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GENERALIZED COMPUTER PROGRAM

HEC-1

Flood Hydrograph Package

User's Manual

June 1998

CPD-1A
Version 4.1

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User's manual for a watershed computer program model that simulates the precipitation-runoff process. Watershed is represented by basic model components; precipitation runoff, channel routing, reservoir routing, diversion and hydrograph combinations that are used to estimate hydrographs at various locations. Other capabilities include automatic parameter estimation and flood damage analysis. The model is limited to single event analysis and routing techniques do not account for downstream backwater conditions.

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The previous versions of HEC-1 are as follows:

Version 1.0	October 1968
Version 2.0	January 1973
Version 3.0	September 1981
Version 4.0	September 1990
Version 4.0.1E	April 1991 (Large-Array Version with Extended Memory Manager)

Preface

Previous versions of this manual were created out of the need to describe a new release of the HEC-1 program which included significant enhancements and improvements. This version, however, was motivated by the need to put the HEC-1 package in order for a final release during the transition to its replacement, the Hydrologic Modeling System, HEC-HMS. Subsequent watershed modeling improvements are being focused on HEC-HMS which was released in March 1998.

The functional differences between the 1990 version of HEC-1 and the 1998 version are not significant. Therefore, the content and format of this manual does not vary appreciably from the previous, 1990, version. Several small errors have been corrected, and references to other updated documents have been changed to include the new documents.

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Foreword

The HEC-1, Flood Hydrograph Package, computer program was originally developed in 1967 by Leo R. Beard and other members of the Hydrologic Engineering Center (HEC) staff. The first version of the HEC-1 package program was published in October 1968. It was expanded and revised and published again in 1969 and 1970. The first package version represented a combination of several smaller programs which had previously been operated independently. These computer programs are still available at the HEC as separate programs.

In 1973, the 1970 version of the program underwent a major revision. The computational methods used by the program remained basically unchanged; however, the input and output formats were almost completely restructured. These changes were made in order to simplify input requirements and to make the program output more meaningful and readable.

In 1981, major revisions were made to the 1973 version of the program. The program input and output formats were completely revised and the computational capabilities of the dam-break (HEC-1DB), project optimization (HEC-1GS) and kinematic wave (HEC-1KW) special versions of HEC-1 were combined in the one program. The new program included the powerful analysis features available in all the previous programs, together with some additional capabilities, in a single easy to use package.

A **microcomputer version (PC version)** of the HEC-1 program was developed in late 1984. The PC version contained all the hydrologic and hydraulic computation capabilities of the mainframe HEC-1; however, the flood damage and ogee spillway capabilities were not included because of microcomputer memory and compiler limitations at that time.

The 1990 version of HEC-1 represented improvements and expansions to the hydrologic simulation capabilities together with interfaces to the HEC Data Storage System, DSS. The entire HEC-1 package, including the DSS interface, was made available on the PC and HARRIS minicomputers. The DSS capability allowed storage and retrieval of data from/for other computer programs as well as the creation of report-quality graphics and tables. New hydrologic capabilities included Green and Ampt infiltration, Muskingum-Cunge flood routing, reservoir releases input over time, and improved numerical solution of kinematic wave equations. The Muskingum-Cunge routing may also be used for the collector and main channels in a kinematic wave land surface runoff calculation.

The current version, 1998, is anticipated to be the final release of HEC-1. Future hydrology model development efforts will be directed towards the successor to HEC-1, the Hydrologic Modeling System (HEC-HMS). As HEC-1 had reached a certain level of maturity at the time of this final release, the changes and additions are not as significant as in past new versions. A few minor changes were made to computational methods. The Holtan loss method was changed to restrict the soil moisture capacity from growing indefinitely, and the storage routing was made more robust for routing of off-stream detention facilities. Other changes were made to the HEC-1 package to take advantage of the latest personal computer environment. Whereas the 1990 version was limited to using conventional computer memory, and the 1991 extended memory version used a memory manager incompatible with certain other applications, this latest version is strictly an extended memory program and is much more widely compatible with commercial software. This version also reflects the eight years of error corrections and code improvement which have occurred since the last release.

Up-to-date information about the program is available from the Center. While the Government is not responsible for the results obtained when using the programs, assistance in resolving malfunctions in the programs will be furnished to the extent that time and funds are available. It is desired that users notify their vendors or the Center of inadequacies in the program.

Section 1

Introduction

1.1 Model Philosophy

The HEC-1 model is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component models an aspect of the precipitation-runoff process within a portion of the basin, commonly referred to as a subbasin. A component may represent a surface runoff entity, a stream channel, or a reservoir. Representation of a component requires a set of parameters which specify the particular characteristics of the component and mathematical relations which describe the physical processes. The result of the modeling process is the computation of streamflow hydrographs at desired locations in the river basin.

1.2 Overview of Manual

This manual describes the concepts, methodologies, input requirements and output formats used in HEC-1. A brief description of each of the model capabilities and the organization of this manual is given below.

Stream Network Model Concepts and Methodologies

Sections 2, 3, and 4: A general description of the components of the HEC-1 watershed (stream network) simulation capability is given in Section 2. The stream network capability (i.e., simulating the precipitation-runoff process in a river basin) is of central importance to virtually any application of HEC-1. Other capabilities of HEC-1 are built around this stream network function. Section 3 describes the detailed computational methods used to simulate the stream network. The use of automatic techniques to determine best estimates of the model parameters is described in Section 4.

Additional Flood Hydrograph Simulation Options

Section 5: Multiplan-multiflood analysis allows the simulation of several ratios of a design flood for several different plans (or characterizations) of a stream network in a single computer run.

Section 6: Dam-break simulation provides the capability to analyze the consequences of dam overtopping and structural failures.

Section 7: The depth-area option computes flood hydrographs preserving a user-supplied precipitation depth versus area relation throughout a stream network.

Flood Damage Analysis

Section 8: The economic assessment of flood damage can be determined for damage reaches defined in a multiplan-multiflood analysis. The expected annual damage occurring in a damage reach and the benefits accrued due to a flood control plan are calculated based on user-supplied damage data and on calculated flows for the reach.

Section 9: The optimal size of a flood control system can be estimated using an optimization procedure provided by HEC-1. The option utilizes data provided for the economic assessment option together with data on flood control project costs to determine a system which maximizes net benefits with or without a specified degree of protection level for the components.

Program Usage

Section 10: The data input conventions are discussed, emphasizing the data card groups used for the various program options.

Section 11: Program output capabilities and error messages are explained.

Section 12: Test examples are displayed, including example input data and computed output generated by the program.

Section 13: The computer hardware requirements are discussed, and computer run times for the example problems are given. A programmers supplement provides detailed information about the operational characteristics of the computer program.

Section 14: References

Appendix A: The input description details the use of each data record and input variable in the program.

Appendix B: A description of the HEC-1 interface capabilities with the HEC Data Storage System.

1.3 Theoretical Assumptions and Limitations

A river basin is represented as an interconnected group of subareas. The assumption is made that the hydrologic processes can be represented by model parameters which reflect average conditions within a subarea. If such averages are inappropriate for a subarea then it would be necessary to consider smaller subareas within which the average parameters do apply. Model parameters represent temporal as well as spatial averages. Thus the time interval to be used should be small enough such that averages over the computation interval are applicable.

There are several important limitations of the model. Simulations are limited to a single storm due to the fact that provision is not made for soil moisture recovery during periods of no precipitation. The model results are in terms of discharge and not stage, although stages can be printed out by the program based on a user specified rating curve. A hydraulic computer program (HEC-RAS for example) is generally used in conjunction with HEC-1 to obtain stages. Streamflow routings are performed by hydrologic routing methods and do not reflect the full St. Venant equations which are required for very flat river slopes. Reservoir routings are based on the modified Puls techniques which are not appropriate where reservoir gates are operated to reduce flooding at downstream locations.

1.4 Computer Requirements

The HEC-1 program is written in ANSI standard FORTRAN77 and requires 2.5 Mb total memory. Disk storage is needed for the 16 output and scratch files used by the program.

For microcomputers (PC's), a MENU package is available to facilitate file management, editing with HELP, execution, and display of results. For further information on the program's computer requirements, see section 13 and the installation instructions provided with the program.

1.5 Acknowledgments

This manual was written by David Goldman and Paul Ely. Paul Ely was also responsible for the design and implementation of the new computer code. John Tracy implemented the first microcomputer version and Gary Brunner was responsible for the 1990 version. Troy Nicolini was responsible for this final version. John Peters, Darryl Davis and Arthur Pabst made many excellent contributions to the development of the modeling concepts and the documentation. The development of the past two versions of HEC-1 was managed by Arlen Feldman, Chief of the HEC Research Division. The word processing for this document was performed by Cathy Lewis, Denise Nakaji, and Penni Baker. This electronic version of the document was created by Anthony Novello. James Doan edited and assembled this final document and created files for the web.

Section 2

Model Components

The stream network simulation model capability is the foundation of the HEC-1 program. All other program computation options build on this option's capability to calculate flood hydrographs at desired locations in a river basin. Section 2.1 discusses the conceptual aspects of using the HEC-1 program to formulate a stream network model from river basin data. Section 2.2 discusses the model formulation as a step-by-step process, where the physical characteristics of the river basin are systematically represented by an interconnected group of HEC-1 model components. Sections 2.3 through 2.8 discuss the functions of each component in representing individual characteristics of the river basin.

2.1 Stream Network Model Development

A river basin is subdivided into an interconnected system of stream network components (e.g., Figure 2.1) using topographic maps and other geographic information. A basin schematic diagram (e.g., Figure 2.2) of these components is developed by the following steps:

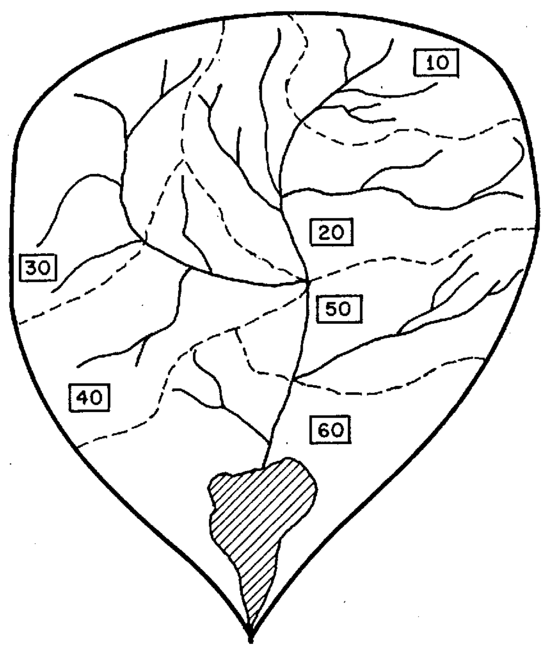


Figure 2.1 Example River Basin

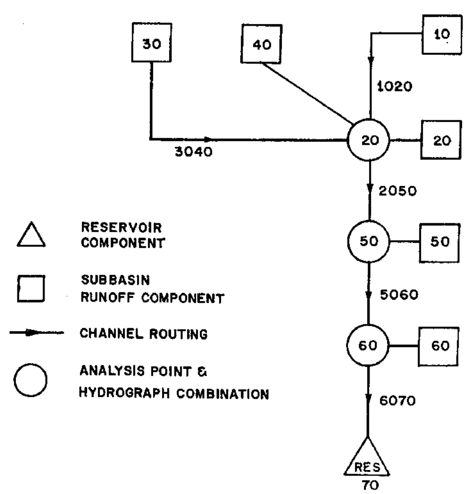


Figure 2.2 Example River Basin Schematic

(1) The study area watershed boundary is delineated first. In a natural or open area this can be done from a topographic map. However, supplementary information, such as municipal drainage maps, may be necessary to obtain an accurate depiction of an urban basin's extent.

(2) Segmentation of the basin into a number of subbasins determines the number and types of stream network components to be used in the model. Two factors impact on the basin segmentation: the study purpose and the hydrometeorological variability throughout the basin. First, the study purpose defines the areas of interest in the basin, and hence, the points where subbasin boundaries should occur.

Second, the variability of the hydrometeorological processes and basin characteristics impacts on the number and location of subbasins. Each subbasin is intended to represent an area of the watershed which, on the average, has the same hydraulic/hydrologic properties. Further, the assumption of uniform precipitation and infiltration over a subbasin becomes less accurate as the subbasin becomes larger. Consequently, if the subbasins are chosen appropriately, the average parameters used in the components will more accurately model the subbasins.

(3) Each subbasin is to be represented by a combination of model components. Subbasin runoff, river routing, reservoir, diversion and pump components are available to the user.

(4) The subbasins and their components are linked together to represent the connectivity of the river basin. HEC-1 has available a number of methods for combining or linking together outflow from different components. This step finalizes the basin schematic.

2.2 Land Surface Runoff Component

The subbasin land surface runoff component, such as subbasins 10, 20, 30, etc. in Figure 2.1 or equivalently as element 10 in Figure 2.2, is used to represent the movement of water over the land surface and in stream channels. The input to this component is a precipitation hyetograph. Precipitation excess is computed by subtracting infiltration and detention losses based on a soil water infiltration rate function. Note that the rainfall and infiltration are assumed to be uniform over the subbasin. The resulting rainfall excesses are then routed by the unit hydrograph or kinematic wave techniques to the outlet of the subbasin producing a runoff hydrograph. The unit hydrograph technique produces a runoff hydrograph at the most downstream point in the subbasin. If that location for the runoff computation is not appropriate, it may be necessary to further subdivide the subbasin or use the kinematic wave method to distribute the local inflow.

The kinematic wave rainfall excess-to-runoff transformation allows for the uniform distribution of the land surface runoff along the length of the main channel (e.g., subbasin 60, Figure 2.2, runoff could be laterally distributed between points 50 and 60 instead of being lumped at point 60). This uniform distribution of local inflow (subbasin runoff) is particularly important in areas where many lateral channels contribute flow along the length of the main channel.

Base flow is computed relying on an empirical method and is combined with the surface runoff hydrograph to obtain flow at the subbasin outlet. The methods for simulating subbasin precipitation, infiltration and runoff are described in Sections 3.1 through 3.5.

2.3 River Routing Component

A river routing component, element 1020, Figure 2.2, is used to represent flood wave movement in a river channel. The input to the component is an upstream hydrograph resulting from individual or combined contributions of subbasin runoff, river routings or diversions. If the kinematic wave method is used, the local subbasin distributed runoff (e.g., subbasin 60 as described above) is also input to the main channel and combined with the upstream hydrograph as it is routed to the end of the reach. The hydrograph is routed to a downstream point based on the characteristics of the channel. There are a number of techniques available to route the runoff hydrograph which are described in Section 3.6 of this report.

