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A DIGITAL MODEL FOR STREAMFLOW ROUTING BY CONVOLUTION METHODS

By W. Harry Doyle, Jr., James O. Shearman, Gloria J. Stiltner, and William R. Krug

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CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSIONS

Inch-pounds units used in this report may be converted to International System of Units (SI) of measurements by the following conversion factors:

Multiply Inch-pound units	By	To obtain SI units
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.6093	kilometer (km)
acre	0.4047	hectare (ha)
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

A DIGITAL MODEL FOR STREAMFLOW ROUTING

BY CONVOLUTION METHODS

By W. Harry Doyle, Jr., James O. Shearman,

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ABSTRACT

U.S. Geological Survey computer model, CONROUT, for routing streamflow by unit-response convolution flow-routing techniques from an upstream channel location to a downstream channel location has been developed and documented. Calibration and verification of the flow-routing model and subsequent use of the model for simulation is also documented. Three hypothetical examples and two field applications are presented to illustrate basic flow-routing concepts. Most of the discussion is limited to daily flow routing since, to date, all completed and current studies of this nature involve daily flow routing. However, the model is programmed to accept hourly input data.

INTRODUCTION

CONROUT, a Digital Model for Streamflow Routing by Convolution Methods, can be used to route a streamflow hydrograph from an upstream location to a user-defined location downstream and produce an outflow discharge hydrograph. The model uses convolution techniques for streamflow routing computations. A convolution model treats a stream reach as a linear, one-dimensional system in which the input (upstream hydrograph) is convoluted with the unit response of the system to determine the output (downstream hydrograph). Two options are available in CONROUT for determining the unit response. Successive downstream routings involve stepwise routing from point to point using the previously computed outflow hydrograph as the inflow hydrograph to the next reach. Also, flows from tributaries, distributaries, and reservoirs have to be considered and adjustments made to compensate for these components.

The product of CONROUT is a simulated outflow discharge hydrograph at the end of the reach. The routing time step is either hourly or daily. The program will also compare simulated discharges to observed discharges (SUBROUTINE COMPAR) for calibration and will also plot (SUBROUTINE PLOT) the results. CONROUT can be used to estimate streamflow for periods of missing records. These data can then be used in statistical analyses to determine streamflow characteristics.

The purpose of this report is to provide a user's manual for CONROUT. The many options and features of CONROUT are described and discussed. Also, an overview of several hypothetical and field flow-routing applications is presented to aid the user. In addition, information is included for retrieving and transforming data for input to CONROUT.

DESCRIPTION OF MODEL

CONROUT is a streamflow routing model which may be used to simulate either hourly or daily streamflow. The model may be used to: (1) copy hydrographs; (2) combine hydrographs; (3) change the timing of hydrographs by lagging one or more routing intervals; (4) multiply hydrographs by ratios; and (5) route hydrographs to downstream locations. These five operations provide the user many different possibilities for streamflow simulation. For example, depending upon where simulation information is needed, a simple transposition of an upstream hydrograph to a downstream location might be sufficient. This can be accomplished by copying the upstream hydrograph directly. In other situations, reach characteristics influencing time of travel, attenuation and dispersion might be such that the upstream hydrograph can be transposed downstream in size and shape as is, but delayed in timing by one or more routing intervals. When reach characteristics are important enough to affect the shaping of the downstream hydrograph then the model can be used to route upstream streamflow to downstream locations. The routing process does consider the effects of wave movement and attenuation and dispersion. Finally, the ability to combine hydrographs and proportion hydrographs by multiplying by ratios enables the user to account for tributary inflows and intervening ungaged flows that may be indexed to a gaged station streamflow.

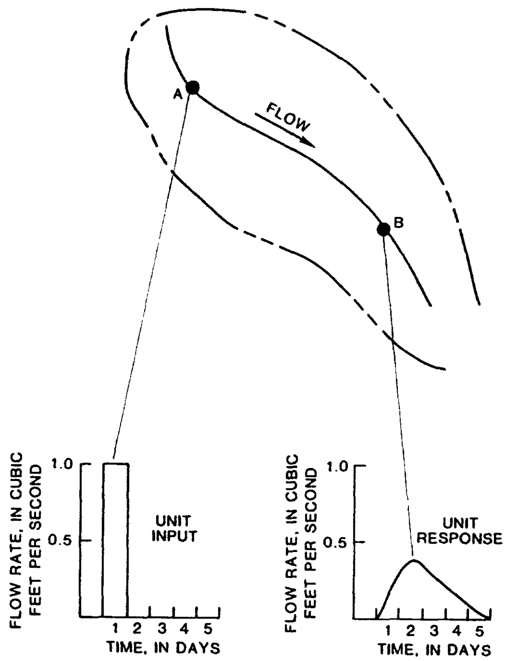
Various combinations of the above operations are also possible. Furthermore, results from one operation (or combination of operations) can be used as input to a subsequent operation (or combination of operations). Such stepwise computations can be made within a single program execution or by a series of program executions. Thus, the model is applicable to modeling studies ranging in scope from a single stream reach to an entire watershed.

CONROUT's hydrologic component for streamflow routing consists of a unit-response function and the convolution technique of Keefer (1974). The unit-response function defines the discharge at the downstream end of a modeling reach as a function of the inflow at the upstream end. Basically, the unit-response function defines the percentage of an upstream inflow that will arrive at the downstream end during the unit time (hourly or daily) and each successive unit time. Discharge at the downstream end for each unit time is the summation of the contribution of inflow at the upstream end from that unit time and each preceding unit time.

The behavior of a flood wave in a channel between an upstream location A and a downstream location B is controlled by the physical characteristics of the reach between the two locations. The type of physical setting along the channel influences the unit response which is reflected in the attenuation and dispersion of a flood wave as it moves along the reach. The determination of the unit response enables us to predict the resulting hydrograph shape as a flood wave proceeds downstream.

Convolution is a concept basic to linear system theory. A system input is combined through the convolution process with a system response function to produce the predicted system output. In the case of flow routing the system input is the upstsream inflow hydrograph, the system response function is the unit-response function, and the system output is the resultant downstream discharge hydrograph. The convolution technique is essentially identical to the unit hydrograph computation in that rainfall is convoluted with a unit hydrograph to produce the basin discharge hydrograph.

The convolution technique can be applied in streamflow routing because the system is assumed to be linear and individual responses may be superimposed to obtain a composite response. The technique first requires determining the system's response to a single unit of input. As an example, figure 1a illustrates that the unit-response function for the reach between A and B distributes a unit input of 1 ft^3/s for a duration of 1 day at A into a hydrograph at B. The unit-response ordinates (0.12, 0.38, 0.30, 0.15, and 0.05) are used to distribute the 1 ft^3/s inflow that passes A into 5 separate parts, each lagged by a time step of 1 day as seen in figure 1b. Figure 1c shows that with the same unit-response ordinates as in figure 1a that 10 days of inflow at A are distributed, lagged, and accumulated accordingly over a 14 day perid at B. Figure 1d is a graphical representation of figure 1c with the system input (inflow hydrograph at A) being disaggregated into separate individual unit responses (in the lower part of figure 1d) and then accumulated into the composite system output (outflow hydrograph at B).



(a)

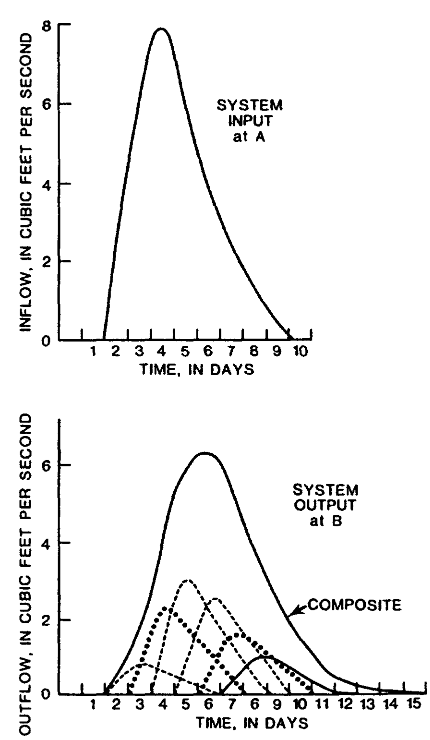
TIME (days)	1	2	3	4	5		
INFLOW AT A (ft3/s)	1.00	0.00	0.00	0.00	0.00		
	0.12					0.12	1
	0.38	0.00				0.38	2
	0.30	0.00	0.00			0.30	3
	0.15	0.00	0.00	0.00		0.15	4
	0.05	0.00	0.00	0.00	0.00	0.05	5
					RESPONSE	OUTFLOW AT B (ft3/s)	TIME (days)

(b)

TIME (days)	1	2	3	4	5
UNIT RESPONSE ORDINATE	0.12	0.38	0.30	0.15	0.05

TIME (days)	1	2	3	4	5	6	7	8	9	10		
INFLOW AT A (ft3/s)	0.00	2.00	5.70	7.80	6.20	4.00	2.50	1.30	0.40	0.00		
	0.00										0.00	1
	0.00	0.24									0.24	2
	0.00	0.76	0.68								1.44	3
	0.00	0.60	2.17	0.96							3.73	4
	0.00	0.30	1.71	2.96	0.74						5.71	5
		0.10	0.86	2.34	2.36	0.48					6.14	6
			0.29	1.17	1.86	1.52	0.30				5.14	7
				0.39	0.93	1.20	0.95	0.16			3.63	8
					0.31	0.60	0.75	0.49	0.05		2.20	9
				RESPONSE		0.20	0.38	0.39	0.15	0.00	1.12	10
							0.13	0.20	0.12	0.00	0.45	11
								0.07	0.06	0.00	0.13	12
									0.02	0.00	0.02	13
										0.00	0.00	14
											OUTFLOW AT B (ft3/s)	TIME (days)

(c)



(d)

Figure 1.-- Streamflow routing along a stream reach using a unit-reponse function and the convolution technique.

Determination of the system's response and convoluting the response with an upstream inflow to produce a downstream discharge is not the total solution for most flow routing problems. The convolution process makes no accounting whatsoever for streamflow from the intervening area between the upstream and downstream locaations. Such streamflow may be totally unknown or some combina- of gaged and ungaged streamflow. Of course the problem of intervening streamflow can be minimized in some cases by proper selection of routing reaches. However, most flow-routing applications will require some procedure for estimating, at least in part, intervening streamflow and combining these streamflow with routed hydrographs. An estimating technique that should prove satisfactory in many instances is the multiplication of known streamflow at an index gaging station by a drainage-area ratio. The drainage-area ratio is computed as the ratio of intervening ungaged drainage area to the drainage area of one or more index stations. Such a procedure can be accomplished easily and directly when using CONROUT. Some flow-routing problems will require varying degrees of increased complexity for estimating intervening streamflow. Such cases require that the streamflow estimates be made externally from CONROUT. However, CONROUT can treat such estimates as tributary inflows if they are stored in compatible data files.

FLOW ROUTING METHODOLOGY

CONROUT provides the user two different methods, diffusion analogy and storage-continuity for determining the unit response. Both methods will compute a single unit-response function while the diffusion analogy method can also be used to compute multiple unit-response functions.

Diffusion Analogy Method

The differential equations derived by Saint-Venant (1871) for one-dimensional unsteady flow are the theoretical basis for the diffusion analogy method. Assuming no lateral inflow the Saint-Venant equations for channel flow are a continuity equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \qquad (1)$$

and a momentum equation:

$$\frac{1}{g}\frac{\partial V}{\partial t} + \frac{V\partial V}{g\partial x} + \frac{\partial Y}{\partial x} + S_f - S_o = 0 \qquad (2)$$

in which

- Q = volumetric rate of flow,
- A = area of flow,
- x = longitudinal distance along channel,
- t = time,
- Y = depth of flow,
- V = average cross-sectional velocity,
- g = acceleration due to gravity,
- S_f = friction slope, and
- S_o = bed slope.

These complex equations have no analytical solutions, except for cases where the channel geometry is unform and the non-linear properties of the equations are neglected or linearized. However, with numerical techniques and computers, the equations are solvable.

While flow routing models use the continuity equation as shown in equation 1, the momentum equation may be used in the form of equation 2 or in an abbreviated form depending on which terms are retained. The individual terms in the momentum equation from left to right are, respectively, dimensionless measures of the local and convective acceleration $\left(\frac{1}{g}\frac{\partial V}{\partial t} + \frac{V\partial V}{g\partial x}\right)$, the pressure $\left(\frac{\partial y}{\partial x}\right)$, frictional ($S_f$), and gravity ($S_o$) forces. Models that retain all five terms are called complete dynamic models. If the acceleration terms are neglected, the resulting equation is referred to as the diffusion wave method, and if, additionally, the pressure term is dropped, the resulting equation is referred to as the kinematic wave method.

The kinematic wave and diffusion wave approximations of the momentum equation provide simpler and faster computer solutions than the full dynamic equation and therefore are often used instead of the complete dynamic model. The choice of the approximation depends on which terms must be retained in equation 2 to accurately describe the stream system. Henderson (1966) gives the following values for terms of the momentum equation taken from a fast-rising flood for an actual river in steep alluvial country:

	S_o,	$\frac{\partial y}{\partial x}$,	$\frac{V \partial V}{g \partial x}$,	$\frac{1}{g}\frac{\partial V}{\partial t}$,
Feet per/mile	26,	1/2,	1/8 to 1/4,	1/20

These figures were computed for a flood in which the discharge increased from 10,000 ft^3/s to 150,000 ft^3/s and decreased again to 10,000 ft^3/s within 24 hours. Even in this case, where the acceleration terms were comparatively large, they still are not as important as the bed slope term (S_o). In some situations, however, the discharge and bed slope can determine the magnitude of the other terms. On very small slopes (S_o small) the pressure term might well be the same order of magnitude as S_o. If the discharge rises fast, then all terms may be important (especially on flat to moderate slopes). Omitting even small terms (in these situations) from the equation can introduce errors into the solution.

It has been shown repeatedly in flow-routing applications that the kinematic wave approximation always predicts a steeper wave with less dispersion and attenuation than may actually occur. This can be traced to the approximations made in the development of the kinematic wave equations wherein the momentum equation is reduced to a uniform flow equation of motion that simply states the friction slope is equal to the bed slope. If the pressure term is retained in the momentum equation (diffusion wave method), then this will help to stop the accumulation of error that occurs when the kinematic wave approximation procedure is applied.

The more general diffusion wave model reduces to the diffusion analogy method by rewriting the continuity and momentum equations for a unit-width channel in terms of unit discharge (q) and depth (y). The equations are then combined and linearized about a reference discharge. The resulting diffusion equation is as follows (Keefer, 1974):

$$\frac{\partial q}{\partial t} = K_o \frac{\partial^2 q}{\partial x^2} - C_o \frac{\partial q}{\partial x} \qquad (3)$$

in which

q = discharge per unit width,
t = time,
x = distance,
K_o = wave dispersion or damping coefficient, and
C_o = flood wave celerity.

K_o controls the spreading of the wave and C_o controls the traveltime.

The wave dispersion coefficient, K_o (in units of ft^2/s), can be computed for a stream reach by the equation

$$K_o = \frac{Q_o}{2\ S_o\ W_o} \qquad (4)$$

where

Q_o = stream discharge in ft^3/s,
S_o = average bed slope in ft/ft, and
W_o = average channel width for a particular study reach in ft.

The flood wave celerity, C_o (in units of ft/s), can be computed from

$$C_o = \frac{1}{W_o} \frac{dQ_o}{dy_o} \qquad (5)$$

where (dQ_o/dy_o) in ft^2/s is the slope of the rating curve (stage-discharge relation) at Q_o; and W_o is as previously defined. Physically a high C_o value means the flood wave will arrive sooner than one at a lower C_o value, and a high K_o value results in a hydrograph being flatter and more spread out than that resulting from using a low K_o value.

The physical characteristics of the channel used to determine K_o and C_o in equations 4 and 5 should be representative of the entire reach. In natural channels, they vary throughout the reach. Therefore, the initial estimated K_o and C_o values will probably require adjustment during model calibration when simulated data are compared to observed data.

Keefer and McQuivey (1974) expressed the solution of equation 3 corresponding to specific boundary conditions by

$$q(x,t) = \frac{1}{(4\pi K_o)^{1/2}} \frac{x}{t^{3/2}} \exp\left[\frac{-(C_o t - x)^2}{4K_o t}\right] \qquad (6)$$

where π is a constant (3.1415927). This equation expresses the instantaneous unit response of a system at location x and time t. It can be seen that with K_o, C_o and x as parts of equation 6, that the physical characteristics of the channel such as bed slope, width and length determine the shape and time of the unit output response of the system. An assumption here is that channel flow losses and gains are negligible.

A mathematical tool, the convolution integral, can be used to obtain output discharges Q(x,t) by integrating the system response(s) and upstream discharges over a time interval from 0 to t or

$$Q(x,t) = \int_0^t Q(0,t-\tau)\, h(\tau)\, d\tau \qquad (7)$$

where equation 6 is computed for a given x and replaces h(τ) in equation 7, and Q(x,t) is the discharge at the downstream location.

Single Linearization

The single linearization method linearizes around a single discharge; therefore, only one K_o and C_o are used. However, wave celerity and dispersion can change with discharge. The computed output may be distorted when wide variations in discharge are considered (Keefer and McQuivey, 1974). Low flows arrive too soon and are over-damped if the model is linearized about a high discharge, whearas high flows arrive late and are under-damped if the model is linearized around a low discharge. Nonetheless, the single linearization method is the easiest and cheapest to use in the model. Also, it is unconditionally stable and mass conservation is guaranteed. Therefore, it is recommended if the magnitude of flow peaks is the primary concern and timing errors are not critical (Keefer, 1976). If flow duration is of concern, then the multiple linearization option should be considered.

Multiple Linearization

Single linear system flow routing models suffer from two major drawbacks. First, single linearization prevents such models from correctly predicting wave celerity and wave dispersion over a wide range of discharge. The range over which a single response function may be used is determined by the stream characteristics. Second, single linear system models are not capable of accurate predictions under backwater conditions. No provision is made for downstream boundary influence. Multiple linearization will correct the first problem but not the second.

It is well documented in the literature (Harley, 1967, Schwarz and Friedland, 1965) that stream channels behave nearly as single linear systems over small discharge ranges. Multiple linearization simply couples several such systems together and divides the inflow among the systems in an appropriate way. A multiple convolution of the divided inputs is performed with the several response functions, and the results are recombined to form the predicted outflow hydrograph.

The difficult part of multiple linearization is selecting the increments for dividing up the inflow and computing the response functions. These two problems are handled internally in the program using the methods described by Keefer and McQuivey, 1974.

The primary variables for the multiple linearization method are a table of discharge (Q_o) versus wave celerity (C_o) and a table of discharge (Q_o) versus wave dispersion coefficients (K_o). The celerity and dispersion at each discharge are computed exactly as for the single response function model, except several discharges of different magnitudes are used instead of one. The program selects an optimum number of response functions and divides the inflow appropriately based on the tables.

Multiple linearization will produce significant improvement in traveltime predictions over a single response function model for hourly data. Root-mean-square errors can typically be reduced from 10 to 50 percent (Keefer and McQuivey, 1974) by using multiple linearization. The improvement in daily routing is less dramatic. In some instances, the errors may actually increase.

Keefer (1976) has compared the multiple linearization technique to a finite-difference technique. In wide rectangular channels the answers are nearly identical when using the procedure described earlier for determining the celerity and dispersion coefficients. In narrow nonrectangular channels some calibration is needed to achieve equivalent accuracy.

Storage-Continuity Method

The Sauer (1973) unit-response model, referred to as the storage-continuity method, does not use the theory of diffusion analogy. Sauer's model derives the unit-response function by modifying a translation hydrograph technique developed by Mitchell (1962). A triangular pulse (Keefer and McQuivey, 1974) is routed through reservoir-type storage and then transformed by a summation curve technique to a unit response of desired duration. Sauer defines a storage coefficient K_s, as the slope of the storage-discharge relation in the routing reach, and W_s, the translation hydrograph time base. These two parameters determine the shape of the resulting response function. K_s behaves like and is comparable to the wave dispersion coefficient K_o in the diffusion analogy method. Also, if the traveltime is held constant, W_s is analogous to the wave celerity C_o.

Sauer (1973) describes in detail the physical significance of K_s and W_s and how initial estimates can be obtained from available streamflow data or from channel characteristics. K_s is equivalent to the time required for the center-of-mass of the flood wave to travel through the reach, minus the travel time, TT, required for the leading edge of the flood wave. The best estimate of K_s can be made from the recession of an outflow hydrograph. W_s is difficult to estimate, even from actual streamflow records, but fortunately it is rather insensitive and successful routing results can be obtained with crude estimates of W_s. In some instances, such as for reservoir releases, timing of critical points of the inflow and outflow hydrograph can be determined fairly accurately. In these cases, the travel time of the end-of-runoff (inflection point of the recession) minus the travel time of the leading edge is roughly equal to W_s.

In Sauer's original model, an attempt was made to adjust the simple linear model to account for variations in traveltime with discharge. Each input discharge was routed using a traveltime based on the antecedent discharge in the reach. This procedure improved the predicted arrival times with streamflow changes but resulted in what Sauer refers to as "stacking" and "separations" in the output hydrograph. These problems resulted from the slowing down or speeding up the entire streamflow rather than varying the velocity of components of the streamflow. The storage-continuity method in CONROUT uses a constant traveltime to avoid these problems.

APPLICATIONS OF THE MODEL

Calibration, Verification and Simulation

Application of a mathematical model typically involves three steps: (1) model calibration, (2) model verification, and (3) system simulation. Sometimes the first two steps are considered one step and referred to as either calibration, verification, or parameter optimization. Nevertheless, the system input and the corresponding system output must be known for some period of time and range of conditions to permit determination of model parameters.

For the typical three-step approach approximately half of the known system input and system output data are utilized for model calibration. The calibration process yields an optimum set of model parameters that best duplicates the relationship between the known system input and system output data. Model parameter optimization techniques range from totally automated objective best-fit procedures to procedures involving various degrees of manual iteration to obtain an "eyeball" best fit.

The remaining observed system input data and the model parameters determined in the calibration step are used to verify the model. Computed system output is compared with corresponding observed system output to evaluate the accuracy of the model. An unsatisfactory comparison means a poor verification and could point out model deficiency, that is, a process that wasn't covered in the calibration phase.

After successful calibration and verification, the model may be used to simulate system output for any input condition(s) of interest. The input data may be actual observed data (for which system output data were not observed) or hypothetical data representing input for any condition(s) to be studied. Resultant simulated system output data may be used to arrive at conclusions relative to the given input condition(s) or to make comparisons of various system input condition(s).

An overview of a typical modeling application was presented above. The following paragraphs relate the above processes to CONROUT applications. Examples presented in the next two sections provide additional detail as well as further clarification of data requirements and approaches to several modeling problems.

Calibration and verification of CONROUT requires concurrent observed streamflow data at both the system input and output sites. The system output site is that downstream station at which it is intended to simulate streamflow data. The input site(s) include any upstream station(s) from which flows are to be routed and any index station(s) to be used for estimating intervening flow. In addition, data describing physical characteristics of the reach are needed to estimate model parameters.

Unfortunately, an automated optimization procedure which can determine optimum model parameters and intervening flow estimates directly from known input and output streamflow data is not available in CONROUT. Therefore, CONROUT calibration requires a high degree of manual iteration and "eyeball" best fitting. Each iteration involves the use of trial estimates of model parameters and intervening flow with known input to compute system output. Correspondingly, computed and observed system output are compared to determine the validity of the trial estimates. Computed mean errors, volume errors and root-mean-square errors are computed by CONROUT and are one primary measure of success. However, for total evaluation of the trial estimates, it is almost imperative to also make some comparisons on a day-to-day basis (using both numerical and plotted daily flow data). Obviously, if long data sequences are used in this process, the task of zeroing in on acceptable estimates of model parameters could be insurmountable. Therefore, CONROUT calibration is based on relatively short segments of the observed data which are chosen to cover a relevant range of flow conditions.

When it appears that the estimated model parameters are satisfactory, model verification is attempted. The final trial estimates from the calibration step are combined with the system input(s) for the entire period for which observed system output data are available. Comparisons of the resultant computed system output with corresponding observed data are made using flow characteristics such as flow volume, flow-frequency relations, and flow-duration relations. Unfavorable comparisons indicate that the model doesn't work or that the modeler may have made a mistake whereas favorable comparisons indicate that the model is suitable for system simulation.

Hypothetical Examples

Examples presented in this section provide a sample of applications for which CONROUT is well suited. These examples are idealized, hypothetical and simple cases designed to introduce some basic concepts of flow-routing. The next section of the report contains actual field examples. Completed modeling studies are documented for the Kentucky River (Shearman and Swisshelm, 1973), the Flambeau River (Krug, 1976), the Susquehanna River (Armbruster, 1977) and the Wisconsin River (Krug and House, 1980). The reader is urged to consult these references for a better understanding of flow-routing applications of varying complexity and requiring diverse approaches.

Example 1

A stream reach for which daily streamflow data have been observed for 10 years at the downstream station (site B) and for 30 years at the upstream station (site A) is illustrated in figure 2. Site B data are concurrent with the middle 10 years of site A data. Knowledge of low-flow frequencies at site B is required to make decisions regarding wastewater discharges into this stream reach.

One obvious approach to obtain the desired information is to use the 10 years of observed data at site B to estimate low-flow frequencies. However, the low-flow events observed at site B over this 10-year period may not be representative of long-term hydrologic conditions, especially if this period was abnormally wet or dry. Use of estimated low-flow frequencies for a 10-year period could thus result in very poor planning.

Another possible approach is utilization of correlation techniques using observed data at both site A and site B to arrive at adjusted low-flow frequency estimates at site B. This involves correlation of low-flow data at sites A and B for the 10 years of concurrent data. This correlation and the long-term (30-year) low-flow frequency estimates at site A are used to adjust the short-term (10-year) low-flow frequency estimates at site B. These adjusted low-flow frequency estimates are equivalent to those that would result from more than 10 but less than 30 years of observed data at site B. The equivalent record length and the reliability of the adjusted low-flow frequency estimates depend upon the strength of the correlation between sites A and B low-flow data for the concurrent period of record.

A third approach would be simulation of 30 years of streamflow data at site B using a streamflow routing model such as CONROUT. A fairly good foundation for model calibration and verification is provided by the 10 years of concurrent data at sites A and B.

Model calibration utilizes relatively short segments of site A streamflow as system input. Several such segments should be selected to cover the entire flow range with emphasis placed on lower flows since low-flow frequency is the desired end product. For each such segment streamflow at site B (system output) may be computed for any trial estimate of model parameters (routing coefficients and intervening flow estimates). These computed flows are compared to corresponding observed flows for each segment. Adequacy of the results is assessed on the basis of visual comparison of computed and observed hydrograph plots and numerical statistics for computed and observed daily flow and total volume differences. Minimum volume errors are not always accompanied by minimum daily volume errors (nor vice versa). Also, the magnitude of errors that are acceptable may vary for different segments. In this low-flow oriented study, for example, significant daily flow errors in the vicinity of a peak may be acceptable if the corresponding volume error is small. Therefore, trial estimates of the model parameters are refined until some optimum balance of errors (both within and among segments) is achieved.

Given: Sites A with 30 years of streamflow record and B with 10 years of streamflow records.

Required: Low-flow estimate (that is, $Q_{7,10}$) at site B.

Alternative I: Use 10 years of observed record for the low-flow frequency analysis.

Alternative II: Correlation of low flows between sites A and B.

Alternative III :

(1) Use 10 years of observed record for calibration and verification of selected streamflow routing model.

(2) Use the best unit response and intervening flow estimation determined from above procedure to simulate 30 years of streamflow data at site B using the 30 years of observed record at site A as the system input.

(3) Use the 30 years of simulated data in the low-flow frequency analysis.

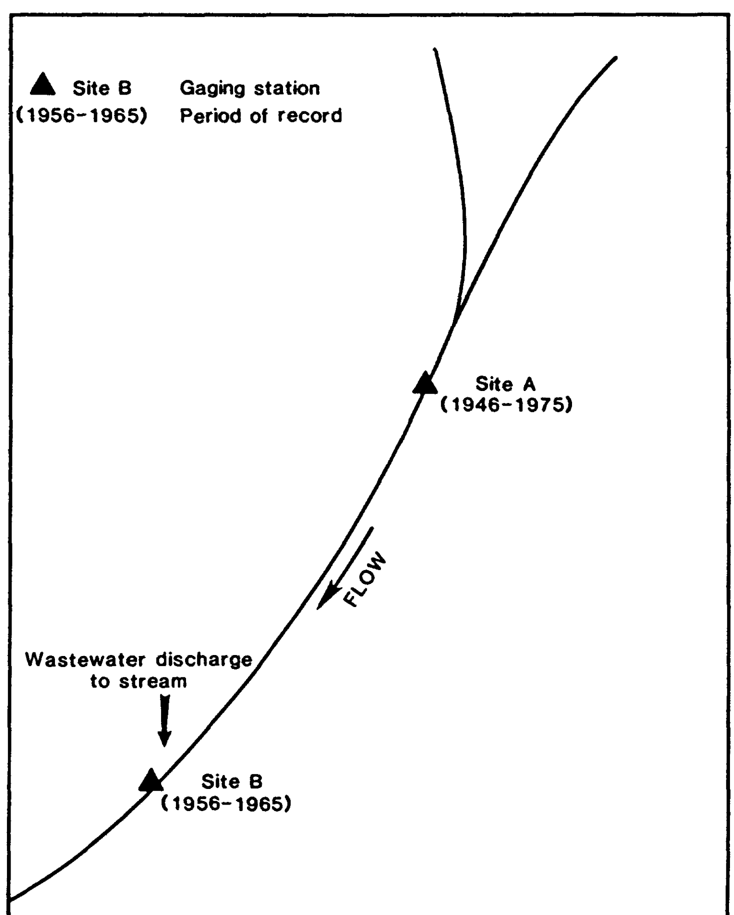


Figure 2.--Stream reach for hypothetical streamflow routing example.

Model verification utilizes the calibrated model parameters and 10 years (1956-65) of observed site A flow to simulate 10 years of site B streamflow. Model parameters are considered verified if these simulated flows agree within predefined error acceptance criteria for the 1956-65 observed data at site B. Adequacy of the agreement can be evaluated on the basis of flow characteristics such as annual and total flow volumes, low-flow frequency relations, and flow-duration relations.

The error acceptance criteria are influenced by the project objectives and time and resources available to fine tune the model. Previous modeling with CONROUT by Maine Water Resources Division personnel demonstrated that the model could reproduce data for 90 percent of the observed population to within 10 percent (Fontaine and others, 1983). The Maine analysis producing these results was an ideal application of CONROUT and results will vary depending upon the complexity of the stream system.

Verified model parameters and 30 years (1946-75) of observed flow at site A provide the necessary data to simulate 30 years of streamflow at site B. Assuming that reasonable error acceptance criteria were used for model calibration and verification, these simulated data are a better representation of long-term hydrologic conditions than are the 10 years of observed data at site B. Therefore, low-flow frequency estimates based on the simulated data provide improved hydrologic input for the planning process.

Example 2

The same stream reach used in example 1 except that in addition to the wastewater discharge near site B there is a proposed reservoir near site A as is illustrated in figure 3. Therefore, the required low-flow frequency estimates must be on regulated flow data rather than the natural flow data that are available.

The following approach to this problem is based upon several assumptions: (1) a mathematical model can be designed to adequately represent the proposed reservoir; (2) natural flow at site A is the inflow to the proposed reservoir; and (3) the reach characteristics and the drainage area between the outflow point of the proposed reservoir and site B are not significantly different from those between site A and site B.

The first two of the above assumptions imply that it is possible to simulate 30 years of reservoir outflow. As per the third assumption, these regulated flows traverse a reach essentially identical with the reach between site A and site B and the intervening flow is likewise unchanged from natural conditions. Therefore, these simulated reservoir outflows can be used as the input to CONROUT which has been calibrated and verified as per the discussion in Example 1. The output represents 30 years of simulated, regulated streamflow at site B. Low-flow frequency estimates based on these data provide the necessary logic input to the planning process.

Given: Identical to previous example except a reservoir is proposed just downstream of site A.

Required: Low-flow estimate for regulated streamflow at site B.

Approach: (1) Calibrate and verify streamflow routing model as in previous example.

(2) Use a digital model of the reservoir with 30 years of observed flow at A as reservoir inflow to simulate 30 years of reservoir outflows.

(3) Use 30 years of simulated resevoir outflow as system input to the streamflow routing model to simulate 30 years of regulated flow at site B.

(4) Use 30 years of simulated, regulated flow at site B in the low-flow analysis.

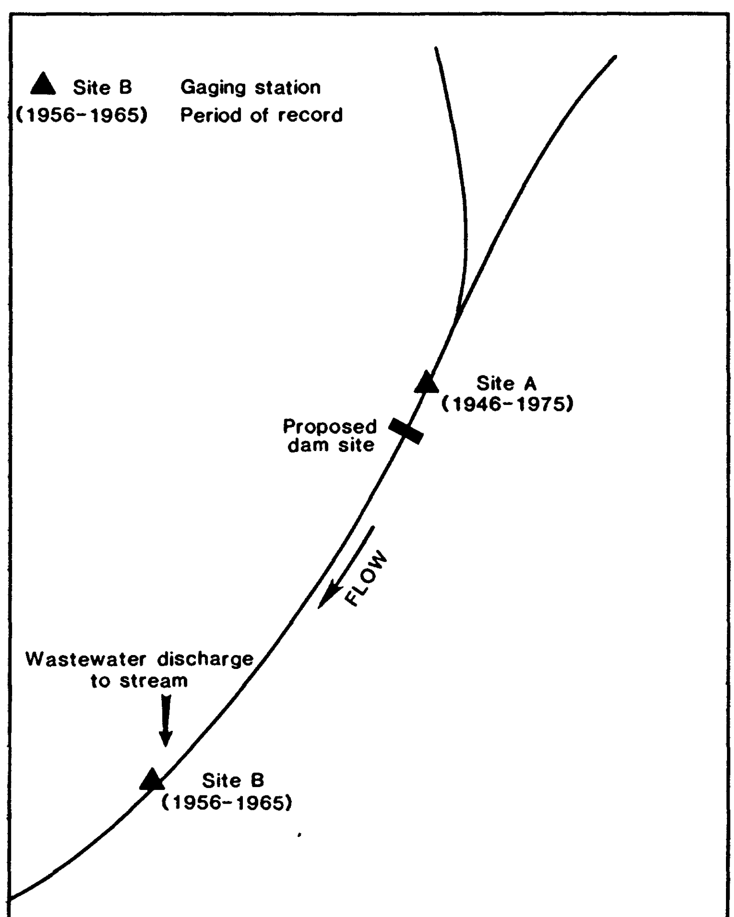


Figure 3.--Hypothetical stream reach with proposed reservoir.

Example 3

A basin in which daily streamflow data have been observed at the six sites indicated by letters A through F is illustrated in figure 4. Drainage areas above the sites are indicated in parentheses. Data have been collected at sites B and F for a much shorter period of time than at the other four sites. Someone wants an estimate of daily flow at site F for the longest possible time period.

The solution to this problem would involve application of CONROUT to two separate stream reaches, site A to site B and sites B and C to site F. Without specific stating of the routing coefficients, the two equations in figure 4 indicate possible relationships resulting from calibration and verification processes.

$$B_s = (A_o)_r + 0.27\ (A_o) \tag{8}$$

$$F_s = (B_s + C_o)_r + 1.33\ (D_o + E_o) \tag{9}$$

where subscripts

o = observed flow at referenced location;
r = routed flow from referenced location; and
s = simulated flow at referenced location.

