                        IER      - ERROR INDICATOR
C                        TERMINAL ERROR = 128+N
C                        N = 1 MEANS THAT BOUNDS WHICH ENCLOSED P
C                        COULD NOT BE FOUND WITHIN 20 (NCT)
C                        ITERATIONS
C                        N = 2 MEANS THAT AN ERROR OCCURRED IN
C                        MDNRIS (P IS NOT A VALID VALUE)
C                        N = 3 MEANS THAT AN ERROR OCCURRED IN MDCH
C                        N = 4 MEANS THAT THE VALUE X COULD NOT BE
C                        FOUND WITHIN 50 (ITMAX) ITERATIONS, SO
C                        THAT THE ABSOLUTE VALUE OF P1-P WAS NOT
C                        .LE. EPS. (P1= CALCULATED PROBABILITY AT X,
C                        EPS= .0001)
C      PRECISION          - SINGLE
C      REQD. INSL ROUTINES - MDCH, MERFI, UERTST
C      LANGUAGE           - FORTRAN
C-----
C      LATEST REVISION    - JANUARY 3, 1972
C
C      SUBROUTINE MDCHI (P,DF,X,IER)
C
C      DATA              EPS/.0001/,ITMAX/50/,NCT/20/,NSIG/5/
C      IC = 0
C      IER = 0
C
C      ESTIMATE STARTING X
C      CALL MMDRIS (P,XP,IER)
C      IF (IER .NE. 0) GO TO 80
C      DFF = .2222222/DF
C      D = SQRT(DFF)
C      X = DF*(1. -DFF + XP*D)**3
C
C      IS THE CASE ASYMPTOTICALLY NORMAL
C      IF (DF .GE. 40.) GO TO 9005
C
C      FIND BOUNDS (IN X) WHICH ENCLOSE P
C      NCNT = 0
C      IST = 0
C      ISW = 0
C      DX = X * .125
C      5 IF (X) 10,15,20
C      10 X = 0.0
C      DX = -DX
C      GO TO 20

```

15 DX = .1		MDCI0580
20 CALL MDCH (X,DF,P1,IER)		MDCI0590
DX = DX + DX		MDCI0600
IF (IER .NE. 0) GO TO 85		MDCI0610
CSS = X		MDCI0620
NCNT = NCNT + 1		MDCI0630
IF (NCNT .GT. NCT) GO TO 90		MDCI0640
IF (P1 - P) 25,9005,30		MDCI0650
25 X = X + DX		MDCI0660
ISW = 1		MDCI0670
IF (IST .EQ. 0) GO TO 5		MDCI0680
GO TO 35		MDCI0690
30 X = X - DX		MDCI0700
IST = 1		MDCI0710
IF (ISW .EQ. 0) GO TO 5		MDCI0720
XR = CSS		MDCI0730
XL = X		MDCI0740
GO TO 40		MDCI0750
35 XL = CSS		MDCI0760
XR = X		MDCI0770
C	PREPARE FOR ITERATION TO FIND X	MDCI0780
40 EPSP = 10.**(-NSIG)		MDCI0790
IF (XL .LT. 0.) XL = 0.0		MDCI0800
CALL MDCH (XL,DF,P1,IER)		MDCI0810
IF (IER .NE. 0) GO TO 85		MDCI0820
FXL = P1 - P		MDCI0830
CALL MDCH (XR,DF,P1,IER)		MDCI0840
IF (IER .NE. 0) GO TO 85		MDCI0850
FXR = P1-P		MDCI0860
IF (FXL*FXR .NE. 0.0) GO TO 45		MDCI0870
X = XR		MDCI0880
IF (FXL .EQ. 0.0) X = XL		MDCI0890
GO TO 9005		MDCI0900
45 IF (DF .LE. 2. .OR. P .GT. .98) GO TO 50		MDCI0910
C	REGULA FALSI METHOD	MDCI0920
X = XL + FXL*(XR-XL)/(FXL-FXR)		MDCI0930
GO TO 55		MDCI0940
C	BISECTION METHOD	MDCI0950
50 X = (XL+XR) * .5		MDCI0960
55 CALL MDCH (X,DF,P1,IER)		MDCI0970
IF (IER .NE. 0) GO TO 85		MDCI0980
FCS = P1-P		MDCI0990
IF (ABS(FCS) .GT. EPS) GO TO 60		MDCI1000
GO TO 9005		MDCI1010
60 IF (FCS * FXL .GT. 0.0) GO TO 65		MDCI1020
XR = X		MDCI1030
FXR = FCS		MDCI1040
GO TO 70		MDCI1050
65 XL = X		MDCI1060
FXL = FCS		MDCI1070
70 IF (XR-XL .GT. EPSP*ABS(XR)) GO TO 75		MDCI1080
GO TO 9005		MDCI1090
75 IC = IC+1		MDCI1100
IF (IC .LE. ITMAX) GO TO 45		MDCI1110
IER = 132		MDCI1120
C	ERROR RETURNED FROM MONRIS	MDCI1130
80 IER = 130		MDCI1140
GO TO 9000		MDCI1150


```

C                                     ERROR RETURNED FROM MDCH                                     MDC11160
C      85 IER = 131                                                             MDC11170
C      GO TO 9000                                                                MDC11180
C      90 IER = 129                                                             MDC11190
C      9000 CONTINUE                                                            MDC11200
C      CALL UERTST (IER,6HMDCHI )                                              MDC11210
C      9005 RETURN                                                              MDC11220
C      END                                                                      MDC11230
C
C      .....
C
C      SUBROUTINE MNDRIS(X,P,IER)
C
C      PURPOSE:
C      TO COMPUTE THE INVERSE NORMAL PROBABILITY DISTRIBUTION FUNCTION.
C      (SOMETIMES CALLED THE GAUSS FUNCTION)
C
C      METHOD:
C      THE RELATION
C       $INVGAUSS(P) = -\sqrt{2} * INVERFC(2*P) = -\sqrt{2} * INVERF(1-2P)$ 
C      IS USED. THE FUNCTION IS EVALUATED BY A CALL TO
C      MERFI WITH THE SUITABLE ARGUMENT.
C
C      COMMENTS:
C      THIS ROUTINE IS CONSTRUCTED TO EMULATE THE ONE WITH THE
C      SAME NAME IN THE IMSL SUBROUTINE LIBRARY PACKAGE. ALL
C      INEFFICIENCIES ARE DULELY RECOGNIZED BY THE METHOD USED
C      IN RELAYING THIS CALL.
C
C      AUTHOR:
C      J. S. JALBERT
C
C      DATE:
C      JUNE 26, 1976
C
C      .....
C
C      SUBROUTINE MNDRIS(P,X,IER)
C      DATA SQRT2/-1.414213562/
C      CALL MERFI(1.0-2.0*P,X,IER)
C      IF(IER.EQ.0)X=X*SQRT2
C      RETURN
C      END
C
C      .....
C
C      SUBROUTINE ERF
C
C      .....
C
C      SUBROUTINE ERF(Y,ERFX)
C      DIMENSION A(6)
C      REAL C,D,A,Y
C      A(1)=.0705230784
C      A(2)=.0422820123
C      A(3)=.0092705272
C      A(4)=.0001520143
C      A(5)=.0002765672

```

```

      A(6)=.0000430638
      C=1
      DO 10 I=1,6
      D=C
10    C=A(I)*Y**(I)+D
      ERFX=1- 1/(C)**16
      RETURN
      END

C
C .....
C
C SUBROUTINE NDI
C .....
C
C SUBROUTINE NDI(P,X,ACC)
C X=0.0
C PX = 2.0*(P-0.5)
C FXL = 0.0
C DFDX = 0.8
C I = 0
C THE FOLLOWING LOOP DOES THE INVERSE NORMAL DISTRIBUTION PROBLEM
1    I = I + 1
      DF = PX - FXL
      DX = DF/DFDX
      X = X + DX
      CALL ERF(X,FX)
      IF (ABS(PX-FX).LT.ACC) GO TO 100
      IF (I.GT.200) GO TO 99
      DFDX= (FX-FXL)/DX
      FXL = FX
      GO TO 1
99   TYPE 200, I,P,FX
200  FORMAT(1X,'DID NOT GET NDI CONVERGENCE: I,P,FX=',I4,2(1X,G12.6))
100  X = X*1.414213562
      RETURN
      END