2.4 Combined Use of River Routing and Subbasin Runoff Components

Consider the use of subbasin runoff components 10 and 20 and river routing reach 1020 in Figure 2.2 and the corresponding subbasins 10 and 20 in Figure 2.1 The runoff from component 10 is calculated and routed to control point 20 via routing reach 1020. The runoff hydrograph at analysis point 20 can be calculated by methods employing either the unit hydrograph or kinematic wave techniques. In the case that the unit hydrograph technique is employed, runoff from component 10 is calculated and routed to control point 20 via routing reach 1020. Runoff from subbasin 20 is calculated and combined with the outflow hydrograph from reach 1020 at analysis point 20. Alternatively, runoff from subbasins 10 and 20 can be combined before routing in the case that the lateral inflows from subarea 20 are concentrated near the upstream end of reach 1020. In the case that the kinematic wave technique is employed, the runoff from subbasin 20 is modeled as a uniformly distributed lateral inflow to reach 1020. The runoff from subbasin 10 is routed in combination with this lateral inflow via reach 1020 to analysis point 20.

A suitable combination of the subbasin runoff component and river routing components can be used to represent the intricacies of any rainfall-runoff and stream routing problem. The connectivity of the stream network components is implied by the order in which the data components are arranged. Simulation must always begin at the uppermost subbasin in a branch of the stream network. The simulation (succeeding data components) proceeds downstream until a confluence is reached. **Before simulating below the confluence, all flows above that confluence must be computed and routed to that confluence.** The flows are combined at the confluence and the combined flows are routed downstream. In Figure 2.2, all flows tributary to control point 20 must be combined before routing through reach 2050.

2.5 Reservoir Component

Use of the reservoir component is similar to that of the river routing component described in Section 2.3. The reservoir component can be used to represent the storage-outflow characteristics of a reservoir, lake, detention pond, highway culvert, etc. The reservoir component functions by receiving upstream inflows and routing these inflows through a reservoir using storage routing methods described in Section 3.6. Reservoir outflow is solely a function of storage (or water surface elevation) in the reservoir and not dependent on downstream controls.

2.6 Diversion Component

The diversion component is used to represent channel diversions, stream bifurcations, or any transfer of flow from one point of a river basin to another point in or out of the basin. The diversion component receives an upstream inflow and divides the flow according to a user prescribed rating curve as described in Section 3.7.

2.7 Pump Component

The pump component can be used to simulate action of pumping plants used to lift runoff out of low lying ponding areas such as behind levees. Pump operation data describes the number of pumps, their capacities, and "on" and "off" elevations. Pumping simulation is accomplished in the level-pool routing option described in Section 3.6.5. Pumped flow can be retrieved in the same manner as diverted flow.

2.8 Hydrograph Transformation

The Hydrograph Transformation options provide a capability to alter computed flows based on user-defined criteria. Although this does not represent a true watershed component, the hydrograph transformation options may be useful in performing a sensitivity analysis or for parameter estimation. The hydrograph transformation options are: ratios of ordinates; hydrograph balance; and local flow computation from a given total flow. The ratio of ordinates and hydrograph balance adjust the computed hydrograph by a constant fraction or a volume-duration relationship, respectively (see BA and HB records in Appendix A, Input Description). The local flow option has a dual purpose (see HL record in the Input Description). First, the difference between a computed and a given hydrograph (e.g., observed flow) is determined and shown as the local flow. Second, the given hydrograph is substituted for the computed hydrograph for the remaining watershed simulations.

Section 3

Rainfall-Runoff Simulation

The HEC-1 model components are used to simulate the rainfall-runoff process as it occurs in an actual river basin. The model components function based on simple mathematical relationships which are intended to represent individual meteorologic, hydrologic and hydraulic processes which comprise the precipitation-runoff process. These processes are separated into precipitation, interception/infiltration, transformation of precipitation excess to subbasin outflow, addition of baseflow and flood hydrograph routing. The subsequent sections discuss the parameters and computation methodologies used by the model to simulate these processes. The computation equations described are equally applicable to English or metric units except where noted.

3.1 Precipitation

3.1.1 Precipitation Hyetograph

A precipitation hyetograph is used as the input for all runoff calculations. The specified precipitation is assumed to be basin average (i.e., uniformly distributed over the subbasin). Any of the options used to specify precipitation produce a hyetograph such as that shown in Figure 3.1. The hyetograph represents average precipitation (either rainfall or snowfall) depths over a computation interval.

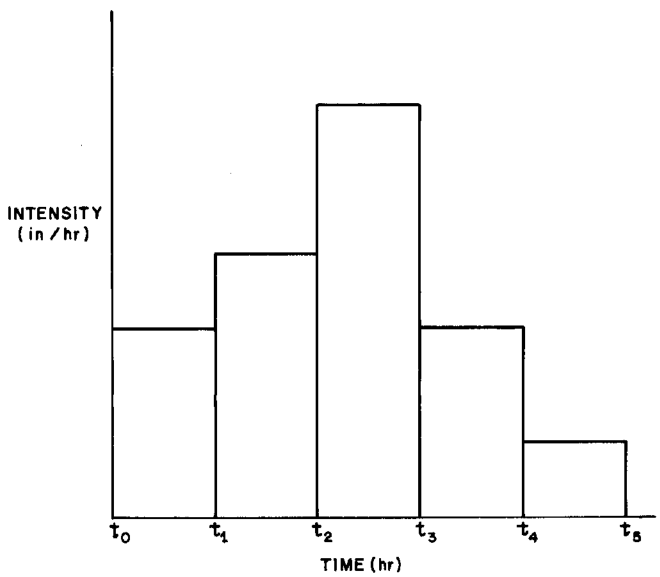


Figure 3.1 Rainfall Hyetograph

3.1.2 Historical Storms

Precipitation data for an observed storm event can be supplied to the program by either of two methods:

(1) **Basin-Average Precipitation.** Any storm may be specified for a subbasin as a total amount of precipitation for the storm and a temporal pattern for distributing the total precipitation.

(2) **Weighted Precipitation Gages.** The total storm precipitation for a subbasin may be computed as the weighted average of measurements from several gages according to the following equations:

$$\mathrm{PRCPA} = \frac{\sum_{J=1}^{n} \mathrm{PRCPN(J)} \times \mathrm{WTN(J)}}{\sum_{J=1}^{n} \mathrm{WTN(J)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

where PRCPA is the subbasin-average total precipitation, PRCPN(J) is the total precipitation for gage J, WTN(J) is the relative weight for gage J, and n is the number of gages.

If normal annual precipitation for the subbasin is given, equation (3.1) is modified to include weighting by station normal annual precipitation.

$$\mathrm{PRCPA} = \mathrm{SNAP} \times \frac{\sum_{J=1}^{n} \mathrm{PRCPN(J)} \times \mathrm{WTN(J)}}{\sum_{J=1}^{n} \mathrm{ANAPN(J)} \times \mathrm{WTN(J)}} \quad \ldots\ldots\ldots\ldots \quad (3.2)$$

where ANAPN is the station normal annual precipitation, and SNAP is the subbasin-average normal annual precipitation. Use of this option may be desirable in cases where precipitation measurements are known to be biased. For example, data obtained from a gage located on the floor of a valley may consistently underestimate subbasin average precipitation for higher elevations. ANAPN may be used to adjust for this bias.

The temporal pattern for distribution of the storm-total precipitation is computed as a weighted average of temporal distributions from recording stations:

$$\mathrm{PRCP(I)} = \frac{\sum_{J=1}^{n} \mathrm{PRCP(I,J)} \times \mathrm{WTR(J)}}{\sum_{J=1}^{n} \mathrm{WTR(J)}} \quad \ldots\ldots\ldots\ldots \quad (3.3)$$

where PRCP(I) is the basin-average precipitation for the Ith time interval, PRCPR(I,J) is the recording station precipitation for the Ith time interval, and WTR(J) is the relative weight for gage J.

The subbasin-average hyetograph is computed using the temporal pattern, PRCP, to distribute the total, PRCPA.

3.1.3 Synthetic Storms

Synthetic storms are frequently used for planning and design studies. Criteria for synthetic storms are generally based on a detailed analysis of long term precipitation data for a region. There are three methods in HEC-1 for generating synthetic storm distributions:

(1) **Standard Project Storm**. The procedure for computing Standard Project Storms, SPS, programmed in HEC-1 is applicable to basins of area 10 to 1,000 square miles located east of 105° longitude. The SPS is determined by specifying an index precipitation, SPFE, a storm reduction coefficient, TRSPC, and the area over which the storm occurs, TRSDA. SPFE and TRSPC are determined by referring to manual EM-1110-2-1411 (Corps of Engineers, 1952). A total storm depth is determined and distributed over a 96-hour duration based on the following formulas which were derived from design charts in the referenced manual.

$$\mathrm{R24HR(3)} = 182.15 - 14.3537 \times \ln(\mathrm{TRSDA} + 80.0) \qquad (3.4)$$

$$\mathrm{R24HR(1)} = 3.5$$

$$\mathrm{R24HR(2)} = 15.5$$

$$\mathrm{R24HR(4)} = 6.0$$

where R24HR(I) is the percent of the index precipitation occurring during the Ith 24-hour period.

Each 24-hour period is divided into four 6-hour periods. The ratio of the 24-hour precipitation occurring during each 6-hour period is calculated as

$$\mathrm{R6HR(3)} = \frac{13.42}{(\mathrm{SPFE} + 11.0)^{0.93}} \qquad (3.5)$$

$$\mathrm{R6HR(2)} = 0.055 \times (\mathrm{SPFE} - 6.0)^{0.51} \qquad (3.6)$$

$$\mathrm{R6HR(4)} = 0.5 \times (1.0 - \mathrm{R6HR(3)} \times \mathrm{R6HR(2)}) + 0.0165$$

$$\mathrm{R6HR(1)} = \mathrm{R6HR(4)} - 0.033$$

where R6HR(I) is the ratio of 24-hour precipitation occurring during the Ith 6-hour period and SPFE is the index precipitation in inches.

The precipitation for each time interval, except during the peak 6-hour period, is computed as

$$\mathrm{PRCP} = 0.01 \times \mathrm{R24HR} \times \mathrm{R6HR} \times \mathrm{SPFE} \times \frac{\mathrm{TRHR}}{6} \qquad (3.7)$$

where TRHR is the computation time interval in hours.

The peak 6-hour precipitation of each day is distributed according to the percentages in Table 3.1 If time intervals less than one hour are used, the peak 1-hour precipitation is distributed according to the percentages in Table 3.2. **The time interval must divide evenly into one hour.** When the time interval is larger than shown in Tables 3.1 and 3.2,

Table 3.1

Distribution of Maximum 6-hour
SPS Or PMP In Percent of 6-hour Amount

Duration Hours	EM 1110-2-1411 Criteria (Default)	Southwestern Division* Criteria for PMP (Optional)
1	10	4
2	12	8
3	15	19
4	38	50
5	14	11
6	11	8

*Distribution of 100-yr precipitation at St. Louis, MO, based on NOAA Technical Memorandum NWS Hydro - 35

the percentage for the peak time interval is the sum of the highest percentages; e.g. for a 2-hour time interval, the values are (14 + 12)%, (38 + 15)%, and (11 + 10)%. The interval with the largest percentage is preceded by the second largest and followed by the third largest. The second largest percentage is preceded by the fourth largest, the third largest percentage is followed by the fifth largest, etc.

Table 3.2
Distribution of Maximum 1-Hour SPS OR PMP*

Duration Hours	Percent of Maximum 1-Hour Precipitation in Each Time Interval	Accumulated Percent of Precipitation
5	3	3
10	4	7
15	5	12
20	6	18
25	9	27
30	17	44
35	25	69
40	11	80
45	8	88
50	5	93
55	4	97
60	3	100

*Distribution of 100-yr precipitation at St. Louis, MO, based on NOAA Technical Memorandum NWS **Hydro** - 35

(2) **Probable Maximum Precipitation.** Current probable maximum precipitation, PMP, computation methods are not available in HEC-1. The PMP must be determined according to the National Weather Service's Hydrometeorological Reports Nos. 36, 43, 49, 51, 52, or 55A, depending upon geographic location. Computer program HMR52 (HEC, 1984) is available to assist with PMP and Probable Maximum Storm determination for the eastern United States. The PMP computed from HMR52 or any other method may be input to HEC-1 to calculate runoff.

The PMP computation procedure programmed in HEC-1 is that required by the outdated Hydrometeorological Report No. 33 (HMR No. 33, National Weather Service, 1956). HMR No. 33 has been superseded by HMR Nos. 51 and 52. The following HMR No. 33 procedure has been retained in HEC-1 for recomputation of previous studies. The method requires an index precipitation, PMS, which can be determined by referring to HMR No. 33 (National Weather Service, 1956). The minimum duration of a PMP is 24 hours, and it may last up to 96 hours. The day with the largest amount of precipitation is preceded by the second largest and followed by the third largest. The fourth largest precipitation day precedes the second largest. The distribution of 6-hour precipitation during each day is according to the following ratios:

$$R6HR(1) = 0.4\frac{(R24 - R12)}{R24} \qquad (3.8a)$$

$$R6HR(2) = \frac{R12 - R6}{R24} \qquad (3.8b)$$

$$R6HR(3) = \frac{R6}{R24} \qquad (3.8c)$$

$$R6HR(4) = 0.6\frac{(R24 - R12)}{R24} \qquad (3.8d)$$

where R6HR(I) is the ratio of 24-hour precipitation occurring during Ith 6-hour period of a day, R6 is the maximum 6-hour precipitation in percent of the PMS index precipitation, R12 is the maximum 12-hour precipitation in percent of PMS, and R24 is the maximum 24-hour precipitation in percent of PMS. Precipitation is then distributed as for the standard project storm.

A transposition coefficient can be applied to reduce the precipitation on a river basin when the storm area is larger than the river basin area. The transposition coefficient may be supplied or computed by the following equation in accordance with the Corps Engineering Circular EC 1110-2-27 (1968).

$$TRSPC = 1 - \frac{0.3008}{TRSDA^{0.17718}} \qquad (3.9)$$

where TRSPC is the ratio of river basin precipitation to storm precipitation (minimum value is 0.80) and TRSDA is the river basin area in square miles.

(3) **Synthetic Storms from Depth-Duration Data.** A synthetic storm of any duration from 5 minutes to 10 days can be generated based on given depth-duration data. A triangular precipitation distribution is constructed such that the depth specified for any duration occurs during the central part of the storm. This is referred to as a "balanced storm." If TP-40 (National Weather Service, 1961) data are used, the program will automatically make the partial-to-annual series conversion using the factors in Table 3.3 (which is Table 2 of TP-40) if desired.

Table 3.3

Partial-duration to Equivalent-Annual Series Conversion Factors

Return Period	Frequency	Conversion Factor
2 year	50%	0.88
5	20%	0.96
10	10%	0.99

Depths for 10-minute and 30-minute durations are interpolated from 5-, 15-, and 60-minute depths using the following equations from HYDRO-35 (National Weather Service, 1977):

$$D_{10} = 0.59\,D_{15} + 0.41\,D_5 \qquad (3.10)$$

$$D_{30} = 0.49\,D_{60} + 0.51\,D_{15} \qquad (3.11)$$

where D_n is the precipitation depth for n-minute duration.