The first equation, for simulated flow at site B (B_s) has a routed flow component and an intervening flow component. The routed component, $(A_o)_r$, is the observed flows at site A routed to site B. The intervening flow component, $0.27(A_o)$, is the observed flow at site A multiplied by the ratio of ungaged drainage area between sites A and B (2100 mi^2 - 1650 mi^2 = 450 mi^2) to the drainage area at site A (1650 mi^2). This ratio is referred to as the drainage-area ratio. The equation for simulated flow at site F (F_s) also has a routed component and an intervening flow component. The routed component, $(B_s + C_o)_r$, is the sum of simulated flow at site B and observed flow at site C routed to site F. The intervening flows are estimated using the sum of observed flows at sites D and E as the index with 0.33 being the ratio of ungaged area (3800 mi^2 - 2100 mi^2 - 1100 mi^2 - 275 mi^2 - 175 mi^2 = 150 mi^2) to the drainage area of the index stations (175 mi^2 + 275 mi^2 = 450 mi^2). Of course, the expression $1.33(D_o + E_o)$ is the total sum of the tributary inflows and estimated intervening flow.

Given: Long-term records at sites A, C, D, and E; short-term records at sites B and F.

Required: Long-term record at site F.

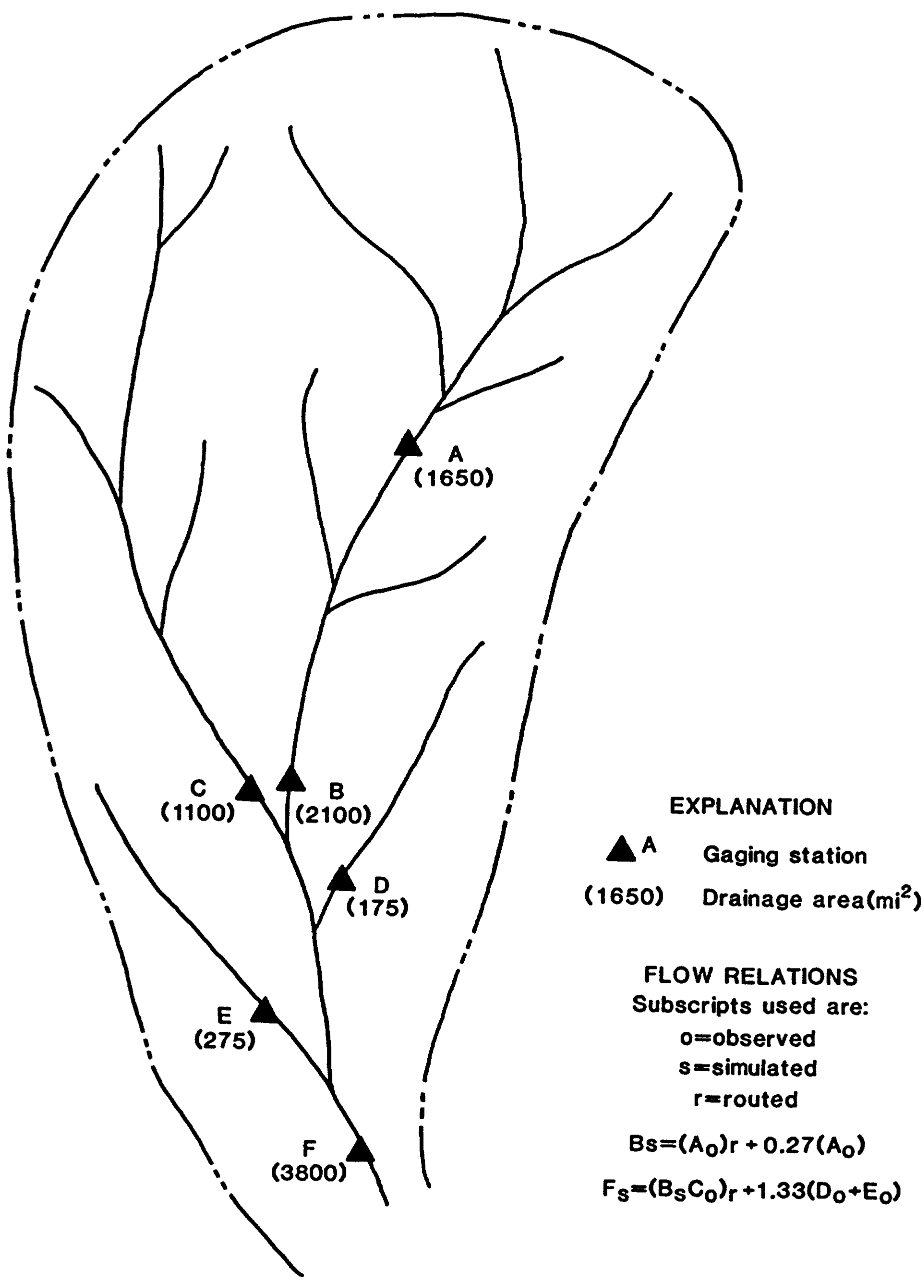


Figure 4.--Hypothetical streamflow routing example for multiple reaches.

Field Examples

Two examples of actual field applications of CONROUT are presented in this section. Although they are fairly simple examples, they do illustrate how the required model input data are prepared. More complicated applications will use these principles as a basic foundation.

Example 1

This example is from the Flambeau River study (Krug, 1976). Briefly, the purpose of the study was to determine the low-flow frequency of the Flambeau River at Park Falls (figure 5). There were no streamflow records at the site. Transfer of low-flow characteristics from other gaging stations was not considered reliable because the stream is highly regulated. Gaging station data available for this study are summarized in table 1.

The basic approach consisted of two simulations with two routing reaches each. The first simulation included routing from Flambeau Flowage to Butternut, then from Butternut to Winter. After these reaches were calibrated and verified, the same model parameters were used for the second simulation, routing from Flambeau Flowage to Park Falls and from Park Falls to Winter. In all cases, a drainage-area ratio (ungaged area/index station area) times the flow of the nearby South Fork Flambeau River near Phillips was used to simulate ungaged inflow.

In order to determine the model parameters C_0 (flood wave celerity) and K_0 (wave dispersion coefficient) for these reaches, it was necessary to determine the width (W_0) and slope (S_0) of the channel and the slope of the stage discharge relation (dQ_0/dy_0). The width of the channel was determined from topographic maps and from discharge measurement notes at gaging stations. The slope was determined from topographic maps while dQ_0/dy_0 was determined from the rating tables for the gaging station.

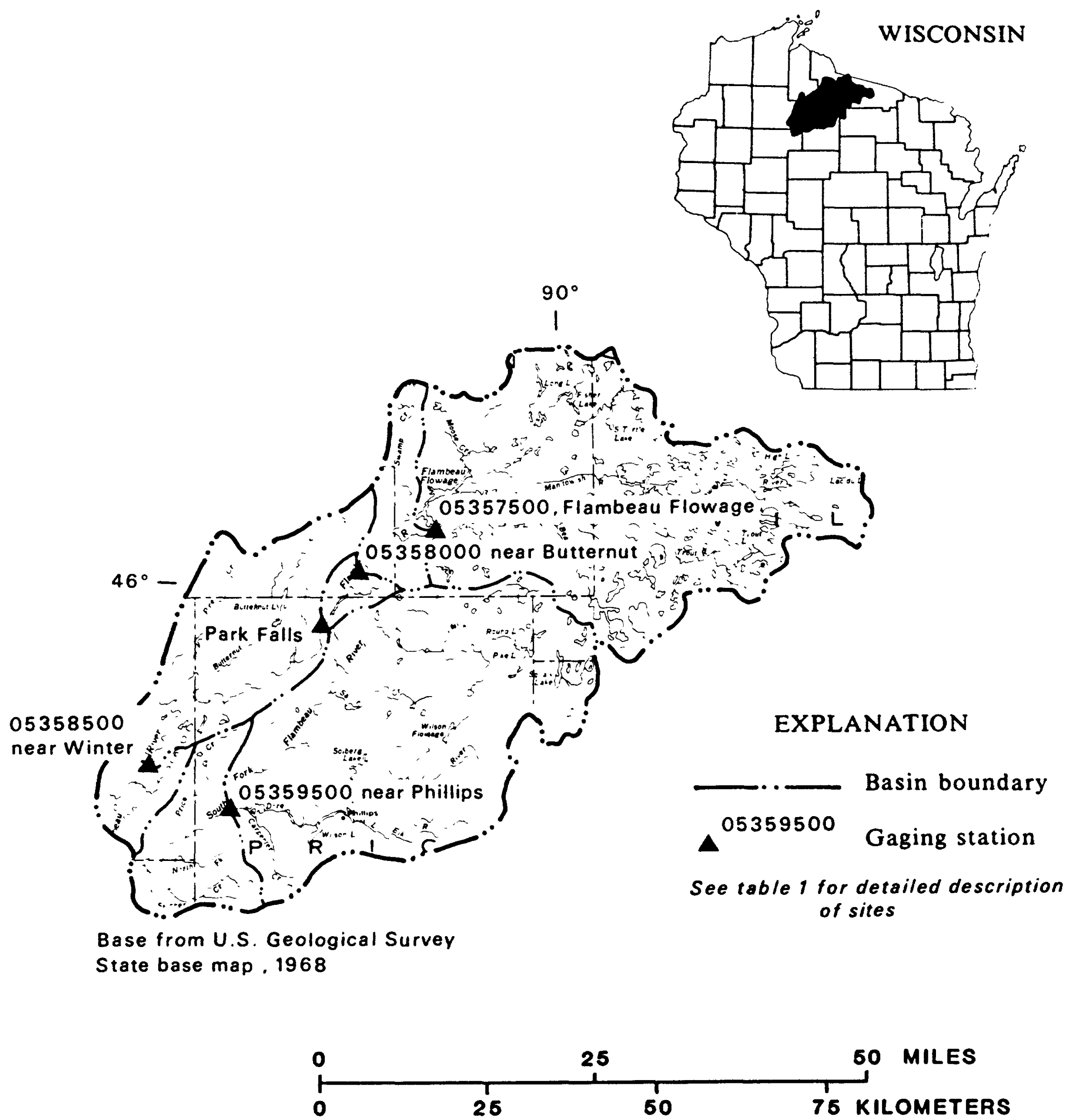


Figure 5.--Map of study basin and its location in Wisconsin.

Table 1.--Drainage areas upstream from sites and availability of surface-water records

Station number	Station name	River miles from Park Falls	Drainage area (mi^2)	Water years of record
05357500	Flambeau River at Flambeau Flowage.	18.34	666	1928-61
05358000	Flambeau River near Butternut.	8.53	737	1915-38 1/
--------	Flambeau River at Park Falls. 2/	0	769	---------
05358500	Flambeau River at Babbs Island near Winter.	35.12	1,000	1930-75 3/
05359500	South Fork Flambeau River near Phillips.	--	615	1930-75

1/Unregulated flows for the 1915-26 period.

2/Not a streamflow gaging station.

3/Streamflow data were collected for the entire period; however, all or part of the data for water years 1940, 1952, and 1960 were missing from the computer files and were not available for analysis at the time of this study.

The single linearization method was selected and the discharge used to linearize the routing was the 2-year, 7-day low flow. This low flow was chosen because the primary purpose of the study was to simulate low flow. The following table lists the parameters determined for the study. Two different widths were used at the Butternut gage, appropriate for the reaches upstream and downstream from the gage, respectively.

Site	Discharge Q_o (ft^3/s)	Average Width W_o (ft)	Slope S_o (ft/ft)	$\frac{dQ_o}{dy_o}$ (ft^2/s)	$C_o = \frac{1}{W_o}\frac{dQ_o}{dy_o}$ (ft/s)	$K_o = \frac{Q_o}{2S_oW_o}$ (ft^2/s)
Flambeau Flowage	110	150		190	1.27	405
			$9.074(10)^{-4}$			
Butternut	289	150		262	1.74	1,060
	289	200	$7.290(10)^{-4}$	262	1.31	990
Winter	547	280		543	1.94	1,340

For the first trial on each reach, the C_o and K_o from the end points were averaged. Thus the first trial was $C_o = 1.50$ and $K_o = 730$ for the upstream reach and $C_o = 1.62$ and $K_o = 1,160$ for the downstream reach. After several trials, adjusting the parameters to improve the fit of the summer low flow periods, the final parameters were $C_o = 1.5$ and $K_o = 600$ for the upstream reach and $C_o = 1.5$ and $K_o = 1,000$ for the downstream reach.

South Fork Flambeau River streamflow data were used to simulate the intervening inflow for all reaches. Several trials were made to simulate ungaged inflow using a variety of ratios times the flow of the South Fork; none of the trials were significantly better than the drainage-area ratio. As one example of the computation of this ratio, the drainage area at the Phillips station (05359500) is 615 mi^2. The increase in drainage area from Flambeau Flowage to Butternut is 71 mi^2 or 12 percent of the Phillips drainage area. Therefore, a ratio of 0.12 times the South Fork flows was used to simulate the intervening flow.

The program control data cards for the routing on this reach are as follows: (An explanation of data entries is presented in a later section of this report)

```
    10      1 1929 1200      9     30 1961 1200
I=21,Φ=26,RΦUTE,DIFFA
05358000  BUTTERNUT RΦUTED FRΦM FLΦWAGE
C=1.5,K=600,X=9.81,REACH=FLΦWAGE-BUTTERNUT
I=22,Φ=26,RATIΦ=0.12,ADD
05358000  SIMUATED FLΦW AT BUTTERNUT
```

This states that file 21 (second card, I=21) contains the observed flow for the Flambeau River at Flambeau Flowage, that file 22 (fifth card, I=22) contains the observed flow data for the South Fork Flambeau River near Phillips, and that file 26 (fifth card, Φ=26) is to receive the simulated flow for the Flambeau River near Butternut. In summary the above cards do the following:

Card 1--The period of analysis is defined.
Card 2--Inflow on file 21 is routed by the diffusion analogy method and output on file 26.
Card 3--Title description card.
Card 4--Model parameters defined for reach.
Card 5--Intervening flow computed.
Card 6--Title description card.

Example 2

This example is from a study performed on the Wisconsin River (Krug and House, 1980). The purpose of the Wisconsin River study was to simulate an equal period of record at all gaging stations on the Wisconsin River including simulation of the present reservoir system. These equal periods of record were needed to compute a consistent set of flood frequency estimates for the Wisconsin River.

Daily streamflow data had been collected at 11 sites on the Wisconsin River for various periods of time. During the period of record at most of the longer term stations, several large reservoirs had been added to the system making the long-term records unreliable for estimating flood frequency. The shorter term stations would give flood frequencies that were inconsistant, depending on whether their period of record included a representative sample of floods.

This example is a segment of a larger model of the Wisconsin River. In this segment, streamflow records are available for the Wisconsin River at Merrill for water years 1915-1976 and for the Wisconsin River at Rothschild for water years 1945-1976 (figure 6). In order to simulate the effects of upstream reservoirs on flood peaks, a flow routing model is required for this reach to simulate flow from Merrill to Rothschild plus the ungaged inflow between them.

Two main tributaries enter the Wisconsin River just upstream from Rothschild; the Rib River and the Eau Claire River. Streamflow records were available on these streams for substantial parts of the period for which flow simulation was required at Rothschild. The Eau Claire River gage had record for water years 1915-1926 and 1940-1976. The Rib River gage had record for water years 1925-1957. Using correlation techniques, it was possible to extend the record for the Rib River gage to 1915-1976, based on streamflow records from an adjacent basin. Because the Eau Claire River basin was not similar to other gaged basins, no satisfactory correlation could be found to extend this record.

With data from Merrill, the Rib River, and the Eau Claire River, it should be possible to extend the record at Rothschild, at least for the period 1915-1926 and 1940-1944.

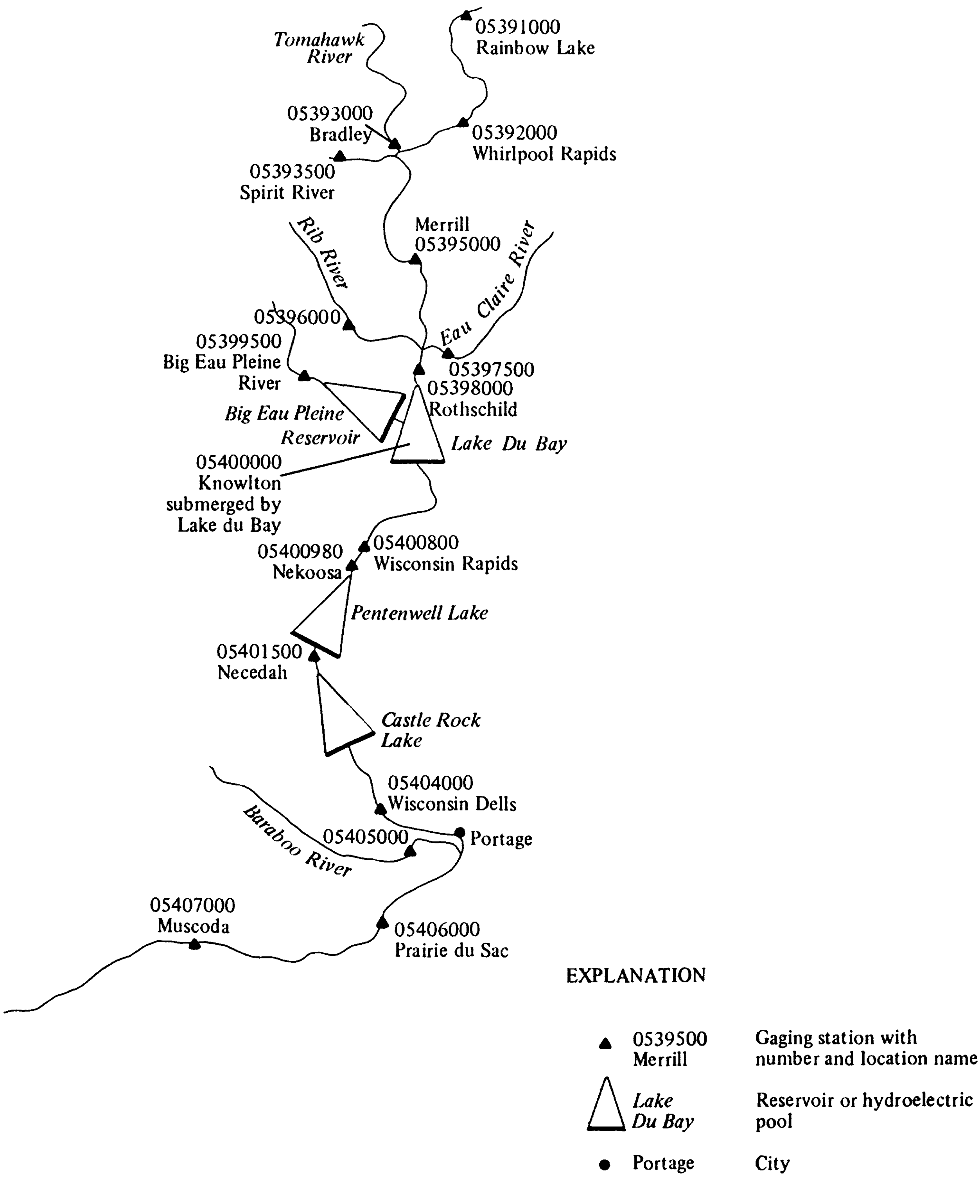


Figure 6.--Schematic diagram of the Wisconsin River.

The basic data required for computing the unit-response function include the length of the reach, width of the channel, slope of the channel, and the slope of the stage discharge relation. The length of the reach (27.4 miles) was readily determined from published reports of river miles along the Wisconsin River. The slope of the channel at normal (long-term mean flow) conditions was computed from the length of the reach and the difference between the elevations of the mean discharge at the gaging stations which was readily determined from the gaging station records. It was determined to initially evaluate the unit response coefficients at three different flow rates: the 7-day, 10-year low flow, the long-term mean flow and the 10-year high flow. These three flow rates for each station were taken from published reports. The corresponding slopes of the rating curves (dO_o/dy_o) were determined from the rating tables for the gaging station. The channel width at normal flow was measured at intervals on topographic maps. The mean width was 380 feet. The widths to use for the higher and lower discharge were determined from a sampling of representative cross sections and gaging stations where channel widths could be determined at various discharges. The computation of model parameters C_o and K_o for the three flow conditions is summarized in table 2 for each gaging station.

For each of the three flow conditions the C_o and K_o computed for the two sites were averaged. This gave three sets of K_o and C_o to be used in the initial calibration. These three sets of parameters together with an estimate of intervening inflow were used to simulate flow at Rothschild for several selected periods. On this initial trial the parameters corresponding to mean flow gave the best simulation. Small adjustments in K_o and C_o did not improve the simulation significantly, so the mean flow parameters were accepted as the final values.

Simultaneous with the calibration of K_o and C_o, the intervening inflow simulation was being calibrated. The increase in drainage area between Merrill and Rothschild is 1,260 mi^2. Of this, 303 mi^2 is upstream of the Rib River gaging station and 375 mi^2 is upstream of the Eau Claire River gaging station. The remaining 582 mi^2 is ungaged. This is 86 percent of the combined area of the two tributary gaging stations. The simplest simulation of the intervening area would be to multiply the combined flows from both tributaries by 1.86 and add the result to the flows routed from Merrill to Rothschild. This was the first trial used for estimating intervening area ungaged flow during model simulation.

Table 2.--Model parameters for Wisconsin River study

Site	Type of flow	Discharge Q_o (ft^3/s)	Average Width W_o (ft)	Slope S_o (ft/ft)	$\frac{dQ_o}{dy_o}$ (ft^2/s)	$C_o = \frac{1}{W_o}\frac{dQ_o}{dy_o}$ (ft/s)	$K_o = \frac{Q_o}{2S_oW_o}$ (ft^2/s)
Merrill 1/	Q_{mean}	2,685	380	$6.53(10)^{-4}$	1,600	4.210	5,410
Merrill 1/	$Q_{7,10}$	880	322	$6.53(10)^{-4}$	900	2.795	2,093
Merrill 1/	Q_{10}	23,900	567	$6.53(10)^{-4}$	4,000	7.055	32,275
Rothschild 2/	Q_{mean}	3,438	416	$4.20(10)^{-4}$	1,500	3.606	9,839
Rothschild 2/	$Q_{7,10}$	950	352	$4.20(10)^{-4}$	900	2.557	3,213
Rothschild 2/	Q_{10}	49,200	620	$4.20(10)^{-4}$	5000	8.064	94,470

1/Drainage area at Merrill = 2,758.35 mi^2

Slope (S_o) and Average width (W_o) are an average of reach between Merrill and Rothschild, a distance of 27.4 mi.

2/Drainage area at Rothschild = 4,020.59 mi^2

Slope (S_o) and Average width (W_o) are an average of reach between Rothschild and next site (Knowlton) downstream, a distance of 18.0 mi.

A second trial for the ungaged simulation was indicated by the fact that the physical characteristics of the intervening area west of the Wisconsin River are different from the area east of the river. The intervening area west of the river is 524 mi^2 and the area east of the river is 736 mi^2. For this trial, the Rib River streamflow was used to simulate all the intervening area west of the river and the Eau Claire streamflow was used to simulate the intervening area east of the River. Based on the respective drainage areas, the Rib River flows were multiplied by 1.73 and the Eau Claire River flows were multiplied by 1.96. This trial gave a more accurate simulation of Rothchild flows than the first trial. Other combinations of ratios were used to try to improve the simulation of intervening inflow, but none of the other ratios gave better results than the second trial.

The program control cards necessary for the best simulation of flows on this reach are as follows:

```
   10     1  1915  1200      9    30  1926  1200
I=21,Φ=26,RΦUTE,DIFFA
05398000   RΦTHSCHILD FLΦW FRΦM MERRILL
C=3.9,K=7600,X=27.4,REACH=MERRILL-RΦTHSCHILD
I=22,Φ=26,RATIΦ=1.73,ADD
05398000   MERRILL & RIB FLΦW ADDED IN
I=23,Φ=26,RATIΦ=1.96,ADD
05398000   SIMULATED FLΦW AT RΦTHSCHILD
```

It is assumed that file 21 (second card, I=21) contains the recorded flow data from Merrill, that file 22 (fifth card, I=22) contains the recorded flow data for the Rib River,that file 23 (seventh card, I=23) contains the recorded flow data for the Eau Claire River, and that file 26 (seventh card, Φ=26) is to receive the simulated flow at Rothschild. In summary the above cards do the following:

<u>Card 1</u>--The period of analysis is defined.
<u>Card 2</u>--Inflows on file 21 routed by the diffusion analogy method and output on file 26.
<u>Card 3</u>--Title description card.
<u>Card 4</u>--Model parameters defined for reach.
<u>Card 5</u>--Intervening flow computed and added to Rothschild flow.
<u>Card 6</u>--Title description card.
<u>Card 7</u>--Intervening flow computed and added to Rothschild flow.
<u>Card 8</u>--Title description card.

SYSTEM ORGANIZATION AND INPUT DATA REQUIREMENTS

CONROUT was developed on an IBM 360/91[1/] and is compiled in a load module under level G Fortran. Input for CONROUT is punched cards and direct access disk files. Core storage required for execution depends upon the number of disk files being used (each file requires slightly more than 3,000 bytes of core). Therefore, the user should specify a REGION size between 160K (when using one file) and 190K (for 10 files). A sample program run as illustrated in Appendix D took 1.42 seconds of execution time. Running under a priority of class B the job cost $2.22 to execute on the U.S. Geological Survey's Amdahl computer.

Several computer programs are used in conjunction with CONROUT. Their relationships to CONROUT are illustrated in figure 7. The streamflow data used in CONROUT are retrieved from the U.S. Geological Survey's WATSTORE system and are transformed and edited for input to the model. After CONROUT has been used to simulate streamflow data, streamflow statistics programs can be used to analyze both the simulated and observed data.

These programs and their operation are described in detail in Appendix D. The remaining sections of this report describe the different operations that CONROUT can perform and the model input data requirements.

[1/]The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

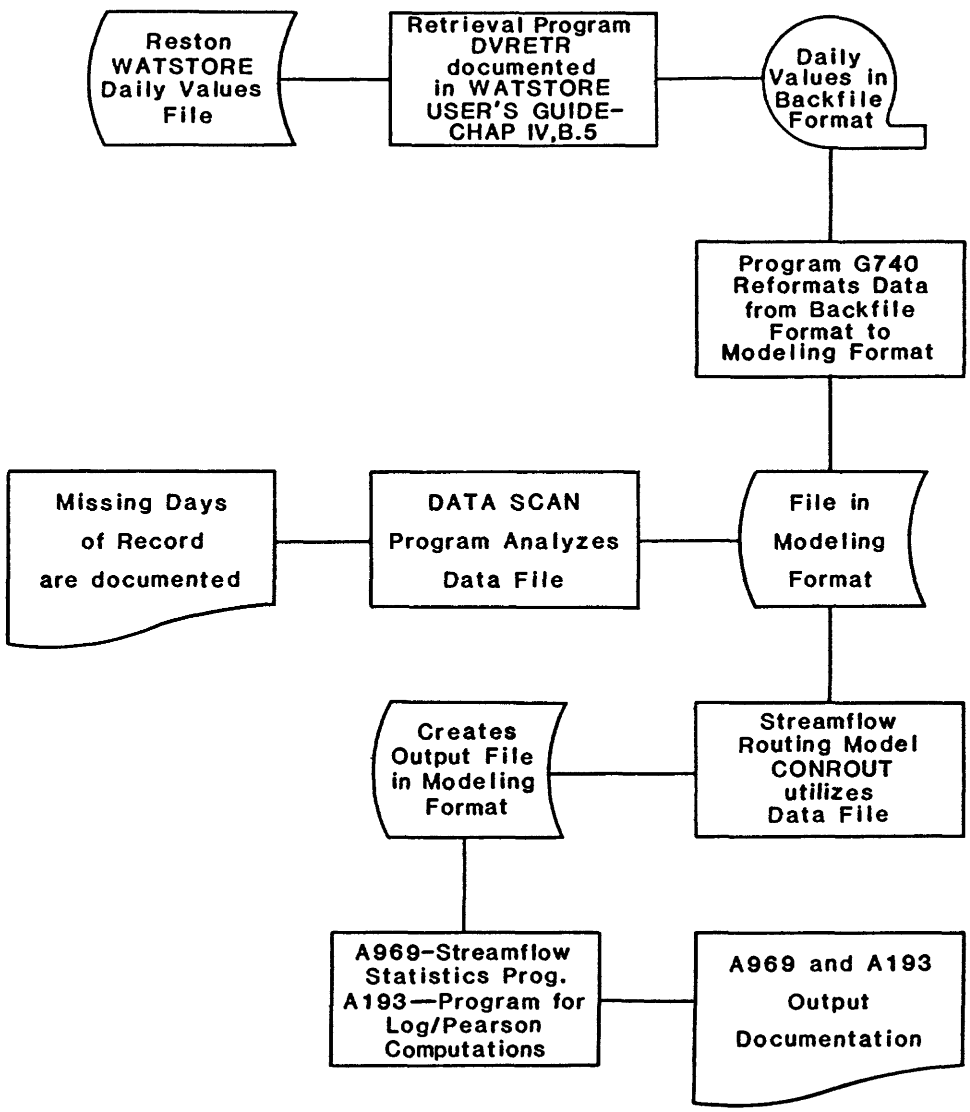


Figure 7.--System Organization of CONROUT.

CONROUT can do five functions which are as follows:

1. Streamflow computations;
2. Data comparison;
3. Data plotting;
4. Data printout; and
5. Restart.

Six different kinds of input data cards are required to perform the above functions. These are:

1. Time data;
2. Instructions;
3. Header information;
4. Title information;
5. Routing parameters; and
6. Discharge/wave-dispersion/wave-celerity data.

The functions and required data cards are documented in table 3.

A job may consist of a single step using one of the first four functions, or it may involve several steps using various combinations of the above functions. If all steps of the job involve the same time period, then a single Time Data Card (preceding the instruction card for the first step of the job) will suffice for the entire job. However, between any two steps in the job which require different time periods, a Restart Instruction Card followed by a Time Data Card must be input to redefine the time period.

Table 3.--Program functions and data card requirements

Program function	Data card(s) required
I. Streamflow computations	A. Time Data card1/
	B. Instruction card
	C. Header Information card
	D. Routing Parameter card (required only when ROUTE instruction specified on B above)
	E. Discharge/wave-dispersion/wave-celerity cards (required only when MULT instruction is specified on B above)
II. Data comparison	A. Time Data card1/
III. Data plotting	B. Instruction card
IV. Data printout	C. Title Information card
V. Restart	A. Instruction card

1/If first step of a job or the first step having a time period different from the previously defined time period.

Time Data Card

The Time Data Card specifies the period of record for model execution. The data are coded as follows:

Input item	Variable name	Format	Card columns
Starting month	INITMØ	I5	1-5
Starting day	INITDY	I5	6-10
Starting year1/	INITYR	I5	11-15
Initial time2/	INITI	I5	16-20
Ending month	LASTMØ	I5	21-25
Ending day	LASTDY	I5	26-30
Ending year1/	LASTYR	I5	31-35
Ending time2/	LASTI	I5	36-40
Number of data records plus 1 for the header record	NRECDS	I5	41-45
Routing interval daily data = 24. hourly data = 1.	RI	F5.0	46-50
Print control option NTSØ = 0, CONROUT Daily printout and summary = 1, CONROUT Summary only = 2, Same as NTSØ = 0 except with additional output files 3/ = 3, Same as NTSØ = 1 except with additional output files 3/	NTSØ	I5	51-55

1/Four-digit year such as 1962, 1963, etc.

2/For daily routing, may leave blank or input time in military notation.

3/Files 17, 18, and 19 have to be defined in JCL to output information. File 17 contains simulated discharge (Q_1) data. File 18 contains observed discharge (Q_2) data. File 19 contains computed differences between simulated and observed discharges in percent and computed as $[(Q_1-Q_2)*100/Q_2]$. Data in each file are stored in 80-byte records in a format of (8F9.2,8x). A complete water year requires 46 records with day 365 the fifth item in the 46th record. If a leap year then day 366 will be be stored in the sixth item.

Streamflow Computations

Table 4 documents information needed for the Instruction Card for the streamflow computation functions. The various instructions are not order-dependent, that is, the program does not expect the options in any specific order. The following types of streamflow computations are possible.

a. Copy hydrographs;

b. Combine hydrographs;

c. Change timing of hydrographs by lagging one or more routing intervals;

d. Multiply hydrographs by ratios;

e. Route hydrographs to downstream locations; and

f. Combinations of the above.

Table 4.--Instructions for streamflow computations

INPUT FILE = xx[1/][2/][3/]	Specifies the file number of the input hydrograph data.
OUTPUT FILE = yy[1/][3/][4/]	Specifies the file number of the output hydrograph data.
RATIO = w.d[5/]	Multiplies the input hydrograph by the ratio, w.d.
LAG = ℓ [5/][6/]	Lags the input hydrograph by ℓ routing intervals.
RØUTE[5/][6/]	Convolutes input hydrograph with the unit-response function(s). If the DIFFA instruction (below) is not specified, a single unit-response function is computed using the storage-continuity method.
DIFFA[3/][7/]	A single unit-response function is computed using the diffusion analogy method.
MULT[3/][8/]	A family of unit-response functions is computed using the diffusion analogy method and multiple linearization.
ADD[5/]	The final output hydrograph is the sum of the initial output hydrograph and the input hydrograph (with any modifications caused by other instructions).

1/Mandatory instruction

2/$21 \leq xx \leq 30$ (suggest $21 \leq xx \leq 25$)

3/Only first letter of instruction word used in the translation

4/$26 \leq yy \leq 30$

5/Whole instruction word used in the translation

6/LAG and RØUTE <u>cannot</u> be used simultaneously

7/Can be used only in conjunction with RØUTE

8/Can be used only in conjunction with RØUTE and DIFFA

Instruction Card Format

The format of the Instruction Card for the streamflow computations function is shown in table 5.

Table 5.--Instruction Card format for streamflow computations function

Input item	Card entry	Format	Card columns
Input file	I = xx1/,	Free field2/	1-80
Output file	Ø = xx1/,	Free field	1-80
------------------Keyword Parameter Instructions-----------------------			
Diffusion analogy	DIFFA,	Free field	1-80
Route	RØUTE,	Free field	1-80
Use multiple linearization	MULT,	Free field	1-80
Add two hydrographs	ADD,	Free field	1-80
Multiply by a ratio	RATIO=w.d3/,	Free field	1-80
Lag a hydrograph	LAG=ℓ 4/,	Free field	1-80

1/xx represents a two-digit file number.

2/Free field entries allow input anywhere on card in columsn 1-80. Differentiation between individual field entries is signified by a separation comma (,) except for the last entry.

3/w.d represents a number in the range $-99999.99999 \leq w.d \leq 99999.99999$ with at least one digit required on each side of the decimal point.

4/An integer representing the number of routing intervals by which the input hydrograph is to be lagged.

Various combinations of instructions for streamflow computations are possible. Table 6 lists four of the simplest combinations and the final result of the operation. It can be noted from table 6 that blank spaces are allowed between and within individual instructions entries.

Table 6.--An example of four streamflow computation instruction combinations

Combination	Result
I = xx, Ø = yy	The discharge hydrograph is input from file xx and then copied to output file yy.
I = xx, ADD, Ø = yy	Two discharge hydrographs from files xx and yy are input, added together, and the resultant hydrograph output to file yy.
I = xx, RATIØ = w.d, Ø = yy	The discharge hydrograph is input from file xx, multiplied by the ratio w.d, and the resultant hydrograph output to file yy.
I = xx, RATIØ = w.d, ADD, Ø=yy	The discharge hydrograph is input from file xx and multiplied by the RATIØ w.d, then a second hydrograph from file yy is input and added to the multiplied hydrograph. This summed hydrograph is then output to file yy.

Each of the instruction combinations illustrated in table 6 may be combined with lagging or routing (not both) operations. Table 7 illustrates the additional instructions that may be used for the lagging and routing operations. Each of the four entries in table 7 may be combined with the combinations in table 6 providing 16 total possible instruction combinations for streamflow computations.

Table 7.--Lagging and routing operations for streamflow computations function

Instruction(s)	Purpose
LAG = ℓ	Lags input hydrograph by ℓ routing intervals.
RØUTE	Performs routing computations using storage-continuity method to determine system response.
RØUTE, DIFFA	Performs routing computations using diffusion analogy method with single linearization to determine system response.
RØUTE, DIFFA, MULT	Performs routing computations using diffusion analogy method with multiple linearization to determine system response.