C
C .....
C
C SUBROUTINE NORMT(T)
C .....
C SUBROUTINE NORMT(T)
C
C DIMENSION PX(10),T(10),TR(10)
C COMMON/RECOUR/TR
C ACC = 0.001
C
C DO 1 K=1,10
C PX(K) = 1.0 - ((TR(K) - 1.0)/ TR(K))
C IF(PX(K) - 0.5) 2,3,4
2    P = 1.0 - PX(K)
      FLAGN = -1.0
      GO TO 5
3    T(K) = 0.0
      GO TO 1
4    P = PX(K)

```

```

      FLAGN = 1.0
5     CALL MDI(P,X,ACC)
      T(K) = X * FLAGN
1     CONTINUE
      RETURN
      END

C
C
C .....
C
C     SUBROUTINE PRSNT
C
C .....
C     SUBROUTINE PRSNT(RSKEW,PT)
C
C     DIMENSION PX(10),U(10),PT(10),TR(10)
C     DOUBLE PRECISION RSKEW
C     DEFINE THE COMMON AREA
C     COMMON /RECOUR/TR
C
C     TWOASQ = 8.0/RSKEW**2.0
C     A = (2.0/RSKEW)
C     DF = TWOASQ
C     DO 1 K=1,10
C       PX(K) = 1.0 - ((TR(K)- 1.0)/TR(K))
C       IF(RSKEW) 10,10,11
10      P = 1.0 - PX(K)
C       GO TO 12
11      P = PX(K)
12      CALL MDCHI(P,DF,X,IER)
C       IF(IER.GT.0) GO TO 2
C       U(K) = X/2.0
1     PT(K) = (U(K)/A) - A
C     RETURN

C
C     ERROR EXIT FROM SUBROUTINE
C     TYPE 100,P,DF,X,IER
100    FORMAT(1X,'THE CHI-SQUARE VALUE RETURNED FROM MDCHI IS IN ERROR'
*      ,/,1X,'THE VALUES OF P,DF,X,IER ARE',3(1X,G10.4,1X,I4))
C     DO 3 I=1,10
3     PT(I) = 0.0
C     RETURN
C     END

C
C .....
C
C     SUBROUTINE PRSN3
C
C .....
C
C     SUBROUTINE PRSN3 (D,N)
C
C     DIMENSION D(N),PX(10),U(10),TR(10)
C     DOUBLE PRECISION RMEAN,RSTDEV,RSKEW
C
C     DEFINE COMMON AREAS
C     COMMON/PSNPAR/RMEAN,RSTDEV,RSKEW,PT(10)
C     COMMON/RECOUR/TR

```

```

C
C   COMPUTE THE BASIC STATISTICS FOR THE DATA ENTERED
C   CALL FLOSTA(D,N,RMEAN,RSTDEV,RSKEW,RKURT)
C
C   CHECK THE SKEWNESS.  LOW SKEWNESS ALLOWS NORMAL DISTRIBUTION
C   TO BE APPROXIMATED.
C
C   IF(ABS(RSKEW).GT.0.01) GO TO 10
C   CALL NORMT(PT)
C   GO TO 100
C
C   NORMT RETURNS THE T(K) VECTOR. (Q(K)=RMEAN + RSTDEV * T(K))
C
C 10  CALL PRSNT(RSKEW,PT)
C
C   PRSNT RETURNS THE T(K) VECTOR. (Q(K)=RMEAN + RSTDEV * T(K))
C
C 100 CONTINUE
C     RETURN
C     END
C
C
C .....
C
C .....
C
C SUBROUTINE PTRECU(FLOWS,N,ANALYS,M)
C
C PURPOSE:
C   TO PRINT OUT THE PREDICTED FLOWS FOR A STANDARD SET OF
C   RECURRENCE INTERVALS.  THESE INTERVALS ARE SET IN COMMON
C
C .....
C
C SUBROUTINE PTRECU(FLOWS,N,ANALYS,M)
C   REAL NT,LT
C   DIMENSION FLOWS(N),TR(10),FLO(4,10)
C   DOUBLE PRECISION XMEAN,STDDEV,REDMOM,XKURT,RMEAN,RSTDEV,RSKEW,PMEA
C   *N,PSTDEV,PSKEW,NMEAN,NSTDEV
C   LOGICAL ANALYS(10),ERRORG
C   COMMON /PSNPAR/RMEAN,RSTDEV,RSKEW,PT(10)
C   COMMON /LPNPAR/PMEAN,PSTDEV,PSKEW,LT(10)
C   COMMON /NORPAR/NMEAN,NSTDEV,NT(10)
C   COMMON /RECOUR/TR
C   COMMON /GUMPAR/XMEAN,STDDEV,REDMOM,XKURT,ALPH,EPSLON,UDROUT,ERRORG
C   COMMON /CUMPAR/FLO
C
C   TEST FOR THE SIMPLE CUMULATIVE STATS
C
C   IF(.NOT.ANALYS(1))GO TO 80
C   WRITE(M,20)
C 20  FORMAT(///,'      ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES',//)
C   WRITE(M,30)
C 30  FORMAT(' RECURRENCE',T22,'SIMPLE',T52,'THOMAS')
C   WRITE(M,40)
C 40  FORMAT(' INTERVAL',T22,'METHOD',T52,'METHOD')
C   WRITE(M,50)
C 50  FORMAT(' (YEARS)',T14,'SIMPL',T29,'INTERP',

```

```

      1T44,'SIMPL',T59,'INTERP')
      UU 70 I=1,10
      WRITE(M,60)TR(I),(FLO(J,I),J=1,4)
60  FORMAT(1X,F6.1,T10,F10.1,T25,F10.1,T40,F10.1,T55,F10.1)
70  CONTINUE

C
C      NOW TEST TO SEE IF THE GUMBEL RECURRENCE IS TO BE PRINTED
C
      80 IF(.NOT.ANALYS(2))GO TO 150
      IF(.NOT.ERRORG)GO TO 88
      WRITE(M,85)
      85 FORMAT(' CANNOT PRODUCE GUMBEL'S STATISTICS',/,
1      ' KURTOSIS OUT OF RANGE')
      GO TO 150
      88 WRITE(M,90)
      90 FORMAT(///,' ANALYSIS BY GUMBEL'S DISTRIBUTION')
      WRITE(M,100)
100  FORMAT(' RECURRENCE',T22,'GUMBEL'S')
      WRITE(M,110)
110  FORMAT(' INTERVAL',T22,'METHOD')
      WRITE(M,120)
120  FORMAT(' (YEARS)')
      DO 140 I=1,10
      Y=-ALOG((TR(I)-1.0)/TR(I))
      FE=(ALOG(Y)/ALPH)+ALOG(UDROUT-EPSON)
      FLOW=EXP(FE)+EPSON
      WRITE(M,130)TR(I),FLOW
130  FORMAT(1X,F6.1,T22,F10.1)
140  CONTINUE

C
C      TEST TO SEE IF PEARSON TYPE III RECURRENCE IS TO BE PRINTED
C
      150 IF(.NOT.ANALYS(3)) GO TO 160
      WRITE (M,151)
      151 FORMAT(///,' ANALYSIS BY PEARSON TYPE III DISTRIBUTION')
      WRITE (M,152)
      152 FORMAT(' RECURRENCE',T22,'PEARSON TYPE III')
      WRITE (M,153)
      153 FORMAT(' INTERVAL',T24,'DISTRIBUTION')
      WRITE (M,154)
      154 FORMAT (3X,'(YEARS)')
      DO 155 I=1,10
      FLOW = RMEAN + RSTDEV * PT(I)
      WRITE (M,156) TR(I),FLOW
      156 FORMAT (1X,F6.1,T22,F10.1)
      155 CONTINUE

C
C      TEST TO SEE IF LOG-PEARSON TYPE III RECURRENCE IS TO BE
C      PRINTED
C
      160 IF(.NOT.ANALYS(4))GO TO 170
      WRITE (M,161)
      161 FORMAT(///,' ANALYSIS BY LOG-PEARSON TYPE III')
      WRITE (M,162)
      162 FORMAT(' RECURRENCE',T22,'LOG-PEARSON')
      WRITE (M,163)
      163 FORMAT (' INTERVAL',T24,'TYPE III')
      WRITE (M,154)

```