Point precipitation is adjusted to the area of the subbasin using the following equation (based on Figure 15, National Weather Service, 1961).

$$\mathrm{FACTOR} = 1.0 - \mathrm{BV} \times (1.0 - e^{(-0.015 \times \mathrm{AREA})}) \qquad (3.12)$$

where FACTOR is the coefficient to adjust point rainfall, BV is the maximum reduction of point rainfall (from Table 3.4), and AREA is the subbasin area in square miles.

Cumulative precipitation for each time interval is computed by log-log interpolation of depths from the depth-duration data. Incremental precipitation is then computed and rearranged so the second largest value precedes the largest value, the third largest value follows the largest value, the fourth largest precedes the second largest, etc.

Table 3.4
Point-to-Areal Rainfall Conversion Factors

Duration (hours)	BV (Equation (3.12))
0.5	.48
1	.35
3	.22
6	.17
24	.09
48	.068
96	.055
168	.049
240	.044

3.1.4 Snowfall and Snowmelt

Where snowfall and snowmelt are considered, there is provision for separate computation in up to ten elevation zones within a subbasin. These zones are usually considered to be in elevation increments of 1,000 feet, but any equal increments of elevation can be used as long as the air temperature lapse rate (TLAPS) corresponds to the change in elevation within the zones. See Figure 12.3 in Example Problems, Section 12. The input temperature data are those corresponding to the bottom of the lowest elevation zone. Temperatures are reduced by the lapse rate in degrees per increment of elevation zone. The base temperature (FRZTP) at which melt will occur, must be specified because variations from 32°F (0°C) might be warranted considering both spatial and temporal fluctuations of temperature within the zone.

Precipitation is assumed to fall as snow if the zone temperature (TMPR) is less than the base temperature (FRZTP) plus 2 degrees. The 2-degree increase is the same for both English and metric units. Melt occurs when the temperature (TMPR) is equal to or greater than the base temperature, FRZTP. Snowmelt is subtracted and snowfall is added to the snowpack in each zone.

Snowmelt may be computed by the degree-day or energy-budget methods. The basic equations for snowmelt computations are from EM 1110-1-1406 (Corps, 1960). These energy-budget equations have been simplified for use in this program.

(1) **Degree-Day Method.** The degree-day method uses the equation

$$\mathrm{SNWMT} = \mathrm{COEF}(\mathrm{TMPR} - \mathrm{FRZTP}) \qquad (3.13)$$

where SNWMT is the melt in inches (mm) per day in the elevation zone, TMPR is the air temperature in °F or °C lapsed to the midpoint of the elevation zone, FRZTP is the temperature in °F or °C at which snow melts, and COEF is the melt coefficient in inches (mm) per degree-day (°F or °C).

(2) **Energy-Budget Method.** Snowmelt by the energy-budget method is accomplished by equations 20 and 24 in EM 1110-2-1406 (Corps, 1960) for rainy and rainfree periods of melt, respectively. For use in this program, k and k' in the aforementioned equations are assumed to be 0.6 and 1.0, respectively. Note that the following equations for snowmelt are for English units of measurement. The program has similar equations for the metric system which use the same variables with coefficients relevant to metric units. The program computes melt during rain by Equation (3.14), below. This equation is applicable to heavily forested areas as noted in EM 1110-2-1406.

$$\mathrm{SNWMT} = \mathrm{COEF}[0.09 + (0.029 + 0.00504\,\mathrm{WIND} + 0.007\,\mathrm{RAIN})(\mathrm{TMPR} - \mathrm{FRZTP})] \tag{3.14}$$

Equation (3.15), below, is for melt during rainfree periods in partly forested areas (the forest cover has been assumed to be 50 percent).

$$\begin{aligned}\mathrm{SNWMT} = \mathrm{COEF}[&0.002\,\mathrm{SOL}(1 - \mathrm{ALBDO}) + (0.0011\,\mathrm{WIND} + 0.0145)(\mathrm{TMPR} - \mathrm{FRZTP}) \\ &+ 0.0039\,\mathrm{WIND}(\mathrm{DEWPT} - \mathrm{FRZPT})]\end{aligned} \tag{3.15}$$

where SNWMT is the melt in inches per day in the elevation zone, TMPR is the air temperature in $^\circ$F lapsed at the rate TLAPS to midpoint of the elevation zone, DEWPT is the dewpoint temperature in $^\circ$F lapsed at a rate 0.2 TLAPS to the midpoint of the elevation zone. A discussion of the decrease in dewpoint temperature with higher elevations is found in (Miller, 1970). FRZTP is the freezing temperature in $^\circ$F, COEF is the dimensionless coefficient to account for variation from the general snowmelt equation referenced in EM 1110-2-1406, RAIN is the rainfall in inches per day, SOL is the solar radiation in langleys per day, ALBDO is the albedo of snow, $.75/(D^{0.2})$, constrained above 0.4, D is the days since last snowfall, and WIND is the wind speed in miles per hour, 50 feet above the snow.

3.2 Interception/Infiltration

Land surface interception, depression storage and infiltration are referred to in the HEC-1 model as precipitation losses. Interception and depression storage are intended to represent the surface storage of water by trees or grass, local depressions in the ground surface, in cracks and crevices in parking lots or roofs, or in an surface area where water is not free to move as overland flow. Infiltration represents the movement of water to areas beneath the land surface.

Two important factors should be noted about the precipitation loss computation in the model. First, precipitation which does not contribute to the runoff process is considered to be lost from the system. Second, the equations used to compute the losses do not provide for soil moisture or surface storage recovery. (The Holtan loss rate option, described in Section 3.2.4, is an exception in that soil moisture recovery occurs by percolation out of the soil moisture storage.) This fact dictates that the HEC-1 program is a single-event-oriented model.

The precipitation loss computations can be used with either the unit hydrograph or kinematic wave model components. In the case of the unit hydrograph component, the precipitation loss is considered to be a subbasin average (uniformly distributed over an entire subbasin). On the other hand, separate precipitation losses can be specified for each overland flow plane (if two are used) in the kinematic wave component. The losses are assumed to be uniformly distributed over each overland flow plane.

In some instances, there are negligible precipitation losses for a portion of a subbasin. This would be true for an area containing a lake, reservoir or impervious area. In this case, precipitation losses will not be computed for a specified percentage of the area labeled as impervious.

There are five methods that can be used to calculate the precipitation loss. Using any one of the methods, an average precipitation loss is determined for a computation interval and subtracted from the rainfall/snowmelt hyetograph as shown in Figure 3.2. The resulting precipitation excess is used to compute an outflow hydrograph for a subbasin. A percent imperviousness factor can be used with any of the loss rate methods to guarantee 100% runoff from that portion of the basin.

A **percent impervious** factor can be used with any of the loss rate methods; it guarantees 100% runoff from that percent of the subbasin.

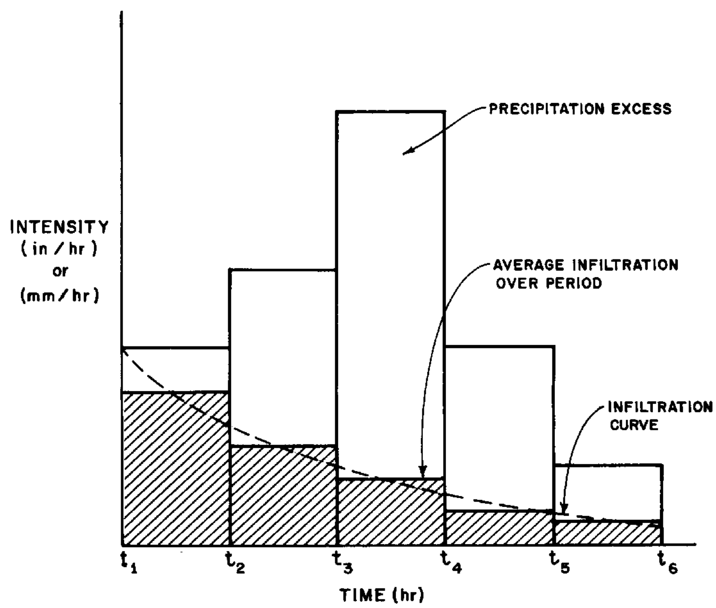


Figure 3.2 Loss Rate, Rainfall Excess Hyetograph

3.2.1 Initial and Uniform Loss Rate

An initial loss, STRTL (units of depth), and a constant loss rate, CNSTL (units of depth/hour), are specified for this method. All rainfall is lost until the volume of initial loss is satisfied. After the initial loss is satisfied, rainfall is lost at the constant rate, CNSTL.

3.2.2 Exponential Loss Rate

This is an empirical method which relates loss rate to rainfall intensity and accumulated losses. Accumulated losses are representative of the soil moisture storage. The equations for computation of loss are given below and shown graphically in Figure 3.3.

$$\text{ALOSS} = (\text{AK} + \text{DLTK})\,\text{PRCP}^{\text{ERAIN}} \quad \text{(3.16a)}$$

$$\text{DLTK} = 0.2\,\text{DLTKR}\left(1 - \left(\frac{\text{CUML}}{\text{DLTKR}}\right)\right)^2 \quad \text{(3.16b)}$$

$$\text{for CUML} \le \text{DLTKR}$$

$$\text{AK} = \frac{\text{STRKR}}{(\text{RTIOL}^{\text{01CUML}})} \quad \text{(3.16c)}$$

where ALOSS is the potential loss rate in inches (mm) per hour during the time interval, AK is the loss rate coefficient at the beginning of the time interval, and DLTK is the incremental increase in the loss rate coefficient during the first DLTKR inches (mm) of accumulated loss, CUML. The accumulated loss, CUML, is determined by summing the actual losses computed for each time interval. Note that there is not a direct conversion between metric and English units for coefficients of this method, consequently separate calibrations to rainfall data are necessary to derive the coefficients for both units of measure.

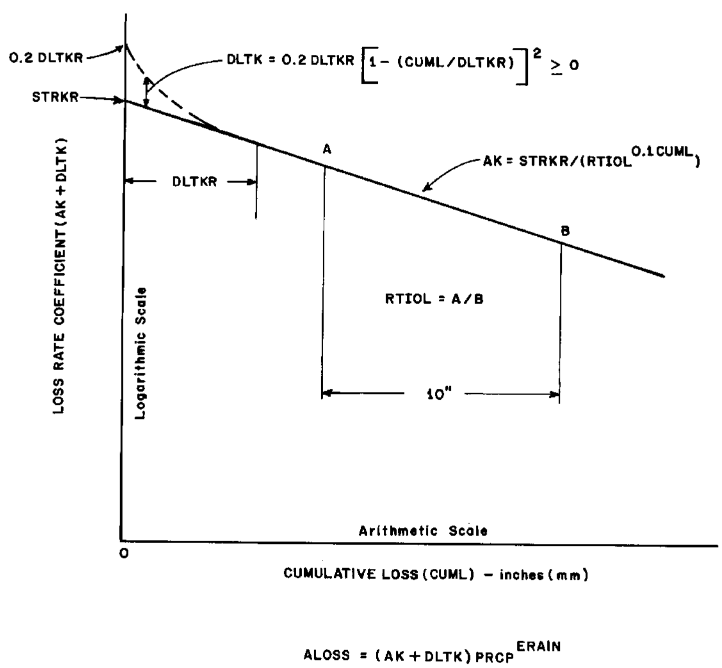


Figure 3.3 General HEC Loss Rate Function for Snow-Free Ground

DLTKR is the amount of initial accumulated rain loss during which the loss rate coefficient is increased. This parameter is considered to be a function primarily of antecedent soil moisture deficiency and is usually storm dependent. STRKR is the starting value of loss coefficient on exponential recession curve for rain losses (snow-free ground). The starting value is considered a function of infiltration capacity and thus depends on such basin characteristics as soil type, land use and vegetal cover.

RTIOL is the ratio of rain loss coefficient on exponential loss curve to that corresponding to 10 inches (10 mm) more of accumulated loss. This variable may be considered a function of the ability of the surface of a basin to absorb precipitation and should be reasonably constant for large rather homogeneous areas. ERAIN is the exponent of precipitation for rain loss function that reflects the influence of precipitation rate on basin-average loss characteristics. It reflects the manner in which storms occur within an area and may be considered a characteristic of a particular region. ERAIN varies from 0.0 to 1.0.

Under certain circumstances it may be more convenient to work with the exponential loss rate as a two parameter infiltration model. To obtain an initial and constant loss rate function, set ERAIN = 0 and RTIOL = 1.0. To obtain a loss rate function that decays exponentially with no initial loss, set ERAIN = 0.0 and DLTKR = 0.0.

Estimates of the parameters of the exponential loss function can be obtained by employing the HEC-1 parameter optimization option described in Section 4.

3.2.3 SCS Curve Number

The Soil Conservation Service (SCS), U.S. Department of Agriculture, has instituted a soil classification system for use in soil survey maps across the country. Based on experimentation and experience, the agency has been able to relate the drainage characteristics of soil groups to a curve number, CN (SCS, 1972 and 1975). The SCS provides information on relating soil group type to the curve number as a function of soil cover, land use type and antecedent moisture conditions.

Precipitation loss is calculated based on supplied values of CN and IA (where IA is an initial surface moisture storage capacity in units of depth). CN and IA are related to a total runoff depth for a storm by the following relationships:

$$\mathrm{ACEXS} = \frac{(\mathrm{ACRAN} - \mathrm{IA})^2}{\mathrm{ACRAN} - \mathrm{IA} + \mathrm{S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3.17)$$

$$\mathrm{S} = \frac{1000 - 10 \times \mathrm{CN}}{\mathrm{CN}} \qquad \text{or}$$

$$\mathrm{S} = \frac{25400 - 254 \times \mathrm{CN}}{\mathrm{CN}} \quad (\text{Metric Units}) \qquad \ldots\ldots\ldots\ldots\ldots \ (3.18)$$

where ACEXS is the accumulated excess in inches (mm), ACRAN is the accumulated rainfall depth in inches (mm), and S is the currently available soil moisture storage deficit in inches (mm).

In the case that the user does not wish to specify IA, a default value is computed as

$$IA = 0.2 \times S \qquad (3.19)$$

This relation is based on empirical evidence established by the Soil Conservation Service.

Since the SCS method gives total excess for a storm, the incremental excess (the difference between rainfall and precipitation loss) for a time period is computed as the difference between the accumulated excess at the end of the current period and the accumulated excess at the end of the previous period.