Figure 8 illustrates the computational sequences for any instruction combination. As shown in the figure the hierarchy of the instructions for streamflow computations is:

1. Multiplying by a ratio;

2. Routing or lagging hydrographs; and

3. Adding hydrographs.

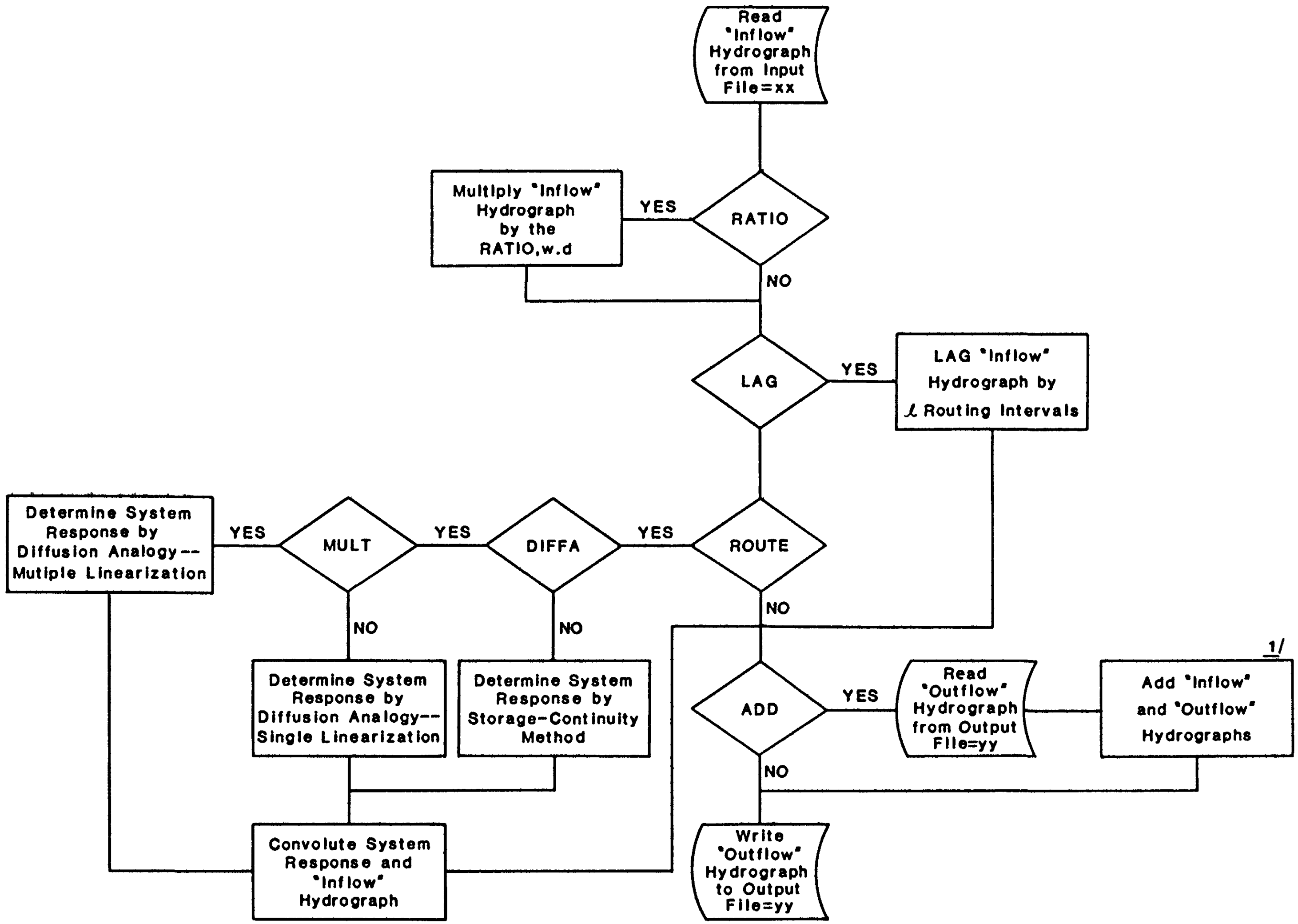
As mentioned above, individual instructions are not order-dependent, thus:

1. I = xx, Ø = yy, RØUTE, RATIØ = w.d, MULT, ADD, DIFFA

2. RØUTE, ADD, I = xx, RATIØ = w.d, DIFFA, MULT, Ø = yy, and

3. DIFFA, MULT, RATIØ = w.d, Ø = yy, ADD, RØUTE, I = xx

are all equivalent instruction cards.



1/ "Inflow" Hydrograph at this point may have been modified by previous operations.

Figure 8.--Flow chart of operations for streamflow computations.

Header Card Format

The format of the header card for streamflow computations is documented in table 8.

Table 8.--Header card format for streamflow computations

Input item	Variable name	Format	Card columns
Station number identification	STANØ1[1/]	2A4	1-8
Station name	STANM1[2/]	12A4	11-58

1/STANØ1 is an array with 2 elements.

2/STANM1 is an array with 12 elements.

Parameter Card Format

The parameter card is required only when the RØUTE instruction has been selected. Tables 9, 10, and 11 document the formats for the three methods of routing.

Storage-Continuity Method

If the storage-continuity method is requested (RØUTE specified on the Instruction card without DIFFA and MULT) then the parameter card is input as described in table 9.

Table 9.--Parameter card format: storage-continuity method

Input item	Card entry	Format	Card columns
Slope of storage-discharge relation 1/	K= ,	Free field	1-80
Time base of translation hydrograph 1/	W= ,	Free field	1-80
Linearity coefficient in storage-discharge relation 1/	X= ,	Free field	1-80
Traveltime of leading edge of flood wave 1/	TT= ,	Free field	1-80
Reach identification 2/	REACH=	Free field	1-80

1/Described in detail in Sauer (1973).

2/Identification information (entered after the = sign) is limited to 20 columns and can include any alphanumeric characters.

Diffusion Analogy Method: Single Linearization

If the diffusion analogy method with single linearization is requested, (RØUTE and DIFFA without MULT on the Instruction Card) then the parameter card format is shown in table 10.

Table 10.--Parameter card format: diffusion analogy method, single linearization

Input item	Card entry	Format	Card columns
Celerity 1/	C= ,	Free field	1-80
Dispersion 2/	K= ,	Free field	1-80
Reach length 3/	X= ,	Free field	1-80
Reach identification 4/	REACH=	Free field	1-80

1/As computed from equation 5.

2/As computed from equation 4.

3/Value entered in units of miles.

4/Limited to 20 columns.

Diffusion Analogy Method: Multiple Linearization

If the diffusion analogy method with multiple linearization is requested, (RØUTE, DIFFA, and MULT on the Instruction Card) then the parameter card format is shown in table 11.

Table 11.--Parameter card format: diffusion analogy method, multiple linearization

Input item	Card entry	Format	Card columns
Reach length 1/	X= ,	Free field	1-80
Reach identification 2/	REACH=	Free field	1-80

1/Value entered in units of miles.

2/Limited to 20 columns.

Discharge/wave-disperison/wave-celerity data cards

For the diffusion analogy method with multiple linearization, the discharge/wave-dispersion/wave-celerity data are input on additional cards (table 12). There must be at least two discharge/wave-dispersion/wave-celerity data entries and the maximum limit is 10 entries.

Table 12.--Formats of discharge/wave-dispersion/wave-celerity data cards

Input item	Variable name	Format	Card columns
Discharge range card			
Minimum discharge should be set to the lowest flow that you are interested in.	QMIN	F8.0	1-8
Maximum discharge must be less than the largest entry in the discharge table	QMAX	F8.0	9-16
Discharge/wave-dispersion table cards			
Discharges, from lowest to highest flows expected in ascending order (Can be 2 to 10 values)	BPW	10F8.0	1-80
Wave-dispersion values matched up with discharge values1/	WBP	10F8.0	1-80
Discharge/wave-celerity table cards			
Discharges, from lowest to highest flows expected in ascending order (Can be 2 to 10 values)	BPC	10F8.0	1-80
Wave-celerity values matched up with discharge values2/	CBP	10F8.0	1-80

1/Wave-dispersion values have to be entered in either increasing or decreasing order.

2/Wave-celerity values have to be entered in increasing order only.

Data Comparison

The data comparison function has both an Instruction Card and a Title Card.

Instruction Card Format

The Instruction Card format for the data comparison function is documented in table 13.

Table 13.--Instruction card format for the data comparison function

Input item	Card entry	Format	Card columns
Compare instruction	COMPARE,1/	Free field	1-80
First input file number	FIRST FILE=xx,2/3/	Free field	1-80
Second input file number	SECOND FILE=yy,3/4/	Free field	1-80

1/The COMPARE function computes a percent error between discharges Q_1 and Q_2 from the formula $[(Q_1-Q_2)*100/Q_2]$. Q_1 and Q_2 are obtained from the FIRST FILE and SECOND FILE, respectively.

2/May be abbreviated to F=xx.

3/$21 \leq xx \leq 30$.

4/May be abbreviated to S=yy.

Title Card Format

The format of the Title Card for the data comparison function is 80A1 which permits coding useful identification information anywhere in columns 1-80.

Data Plotting

The data plotting function also has both an Instruction Card and a Title Card.

Instruction Card Format

The Instruction Card format for the data plotting function is documented in table 14.

Table 14.--Instruction card format for the data plotting function

Input item	Card entry	Format	Card columns
Plot instruction	PLØT,	Free field	1-80
First input file number	FIRST FILE=xx,1/2/	Free field	1-80
Second input file number	SECOND FILE=yy,2/3/4/	Free field	1-80
Minimum discharge	QMIN = q,5/6/	Free field	1-80

1/May be abbreviated F=xx.

2/$21 \leq xx \leq 30$.

3/A second input file is optional.

4/May be abbreviated S=yy.

5/Optional with default of q = 1

6/q must be an integer. The plot consists of four 3-inch log cycles on the discharge scale. Thus if q is specified as 10^a, flows less than q and greater than 10^{a+3} will not be plotted.

Title Card Format

The format of the Title Card for the data plotting function is 80A1 which permits coding useful identification information anywhere in columns 1-80.

Data Printout

The data printout function has both an Instruction Card and a Title Card.

Instruction Card Format

The Instruction Card format for the data printout function is documented in table 15.

Table 15.--Instruction card format for the data printout function

Input item	Card entry	Format	Card columns
Print instruction	PRINT,	Free field	1-80
First input file number	FIRST FILE=xx,1/2/	Free field	1-80
Second input file number	SECOND FILE=yy,2/3/4/	Free field	1-80

1/May be abbreviated F=xx.

2/21 $\leq$ xx $\leq$ 30.

3/A second input file is optional.

4/May be abbreviated S=yy.

Title Card Format

The format of the Title Card for the data printout function is 80A1 which permits coding useful identification information anywhere in columns 1-80.

Restart

The Restart function requires only an Instruction Card.

Instruction Card Format

The Instruction Card format for the Restart function is documented in table 16.

Table 16.--Instruction card format for restart function

Input item	Card entry	Format	Card columns
Restart instruction (necessary only when next step requires a new time period).	RESTART	Free field	1-80

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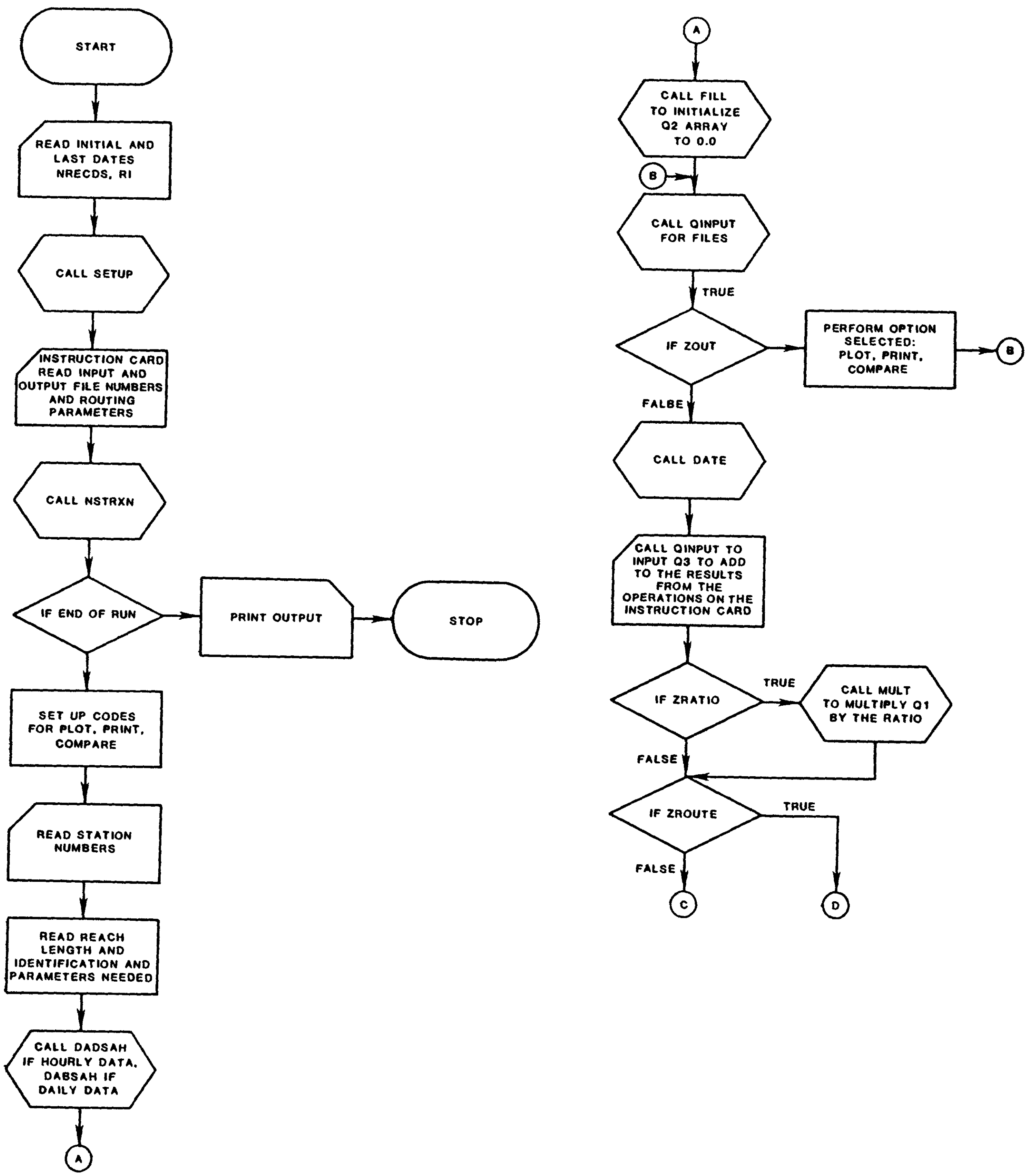
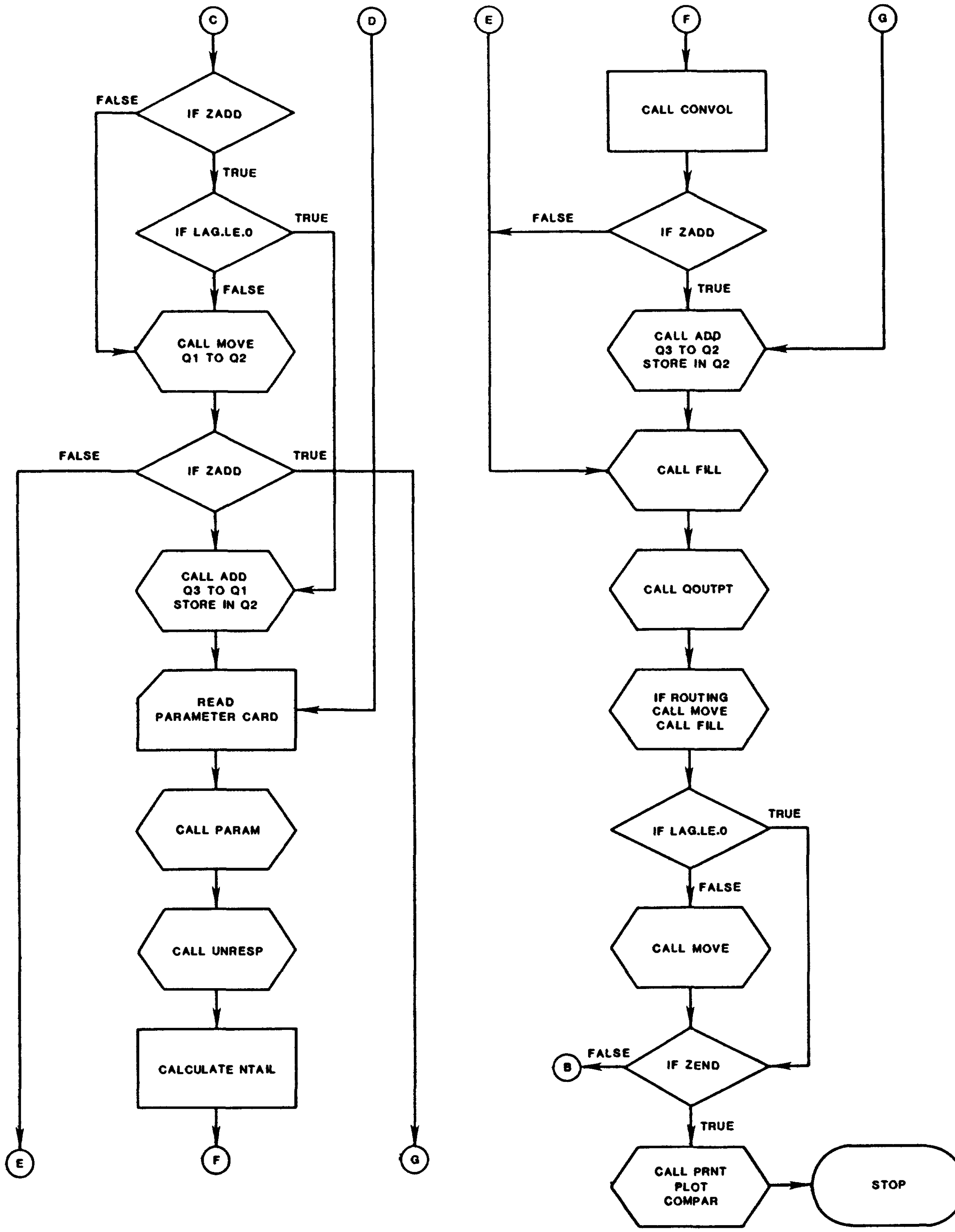
APPENDICES

APPENDIX A. GENERALIZED PROGRAM FLOW CHART

GENERALIZED PROGRAM FLOW CHART




C
D
E
F
G
FALSE
IF ZADD
TRUE
IF LAG.LE.0
TRUE
FALSE
CALL MOVE
Q1 TO Q2
FALSE
IF ZADD
TRUE
CALL ADD
Q3 TO Q1
STORE IN Q2
READ
PARAMETER CARD
CALL PARAM
CALL UNRESP
CALCULATE NTAIL
E
F
G
CALL CONVOL
FALSE
IF ZADD
TRUE
CALL ADD
Q3 TO Q2
STORE IN Q2
CALL FILL
CALL QOUTPT
IF ROUTING
CALL MOVE
CALL FILL
IF LAG.LE.0
TRUE
FALSE
CALL MOVE
B
FALSE
IF ZEND
TRUE
CALL PRNT
PLOT
COMPAR
STOP

APPENDIX B. DESCRIPTION OF CONROUT SUBROUTINES

SUBROUTINE DESCRIPTION

COMPAR

Computes and prints deviations of two hydrographs for individual data points and summarizes mean deviations and volume error.

DABSAH

Used for daily data. Sets the record pointer to the first record for data you are interested in.

DADSAH

Used for hourly data. Sets the record pointer to the first record of data you are interested in.

DATE

Fills up arrays with the day, month, year, and time for printout of the hydrograph.

GETINT

Translates a string of digits from either instruction or parameter cards to integer or real numbers.

HYDROG

Routes the triangular translation hydrograph through channel storage for computing the unit response using the storage-continuity method.

INFLOW

Computes the triangular translation hydrograph for computing the unit response using the storage-continuity method.

JNWYDY

Computes a julian day number on a water year basis (October 1 = 1 and September 30 = 365 or 366, depending on whether or not it is a a leap year).

NSTRXN

Translates the instruction coded on the instruction cards and the parameters coded on the parameter cards.

PLOTIT

Sets up the data for subsequent plotting by PRPLOT.

PRNT

Provides a printout of one or two hydrographs.

PRPLOT

Reads and writes data records on direct access device.

SETUP

Creates space on direct access files.

TABL

This is a linear interpolation routine called when using multiple linearization. Used to compute discharge celerity and dispersion values.

TRANSL8

Checks for proper instructions on the instruction card.

UNRESP

This subroutine calculates unit-response functions for either the storage-continuity method or diffusion analogy method. For the diffusion analogy method, unit-response functions may be calculated for either single linearization (one unit-response function) or multiple linearization (family of unit-response functions).

UTILIT

This subroutine, with various entry points, provides the user with the following capabilities: 1) fill an array with a constant; 2) multiply an array by a constant; 3) move one array to another array, with offsets; 4) add two arrays; and 5) convolute two arrays and accumulate the result in a third array.