```

DO 164 I=1,10
FLOW = EXP(PMEAN + PSTDEV * LT(I))
WRITE (M,156) TR(I), FLOW
164 CONTINUE
C
C   TEST TO SEE IF LOG NORMAL RECURRENCE IS TO BE PRINTED
C
170 IF(.NOT.ANALYS(5)) GO TO 180
WRITE (M,171)
171 FORMAT(///,' ANALYSIS BY LOG-NORMAL DISTRIBUTION')
WRITE (M,172)
172 FORMAT (' RECURRENCE',T22,'LOG-NORMAL')
WRITE (M,153)
WRITE (M,154)
DO 173 I=1,10
FLOW = EXP(NMEAN + NSTDEV * NT(I))
WRITE (M,156) TR(I), FLOW
173 CONTINUE
180 CONTINUE
WRITE(M,999)
999 FORMAT(///)
RETURN
END
C
C .....
C
C   SUBROUTINE PTSTAT(FLOWS,N,ANALYS,ASCII,M)
C
C   PURPOSE:
C   TO PRINT THE STATISTICS THAT ARE STORED IN THE COMMON AREAS
C   FOR EACH OF THE DISTRIBUTIONS PROCESSED FOR THIS STATION
C
C .....
C
C   SUBROUTINE PTSTAT(FLOWS,N,ANALYS,ASCII,M)
C   REAL NT,LT
C   DIMENSION THOMAS(100),SIMP(100),FLOWS(N),ASCII(78),TR(10)
C   DOUBLE PRECISION XMEAN,STDEV,REDMOM,XKURT,RMEAN,RSTDEV,RSKEW,PME
C   *AN,PSTDEV,PSKEW,NMEAN,NSTDEV
C
C   LOGICAL ANALYS(10),ERRORG
C
C   COMMON /PSNPAR/RMEAN,RSTDEV,RSKEW,PT(10)
C   COMMON /LPNPAR/PMEAN,PSTDEV,PSKEW,LT(10)
C   COMMON /NUPAR/NMEAN,NSTDEV,NT(10)
C   COMMON /RECOUR/TR
C   COMMON /GUMPAR/XMEAN,STDEV,REDMOM,XKURT,ALPH,EPSLON,UDROUT,ERRORG
C   WRITE(M,10)(ASCII(I),I=1,8),(ASCII(I),I=31,78)
10 FORMAT(3(/),' STATISTICS FOR STATION # ',8A1,/,10X,48A1)
C
C   NOW TEST TO SEE IF THE SIMPLE CUMULATIVE PROBABILITIES
C   ARE TO BE WRITEN. IF SO THEY WILL HAVE TO BE RECOMPUTED
C
C   IF(.NOT.ANALYS(1))GO TO 50
C   WRITE(M,20)
20 FORMAT(2(6X,'FLOW',6X,'SIMPLE',5X,'THOMAS',,2X))
DO 25 I=1,N
SIMP(I)=FLOAT(N+1-I)/FLOAT(N+1)

```

```

25 THOMAS(I)=FLOAT((3*N+1)*(N-I)+2)/FLOAT(3*(N*N-1))
   WRITE(M,30) (FLOWS(I), SIMP(I), THOMAS(I), FLOWS(I+1), SIMP(I+1),
1       THOMAS(I+1), I=1, N, 2)
30 FORMAT(2(1X, F10.1, 3X, F8.6, 3X, F8.6, 3X))
   WRITE(M,40)
40 FORMAT(3(/))

```

C
C
C

NOW TEST FOR GUMBEL STATISTICS

```

50 IF(.NOT.ANALYS(2)) GO TO 90
   IF(.NOT.ERRORG) GO TO 70
   WRITE(M,60)
60 FORMAT(' CANNOT PRINT GUMBEL'S STATISTICS',/,
1       ' SKEWNESS OUT OF RANGE')
   GO TO 90
70 WRITE(M,80) XMEAN, STDDEV, REDMOM, XKURT, ALPHA, EPSLON, UDROUT
80 FORMAT(20X, ' GUMBEL'S STATISTICS',/,
1       ' MEAN = ', F10.1, /,
2       ' STDDEV = ', F10.3, /,
X       ' REDMOM = ', F10.3, /,
3       ' KURT = ', F10.4, /,
4       ' ALPHA = ', F10.4, /,
5       ' EPSILON = ', F10.4, /,
6       ' U = ', F10.4)

```

C
C
C

TEST FOR PEARSON TYPE III STATISTICS

```

90 IF(.NOT.ANALYS(3)) GO TO 100
   WRITE (M,91) RMEAN, RSTDDEV, RSKEW
91 FORMAT (15X, ' PEARSON TYPE III STATISTICS', /,
1       ' MEAN = ', F10.1, /,
2       ' STDDEV = ', F10.3, /,
3       ' SKEW = ', F10.4)
   WRITE (M,92)
92 FORMAT(/, ' RECURRENCE', T22, ' T-STATISTIC', /, ' INTERVAL')
   DO 94 I=1,10
   WRITE (M,93) TR(I), PT(I)
93 FORMAT (2X, F6.1, T22, F10.5)
94 CONTINUE

```

C
C
C

TEST FOR LOG-PEARSON STATISTICS

```

100 IF(.NOT.ANALYS(4)) GO TO 110
   WRITE (M,101) PMEAN, PSTDEV, PSKEW
101 FORMAT (10X, ' LOG-PEARSON TYPE III STATISTICS', /,
1       ' MEAN = ', F10.1, /,
2       ' STDDEV = ', F10.3, /,
3       ' SKEW = ', F10.4)
   WRITE (M,92)
   DO 102 I=1,10
   WRITE (M,93) TR(I), LT(I)
102 CONTINUE

```

C
C

TEST FOR LOG-NORMAL STATISTICS

```

110 IF(.NOT.ANALYS(5)) GO TO 120
   WRITE (M,111) NMEAN, NSTDEV
111 FORMAT (20X, ' LOG-NORMAL STATISTICS', /,
1       ' MEAN = ', F10.1, /,

```

```

2      '   STDDEV=',F10.3)
      WRITE (M,92)
      DO 112 I=1,10
      WRITE (M,93) TR(I),NT(I)
112  CONTINUE
120  CONTINUE
      RETURN
      END

.....

SUBROUTINE STORIT(ANALYS,ASCII)

PURPOSE:
  THIS SUBROUTINE TAKES THE STATISTICAL PARAMETERS FOR
  THE STREAM THAT ARE STORED IN THE COMMON AREAS FOR THIS
  STATION AND WRITES THEM, IN A FORMATTED FASHION ON THE
  DISK IN A FILE GIVEN BY THE DATA STATEMENT
  FOR M.

ARGUMENTS:
  ANALYS = A 10 ELEMENT LOGICAL ARRAY TELLING WHICH ANALYSIS IS DONE
  ASCII  = THE STATION IDENTIFICATION DATA (INCL NAME ETC.)

.....

SUBROUTINE STORIT(ANALYS,ASCII)
  LOGICAL ANALYS(10), ERRORG
  DIMENSION ASCII(78)
  DOUBLE PRECISION XMEAN,STDDEV,REDMON,XKURT
  COMMON /GUMPAR/XMEAN,STDDEV,REDMON,XKURT,ALPH,EPSLON,UDROUT,ERRORG
  COMMON /CUMPAR/FLO(4,10)
  DATA M/11/

  WRITE OUT THE IDENTIFICATION AND THE LOGICAL ARRAY SO THE
  READER KNOWS WHAT TO EXPECT

  WRITE(M,10)(ASCII(I),I=1,8),ANALYS
10  FORMAT(8A1,10L1)

  NOW WRITE THE SELECTED COMMON AREAS

  IF(ANALYS(1))WRITE(M,20)XMEAN,STDDEV,REDMON,XKURT,
1      ALPH,EPSLON,UDROUT,ERRORG
20  FORMAT(7F10.4,L1)
  IF(ANALYS(2))WRITE(M,30)FLO
30  FORMAT(10F10.1)
  RETURN
  END

.....