3.2.4 Holtan Loss Rate

Holtan et al. (1975) compute loss rate based on the infiltration capacity given by the formula:

$$f = GIA \times SA^{BEXP} + FC \qquad (3.20)$$

where f is the infiltration capacity in inches per hour, GIA is the product of GI a "growth index" representing the relative maturity of the ground cover and A the infiltration capacity in inches per hour ($inch^{1.4}$ of available storage), SA is the equivalent depth in inches of pore space in the surface layer of the soil which is available for storage of infiltrated water, FC is the constant rate of percolation of water through the soil profile below the surface layer, and BEXP is an empirical exponent, typically taken equal to 1.4.

The factor "A" is interpreted as an index of the pore volume which is directly connected to the soil surface. The number of surface-connected pores is related to the root structure of the vegetation, so the factor "A" is related to the cover crop as well as the soil texture. Since the surface-connected porosity is related to root structure, the growth index, GI, is used to indicate the development of the root system and in agricultural basins GI will vary from near zero when the crop is planted to 1.0 when the crop is full-grown.

Holtan et al. (1975) have made estimates of the value of "A" for several vegetation types. Their estimates were evaluated at plant maturity as the percent of the ground surface occupied by plant stems or root crowns.

Estimates of FC can be based on the hydrologic soil group given in the SCS Handbook (1972 and 1975). Musgrave (1955) has given the following values of FC in inches per hour for the four hydrologic soil groups: A, 0.45 to 0.30; B, 0.30 to 0.15; C, 0.15 to 0.05; D, 0.05 or less.

The available storage, SA, is decreased by the amount of infiltrated water and **increased at the percolation rate,** FC. Note, by calculating SA in this manner, soil moisture recovery occurs at the deep percolation rate. The amount of infiltrated water during a time interval is computed as the smaller of 1) the amount of available water, i.e., rain or snowmelt, or 2) the average infiltration capacity times the length of the time interval.

In HEC-1, the infiltration equation used is

$$F = \frac{F1 + F2}{2} \times TRHR \qquad (3.21)$$

where F1 and F2 and SA1 and SA2 are the infiltration rates and available storage, respectively, at the beginning and end of the time interval TRHR, and

$$F1 = GIA \times SA1^{BEXP} + FC \qquad (3.22)$$

$$F2 = GIA \times SA2^{BEXP} + FC \qquad (3.23)$$

$$SA2 = SA1 - F + FC \times TRHR \qquad (3.24)$$

3.2.5 Green and Ampt Infiltration Function

The Green and Ampt infiltration function (see Mein and Larson, 1973) is combined with an initial abstraction to compute rainfall losses. The initial abstraction is satisfied prior to rainfall infiltration as follows:

$$r(t) = 0 \qquad \text{for} \quad P(t) \le IA \quad T > 0 \qquad (3.25)$$

$$r(t) = r_0(t) \qquad \text{for} \quad P(t) > IA \quad T > 0 \qquad (3.26)$$

where P(t) is the cumulative precipitation over the watershed, r(t) is the rainfall intensity adjusted for surface losses, t is the time since the start of rainfall, $r_0(t)$, and IA is the initial abstraction. The Green and Ampt infiltration is applied to the remaining rainfall by applying the following equation:

$$F(t) = \frac{PSIF \times DTHETA}{\left[\frac{f(t)}{XKSAT - 1}\right]} \qquad f(t) > XKSAT \qquad (3.27)$$

$$f(t) = r(t) \qquad f(t) \le XKSAT \qquad (3.28)$$

where F(t) is the cumulative infiltration, f(t) = dF(t)/dt is the infiltration rate, and the parameters of the Green and Ampt method are PSIF, the wetting front suction, DTHETA, the volumetric moisture deficit and XKSAT, the hydraulic conductivity at natural saturation. The application of this equation is complicated by the fact that it is only applicable to a uniform rainfall rate. The difficulty is overcome by calculating a time to ponding (see Mein and Larson, 1973; and Morel-Seytoux, 1980). Time to ponding (the time at which the ground surface is saturated) is calculated by applying Equation (3.27) over the computation interval Δt:

$$\Delta F = F_j - F_{j-1} = \left[\frac{PSIF \times DTHETA}{\dfrac{r_j}{XKSAT} - 1}\right] - \sum_{i=1}^{j-1} r_i vt \qquad r_j \geq XKSAT \qquad \text{. . . . (3.29)}$$

where its recognized that at ponding the infiltration and rainfall rates are equal (i(t) = r(t)), r_j is the average rainfall rate during period j, F_j and F_{j-1} are the cumulative infiltration rates at the end of periods j and j-1, ΔF is the incremental infiltration over period j.

Ponding occurs if the following condition is satisfied:

$$\Delta F < r_i \Delta t \qquad \text{. . . . . (3.30)}$$

otherwise the rainfall over the period will be completely infiltrated. Once ponding has occurred, the infiltration and rainfall rates are independent and Equation (3.27) can be easily integrated to calculate the infiltration over the computation interval. The ponded surface condition might not be maintained during the entire storm. This occurs when the rainfall rate falls below the post-ponding infiltration rate. In this case, a new ponding time is calculated and the infiltration calculation is applied as previously described.

3.2.6 Combined Snowmelt and Rain Losses

Either a snowmelt uniform loss rate or exponential loss rate can be applied to combined snowmelt and rainfall. The difference between these loss rates and the analogous rainfall loss rates described in Sections 3.2.1 and 3.2.2 is that no initial losses are considered. The snowmelt uniform loss rate is applied in the same manner as in the calculation of rainfall loss. The snowmelt exponential loss rate is calculated using the following formula:

$$AK = \frac{STRKS}{RTIOK^{0.1CUML}} \qquad \text{. . . . . (3.31)}$$

where AK is the potential loss rate, CUML is the cumulative loss and STRKS and RTIOK are parameters analogous to those used in the rainfall exponential loss rate (see Section 3.2.2). If AK is greater then the available snowmelt and rainfall then the loss rate is equal to the total available snowmelt and rainfall. Either the initial and uniform (Section 3.2.1) or the exponential loss rates (Section 3.2.2) can be applied in conjunction with the corresponding snowmelt loss rates. These loss rates are applied to rainfall when the snowmelt is less then zero.

3.3 Unit Hydrograph

The unit hydrograph technique has been discussed extensively in the literature (Corps of Engineers, 1959, Linsley et al., 1975, and Viessman et al., 1972). This technique is used in the subbasin runoff component to transform rainfall/snowmelt excess to subbasin outflow. A unit hydrograph can be directly input to the program or a synthetic unit hydrograph can be computed from user supplied parameters.

3.3.1 Basic Methodology

A 1-hour unit hydrograph is defined as the subbasin surface outflow due to a unit (1 inch or mm) rainfall excess applied uniformly over a subbasin in a period of one hour. Unit hydrograph durations other than an hour are common. HEC-1 automatically sets the **duration of unit excess** equal to the **computation interval** selected for watershed simulation.

The rainfall excess hyetograph is transformed to a subbasin outflow by utilizing the general equation:

$$Q(i) = \sum_{j=1}^{i} U(j) \times X(i - j + 1) \qquad \text{(3.32)}$$

where Q(i) is the subbasin outflow at the end of computation interval i, U(j) is the jth ordinate of the unit hydrograph, X(i) is the average rainfall excess for computation interval i.

The equation is based on two important assumptions. First, the unit hydrograph is characteristic for a subbasin and is not storm dependent. Second, the runoff due to excess from different periods of rainfall excess can be linearly superposed.

3.3.2 Synthetic Unit Hydrographs

The parameters for the synthetic unit hydrograph can be determined from gage data by employing the parameter optimization option described in Section 4. Otherwise, these parameters can be determined from regional studies or from guidelines given in references for each synthetic technique. There are three synthetic unit hydrograph methods available in the model.

(1) **Clark Unit Hydrograph.** The Clark method (1945) requires three parameters to calculate a unit hydrograph: TC, the time of concentration for the basin, R, a storage coefficient, and a time-area curve. A time-area curve defines the cumulative area of the watershed contributing runoff to the subbasin outlet as a function of time (expressed as a proportion of TC).

In the case that a time area curve is not supplied, the program utilizes a dimensionless time area curve:

$$AI = 1.414\, T^{1.5} \qquad 0 \le T < 0.5 \qquad \text{(3.33)}$$

$$1 - AI = 1.414(1 - T)^{1.5} \qquad 0.5 < T < 1 \qquad \text{(3.34)}$$

where AI is the cumulative area as a fraction of total subbasin area and T is the fraction of time of concentration. The ordinates of the time-area curve are converted to volume of runoff per second for unit excess and interpolated to the given time interval. The resulting translation hydrograph is then routed through a linear reservoir to simulate the storage effects of the basin; and the resulting unit hydrograph for instantaneous excess is averaged to produce the hydrograph for unit excess occurring in the given time interval.

The linear reservoir routing is accomplished using the general equation:

$$Q(2) = CA \times I + CB \times Q(1) \qquad \text{(3.35)}$$

The routing coefficients are calculated from:

$$CA = \frac{\Delta t}{(R + 0.5\Delta t)} \qquad (3.36)$$

$$CB = 1 - CA \qquad (3.37)$$

$$QUNGR = 0.5[Q(1) + Q(2)] \qquad (3.38)$$

where Q(2) is the instantaneous flow at end of period, Q(1) is the instantaneous flow at the beginning of period, I is the ordinate of the translation hydrograph, Δt is the computation time interval in hours (also duration of unit excess), R is the basin storage factor in hours, and QUNGR is the unit hydrograph ordinate at end of computation interval. The computation of unit hydrograph ordinates is terminated when its volume exceeds 0.995 inch (mm) or 150 ordinates, whichever occurs first.

(2) **Snyder Unit Hydrograph.** The Snyder method (1938) determines the unit graph peak discharge, time to peak, and widths of the unit graph at 50% and 75% of the peak discharge. The method does not produce the complete unit graph required by HEC-1. Thus, HEC-1 uses the Clark method to affect a Snyder unit graph. The initial Clark parameters are estimated from the given Snyder's parameters, Tp and Cp. A unit hydrograph is computed using Clark's method and Snyder parameters are computed from the resulting unit hydrograph by the following equations:

$$CPTMP = QMAX \times \frac{Tpeak - 0.5 \times \Delta t}{C \times A} \qquad (3.39)$$

$$ALAG = 1.048 \times (Tpeak - 0.75 \times \Delta t) \qquad (3.40)$$

where CPTMP is Snyder's Cp for computed unit hydrograph, QMAX is the maximum ordinate of unit hydrograph, Tpeak is the time when QMAX occurs, in hours, Δt is the duration of excess, in hours, A is the subbasin area in square miles (sq km), C is a conversion factor, and ALAG is Snyder's standard Lag, Tp for the computed unit hydrograph. Snyder's standard Lag is for a unit hydrograph which has a duration of excess equal to Tp/5.5. The coefficient, 1.048, in equation results from converting the duration of excess to the given time interval.

Clark's TC and R are adjusted to compensate for differences between values of Tp and Cp calculated by Equations (3.39) and (3.40) and the given values. A new unit hydrograph is computed using these adjusted values. This procedure continues through 20 iterations or until the differences between computed and given values of Tp and Cp are less than one percent of the given values.

(3) **SCS Dimensionless Unit Hydrograph.** Input data for the Soil Conservation Service, SCS, dimensionless unit hydrograph method (1972) consists of a single parameter, TLAG, which is equal to the lag (hrs) between the center of mass of rainfall excess and the peak of the unit hydrograph. Peak flow and time to peak are computed as:

$$\mathrm{TPEAK} = 0.5 \times \Delta t + \mathrm{TLAG} \qquad (3.41)$$

$$\mathrm{QPK} = 484 \times \frac{\mathrm{AREA}}{\mathrm{TPEAK}} \qquad (3.42)$$

where TPEAK is the time to peak of unit hydrograph in hours, Δt is the duration of excess in hours or computation interval, QPK is the peak flow of unit hydrograph in cfs/inch, and AREA is the subbasin area in square miles. The unit hydrograph is interpolated for the specified computation interval and computed peak flow from the dimensionless unit hydrograph shown in Figure 3.4.

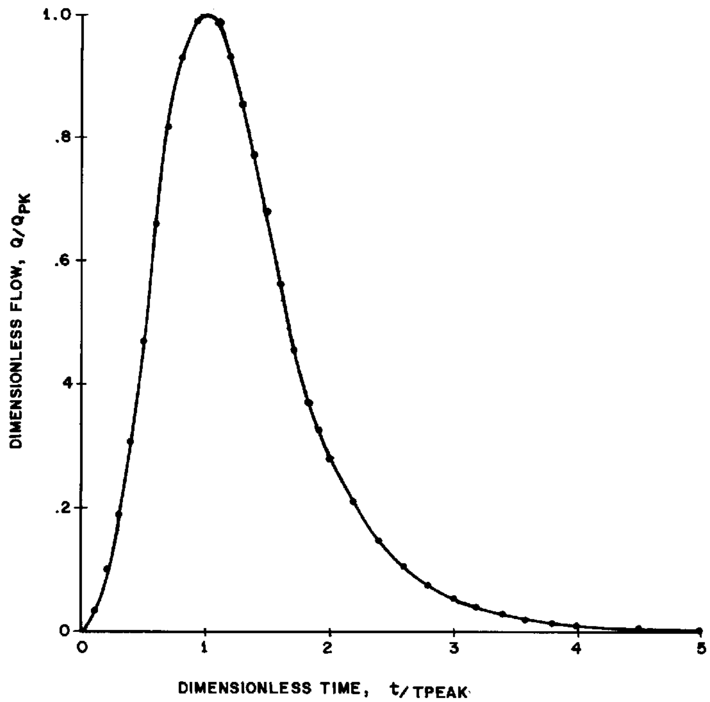


Figure 3.4 SCS Dimensionless Unit Graph

The selection of the program computation interval, which is also the duration of the unit hydrograph, is based on the relationship Δt = 0.2 * TPEAK (SCS, 1972, Chapters 15, 16). There is some latitude allowed in this relationship; however, the duration of the unit graph should not exceed Δt ≤ 0.25 * Tpeak. These relations are based on an empirical relationship, TLAG = 0.6 * Tc, and 1.7 * TPEAK = Δt + Tc where Tc is the time of concentration of the watershed. Using these relationships, along with equation (3.34) it is found that the duration should not be greater than Δt ≤ 0.29 * TLAG.

3.4 Distributed Runoff Using Kinematic Wave and Muskingum-Cunge Routing

Distributed outflow from a subbasin may be obtained by utilizing combinations of three conceptual elements: overland flow planes, collector channels and a main channel as shown in Figure 3.5. The kinematic wave routing technique can be used to route rainfall excess over the overland flow planes. Either the kinematic wave or Muskingum-Cunge technique can be used to route lateral inflows through a collector channel and upstream and lateral inflows through the main channel. **Note**, kinematic wave and Muskingum-Cunge channel elements cannot be inter-mixed. This section deals with the application of the conceptual elements to precipitation-runoff routing and the development of the kinematic wave and Muskingum-Cunge equations utilized to perform the routing. Refer to HEC, 1979, for details on development of the kinematic wave equations.