APPENDIX C. PROGRAM LISTING

```
C     ------------------------------------------------------------------
C
C
C                       UNIT RESPONSE ROUTING PROGRAM
C
C                       PROGRAMMED BY
C                       J. O. SHEARMAN AND G. J. STILTNER
C                       DECEMBER 1976
C     REVISED 27 JUNE 1978 FOR PROGRAM J351 BY JOS
C     COMPARE SUBROUTINE MODIFIED IN 1983 BY W.H.DOYLE, JR.
C             TO PRINTOUT AN ERROR DISTRIBUTION TABLE.
C
C
C     ------------------------------------------------------------------
C
C     THIS VERSION MODIFIED FOR DIRECT ACCESS
C
C                      MAIN   PROGRAM
C
C     1 OCT 76
C
      IMPLICIT LOGICAL(Z),INTEGER(A)
      INTEGER STANO1(2),STANO2(2),STANM1(12),STANM2(12)
      INTEGER IPFILE,OPFILE
      INTEGER REACH(20)
      REAL K,ZERO/0.0/,NOVAL/999999./
      DIMENSION INFO(20), ITT(20)
      DIMENSION Q1(384), IAV(10), LREC(10), Q3(384), Q2(484), NRESP(20)
      COMMON /INSTCD/ ICARD(80),ICOL
      COMMON /ZLOGIC/ ZOPER(20),ZDONE,ZBORT
      COMMON /DISCHG/ Q1,Q2
      COMMON /IQVALU/ IQF,IQL
      COMMON /FILES/ ID21,ID22,ID23,ID24,ID25,ID26,ID27,ID28,ID29,ID30
      COMMON /RTPARM/ REACH,K,X,TT,W,CZERO,NURS,RI,UR(20,100),NRO,HWAY(20
     10)
      COMMON /PLT/ INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR,STANO1
     1,STANM1,STANO2,STANM2
      COMMON /UNITS/ LCARD,LPRNT
      EQUIVALENCE (ZADD,ZOPER(3)), (ZRATIO,ZOPER(1)), (ZROUTE,ZOPER(2)),
     1 (ZPLOT,ZOPER(4)), (ZPRINT,ZOPER(5)), (ZDIFFA,ZOPER(6)), (ZFILE2,Z
     2OPER(7)), (ZCOMPR,ZOPER(9)), (ZRSTRT,ZOPER(10)), (ZMULT,ZOPER(15))
C
      LCARD=5
      LPRNT=6
      ZSET=.FALSE.
      ZBORT=.FALSE.
      WRITE (LPRNT,460)
C     READ PROBLEM CONSTANTS
   10 READ (LCARD,470,END=430) INITMO,INITDY,INITYR,INITI,LASTMO,LASTDY,
     1LASTYR,LASTI,NRECDS,RI,NTSO
      WRITE (LPRNT,480) INITMO,INITDY,INITYR,INITI,LASTMO,LASTDY,LASTYR,
     1LASTI
      NSTEP=0
      IF (ZSET) GO TO 20
C     SET AND DEFINE FILES
      IF (NRECDS.LE.0) NRECDS=20
C
```

```
      CALL SETUP (NRECDS)
      ZSET=.TRUE.
   20 CONTINUE
C
C
      IF (RI.EQ.24.) GO TO 30
      IDAY=INITDY
      IF (INITDY.GT.15) IDAY=INITDY-15
      IQBEG=(IDAY-1)*24+(INITI/100)
      IDAY=LASTDY
      IF (LASTDY.GT.15) IDAY=LASTDY-15
      IQEND=(IDAY-1)*24+(LASTI/100)
      GO TO 40
   30 IQBEG=JNWYDY(INITMO,INITDY,INITYR)
      IQEND=JNWYDY(LASTMO,LASTDY,LASTYR)
   40 READ (LCARD,490,END=430) ICARD
      ZOUT=.FALSE.
      CALL NSTRXN (RATIO,IPFILE,OPFILE,MINQ,LAG)
      IF (ZBORT) GO TO 410
      NSTEP=NSTEP+1
      WRITE (LPRNT,500) NSTEP,ICARD
      IF (ZRSTRT) GO TO 10
      IF (ZPLOT.OR.ZPRINT.OR.ZCOMPR) ZOUT=.TRUE.
      ZBEGIN=.TRUE.
      ZEND=.FALSE.
      FTIME=12.
      IF(RI.NE.24.) FTIME=INITI/100
      IQF=IQBEG
      JYEAR=INITYR
      LYEAR=JYEAR
      IF (RI.NE.24.) GO TO 60
      IF (IQF.GT.92) JYEAR=JYEAR-1
      LYEAR=JYEAR-1
   60 LMON=INITMO
      LDAY=INITDY
      JIN=IPFILE-20
      JOUT=OPFILE-20
      IF (JOUT.GT.5) GO TO 70
      IF (ZOUT) GO TO 70
      WRITE (LPRNT,600) OPFILE
      STOP
   70 IF (ZOUT) GO TO 80
      READ (LCARD,510) STANO1,STANM1
      WRITE (LPRNT,520) STANO1,STANM1
      GO TO 90
   80 READ (LCARD,530) (INFO(J),J=1,20)
      WRITE (LPRNT,540) INFO
      READ (IPFILE'1) KRECDS,STANO1,STANM1
      IF (.NOT.ZFILE2) GO TO 100
      READ (OPFILE'1) KRECDS,STANO2,STANM2
   90 IAV(JOUT)=2
  100 IF (RI.EQ.24.) GO TO 110
      CALL DABSAH (IPFILE,JYEAR,IAV(JIN),ZBORT,LREC(JIN),INITMO,INITDY)
      GO TO 120
  110 CALL DABSAH (IPFILE,JYEAR,IAV(JIN),ZBORT,LREC(JIN))
  120 IF (ZBORT) GO TO 420
      IF (.NOT.ZOUT) GO TO 150
      IF (.NOT.ZFILE2) GO TO 150
      IF (RI.EQ.24.) GO TO 130
      CALL DABSAH (OPFILE,JYEAR,IAV(JOUT),ZBORT,LREC(JOUT),INITMO,INITDY
     1)
```

```
      GO TO 140
  130 CALL DABSAH (OPFILE,JYEAR,IAV(JOUT),ZBORT,LREC(JOUT))
  140 IF (ZBORT) GO TO 420
      GO TO 160
C
C
C     INITIALIZE Q2 ARRAY TO 0.0
C
  150 CALL FILL (Q2,1,484,ZERO)
C
C
  160 CALL QINPUT (IPFILE,IAV(JIN),ITEMS,Q1,JYEAR,JMON,JDAY)
C
      IF (RI.EQ.24.) GO TO 170
      IF (JYEAR.EQ.LYEAR.AND.JMON.EQ.LMON.OR.JMON.EQ.LMON+1) GO TO 180
      IF (JYEAR.EQ.LYEAR+1.AND.JMON.EQ.1.AND.LMON.EQ.12) GO TO 180
      GO TO 440
  170 IF (JYEAR.NE.LYEAR+1) GO TO 440
  180 LYEAR=JYEAR
      LMON=JMON
      LDAY=JDAY
      IF (.NOT.ZOUT) GO TO 190
      IF (.NOT.ZFILE2) GO TO 190
C
      CALL QINPUT (OPFILE,IAV(JOUT),ITEMZ,Q2,KYEAR,KMON,KDAY)
C
      IF (KYEAR.EQ.JYEAR) GO TO 190
      WRITE (LPRNT,550)
      STOP
  190 IF (RI.EQ.24.) GO TO 200
      IF (JMON.EQ.LASTMO.AND.JDAY.GE.(LASTDY-15).AND.JYEAR.EQ.LASTYR) GO
     1 TO 220
      GO TO 210
  200 IF (IQEND.LT.93.AND.JYEAR.EQ.LASTYR) GO TO 220
      IF (IQEND.GT.92.AND.JYEAR.EQ.LASTYR-1) GO TO 220
  210 IQL=ITEMS
      GO TO 230
  220 IQL=IQEND
      ZEND=.TRUE.
  230 IF (.NOT.ZOUT) GO TO 240
C
      IF (ZPLOT) GO TO 390
      CALL DATE (RI,ITEMS,FTIME,JMON,JDAY,JYEAR)
      IF (ZPRINT) GO TO 380
      IF (ZCOMPR) GO TO 400
C
C
C     ROUTE HYDROGRAPH ORDINATES
C
  240 IF (.NOT.ZADD) GO TO 250
C
C     INPUT Q3 TO ADD TO THE HYDROGRAPH RESULTING FROM
C     THE OPERATIONS SPECIFIED ON THE INSTRUCTION CARD.
C
      CALL QINPUT (OPFILE,IAV(JOUT),ITEMS,Q3,KYEAR,KMON,KDAY)
C
      IAV(JOUT)=IAV(JOUT)-1
C
  250 IF (.NOT.ZRATIO) GO TO 250
C
C     MULTIPLY Q1 BY THE RATIO SPECIFIED ON THE INSTRUCTION CARD.
```

```
C
      CALL MULT (Q1,IQF,IQL,RATIO)
C
  260 IF (ZROUTE) GO TO 290
      IF (.NOT.ZADD) GO TO 270
      IF (LAG.LE.0) GO TO 280
C     MOVE Q1 TO Q2
  270 CALL MOVE (Q1,Q2,IQF,IQL,LAG,0)
      IF (ZADD) GO TO 320
      GO TO 330
C     ADD Q3 TO Q1 AND STORE IN Q2 FOR OUTPUT
  280 CALL ADD (Q3,Q1,Q2,IQF,IQL)
      GO TO 330
  290 IF (.NOT.ZBEGIN) GO TO 310
C     READ PARAMETER CARD
C
      READ (LCARD,490,END=430) ICARD
      WRITE (LPRNT,580) ICARD
C
C     DETERMINE PARAMETERS
C
      CALL PARAM
C     CHECK FOR ABORT
      IF (.NOT.ZBORT) GO TO 300
      WRITE (LPRNT,590) ICOL
      GO TO 420
C
C     GENERATE UNIT-RESPONSE FUNCTION ALLI
C
  300 CALL UNRESP (ZDIFFA,ZMULT,NRESP,ITT)
C
C
      NTAIL=NRESP(1)-1+ITT(1)
C
C     CONVOLUTE Q1 WITH UR TO OBTAIN Q2
C
  310 CALL CONVOLI (Q2,Q1,UR,IQF,IQL,NRO,NURS,HWAY,ITT,NRESP)
      IF (.NOT.ZADD) GO TO 330
C
C     ADD Q3 TO Q2 AND STORE IN Q2 FOR OUTPUT
C
  320 CALL ADD (Q3,Q2,Q2,IQF,IQL)
C
  330 IF (ZBEGIN.AND.IQBEG.GT.1) CALL FILL (Q2,1,IQF-1,NOVAL)
      IF (ZEND.AND.IQEND.LT.ITEMS) CALL FILL (Q2,IQL+1  ,ITEMS,NOVAL)
      CALL QOUTPT (OPFILE,IAV(JOUT),ITEMS,Q2,JMON,JDAY,JYEAR)
      IF (ZEND) GO TO 370
      IF (.NOT.ZROUTE) GO TO 340
C
C     MOVE RESIDUAL SUMS TO BEGINNING OF Q2 FOR NEXT YEAR
C
      CALL MOVE (Q2,Q2,1,NTAIL,0,ITEMS)
C
      CALL FILL (Q2,NTAIL+1,ITEMS+NTAIL,ZERO)
C
  340 IF (LAG.LE.0) GO TO 350
C
      CALL MOVE (Q2,Q2,1,LAG,0,ITEMS)
C
  350 IF (.NOT.ZBEGIN) GO TO 150
  360 ZBEGIN=.FALSE.
```

```
      IQF=1
      IF(RI.NE.24.)FTIME=1.0
      GO TO 160
C
C     WRITE HEADER RECORD ON OUTPUT FILE
C
  370 NRECDS=IAV(JOUT)-1
      WRITE (OPFILE'1) NRECDS,STANOI,STANMI
      GO TO 40
C
C
  380 CALL PRNT (ZBEGIN,ZFILE2)
C
      IF (ZEND) GO TO 40
      IF (ZBEGIN) GO TO 360
      GO TO 160
C
  390 CALL PLOTIT (ZFILE2,ZEND,ZBEGIN,MINQ)
C
      IF (ZEND) GO TO 40
      IF (ZBEGIN) GO TO 360
      GO TO 160
C
  400 CALL COMPAR (ZFILE2,ZEND,ZBEGIN,NTSO)
C
      IF (ZEND) GO TO 40
      IF (ZBEGIN) GO TO 360
      GO TO 160
C
  410 WRITE (LPRNT,590) ICOL
C
  420 WRITE (LPRNT,560)
  430 STOP
C
C       GAP IN DATA ***
  440 WRITE (LPRNT,570) JMON,JDAY,JYEAR,LMON,LDAY,LYEAR
      GO TO 420
C
C
C
  450 FORMAT (1H1)
  460 FORMAT (1H1,27HUNIT RESPONSE ROUTING MODEL)
  470 FORMAT (9I5,F5.0,I5)
  480 FORMAT (1H0,11X,14HFOR THE PERIOD,2I3,2I5,3H TO,2I3,2I5/11X,40HTHE
     1 FOLLOWING STEPS HAVE BEEN PERFORMED./)
  490 FORMAT (80A1)
  500 FORMAT (1H0//11X,11H*****STEP =,I3,3X,21HDATA INPUT CARDS*****/11X
     1,80A1)
  510 FORMAT (2A4,2X,12A4)
  520 FORMAT (1H ,11X,2A4,2X,12A4)
  530 FORMAT (20A4)
  540 FORMAT (1H ,11X,20A4)
  550 FORMAT (1H0,11X,16HYEARS MISMATCHED)
  560 FORMAT (1H0,11X,5(1H*),11HJOB ABORTED,5(1H*))
  570 FORMAT (1H0,11X,30HGAP IN DATA,JMON,JDAY,JYEAR = ,3I4,19H LMON,LDA
     1Y,LYEAR = ,3I4)
  580 FORMAT (1H ,11X,80A1)
  590 FORMAT (1H0,11X,23HINVALID DATA IN COL. = ,I3)
  600 FORMAT (1H0,11X,25HINVALID OUTPUT FILE NO.  ,I2)
      END
      BLOCK DATA
```

```
C
C     1 OCT 76
C
      IMPLICIT LOGICAL(Z),INTEGER(A)
      COMMON /DAYSMO/ MODAYS(12)
      COMMON /ZLOGIC/ ZOPER(20),ZDONE,ZBORT
      COMMON /ALFWRD/ ARATIO(5),AROUTE(5),AADD(3),APLOT(4),APRINT(5),AQM
     1IN(4),ACOMPR(7),ARSTRT(7),ALAG(3)
      COMMON /ALFCHI/ ALPHAI,ALPHAR,ALPHAA,ALPHAO,ALPHAP,ALPHAF,ALPHAS,A
     1LPHAQ,ALPHAC
      COMMON /ALFDIG/ ADIGIT(9),AZERO
      COMMON /ALFCHS/ ANEQSN,APOINT,ACOMMA,AMINUS,APLUS,AQUEST
      DATA MODAYS/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA ARATIO/'R','A','T','I','O'/,AROUTE/'R','O','U','T','E'/,AADD/
     1'A','D','D'/,APLOT/'P','L','O','T'/,APRINT/'P','R','I','N','T'/,AQ
     2MIN/'Q','M','I','N'/,ALPHAS/'S'/,ALPHAF/'F'/,AZERO/'0'/,ADIGIT/'1'
     3,'2','3','4','5','6','7','8','9'/,APOINT/'.'/,ANEQSN/'='/,ACOMMA/'
     4,'/,ZDONE/.FALSE./,ALPHAI/'I'/,ALPHAR/'R'/,ALPHAP/'P'/,ALPHAA/'A'/
     5,ALPHAO/'O'/,ALPHAQ/'Q'/,ALPHAC/'C'/,ACOMPR/'C','O','M','P','A','R
     6','E'/,AMINUS/'-'/,APLUS/'+'/,AQUEST/'?'/,ARSTRT/'R','E','S','T','
     7A','R','T'/,ALAG/'L','A','G'/
      END
      SUBROUTINE COMPAR (ZFILE2,ZEND,ZBEGIN,NTSO)
C
C     27 JUNE 1978
C     THIS VERSION OF COMPAR FOR PROGRAM J351
C
      LOGICAL ZBEGIN,ZEND,ZFILE2
      DIMENSION Q1(384),Q2(484),DEV(384),INFO(20),CARD(24)
      INTEGER STANO1(2),STANO2(2),STANM1(12),STANM2(12)
      COMMON /B2/ IYEAR(384),IDAY(384),IMON(384),TIME(384)
      COMMON /DISCHG/ Q1,Q2
      COMMON /IQVALU/ IQF,IQL
      COMMON /PLT/ INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR,STANO1
     1,STANM1,STANO2,STANM2
      COMMON /UNITS/ LCARD,LPRNT
C
      IF (ZBEGIN) GO TO 1
      IF (ICNT.LT.50) GO TO 10
    1 WRITE (LPRNT,80) INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
      WRITE (LPRNT,90) STANO1,STANM1,STANO2,STANM2
      IF(NTSO.EQ.1.OR.NTSO.EQ.3) GO TO 2
      WRITE (LPRNT,120)
    2 ICNT=0
      IF(.NOT.ZBEGIN) GO TO 10
      IF (NTSO.LT.2) GO TO 5
      ND=0
      WRITE(17,140) STANO1,STANM1,INITMO,INITDY,INITYR,
     *   LASTMO,LASTDY,LASTYR
      WRITE(18,140) STANO2,STANM2,INITMO,INITDY,INITYR,
     *   LASTMO,LASTDY,LASTYR
      WRITE(19,150) INFO,STANO1,STANM1,STANO2,STANM2,
     *   INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
    5 DEVRT=0
      DNEGT=0.0
      DPOST=0.0
      VOLQ1T=0.00
      VOLQ2T=0.00
      NONEGT=0
      NOPOST=0
      IETT05 = 0
```

```
      IETT10 = 0
      IETT15 = 0
      IETT20 = 0
      IETT25 = 0
   10 DEV2=0.0

      DEVPOS=0.0
      VOLQ1=0.00
      VOLQ2=0.00
      NONEG=0
      NOPOS=0
      IERR05 = 0
      IERR10 = 0
      IERR15 = 0
      IERR20 = 0
      IERR25 = 0
      DO 40 IQ=IQF,IQL
      DEV(IQ)=(Q1(IQ)-Q2(IQ))*100.0/Q2(IQ)
      DEV2=DEV2+(DEV(IQ)**2)
      IF (DEV(IQ).LT.0.0) GO TO 20
      DEVPOS=DEVPOS+DEV(IQ)
      NOPOS=NOPOS+1
      GO TO 30
   20 DEVNEG=DEVNEG+DEV(IQ)
      NONEG=NONEG+1
   30 VOLQ1=VOLQ1+Q1(IQ)
      VOLQ2=VOLQ2+Q2(IQ)
   40 CONTINUE
      IF(NTSO.EQ.1.OR.NTSO.EQ.3) GO TO 61
      DO 60 J=IQF,IQL
      IF (ICNT.LT.50) GO TO 50
      WRITE (LPRNT,80) INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
      WRITE (LPRNT,90) STANO1,STANM1,STANO2,STANM2
      WRITE (LPRNT,120)
      ICNT=0
   50 WRITE(LPRNT,100) (IMON(J),IDAY(J),IYEAR(J),TIME(J),Q1(J),
     *  Q2(J),DEV(J))
      ICNT=ICNT+1
      ERROR = DEV(J)
      IF(ABS(ERROR).LE.5.0)  IERR05 = IERR05 + 1
      IF(ABS(ERROR).LE.10.0) IERR10 = IERR10 + 1
      IF(ABS(ERROR).LE.15.0) IERR15 = IERR15 + 1
      IF(ABS(ERROR).LE.20.0) IERR20 = IERR20 + 1
      IF(ABS(ERROR).LE.25.0) IERR25 = IERR25 + 1
   60 CONTINUE
C
   61 IF(NTSO.LT.2) GO TO 66
      DO 65 IQ = IQF,IQL
      ND=ND+1
      CARD(ND)=Q1(IQ)
      CARD(ND+8)=Q2(IQ)
      CARD(ND+16)=DEV(IQ)
      IF(ND.EQ.8) GO TO 63
      IF(IQ.EQ.IQL.AND.ZEND) GO TO 63
      GO TO 65
   63 WRITE(17,130) (CARD(N),N=1,ND)
      ND=ND+8
      WRITE(18,130) (CARD(N),N=9,ND)
      ND=ND+8
      WRITE(19,130) (CARD(N),N=17,ND)
      ND=0
```

```
   65 CONTINUE
   66 NOBS=NONEG+NOPOS
      DEVTOT=(DEVPOS-DEVNEG)/NOBS
      DEV2T=DEV2T+DEV2
      DNEGT=DNEGT+DEVNEG
      DPOST=DPOST+DEVPOS
      NONEGT=NONEGT+NONEG
      NOPOST=NOPOST+NOPOS
      VOLQ1T=VOLQ1T+VOLQ1
      VOLQ2T=VOLQ2T+VOLQ2
      DEV2=SQRT(DEV2/NOBS)
      IF(NONEG.EQ.0) GO TO 67
      DEVNEG=DEVNEG/NONEG
   67 IF(NOPOS.EQ.0) GO TO 68
      DEVPOS=DEVPOS/NOPOS
   68 VOLERR=(VOLQ1-VOLQ2)*100.0/VOLQ2
      WRITE(LPRNT,105) IYEAR(365)
      WRITE (LPRNT,110) NOBS,DEVTOT,NONEG,DEVNEG,NOPOS,DEVPOS,
     *VOLQ1,VOLQ2,VOLERR,DEV2
      IETT05 = IETT05 + IERR05
      IETT10 = IETT10 + IERR10
      IETT15 = IETT15 + IERR15
      IETT20 = IETT20 + IERR20
      IETT25 = IETT25 + IERR25
      IERR05 = (IERR05 * 100 + .0001 ) / NOBS
      IERR10 = (IERR10 * 100 + .0001 ) / NOBS
      IERR15 = (IERR15 * 100 + .0001 ) / NOBS
      IERR20 = (IERR20 * 100 + .0001 ) / NOBS
      IERR25 = (IERR25 * 100 + .0001 ) / NOBS
      IREST =  100 -  IERR25 + .0001
      WRITE(LPRNT,900) IERR05,IERR10,IERR15,IERR20,IERR25,IREST
  900 FORMAT(//,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <=  5
     *PERCENT',
     */,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 10 PERCENT'
     */,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 15 PERCENT'
     */,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 20 PERCENT'
     */,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 25 PERCENT'
     */,1X,I5,' PERCENT OF TOTAL OBSERVATIONS HAD ERRORS >  25 PERCENT'
     *)
      ICNT=ICNT+20
      IF (ZEND) GO TO 70
C
      RETURN
C
   70 IF(ZBEGIN) RETURN
      NOBS=NONEGT+NOPOST
      DEVTOT=(DPOST-DNEGT)/NOBS
      IF(NONEGT.EQ.0) GO TO 71
      DNEGT=DNEGT/NONEGT
   71 IF(NOPOST.EQ.0) GO TO 72
      DPOST=DPOST/NOPOST
   72 VOLERR=(VOLQ1T-VOLQ2T)*100.0/VOLQ2T
      DEV2T=SQRT(DEV2T/NOBS)
      WRITE(LPRNT,106)
      WRITE (LPRNT,110) NOBS,DEVTOT,NONEGT,DNEGT,NOPOST,DPOST,
     *  VOLQ1T,VOLQ2T,VOLERR,DEV2T
      IETT05 = (IETT05 * 100 + .0001) / NOBS
      IETT10 = (IETT10 * 100 + .0001) / NOBS
      IETT15 = (IETT15 * 100 + .0001) / NOBS
      IETT20 = (IETT20 * 100 + .0001) / NOBS
      IETT25 = (IETT25 * 100 + .0001) / NOBS
```

```
      IREST  = 100 - IETT25 + .0001
      WRITE(LPRNT,900) IETT05,IETT10,IETT15,IETT20,IETT25,IREST
C
      RETURN
C
C
   80 FORMAT (1H1,11X,20A4/11X,4HFROM,2I3,I5,3H TO,2I3,I5)
   90 FORMAT (16X,27HQ1 IS DISCHARGE AT STATION ,2A4,2H, ,12A4/16X,27HQ2
     1 IS DISCHARGE AT STATION ,2A4,2H, ,12A4)
  100 FORMAT (11X,2I3,I5,F10.2,3F10.1)
  110 FORMAT (1H ,10X,18HMEAN ERROR (%) FOR,I5,7H DAYS =,F7.2/1H ,10X,20
     1HMEAN - ERROR (%) FOR,I5,7H DAYS =,F7.2/1H ,10X,20HMEAN + ERROR (%
     2) FOR,I5,7H DAYS =,F7.2/1H ,10X,17HQ1 VOLUME (SFD) =,F9.0,/
     3 1H ,10X,17HQ2 VOLUME (SFD) =,F9.0,/1H ,10X,18HVOLUME ERROR (%) =,
     4 F7.2/1H ,10X,15HRMS ERROR (%) =,F7.2)
  120 FORMAT (/15X,4HDATE,9X,4HTIME,7X,2HQ1,8X,2HQ2,5X,5HERROR/
     *    37X,2(5H(CFS),5X),3H(%)/)
  130 FORMAT(8F9.2)
  140 FORMAT(1H /1H /2A4,2H; ,12A4/6I5)
  150 FORMAT(20A4/2A4,2H; ,12A4/2A4,2H; ,12A4/6I5)
  105 FORMAT(1H0,10X,7H  *****,I5,17H WY SUMMARY *****)
  106 FORMAT(1H0,10X,27H  ***** TOTAL SUMMARY *****)
      END
      SUBROUTINE DABSAH (IFILE,IYEAR,IREC,ABORT,NRECDS)
C
C     1 OCT 76
C     SETS THE RECORD POINTER TO THE FIRST RECORD OF
C     DAILY DATA YOU ARE INTERESTED IN.
C
      DIMENSION ISKIP(2)
      LOGICAL ABORT
C     NRECDS IS THE NUMBER OF LAST DATA RECORD.
      READ (IFILE'1) NRECOS
      READ (IFILE'2) ISKIP,IYRLO
      IF (IYEAR.LT.IYRLO) GO TO 90
      IF (IYEAR.NE.IYRLO) GO TO 10
      IREC=2
      RETURN
   10 IREC=2+IYEAR-IYRLO
      IRECLO=2
      IF (IREC.GT.NRECDS) GO TO 20
      READ (IFILE'IREC) ISKIP,MIDYR
      IF (IYEAR.EQ.MIDYR) RETURN
      IRECHI=IREC
      IYRHI=MIDYR
      GO TO 40
   20 READ (IFILE'NRECDS) ISKIP,IYRHI
      IF (IYEAR.GT.IYRHI) GO TO 90
      IF (IYEAR.NE.IYRHI) GO TO 30
      IREC=NRECDS
      RETURN
   30 IRECHI=NRECDS
   40 IREC=IRECHI-IYRHI+IYEAR
      IF (IREC.LT.IRECLO) GO TO 50
      READ (IFILE'IREC) ISKIP,MIDYR
      IF (IYEAR.EQ.MIDYR) RETURN
      IRECLO=IREC
      IYRLO=MIDYR
   50 DO 80 IDO=1,10
      IF (IRECLO.EQ.IRECHI-1) GO TO 90
      IREC=(IRECLO+IRECHI)/2
```

```
      READ (IFILE'IREC) ISKIP,MIDYR
      IF (IYEAR.EQ.MIDYR) RETURN
      INCYR=IYEAR-MIDYR
      JREC=IREC+(INCYR-ISIGN(1,INCYR))
      IF (JREC.LE.IRECLO.OR.JREC.GE.IRECHI) GO TO 60
      READ (IFILE'JREC) ISKIP,JYEAR
      IF (IYEAR.NE.JYEAR) GO TO 60
      IREC=JREC
      RETURN
   60 IF (MIDYR.GT.IYEAR) GO TO 70
      IRECLO=IREC
      GO TO 80
   70 IRECHI=IREC
   80 CONTINUE
   90 WRITE (6,100) IYEAR,IFILE
      ABORT=.TRUE.
      RETURN
C
  100 FORMAT (1H0,I4,25H (INITY) NOT IN FILE NO. ,I2)
      END
      SUBROUTINE DADSAH (IFILE,IYEAR,IREC,ABORT,NRECDS,INITMO,INITDY)
C
C     1 OCT 76
C     SETS THE RECORD POINTER TO THE FIRST RECORD OF
C     HOURLY DATA YOU ARE INTERESTED IN.
C
      LOGICAL ABORT
C     NRECDS IS THE NUMBER OF LAST DATA RECORD.
      READ (IFILE'1) NRECDS
      READ (IFILE'2) JMON,JDAY,IYRLO
      IF (IYEAR.LT.IYRLO) GO TO 110
      IYROF=IYEAR
      IF (INITMO.LT.10) IYROF=IYEAR-1
      IREC=1+(IYROF-IYRLO)*24+2*(INITMO+13-JMON-(INITMO/10)*12)
      IF (JDAY.GT.15) IREC=IREC-1
      IF (INITDY.LT.16) IREC=IREC-1
      IF (IREC.EQ.2) RETURN
      IRECLO=2
      IF (IREC.GT.NRECDS) GO TO 20
      READ (IFILE'IREC) MIDMO,MIDDY,MIDYR
      IF (IYEAR.NE.MIDYR.OR.INITMO.NE.MIDMO) GO TO 10
      IF (INITDY.LT.16.AND.MIDDY.EQ.1.OR.INITDY.GT.15.AND.MIDDY.EQ.16) R
     1ETURN
   10 IRECHI=IREC
      IYRHI=MIDYR
      IMOHI=MIDMO
      IDYHI=MIDDY
      GO TO 40
   20 READ (IFILE'NRECDS) IMOHI,IDYHI,IYRHI
      IF (IYEAR.GT.IYRHI) GO TO 110
      IF (IYEAR.NE.IYRHI.OR.INITMO.NE.IMOHI) GO TO 30
      IREC=NRECDS
      IF (IDYHI.GT.15) IREC=NRECDS-1
      IF (INITDY.GT.15) IREC=NRECDS
      RETURN
   30 IRECHI=NRECDS
   40 IREC=24*(-IYRHI+IYEAR)+IRECHI-(IMOHI-INITMO)*2+1
      IF (IREC.LT.IRECLO) GO TO 60
      IF (INITDY.LT.16) IREC=IREC-1
      IF (IDYHI.GT.15) IREC=IREC-1
      READ (IFILE'IREC) MIDMO,MIDDY,MIDYR
```

```
      IF (IYEAR.NE.MIDYR.OR.INITMO.NE.MIDMO) GO TO 50
      IF (INITDY.LT.16.AND.MIDDY.EQ.1.OR.INITDY.GT.15.AND.MIDDY.EQ.16) R
     1ETURN
   50 IRECLO=IREC
   60 DO 100 IDO=1,10
      IF (IRECLO.EQ.IRECHI-1) GO TO 110
      IREC=(IRECLO+IRECHI)/2
      READ (IFILE'IREC) MIDMO,MIDDY,MIDYR
      IF (IYEAR.NE.MIDYR.OR.INITMO.NE.MIDMO) GO TO 70
      IF (INITDY.LT.16.AND.MIDDY.EQ.1.OR.INITDY.GT.15.AND.MIDDY.EQ.16) R
     1ETURN
   70 INCYR=24*(IYEAR-MIDYR)+2*(INITMO-MIDMO)
      JREC=IREC+INCYR
      IF (INITDY.LT.16.AND.MIDDY.GT.15) JREC=JREC-1
      IF (INITDY.GT.15.AND.MIDDY.LT.16) JREC=JREC+1
      IF (JREC.LE.IRECLO.OR.JREC.GE.IRECHI) GO TO 80
      READ (IFILE'JREC) JMON,JDAY,JYEAR
      IF (IYEAR.NE.JYEAR.OR.INITMO.NE.JMON) GO TO 80
      IF (INITDY.LT.16.AND.JDAY.NE.1.OR.INITDY.GT.15.AND.JDAY.NE.16) GO
     1TO 80
      IREC=JREC
      RETURN
   80 IF (MIDYR.GT.IYEAR.OR.MIDMO.GT.INITMO) GO TO 90
      IRECLO=IREC
      GO TO 100
   90 IRECHI=IREC
  100 CONTINUE
  110 WRITE (6,120) IYEAR,INITMO,INITDY,IFILE
      ABORT=.TRUE.
      RETURN
C
  120 FORMAT (1H0,I4,2I2,25H (INITY) NOT IN FILE NO. ,I2)
      END
      SUBROUTINE DATE (DD,NORDS,FTIME,INITM,INITD,INITY)
C
C     1 OCT 78
C     FILLS UP ARRAYS WITH THE DAY, MONTH, YEAR, AND
C     TIME FOR PRINTOUT OF THE HYDROGRAPH.
C
      COMMON /DAYSMO/ MODAYS(12)
      COMMON /B2/ IYEAR(384),IDAY(384),IMON(384),TIME(384)
      IYEAR(1)=INITY
      IF (MOD(INITY,4).EQ.0) MODAYS(2)=29
      IDAY(1)=INITD
      IMON(1)=INITM
      NOMON=INITM
      TIME(1)=FTIME
      DO 10 J=2,NORDS
      TIME(J)=TIME(J-1)+DD
      IDAY(J)=IDAY(J-1)
      IMON(J)=IMON(J-1)
      IYEAR(J)=IYEAR(J-1)
      IF (TIME(J).LE.24.0) GO TO 10
      TIME(J)=TIME(J)-24.0
      IDAY(J)=IDAY(J)+1
      IF (IDAY(J).LE.MODAYS(NOMON)) GO TO 10
      IDAY(J)=1
      NOMON=NOMON+1
      IF (NOMON.GT.12) NOMON=1
      IMON(J)=NOMON
      IF (NOMON.GT.1) GO TO 10
```

```
      IYEAR(J)=IYEAR(J)+1
      MODAYS(2)=28
      NYEAR=IYEAR(J)
      IF (MOD(NYEAR,4).EQ.0) MODAYS(2)=29
   10 CONTINUE
      IF (MODAYS(2).EQ.29) MODAYS(2)=28
      MODAYS(2)=28
      RETURN
      END
      SUBROUTINE GETINT (INTNO)
C
C     1 OCT 76
C     TRANSLATES A STRING OF DIGITS FROM EITHER INSTRUCTION
C     OR PARAMETER CARDS TO INTEGER OR REAL NUMBERS.
C
      IMPLICIT LOGICAL(Z),INTEGER(A)
      COMMON /ZLOGIC/ ZOPER(20),ZDONE,ZBORT
      COMMON /INSTCD/ ICARD(80),ICOL
      COMMON /ALFCHS/ ANEQSN,APOINT,ACOMMA,AMINUS,APLUS
      COMMON /ALFDIG/ ADIGIT(9),AZERO
      DIMENSION INTGR(10)
      ZINT=.TRUE.
      GO TO 10
      ENTRY GETFLT(FLTNO)
      ZINT=.FALSE.
      ZDEC=.FALSE.
   10 CALL FIND (ANEQSN)
      CALL SKIP
   20 DO 30 I=1,10
      INTGR(I)=0
   30 CONTINUE
      NDIG=0
      IF (ZDEC.OR.ZINT) GO TO 50
      SIGN=1.0
      IF (ICARD(ICOL).EQ.APLUS) GO TO 70
      IF (ICARD(ICOL).NE.AMINUS) GO TO 40
      SIGN=-1.0
      GO TO 70
   40 IF (ICARD(ICOL).NE.APOINT) GO TO 50
      ZDEC=.TRUE.
      GO TO 70
   50 IF (ICARD(ICOL).NE.AZERO) GO TO 80
      IDIG=0
   60 NDIG=NDIG+1
      INTGR(NDIG)=IDIG
   70 ICOL=ICOL+1
      IF (ICOL.LE.80) GO TO 50
      ZDONE=.TRUE.
      GO TO 100
   80 DO 90 I=1,9
      IDIG=I
      IF (ICARD(ICOL).EQ.ADIGIT(I)) GO TO 60
   90 CONTINUE
  100 INTNO=0
      DO 110 I=1,NDIG
      INTNO=INTNO+INTGR(I)*(10**(NDIG-I))
  110 CONTINUE
      IF (ZINT) RETURN
      IF (ZDEC) GO TO 120
      FLTNO=INTNO*SIGN
      IF (ICARD(ICOL).NE.APOINT) RETURN
```

```
      ZDEC=.TRUE.
      ICOL=ICOL+1
      GO TO 20
  120 FLTNO=FLTNO+SIGN*(FLOAT(INTNO))/(10**NDIG)
      RETURN
      END
      SUBROUTINE HYDROG (K,DELTAT,X)
C
C     1 OCT 76
C     ROUTES THE TRIANGULAR TRANSLATION HYDROGRAPH THROUGH
C     CHANNEL STORAGE FOR COMPUTING THE UNIT RESPONSE USING
C     THE STORAGE CONTINUITY METHOD.
C
      REAL I,K
      COMMON /INFLO/ I(999)
      COMMON /INSTQ/ Q(999)
      CALL FILL (Q,1,999,0.0)
      QQ=0.0
      DO 50 J=2,999
      IF (QQ) 20,10,20
   10 Q(J)=I(J)
      GO TO 30
   20 Q(J)=(I(J-1)+I(J)-Q(J-1)+(2.0*X*K*Q(J-1))/DELTAT*((Q(J-1)+QQ)/2.0)
     1**(X-1.0))/(((2.0*X*K)/DELTAT)*((Q(J-1)+QQ)/2.0)**(X-1.0)+1.0)
      IF (Q(J).LE.0.00001) RETURN
   30 IF (ABS((QQ-Q(J))/Q(J)).LE.0.001) GO TO 40
      QQ=Q(J)
      GO TO 20
   40 IF (Q(J).GT.Q(J-1)) QQ=1.10*Q(J)
      IF (Q(J).LE.Q(J-1)) QQ=0.90*Q(J)
   50 CONTINUE
      RETURN
      END
      SUBROUTINE INFLOW (D,DELTAT)
C     1 OCT 76
C     COMPUTES THE TRIANGULAR TRANSLATION HYDROGRAPH FOR
C     COMPUTING THE UNIT RESPONSE USING THE STORAGE
C     CONTINUITY METHOD.
C
      COMMON /INFLO/ I(999)
      REAL I,INSTR,INSTF
      INSTR(T)=2581.333*T
      INSTF(T)=2581.333*(1.0-T)
      T2=0.0
      CALL FILL (I,1,999,0.0)
      DO 30 J=2,999
      T2=T2+DELTAT
      T1=T2-D
      IF (T2.GE.0.0.AND.T2.LE.0.5) GO TO 10
      IF (T2.GE.0.5.AND.T2.LE.1.0) GO TO 20
      IF (T1.GT.1.0) I(J)=0.0
      IF (T1.LE.0.0) I(J)=645.333/D
      IF (T1.LE.0.0) GO TO 30
      IF ((T1.GE.0.0).AND.(T1.LE.0.5)) I(J)=(322.667+(((0.5-T1)*(1290.66
     17+INSTR(T1)))/2.0))/D
      IF (T1.GE.0.0.AND.T1.LE.0.5) GO TO 30
      IF (T1.GE.0.5.AND.T1.LE.1.0) I(J)=((1.0-T1)*(INSTF(T1)))/(2.0*D)
      GO TO 30
   10 IF (T1.LE.0.0) I(J)=INSTR(T2)*T2/(2.0*D)
      IF (T1.LE.0.0) GO TO 30
      IF (T1.LE.0.5) I(J)=(INSTR(T2)+INSTR(T1))*0.5
```

```
      GO TO 30
   20 IF (T1.LE.0.0) I(J)=(322.667+(T2-0.5)*(1290.667+INSTF(T2))*0.5)/D
      IF (T1.LE.0.0) GO TO 30
      IF (T1.GE.0.0.AND.T1.LE.0.5) I(J)=((T2-0.5)*(1290.667+INSTF(T2))+(
     10.5-T1)*(1290.667+INSTR(T1)))/(2.0*D)
      IF (T1.GE.0.0.AND.T1.LE.0.5) GO TO 30
      IF (T1.GE.0.5) I(J)=(INSTF(T2)+INSTF(T1))*0.5
   30 CONTINUE
      RETURN
      END
      FUNCTION JNWYDY (JMON,JDAY,JYEAR)
C
C     1 OCT 76
C     COMPUTES A JULIAN DAY NUMBER ON A WATER YEAR BASIS
C     (OCTOBER FIRST = 1 AND SEPTEMBER 30 = 366).
C
      COMMON /DAYSMO/ MODAYS(12)
      IWTRYR=JYEAR
      IF (JMON.GT.9) IWTRYR=IWTRYR+1
      LEAP=0
      IF (MOD(IWTRYR,4).EQ.0) LEAP=1
      JNWYDY=JDAY+92
      IF (JMON.EQ.1) GO TO 20
      MOS=JMON-1
      DO 10 I=1,MOS
   10 JNWYDY=JNWYDY+MODAYS(I)
   20 IF (JNWYDY.GT.365) JNWYDY=JNWYDY-(LEAP+365)
      IF (JMON.GT.2) JNWYDY=JNWYDY+LEAP
      RETURN
      END
      SUBROUTINE NSTRXN (RATIO,IFILE1,IFILE2,MINQ,LAG)
C
C     1 OCT 76
C     TRANSLATES THE INSTRUCTION CODED ON THE INSTRUCTION
C     CARDS AND THE PARAMETERS CODED ON THE PARAMETER CARDS.
C
      IMPLICIT LOGICAL(Z),INTEGER(A)
      REAL K
      DIMENSION AREACH(20)
      COMMON /RTPARM/ AREACH,K,X,TT,W,CZERO,NURS,RI,UR(20,100),NRO,HWAY(
     120)
      COMMON /UNITS/ LCARD,LPRNT
      COMMON /ZLOGIC/ ZOPER(20),ZDONE,ZBORT
      COMMON /INSTCD/ ICARD(80),ICOL
      COMMON /ALFWRD/ ARATIO(5),AROUTE(5),AADD(3),APLOT(4),APRINT(5),AQM
     1IN(4),ACOMPR(7),ARSTRT(7),ALAG(3)
      COMMON /ALFCHS/ ANEQSN,APOINT,ACOMMA,AMINUS,APLUS,AQUEST
      DATA ABLANK/1H /
      DIMENSION ALPHA(16)
      DATA ALPHA/1HA,1HD,1HF,1HI,1HL,1HO,1HP,1HQ,1HS,1HM,1HR,1HC,1HK,1HT
     1,1HW,1HX/
      EQUIVALENCE (ZK,ZOPER(20)), (ZCO,ZOPER(19)), (ZX,ZOPER(18)), (ZDIF
     1FA,ZOPER(6)), (ZW,ZOPER(17)), (ZMULT,ZOPER(15))
      MINQ=1
      LAG=0
      ICOL=1
      ZBORT=.FALSE.
      ZDONE=.FALSE.
      DO 10 I=1,20
      ZOPER(I)=.FALSE.
   10 CONTINUE
```

```
      GO TO 30
   20 CALL FIND (ACOMMA)
      IF (ZDONE) RETURN
   30 CALL SKIP
      DO 40 I=1,12
      IGO=I
      IF (ICARD(ICOL).EQ.ALPHA(I)) GO TO 50
   40 CONTINUE
      IGO=13
   50 GO TO (80,100,110,110,120,140,90,150,130,180,60,160,190), IGO
C
C               A   D   F   I   L   O   P   Q   S   R   C   M   INVALID
C
   60 IF (ZOPER(1)) GO TO 70
      CALL TRNSL8 (ARATIO,5,1)
      IF (.NOT.ZOPER(1)) GO TO 70
      CALL GETFLT (RATIO)
      GO TO 20
   70 CALL TRNSL8 (AROUTE,5,2)
      IF (.NOT.ZOPER(2)) GO TO 170
      GO TO 20
   80 CALL TRNSL8 (AADD,3,3)
      IF (.NOT.ZOPER(3)) GO TO 190
      GO TO 20
   90 CALL TRNSL8 (APLOT,4,4)
      IF (ZOPER(4)) GO TO 20
      CALL TRNSL8 (APRINT,5,5)
      IF (.NOT.ZOPER(5)) GO TO 190
      GO TO 20
  100 ZOPER(6)=.TRUE.
      GO TO 20
  110 CALL GETINT (IFILE1)
      GO TO 20
  120 CALL TRNSL8 (ALAG,3,16)
      IF (.NOT.ZOPER(16)) GO TO 190
      CALL GETINT (LAG)
      GO TO 20
  130 ZOPER(7)=.TRUE.
  140 CALL GETINT (IFILE2)
      GO TO 20
  150 CALL TRNSL8 (AQMIN,4,8)
      IF (.NOT.ZOPER(8)) GO TO 190
      CALL GETINT (MINQ)
      GO TO 20
  160 CALL TRNSL8 (ACOMPR,7,9)
      IF (.NOT.ZOPER(9)) GO TO 190
      GO TO 20
  170 CALL TRNSL8 (ARSTRT,7,10)
      IF (.NOT.ZOPER(10)) GO TO 190
      RETURN