SUBROUTINE TTYPLOT(D,N,ANALYS,MM)

PURPOSE:

```



```

C      THIS ROUTINE CREATES TTY PLOTS OF ALL DISTRIBUTIONS
C      SELECTED IN THE MAIN PROGRAM.
C
C      ASSUMPTIONS:
C      ALL NECESSARY STATISTICAL ANALYSES HAVE BEEN PERFORMED
C      AND THEIR RESPECTIVE COMMON AREAS INITIALIZED
C
C      CALLED SUBROUTINES:
C      NONE
C
C      ALGORITHM:
C      THE ROUTINE PROCEEDS BY LOADING A VECTOR V WITH THE
C      PREDICTED CUMULATIVE PROBABILITY FOR THE OBSERVED FLOWS.
C      THIS IS DONE FOR EACH OF THE SELECTED DISTRIBUTIONS.
C      THIS VALUE IS THEN CONVERTED TO A LOGARITHMIC BASE AND SCALED
C      SO THAT THE INTERVAL 0.001 TO 1 FILLS 50 LINES. THE RESULTANT
C      VALUES ARE THEN CONVERTED TO TTY POSITIONS AND PLOTTED.
C
C      .....
C
C      SUBROUTINE TTYPLO(D,N,ANALYS,MM)
C      LOGICAL ANALYS(10),ERRORG
C      DIMENSION D(N)
C      DIMENSION V(4,100),V3(100),LINE(50)
C      INTEGER DOT,STAR,DASH,OH,BLANK
C      DOUBLE PRECISION PMEAN,PSTDEV,PSKEW,LPMEAN,LPSTDV,LPSKEW
C      INTEGER PLUS,ATSIGN
C      DOUBLE PRECISION XMEAN,STDDEV,REDMOM,XKURT
C      COMMON/GUMPAR/XMEAN,STDDEV,REDMOM,XKURT,ALPH,EPSLON,UDROUT,ERRORG
C      COMMON /PSNPAR/PMEAN,PSTDEV,PSKEW
C      COMMON /LPNPAR/LPMEAN,LPSTDV,LPSKEW
C      DATA PLUS,ATSIGN/'+', '@' /
C      DATA DOT,STAR,DASH,OH,BLANK/'.', '*', 'I', 'O', ' ' /
C      WRITE(MM,1)
C      1 FORMAT(///)
C
C      SET THE SCALE AND THE LOWEST VALUE TO BE
C      PLOTTED.
C
C      A=ALOG(.001)
C      SCALE=50./ABS(A)
C
C      NOW LOAD UP THE VECTORS WITH THE OBSERVED DATA
C
C      DO 30 I=1,N
C      SIMPLE THOMAS CUMULATIVE PROBABILITY FROM DATA
C      IF(.NOT.ANALYS(1))GO TO 10
C      VII=FLOAT(((3*N+1)*(N-I)+2)/FLOAT(3*(N*N-1)))
C      IF(I.EQ.N)VII=.001
C      IF(VII.LT.0.001) VII=0.0011
C      VII=ALOG(VII)-A
C      V(1,I)=AINT(VII*SCALE+0.5)
C      GUMBEL'S 3-PARAMETER CUMULATIVE PROBABILITY FROM PDF.
C      10 IF(.NOT.ANALYS(2))GO TO 20
C      IF(ERRORG)GO TO 20
C      V2I=1.0-EXP(-((D(I)-EPSLON)/(UDROUT-EPSLON))*ALPH)
C      IF(V2I.LT.0.001) V2I=0.0011
C      V2I=ALOG(V2I)-A

```

```

V(2,I)=AINT(V2I*SCALE+0.5)
C   PEARSON TYPE-III CUMULATIVE PROBABILITY FROM CHI-SQUARE DIST.
20 IF (.NOT.ANALYS(3)) GO TO 25
   TAS = 8.0/(PSKEW**2)
   T = (D(I) - PMEAN)/PSTDEV
   PA = 2.0 / PSKEW
   CS = 2.0 * PA * (T+PA)
   CALL MDCH(CS,TAS,V3I,IER)
C   ADJUST THE PROBABILITY VALUES WHEN SKEW > 0.0 & NORMAL IS OK
   IF ((PA.LT.0.)) V3I = 1. - V3I
   IF (V3I.GT.0.9999) V3I = 0.9999
   IF (V3I.LT.0.001) V3I = 0.001
   V3I = ALOG(V3I) - A
   V(3,I) = AINT(V3I*SCALE + 0.5)
C   LOG PEARSON TYPE-III CUMULATIVE PROBABILITY FROM CHI-SQUARE
25 IF(.NOT.ANALYS(4)) GO TO 30
   TASL = 8.0/(LPSKEW**2)
   TL = (ALOG(D(I))-LPMEAN)/LPSTDV
   PAL = 2.0/LPSKEW
   CSL = 2.0 * PAL * (TL + PAL)
   CALL MDCH(CSL,TASL,V4I,IER)
C   ADJUST THE PROBABILITY VALUES WHEN SKEW > 0 & NORMAL IS OK
   IF ((PAL.LT.0.)) V4I = 1.0 - V4I
   IF (V4I.GT.0.9999) V4I = 0.9999
   IF (V4I.LT.0.001) V4I = 0.001
   V4I = ALOG(V4I) - A
   V(4,I) = AINT(V4I*SCALE + 0.5)
30 CONTINUE

C   NOW COMPUTE POSITIONS FOR TIC MARKS ON THIS SCALE
C   THREE DECADES ARE USED WITH 10 ELEMENTS IN EACH DECADE
C
DO 40 I=1,3
  DECIM=10.** (I-4)
  DO 40 J=1,9
    K=9*(I-1)+J
    VALUE = ALOG(FLOAT(J)*DECIM)
    VALUE=VALUE-A
    V3(K)=AINT(VALUE*SCALE+0.5)
40 CONTINUE

C   NOW FILL IN THE LINE WITH THE TIC MARKS, FIRST BLANK
C   OUT THE LINE
C
DO 50 I=1,50
50 LINE(I)=BLANK

C   NOW PUT TIC MARKS IN AND PRINT IT
C
DO 60 I=1,27
  K=V3(I)
60 LINE(K)=DASH
  LINE(50)=DASH
  WRITE(MM,80)
80 FORMAT(T20,'CUMULATIVE PROBABILITY',/,
1      T13,'.001',T28,'.01',T43,'0.1',T60,'1.0')
  WRITE(MM,90)LINE
90 FORMAT(T9,'.',T13,50A1,'.')

```

```

C
C   NOW COMPUTE THE VERTICAL SCALE.  THE LOWEST VALUE IS IN
C   D(N) AND THE HIGHEST IN D(1).  WE WANT 25 LINES TO REPRESENT THE
C   INTERVAL 0 TO D(1).
C
HIGH=D(1)
DO 100 I=1,5
  IF(HIGH/10.**I.GT.10.) GO TO 100
  HIGH=AINT(HIGH/10.**I)+1.0
  HIGH=HIGH*10.0**I
  GO TO 110
100 CONTINUE
  STOP
110 SPACIN=HIGH/50.
C
C   NOW SCAN UP THE INPUT ARRAY.  STARTING WITH ZERO GO UP TO
C   THE FIRST INCREMENT IN THE SPACING LOADING VALUES INTO
C   THE LINE.
C
FLOW=SPACIN
K=N
L=0
120 DO 130 I=1,50
130 LINE(I)=BLANK
140 IF(D(K).GT.FLOW)GO TO 150
C
C   WE HAVE A POINT IN THIS INTERVAL
C
  IF(.NOT.ANALYS(1))GO TO 141
  M=V(1,K)
  LINE(M)=OH
141 CONTINUE
  IF(.NOT.ANALYS(2))GO TO 142
  IF(ERRORG)GO TO 142
  M=V(2,K)
  LINE(M)=STAR
142 IF(.NOT.ANALYS(3)) GO TO 143
  M = V(3,K)
  LINE(M) = PLUS
143 IF(.NOT.ANALYS(4)) GO TO 144
  M = V(4,K)
  LINE(M) = ATSIGN
144 CONTINUE
  K=K-1
  IF(K.EQ.0)GO TO 150
  GO TO 140
C
C   GOT ALL THE POINTS IN THIS INTERVAL PLOTTED
C
150 IF((L/5)*5.EQ.L)GO TO 160
  WRITE(MM,90)LINE
  GO TO 180
160 WRITE(MM,170)FLOW,LINE
170 FORMAT(1X,F8.0,T13,50A1,'.')
180 IF(K.EQ.0)GO TO 190
  L=L-1
  FLOW=FLOW+SPACIN
  GO TO 120

```

```

190 WRITE(MM,200)
200 FORMAT(T13,50('.'),/,
1 ' LEGEND:',/,
2 ' 0-----THOMAS CUMULATIVE PROBABILITY',/,
3 ' *-----GUMBELS CUMULATIVE PROBABILITY',/
4 ' +-----PEARSON TYPE III CUMULATIVE PROBABILITY',/
5 ' @-----LOG PEARSON TYPE-III CUMULATIVE PROBABILITY'//)
IF(ERRORG)WRITE(MM,210)
210 FORMAT(' CANNOT PRODUCE GUMBEL'S GRAPH',/,
1 ' KURTOSIS OUTSIDE RANGE')

```