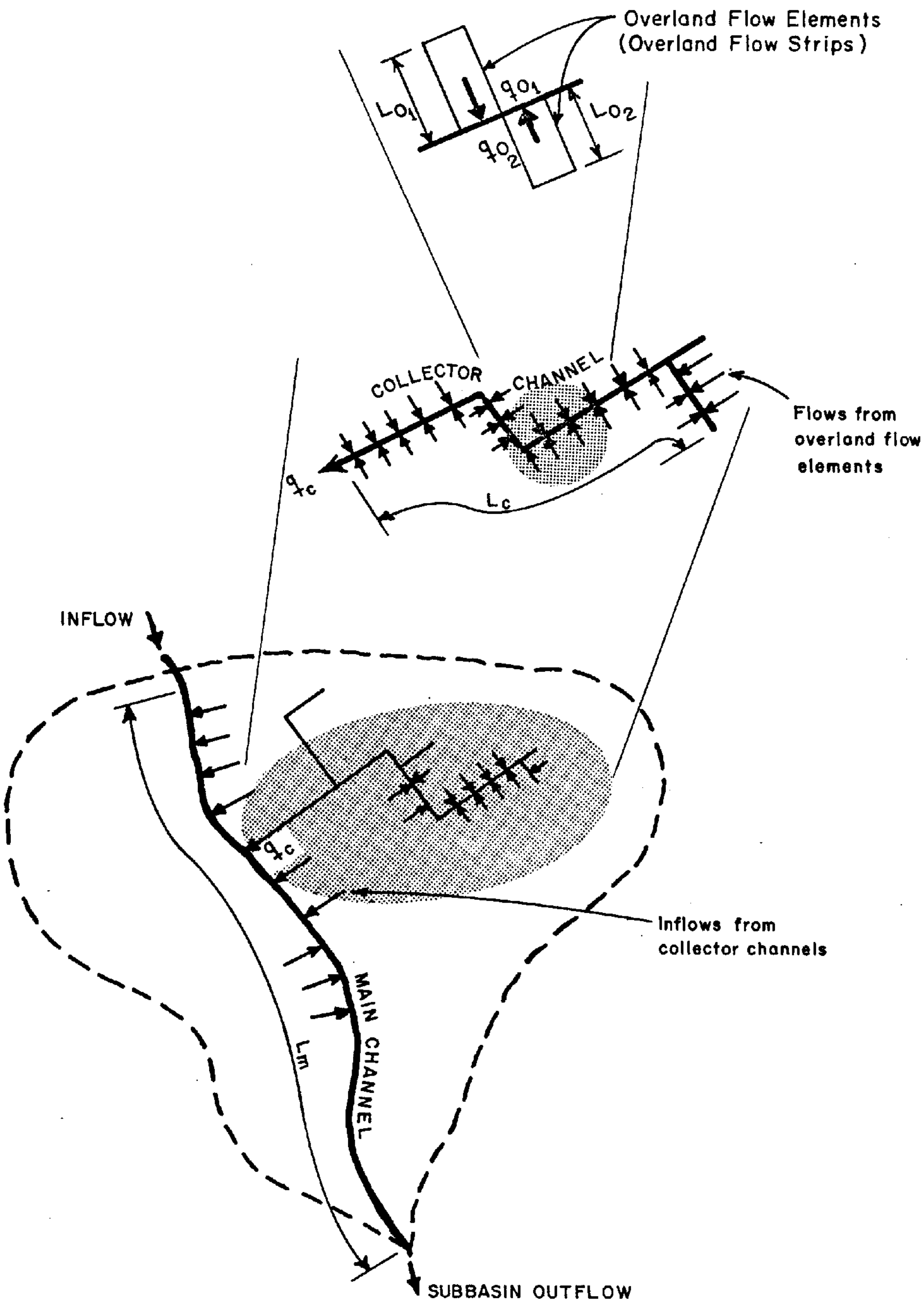


Figure 3.5 Relationship Between Flow Elements

3.4.1 Basic Concepts for Kinematic Wave Routing

In the kinematic wave interpretation of the equations of motion, it is assumed that the bed slope and water surface slope are equal and acceleration effects are negligible (parameters given in metric units are converted to English units for use in these equations). The momentum equation then simplifies to

$$S_f = S_o \qquad (3.43)$$

where S_f is the friction slope and S_o is the channel bed slope. Thus flow at any point in the channel can be computed from Manning's formula.

$$Q = \frac{1.486}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad (3.44)$$

where Q is flow, S is the channel bed slope, R is hydraulic radius, A is cross-sectional area, and n is Manning's resistance factor. Equation (3.44) can be simplified to

$$Q = \alpha A^{m} \qquad (3.45)$$

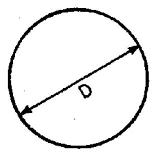
where α and m are related to flow geometry and surface roughness. Figure 3.6 gives relations for a and m for channel shapes used in HEC-1. Note that flow depths greater than the diameter of the circular channel shape are possible, which only approximates the storage characteristics of a pipe or culvert.

Since the momentum equation has been reduced to a simple functional relation between area and discharge, the movement of a flood wave is described solely by the continuity equation

$$\frac{\delta A}{\delta t} + \frac{\delta Q}{\delta x} = q \qquad (3.46)$$

The overland flow plane initial condition is initially dry and there is no inflow at the upstream boundary of the plane. The initial and boundary conditions for the kinematic wave channel are determined based on an upstream hydrograph.

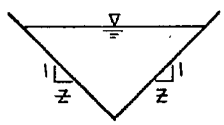
CIRCULAR



$$\alpha = \frac{.804}{n} S^{1/2} D^{1/6}$$

$$m = 5/4$$

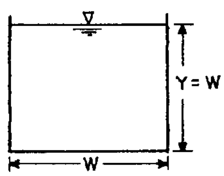
TRIANGULAR



$$\alpha = \frac{0.94}{n} S^{1/2} \left(\frac{Z}{1+Z^2}\right)^{1/3}$$

$$m = 4/3$$

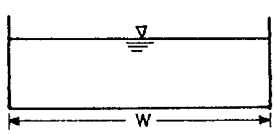
SQUARE



$$\alpha = \frac{.72}{n} S^{1/2}$$

$$m = 4/3$$

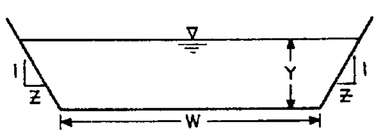
RECTANGULAR



$$\alpha = \frac{1.49}{n} S^{1/2} W^{-2/3}$$

$$m = 5/3$$

TRAPEZOIDAL



$$Q = \frac{1.49}{n} S^{1/2} A^{5/3} \left(\frac{1}{W+2Y\sqrt{1+Z^2}}\right)^{2/3}$$

Figure 3.6 Kinematic Wave Parameters for Various Channel Shapes

3.4.2 Solution Procedure

The governing equations for either overland flow or channel routing are solved in the same manner. The method assumes that inflows, whether it be rainfall excess or lateral inflows, are constant within a time step and uniformly distributed along the element. By combining Equations (3.45) and (3.46), the governing equation is obtained as:

$$\frac{\delta A}{\delta t} + \alpha m A^{(m-1)} \frac{\delta A}{\delta x} = q \qquad \text{(3.47)}$$

A is the only dependent variable in the equation; α and m are considered constants. The equation can be solved using a finite difference approximation proposed by Leclerc and Schaake (1973). The standard form of the finite difference approximation to this equation is developed as:

$$\frac{A_{(i,j)} - A_{(i,j-1)}}{\Delta t} + \alpha m\left[\frac{A_{(i,j-1)} + A_{(i-1,j-1)}}{2}\right]^{m-1} \times \left[\frac{A_{(i,j-1)} - A_{(i-1,j-1)}}{\Delta x}\right] = q_a \qquad \text{(3.48)}$$

where q_a is defined as:

$$q_a = \frac{q_{(i,j)} + q_{(i,j-1)}}{2} \qquad \text{(3.49)}$$

The indices of the approximation refer to positions on a space-time grid (Figure 3.7). The grid indicates the position of the solution scheme as it solves for the unknown values of A at various positions and times. The index i indicates the current position of the solution scheme along the length, L, of the channel or overland flow plane:

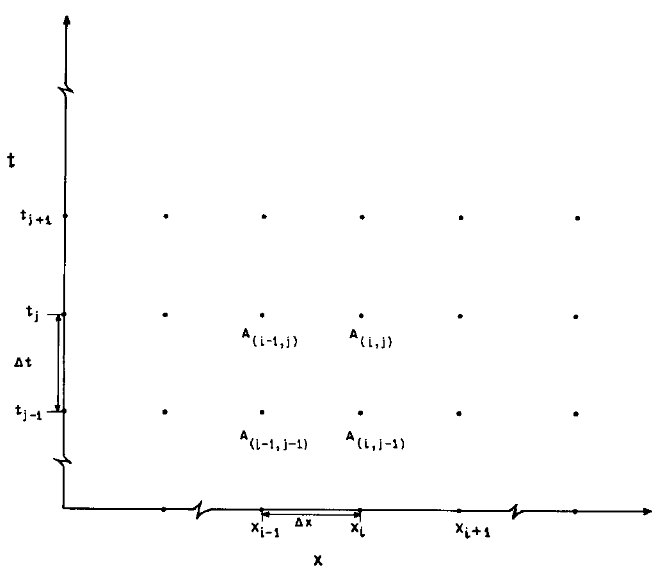


Figure 3.7 Finite Difference Method Space-Time Grid

j indicates the current time step of the solution scheme. i-1, j-1 indicate, respectively, positions and times removed a value Δx and Δt from the current position of the solution scheme. The only unknown value in the equation is the current value $A_{(i,j)}$. All other values are known from either a solution of the equation at a previous position i-1 and time j-1, or from a boundary condition. Solving for the unknown:

$$A_{(i,j)} = q_a \Delta t + A_{(i,j-1)} - \alpha m \left[\frac{\Delta t}{\Delta x}\right]\left[\frac{A_{(i,j-1)} + A_{(i-1,j-1)}}{2}\right]^{m-1} \times \left[A_{(i,j-1)} - A_{(i-1,j-1)}\right] \qquad \text{. . . (3.50)}$$

Once $A_{(i,j)}$ is known, the flow can be computed as:

$$Q_{(i,j)} = \alpha \left[A_{(i,j)}\right]^m \qquad \text{. . . (3.51)}$$

The standard form of the finite difference equation is applied when the following stability factor, R is less than unity (see Alley and Smith, 1987):

$$R = \frac{\alpha}{q_a \Delta x}\left[(q_a \Delta t + A_{i-1,j-1})^m - A^m_{i-1,j-1}\right] \qquad q_a > 0 \qquad \text{. . . (3.52)}$$

or

$$R = \alpha m A^{m-1}_{i-1,j-1} \frac{\Delta t}{\Delta x} \qquad q_a = 0 \qquad \text{. . . (3.53)}$$

If R is less than unity then the "conservation" form of the finite difference equation applies:

$$\frac{Q_{(i,j)} - Q_{(i-1,j)}}{\Delta x} + \left[\frac{A_{(i-1,j)} - A_{(i-1,j-1)}}{\Delta t}\right] = q_a \qquad \text{. . . (3.54)}$$

where $Q_{(i,j)}$ is the only unknown. Solving for the unknown:

$$Q_{(i,j)} = Q_{(i-1,j)} + q \Delta x - \left[A_{(i-1,j)} - A_{(i-1,j-1)}\right] \qquad \text{. . . (3.55)}$$

knowing the value of $Q_{(i,j)}$:

$$A_{(i,j)} = \left[\frac{Q_{(i,j)}}{\alpha}\right]^{\frac{1}{m}} \qquad \text{. . . (3.56)}$$

The accuracy and stability of the finite difference scheme depends on approximately maintaining the relationship $c\Delta t = \Delta x$, where c is the average kinematic wave speed in an element. The kinematic wave speed is a function of flow depth, and, consequently, varies during the routing of the hydrograph through and element. Since

Δx is a fixed value, the finite difference scheme utilizes a variable Δt internally to maintain the desired relationship between Δx, Δt and c. However, HEC-1 performs all other computations at a constant time interval specified by the user. Necessarily, the variable Δt hydrograph computed for a subbasin by the finite difference scheme is interpolated to the user specified computation interval prior to other HEC-1 computations. The resulting interpolation error is displayed in both intermediary and summary output (see Example Problem #2).

The accuracy of the finite difference scheme depends on the selection of the distance increment, Δx. The distance increment is initially chosen by the formula $\Delta x = c\Delta t_m$ where c in this instance is an estimated maximum wave speed depending on the lateral and upstream inflows and Δt_m is the time step equal to the minimum of (1) one third the travel time through the reach, the travel time being the element length divided by the wave speed (2) one-fourth the upstream hydrograph rise time and (3) the user specified computation interval. Finally, the computed Δx is chosen as the minimum of the computed Δx and L/NDXMIN, where NDXMIN is a user specified number of Δx values to be used by the finite difference scheme (minimum default value, NDXMIN = 5, for overland flow planes and 2 for channels, maximum NDXMIN = 50).

Consequently, the accuracy of the finite difference solution depends on **both the selection of Δx and the interpolation of the kinematic wave hydrograph to the user specified computation interval.** The default selection of the Δx value by the program will probably be accurate enough for most purposes. The user may wish to check the accuracy by altering NDXMIN (see Example Problem #2). **More importantly**, the user should always **check** the error in interpolating to the user specified computation interval as summarized at the end of the HEC-1 output. The interpolation error may be **reduced** by **reducing** the **computation interval**.

3.4.3 Basic Concepts for Muskingum-Cunge Routing

The Muskingum-Cunge routing technique can be used to route either lateral inflow from either kinematic wave overland flow plane or lateral inflow from collector channels and/or an upstream hydrograph through a main channel.

The channel routing technique is a non-linear coefficient method that accounts for hydrograph diffusion based on physical channel properties and the inflowing hydrograph. The advantages of this method over other hydrologic techniques are: (1) the parameters of the model are physically based; (2) the method has been shown to compare well against the full unsteady flow equations over a wide range of flow situations (Ponce, 1983 and Brunner, 1989); and (3) the solution is independent of the user specified computation interval. The major limitations of the Muskingum-Cunge application in HEC-1 are that: (1) it can not account for backwater effects; and (2) the method begins to diverge from the full unsteady flow solution when very rapidly rising hydrographs are routed through very flat slopes (i.e. channel slopes less than 1 ft./mile).