  180 ZOPER(15)=.TRUE.
      GO TO 20
  190 CONTINUE
  200 ZBORT=.TRUE.
      RETURN
      ENTRY PARAM
      ZDONE=.FALSE.
      ICOL=1
      DO 210 I=1,20
      AREACH(I)=AQUEST
  210 CONTINUE
```

```
      TT=0.
      W=0.
      K=0.
      X=1.0
      CZERO=0.
      GO TO 230
  220 CALL FIND (ACOMMA)
      IF (ZDONE) GO TO 360
  230 CALL SKIP
      IF (ZDONE) GO TO 360
      DO 240 I=11,16
      IGO=I-10
      IF (ICARD(ICOL).EQ.ALPHA(I)) GO TO 250
  240 CONTINUE
      IGO=7
  250 GO TO (260,310,320,330,340,350,200), IGO
C
C               R   C   K   T   W   X  ERROR
C
  260 CALL FIND (ANEQSN)
      CALL SKIP
      IF (ZDONE) GO TO 360
      JCOL=ICOL
      CALL FIND (ACOMMA)
      IF (ZDONE) GO TO 270
      KCOL=ICOL-2
      GO TO 280
  270 KCOL=JCOL+19
  280 IF (KCOL.GT.80) KCOL=80
      J=0
      DO 290 I=JCOL,KCOL
      J=J+1
      AREACH(J)=ICARD(I)
  290 CONTINUE
      ICOL=KCOL+1
      IF (J.EQ.20) GO TO 220
      J=J+1
      DO 300 JB=J,20
      AREACH(JB)=ABLANK
  300 CONTINUE
      GO TO 220
  310 IF (.NOT.ZDIFFA) GO TO 200
      IF (ZMULT) RETURN
      CALL GETFLT (CZERO)
      ZCO=.TRUE.
      GO TO 220
  320 CALL GETFLT (K)
      ZK=.TRUE.
      GO TO 220
  330 CALL GETFLT (TT)
      GO TO 220
  340 CALL GETFLT (W)
      ZW=.TRUE.
      GO TO 220
  350 CALL GETFLT (X)
      ZX=.TRUE.
      GO TO 220
  360 IF (ZDIFFA) GO TO 380
      IF (ZK) GO TO 370
      WRITE (LPRNT,390)
      GO TO 200
```

```
  370 IF (.NOT.ZW) W=K
      RETURN
  380 IF (ZMULT) RETURN
      IF (ZCO.AND.ZX.AND.ZK) RETURN
      WRITE (LPRNT,400)
      GO TO 200
C
  390 FORMAT (16HOK NOT SPECIFIED)
  400 FORMAT (30HOK OR X OR CZERO NOT SPECIFIED)
      END
      SUBROUTINE PLOTIT (ZFILE2,ZEND,ZBEGIN,MINQ)
C
C     1 OCT 78
C     SETS UP THE DATA FOR SUBSEQUENT PLOTTING BY PRPLOT.
C
      DIMENSION INFO(20), MINQA(5)
      INTEGER STANO1(2),STANO2(2),STANM1(12),STANM2(12)
      LOGICAL ZBEGIN,ZEND,ZFILE2
      LOGICAL*1 GRID(44407)
      DIMENSION Q1(384), Q2(484), Q1LOG(366), Q2LOG(366), XI(366), NSCAL
     1E(5)
      COMMON /IQVALU/ IQF,IQL
      COMMON /DISCHG/ Q1,Q2
      COMMON /PLT/ INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR,STANO1
     1,STANM1,STANO2,STANM2
      COMMON /UNITS/ LCARD,LPRNT
      DATA NSCALE/1,0,0,0,0/
C
C
      IF (.NOT.ZBEGIN) GO TO 50
      XMIN=0.0
      MINLO=1
      IF (MINQ.LT.MINLO) GO TO 20
      DO 10 J=1,3
      MINHI=10**J
      IF (MINQ.GE.MINLO.AND.MINQ.LT.MINHI) GO TO 20
      XMIN=XMIN+1.0
      MINLO=MINHI
   10 CONTINUE
   20 MINQ=MINLO
      XMAX=XMIN+4.0
      DO 30 J=1,5
      MINQA(J)=MINQ*10**(J-1)
   30 CONTINUE
      WRITE (LPRNT,90) INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
      WRITE (LPRNT,100) STANO1,STANM1
      IF (.NOT.ZFILE2) GO TO 40
      WRITE (LPRNT,110) STANO2,STANM2
   40 WRITE (LPRNT,120)
      WRITE (LPRNT,130) MINQA
   50 CONTINUE
      DO 60 I=IQF,IQL
      XI(I)=IQL-I+IQF
      IF (Q1(I).LE.0.0) Q1(I)=0.001
      Q1LOG(I)=ALOG10(Q1(I))
      IF (.NOT.ZFILE2) GO TO 60
      IF (Q2(I).LE.0.0) Q2(I)=0.001
      Q2LOG(I)=ALOG10(Q2(I))
   60 CONTINUE
      NPTS=IQL-IQF+1
      NLINES=NPTS
```

```
      IF (ZBEGIN) NLINES=NLINES-1
      XQ1=IQF
      XQ2=IQL
      CALL PLOT1 (NSCALE,NLINES,1,4,30)
      CALL PLOT2 (GRID,XMAX,XMIN,XQ2,XQ1,6)
      CALL PLOT3 (1H*,Q1LOG(IQF),XI(IQF),NPTS)
      IF (ZFILE2) CALL PLOT3 (1H0,Q2LOG(IQF),XI(IQF),NPTS)
      IF (ZEND) GO TO 70
      CALL OMIT (7)
      GO TO 80
   70 CALL OMIT (3)
   80 CALL PLOT4 (5,5H DATE)
      IF (.NOT.ZEND) RETURN
      WRITE (LPRNT,130) MINQA
      WRITE (LPRNT,120)
      RETURN
C
C
C
C
   90 FORMAT (1H1//11X,20A4/11X,4HFROM,2I3,I5,3H TO,2I3,I5)
  100 FORMAT (16X,25H* = DISCHARGE AT STATION ,2A4,2H, ,12A4)
  110 FORMAT (16X,25H0 = DISCHARGE AT STATION ,2A4,2H, ,12A4)
  120 FORMAT (//55X,13HDISCHARGE,CFS)
  130 FORMAT (9X,I3,4(23X,I7))
      END
      SUBROUTINE PRNT (ZBEGIN,ZFILE2)
C
C     1 OCT 76
C     PROVIDES A PRINTOUT OF ONE  OR TWO HYDROGRAPHS.
C
      LOGICAL ZBEGIN,ZEND,ZFILE2
      DIMENSION INFO(20)
      DIMENSION Q1(384), Q2(484)
      INTEGER STANO1(2),STANO2(2),STANM1(12),STANM2(12)
      COMMON /DISCHG/ Q1,Q2
      COMMON /IQVALU/ IQF,IQL
      COMMON /PLT/ INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR,STANO1
     1,STANM1,STANO2,STANM2
      COMMON /B2/ IYEAR(384),IDAY(384),IMON(384),TIME(384)
      COMMON /UNITS/ LCARD,LPRNT
C
C
      IF (ZFILE2) GO TO 40
      IF (.NOT.ZBEGIN) GO TO 10
      ICNT=0
      WRITE (LPRNT,80) INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
      WRITE (LPRNT,140) STANO1,STANM1
      WRITE (LPRNT,120)
C
   10 DO 30 J=IQF,IQL
      IF (ICNT.LT.45) GO TO 20
      WRITE (LPRNT,130)
      WRITE (LPRNT,120)
      ICNT=0
   20 WRITE (LPRNT,150) (IMON(J),IDAY(J),IYEAR(J),TIME(J),Q1(J))
      ICNT=ICNT+1
   30 CONTINUE
C
      RETURN
C
```

```
C
   40 IF (.NOT.ZBEGIN) GO TO 50
      ICNT=0
      WRITE (LPRNT,80) INFO,INITMO,INITDY,INITYR,LASTMO,LASTDY,LASTYR
      WRITE (LPRNT,90) STANO1,STANM1,STANO2,STANM2
      WRITE (LPRNT,110)
   50 DO 70 J=IQF,IQL
      IF (ICNT.LT.45) GO TO 60
      WRITE (LPRNT,130)
      WRITE (LPRNT,110)
      ICNT=0
   60 WRITE (LPRNT,100) (IMON(J),IDAY(J),IYEAR(J),TIME(J),Q1(J),Q2(J))
      ICNT=ICNT+1
   70 CONTINUE
C
      RETURN
C
C
C
C
   80 FORMAT (1H1//11X,20A4/11X,4HFROM,2I3,I5,3H TO,2I3,I5)
   90 FORMAT (16X,27HQ1 IS DISCHARGE AT STATION ,2A4,2H, ,12A4/16X,27HQ2
     1 IS DISCHARGE AT STATION ,2A4,2H, ,12A4)
  100 FORMAT (11X,2I3,I5,F10.2,2F10.1)
  110 FORMAT (//15X,4HDATE,9X,4HTIME,7X,2HQ1,8X,2HQ2/37X,2(5H(CFS),5X)//
     1)
  120 FORMAT (//15X,4HDATE,9X,4HTIME,7X,2HQ1/37X,5H(CFS)//)
  130 FORMAT (1H1//)
  140 FORMAT (16X,27HQ1 IS DISCHARGE AT STATION ,2A4,2H, ,12A4)
  150 FORMAT (11X,2I3,I5,F10.2,F10.1)
      END
      SUBROUTINE PRPLOT
C
C     1 OCT 76
C     PRODUCES THE PRINTER PLOT OF ONE OR TWO HYDROGRAPHS.
C
      IMPLICIT LOGICAL*1(W),LOGICAL*1(K)
      DIMENSION NSCALE(5), ABNOS(26), X(1), Y(1)
      LOGICAL*1 NOS(10)/'0','1','2','3','4','5','6','7','8','9'/
      LOGICAL*1 IMAGE(1),CH,LABEL(1),ERR1,ERR3,ERR5
      LOGICAL*1 VC,HC,FOR1(19),FOR2(15),FOR3(19),NC,BL,HF,HF1
      REAL*8 FOX1(3),FOX2(2),FOX3(3)
      INTEGER*2 VCR
      EQUIVALENCE (FOR1,FOX1), (FOR2,FOX2), (FOR3,FOX3), (VC,VCR)
      INTEGER FILE
      DATA HC/'-'/,NC/'+'/,BL/' '/,HF/'F'/,HF1/'.'/
      DATA FOX1/'(1XA1,F9','.2,  121','A1)     '/
      DATA FOX2/'(1XA1, 9','X121A1) '/
      DATA FOX3/'(1HOF  .',' ,  F  ','. )     '/
      DATA VCR/Z4F00/
      DATA KPLOT1/.FALSE./,KPLOT2/.FALSE./
      DATA KABSC,KORD,KBOTGL/3*.FALSE./
C
      ENTRY PLOT1(NSCALE,NHL,NSBH,NVL,NSBV)
      IFL=FILE
      ERR1=.FALSE.
      ERR3=.FALSE.
      ERR5=.FALSE.
      KPLOT1=.TRUE.
      KPLOT2=.FALSE.
      NH=IABS(NHL)
```

```
      NSH=IABS(NSBH)
      NV=IABS(NVL)
      NSV=IABS(NSBV)
      NSCL=NSCALE(1)
      IF (NH*NSH*NV*NSV.NE.0) GO TO 10
      KPLOT=.FALSE.
      ERR1=.TRUE.
      RETURN
   10 KPLOT=.TRUE.
      IF (NV.LE.25) GO TO 20
      KPLOT=.FALSE.
      ERR3=.TRUE.
      RETURN
   20 CONTINUE
      NVM=NV-1
      NVP=NV+1
      NDH=NH*NSH
      NDHP=NDH+1
      NDV=NV*NSV
      NDVP=NDV+1
      NIMG=(NDHP*NDVP)
      IF (NDV.LE.120) GO TO 30
      KPLOT=.FALSE.
      ERR5=.TRUE.
      RETURN
   30 CONTINUE
      IF (NSCL.EQ.0) GO TO 40
      FSY=10.**NSCALE(2)
      FSX=10.**NSCALE(4)
      IY=MIN0(IABS(NSCALE(3)),7)+1
      IX=MIN0(IABS(NSCALE(5)),9)+1
      GO TO 50
   40 FSY=1.
      FSX=1.
      IY=4
      IX=4
   50 FOR1(10)=NOS(IY)
      NA=MIN0(IX,NSV)-1
      NS=NA-MIN0(NA,120-NDV)
      NB=11-NS+NA
      I1=NB/10
      I2=NB-I1*10
      FOR3(6)=NOS(I1+1)
      FOR3(7)=NOS(I2+1)
      FOR3(9)=NOS(NA+1)
      IF (NV.GT.0) GO TO 70
      DO 60 J=11,18
   60 FOR3(J)=BL
      GO TO 80
   70 I1=NV/10
      I2=NV-I1*10
      FOR3(11)=NOS(I1+1)
      FOR3(12)=NOS(I2+1)
      FOR3(13)=HF
      I1=NSV/100
      I3=NSV-I1*100
      I2=I3/10
      I3=I3-I2*10
      FOR3(14)=NOS(I1+1)
      FOR3(15)=NOS(I2+1)
      FOR3(16)=NOS(I3+1)
```

```
      FOR3(17)=HF1
      FOR3(18)=FOR3(9)
   80 IF (KPLOT1) RETURN
      KPLOT1=.TRUE.
C
      ENTRY PLOT2(IMAGE,XMAX,XMIN,YMAX,YMIN,FILE)
      IFL=FILE
      KPLOT2=.TRUE.
      IF (KPLOT1) GO TO 90
      NSCL=0
      NH=5
      NSH=10
      NV=10
      NSV=10
      GO TO 10
   90 CONTINUE
      IF (KPLOT) GO TO 100
      IF (ERR1) WRITE (IFL,300)
      IF (ERR3) WRITE (IFL,310)
      IF (ERR5) WRITE (IFL,320)
      RETURN
  100 YMX=YMAX
      DH=(YMAX-YMIN)/FLOAT(NDH)
      DV=(XMAX-XMIN)/FLOAT(NDV)
      DO 110 I=1,NVP
  110 ABNOS(I)=(XMIN+FLOAT((I-1)*NSV)*DV)*FSX
      DO 120 I=1,NIMG
  120 IMAGE(I)=BL
      DO 160 I=1,NDHP
      I2=I*NDVP
      I1=I2-NDV
      KNHOR=MOD(I-1,NSH).NE.0
      IF (KNHOR) GO TO 140
      DO 130 J=I1,I2
  130 IMAGE(J)=HC
  140 CONTINUE
      DO 160 J=I1,I2,NSV
      IF (KNHOR) GO TO 150
      IMAGE(J)=NC
      GO TO 160
  150 IMAGE(J)=VC
  160 CONTINUE
      XMIN1=XMIN-DV/2.
      YMIN1=YMIN-DH/2.
      RETURN
C
      ENTRY PLOT3(CH,X,Y,N3)
      IF (KPLOT2) GO TO 180
  170 WRITE (IFL,330)
  180 CONTINUE
      IF (.NOT.KPLOT) RETURN
      IF (N3.GT.0) GO TO 190
      KPLOT=.FALSE.
      WRITE (IFL,340)
      RETURN
  190 DO 260 I=1,N3
      IF (DV) 210,200,210
  200 DUM1=0
      GO TO 220
  210 CONTINUE
      DUM1=(X(I)-XMIN1)/DV
```

```
  220 IF (DH) 240,230,240
  230 DUM2=0
      GO TO 250
  240 CONTINUE
      DUM2=(Y(I)-YMIN1)/DH
  250 CONTINUE
      IF (DUM1.LT.0..OR.DUM2.LT.0.) GO TO 260
      IF (DUM1.GE.NDVP.OR.DUM2.GE.NDHP) GO TO 260
      NX=1+INT(DUM1)
      NY=1+INT(DUM2)
      J=(NDHP-NY)*NDVP+NX
      IMAGE(J)=CH
  260 CONTINUE
      RETURN
C
      ENTRY PLOT4(NL,LABEL)
      ENTRY FPLOT4(NL,LABEL)
      IF (.NOT.KPLOT) RETURN
      IF (.NOT.KPLOT2) GO TO 170
      DO 280 I=1,NDHP
      IF (I.EQ.NDHP.AND.KBOTGL) GO TO 280
      WL=BL
      IF (I.LE.NL) WL=LABEL(I)
      I2=I*NDVP
      I1=I2-NDV
      IF (MOD(I-1,NSH).EQ.0.AND..NOT.KORD) GO TO 270
      WRITE (IFL,FOR2) WL,(IMAGE(J),J=I1,I2)
      GO TO 280
  270 CONTINUE
      ORDNO=(YMX-FLOAT(I-1)*DH)*FSY
      IF (I.EQ.NDHP) ORDNO=YMIN
      WRITE (IFL,FOR1) WL,ORDNO,(IMAGE(J),J=I1,I2)
  280 CONTINUE
      IF (KABSC) GO TO 290
      WRITE (IFL,FOR3) (ABNOS(J),J=1,NVP)
  290 RETURN
C
      ENTRY OMIT(LSW)
      KABSC=MOD(LSW,2).EQ.1
      KORD=MOD(LSW,4).GE.2
      KBOTGL=LSW.GE.4
      RETURN
C
  300 FORMAT (T5,'SOME PLOT1 ARG. ILLEGALLY 0')
  310 FORMAT (T5,'NO. OF VERTICAL LINES >25')
  320 FORMAT (T5,'WIDTH OF GRAPH >121')
  330 FORMAT (T5,'PLOT2 MUST BE CALLED')
  340 FORMAT (T5,'PLOT3, ARG2 < 0')
      END
      SUBROUTINE QINPUT (IFILE,IAVI,ITEMS,Q,JYEAR,JMON,JDAY)
C
C     1 OCT 76
C     READS AND WRITES DATA RECORDS ON DIRECT ACCESS DEVICE.
C
      DIMENSION Q(384), ISKIP(4)
      READ (IFILE'IAVI) JMON,JDAY,JYEAR,ITEMS,(Q(I),I=1,ITEMS)
      IAVI=IAVI+1
      RETURN
      ENTRY QOUTPT(IFILE,IAVO,ITEMS,Q,JMON,JDAY,JYEAR)
      WRITE (IFILE'IAVO) JMON,JDAY,JYEAR,ITEMS,(Q(I),I=1,ITEMS)
      IAVO=IAVO+1
```

```
      RETURN
C
      ENTRY QINFEW(NUMBR,Q)
      I1=ITEMS+1
      I2=ITEMS+NUMBR
      READ (IFILE'IAVI) ISKIP,(Q(I),I=I1,I2)
C
      RETURN
      END
      SUBROUTINE SETUP (NRECDS)
C
C     1 OCT 76
C     CREATES SPACE ON DIRECT ACCESS FILES.
C
      COMMON /FILES/ ID21,ID22,ID23,ID24,ID25,ID26,ID27,ID28,ID29,ID30
      COMMON /UNITS/ LCARD,LPRNT
C     +----                                                      ----+
C     I  CREATE SPACE ON DIRECT ACCESS FILES AS FOLLOWS:             I
C     I       1) REQUESTED SPACE (NRECDS) ON OUTPUT FILES (26-30)    I
C     I       2) 100 RECORDS ON INPUT FILES (21-25)                  I
C     +----                                                      ----+
      DO 10 I=1,5
      IGO=I
      IF ((NRECDS-20*I).LE.0) GO TO 20
   10 CONTINUE
      IGO=5
   20 GO TO (30,40,50,60,70), IGO
C
   30 CONTINUE
C     +----                                                      ----+
C     I  CREATE SPACE FOR  20 RECORDS FOR OUTPUT FILES               I
C     +----                                                      ----+
      DEFINE FILE 26(20,1552,L,ID26),27(20,1552,L,ID27),28(20,1552,L,ID2
     18),29(20,1552,L,ID29),30(20,1552,L,ID30)
      GO TO 80
C
   40 CONTINUE
C     +----                                                      ----+
C     I  CREATE SPACE FOR  40 RECORDS FOR OUTPUT FILES               I
C     +----                                                      ----+
      DEFINE FILE 26(40,1552,L,ID26),27(40,1552,L,ID27),28(40,1552,L,ID2
     18),29(40,1552,L,ID29),30(40,1552,L,ID30)
      GO TO 80
C
   50 CONTINUE
C     +----                                                      ----+
C     I  CREATE SPACE FOR  60 RECORDS FOR OUTPUT FILES               I
C     +----                                                      ----+
      DEFINE FILE 26(60,1552,L,ID26),27(60,1552,L,ID27),28(60,1552,L,ID2
     18),29(60,1552,L,ID29),30(60,1552,L,ID30)
      GO TO 80
C
   60 CONTINUE
C     +----                                                      ----+
C     I  CREATE SPACE FOR  80 RECORDS FOR OUTPUT FILES               I
C     +----                                                      ----+
      DEFINE FILE 26(80,1552,L,ID26),27(80,1552,L,ID27),28(80,1552,L,ID2
     18),29(80,1552,L,ID29),30(80,1552,L,ID30)
      GO TO 80
C
   70 CONTINUE
```

```
C     +-----                                                      -----+
C     |  CREATE SPACE FOR 100 RECORDS FOR OUTPUT FILES                 |
C     +-----                                                      -----+
      DEFINE FILE 26(100,1552,L,ID26),27(100,1552,L,ID27),28(100,1552,L,
     1ID28),29(100,1552,L,ID29),30(100,1552,L,ID30)
C
   80 NRECDS=20*IGO
      WRITE (LPRNT,90) NRECDS
C     +-----                                                      -----+
C     |  CREATE SPACE FOR 100 RECORDS FOR INPUT FILES                  |
C     +-----                                                      -----+
      DEFINE FILE 21(100,1552,L,ID21),22(100,1552,L,ID22),23(100,1552,L,
     1ID23),24(100,1552,L,ID24),25(100,1552,L,ID25)
      RETURN
C
   90 FORMAT (11X,9HSPACE FOR,I4,50H RECORDS HAS BEEN ALLOCATED FOR OUTP
     1UT HYDROGRAPHS)
      END
      SUBROUTINE TABL (X1,Y1,X,Y,I1,NQ)
C
C     1 OCT 76
C
C     THIS IS A LINEAR INTERPOLATION ROUTINE CALLED WHEN
C     USING MULTIPLE LINEARIZATION.  USED TO COMPUTE
C     DISCHARGE, CELERITY AND DISPERSION VALUES.
C
C     MODIFIED 2/14/80 & 3/07/80 BY J.M.B. AND J.D.S. TO
C     BETTER HANDLE REVERSALS IN Q VS. C RELATION.
C
      DIMENSION X(1), Y(1)
      IF (X1.LT.X(1)) GO TO 40
      DO 10 I=I1,9
      NQ=I
      IF (X1.GE.X(I).AND.X1.LT.X(I+1)) GO TO 20
      IF (X1.LE.X(I).AND.X1.GT.X(I+1)) GO TO 20
   10 CONTINUE
      NQ=9
   20 Y1=Y(NQ)+(((Y(NQ+1)-Y(NQ))/(X(NQ+1)-X(NQ)))*(X1-X(NQ)))
      RETURN
   40 WRITE (6,50)
      STOP
C
   50 FORMAT (1H ,30HVARIABLE OUT OF RANGE OF TABLE)
      END
      SUBROUTINE TRNSLB (ARRAY,NCHAR,ILOG)
C
C     1 OCT 76
C     CHECKS FOR PROPER INSTRUCTIONS ON THE INSTRUCTION CARD.
C
      IMPLICIT LOGICAL(Z),INTEGER(A)
      INTEGER BLANK/' '/
      COMMON /INSTCD/ ICARD(80),ICOL
      COMMON /ZLOGIC/ ZOPER(20),ZDONE
      DIMENSION ARRAY(1)
      DO 10 I=1,NCHAR
      KOL=ICOL+I-1
      IF (KOL.GT.80) GO TO 50
      IF (ICARD(KOL).NE.ARRAY(I)) RETURN
   10 CONTINUE
      ICOL=KOL+1
      ZOPER(ILOG)=.TRUE.
```

```
      RETURN
      ENTRY SKIP
      IF (ZDONE) RETURN
   20 IF (ICARD(ICOL).NE.BLANK) RETURN
      ICOL=ICOL+1
      IF (ICOL.GT.80) GO TO 50
      GO TO 20
      ENTRY FIND(ICHAR)
   30 IF (ICARD(ICOL).EQ.ICHAR) GO TO 40
      ICOL=ICOL+1
      IF (ICOL.GT.80) GO TO 50
      GO TO 30
   40 ICOL=ICOL+1
      IF (ICOL.GT.80) GO TO 50
      RETURN
   50 ZDONE=.TRUE.
      RETURN
      END
      SUBROUTINE UNRESP (ZDIFFA,ZMULT,NRESP,ITT)
C
C     1 OCT 78
C     THIS SUBROUTINE CALCULATES UNIT RESPONSE FUNCTIONS
C     FOR EITHER THE STORAGE CONTINUITY METHOD OR DIFFUSION
C     ANALOGY METHOD.  FOR THE DIFFUSION ANALOGY METHOD,
C     UNIT-RESPONSE FUNCTIONS MAY BE CALCULATED FOR EITHER
C     SINGLE LINEARIZATION (ONE UNIT-RESPONSE OR
C     MULTIPLE LINEARIZATION (FAMILY OF UNIT-RESPONSES).
C
C     REVISED 6/22/78 BY J.O.S. TO CORRECT UNIT RESPONSE GENERATION
C     PROBLEMS -- PUT IN MULTIPLE OF 1.0E+50 FOR H-VALUES AND
C     ALLOWED POWER TO GO TO -170 INSTEAD OF -50
C
C     REVISED 2/13/80 & 3/07/80 BY J.O.S. AND J.M.B. TO BETTER
C     HANDLE Q VS. C REVERSALS.
C
      INTEGER REACH(20)
      LOGICAL ZDIFFA,ZMULT
      REAL K
      COMMON /INSTQ/ Q(999)
      COMMON /RTPARM/ REACH,K,X,TT,W,CZERO,NURS,RI,UR(20,100),NRO,HWAY(2
     1 0)
      COMMON /UNITS/ LCARD,LPRNT
      DIMENSION C(20),QCQ(11),QCC(11),QKQ(11),QKK(11),Q1T(20),
     1     NRESP(20),ITT(20),CBRK(4),TBRK(4),NBRK(4),NSL(3)
      QCQ(11)=0.0
      QCC(11)=0.0
      QKQ(11)=0.0
      QKK(11)=0.0
C     INITIALIZE UNIT RESPONSE ARRAY.
      CALL FILL (UR,1,2000,0.0)
      NURS=1
      NRF=1
      ITT(1)=0
C     NURS=NUMBER OF UNIT RESPONSE FUNCTIONS.
C     NRF=RESPONSE FUNCTION NUMBER.
C     NRO=NUMBER OF ORDINATES IN RESPONSE FUNCTION.
      SUM=0.0
      IF (ZDIFFA) GO TO 30
C     COMPUTES UNIT-RESPONSE FUNCTION BY THE STORAGE
C     CONTINUITY METHOD.
      WRITE (LPRNT,300)
```

```
      DELTAT=0.1
      DK=K/W
      D=RI/W
      CALL INFLOW (D,DELTAT)
      CALL HYDROG (DK,DELTAT,X)
      T=0.0
      DO 10 J=2,101
      NRO=J-1
      T=T+D
      N=T/DELTAT+1.05
      UR(NRF,NRO)=0.00155*D*Q(N)
      SUM=SUM+UR(NRF,NRO)
      IF (SUM.GE.1.00) GO TO 20
      IF (UR(NRF,NRO).LT.0.0001) GO TO 20
   10 CONTINUE
   20 WRITE (LPRNT,310) RI,K,W,X,NRO
      GO TO 260
   30 IF (ZMULT) GO TO 40
      WRITE (LPRNT,300)
      GO TO 160
   40 READ (LCARD,320) QMIN,QMAX
C     QMIN SHOULD BE THE LOWEST VALUE YOU ARE INTERESTED
C     IN. QMIN MUST BE > OR = TO THE LOWEST VALUE IN
C     THE TABLE.  QMAX SHOULD BE < OR = TO THE LARGEST ENTRY
C     IN THE TABLE.
      WRITE(LPRNT,325) QMIN,QMAX
  325 FORMAT(1H0,10X,'QMIN = ',F10.2,' CFS'/10X,' QMAX = ',F10.2,' CFS')
C     READ DISCHARGE VS. DISPERSION TABLE.
      READ (LCARD,320) (QKQ(I),I=1,10)
      READ (LCARD,320) (QKK(I),I=1,10)
C     READ DISCHARGE VS. CELERITY TABLE.
      READ (LCARD,320) (QCQ(I),I=1,10)
      READ (LCARD,320) (QCC(I),I=1,10)
      WRITE (LPRNT,330) (QKQ(I),I=1,10)
      WRITE (LPRNT,340) (QKK(I),I=1,10)
      WRITE (LPRNT,350) (QCQ(I),I=1,10)
      WRITE (LPRNT,360) (QCC(I),I=1,10)
      WRITE (LPRNT,300)
      WRITE (LPRNT,430) RI,X
      WRITE (LPRNT,300)
C
C     DETERMINE THE BREAKPOINTS (IF ANY) OF Q VS. C
C
      IF(QCC(1).GT.0.0) GO TO 42
      WRITE (LPRNT,444)
  444 FORMAT ('0 C(1)=0.0  INVALID---CHECK CELERITY TABLE CARD')
      STOP
   42 CALL TABL (QMIN,CBRK(1),QCQ,QCC,1,NBRK(1))
      CALL TABL (QMAX,CMAX,QCQ,QCC,1,NMAX)
      J=2
      I1=NBRK(1)
      IF(I1.LT.2) I1=2
      TBRK(1)=((5280.*X)/CBRK(1))/3600.
      DO 44 I=I1,10
      IF((QCC(I)-QCC(I-1))*(QCC(I+1)-QCC(I)).GT.0.0)GO TO 44
      CBRK(J)=QCC(I)
      NBRK(J)=I
      J=J+1
      IF(QCQ(I).LT.QMAX) GO TO 43
      CBRK(J-1)=CMAX
      NBRK(J-1)=NMAX
```

```
      GO TO 46
   43 IF (QCC(I+1).LE.0.0) GO TO 45
   44 CONTINUE
   45 IF(J.GT.4) GO TO 47
      DO 46 I=J,4
      CBRK(I)=CBRK(I-1)
      NBRK(I)=NBRK(I-1)
   46 CONTINUE
   47 TCHK=0.0
      DO 48 I=2,4
      TBRK(I)=((5280.*X)/CBRK(I))/3600.
      TCHK=TCHK+ABS(TBRK(I-1)-TBRK(I))
   48 CONTINUE
      NURS=TCHK/RI
C     A MAXIMUM OF 20 RESPONSE FUNCTIONS ARE CALCULATED.
      IF (RI.EQ.24.) NURS=20
      IF (NURS.GT.5) GO TO 50
      WRITE (LPRNT,360)
   50 IF (NURS.GT.20) NURS=20
      TCHK=TCHK/(NURS-1)
      IF (NURS.LT.20) TCHK=RI
   51 NSUM=0
      DO 52 I=1,3
      NSL(I)=0
      IF(TBRK(I).EQ.TBRK(I+1)) GO TO 53
      TSL=ABS(TBRK(I)-TBRK(I+1))/TCHK
      NSL(I)=INT(TSL+0.5001)
      IF(NSL(I).LE.0) NSL(I)=1
      NSUM=NSUM+NSL(I)
   52 CONTINUE
   53 IF(NSUM.LE.19)GO TO 60
      TCHK=(TCHK/(NURS-1))*NSUM
      GO TO 51
   60 NRF=1
      DO 105 NB=1,3
      IF(NSL(NB).EQ.0) GO TO 110
      NS=NSL(NB)
      NXT=NBRK(NB)
      IF(NB.GT.1) GO TO 65
      C(1)=CBRK(1)
      CALL TABL(C(1),QIT(1),QCC,QCQ,NXT,NQ)
      NXT=NQ
   65 TNEXT=TBRK(NB)
      TCHK=(TNEXT-TBRK( NB+1))/NS
      DO 100 NN=1,NS
      NRF=NRF+1
      IF (NN.LT.NS) GO TO 70
      C(NRF)=CBRK(NB+1)
      GO TO 80
   70 TNEXT=TNEXT-TCHK
      C(NRF)=((5280.*X)/TNEXT)/3600.
C
C     FIND A DISCHARGE VALUE TO MATCH CELERITY.
C
   80 CALL TABL(C(NRF),QIT(NRF),QCC,QCQ,NXT,NQ)
      NXT=NQ
  100 CONTINUE
  105 CONTINUE
  110 NURS=NRF
C
C       GENERATE FLAGGING TABLE, HWAY=LINEARIZATION DISCHARGES
```

```
C
  130 LF=NURS-1
      DO 140 NRF=1,LF
  140 HWAY(NRF)=(Q1T(NRF)+Q1T(NRF+1))/2.
      HWAY(NURS)=Q1T(NURS)
      NRF=1
      NXT=1
C     FIND DISPERSION COEFFICIENT TO MATCH DISCHARGE.
  150 CALL TABL (Q1T(NRF),K,QK2,QKK,NXT,NQ)
      CZERO=C(NRF)
C     BEGIN CALCULATIONS FOR UNIT-RESPONSE USING KNOWN
C     DISPERSION AND CELERITY.
  160 SK=3600.*K
      SC=3600.*CZERO
      XFT=5280.*X
      SC2=SC*SC
      TMEAN=XFT/SC+2*SK/SC2
      TT=TMEAN-(2.78*SQRT(2.*SK*XFT/(SC2*SC)+(8.*SK/SC2)*(SK/SC2)))
      IF (TT.LE.0.0) TT=0.0
      TT=TT/RI
      ITT(NRF)=IFIX(TT+0.5)
      TT=ITT(NRF)*RI
      TIME=TT
      IF (TIME.LE.0.0) TIME=0.001
      TINT=0.2
      ILIM=IFIX((1.0/TINT)+0.5)
      ICYCLE=0
      URSUM=0.0
      NRO=1
      NFLAG=0
      JNO=0
  170 POWER=SC*TIME-XFT
      POWER=-(POWER*POWER)
      POWER=POWER/(4.*SK*TIME)
      IF (POWER.LT.-170.) POWER=-170.
      H=(1.0E+50/(2.*SQRT(3.1415927*SK)))*XFT/(TIME**(3./2.))
      H=H*EXP(POWER)
      IF (NFLAG.EQ.1) GO TO 210
      JNO=JNO+1
      ICYCLE=ICYCLE+1
      URSUM=URSUM+H
      IF (JNO.GT.ILIM) GO TO 200
  180 REO=TINT*URSUM
      UR(NRF,NRO)=UR(NRF,NRO)+TINT*REO
      IF (ICYCLE.EQ.ILIM) GO TO 220
  190 TIME=TIME+RI*TINT
      GO TO 170
  200 NFLAG=1
      TIME=TIME-RI
      IF (TIME.LE.0.0) TIME=0.001
      GO TO 170
  210 TIME=TIME+RI
      NFLAG=0
      URSUM=URSUM-H
      GO TO 180
  220 IF (UR(NRF,NRO).LT.0.0) UR(NRF,NRO)=0.0
      SUM=SUM+UR(NRF,NRO)
C     ***SUM CHECK DELETED 6/22/78 BY J.O.S.***
      IF (UR(NRF,NRO).LT.1.0E+46.AND.(UR(NRF,NRO)/SUM).LT.0.002)
     *   GO TO 230
      IF (NRO.EQ.100) GO TO 240
```

```
      ICYCLE=0
      NRO=NRO+1
      GO TO 190
  230 SUM=SUM-UR(NRF,NRO)
      NRO=NRO-1
  240 IF (ZMULT) GO TO 250
      WRITE (LPRNT,390) RI,X,CZERO,K,NRO
      GO TO 260
  250 WRITE (LPRNT,440) CZERO,K,NRF,NRO
  260 DO 270 I=1,NRO
      UR(NRF,I)=UR(NRF,I)/SUM
  270 CONTINUE
      DO 280 I=1,NRO,5
      I1=I
      I2=I+4
      IF (I2.GT.NRO) I2=NRO
      WRITE (LPRNT,400) (J,UR(NRF,J),J=I1,I2)
  280 CONTINUE
      WRITE (LPRNT,410) TT
      IF (ZMULT) GO TO 290
      NRESP(1)=NRO
      WRITE (LPRNT,300)
      RETURN
  290 WRITE (LPRNT,420) HWAY(NRF)
      WRITE (LPRNT,300)
      NRESP(NRF)=NRO
      NRF=NRF+1
      IF (NRF.GT.NURS) RETURN
      NRO=1
      SUM=0.0
      GO TO 150
C
C
  300 FORMAT (1H0,10X,80(1H-))
  310 FORMAT (1H0,10X,62HTHE STORAGE-CONTINUITY METHOD USING: 1) A ROUTI
     1NG INTERVAL OF ,F4.1,6H HRS.;/11X,39H2) A STORAGE-DISCHARGE COEFFI
     2CIENT, K =,F5.1,34H HRS.; 3) A TRANSLATION HYDROGRAPH/11X,14HTIME
     3BASE, W =,F5.1,50H HRS.; AND 4) A STORAGE LINEARITY COEFFICIENT, X
     4 =,F5.2/11X,38HCOMPUTES A UNIT-RESPONSE FUNCTION WITH,I3,22H ORDIN
     5ATES AS FOLLOWS:/)
  320 FORMAT (10F8.0)
  330 FORMAT (1H0,10X,31HDISCHARGE VS. DISPERSION TABLE,/,11X,10F10.2)
  340 FORMAT (1H ,10X,10F10.2)
  350 FORMAT (1H0,10X,28HDISCHARGE VS. CELERITY TABLE,/,11X,10F10.2)
  360 FORMAT (1H0,5HNOTE:/1H ,73HCONSIDER USING SINGLE LINEARIZATION MET
     1HOD, NOT ENOUGH RESPONSE FUNCTIONS/,75H HAVE BEEN CALCULATED TO MA
     2KE THE MULTIPLE LINEARIZATION METHOD BENEFICIAL.)
  370 FORMAT (1H0,87HMORE THAN 20 RESPONSE FUNCTIONS WERE CALCULATED. AD
     1JUST TIME CHECK TO CALCULATE ONLY 20)
  380 FORMAT (1H0,F15.0)
  390 FORMAT (1H0,10X,59HTHE DIFFUSION ANALOGY METHOD WITH: 1) A ROUTING
     1 INTERVAL OF,F5.1,11H HRS.; 2) A/11X,17HREACH LENGTH, X =,F6.2,35H
     2 MILES; 3) A WAVE CELERITY, CZERO =,F6.2,14H FT./SEC.; AND/11X,37H
     34) A WAVE DISPERSION COEFFICIENT, K =,F9.1,12H SQ.FT./SEC.,/11X,39
     4HCOMPUTES A UNIT-RESPONSE FUNCTION WITH ,I3,22H ORDINATES AS FOLLO
     5WS:/)
  400 FORMAT (1H ,10X,5(I2,1H),F7.4,5X))
  410 FORMAT (1H0,10X,21HTHE TRAVEL TIME, TT =,F8.1,5H HRS.)
  420 FORMAT (1H ,10X,29HLINEARIZATION DISCHARGE, Q = ,F9.1,4H CFS)
  430 FORMAT (1H0,10X,55HTHE DIFFUSION ANALOGY METHOD WITH A ROUTING INT
     1ERVAL OF,F5.1,11H HRS. AND A/11X,17HREACH LENGTH, X =,F6.2,61H MIL
```

```
     2ES, COMPUTES MULTIPLE UNIT-RESPONSE FUNCTIONS AS FOLLOWS:/)
  440 FORMAT (1H0,10X,30HUSING A WAVE CELERITY, CZERO =,F6.2,14H FT./SEC
     1.; AND/11X,34HA WAVE DISPERSION COEFFICIENT, K =,F9.1,12H SQ.FT./S
     2EC.,/11X,29HCOMPUTES UNIT-RESPONSE NUMBER,I3,6H WITH ,I3,22H ORDIN
     3ATES AS FOLLOWS:/)
      END
      SUBROUTINE UTILIT
C
C     1 OCT 76
C
C        THIS SUBROUTINE, WITH VARIOUS ENTRY POINTS, PROVIDES THE USER
C        WITH THE FOLLOWING CAPABILITIES:
C              1) FILL AN ARRAY WITH A CONSTANT;
C              2) MULTIPLY AN ARRAY BY A CONSTANT;
C              3) MOVE ONE ARRAY TO ANOTHER ARRAY, WITH OFFSETS;
C              4) ADD TWO ARRAYS; AND
C              5) CONVOLUTE TWO ARRAYS, ACCUMULATE RESULT IN A THIRD.
C
      DIMENSION A(1), B(1), C(1), HWAY(20), CC(20,100), NRESP(20), LAG(20
     10)
C
C        FILL SETS A(I),I=I1,I2 EQUAL TO VALU.
C
      ENTRY FILL(A,I1,I2,VALU)
      DO 10 I=I1,I2
      A(I)=VALU
   10 CONTINUE
      RETURN
C
C        MULT MULTIPLIES A(I),I=I1,I2 BY VALU.
C
      ENTRY MULT(A,I1,I2,VALU)
      DO 20 I=I1,I2
      A(I)=A(I)*VALU
   20 CONTINUE
      RETURN
C
C        MOVE MOVES B(I+ISHFTB) INTO A(I+ISHFTA),I=I1,I2.
C
      ENTRY MOVE(B,A,I1,I2,ISHFTA,ISHFTB)
      DO 30 I=I1,I2
      A(I+ISHFTA)=B(I+ISHFTB)
   30 CONTINUE
      RETURN
C
C        ADD STORES B(I)+C(I) IN A(I),I=I1,I2
C
      ENTRY ADD(C,B,A,I1,I2)
      DO 40 I=I1,I2
      A(I)=B(I)+C(I)
   40 CONTINUE
      RETURN
C
C        CONVOL CONVOLUTES ELEMENTS I1 THRU I2 OF ARRAY B (THE
C        INPUT FUNCTION) WITH ELEMENTS 1 THRU NRO OF ARRAY C (THE
C        RESPONSE FUNCTION) AND ACCUMULATES THE RESULT IN ARRAY A
C        (THE OUTPUT FUNCTION),WHICH MAY BE LAGGED BY LAG TIME
C        INTERVALS.
C
      ENTRY CONVOL(A,B,CC,I1,I2,NRO,NURS,HWAY,LAG,NRESP)
      IF (NURS.GT.1) GO TO 60
```

```
      L=1
      DO 50 I=I1,I2
      DO 50 J=1,NRO
      K=I+J-1+LAG(L)
      A(K)=A(K)+B(I)*CC(L,J)
   50 CONTINUE
      RETURN
   60 DO 120 I=I1,I2
      QB=B(I)
      DO 70 LL=1,NURS
      IF (QB.LE.HWAY(LL)) GO TO 80
   70 CONTINUE
      L=NURS
      GO TO 90
   80 L=LL
   90 IF (L.EQ.1) GO TO 100
      QB=QB-HWAY(L-1)
  100 NRO=NRESP(L)
      DO 110 J=1,NRO
      K=I+J-1+LAG(L)
      A(K)=A(K)+QB*CC(L,J)
  110 CONTINUE
      IF (L.EQ.1) GO TO 120
      QB=HWAY(L-1)
      L=L-1
      GO TO 90
  120 CONTINUE
      RETURN
      END
```