```

RETURN
END

```

```

.....
SUBROUTINE FINDST(ASCII, FLOWS, NSTAS, NYEARS, FOUND, ALL, ISTATN)

```

PURPOSE:

TO READ THE DAILY VALUES FILE AND RETRIEVE THE LOW FLOW
RECORDS FOR A GIVEN STATION

ARGUMENTS:

ASCII = THE 78 CHARACTERS OF IDENTIFICATION DATA
FLOWS = THE RETURNED ARRAY WITH LOW FLOW DATA IN IT
NYEARS = THE NUMBER OF ENTRIES WITH ACTUAL DATA IN THEM
FOUND = SET TO TRUE IF STATION FOUND, OTHERWISE IS FALSE
NSTAS = THE NUMBER OF STATIONS IN THE INPUT TABLE
ISTATN = THE TABLE OF STATIONS TO BE OBTAINED
ALL = LOGICAL VARIABLE - TRUE IF ALL STATIONS ARE TO BE USED

METHOD:

AT THE START THE ROUTINE ASSUMES THAT THE NEXT RECORD TO BE READ
IN IS AN IDENTIFICATION RECORD. THIS IS READ. IF ALL = .TRUE.
THE RECORD IS ACCEPTED, OTHERWISE THE INPUT TABLE IS SEARCHED.
IF THE STATION IS IN THE TABLE IT IS ACCEPTED, OTHERWISE
IT IS REJECTED. IF IT IS NOT ACCEPTED IT IS FLUSHED AND THE
ROUTINE POSITIONNS AT THE NEXT IDENTIFICATION RECORD AND
TRIES AGAIN. IF A STATION IS ACCEPTED ITS CHARACTERISTICS
ARE STORED AND THE FILE IS POSITIONED AT THE NEXT STATION.

NOTE:

A RUNNING COUNT IS MADE OF ACCEPTED STATIONS. WHEN THIS
EQUALS THE VARIABLE NSTAS, ALL FURTHER STATIONS ARE
REJECTED.

AUTHOR:

J.S. JALBERT

DATE:

JULY 5, 1976

```

.....
SUBROUTINE FINDST(ASCII, FLOWS, NSTAS, NYEARS, FOUND, ALL, ISTATN)
DIMENSION FLOWS(100), ISTATN(100,8), RECOUR(10)
LOGICAL ALL, FOUND
INTEGER ASCII(78)
DATA ICOUNT, INFIL/0,20/

```

```

        FOUND=.FALSE.
10  READ(INFIL,END=90)ASCII,DRAIN,NYEARS,LASTDY,IDETAL,IWET,RECOUR
    IF(ALL)GO TO 50
C
C      TEST TO SEE IF IT IS A STATION IN THE LIST
C
        DO 30 I=1,NSTAS
        DO 20 J=1,8
        IF(ISTATN(I,J).NE.ASCII(J))GO TO 30
20  CONTINUE
        GO TO 50
30  CONTINUE
C
C      STATION JUST READ WAS NOT IN THE INPUT TABLE SO FLUSH IT
C      AND GET THE NEXT ONE TO LOOK AT
C
        BYPASS YEAR'S ARRAY
        READ(INFIL)I
C
C      BYPASS DAYS ARRAY
        READ(INFIL)I
C      PASS THE 3 LOWFLOW RECORDS
        READ(INFIL)X
        READ(INFIL)X
        READ(INFIL)X
C      SKIP THE DAILY VALUES DATA
C      BUT CHECK FIRST TO SEE IF THERE IS ANY THERE
        IF(IDETAL.NE.1)GO TO 10
        IDATA=LASTDY
        IRECS=IDATA/127
        IF(IRECS*127.LT.IDATA)IRECS=IRECS+1
        DO 40 I=1,IRECS
        READ(INFIL)X
40  CONTINUE
C
C      FINISHED SKIPPING THE DATA FOR THIS STATION SO GO LOOK AT THE
C      NEXT ONE
C
        GO TO 10
C
C      STATION LOCATED NOW GET THE DATA AND POSTION THE FILE PROPERLY
C
        BYPASS YEARS AND DAYS ARRAY
50  FOUND=.TRUE.
        READ(INFIL)I
        READ(INFIL)I
C      GET THE 1 DAY FLOWS OUT
        READ(INFIL)X
C      GET THE 7 DAY LOW FLOW RECORD
        READ(INFIL)FLOWS
C      SKIP OVER THE 14 DAY FLOW
        READ(INFIL)X
C
C      THE DATA HAS BEEN FOUND, NOW NOTIFY THE USER AND EXIT (ALSO FIX
C      UP A POSSIBLE ZERO IN THE FIRST DATA POSITION BECAUSE OF
C      INSUFFICIENT DATA IN THE FIRST YEAR.
C

```