The basic formulation of the equations is derived from the continuity equation and the diffusion form of the momentum equation:

$$\frac{\delta A}{\delta t} + \frac{\delta Q}{\delta x} = q_L \qquad \text{(continuity)} \quad (3.57)$$

$$S_f = S_O - \frac{\delta Y}{\delta x} \qquad \text{(diffusion form of Momentum equation)} \quad (3.58)$$

By combining Equations (3.57) and (3.58) and linearizing, the following convective diffusion equation is formulated (Miller and Cunge, 1975):

$$\frac{\delta Q}{\delta t} + c\frac{\delta Q}{\delta x} = \mu \frac{\delta^2 Q}{\delta x^2} + c q_L \qquad (3.59)$$

where: Q = Discharge in cfs
A = Flow area in ft^2
t = Time in seconds
x = Distance along the channel in feet
Y = Depth of flow in feet
q_L = Lateral inflow per unit of channel length
S_f = Friction slope
S_o = Bed Slope
c = The wave celerity in the x direction as defined below.

$$c = \frac{dQ}{dA}\Big|_x \qquad (3.60)$$

The hydraulic diffusivity (μ) is expressed as follows:

$$\mu = \frac{Q}{2BS_o} \qquad (3.61)$$

where B is the top width of the water surface.

Following a Muskingum-type formulation, with lateral inflow, the continuity Equation (3.57) is discretized on the x-t plane (Figure 3.8) to yield:

$$Q_{j+1}^{n+1} = C_1 Q_j^n + C_2 Q_j^{n+1} + C_3 Q_{j+1}^n + C_4 Q_L \qquad (3.62)$$

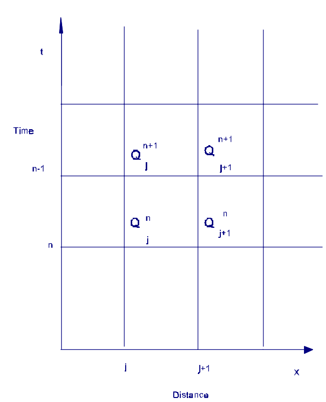


Figure 3.8 Discretization on x-t Plane of the Variable Parameter Muskingum-Cunge Model.

where:

$$C_1 = \frac{\frac{\Delta t}{K} + 2X}{\frac{\Delta t}{K} + 2(1 - X)} \qquad C_2 = \frac{\frac{\Delta t}{K} - 2X}{\frac{\Delta t}{K} + 2(1 - X)}$$

$$C_3 = \frac{2(1 - X) - \frac{\Delta t}{K}}{\frac{\Delta t}{K} + 2(1 - X)} \qquad C_4 = \frac{2(\frac{\Delta t}{K})}{\frac{\Delta t}{K} + 2(1 - X)}$$

$$Q_L = q_L \Delta x$$

It is assumed that the storage in the reach is expressed as the classical Muskingum storage:

$$S = K[XI + (1 - X)O] \qquad (3.63)$$

where:

where:	S	=	channel storage
	K	=	cell travel time (seconds)
	X	=	weighing factor
	I	=	inflow
	O	=	outflow

In the Muskingum equation the amount of diffusion is based on the value of X, which varies between 0.0 and 0.5. The Muskingum X parameter is not directly related to physical channel properties. The diffusion obtained with the Muskingum technique is a function of how the equation is solved, and is therefore considered numerical diffusion rather than physical. In the Muskingum-Cunge formulation, the amount of diffusion is controlled by forcing the numerical diffusion to match the physical diffusion (μ) from Equation (3.59) and (3.61). The Muskingum-Cunge equation is therefore considered an approximation of the convective diffusion Equation (3.59). As a result, the parameters K and X are expressed as follows (Cunge, 1969 and Ponce, 1983):

$$K = \frac{\Delta x}{c} \qquad (3.64)$$

$$X = \frac{1}{2}(1 - \frac{Q}{B S_0 c \Delta x}) \qquad (3.65)$$

Then the Courant (C) and cell Reynolds (D) numbers can be defined as:

$$C = c\frac{\Delta t}{\Delta x} \qquad (3.66)$$

and

$$D = \frac{Q}{B S_0 c \Delta x} \qquad (3.67)$$

The routing coefficients for the non-linear diffusion method (Muskingum- Cunge) are then expressed as follows:

$$C_1 = \frac{1 + C - D}{1 + C + D} \qquad C_2 = \frac{-1 + C + D}{1 + C + D}$$

$$C_3 = \frac{1 - C + D}{1 + C + D} \qquad C_4 = \frac{2C}{1 + C + D}$$

in which the dimensionless numbers C and D are expressed in terms of physical quantities (Q, B, S_o, and c) and the grid dimensions (Δx and Δt).

The method is non-linear in that the flow hydraulics (Q, B, c), and therefore the routing coefficients (C_1, C_2, C_3, and C_4) are re-calculated for every Δx distance step and Δt time step. An iterative four-point averaging scheme is used to solve for c, B and Q. This process has been described in detail by Ponce (1986).

Values for Δt and Δx are chosen internally by the model for accuracy and stability. First, Δt is evaluated by looking at the following 3 criteria and selecting the smallest value:

(1) The user defined computation interval, NMIN, from the first field of the IT record.

(2) The time of rise of the inflow hydrograph divided by 20 ($^{Tr}/_{20}$).

(3) The travel time of the channel reach.

Once Δt is chosen, Δx is evaluated as follows:

$$\Delta x = c\Delta t \qquad (3.68)$$

but Δx must also meet the following criteria to preserve consistency in the method (Ponce, 1983):

$$\Delta x < \frac{1}{2}\left(c\Delta t + \frac{Q_0}{B S_0 c}\right) \qquad (3.69)$$

where Q_o is the reference flow and Q_B is the baseflow taken from the inflow hydrograph as:

$$Q_0 = Q_B + 0.50\,(Q_{peak} - Q_B)$$

Δx is chosen as the smaller value from the two criteria. The values chosen by the program for Δx and Δt are printed in the output, along with computed peak flow. Before the hydrograph is used in subsequent operations, or printed in the hydrograph tables, it is converted back to the user-specified computation interval. The user should always check to see if the interpolation back to the user-specified computation interval has reduced the peak flow significantly. If the peak flow computed from the internal computation interval is markedly greater than the hydrograph interpolated back to the user-specified computation interval, the user specified computation interval should be reduced and the model should be executed again.

Data for the Muskingum-Cunge method consist of the following for either a main or collector channel:

(1) Representative channel cross section.

(2) Reach length, L.

(3) Manning roughness coefficients, n (for main channel and overbanks).

(4) Channel bed slope, S_0.

The method can be used with a simple cross section, as shown in Figure 3.6 under kinematic wave routing, or a more detailed 8-point cross section can be provided. If the simple channel configurations shown in Figure 3.6 are used, Muskingum-Cunge routing can be accomplished through the use of a single RD record as follows:

KK . . . . Station Computation Identifier
RD . . . . Muskingum-Cunge Data

If the more detailed 8-point cross section (Figure 3.10) is used, enter the following sequence of records:

KK . . . . Station Computation Identifier
RD . . . . Blank record to indicate Muskingum - Cunge routing

$$\left.\begin{matrix}\text{RC}\\ \text{RX}\\ \text{RY}\end{matrix}\right\} \text{ . . . . 8-point Cross-Section Data}$$

When using the 8-point cross section, it is not necessary to fill out the data for the RD record. All of the necessary information is taken from the RC, RX and RY records. For more details see Example Problem #15.

3.4.4 Element Application

(1) **Overland Flow.** The overland flow element is a wide rectangular channel of unit width; so, referring to Figure 3.6, $\alpha = 1.486S^{½}/N$ and $m = 5/3$. Notice that Manning's n has been replaced by an overland flow roughness factor, N. Typical values of N are shown in Table 3.5. When applying Equations (3.43) and (3.46) to an overland flow element, the lateral inflow is rainfall excess (previously computed using methods described in Section 3.2) and the outflow is a flow per unit width.

An overland flow element is described by four parameters: a typical overland flow length, L, slope and roughness factor which are used to compute α, and the percent of the subbasin area represented by this element.

Two overland flow elements may be used for each subbasin. The total discharge, Q, from each element is computed as

$$Q = q \times \frac{AREA}{L} \qquad (3.70)$$

where q is the discharge per unit width from each overland flow element computed from Equations (3.44) or (3.46), AREA is the area represented by each element, and L is the overland flow length.

Table 3.5

Resistance Factor for Overland Flow

Surface	N value	Source
Asphalt/Concrete*	0.05 - 0.15	a
Bare Packed Soil Free of Stone	0.10	c
Fallow - No Residue	0.008 - 0.012	b
Convential Tillage - No Residue	0.06 - 0.12	b
Convential Tillage - With Residue	0.16 - 0.22	b
Chisel Plow - No Residue	0.06 - 0.12	b
Chisel Plow - With Residue	0.10 - 0.16	b
Fall Disking - With Residue	0.30 - 0.50	b
No Till - No Residue	0.04 - 0.10	b
No Till (20-40 percent residue cover)	0.07 - 0.17	b
No Till (60-100 percent residue cover)	0.17 - 0.47	b
Sparse Rangeland with Debris:		
0 Percent Cover	0.09 - 0.34	b
20 Percent Cover	0.05 - 0.25	b
Sparse Vegetation	0.053 - 0.13	f
Short Grass Prairie	0.10 - 0.20	f
Poor Grass Cover On Moderately Rough	0.30	c
Bare Surface		
Light Turf	0.20	a
Average Grass Cover	0.4	c
Dense Turf	0.17 - 0.80	a,c,e,f
Dense Grass	0.17 - 0.30	d
Bermuda Grass	0.30 - 0.48	d
Dense Shrubbery and Forest Litter	0.4	a

Legend: a) Harley (1975), b) Engman (1986), c) Hathaway (1945), d) Palmer (1946),e) Ragan and Duru (1972), f) Woolhiser (1975). (See Hjemfelt, 1986)

*Asphalt/Concrete n value for open channel flow 0.01 - 0.016

(2) **Channel Elements.** Flow from the overland flow elements travels to the subbasin outlet through one or two successive channel elements, Figure 3.5. A channel is defined by length, slope, roughness, shape, width or diameter, and side slope, Figure 3.6. The last channel in a subbasin is called the main channel, and any intermediate channels between the overland flow elements and the main channel are called collector channels. The main channel may be described by either the simple cross-sections shown in Figure 3.6 or by specifying an eight-point cross section when choosing Muskingum-Cunge routing. Note that Muskingum-Cunge and kinematic wave channels cannot be used within the same subbasin and the use of a collector channel is optional.

Lateral inflow into a channel element from overland flow is the sum of the total discharge computed by Equation (3.50) for both elements divided by the channel length. If the channel is a collector, the area used in Equation (3.50) is the area serviced by the collector. Lateral inflow, q, from a collector channel is computed as:

$$q = Q \times \frac{\text{AREA2}}{\text{AREA1}} \times \frac{1}{L} \qquad (3.71)$$

where Q is the discharge from the collector, AREA1 is a typical area served by this collector, AREA2 is the area served by the channel receiving flow from the collector, and L is the length of the receiving channel. If the receiving channel is the main channel, AREA2 is the subbasin area.

(3) **Element Combination.** The relationship between the overland flow elements and collector and main channels is best described by an example (see Figure 3.5). Consider that the subbasin being modeled is in a typical suburban community and has a drainage area of one square mile. The typical suburban housing block is approximately .05 square miles. Runoff from this area (lawns, roofs, driveways, etc.) is intercepted by a local drainage system of street gutters and drainage pipes (typically 10-15 inch diameter). Flow from local drainage systems is intercepted by drainage pipes (typically 21 to 27 inches in diameter) and conveyed to a small stream flowing through the community. Typically each of the drainage pipes service about a .25 square mile area.

One approach to modeling the subbasin employs two overland flow elements, two collector channels and a main channel. One overland flow plane is used to model runoff from pervious land uses and the other plane is used to model impervious surfaces. The first collector channel models the local drainage system, the second collector channel models the interceptor drainage system and the main channel models the stream. The model parameters which might typically be used to characterize the runoff from the subbasin are shown in Table 3.6. These parameters can be obtained from topographic maps, town or city drainage maps or any other source of land survey information. Note that the parameters are **average or typical** for the subbasin and do not necessarily reflect any particular drainage component in the subbasin (i.e., these are parameters which are representative for the entire subbasin).

The model requires that at least one overland flow plane and one main channel be used in kinematic wave applications. In the above example, fewer elements might have been used depending on the level of detail required for the hydrologic analysis.

3.5 Base Flow

Two distinguishable contributions to a stream flow hydrograph are direct runoff (described earlier) and base flow which results from releases of water from subsurface storage. The HEC-1 model provides means to include the effects of base flow on the streamflow hydrograph as a function of three input parameters, STRTQ, QRCSN and RTIOR. Figure 3.8 defines the relation between the streamflow hydrograph and these variables.

Table 3.6

Typical Kinematic Wave/Muskingum-Cunge Data

Overland Flow Plane Data

Identification	**Overland Flow Length (ft)**	**Average Slope (ft/ft)**	**Roughness Coefficient**	**Percentage of Subbasin Area**
Pervious Area	200	.01	.3	80%
Impervious Area	100	.01	.1	20%

Channel Data

	Channel Length (ft)	**Channel Slope (ft/ft)**	**Contributing Channel Roughness**	**Area (sq mi)**	**Shape**
Collector Channel	500	.005	.02	.05	2.0 (ft) (Diameter)
Collector Channel	1500	.001	.015	.25	2.0 (ft) (Diameter)
**Main Channel	4000	.001	.03	1.0*	Trapezoidal

* Main channel always assumed to service total subbasin area.

**Note main channel may be eight-point cross section when using Muskingum-Cunge routing, Muskingum-Cunge and kinematic wave channel elements cannot be inter-mixed.

The variable STRTQ represents the initial flow in the river. It is affected by the long term contribution of groundwater releases in the absence of precipitation and is a function of antecedent conditions (e.g., the time between the storm being modeled and the last occurrence of precipitation). The variable QRCSN indicates the flow at which an exponential recession begins on the receding limb of the computed hydrograph. Recession of the starting flow and "falling limb" follow a user specified exponential decay rate, RTIOR, which is assumed to be a characteristic of the basin. RTIOR is equal to the ratio of a recession limb flow to the recession limb flow occurring one hour later. The program computes the recession flow Q as:

$$Q = Q_0 (RTIOR)^{-n\Delta t} \qquad (3.72)$$

where Q_o is STRTQ or QRCSN, and $n\Delta t$ is the time in hours since recession was initiated. QRCSN and RTIOR can be obtained by plotting the log of observed flows versus time. The point at which the recession limb fits a straight line defines QRCSN and the slope of the straight line is used to define RTIOR.