APPENDIX D. ILLUSTRATIVE EXAMPLE OF USING CONROUT MODEL

Statement of Problem and Summary of Results

The purpose of this flow-routing analysis is to investigate the potential for use of the CONROUT model for streamflow routing to simulate daily mean discharges at station 11520500, Klamath River near Seiad Valley, California. A schematic diagram of the Klamath River study area is presented in figure D1. In this application a best-fit model for the entire flow range is the desired product. Streamflow data available for this analysis are summarized in table D1.

Table D1.--Gaging stations used in the Klamath River flow-routing study

Station no.	Station name	Drainage area (mi^2)	Period of record
11516530	Klamath River below Iron Gate Dam, CA.	4,630	Oct 1960-present
11517500	Shasta River near Yreka, Ca.	793	Oct 1933-Sep 1941 Oct 1944-present
11519500	Scott River near Fort Jones, Ca.	653	Oct 1941-present
11520500	Klamath River near Seiad Valley, Ca.	6,940	Oct 1912-Sep 1925 Oct 1951-present

The distance between the two gages on the Klamath River is 36.80 miles. Two tributaries confluence with the Klamath at 14.65 and 23.80 miles upstream of station 11520500. Intervening ungaged drainage area between stations 11516530 and 11520500 is 864 mi^2 or 12.45 percent of the total drainage area contributing to the Seiad Valley site. The tributary station at 11519500 with a drainage area of 653 mi^2 was selected as the index station to estimate the flow response from the intervening ungaged area.

To simulate the daily mean discharges, the approach was to route the flow along the Klamath from Iron Gate Dam to Seiad Valley using the diffusion analogy method with a single linearization. Flow was also routed along the Scott River and combined with the Klamath at its confluence. Since the Shasta River gage is near the confluence with the Klamath, flows from the Shasta River were added directly to the Klamath River flow at the confluence. The intervening drainage area was accounted for by using data from station 11519500 adjusted by a drainage area ratio. The total discharge at Seiad Valley was the summation of the routed discharge along the Klamath and an adjusted discharge from station 11519500.

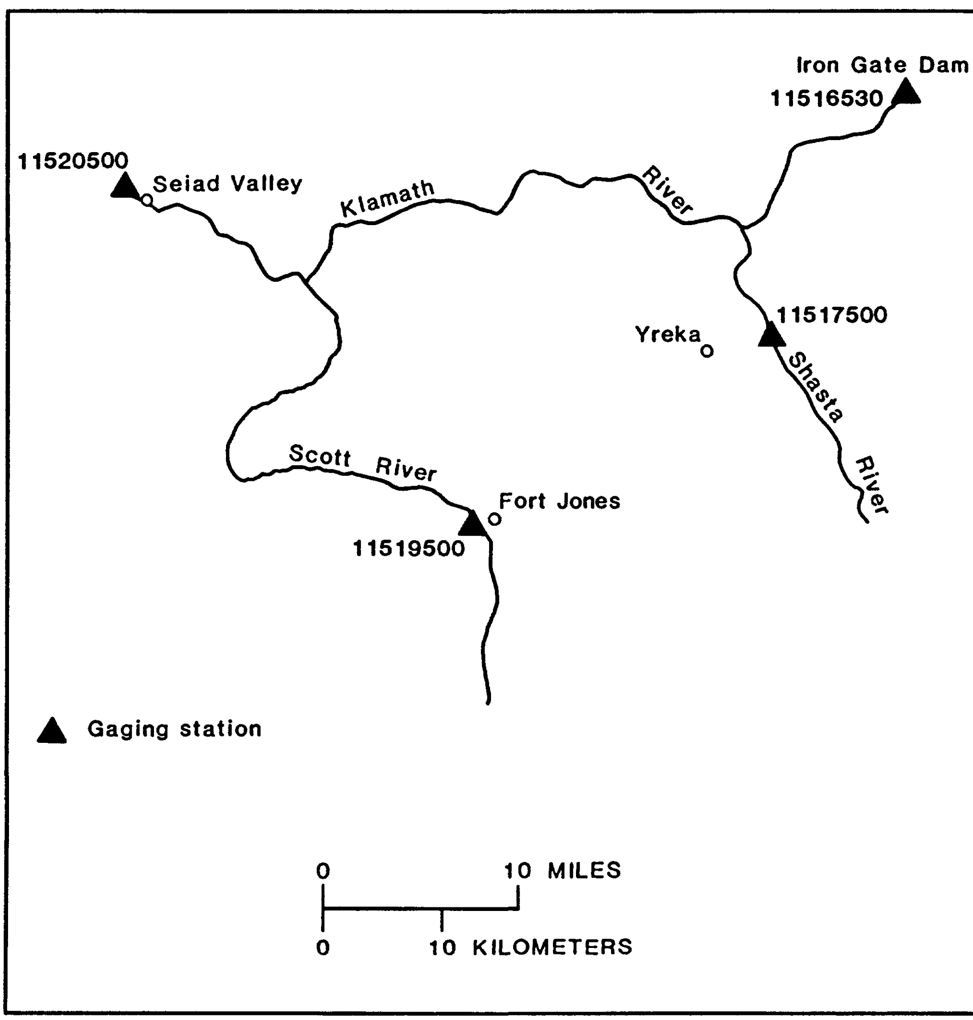


Figure D1.--The Klamath River study area.

Data for station 11520500 for the 1980 water year were used to calibrate the model while 1981 and 1982 water year data were used to verify the model. The model requires concurrent data for all stations used in the analysis and while concurrent data were also available for water years 1961 through 1979, only the last three years were used. In restricting the analysis to the most recent data for comparison, the model will better represent the present conditions. Previous undocumented changes in the system might invalidate the model's application to the earlier period.

To route flow in the Klamath River system, it was necessary to determine the model parameters C_o (flood wave celerity) and K_o (wave dispersion coefficient). The coefficients C_o and K_o are functions of channel width (W_o), in feet, channel slope (S_o) in feet per foot (ft/ft), the slope of the stage discharge relation (dQ_o/dy_o) in square feet per second (ft^2/s), and the discharge (Q_o) in cubic feet per second (ft^3/s) representative of the reach in question and are determined as follows:

$$C_o = \frac{1}{W_o} \frac{dQ_o}{dy_o} \qquad \text{(D1)}$$

$$K_o = \frac{Q_o}{2 S_o W_o} \qquad \text{(D2)}$$

Values for C_o and K_o were computed from information obtained at stations 11516530, 11519500 and 11520500. The discharge Q_o, for which initial values of C_o and K_o were linearized was the long-term mean daily discharge at each of these stations. Also, at each station, the channel width, W_o, was obtained from width-discharge relationships; channel slope, S_o, was determined from gage-elevation information; and (dQ_o/dy_o), was determined from the rating curves by bracketing the mean discharge and computing for an incremental change in gage height the associated change in discharge. There were four reaches in which routing were performed and average values of C_o and K_o were computed for each reach by averaging the values computed at the stations. Along the Klamath, adjustments were made to C_o and K_o in proportion to the distance each reach was upstream of station 11520500.

Table D2 identifies each reach and final calibrated values of C_o and K_o used for routing flow through the reach.

Table D2.--Calibrated model parameters for Klamath system reaches

Reach	Begin (B) End (E)	Length (mi)	C_o (ft/s)	K_o (ft^2/s)
1	(B) Station 11516530 (E) Confluence of 11517500 with Klamath	13.00	6.375	1,343
2	(B) Confluence of 11517500 with Klamath (E) Confluence of 11519500 with Klamath	9.15	7.000	1,840
3	(B) Station 11519500 (E) Confluence of 11519500 with Klamath	18.40	4.670	459
4	(B) Confluence of 11519500 with Klamath (E) Station 11520500	14.65	7.440	2,150

To simulate flow from the intervening ungaged drainage area of 864 mi^2, a drainage-area ratio was calculated by using the drainage area at the index station 11519500 (653 mi^2) and dividing it into the ungaged area (864/653 = 1.32). This value was adjusted to 1.34 during calibration.

During calibration C_o and K_o were varied, as well as the computed drainage area ratio. The best fit single linearization model was with the originally determined C_o, K_o and slightly adjusted drainage area ratio. Table D3 presents the results of the routing model for simulated flows at station 11520500.

Table D3.--Calibration results of routing model for station 11520500

```
      ***** 1980 WY SUMMARY *****
Mean Error (%) for    366 days =   5.80
Mean - Error  (%)  for    253 days =  -6.17
Mean + Error  (%)  for    113 days =   4.97
Q1 Volume  (SFD) = 1321710.
Q2 Volume  (SFD) = 1325723.
Volume Error  (%) =  -0.30
RMS Error  (%)  =   7.57
```

```
56 Percent of total observations had Errors <=    5 Percent
84 Percent of total observations had Errors <=   10 Percent
93 Percent of total observations had Errors <=   15 Percent
98 Percent of total observations had Errors <=   20 Percent
99 Percent of total observations had Errors <=   25 Percent
 1 Percent of total observations had Errors >    25 Percemt
```

The summary in table D3 includes the 1980 water year from October 1, 1979 to September 30, 1980. It can be noted that the mean error for 366 days is 5.80 percent with a volume error less than 1 percent. The bottom half of table D3 lists the percent of total observations that had errors less than or equal to 5, 10, 15, etc. percent. Depending upon what the error acceptance criteria are for station 11520500, simulation of discharge data at the station could be performed with the routing model in lieu of actually gaging the flow.

Table D4 presents summary statistics for the verification period --1981 and 1982 water years. The results in table D4 are comparable to the calibration results.

Table D4.--Verification results of routing model for station 11520500

```
          ***** 1981 & 1982 WY SUMMARY *****
         Mean Error (%) for   730 days =   6.36
         Mean - Error (%)  for 437 days =   -5.60
         Mean + Error (%)  for 293 days =    7.50
         Q1 Volume   (SFD) = 2971071.
         Q2 Volume   (SFD) = 2966621.
         Volume Error (%) =   0.15
         RMS Error   (%) =   9.46

54 Percent of total observations had Errors <=   5 Percent
85 Percent of total observations had Errors <=  10 Percent
92 Percent of total observations had Errors <=  15 Percent
96 Percent of total observations had Errors <=  20 Percent
97 Percent of total observations had Errors <=  25 Percent
 3 Percent of total observations had Errors >   25 Percent
```

The flow developed for the Klamath River system produced very good results. This indicates that computed model parameters, selected index station and calculated drainage-area ratio can be expected to give optimum results. Certainly, the small amount of ungaged area and a representative index station contributed significantly to these results.

Figure D2 is a comparison of the observed and simulated discharge at station 11520500 for a high flow period in January, 1980. The fit for this period is very good as was the other periods used in the comparison.

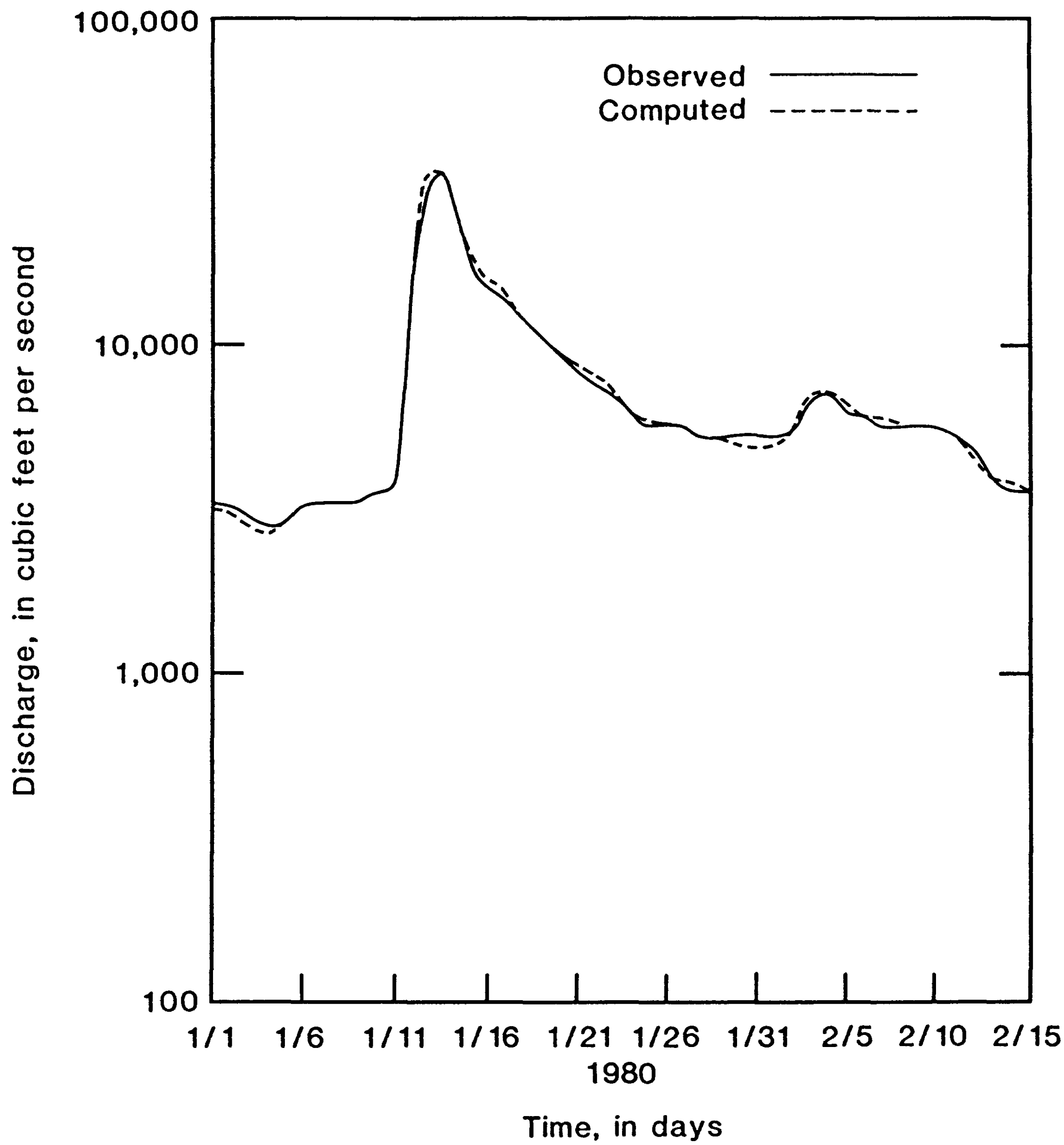


Figure D2.--Comparison of observed and simulated discharge at station 11520500.

Model Processing Instructions

This section of Appendix D describes the data processing procedures used in the Klamath River Modeling analysis. Figure D3 illustrates how the data flows into and out of the model and these steps describe the path of the data.

1. Data are retrieved from WATSTORE;
2. The data are transformed;
3. The data are edited;
4. The data are used in the model; and
5. Statistical analyses are performed on model-generated data.

These steps are described in more detail in the following paragraphs.

First, the station data that were used in the Klamath modeling analysis had to be located. Data not on the current WATSTORE Daily Values File had to be identified as to which historic tape contained the data. A computer program execution of the "WATSTORE MESSAGE" generated a listing of tapes and related states for which Daily Values data in the backfile format were stored. JCL cards used were as follows:

```
//AG4J31JD JOB (4385028001/,RPT,2,9),'H_DOYLE',CLASS=B2/
//PROCLIB DD DSN=WRD.PROCLIB,DISP=SHR
//   EXEC MESSAGE,WRDMSG='WRD02'
/*
//
```

Data that have been identified for retrieval can be retrieved from WATSTORE with the cataloged "Daily Values" retrieval program.

Figure D4 illustrates an example of the necessary information to retrieve data from WATSTORE for four surface-water stations in the Klamath River study. Figure D4 shows that the cataloged procedure DVRETR (line 00000050) is run on tape 115613 to retrieve historic daily streamflow data (parameter code 00060 in lines 00000180, 00000210, 00000240 and 00000270) for the complete period of record for stations 11516530, 11517500, 11519500 and 11520500. Current data were also included in these retrievals by coding a '3' in column 2 on lines 00000170, 00000200, 00000230 and 00000260. The retrieved data were stored in an online disk file named 'AG40XEJ.MENLOPRK.DAILYQ3' (line 00000060).

1/Account number displayed for illustration purpose only. Please use appropriate account number here and in all other illustrated JCL.
2/All JCL documented in Appendix D are for running jobs on the U.S. Geological Survey's Amdahl computer system in Reston, VA.

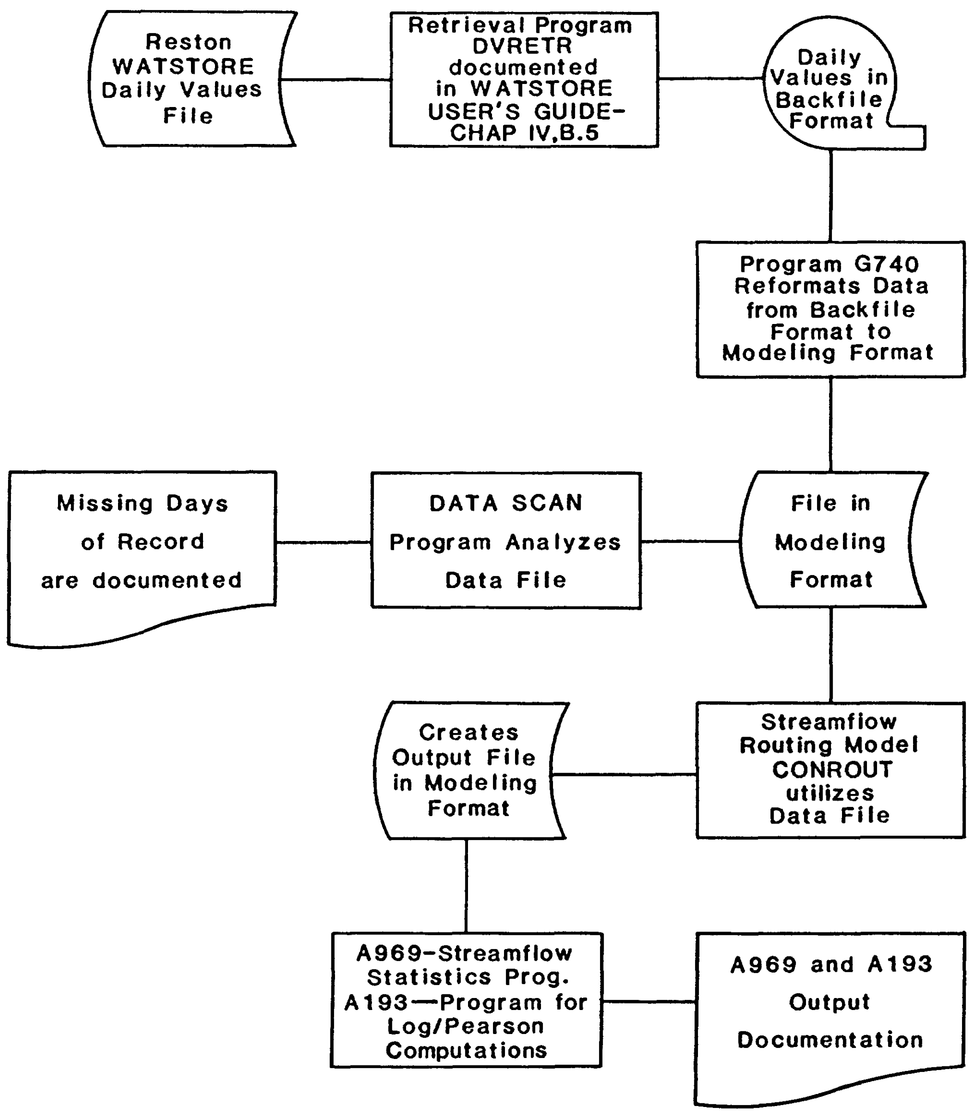


Figure D3.--Flowchart of CONROUT and related programs.

```
//AG40XEJH JOB (470698870,RPT,4,10),'H DOYLE',CLASS=B
/*ROUTE  PRINT RMT046
/*SETUP    115613/H
//PROCLIB  DD DSN=WRD.PROCLIB,DISP=SHR
//     EXEC DVRETR,AGENCY=USGS,VOL1=115613,
//  NAME4='AG40XEJ.MENLOPRK.DAILYQ3',UNIT4=ONLINE,BLK4=11592,SP4=25,
//  DISP4='(NEW,CATLG)'
//* IN THE DATA CARDS THAT FOLLOW //HDR.SYSIN DD * THE
//* FIRST CARD STATES THAT BOTH CURRENT AND HISTORICAL DATA
//* ARE TO BE RETRIEVE.  THE 2ND CARD STATES THAT PARAMETER
//* CODE 00060 FOR DAILY DISCHARGE IS TO BE RETRIEVED.
//* THE LAST CARD IDENTIFIES THE STATION DOWNSTREAM ORDER #.
//* AS MANY RETRIEVALS AS NECESSARY CAN BE MADE WITH THE
//* PROCEDURE BEING JUST TO ADD THE NECESSARY 3 CARDS
//* FOR EACH STATION THAT YOU WANT TO RETRIEVE DATA FOR.
//HDR.SYSIN DD *
M3
R00060
D        11516530
M3
R00060
D        11517500
M3
R00060
D        11519500
M3
R00060
D        11520500
/*
//
```

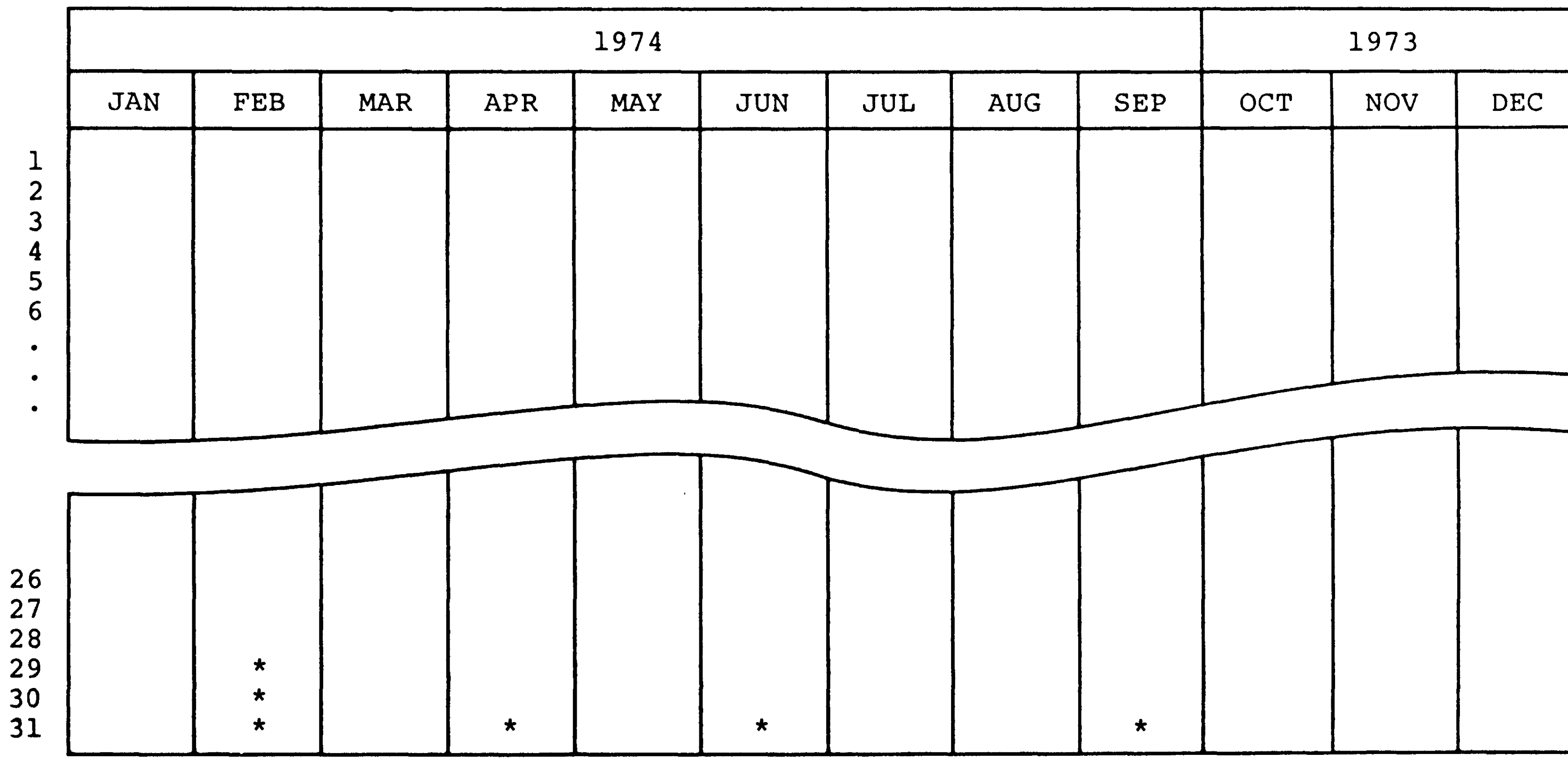
Figure D4.--JCL for Daily-Value Retrieval from WATSTORE.

Figure D5 illustrates the format of a retrieved record containing one water-year of data in the standard 1656-byte backfile record format. The data retrieved from WATSTORE were transformed by program G740 (fig. D6) for input to the streamflow routing model. Data for the four stations were retrieved from the computer file previously named 'AG40XEJ.MENLOPRK,DAILY03' (line 00000230 //FT10F001...) that was created in the WATSTORE retrieval (fig. D4). The individual station data were output on separate files as identified by data set names in lines 00000310 to 00000340 (fig. D6). The variable NRECXX in the same lines was assigned values corresponding to the number of years of data to be transformed into the modeling format. An additional record had to be allocated for a header record. NRECXX is expressed in increments of 20 (20, 40, 60, 80 and 100). For example, in line 00000370 22 years of data plus 1 header record were processed, so that space for 23 records had to be reserved. Therefore, NRECXX was set equal to 40, the next largest increment of 20. The respective file (26-29) for each station and the number of records were established in lines 00000370 to 00000400. The relationship between the input data and the JCL file descriptions is illustrated in the chart in the lower right-hand part of figure D6.

Figure D7 illustrates an example of a direct-access disk file of records in the modeling format. Each year of daily data requires one record, and for the four stations, the data are stored in records 2-NRECDS on each file. The first record of each file is reserved for header identification of the station and the number of years of data on the file. Hourly data can also be stored in the modeling format. If the data are hourly then these data are stored in consecutive records, two per month, and contiguous months for the specified time period. For a given month, the first 15 days of hourly data are stored in the first record and the remaining days in the next record. Therefore, a complete year of hourly data would require 24 records.

Figure D8 documents an editing program called "DATA SCAN" that can be used to analyze modeling format data to determine individual days of missing data. This program, like G740 and CONROUT, makes use of an inline procedure that allows the user greater flexibility in identifying the files. Figure D8 also shows where input JCL are placed (lines 00000350 to 00000390) and that description data for identfying the stations and files follow line 00000400 //G.SYSIN DD *.

Figure D9 documents the JCL for executing CONROUT. The inline procedure CONROUT (fig. D9, lines 00000040 to 00000130 and lines 00000310 to 00000350) allows as many as five input and five output files to be processed by CONROUT. Input files are designated as FILE 21 through FILE 25 and output files, FILE 26 through FILE 30. These JCL file declaration cards follow line 00000300. The input/output file associations are declared in the INPUT DATA that follows line 00000390. Input and output files are in the modeling format (fig. D7). Additional output files (See footnote 3/ in Time Data Card section of report) 17, 18, and 19, can also be defined (lines 00000360 to 00000380). In this example they have been "dummied out."



* No value indicator (999999.00) stored.

Figure D5.--Example of WATSTORE Daily Values Format for the 1974 water year.

```
//AG40XEJH JOB (470698870,RPT,2,5),'H DOYLE',CLASS=B
/*ROUTE  PRINT RMT046
//* THIS JCL IS STORED IN AG4J31J.KLAMATH.G740PROC.CNTL
//* AND CAN BE EXECUTED BY SIGNING ON TO THE TSO AND THEN
//* EDIT 'AG4J31J.KLAMATH.G740PROC.CNTL'
//* AND CHANGING INPUT DATA CARDS AS NEEDED AND THEN
//* SUBMIT *
//G740PROC PROC NAME26='&&F',NAME27='&&G',NAME28='&&H',
// NAME29='&&I',NAME30='&&J',R=,
// COND26='(,CATLG,DELETE)',UNIT=ONLINE',NREC26=20,
// COND27='(,CATLG,DELETE)',UNIT=ONLINE',NREC27=20,
// COND28='(,CATLG,DELETE)',UNIT=ONLINE',NREC28=20,
// COND29='(,CATLG,DELETE)',UNIT=ONLINE',NREC29=20,
// COND30='(,CATLG,DELETE)',UNIT=ONLINE',NREC30=20,
// SP='(1552,(',ETC='),,CONTIG),DCB=(DSORG=DA)'
//G  EXEC PGM=G740,REGION=&R
//STEPLIB DD DSN=AG4J31J.DOYLE.PGMLIBE,DISP=SHR
//        DD DSN=SYS1.FORTG.LINKLIBX,DISP=SHR
//        DD DSN=SYS1.PLIX.TRANSLIB,DISP=SHR
//SYSPRINT  DD SYSOUT=A
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//FT05F001 DD DDNAME=SYSIN
//FT10F001 DD DSN=AG40XEJ.MENLOPRK.DAILY33,UNIT=ONLINE,DISP=OLD
//FT26F001 DD DSN=&NAME26,DISP=&COND26,SPACE=&SP&NREC26&ETC
//FT27F001 DD DSN=&NAME27,DISP=&COND27,SPACE=&SP&NREC27&ETC
//FT28F001 DD DSN=&NAME28,DISP=&COND28,SPACE=&SP&NREC28&ETC
//FT29F001 DD DSN=&NAME29,DISP=&COND29,SPACE=&SP&NREC29&ETC
//FT30F001 DD DSN=&NAME30,DISP=&COND30,SPACE=&SP&NREC30&ETC
//  PEND
//  EXEC G740PROC,
//  NAME26='AB40XEJ.KL516530.G740FMT',NREC26=40,   } Input
//  NAME27='AB40XEJ.KL517500.G740FMT',NREC27=60,   } JCL
//  NAME28='AB40XEJ.KL519500.G740FMT',NREC28=60,
//- NAME29='AB40XEJ.KL520500.G740FMT',NREC29=60,
// R=150K
//G.SYSIN DD *
  11516530    26    23   } Input
  11517500    27    47   } Data
  11519500    28    42
  11520500    29    45
/*
//
```

Station No. Cols. 3-10

File No. XX Cols. 14-15

Number of years of data retrieved from WATSTORE + 1 record for header Cols. 19-20

# of WATSTORE RECORDS	NRECDS	NRECXX
1-19	2-20	20
20-39	21-40	40
40-59	41-60	60
60-79	61-80	80
80-99	81-100	100

Figure D6.--JCL for executing G740 Program.