```

      TYPE 60,ASCII
60  FORMAT(' LOCATED STATION # ',8A1,' LAT-LONG = ',2A1,'/',2A1,'/',
1    2A1,' ',3A1,'/',2A1,'/',2A1,'/', CODES =',2A1,1X,2A1,1X,3A1,1X,
3    2A1,1X,48A1,/)
C    SKIP THE DAILY VALUES DATA
      IF(IDETAL.NE.1)GO TO 75
      IDATA=LASTDY
      IRECS=IDATA/127
      IF(IRECS*127.LT.IDATA)IRECS=IRECS+1
      DO 70 I=1,IRECS
      READ(INFIL)X
70  CONTINUE
75  JYEARS=NYEARS
      IMD = 0
      DO 80 I=1,NYEARS
      IMJ = I - IMD
      IF((FLOWS(IMJ).GE.0.).AND.(FLOWS(IMJ).LT.9999999.9)) GO TO 80
      JYEARS=JYEARS-1
      DO 85 J=IMJ,JYEARS
85  FLOWS(J)=FLOWS(J+1)
      IMD = IMD+1
80  CONTINUE
      NYEARS=JYEARS
90  TYPE 95, NYEARS
95  FORMAT (' NUMBER OF YEARS OF LOW FLOW =',I5)
      RETURN
      END

```

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APPENDIX B

LOFL02 Output For Six Sample Stations

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STATISTICS FOR STATION # 03501000
CULLASAJA RIVER AT CULLASAJA, N. C.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
146.1	.980769	.987436	122.4	.961538	.967692
117.0	.942308	.947949	104.1	.923077	.928205
101.1	.903846	.908462	89.2	.884615	.888718
84.8	.865385	.868974	84.8	.846154	.849231
84.4	.826923	.829487	83.7	.807692	.809744
82.2	.788462	.790000	78.0	.769231	.770256
76.2	.750000	.750513	75.7	.730769	.730769
74.8	.711538	.711026	74.1	.692308	.691282
73.8	.673077	.671538	67.4	.653846	.651795
67.1	.634615	.632051	66.4	.615385	.612308
66.1	.596154	.592564	65.5	.576923	.572821
63.2	.557692	.553077	62.8	.538462	.533333
60.4	.519231	.513590	59.1	.500000	.493846
58.8	.480769	.474103	58.2	.461538	.454359
57.5	.442308	.434615	57.1	.423077	.414872
56.1	.403846	.395128	54.8	.384615	.375385
54.1	.365385	.355641	53.4	.346154	.335897
52.1	.326923	.316154	49.8	.307692	.296410
48.1	.288462	.276667	47.7	.269231	.256923
45.2	.250000	.237179	43.1	.230769	.217436
43.0	.211538	.197692	42.1	.192308	.177949
42.0	.173077	.158205	41.4	.153846	.138462
40.2	.134615	.118718	40.2	.115385	.098974
39.0	.096154	.079231	35.1	.076923	.059487
33.0	.057692	.039744	29.2	.038462	.020000
19.7	.019231	.000256	84.8	.000000	.000000

GUMBEL'S STATISTICS

MEAN = 64.1
 STDDEV= 24.597
 REDMOM= 1.075
 KURT = 1.7248
 ALPHA = 1.5198
 EPSILON = 27.4761
 U = 68.1562

(STATION 03501000)

PEARSON TYPE III STATISTICS

MEAN = 64.1
 STDDEV= 24.597
 SKEW = 1.0755

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.41881
2.0	-0.17575
3.0	-0.54969
5.0	-0.84908
10.0	-1.11262
20.0	-1.28928
25.0	-1.33447
30.0	-1.36809
40.0	-1.41642
50.0	-1.44967

LOG-PEARSON TYPE III STATISTICS

MEAN = 4.1
 STDDEV= 0.380
 SKEW = -0.2056

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.30618
2.0	0.03423
3.0	-0.40187
5.0	-0.82989
10.0	-1.30136
20.0	-1.70112
25.0	-1.81936
30.0	-1.91292
40.0	-2.05557
50.0	-2.16247

LOG-NORMAL STATISTICS

MEAN = 4.1
 STDDEV= 0.380

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.84175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03501000)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	104.1	101.9	89.2	85.0
2.0	59.1	59.1	58.8	58.4
3.0	53.4	52.5	49.8	49.6
5.0	43.0	42.5	42.1	42.0
10.0	40.2	39.2	39.0	35.4
20.0	33.0	31.5	29.2	24.8
25.0	33.0	29.5	29.2	19.9
30.0	29.2	26.7	19.7	19.7
40.0	29.2	22.6	19.7	19.7
50.0	29.2	20.1	19.7	19.7

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	99.8
2.0	59.4
3.0	49.9
5.0	42.6
10.0	36.7
20.0	33.2
25.0	32.4
30.0	31.9
40.0	31.1
50.0	30.6

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	99.0
2.0	59.8
3.0	50.6
5.0	43.3
10.0	36.8
20.0	32.4
25.0	31.3
30.0	30.5
40.0	29.3
50.0	28.5

(STATION 03524000)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	98.3
2.0	60.6
3.0	51.4
5.0	43.7
10.0	36.5
20.0	31.4
25.0	30.0
30.0	28.9
40.0	27.4
50.0	26.3

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	99.4
2.0	59.8
3.0	50.8
5.0	43.5
10.0	36.8
20.0	32.0
25.0	30.8
30.0	29.8
40.0	28.5
50.0	27.4

(STATION 03501000)

LEGEND:

- THOMAS CUMULATIVE PROBABILITY
- *-----GUMBEL'S CUMULATIVE PROBABILITY
- +-----PEARSON TYPE III CUMULATIVE PROBABILITY
- ◻-----LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

STATISTICS FOR STATION # 03524000
CLINCH RIVER AT CLEVELAND, VA.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
172.2	.981132	.987668	151.0	.962264	.968307
146.4	.943396	.948946	141.0	.924528	.929584
127.8	.905660	.910223	123.2	.886792	.890862
122.1	.867925	.871501	115.7	.849057	.852140
114.7	.830189	.832778	113.8	.811321	.813417
109.8	.792453	.794056	106.8	.773585	.774695
105.2	.754717	.755334	103.1	.735849	.735972
98.1	.716981	.716611	96.0	.698113	.697250
92.4	.679245	.677889	86.0	.660377	.658528
85.7	.641509	.639166	84.0	.622642	.619805
83.5	.603774	.600444	81.7	.584906	.581083
81.2	.566038	.561722	80.0	.547170	.542360
78.1	.528302	.522999	75.8	.509434	.503638
75.8	.490566	.484277	75.4	.471698	.464916
75.0	.452030	.445554	72.5	.433962	.426193
72.2	.415094	.406832	70.0	.396226	.387471
69.2	.377358	.368110	68.8	.358491	.348748
65.4	.339623	.329387	64.1	.320755	.310026
62.0	.301887	.290665	62.0	.283019	.271303
61.0	.264151	.251942	60.2	.245283	.232581
59.4	.226415	.213220	59.0	.207547	.193859
58.8	.188679	.174497	58.0	.169811	.155136
57.7	.150943	.135775	56.4	.132075	.116414
55.7	.113208	.097053	50.5	.094340	.077691
48.7	.075472	.058330	48.7	.056604	.038969
46.0	.037736	.019608	39.5	.018868	.000247

GUMBEL'S STATISTICS

MEAN = 84.0
STO DEV = 29.864
RED MOM = 0.982
KURT = 0.5210
ALPHA = 1.6057
EPSILON = 37.1646
U = 89.4048

(STATION 03524000)

PEARSON TYPE III STATISTICS

MEAN = 84.0
 STDDEV= 29.864
 SKEW = 0.9824

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.41634
2.0	-0.16111
3.0	-0.54177
5.0	-0.85224
10.0	-1.13118
20.0	-1.32341
25.0	-1.37334
30.0	-1.41077
40.0	-1.46446
50.0	-1.50213

LOG-PEARSON TYPE III STATISTICS

MEAN = 4.4
 STDDEV= 0.337
 SKEW = 0.2967

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.36921
2.0	-0.04933
3.0	-0.46887
5.0	-0.85238
10.0	-1.24531
20.0	-1.55630
25.0	-1.64464
30.0	-1.71339
40.0	-1.81634
50.0	-1.89202

LOG-NORMAL STATISTICS

MEAN = 4.4
 STDDEV= 0.337

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.84175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03524000)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	141.0	130.2	122.1	121.8
2.0	75.8	75.8	75.4	75.3
3.0	65.4	65.0	64.1	62.5
5.0	59.0	58.9	58.8	58.3
10.0	55.7	52.1	50.5	49.0
20.0	48.7	47.8	46.0	43.3
25.0	48.7	46.3	46.0	39.9
30.0	46.0	44.5	39.5	39.5
40.0	46.0	41.6	39.5	39.5
50.0	46.0	39.9	39.5	39.5

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	127.2
2.0	78.7
3.0	66.9
5.0	57.7
10.0	50.0
20.0	45.4
25.0	44.3
30.0	43.5
40.0	42.5
50.0	41.8

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	126.3
2.0	79.2
3.0	67.8
5.0	58.5
10.0	50.2
20.0	44.5
25.0	43.0
30.0	41.9
40.0	40.3
50.0	39.1

(STATION 03524000)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	125.9
2.0	78.0
3.0	67.7
5.0	59.5
10.0	52.1
20.0	46.9
25.0	45.5
30.0	44.5
40.0	43.0
50.0	41.9

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	124.4
2.0	79.3
3.0	68.6
5.0	59.7
10.0	51.5
20.0	45.6
25.0	44.0
30.0	42.8
40.0	41.1
50.0	39.7

(STATION 03524000)

LEGEND:

- O-----THOMAS CUMULATIVE PROBABILITY
- *-----GUMBEL'S CUMULATIVE PROBABILITY
- +-----PEARSON TYPE III CUMULATIVE PROBABILITY
- a-----LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

STATISTICS FOR STATION # 03528000
CLINCH RIVER ABOVE TAZEWEEL, TENN.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
531.4	.981481	.987892	464.0	.962963	.968898
392.0	.944444	.949905	365.5	.925926	.930912
357.0	.907407	.911918	337.1	.888889	.892925
328.0	.870370	.873932	314.8	.851852	.854938
307.0	.833333	.835945	295.8	.814815	.816952
286.8	.796296	.797958	285.0	.777778	.778965
274.7	.759259	.759972	259.5	.740741	.740978
256.4	.722222	.721985	256.0	.703704	.702991
250.5	.685185	.683998	246.1	.666667	.665005
233.4	.648148	.646011	229.2	.629630	.627018
226.8	.611111	.608025	222.8	.592593	.589031
220.8	.574074	.570038	217.4	.555556	.551045
217.0	.537037	.532051	216.2	.518519	.513058
215.1	.500000	.494065	213.5	.481481	.475071
203.5	.462963	.456078	203.1	.444444	.437085
196.2	.425926	.418091	187.7	.407407	.399098
183.4	.388889	.380104	182.1	.370370	.361111
179.4	.351852	.342118	172.5	.333333	.323124
169.2	.314815	.304131	163.0	.296296	.285138
163.0	.277778	.266144	160.0	.259259	.247151
157.2	.240741	.228158	151.7	.222222	.209164
143.4	.203704	.190171	142.8	.185185	.171178
140.0	.166667	.152184	135.4	.148148	.133191
135.4	.129630	.114198	133.4	.111111	.095204
132.5	.092593	.076211	131.4	.074074	.057217
122.1	.055556	.038224	116.8	.037037	.019231
116.4	.018519	.000237	365.5	.000000	.000000

GUMBEL'S STATISTICS

MEAN = 225.3
STDEV= 88.443
REDMOM= 1.309
KURT = 2.0900
ALPHA = 1.3413
EPSILON = 107.9008
U = 235.7884

(STATION 03528000)

PEARSON TYPE III STATISTICS

MEAN = 225.3
 STDDEV= 88.443
 SKEW = 1.3091

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.42165
2.0	-0.21164
3.0	-0.56701
5.0	-0.83803
10.0	-1.06214
20.0	-1.20244
25.0	-1.23654
30.0	-1.26139
40.0	-1.29587
50.0	-1.31964

LOG-PEARSON TYPE III STATISTICS

MEAN = 5.4
 STDDEV= 0.362
 SKEW = 0.3837

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.37737
2.0	-0.06368
3.0	-0.47919
5.0	-0.85414
10.0	-1.23306
20.0	-1.52889
25.0	-1.61222
30.0	-1.67686
40.0	-1.77328
50.0	-1.84388

LOG-NORMAL STATISTICS

MEAN = 5.4
 STDDEV= 0.362

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.84175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03528000)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	365.5	357.8	328.0	326.2
2.0	215.1	215.1	213.5	206.8
3.0	172.5	172.5	169.2	166.4
5.0	143.4	143.3	142.8	141.5
10.0	133.4	132.9	132.5	131.7
20.0	122.1	120.5	116.8	116.7
25.0	122.1	117.6	116.8	116.4
30.0	116.8	116.7	116.4	116.4
40.0	116.8	116.5	116.4	116.4
50.0	116.8	116.4	116.4	116.4

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	353.4
2.0	205.2
3.0	173.1
5.0	149.7
10.0	131.8
20.0	121.9
25.0	119.7
30.0	118.2
40.0	116.2
50.0	114.9

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	351.0
2.0	206.6
3.0	175.2
5.0	151.2
10.0	131.4
20.0	119.0
25.0	115.9
30.0	113.7
40.0	110.7
50.0	108.6

(STATION 03528000)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	347.0
2.0	205.9
3.0	177.2
5.0	154.7
10.0	134.8
20.0	121.1
25.0	117.5
30.0	114.8
40.0	110.9
50.0	108.1

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	341.8
2.0	210.7
3.0	180.3
5.0	155.4
10.0	132.5
20.0	116.2
25.0	111.8
30.0	108.5
40.0	103.9
50.0	100.2

(STATION 03528000)

LEGEND:

- O-----THOMAS CUMULATIVE PROBABILITY
- *-----GUMBEL'S CUMULATIVE PROBABILITY
- +-----PEARSON TYPE III CUMULATIVE PROBABILITY
- *+-----LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

STATISTICS FOR STATION # 03533000
CLINCH RIVER BELOW NUKKIS DAM, TENN.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
1508.5	.985714	.990616	1243.4	.971429	.976050
944.2	.957143	.961485	818.5	.942857	.946919
817.1	.928571	.932353	795.7	.914286	.917787
792.1	.900000	.903221	732.2	.885714	.888655
722.8	.871429	.874090	686.8	.857143	.859524
664.8	.842857	.844958	648.5	.828571	.830392
632.8	.814286	.815826	629.0	.800000	.801261
617.1	.785714	.786695	598.7	.771429	.772129
556.5	.757143	.757563	535.0	.742857	.742997
525.7	.728571	.728431	524.2	.714286	.713866
498.5	.700000	.699300	496.4	.685714	.684734
470.0	.671429	.670168	432.1	.657143	.655602
431.4	.642857	.641036	420.0	.628571	.626471
392.0	.614286	.611905	383.4	.600000	.597339
381.1	.585714	.582773	378.5	.571429	.568207
375.0	.557143	.553641	344.2	.542857	.539076
285.0	.528571	.524510	272.0	.514286	.509944
249.0	.500000	.495378	232.1	.485714	.480812
227.8	.471429	.466246	208.5	.457143	.451681
191.7	.442857	.437115	177.4	.428571	.422549
125.7	.414286	.407983	121.4	.400000	.393417
116.5	.385714	.378852	102.4	.371429	.364286
91.8	.357143	.349720	82.8	.342857	.335154
81.1	.328571	.320588	80.8	.314286	.306022
79.1	.300000	.291457	77.1	.285714	.276891
70.5	.271429	.262325	70.2	.257143	.247759
66.8	.242857	.233193	64.0	.228571	.218627
62.0	.214286	.204062	56.5	.200000	.189496
54.4	.185714	.174930	50.4	.171429	.160364
40.2	.157143	.145798	47.0	.142857	.131232
44.8	.128571	.116667	40.0	.114286	.102101
34.8	.100000	.087535	29.7	.085714	.072969
27.1	.071429	.058403	21.0	.057143	.043838
20.2	.042857	.029272	19.2	.028571	.014706
5.8	.014286	.000140	81.1	.000000	.000000

GUMBEL'S STATISTICS

MEAN = 342.5
 STDEV= 320.379
 REOMOM= 1.196
 KURT = 1.6309
 ALPHA = 1.4215
 EPSILON = -106.4926
 U = 387.2591

(STATION 03533000)

PEARSON TYPE III STATISTICS

MEAN = 342.5
 STDDEV= 320.379
 SKEW = 1.1963

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.42118
2.0	-0.19449
3.0	-0.55915
5.0	-0.84388
10.0	-1.08698
20.0	-1.24466
25.0	-1.28396
30.0	-1.31291
40.0	-1.35359
50.0	-1.38149

LOG-PEARSON TYPE III STATISTICS

MEAN = 5.2
 STDDEV= 1.250
 SKEW = -0.4898

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.25995
2.0	0.08131
3.0	-0.35967
5.0	-0.80932
10.0	-1.32289
20.0	-1.77288
25.0	-1.90872
30.0	-2.01633
40.0	-2.18247
50.0	-2.30854

LOG-NORMAL STATISTICS

MEAN = 5.2
 STDDEV= 1.250

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.84175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03533000)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	795.7	794.4	732.2	726.7
2.0	249.0	249.0	232.1	229.2
3.0	82.8	81.7	80.8	80.6
5.0	56.5	56.5	54.4	53.3
10.0	34.8	34.8	29.7	29.4
20.0	21.0	20.6	20.2	19.6
25.0	20.7	20.0	19.2	15.8
30.0	20.2	19.5	19.2	9.7
40.0	19.2	15.9	5.8	5.8
50.0	19.2	11.2	5.8	5.8

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	807.0
2.0	275.0
3.0	155.1
5.0	65.4
10.0	-5.1
20.0	-45.4
25.0	-54.5
30.0	-60.8
40.0	-69.3
50.0	-74.8

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	797.8
2.0	280.2
3.0	163.3
5.0	72.1
10.0	-5.8
20.0	-56.3
25.0	-68.9
30.0	-78.1
40.0	-91.2
50.0	-100.1

(STATION 03533000)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	916.0
2.0	210.1
3.0	121.1
5.0	69.0
10.0	36.3
20.0	20.7
25.0	17.5
30.0	15.3
40.0	12.4
50.0	10.6

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	1006.5
2.0	189.8
3.0	110.8
5.0	66.3
10.0	38.3
20.0	24.3
25.0	21.3
30.0	19.2
40.0	16.5
50.0	14.6

(STATION 03533000)

LEGEND:

- THOMAS CUMULATIVE PROBABILITY
- *———GUMBEL'S CUMULATIVE PROBABILITY
- +———PEARSON TYPE III CUMULATIVE PROBABILITY
- LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

STATISTICS FOR STATION # 03571850
TENNESSEE RIVER AT SOUTH PITTSBURG, TENN.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
24000.0	.976190	.984524	23685.7	.952381	.959921
23485.7	.928571	.935317	21114.2	.904762	.910714
21028.5	.880952	.886111	20400.0	.857143	.861508
20342.8	.833333	.836905	20271.4	.809524	.812302
19985.7	.785714	.787698	19142.8	.761905	.763095
18800.0	.738095	.738492	18571.4	.714286	.713889
18385.7	.690476	.689286	17957.1	.666667	.664683
17914.2	.642857	.640079	17842.8	.619048	.615476
17100.0	.595238	.590873	16942.8	.571429	.566270
16557.1	.547619	.541667	16242.8	.523810	.517063
15900.0	.500000	.492460	15657.1	.476190	.467857
15414.2	.452381	.443254	14500.0	.428571	.418651
13971.4	.404762	.394048	13357.1	.380952	.369444
13028.5	.357143	.344841	12884.2	.333333	.320238
12401.4	.309524	.295635	11895.7	.285714	.271032
11571.4	.261905	.246429	11180.0	.238095	.221825
11158.5	.214286	.197222	11085.7	.190476	.172619
10160.0	.166667	.148016	9200.0	.142857	.123413
7614.2	.119048	.098810	7571.4	.095238	.074206
7474.2	.071429	.049603	6830.0	.047619	.025000
6121.4	.023810	.000397	*****	.400000	.393417

GUMBEL'S STATISTICS

MEAN = 15335.3
 STDDEV= 4890.870
 REDMOM= -0.159
 KURT = -0.8460
 ALPHA = 4.5881
 EPSILON = -4407.8524
 U = 17202.3938

(STATION 03571850)

PEARSON TYPE III STATISTICS

MEAN = 15335.3
 STDDEV= 4890.870
 SKEW = -0.1593

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.31309
2.0	0.02653
3.0	-0.40853
5.0	-0.83284
10.0	-1.29728
20.0	-1.68883
25.0	-1.80427
30.0	-1.89548
40.0	-2.03436
50.0	-2.13827

LOG-PEARSON TYPE III STATISTICS

MEAN = 9.6
 STDDEV= 0.361
 SKEW = -0.7613

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.20850
2.0	0.12572
3.0	-0.31662
5.0	-0.78403
10.0	-1.33565
20.0	-1.83244
25.0	-1.98411
30.0	-2.10639
40.0	-2.29470
50.0	-2.43163

LOG-NORMAL STATISTICS

MEAN = 9.6
 STDDEV= 0.361

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.04175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03571850)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	23485.7	21545.4	20400.0	20397.1
2.0	15900.0	15900.0	15657.1	15492.6
3.0	12884.2	12884.2	12401.4	12173.0
5.0	11158.5	11114.8	11085.7	10279.4
10.0	7614.2	7580.0	7571.4	7480.5
20.0	7474.2	6894.4	6830.0	6144.3
25.0	6830.0	6603.2	6121.4	6121.4
30.0	6830.0	6404.8	6121.4	6121.4
40.0	6830.0	6156.8	6121.4	6121.4
50.0	6121.4	6121.4	6121.4	6121.4

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	21740.6
2.0	15543.2
3.0	13342.6
5.0	11176.2
10.0	8824.8
20.0	6903.4
25.0	6354.2
30.0	5927.2
40.0	5290.0
50.0	4824.5

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	21757.4
2.0	15465.1
3.0	13337.2
5.0	11262.0
10.0	8990.5
20.0	7075.4
25.0	6510.9
30.0	6064.7
40.0	5385.5
50.0	4877.3

(STATION 03571850)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	22395.6
2.0	15142.7
3.0	12905.4
5.0	10899.4
10.0	8929.3
20.0	7461.7
25.0	7063.7
30.0	6758.3
40.0	6313.6
50.0	5955.7

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	23446.1
2.0	14470.0
3.0	12385.9
5.0	10674.4
10.0	9104.8
20.0	7989.2
25.0	7687.0
30.0	7463.0
40.0	7145.4
50.0	6851.0

(STATION 03571850)

LEGEND:

- THOMAS CUMULATIVE PROBABILITY
- *-----GUMBEL'S CUMULATIVE PROBABILITY
- +-----PEARSON TYPE III CUMULATIVE PROBABILITY
- LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

STATISTICS FOR STATION # 03584500
CLK RIVER NEAR PROSPECT, TENN.

FLOW	SIMPLE	THOMAS'	FLOW	SIMPLE	THOMAS'
1027.5	.982456	.988517	703.4	.964912	.970548
551.0	.947368	.952578	485.0	.929825	.934609
433.4	.912281	.916640	415.0	.894737	.898671
377.2	.877193	.880702	375.7	.859649	.862733
351.2	.842105	.844763	330.8	.824561	.826794
322.8	.807018	.808825	322.2	.789474	.790856
320.8	.771930	.772887	306.8	.754386	.754918
302.1	.736842	.736948	295.2	.719298	.718979
292.1	.701754	.701010	291.8	.684211	.683041
284.2	.666667	.665072	273.1	.649123	.647103
272.7	.631579	.629133	270.7	.614035	.611164
257.7	.596491	.593195	250.0	.578947	.575226
248.0	.561404	.557257	247.7	.543860	.539288
237.0	.526316	.521318	235.2	.508772	.503349
234.7	.491228	.485380	231.1	.473684	.467411
230.2	.456140	.449442	229.0	.438596	.431473
226.5	.421053	.413503	220.0	.403509	.395534
218.4	.385965	.377565	218.1	.368421	.359596
217.8	.350877	.341627	214.5	.333333	.323658
208.0	.315789	.305688	207.0	.298246	.287719
203.1	.280702	.269750	202.7	.263158	.251781
199.4	.245614	.233812	196.2	.228070	.215843
193.7	.210526	.197873	191.5	.192982	.179904
189.0	.175439	.161935	188.2	.157895	.143966
178.4	.140351	.125997	175.4	.122807	.108028
172.4	.105263	.090058	162.4	.087719	.072089
154.4	.070175	.054120	130.0	.052632	.036151
118.7	.035088	.018182	93.5	.017544	.000213

GUMBEL'S STATISTICS

MEAN = 276.5
 STDEV= 146.522
 REDMOM= 3.082
 KURT = 12.8212
 ALPHA = 0.7563
 EPSILON = 167.2034
 U = 259.6339

(STATION 03584500)

PEARSON TYPE III STATISTICS

MEAN = 276.5
 STDDEV= 146.522
 SKEW = 3.0822

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.27885
2.0	-0.39967
3.0	-0.56025
5.0	-0.62331
10.0	-0.64400
20.0	-0.64795
25.0	-0.64833
30.0	-0.64853
40.0	-0.64870
50.0	-0.64878

LOG-PEARSON TYPE III STATISTICS

MEAN = 5.5
 STDDEV= 0.406
 SKEW = 0.8263

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.40990
2.0	-0.13620
3.0	-0.52734
5.0	-0.85571
10.0	-1.16100
20.0	-1.37948
25.0	-1.43769
30.0	-1.48180
40.0	-1.54586
50.0	-1.59143

LOG-NORMAL STATISTICS

MEAN = 5.5
 STDDEV= 0.406

RECURRENCE INTERVAL	T-STATISTIC
1.1	1.33534
2.0	0.00000
3.0	-0.43028
5.0	-0.84175
10.0	-1.28178
20.0	-1.64345
25.0	-1.75014
30.0	-1.83197
40.0	-1.95229
50.0	-2.05257

(STATION 03584500)

ANALYSIS BY SIMPLE CUMULATIVE PROBABILITIES

RECURRENCE INTERVAL (YEARS)	SIMPLE METHOD		THOMAS METHOD	
	SIMPL	INTERP	SIMPL	INTERP
1.1	433.4	430.1	377.2	376.6
2.0	235.2	235.0	231.1	230.9
3.0	214.5	214.5	208.0	207.6
5.0	193.7	192.4	191.5	189.3
10.0	172.4	169.4	162.4	158.9
20.0	130.0	128.3	118.7	113.2
25.0	130.0	121.9	118.7	99.2
30.0	118.7	116.2	93.5	93.5
40.0	118.7	104.2	93.5	93.5
50.0	118.7	97.0	93.5	93.5

ANALYSIS BY GUMBEL'S DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	GUMBEL'S METHOD
1.1	461.0
2.0	224.1
3.0	195.2
5.0	179.9
10.0	171.9
20.0	169.0
25.0	168.5
30.0	168.3
40.0	167.9
50.0	167.7

ANALYSIS BY PEARSON TYPE III DISTRIBUTION

RECURRENCE INTERVAL (YEARS)	PEARSON TYPE III DISTRIBUTION
1.1	463.9
2.0	218.0
3.0	194.4
5.0	185.2
10.0	182.2
20.0	181.6
25.0	181.5
30.0	181.5
40.0	181.5
50.0	181.5

(STATION 03584500)

ANALYSIS BY LOG-PEARSON TYPE III	
RECURRENCE INTERVAL (YEARS)	LOG-PEARSON TYPE III
1.1	446.8
2.0	238.7
3.0	203.7
5.0	178.3
10.0	157.5
20.0	144.2
25.0	140.8
30.0	138.3
40.0	134.8
50.0	132.3

ANALYSIS BY LOG-NORMAL DISTRIBUTION	
RECURRENCE INTERVAL (YEARS)	LOG-NORMAL DISTRIBUTION
1.1	433.5
2.0	252.3
3.0	211.9
5.0	179.3
10.0	150.0
20.0	129.5
25.0	124.1
30.0	120.0
40.0	114.3
50.0	109.7

(STATION 03584500)

LEGEND:

- O-----THOMAS CUMULATIVE PROBABILITY
- *-----GUMBELS CUMULATIVE PROBABILITY
- +-----PEARSON TYPE III CUMULATIVE PROBABILITY
- a-----LOG PEARSON TYPE-III CUMULATIVE PROBABILITY

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