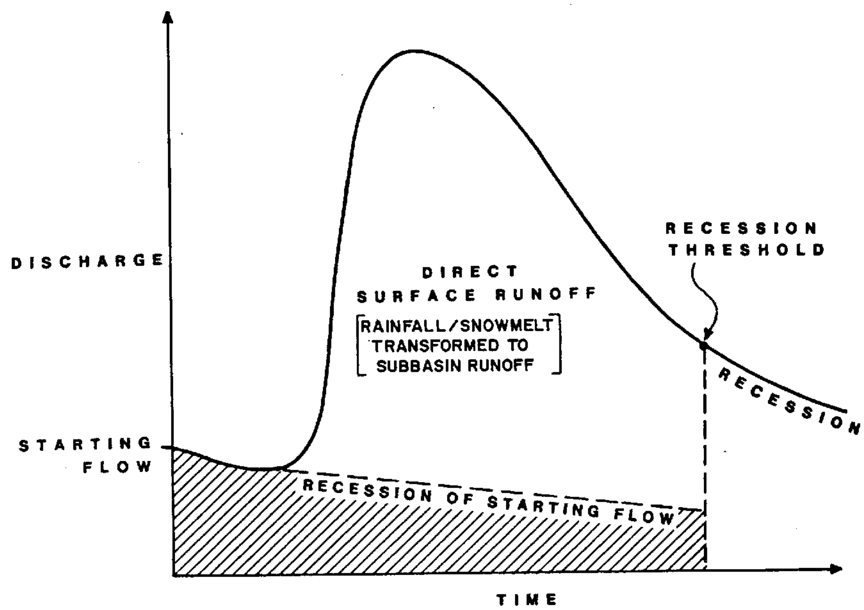


Figure 3.9 Base Flow Diagram

Alternatively, QRCSN can be specified as a ratio of the peak flow. For example, the user can specify that the exponential recession is to begin when the "falling limb" discharge drops to 0.1 of the calculated peak discharge.

The rising limb of the streamflow hydrograph is adjusted for base flow by adding the recessed starting flow to the computed direct runoff flows. The falling limb is determined in the same manner until the computed flow is determined to be less than QRCSN. At this point, the time at which the value of QRCSN is reached is estimated from the computed hydrograph. From this time on, the streamflow hydrograph is computed using the recession equation unless the computed flow rises above the base flow recession. This is the case of a double peaked streamflow hydrograph where a rising limb of the second peak is computed by combining the starting flow recessed from the beginning of the simulation and the direct runoff.

3.6 Flood Routing

Flood routing is used to simulate flood wave movement through river reaches and reservoirs. Most of the flood-routing methods available in HEC-1 are based on the continuity equation and some relationship between flow and storage or stage. These methods are Muskingum, Muskingum-Cunge, Kinematic wave, Modified Puls, Working R and D, and Level-pool reservoir routing. In all of these methods, routing proceeds on an independent-reach basis from upstream to downstream; neither backwater effects nor discontinuities in the water surface such as jumps or bores are considered.

Storage routing methods in HEC-1 are those methods which require data that define the storage characteristics of a routing reach or reservoir. These methods are: modified Puls, working R and D, and level-pool reservoir routing.

There are also two routing methods in HEC-1 which are based on lagging averaged hydrograph ordinates. These methods are not based on reservoir storage characteristics, but have been used on several rivers with good results.

3.6.1 Channel Infiltration

Channel infiltration losses may be simulated by either of two methods. The first method simulates losses by using the following equation:

$$Q(I) = [QIN(I) - QLOSS] \times (1 - CLOSS) \qquad (3.73)$$

where QIN(I) is the inflowing hydrograph ordinate at time I before losses, QLOSS is a constant loss in cfs (m^3/sec), CLOSS is a fraction of the remaining flow which is lost, and Q(I) is the hydrograph ordinate after losses have been removed. Hydrographs are adjusted for losses after routing for all methods except modified Puls; for modified Puls losses are computed before routing.

A second methods computes channel loss during storage routing based on a constant channel loss (cfs/acre) per unit area and the surface area of channel flow. The surface area of channel flow is computed as:

$$WTACRE = \frac{STR(I)}{DEPTH} \qquad (3.74)$$

where STR(I) is the channel storage at time I corresponding to the routed outflow at the end of a period, WTACRE is the corresponding channel surface area, and the depth of flow is the average flow depth in the channel. The flow depth in the channel is computed as:

$$DEPTH = FLOELV(I) - ELVINV \qquad (3.75)$$

where FLOELV(I) is the flow elevation corresponding to STR(I) and ELVINV is the channel invert elevation. ELVINV must be chosen carefully to give the proper values for WTACRE. The resulting hydrograph is then computed as:

$$QO(I) = Q(I) - WTACRE \times PERCRT \qquad (3.76)$$

where Q(I) is the routed outflow and QO(I) is the flow adjusted for the constant channel loss rate PERCRT (cfs/acre).

3.6.2 Muskingum

The Muskingum method (Corps of Engineers, 1960) computes outflow from a reach using the following equation:

$$\mathrm{QOUT}(2) = (\mathrm{CA}-\mathrm{CB})\times\mathrm{QIN}(1) + (1-\mathrm{CA})\times\mathrm{QOUT}(1) + \mathrm{CB}\times\mathrm{QIN}(2) \qquad \text{...... (3.77)}$$

$$\mathrm{CA} = \frac{2\times\Delta t}{2\times\mathrm{AMSKK}\times(1-\mathrm{X})+\Delta t} \qquad \text{...... (3.78)}$$

$$\mathrm{CB} = \frac{\Delta t - 2\times\mathrm{AMSKK}\times\mathrm{X}}{2\times\mathrm{AMSKK}\times(1-\mathrm{X})+\Delta t} \qquad \text{...... (3.79)}$$

where QIN is the inflow to the routing reach in cfs (m^3/sec), QOUT is the outflow from the routing reach in cfs (m^3/sec), AMSKK is the travel time through the reach in hours, and X is the Muskingum weighting factor ($0 \leq X \leq .5$). The routing procedure may be repeated for several subreaches (designated as NSTPS) so the total travel time through the reach is AMSKK. To insure the method's computational stability and the accuracy of computed hydrograph, the routing reach should be chosen so that:

$$\frac{1}{2(1-\mathrm{X})} \leq \frac{\mathrm{AMSKK}}{\mathrm{NSTPS}\times\Delta t} \leq \frac{1}{2\mathrm{X}} \qquad \text{................................ (3.80)}$$

3.6.3 Muskingum-Cunge

Muskingum-Cunge routing was described in detail in Section 3.4.3. This routing technique can also be used independently of the subbasin runoff computation; it can be used for any routing reach. The advantages and disadvantages for the method were discussed in Section 3.4.3. A discussion of Muskingum-Cunge versus kinematic wave routing is given in Section 3.6.10. The Muskingum-Cunge method is not limited to the standard prismatic channel shapes shown for kinematic wave, although it can use them. Muskingum-Cunge allows more detailed main channel and overbank flow areas to be specified with an eight-point cross section. That is the same channel geometry representation as for the Normal-Depth Storage routing, Section 3.6.4. The Muskingum-Cunge routing is applicable to a wide range of channel and hydrograph conditions. It has the same limitation as all other HEC-1 routing methods in that downstream backwater effects cannot be simulated.

3.6.4 Modified Puls

The modified Puls routing method (Chow, 1964) is a variation of the storage routing method described by Henderson (1966). It is applicable to both channel and reservoir routing. Caution must be used when applying this method to channel routing. The degree of attenuation introduced in the routed flood wave varies depending on the river reach lengths chosen, or alternatively, on the number of routing steps specified for a single reach. The number of routing steps (variable NSTPS) is a calibration parameter for the storage routing methods; it can be varied to produce desired routed hydrographs. A storage indication function is computed from given storage and outflow data.

$$\text{STRI(I)} \;=\; C \times \frac{\text{STOR(I)}}{\Delta t} + \frac{\text{OUTFL(I)}}{2} \qquad (3.81)$$

where STRI is the storage indication in cfs (m^3/sec), STOR is the storage in the routing reach for a given outflow in acre-ft (1000 m^3), OUTFL is the outflow from routing reach in cfs (m^3/sec), C is the conversion factor from acre-ft/hr to cfs (1000 m^3/hr to m^3/sec), Δt is the time interval in hours, and I is a subscript indicating corresponding values of storage and outflow. Storage indication at the end of each time interval is given by

$$\text{STRI(I)} \;=\; \text{STRI(1)} + \text{QIN} - \text{Q(1)} \qquad (3.82)$$

where QIN is the average inflow in cfs (m^3/sec), and Q is the outflow in cfs (m^3/sec), and subscripts 1 and 2 indicate beginning and end of the current time interval.

The outflow at the end of the time interval is interpolated from a table of storage indication (STRI) versus outflow (OUTFL). Storage (STR) is then computed from

$$\text{STR} \;=\; (\text{STRI} - \frac{Q}{2}) \times \frac{\Delta t}{C} \qquad (3.83)$$

When stage data are given, stages are interpolated for computed storages.

Initial conditions can be specified in terms of storage, outflow, or stage. The corresponding value of storage or outflow is computed from the given initial value.

(1) **Given Storage versus Outflow Relationship.** The modified Puls routing may be accomplished by providing a storage versus outflow relationship as direct input to HEC-1. Such a relationship can be derived from water surface profile studies or other hydraulic analyses of rivers or reservoirs.

(2) **Normal-Depth Storage and Outflow.** Storage and outflow data for use in modified Puls or working R&D (see next subsection) routing may be computed from channel characteristics. The program uses an 8-point cross section which is representative of the routing reach (Figure 3.10). Outflows are computed for normal depth using Manning's equation. Storage is cross-sectional area times reach length. Storage and outflow values are computed for 20 evenly-spaced stages beginning at the lowest point on the cross section to a specified maximum stage. The cross section is extended vertically at each end to the maximum stage.

As shown in Figure 3.10, the input variables to the program are the hydraulic and geometric data: ANL, ANCH, ANR, RLNTH, SEL, ELMAX, and (X,Y) coordinates. ANL, ANCH, ANR are Manning's n values for left overbank, main channel, and right overbank, respectively. RLNTH is routing reach length in feet (meters). SEL is the energy gradient used for computing outflows. (X,Y) are coordinates of an 8-point cross section.

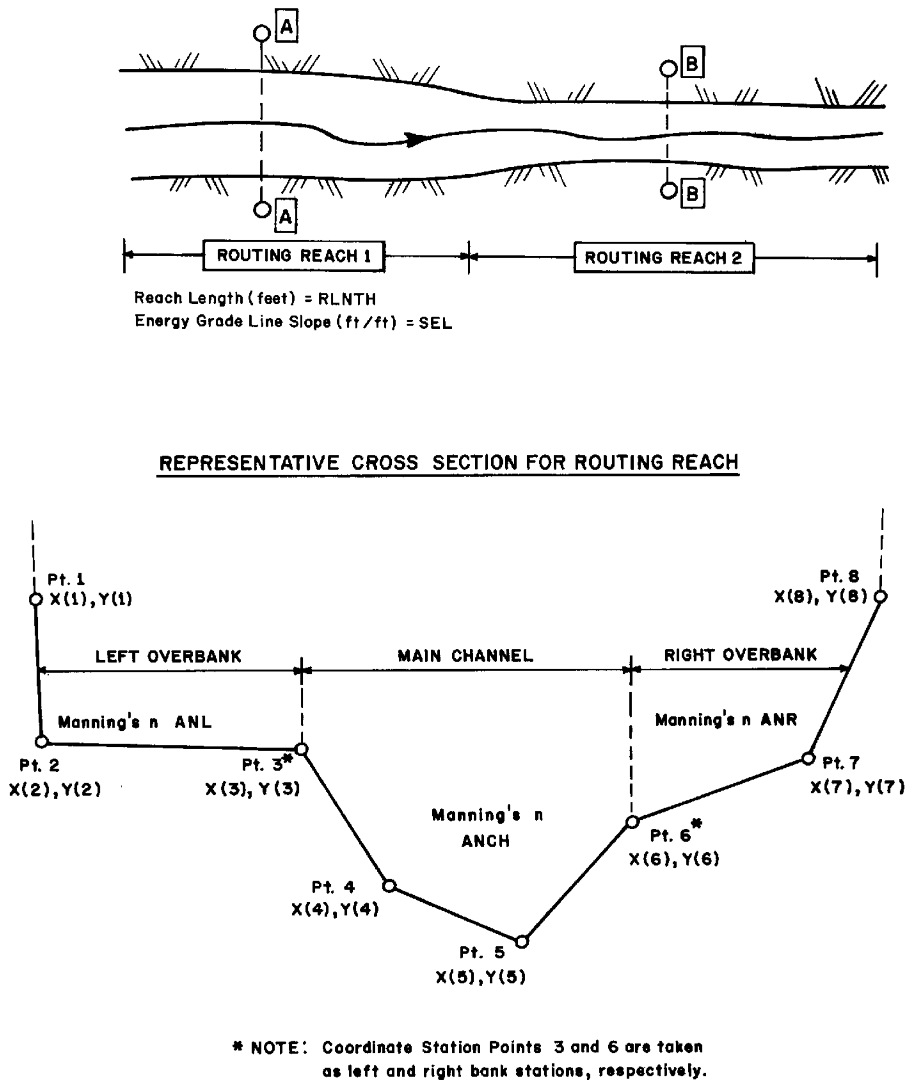


Figure 3.10 Normal Depth Storage-Outflow Channel Routing

Storage and outflow should not be calculated from normal depth when the storage limits and conveyance limits are significantly different. Also, if the cross section is "representative" for a reach that is not uniform, the stages will not be applicable to any specific location. Generally, the stages produced by the method are of limited value because downstream effects are not taken into account.

3.6.5 Working R and D

The working R and D method (Corps of Engineers, 1960) is a variation of modified Puls method which accounts for wedge storage as in the Muskingum method. The number of steps and the X factor are calibration parameters of the method and can have a significant effect on the routed hydrograph.

The "working discharge," D, is given by

$$D = X \times I + (1 - X) \times O \quad (3.84)$$

and storage indication, R, is given by

$$R = \frac{S}{\Delta t} + \frac{D}{2} \quad (3.85)$$

where I is the inflow hydrograph ordinate, O is the outflow hydrograph ordinate, S is the storage volume in routing reach, and X is the Muskingum coefficient which accounts for wedge storage. The calculation sequence is as follows:

(1) set initial D and R from initial inflow, outflow, and storage
(2) compute R for next step from

$$R_2 = R_1 + \frac{I_1 + I_2}{2} - D_1 \quad (3.86)$$

(3) interpolate D_2 from R vs. D data
(4) compute outflow from

$$O_2 = D_2 - \frac{X}{(1 - X)} \times (I_2 - D_2) \quad (3.87)$$

The storage versus outflow relationship may be specified as direct input or computed by the normal-depth option as described above.