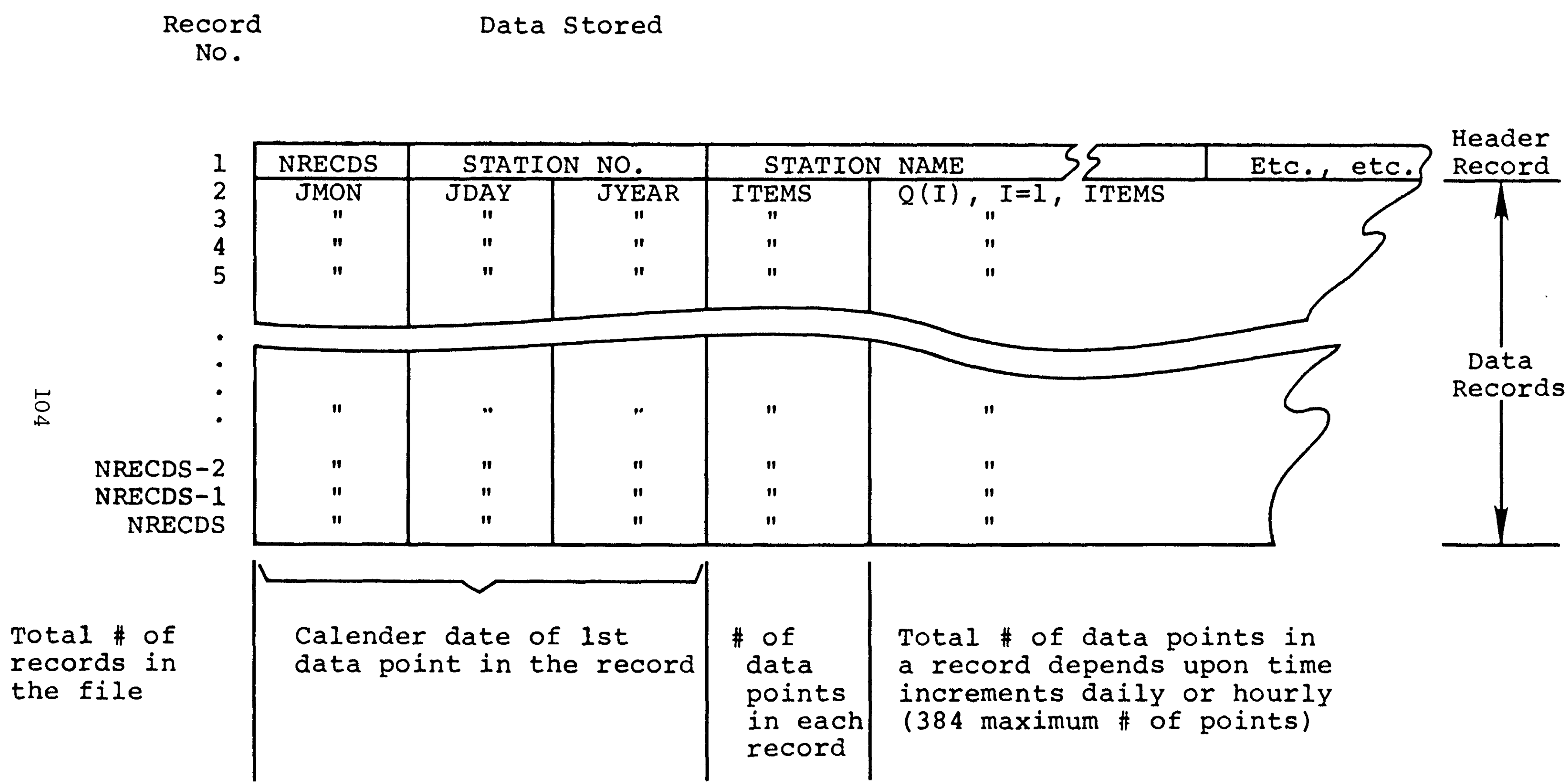


Figure D7.--Example of a file of records for modeling format.

```
//AG40XEJH JOB (470698870,RPT,2,3),'H DOYLE',CLASS=B
/*ROUTE  PRINT RM046
//* THIS JCL IS STORED IN AG4J31J.KLAMATH.DATASCAN.CNTL
//* AND CAN BE EXECUTED BY SIGNING ON TO THE TSO AND THEN
//* EDIT 'AG4J31J.KLAMATH.DATASCAN.CNTL'
//* AND CHANGING INPUT DATA CARDS AS NEEDED AND THEN
//* SUBMIT *
//DATA CAN PROC NAME21='&&F',NAME22='&&G',NAME23='&&H',
// NAME24='&&I',NAME25='&&J',COND21='(,PASS),UNIT=SYSDK',
// COND22='(,PASS),UNIT=SYSDK',COND23='(,PASS),UNIT=SYSDK',
// COND24='(,PASS),UNIT=SYSDK',COND25='(,PASS),UNIT=SYSDK',
// ETC=',SPACE=(1552,1),DCB=(DSORG=DA)',R=
//*
//G  EXEC  PGM=SCAN,REGION=&R
//STEPLIB DD DSN=AG4J31J.DOYLE.PGMLIBE,DISP=SHR
//         DD DSN=SYS1.FORTG.LINKLIBX,DISP=SHR
//         DD DSN=SYS1.PLIX.TRANSLIB,DISP=SHR
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//FT15F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//SYSPUNCH DD SYSOUT=B
//FT07F001 DD SYSOUT=B
//FT05F001 DD DDNAME=SYSIN
//FT21F001 DD DSN=&NAME21,DISP=&COND21&ETC
//FT22F001 DD DSN=&NAME22,DISP=&COND22&ETC
//FT23F001 DD DSN=&NAME23,DISP=&COND23&ETC
//FT24F001 DD DSN=&NAME24,DISP=&COND24&ETC
//FT25F001 DD DSN=&NAME25,DISP=&COND25&ETC
//*
//* ILLUSTRATED IS JCL FOR ONLY 4 FILES. A MAXIMUM OF 5 FILES CAN BE
//* INPUT IN ANY ONE RUN WITH FILE NUMBERS 21 THRU 25.
//*
//  PEND
//  EXEC DATASCAN,
//  NAME21='AB40XEJ.KL516530.G740FMT',COND21=SHR,
//  NAME22='AB40XEJ.KL517500.G740FMT',COND22=SHR,
//  NAME23='AB40XEJ.KL519500.G740FMT',COND23=SHR,
//  NAME24='AB40XEJ.KL520500.G740FMT',COND24=SHR,
//  R=150K
//G.SYSIN DD *
   21  11516530
   22  11517500
   23  11519500
   24  11520500
/*
//
```

Figure D8.--JCL for executing DATA SCAN Program.

```
//AG40XEJH JOB (470698870,RPT,2,9),'H DOYLE',CLASS=B
/*ROUTE  PRINT RMT046
//* THIS PROC STORED IN AG4J31J.KLAMATH.CONROUT.CNTL
//CONROUT PROC NAME21='&&A',NAME22='&&B',NAME23='&&C',
// NAME24='&&B',NAME25='&&E',NAME26='&&F',NAME27='&&G',
// NAME28='&&H',NAME29='&&I',NAME30='&&J',
// COND21='(,PASS),UNIT=SYSDK',COND26='(,CATLG,DELETE),UNIT=ONLINE',
// COND22='(,PASS),UNIT=SYSDK',COND27='(,CATLG,DELETE),UNIT=ONLINE',
// COND23='(,PASS),UNIT=SYSDK',COND28='(,CATLG,DELETE),UNIT=ONLINE',
// COND24='(,PASS),UNIT=SYSDK',COND29='(,CATLG,DELETE),UNIT=ONLINE',
// COND25='(,PASS),UNIT=SYSDK',COND30='(,CATLG,DELETE),UNIT=ONLINE',
// ETC1=',SPACE=(1552,1),DCB=(DSORG=DA)',R=150K,
// SP='(1552,(',NREC=,ETC2='),,CONTIG),DCB=(DSORG=DA)'
//G  EXEC PGM=T351,REGION=&R
//STEPLIB DD DSN=AG4J31J.DOYLE.PGMLIBE,DISP=SHR
//SYSPRINT  DD SYSOUT=A
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//FT05F001 DD DDNAME=SYSIN
//FT21F001 DD DSN=&NAME21,DISP=&COND21&ETC1
//FT22F001 DD DSN=&NAME22,DISP=&COND22&ETC1
//FT23F001 DD DSN=&NAME23,DISP=&COND23&ETC1
//FT24F001 DD DSN=&NAME24,DISP=&COND24&ETC1
//FT25F001 DD DSN=&NAME25,DISP=&COND25&ETC1
//FT26F001 DD DSN=&NAME26,DISP=&COND26,SPACE=&SP&NREC&ETC2
//FT27F001 DD DSN=&NAME27,DISP=&COND27,SPACE=&SP&NREC&ETC2
//FT28F001 DD DSN=&NAME28,DISP=&COND28,SPACE=&SP&NREC&ETC2
//FT29F001 DD DSN=&NAME29,DISP=&COND29,SPACE=&SP&NREC&ETC2
//FT30F001 DD DSN=&NAME30,DISP=&COND30,SPACE=&SP&NREC&ETC2
//  PEND
//  EXEC CONROUT,
// NAME21='AG40XEJ.KL516530.G740FMT',COND21=SHR,
// NAME22='AG40XEJ.KL517500.G740FMT',COND22=SHR,
// NAME23='AG40XEJ.KL519500.G740FMT',COND23=SHR,
// NAME24='AG40XEJ.KL520500.G740FMT',COND24=SHR,
// NREC=20
//G.FT17F001 DD DUMMY
//G.FT18F001 DD DUMMY
//G.FT19F001 DD DUMMY
//G.SYSIN DD *
  10    01 1979 1200    09    30 1980 1200    20    24     0
I=21,O=26,ROUTE,DIFFA
11516530   11516530 FLOW ROUTED DOWN TO 1ST CONFLUENCE
C=6.375,K=1343,X=13.0,REACH=11516530 TO 1ST CONFLUENCE
I=22,O=26,ADD
99999999  11517500 FLOW ADDED AT KLAMATH CONFLUENCE
I=26,O=27,ROUTE,DIFFA
99999999  FLOW ROUTED ALONG MIDDLE OF KLAMATH
C=7.00,K=1840,X=9.15,REACH=MIDDLE ROUTED FLOW
I=23,O=28,ROUTE,DIFFA
99999999  11519500 FLOW ROUTED TO KLAMATH CONFLUENCE
C=4.67,K=459,X=18.4,REACH=11519500 TO KLAMATH
I=27,O=28,ADD
99999999  11519500 FLOW ADDED AT CONFLUENCE
I=28,O=29,ROUTE,DIFFA
11520500  FINAL ROUTED FLOW TO 11520500
C=7.44,K=2150,X=14.65,REACH=LAST REACH
I=23,O=29,RATIO=1.34,ADD
11519500  INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
COMPARE,F=29,S=24
COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500
PLOT,F=29,S=24,QMIN=10
PLOT OF SIMULATED AND OBSERVED FLOWS AT 11520500
/*
//
```

Figure D9.--JCL for executing CONROUT Program.

Operations to be performed by CONROUT are defined on data cards that follow line 00000390//G.SYSIN DD * in figure D9. The following is a general description of the individual steps performed by CONROUT in the Klamath River analysis. All the available model options are described in detail in a previous section of this report and can be used to explain the individual data entries listed in lines 00000400 to 00000620.

a. The period of record used in the analysis is defined in line 00000400.

b. Step 1 (lines 00000410 to 00000430) defines model parameter information for routing flow from station 11516530 to the Shasta River confluence 13.0 miles downstream on the Klamath River.

c. Step 2 (lines 00000440 and 00000450) state that flow from station 11517500 is added to the Klamath River flow at its confluence with the Klamath.

d. Step 3 (lines 00000460 to 00000480) defines model parameter information for routing the combined flow at the Shasta River confluence for 9.15 miles downstream to the Scott River confluence with the Klamath.

e. Step 4 (lines 00000490 to 00000510) defines model parameter information for routing flow along the Scott River from station 11519500 to its confluence with the Klamath.

f. Step 5 (lines 00000520 and 00000530) combines the routed Scott River and Klamath River flows at their confluence with each other.

g. Step 6 (lines 00000540 to 00000560) defines model parameter information for routing the combined flows from step 5 along the final reach (14.65 miles) of the Klamath to station 11520500.

h. Step 7 (lines 00000570 and 00000580) accounts for intervening ungaged flow by using a ratio of 1.34 times the flow at index station 11519500 and adding it to the routed Klamath flows at station 11520500.

i. The last two steps (lines 00000590 to 00000620) use the model options COMPARE and PLOT to compute and illustrate the difference between simulated and observed flows at station 11520500.

Finally, if the user wants to perform statistical analyses such as those that are available in the Streamflow Statistics Program A969 and asssociated Log Pearson Type III Computational Program A193 then the JCL in figure D10 can be used. Step 1 (line 00000170 in fig. D10) refers to PGM=S969 which is a transformed A969 program that can read the input data in the modeling format (fig. D7). Step 2 (line 00000400 in fig. D10) activates program A193 execution. Line 00000490 illustrates that FILE 21 is to supply input streamflow data from station 11520500. This example is for observed streamflow data at station 11520500. If streamflow statistics are to be computed for the simulated streamflow at station 11520500 then the model would have to be executed for the period of record and the simulated streamflow at station 11520500 stored in a permanent disk file. This disk file would then be input to the streamflow statistics programs for analysis. Identification of analysis time period, station identification and program options are input behind line 00000510 //STEP1.SYSIN DD *. The three data cards (lines 00000520 to 00000540 in fig. D10) are as follows:

Line 00000520--Name Card

Col.	1	- Type (always 1)
Cols.	2-9	- Station Number
Cols.	10-80	- Station Name (including all punctuation)

```
//AG40XEJH JOB (470698870,RPT,2,),'H DOYLE',CLASS=B
/*ROUTE  PRINT RM046
//* THIS JCL IS STORED IN AG4J31J.KLAMATH.S969PROC.CNTL
//* AND CAN BE EXECUTED BY SIGNING ON TO THE TSO AND THEN
//* EDIT 'AG4J31J.KLAMATH.S969PROC.CNTL' AND CHANGING
//* INPUT DATA CARDS AS NEEDED AND THEN SUBMIT *
//SWSTAT PROC NAME21='&&A',NAME22='&&B',NAME23='&&C',
// NAME24='&&D',NAME25='&&E',NAME26='&&F',NAME27='&&G',
// NAME28='&&H',NAME29='&&I',NAME30='&&J',
// COND21='(,PASS),UNIT=SYSDK',COND22='(,PASS),UNIT=SYSDK',
// COND23='(,PASS),UNIT=SYSDK',COND24='(,PASS),UNIT=SYSDK',
// COND25='(,PASS),UNIT=SYSDK',COND26='(,PASS),UNIT=SYSDK',
// COND27='(,PASS),UNIT=SYSDK',COND28='(,PASS),UNIT=SYSDK',
// COND29='(,PASS),UNIT=SYSDK',COND30='(,PASS),UNIT=SYSDK',
// ETC=',SPACE=(1552,1),DCB=(DSORG=DA)',R=
//STEP1  EXEC  PGM=S969,REGION=&R
//***** STREAMFLOW STATISTICS BY PROGRAM S969 *****
//STEPLIB DD DSN=AG4J31J.DOYLE.PGMLIBE,DISP=SHR
//         DD DSN=SYS1.FORTG.LINKLIBX,DISP=SHR
//         DD DSN=SYS1.PLIX.TRANSLIB,DISP=SHR
//SYSPRINT DD SYSOUT=A
//LOGPEAR  DD  DSN=&&TEMP,UNIT=SYSDK,DISP=(NEW,PASS,DELETE),
//             DCB=(RECFM=VB,LRECL=512,BLKSIZE=7172),
//             SPACE=(CYL,(4,1),RLSE)
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//FT21F001 DD DSN=&NAME21,DISP=&COND21&ETC
//FT22F001 DD DSN=&NAME22,DISP=&COND22&ETC
//FT23F001 DD DSN=&NAME23,DISP=&COND23&ETC
//FT24F001 DD DSN=&NAME24,DISP=&COND24&ETC
//FT25F001 DD DSN=&NAME25,DISP=&COND25&ETC
//FT26F001 DD DSN=&NAME26,DISP=&COND26&ETC
//FT27F001 DD DSN=&NAME27,DISP=&COND27&ETC
//FT28F001 DD DSN=&NAME28,DISP=&COND28&ETC
//FT29F001 DD DSN=&NAME29,DISP=&COND29&ETC
//FT30F001 DD DSN=&NAME30,DISP=&COND30&ETC
//* ILLUSTRATED IS JCL FOR ALL 10 FILES, IF LESS THAN 10 FILES ARE
//* USED THEN ONLY INPUT THAT NUMBER OF DATA CARDS FOR THE NUMBER
//* OF FILES ACTUALLY USED.
//STEP2  EXEC PGM=A193,REGION=200K,TIME=3
//***** LOG/PEARSON COMPUTATIONS BY PROGRAM A193 *****
//STEPLIB DD DSN=AG4J31J.DOYLE.PGMLIBE,DISP=SHR
//         DD DSN=SYS1.FORTG.LINKLIBX,DISP=SHR
//         DD DSN=SYS1.PLIX.TRANSLIB,DISP=SHR
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)
//FT17F001 DD DSN=&&TEMP,DISP=(OLD,DELETE,DELETE)
//  PEND
//  EXEC SWSTAT,
//  NAME21='AB40XEJ.KL520500.G740FMT',COND21=SHR,
//  R=200K
//STEP1.SYSIN DD *
111520500OBSERVED FLOW ON KLAMATH R. NR. SEIAD VALLEY, CA.
211520500    196010198009108000    792
31152050011  21        1      7     30                    1      7      30
/*
//
```

Figure D10.--JCL for executing streamflow statistics programs.

Line 00000530--(First Option Card)

Col. 1 - Type (Always 2)

Cols. 2-9 - Station number

Cols. 10-12 - Blank

Cols. 13-16 - Beginning year (i.e., 1930)

Cols. 17-18 - Beginning month '10', processings limited to one or more water years of data.

Cols. 19-22 - Ending year (i.e., 1980)

Cols. 23-24 - Ending month '09', processing limited to one or more water years of data.

Note: Columns 13-24 are left blank if the entire period is to be processed.

Cols. 25-30 - Second highest discharge of period to be processed.

Cols. 31-36 - Lowest non-zero discharge

Cols. 37-38 - Beginning month of low-flow summary if different from climatic year

Cols. 39-40 - Ending month of low-flow summary if partial year or if different from climatic year

Cols. 41-42 - Beginning month of high-flow summary if different from water year

Cols. 43-44 - Ending month of high-flow summary if partial year or if different from water year

Cols. 45-80 - Blank

Line 00000540--(Second Option Card)

Col. 1 - Type (always 3)

Cols. 2-9 - Station number

Col. 10 - '1' if all requested low-flow data (coded in columns 21-50) are to be plotted. Blank is all low-flow data are not to be plotted.

Col. 11 - '1' if all high-flow data (coded in columns 51-80) are to be plotted. Blank is all high-flow data are not to be plotted.

Cols. 12-15 - File number containing data (i.e., 21 from card 00490 in fig. D10).

Cols. 16-20 - Blank

Cols. 21-80 - Twenty sets of from one to three digit numbers. The number is punched if that particular set of data is requested for a Log Pearson fit. The three columns are blank if that set of data is not to be fitted.

Cols. 21-22 - Blank

Col. 23 - '1'

Cols. 24-25 - Blank

Col. 26 - '3'

Cols. 27-28 - Blank

Col. 29 - '7'

Col. 30 - Blank

Cols. 31-32 - '14'

Col. 33 - Blank

Cols. 34-35 - '30'

Col. 36 - Blank

Cols. 51-52 - Blank

Col. 53 - '1'

Cols. 54-55 - Blank

Col. 56 - '3'

Cols. 57-58 - Blank

Col. 59 - '7'

Col. 60 - Blank

Cols. 61-62 - '15'

Col. 63 - Blank

Cols. 64-65 - '30'

Col. 66 - Blank

Cols. 37-38 - '60'		Cols. 67-68 - '60'	
Col. 39 - Blank		Col. 69 - Blank	
Cols. 40-41 - '90'		Cols. 70-71 - '90'	
Cols. 42-44 - '120'		Cols. 72-74 - '120'	
Cols. 45-47 - '183'		Cols. 75-77 - '183'	
Cols. 48-50 - '365'		Cols. 78-80 - '365'	

Note: Columns 21-50 apply to selection of low flow data.

Columns 51-80 apply to selection of high flow data.

Columns 10-11 and 21-80 are to be left blank if no Log Pearson data (statistics or plot) are requested.

This example is for only one input file. If additional files are input for analysis then lines similar to 00000490 and 00000520 to 00000540 have to be prepared for each file and can be included in the data stream like this example:

```
//  EXEC SWSTAT,                                   00000480
//  NAME21='1ST FILE NAME',COND21=SHR,             00000490
//  NAME22='2ND FILE NAME',COND22=SHR,             00000491
                        .
                        .
              Other File Names
                        .
                        .
//  R=200K                                         00000500

//STEP1.SYSIN DD *                                 00000510
     "1st Data Card for 1st File"                  00000520
     "2nd Data Card for 1st File"                  00000530
     "3rd Data Card for 1st File"                  00000540
     "1st Data Card for 2nd File"
     "2nd Data Card for 2nd File"
     "3rd Data Card for 2nd File"
                        .
                        .
             Data for other files
                        .
                        .
/*                                                 00000550
//                                                 00000560
```

CONROUT Model Run and Output

The remaining pages of this report illustrate the computer output listing for an execution of the CONROUT model for the 9-step run described in the previous sections of Appendix D. The general output format lists the following information:

a. The period of record for which CONROUT was executed.

b. The number of records allocated for output hydrographs.

c. The individual step functions such as routing, plotting, etc.

d. Options selected for each step.

e. Method of routing selected, routing interval, reach length, and model parameters such as the wave celerity and wave dispersion coefficients.

f. Computed unit-response function ordinates.

g. The computed traveltime TT (for a TT = 0, no lagging of output occurs; for a TT = 24, the output is lagged by one routing interval of 24 hours, for a TT = 48, the output is lagged by two routing intervals, etc.).

h. Simulated and observed flows with percentage of error for computed flows. In this example individual daily listings and total period summaries were generated. The final output of the COMPARE option in this example was an error distribution table.

i. A plot of simulated and observed Klamath River streamflow at station 11520500.

```
UNIT RESPONSE ROUTING MODEL

         FOR THE PERIOD 10  1 1979 1200 TO  9 30 1980 1200
         THE FOLLOWING STEPS HAVE BEEN PERFORMED.

         SPACE FOR  20 RECORDS HAS BEEN ALLOCATED FOR OUTPUT HYDROGRAPHS


         *****STEP =  1   DATA INPUT CARDS*****
         I=21,O=26,ROUTE,DIFFA                                                  00000410
          11516530  11516530 FLOW ROUTED DOWN TO 1ST CONFLUENCE
          C=6.375,K=1343,X=13.0,REACH=11516530 TO 1ST CONFLUENCE                 00000430

         ------------------------------------------------------------------------

         THE DIFFUSION ANALOGY METHOD WITH: 1) A ROUTING INTERVAL OF 24.0 HRS.; 2) A
         REACH LENGTH, X = 13.00 MILES; 3) A WAVE CELERITY, CZERO =  6.38 FT./SEC.; AND
         4) A WAVE DISPERSION COEFFICIENT, K =   1343.0 SQ.FT./SEC.
         COMPUTES A UNIT-RESPONSE FUNCTION WITH   2 ORDINATES AS FOLLOWS:

          1) 0.8997      2) 0.1003

         THE TRAVEL TIME, TT =     0.0 HRS.

         ------------------------------------------------------------------------


         *****STEP =  2   DATA INPUT CARDS*****
         I=22,O=26,ADD                                                          00000440
          99999999  11517500 FLOW ADDED AT KLAMATH CONFLUENCE


         *****STEP =  3   DATA INPUT CARDS*****
         I=26,O=27,ROUTE,DIFFA                                                  00000460
          99999999  FLOW ROUTED ALONG MIDDLE OF KLAMATH
          C=7.00,K=1840,X=9.15,REACH=MIDDLE ROUTED FLOW                          00000480

         ------------------------------------------------------------------------

         THE DIFFUSION ANALOGY METHOD WITH: 1) A ROUTING INTERVAL OF 24.0 HRS.; 2) A
         REACH LENGTH, X =  9.15 MILES; 3) A WAVE CELERITY, CZERO =  7.00 FT./SEC.; AND
         4) A WAVE DISPERSION COEFFICIENT, K =   1840.0 SQ.FT./SEC.
         COMPUTES A UNIT-RESPONSE FUNCTION WITH   2 ORDINATES AS FOLLOWS:

          1) 0.9002      2) 0.0998

         THE TRAVEL TIME, TT =     0.0 HRS.

         ------------------------------------------------------------------------


         *****STEP =  4   DATA INPUT CARDS*****
         I=23,O=28,ROUTE,DIFFA                                                  00000490
          99999999  11519500 FLOW ROUTED TO KLAMATH CONFLUENCE
          C=4.67,K=459,X=18.4,REACH=11519500 TO KLAMATH                          00000510

         ------------------------------------------------------------------------
```

```
THE DIFFUSION ANALOGY METHOD WITH: 1) A ROUTING INTERVAL OF 24.0 HRS.; 2) A
REACH LENGTH, X = 18.40 MILES; 3) A WAVE CELERITY, CZERO =  4.67 FT./SEC.; AND
4) A WAVE DISPERSION COEFFICIENT, K =     459.0 SQ.FT./SEC.
COMPUTES A UNIT-RESPONSE FUNCTION WITH   2 ORDINATES AS FOLLOWS:

 1) 0.7979      2) 0.2021

THE TRAVEL TIME, TT =      0.0 HRS.

---------------------------------------------------------------------------------


*****STEP =  5   DATA INPUT CARDS*****
I=27,O=28,ADD                                                           00000520
 99999999  11519500 FLOW ADDED AT CONFLUENCE


*****STEP =  6   DATA INPUT CARDS*****
I=28,O=29,ROUTE,DIFFA                                                   00000540
 11520500  FINAL ROUTED FLOW TO 11520500
 C=7.44,K=2150,X=14.65,REACH=LAST REACH                                  00000560

---------------------------------------------------------------------------------

THE DIFFUSION ANALOGY METHOD WITH: 1) A ROUTING INTERVAL OF 24.0 HRS.; 2) A
REACH LENGTH, X = 14.65 MILES; 3) A WAVE CELERITY, CZERO =  7.44 FT./SEC.; AND
4) A WAVE DISPERSION COEFFICIENT, K =    2150.0 SQ.FT./SEC.
COMPUTES A UNIT-RESPONSE FUNCTION WITH   2 ORDINATES AS FOLLOWS:

 1) 0.8998      2) 0.1002

THE TRAVEL TIME, TT =      0.0 HRS.

---------------------------------------------------------------------------------


*****STEP =  7   DATA INPUT CARDS*****
I=23,O=29,RATIO=1.34,ADD                                                00000570
 11519500  INDEXED STATION FOR UNGAGED WITH R=864/653=1.34


*****STEP =  8   DATA INPUT CARDS*****
COMPARE,F=29,S=24                                                       00000590
 COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500                  00000600
```

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
10 1 1979	12.00	1086.6	1520.0	-28.5
10 2 1979	12.00	1421.3	1500.0	-5.2
10 3 1979	12.00	1470.0	1500.0	-2.0
10 4 1979	12.00	1458.1	1490.0	-2.1
10 5 1979	12.00	1429.6	1490.0	-4.1
10 6 1979	12.00	1415.3	1470.0	-3.7
10 7 1979	12.00	1420.2	1470.0	-3.4
10 8 1979	12.00	1433.2	1480.0	-3.2
10 9 1979	12.00	1448.3	1500.0	-3.4
10 10 1979	12.00	1452.6	1490.0	-2.5
10 11 1979	12.00	1456.4	1490.0	-2.3
10 12 1979	12.00	1463.6	1500.0	-2.4
10 13 1979	12.00	1465.9	1520.0	-3.6
10 14 1979	12.00	1471.8	1550.0	-5.0
10 15 1979	12.00	1522.9	1620.0	-6.0
10 16 1979	12.00	1531.9	1630.0	-6.0
10 17 1979	12.00	1523.4	1610.0	-5.4
10 18 1979	12.00	1518.5	1620.0	-6.3
10 19 1979	12.00	1540.0	1810.0	-14.9
10 20 1979	12.00	1573.8	1980.0	-20.5
10 21 1979	12.00	1603.4	1890.0	-15.2
10 22 1979	12.00	1628.9	1830.0	-11.0
10 23 1979	12.00	1632.7	1910.0	-14.5
10 24 1979	12.00	1677.8	2010.0	-16.5
10 25 1979	12.00	3705.7	3750.0	-1.2
10 26 1979	12.00	3368.4	3310.0	1.8
10 27 1979	12.00	2480.6	2500.0	-0.8
10 28 1979	12.00	2161.1	2280.0	-5.2
10 29 1979	12.00	2036.3	2120.0	-3.9
10 30 1979	12.00	1991.0	2070.0	-3.8
10 31 1979	12.00	1955.8	2090.0	-6.4
11 1 1979	12.00	1945.5	2030.0	-4.2
11 2 1979	12.00	1918.1	2000.0	-4.1
11 3 1979	12.00	1928.4	2020.0	-4.5
11 4 1979	12.00	1948.5	2070.0	-5.9
11 5 1979	12.00	1973.2	2120.0	-6.9
11 6 1979	12.00	2015.4	2110.0	-4.5
11 7 1979	12.00	2124.8	2120.0	0.2
11 8 1979	12.00	2062.0	2110.0	-2.3
11 9 1979	12.00	1996.5	2030.0	-1.6
11 10 1979	12.00	1943.5	2000.0	-2.8
11 11 1979	12.00	1924.5	1960.0	-1.8
11 12 1979	12.00	1941.7	1930.0	0.6
11 13 1979	12.00	1866.2	1910.0	-2.3
11 14 1979	12.00	1846.2	1890.0	-2.3
11 15 1979	12.00	1833.8	1880.0	-2.5
11 16 1979	12.00	2114.1	2130.0	-0.7
11 17 1979	12.00	3118.7	3010.0	3.6
11 18 1979	12.00	2840.8	2910.0	-2.4
11 19 1979	12.00	2486.0	2570.0	-3.3

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500. INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500. KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
11 20 1979	12.00	2269.4	2370.0	-4.2
11 21 1979	12.00	2157.3	2250.0	-4.1
11 22 1979	12.00	2164.7	2340.0	-7.5
11 23 1979	12.00	2347.2	2580.0	-9.0
11 24 1979	12.00	5754.6	5240.0	9.8
11 25 1979	12.00	6905.3	6470.0	6.7
11 26 1979	12.00	5017.5	4350.0	15.3
11 27 1979	12.00	3927.1	3560.0	10.3
11 28 1979	12.00	3388.4	3110.0	9.0
11 29 1979	12.00	3084.5	2880.0	7.1
11 30 1979	12.00	2884.3	2730.0	5.7
12 1 1979	12.00	2744.7	2610.0	5.2
12 2 1979	12.00	4717.2	3860.0	22.2
12 3 1979	12.00	8558.2	8470.0	1.0
12 4 1979	12.00	6210.7	5710.0	8.8
12 5 1979	12.00	5130.9	4920.0	4.3
12 6 1979	12.00	4499.3	4350.0	3.4
12 7 1979	12.00	4029.0	3990.0	1.0
12 8 1979	12.00	3646.9	3510.0	3.9
12 9 1979	12.00	3440.7	3330.0	3.3
12 10 1979	12.00	3242.1	3200.0	1.3
12 11 1979	12.00	3006.0	2880.0	4.4
12 12 1979	12.00	2843.7	2740.0	3.8
12 13 1979	12.00	2724.0	2650.0	2.8
12 14 1979	12.00	2628.8	2570.0	2.3
12 15 1979	12.00	2569.1	2510.0	2.4
12 16 1979	12.00	2506.2	2450.0	2.3
12 17 1979	12.00	2462.1	2410.0	2.2
12 18 1979	12.00	2422.5	2380.0	1.8
12 19 1979	12.00	2405.7	2400.0	0.2
12 20 1979	12.00	2409.9	2400.0	0.4
12 21 1979	12.00	2546.3	2630.0	-3.2
12 22 1979	12.00	2564.8	2620.0	-2.1
12 23 1979	12.00	2507.0	2620.0	-4.3
12 24 1979	12.00	2516.8	2720.0	-7.5
12 25 1979	12.00	2538.8	2720.0	-6.7
12 26 1979	12.00	2506.2	2630.0	-4.7
12 27 1979	12.00	2471.1	2550.0	-3.1
12 28 1979	12.00	2419.1	2490.0	-2.8
12 29 1979	12.00	2389.5	2450.0	-2.5
12 30 1979	12.00	2443.9	2510.0	-2.6
12 31 1979	12.00	2838.8	3000.0	-5.4
1 1 1980	12.00	3171.0	3350.0	-5.3
1 2 1980	12.00	3156.8	3480.0	-9.3
1 3 1980	12.00	2911.9	3080.0	-5.5
1 4 1980	12.00	2795.8	2930.0	-4.6
1 5 1980	12.00	2897.7	2980.0	-2.8
1 6 1980	12.00	3363.6	3400.0	-1.1
1 7 1980	12.00	3394.1	3340.0	1.6
1 8 1980	12.00	3502.2	3480.0	0.6

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
1 9 1980	12.00	3511.9	3540.0	-0.8
1 10 1980	12.00	3653.9	3620.0	0.9
1 11 1980	12.00	3647.0	3600.0	1.3
1 12 1980	12.00	14957.7	15200.0	-1.6
1 13 1980	12.00	32981.5	30400.0	8.5
1 14 1980	12.00	33978.1	35200.0	-3.5
1 15 1980	12.00	22915.3	22000.0	4.2
1 16 1980	12.00	16817.3	16000.0	5.1
1 17 1980	12.00	15289.5	14900.0	2.6
1 18 1980	12.00	12901.3	12400.0	4.0
1 19 1980	12.00	11124.8	10500.0	6.0
1 20 1980	12.00	10018.2	9710.0	3.2
1 21 1980	12.00	9131.7	8760.0	4.2
1 22 1980	12.00	8462.8	8230.0	2.8
1 23 1980	12.00	7783.8	7510.0	3.6
1 24 1980	12.00	6850.5	6710.0	2.1
1 25 1980	12.00	6253.8	5900.0	6.0
1 26 1980	12.00	6009.5	5870.0	2.4
1 27 1980	12.00	5837.7	5700.0	2.4
1 28 1980	12.00	5547.5	5530.0	0.3
1 29 1980	12.00	5217.5	5330.0	-2.1
1 30 1980	12.00	5130.3	5230.0	-1.9
1 31 1980	12.00	5177.0	5320.0	-2.7
2 1 1980	12.00	5143.9	5310.0	-3.1
2 2 1980	12.00	5209.2	5370.0	-3.0
2 3 1980	12.00	7271.4	7060.0	3.0
2 4 1980	12.00	7486.7	7360.0	1.7
2 5 1980	12.00	6726.9	6540.0	2.9
2 6 1980	12.00	6517.1	6340.0	2.8
2 7 1980	12.00	6187.5	6000.0	3.1
2 8 1980	12.00	6021.7	5950.0	1.2
2 9 1980	12.00	5861.0	5830.0	0.5
2 10 1980	12.00	5687.7	5690.0	-0.0
2 11 1980	12.00	5473.3	5570.0	-1.7
2 12 1980	12.00	4761.9	5080.0	-6.3
2 13 1980	12.00	4069.5	4020.0	1.2
2 14 1980	12.00	3834.2	3810.0	0.6
2 15 1980	12.00	3744.5	3750.0	-0.1
2 16 1980	12.00	3777.5	3710.0	1.8
2 17 1980	12.00	4742.2	4130.0	14.8
2 18 1980	12.00	9779.4	7510.0	30.2
2 19 1980	12.00	11158.1	8670.0	28.7
2 20 1980	12.00	11858.4	9930.0	19.4
2 21 1980	12.00	11145.7	10500.0	6.1
2 22 1980	12.00	10548.9	10000.0	5.5
2 23 1980	12.00	9766.5	9370.0	4.2
2 24 1980	12.00	9167.2	8900.0	3.0
2 25 1980	12.00	8839.8	8690.0	1.7
2 26 1980	12.00	8871.9	8690.0	2.1
2 27 1980	12.00	9532.5	8940.0	6.6

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
2 28 1980	12.00	12643.1	11000.0	14.9
2 29 1980	12.00	10918.0	9700.0	12.6
3 1 1980	12.00	9750.1	8980.0	8.6
3 2 1980	12.00	9108.0	8630.0	5.5
3 3 1980	12.00	8598.8	8420.0	2.1
3 4 1980	12.00	7986.5	7690.0	3.9
3 5 1980	12.00	7489.9	7510.0	-0.3
3 6 1980	12.00	6753.7	6690.0	1.0
3 7 1980	12.00	6285.1	6310.0	-0.4
3 8 1980	12.00	6022.9	6080.0	-0.9
3 9 1980	12.00	5832.6	5920.0	-1.5
3 10 1980	12.00	5687.5	5790.0	-1.8
3 11 1980	12.00	5575.8	5740.0	-2.9
3 12 1980	12.00	5465.8	5610.0	-2.6
3 13 1980	12.00	5464.9	5730.0	-4.6
3 14 1980	12.00	6237.8	6870.0	-9.2
3 15 1980	12.00	6319.3	7190.0	-12.1
3 16 1980	12.00	5815.2	6420.0	-9.4
3 17 1980	12.00	5846.7	6230.0	-6.2
3 18 1980	12.00	6302.4	7140.0	-11.7
3 19 1980	12.00	5980.7	6730.0	-11.1
3 20 1980	12.00	5586.3	6200.0	-9.9
3 21 1980	12.00	5444.0	6070.0	-10.3
3 22 1980	12.00	5358.4	5950.0	-9.9
3 23 1980	12.00	5295.1	5910.0	-10.4
3 24 1980	12.00	5141.7	5780.0	-11.0
3 25 1980	12.00	4923.5	5540.0	-11.1
3 26 1980	12.00	4309.8	4740.0	-9.1
3 27 1980	12.00	3958.1	4350.0	-9.0
3 28 1980	12.00	3653.8	3960.0	-7.7
3 29 1980	12.00	3545.4	3830.0	-7.4
3 30 1980	12.00	3494.9	3780.0	-7.5
3 31 1980	12.00	3499.5	3770.0	-7.2
4 1 1980	12.00	3520.5	3700.0	-4.9
4 2 1980	12.00	3496.5	3620.0	-3.4
4 3 1980	12.00	3360.0	3600.0	-6.7
4 4 1980	12.00	3187.1	3360.0	-5.1
4 5 1980	12.00	3232.0	3400.0	-4.9
4 6 1980	12.00	3393.7	3540.0	-4.1
4 7 1980	12.00	3309.3	3440.0	-3.8
4 8 1980	12.00	3205.0	3380.0	-5.2
4 9 1980	12.00	3293.5	3600.0	-8.5
4 10 1980	12.00	3381.9	3600.0	-6.1
4 11 1980	12.00	3383.0	3510.0	-3.6
4 12 1980	12.00	3489.4	3730.0	-6.5
4 13 1980	12.00	3608.9	3850.0	-6.3
4 14 1980	12.00	3783.4	3950.0	-4.2
4 15 1980	12.00	3872.3	3940.0	-1.7
4 16 1980	12.00	3844.8	3910.0	-1.7
4 17 1980	12.00	4009.7	4000.0	0.2

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
4 18 1980	12.00	4327.1	4150.0	4.3
4 19 1980	12.00	4569.3	4320.0	5.8
4 20 1980	12.00	5391.0	4900.0	10.0
4 21 1980	12.00	6180.2	5460.0	13.2
4 22 1980	12.00	5565.9	4980.0	11.8
4 23 1980	12.00	5357.5	5190.0	3.2
4 24 1980	12.00	5046.9	4800.0	5.1
4 25 1980	12.00	4661.4	4570.0	2.0
4 26 1980	12.00	4421.4	4200.0	5.3
4 27 1980	12.00	4533.6	4270.0	6.2
4 28 1980	12.00	5005.5	4520.0	10.7
4 29 1980	12.00	5404.5	5070.0	6.6
4 30 1980	12.00	5414.6	4920.0	10.1
5 1 1980	12.00	5273.9	5180.0	1.8
5 2 1980	12.00	5125.1	5090.0	0.7
5 3 1980	12.00	5085.0	5180.0	-1.8
5 4 1980	12.00	5193.1	5430.0	-4.4
5 5 1980	12.00	5292.2	5570.0	-5.0
5 6 1980	12.00	5022.9	5600.0	-10.3
5 7 1980	12.00	4400.5	4800.0	-8.3
5 8 1980	12.00	3988.7	4260.0	-6.4
5 9 1980	12.00	3822.6	4040.0	-5.4
5 10 1980	12.00	3805.9	3880.0	-1.9
5 11 1980	12.00	3704.7	3650.0	1.5
5 12 1980	12.00	3553.2	3530.0	0.7
5 13 1980	12.00	3589.4	3420.0	5.0
5 14 1980	12.00	3704.0	3610.0	2.6
5 15 1980	12.00	3869.2	3730.0	3.7
5 16 1980	12.00	4051.6	4110.0	-1.4
5 17 1980	12.00	3733.6	3780.0	-1.2
5 18 1980	12.00	3563.4	3670.0	-2.9
5 19 1980	12.00	3606.9	3730.0	-3.3
5 20 1980	12.00	3660.5	3840.0	-4.7
5 21 1980	12.00	3577.9	4030.0	-11.2
5 22 1980	12.00	3113.3	3670.0	-15.2
5 23 1980	12.00	2787.2	3130.0	-11.0
5 24 1980	12.00	2636.3	2930.0	-10.0
5 25 1980	12.00	2559.4	2850.0	-10.2
5 26 1980	12.00	2473.1	2710.0	-8.7
5 27 1980	12.00	2389.7	2610.0	-8.4
5 28 1980	12.00	2335.3	2560.0	-8.8
5 29 1980	12.00	2299.6	2490.0	-7.6
5 30 1980	12.00	2274.0	2490.0	-8.7
5 31 1980	12.00	2255.7	2470.0	-8.7
6 1 1980	12.00	2062.5	2380.0	-13.3
6 2 1980	12.00	1993.4	2230.0	-10.6
6 3 1980	12.00	2018.0	2190.0	-7.9
6 4 1980	12.00	2106.0	2180.0	-3.4
6 5 1980	12.00	2284.8	2320.0	-1.5
6 6 1980	12.00	2363.3	2380.0	-0.7

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
6 7 1980	12.00	2247.3	2260.0	-0.6
6 8 1980	12.00	2168.1	2210.0	-1.9
6 9 1980	12.00	2184.8	2230.0	-2.0
6 10 1980	12.00	2193.1	2210.0	-0.8
6 11 1980	12.00	2117.5	2140.0	-1.1
6 12 1980	12.00	2176.2	2160.0	0.7
6 13 1980	12.00	2319.9	2230.0	4.0
6 14 1980	12.00	2512.0	2320.0	8.3
6 15 1980	12.00	2408.9	2310.0	4.3
6 16 1980	12.00	2279.2	2210.0	3.1
6 17 1980	12.00	2228.9	2160.0	3.2
6 18 1980	12.00	2243.5	2130.0	5.3
6 19 1980	12.00	2212.9	2110.0	4.9
6 20 1980	12.00	2151.0	2100.0	2.4
6 21 1980	12.00	2049.4	2000.0	2.5
6 22 1980	12.00	1995.7	1920.0	3.9
6 23 1980	12.00	2044.9	2020.0	1.2
6 24 1980	12.00	1825.0	1940.0	-5.9
6 25 1980	12.00	1698.7	1730.0	-1.8
6 26 1980	12.00	1594.7	1690.0	-5.6
6 27 1980	12.00	1524.4	1660.0	-8.2
6 28 1980	12.00	1476.8	1610.0	-8.3
6 29 1980	12.00	1466.2	1600.0	-8.4
6 30 1980	12.00	1478.1	1580.0	-6.4
7 1 1980	12.00	1443.1	1550.0	-6.9
7 2 1980	12.00	1381.9	1510.0	-8.5
7 3 1980	12.00	1343.1	1500.0	-10.5
7 4 1980	12.00	1305.1	1490.0	-12.4
7 5 1980	12.00	1277.5	1460.0	-12.5
7 6 1980	12.00	1238.5	1440.0	-14.0
7 7 1980	12.00	1203.5	1430.0	-15.8
7 8 1980	12.00	1156.0	1400.0	-17.4
7 9 1980	12.00	1118.9	1370.0	-18.3
7 10 1980	12.00	1091.4	1370.0	-20.3
7 11 1980	12.00	1084.8	1370.0	-20.8
7 12 1980	12.00	1047.6	1300.0	-19.4
7 13 1980	12.00	1027.9	1280.0	-19.7
7 14 1980	12.00	1013.4	1250.0	-18.9
7 15 1980	12.00	1002.3	1230.0	-18.5
7 16 1980	12.00	998.0	1220.0	-18.2
7 17 1980	12.00	990.5	1190.0	-16.8
7 18 1980	12.00	971.9	1160.0	-16.2
7 19 1980	12.00	962.5	1140.0	-15.6
7 20 1980	12.00	971.4	1130.0	-14.0
7 21 1980	12.00	962.5	1100.0	-12.5
7 22 1980	12.00	962.5	1080.0	-10.9
7 23 1980	12.00	938.1	1040.0	-9.8
7 24 1980	12.00	922.8	1020.0	-9.5
7 25 1980	12.00	913.1	999.0	-8.6
7 26 1980	12.00	907.8	980.0	-7.4

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
7 27 1980	12.00	904.5	984.0	-8.1
7 28 1980	12.00	922.1	1010.0	-8.7
7 29 1980	12.00	940.0	1030.0	-8.7
7 30 1980	12.00	938.1	1030.0	-8.9
7 31 1980	12.00	937.5	1010.0	-7.2
8 1 1980	12.00	1136.3	1100.0	3.3
8 2 1980	12.00	1197.4	1300.0	-7.9
8 3 1980	12.00	1193.5	1290.0	-7.5
8 4 1980	12.00	1182.0	1270.0	-6.9
8 5 1980	12.00	1179.7	1260.0	-6.4
8 6 1980	12.00	1180.0	1260.0	-6.3
8 7 1980	12.00	1182.3	1260.0	-6.2
8 8 1980	12.00	1173.1	1250.0	-6.1
8 9 1980	12.00	1173.4	1250.0	-6.1
8 10 1980	12.00	1179.1	1260.0	-6.4
8 11 1980	12.00	1181.3	1260.0	-6.2
8 12 1980	12.00	1175.1	1250.0	-6.0
8 13 1980	12.00	1166.8	1230.0	-5.1
8 14 1980	12.00	1165.3	1230.0	-5.3
8 15 1980	12.00	1160.8	1230.0	-5.6
8 16 1980	12.00	1161.2	1210.0	-4.0
8 17 1980	12.00	1161.9	1220.0	-4.8
8 18 1980	12.00	1152.9	1220.0	-5.5
8 19 1980	12.00	1146.2	1210.0	-5.3
8 20 1980	12.00	1144.2	1220.0	-6.2
8 21 1980	12.00	1141.0	1200.0	-4.9
8 22 1980	12.00	1141.0	1180.0	-3.3
8 23 1980	12.00	1157.4	1200.0	-3.5
8 24 1980	12.00	1155.4	1210.0	-4.5
8 25 1980	12.00	1162.9	1210.0	-3.9
8 26 1980	12.00	1161.1	1210.0	-4.0
8 27 1980	12.00	1153.7	1200.0	-3.9
8 28 1980	12.00	1158.9	1210.0	-4.2
8 29 1980	12.00	1169.0	1220.0	-4.2
8 30 1980	12.00	1172.7	1240.0	-5.4
8 31 1980	12.00	1177.2	1230.0	-4.3
9 1 1980	12.00	1381.0	1320.0	4.6
9 2 1980	12.00	1443.8	1500.0	-3.7
9 3 1980	12.00	1449.1	1500.0	-3.4
9 4 1980	12.00	1456.4	1510.0	-3.5
9 5 1980	12.00	1454.0	1520.0	-4.3
9 6 1980	12.00	1453.4	1500.0	-3.1
9 7 1980	12.00	1462.1	1490.0	-1.9
9 8 1980	12.00	1470.9	1510.0	-2.6
9 9 1980	12.00	1459.4	1510.0	-3.4
9 10 1980	12.00	1466.9	1500.0	-2.2
9 11 1980	12.00	1497.4	1510.0	-0.8
9 12 1980	12.00	1499.9	1560.0	-3.9
9 13 1980	12.00	1501.3	1550.0	-3.1
9 14 1980	12.00	1507.2	1560.0	-3.4

COMPARISON OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000600
FROM 10 1 1979 TO 9 30 1980
Q1 IS DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
Q2 IS DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

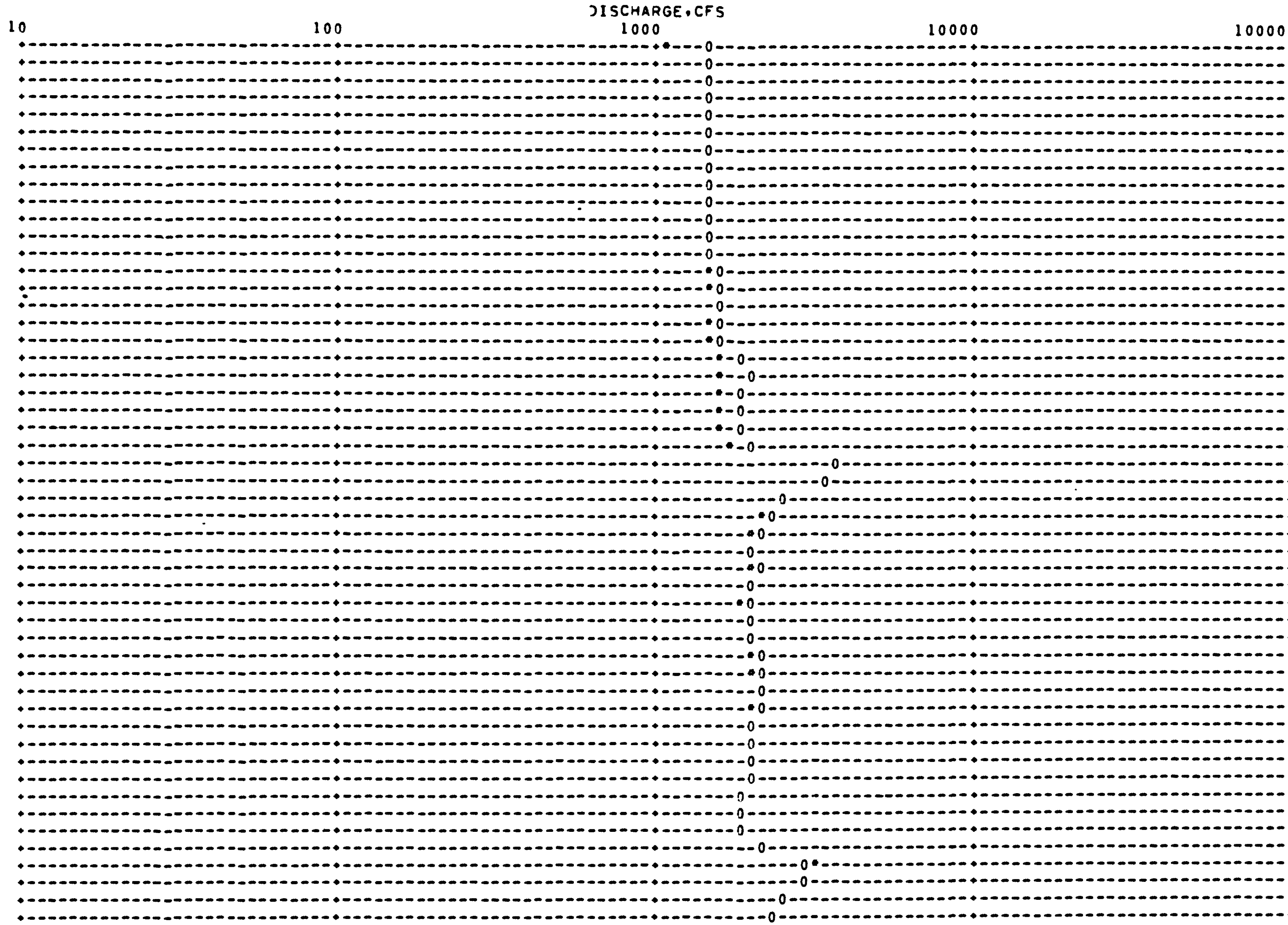
DATE	TIME	Q1 (CFS)	Q2 (CFS)	ERROR (%)
9 15 1980	12.00	1497.2	1560.0	-4.0
9 16 1980	12.00	1468.9	1530.0	-4.0
9 17 1980	12.00	1452.0	1490.0	-2.5
9 18 1980	12.00	1463.9	1510.0	-3.1
9 19 1980	12.00	1466.2	1520.0	-3.5
9 20 1980	12.00	1463.0	1520.0	-3.8
9 21 1980	12.00	1471.2	1520.0	-3.2
9 22 1980	12.00	1495.8	1540.0	-2.9
9 23 1980	12.00	1520.5	1560.0	-2.5
9 24 1980	12.00	1519.1	1560.0	-2.6
9 25 1980	12.00	1524.1	1560.0	-2.3
9 26 1980	12.00	1525.1	1560.0	-2.2
9 27 1980	12.00	1523.9	1560.0	-2.3
9 28 1980	12.00	1525.5	1560.0	-2.2
9 29 1980	12.00	1520.5	1550.0	-1.9
9 30 1980	12.00	1516.0	1550.0	-2.2

***** 1980 WY SUMMARY *****
MEAN ERROR (%) FOR 366 DAYS = 5.80
MEAN - ERROR (%) FOR 253 DAYS = -6.17
MEAN + ERROR (%) FOR 113 DAYS = 4.97
Q1 VOLUME (SFD) = 1321710.
Q2 VOLUME (SFD) = 1325723.
VOLUME ERROR (%) = -0.30
RMS ERROR (%) = 7.57

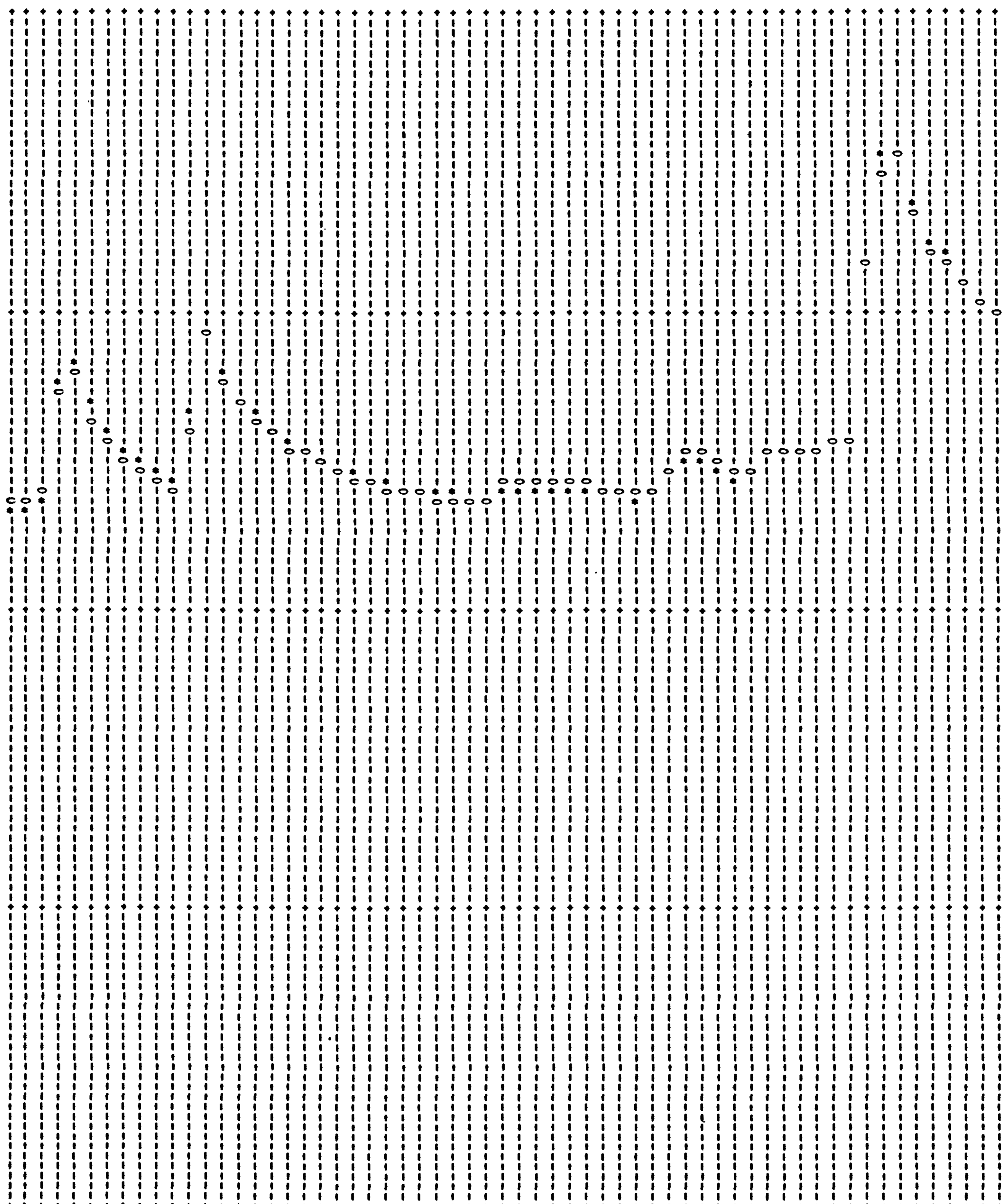
56 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 5 PERCENT
84 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 10 PERCENT
93 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 15 PERCENT
98 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 20 PERCENT
99 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS <= 25 PERCENT
1 PERCENT OF TOTAL OBSERVATIONS HAD ERRORS > 25 PERCENT

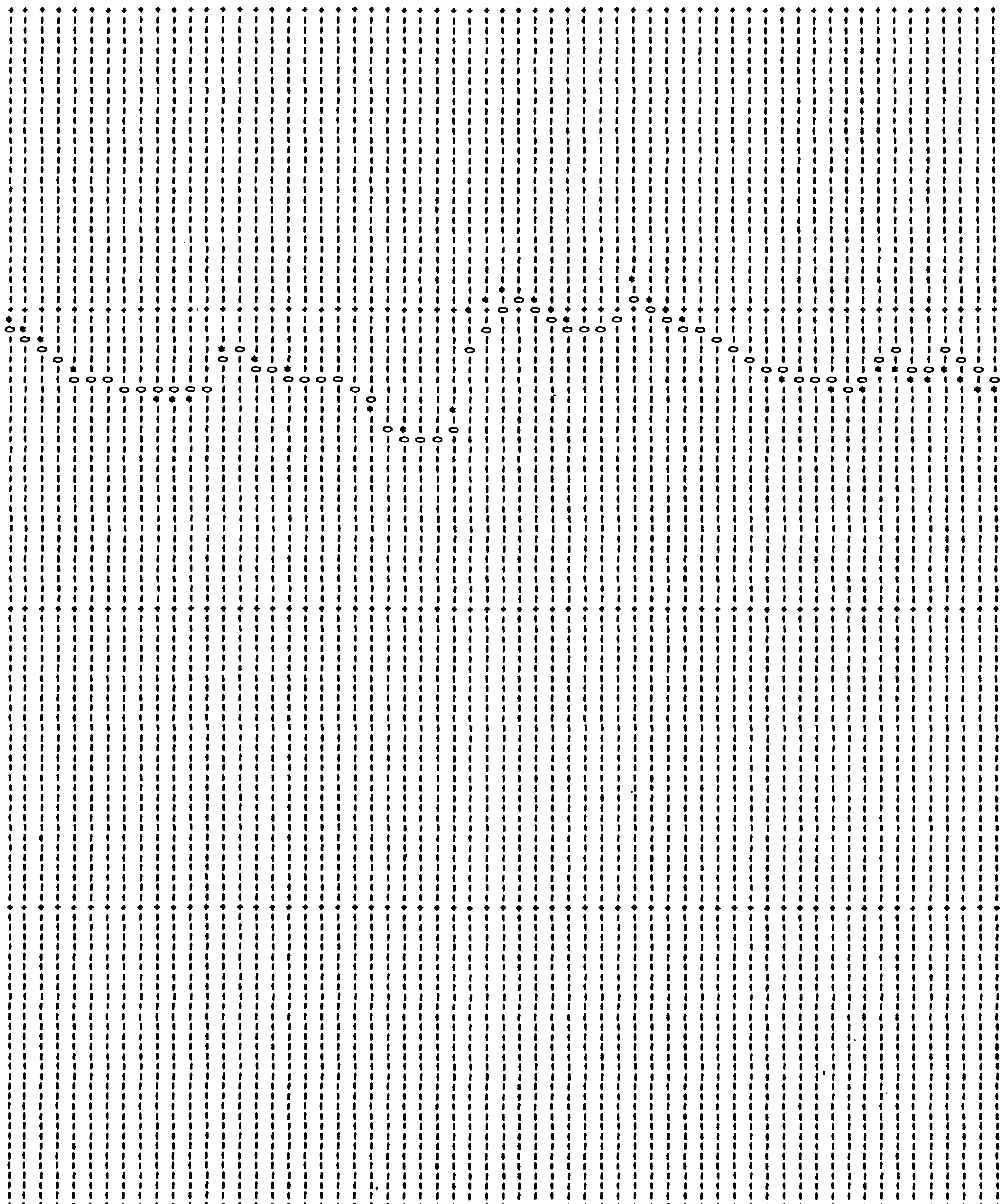
*****STEP = 9 DATA INPUT CARDS*****
PLOT,F=29,S=24,QMIN=10 00000610
PLOT OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000620

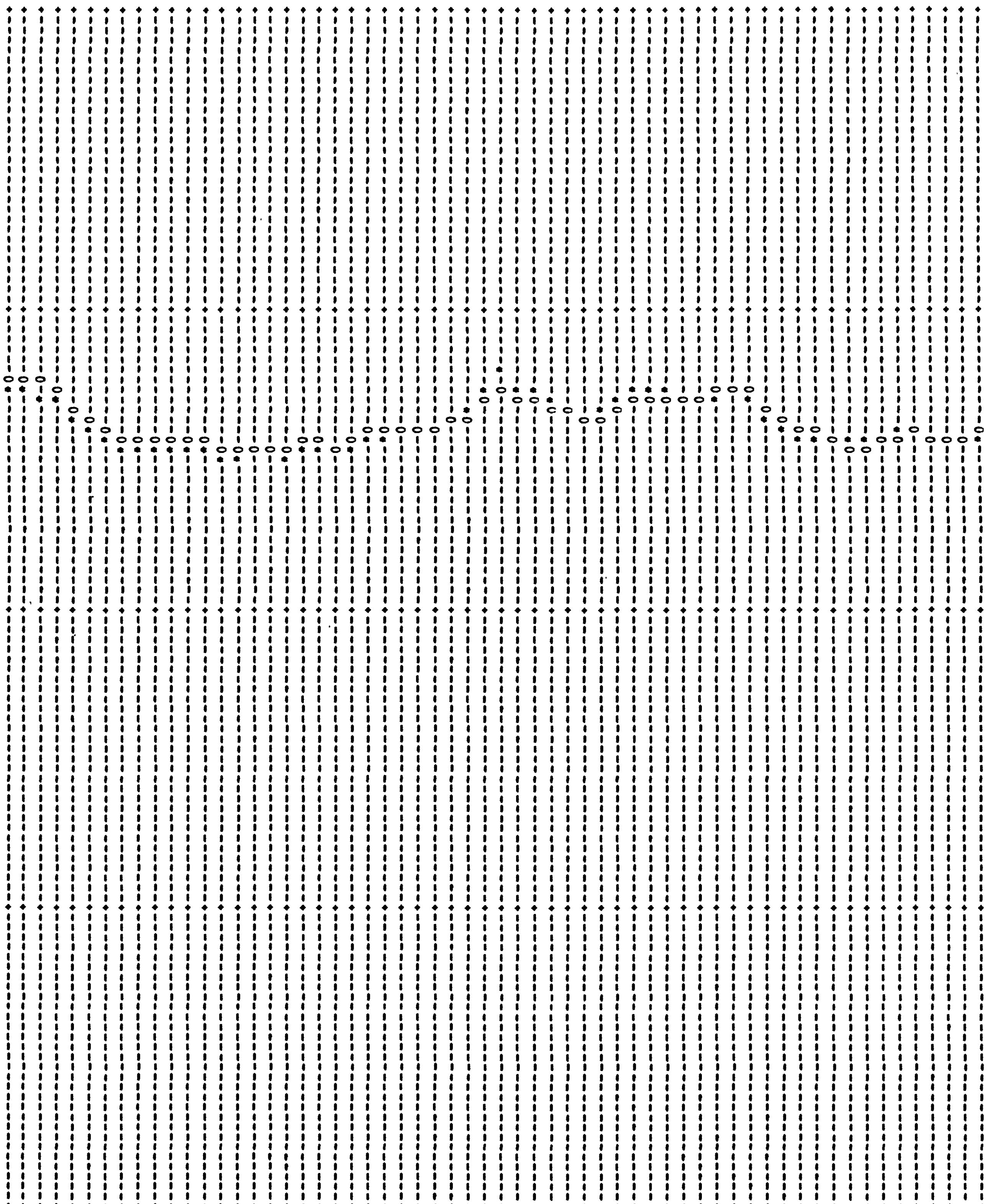
PLOT OF SIMULATED AND OBSERVED FLOWS AT 11520500 00000620
FROM 10 1 1979 TO 9 30 1980
* = DISCHARGE AT STATION 11519500, INDEXED STATION FOR UNGAGED WITH R=864/653=1.34
0 = DISCHARGE AT STATION 11520500, KLAMATH RIVER NR SEIAD VALLEY CALIF

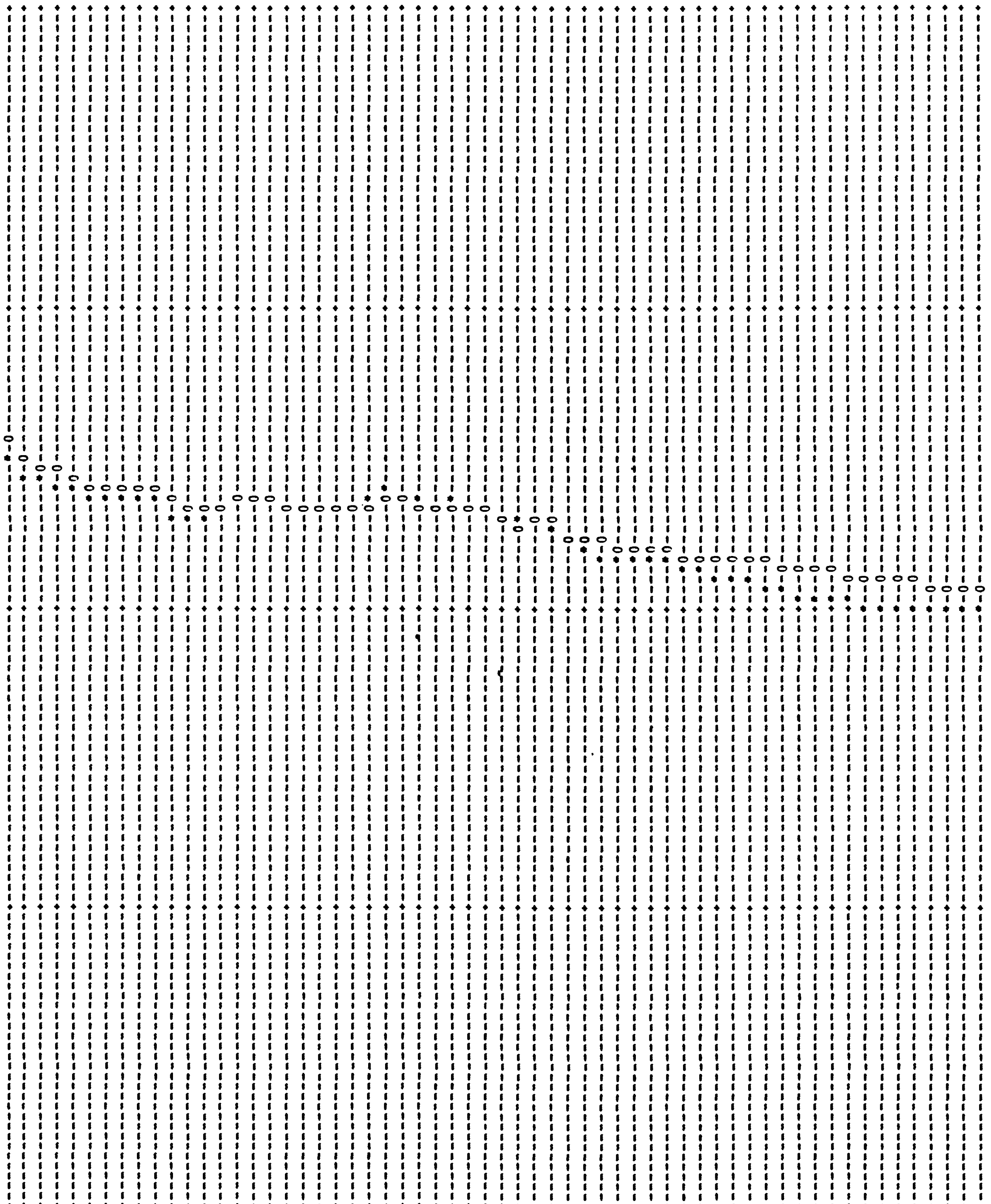


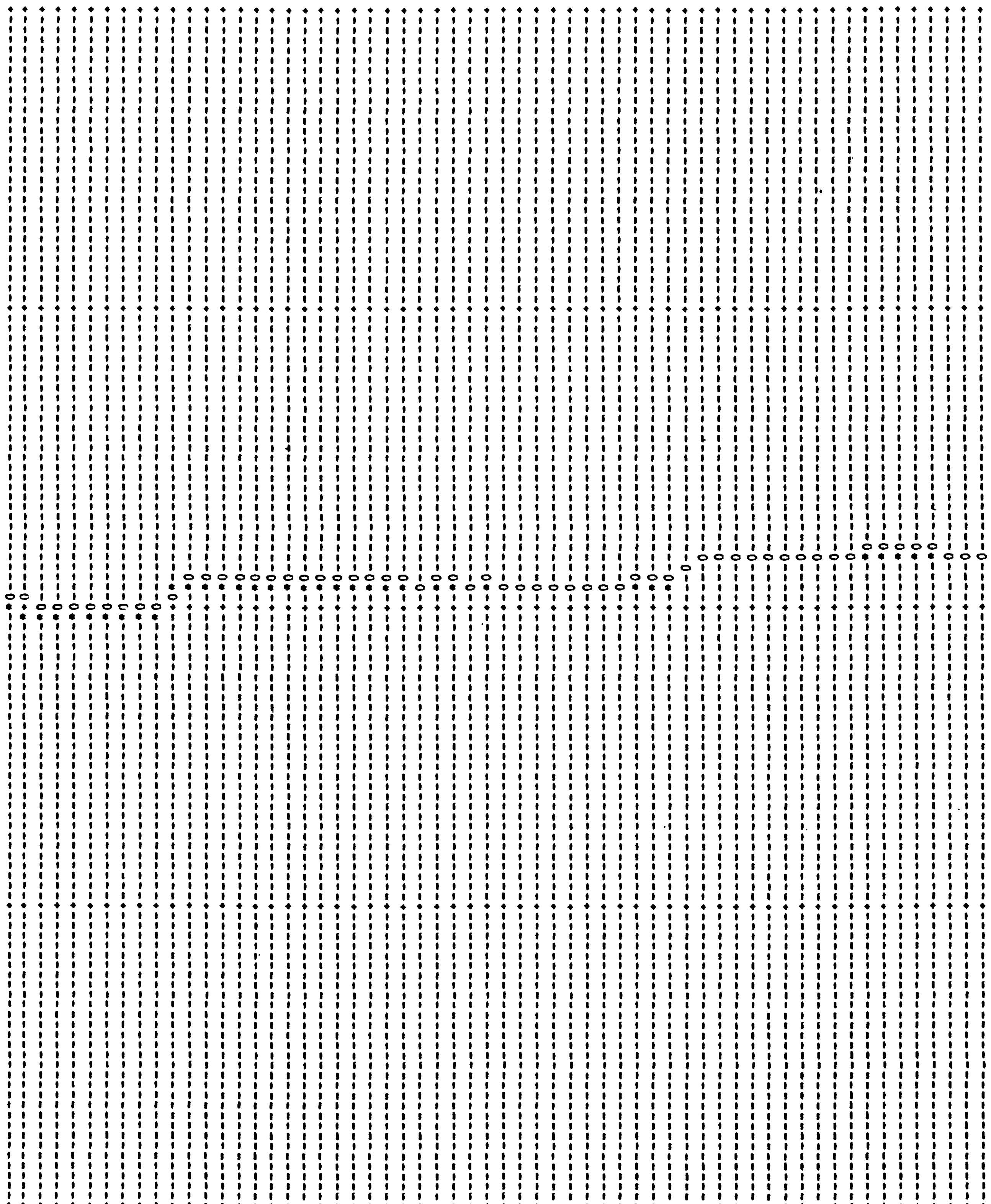
DATE

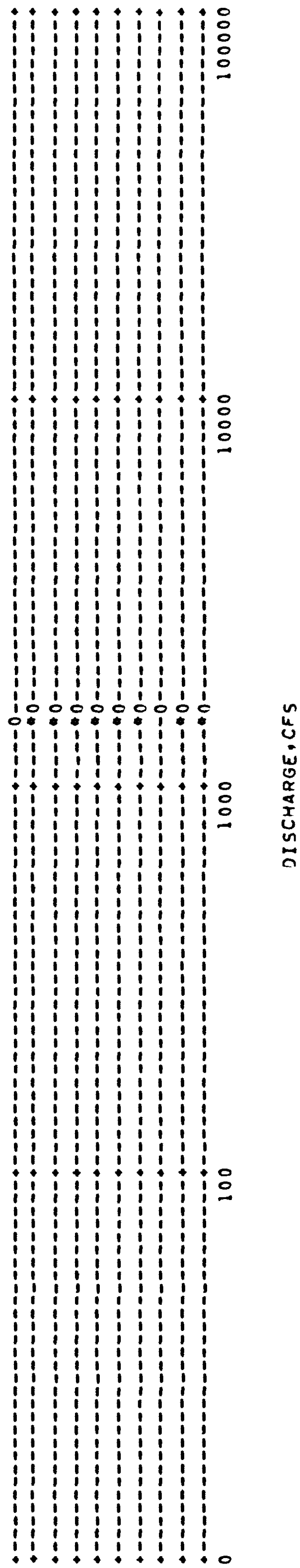











10
100
1000
10000
100000
DISCHARGE,CFS