3.6.6 Level-Pool Reservoir Routing

Level-pool reservoir routing assumes a level water surface behind the reservoir. It is used in conjunction with the pump option described in Section 3.8 and with the dam-break calculation described in Section 6. Using the principle of conservation of mass, the change in reservoir storage, S, for a given time period, Δt, is equal to average inflow, I, minus average outflow, O.

$$\frac{S_2 - S_1}{\Delta t} = \frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} \quad (3.88)$$

An iterative procedure is used to determine end-of-period storage, S_2, and outflow, O_2. An initial estimate of the water surface elevation at the end of the time period is made. S_2 and O_2 are computed for this elevation and substituted in the following equation:

$$Y = \frac{S_2 - S_1}{\Delta t} - \frac{I_1 + I_2}{2} + \frac{O_1 + O_2}{2} \quad (3.89)$$

where Y is the continuity error for the estimated elevation. The estimated elevation is adjusted until Y is within ±1 cfs (m^3/sec).

(1) **Reservoir Storage Data.** A reservoir storage volume versus elevation relationship is required for level-pool reservoir routing. The relationship may be specified in two ways: 1) direct input of precomputed storage versus elevation data, or 2) computed from surface area versus elevation data. The conic method is used to compute reservoir volume from surface area versus elevation data, Figure 3.10. The volume is assumed to be zero at the lowest elevation given, even if the surface area is greater than zero at that point.

Reservoir outflow may be computed from a description of the outlet works (low-level outlet and spillway). There are two subroutines in HEC-1 which compute outflow rating curves. The first uses simple orifice and weir flow equations while the second computes outflow from specific energy or design graphs and corrects for tailwater submergence.

(2) **Orifice and Weir Flow.** This option is often used in spillway adequacy investigations of dam safety, see Example Problems, Sections 12.7 and 12.8.

Flow through a **low-level outlet** is computed from

$$Q = COQL \times CAREA \times \sqrt{2g} \times (WSEL - ELEVL)^{EXPL} \qquad \text{(3.90)}$$

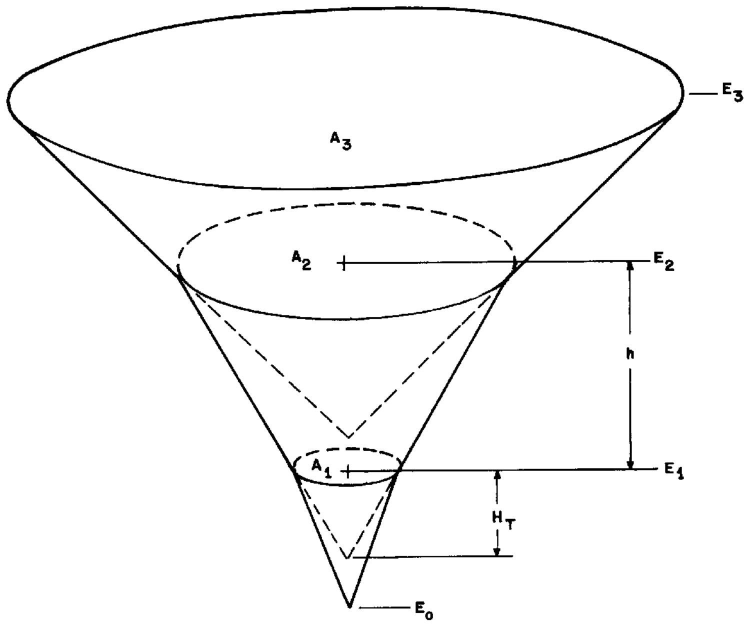
where Q is the computed outflow, COQL is an orifice coefficient, CAREA is the cross-sectional area of conduit, WSEL is the water surface elevation, ELEVL is the elevation at center of low-level outlet, and EXPL is an exponent.

Flow over the **spillway** is computed from

$$Q = COQW \times SPWID \times (WSEL - CREL)^{EXPW} \qquad \text{(3.91)}$$

where Q is computed outflow, COQW is a weir coefficient, SPWID is the effective width of spillway, WSEL is the water surface elevation, CREL is the spillway crest elevation, and EXPW is an exponent.

If pumps or dam breaks are not being simulated, an outflow rating curve is computed for 20 elevations which span the range of elevations given for storage data. Storages are computed for those elevations. The routing is then accomplished by the modified Puls method using the derived storage-outflow relation. For level-pool reservoir routing with pumping or dam-break simulation, outflows are computed for the orifice and weir equations for each time interval.



$\Delta V_{12} = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1 A_2})$

$H_T = h/(\sqrt{A_2/A_1} - 1)$

Where

ΔV_{12} = volume between base areas 1 and 2,

Ai = surface area of base i,

E_i = elevation of base i,

h = vertical distance ($E_2 - E_1$) between bases A_1 and A_2, and

H_T = height of truncated part of cone.

Figure 3.11 Conic Method for Reservoir Volumes

(3) **Trapezoidal and Ogee Spillways.** Trapezoidal and ogee spillways (Corps of Engineers, 1965) may be simulated as shown in Figure 3.12. The outflow rating curve is computed for 20 stages which span the range of given storage data. If there is a low-level outlet, the stages are evenly spaced between the low-level outlet and the maximum elevation, with the spillway crest located at the tenth elevation. In the absence of a low-level outlet, the second stage is at the spillway crest. The available energy head HE for flow over the spillway is computed as

$$HE = HEAD - [APLOSS \times \frac{HEAD}{DESHD}] \qquad (3.92)$$

where APLOSS is the approach loss at design head, HEAD is the water surface elevation minus spillway crest elevation, and DESHD is the design head. Design head is the difference between the normal maximum pool elevation and the spillway crest elevation.

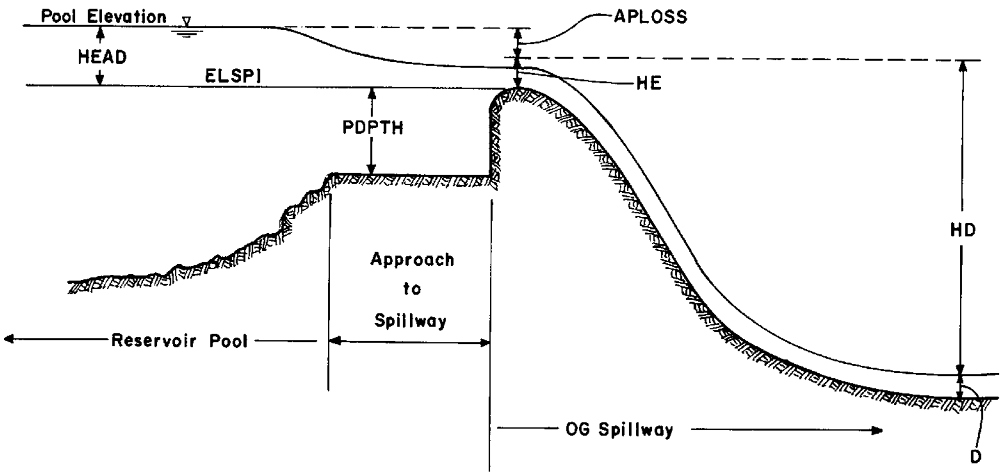


Figure 3.12 Ogee Spillway

Pier and abutment energy losses are computed by interpolation of the data shown in Table 3.7 based on HE/DESHD.

Effective length of the spillway crest ZEFFL is computed as

$$\mathrm{ZEFFL} = \mathrm{SPWID} - 2 \times \mathrm{HE} \times (\mathrm{N} \times \mathrm{KP} + \mathrm{KA}) \qquad (3.93)$$

where SPWID is the spillway crest length, N is the number of piers, KP is the pier contraction coefficient, and KA is the abutment contraction coefficient.

For a **trapezoidal spillway**, outflow is computed from critical depth; submergence of the spillway and low-level outlet are not considered. The expression for velocity head HV at critical depth D is:

$$\mathrm{HV} = \frac{V^2}{2g} = \frac{A}{2T} \qquad (3.94)$$

where A is the cross-sectional area of flow, and T is the top width at critical depth. The velocity head is computed by trial and error until HE = HV + D ±.001.

Table 3.7

Spillway Rating Coefficients

Specific Energy/ Design Head, HE DESHD	Discharge Coefficient, CC	Approach Depth Adjustment Exponent, EC	Pier Contraction Coefficients, KP (3)	Abutment Contraction Coefficients, KA Concrete (1)	Earth (2)
0	3.100	0	.123	-.008	.005
.1	3.205	.0059	.101	.023	.030
.2	3.320	.0090	.082	.045	.053
.3	3.415	.0114	.063	.062	.074
.4	3.520	.0135	.046	.074	.092
.5	3.617	.0155	.034	.081	.112
.6	3.710	.0174	.026	.089	.123
.7	3.800	.0191	.017	.093	.137
.8	3.880	.0208	.009	.097	.150
.9	3.943	.0224	.003	.099	.162
1.0	4.000	.0241	0	.100	.174
1.1	4.045	.0260	-.006	.100	.182
1.2	4.070	.0281	-.012	.100	.189
1.3	4.090	.0307	-.013	.100	.194

(1) Abutment contraction coefficients for adjacent concrete non overflow section using Waterways Experiment Station (W.E.S.). Hydraulic Design Chart III - 3/1 dated August 1960 and making KA = .1 and HE/HD = 1.0.

(2) Abutment contraction coefficients for adjacent embankment non-overflow section from W.E.S. Hydraulic Design Chart III - 3/2 Rev. January 1964.

(3) Pier contraction coefficients for type 3 piers are from Plate 7 of EM 1110-2-1603 (Corps of Engineers, 1965).

For an **ogee spillway** the discharge coefficient COFQ is

$$COFQ = CC \times (\frac{PDPTH}{DESHD})^{EC} \qquad (3.95)$$

where PDPTH is the approach depth to spillway, and CC and EC are interpolated from Table 3.7 based on HE/DESHD. The spillway discharge QFREE assuming no tailwater submergence is

$$QFREE = COFQ \times ZEFFL \times HE^{1.5} \qquad (3.96)$$

Tailwater elevation may be computed from specific energy or by interpolation from a tailwater rating table. If tailwater elevation is computed from specific energy, the downstream specific energy is assumed to be

$$h_{et} = 0.9 \times (HE + \frac{ELSPI}{APEL}) \qquad (3.97)$$

where h_{et} is the specific energy at toe of spillway, HE is the specific energy at crest of spillway, ELSPI is the spillway crest elevation, and APEL is the spillway apron (toe) elevation. Tailwater depth is then computed by trial and error until:

$$(h_{et} - D) \times D^2 = \frac{1}{2g} \times (\frac{QASSM}{APWID})^2 \pm 0.001 \qquad (3.98)$$

where D is the tailwater depth, APWID is the spillway apron width, and QASSM is the assumed spillway discharge corrected for tailwater submergence.

A submergence coefficient is interpolated from Table 3.8 using:

$$\frac{HD + D}{HE} = \frac{HE + ELSPI - APEL}{HE} \qquad (3.99)$$

and

$$\frac{HD}{HE} = \frac{HE + ELSPI - APEL - D}{HE} \qquad (3.100)$$

Table 3.8

Submergence Coefficients

(HE + D)/HE																		HD/HE
1.07	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.25	2.50	3.00	3.50	4.00	4.50	
PERCENT SUBMERGENCE																		
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	.00
55.0	54.0	52.0	49.0	45.0	42.0	40.0	39.0	38.0	38.0	37.5	39.0	40.5	43.0	53.0	58.0	60.0	60.0	.05
36.5	35.0	33.0	31.0	27.0	23.5	21.0	19.0	18.5	18.0	18.785	18.88	19.52	21.15	26.25	29.0	31.0	32.0	.10
27.5	25.0	22.0	19.5	17.5	15.5	14.0	13.5	13.0	12.5	12.45	12.21	12.63	13.44	15.0	17.0	18.3	21.0	.15
21.0	18.0	17.0	15.0	13.0	11.3	9.8	9.0	8.5	8.2	8.0	8.0	8.19	8.56	9.41	11.2	12.0	13.0	.20
18.0	15.5	13.5	12.0	10.0	8.4	7.2	6.0	5.4	5.0	4.9	4.914	5.375	5.88	7.0	7.85	8.5	9.0	.25
16.0	13.5	12.0	10.5	8.0	6.1	4.3	3.7	3.3	3.1	3.00	3.02	3.333	3.82	5.123	6.08	6.66	7.0	.30
15.0	13.0	10.0	8.0	5.5	3.6	2.5	1.8	1.7	1.5	1.45	1.438	1.625	1.88	2.717	3.73	4.19	4.5	.40
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.2	.96	.87	.857	.842	.853	.933	1.62	2.24	2.70	2.9	.50
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.90	.75	.525	.515	.562	.600	.860	1.27	1.65	1.8	.60
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.80	.50	.475	.450	.390	.385	.470	.69	0.93	1.0	.70
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.450	.415	.323	.250	.110	.20	0.34	0.3	80
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.445	.410	.310	.220	.030	0.0	0.0	0.0	.85
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.445	.400	.300	.200	0.0	0.0	0.0	0.0	.90

The corrected flow is then

$$QCORR = QFREE - 0.01 \times SUBQ \times QFREE \qquad (3.101)$$

where QCORR is the spillway discharge corrected for tailwater submergence, and SUBQ is the submergence coefficient in percent. A new corrected discharge is assumed, and tailwater and submergence correction is computed until the change in QCORR is less than one percent.

Free discharge from the low-level outlet is

$$CQFREE = COQL \times CAREA \times (2g)^{0.5} \times (EL - ELEVL)^{0.5} \qquad (3.102)$$

where CQFREE is the conduit discharge for unsubmerged outlet, COQL is the discharge coefficient, CAREA is the conduit cross-sectional area, EL is the reservoir water surface elevation, and ELEVL is the center elevation of the conduit outlet. Tailwater elevation is interpolated from the tailwater rating table and the corrected conduit flow is computed from

$$CQCOND = COQL - CAREA \times (2g)^{0.5} \times (EL - ZXTWEL)^{0.5} \qquad (3.103)$$

where CQCOND is the conduit discharge corrected for submergence, and ZXTWEL is the conduit tailwater elevation. ZXTWEL and CQCOND are recomputed until the change in CQCOND is less than 0.1 percent.

3.6.7 Average-Lag

The Straddle-Stagger (Progressive Average-Lag) Method (Corps of Engineers, 1960) routes by lagging flows LAG time intervals then averaging NSTDL flows.

$$Q(I) = QIN(1) \qquad I \leq LAG \qquad (3.104)$$

$$Q(I) = QIN(I - LAG) \qquad I \times LAG \qquad (3.105)$$

$$QOUT(I) = \sum_{L = I - \frac{NSTDL}{2}}^{I + \frac{NSTDL}{2}} \frac{Q(L)}{NSTDL} \qquad (3.106)$$

where LAG is the number of time intervals to lag inflow hydrograph, NSTDL is the number of ordinates to average to compute the outflow, QIN is the inflow hydrograph ordinate, Q is the lagged hydrograph ordinate, and QOUT is the outflow hydrograph ordinate.

The Tatum (Successive Average-Lag) Method (Corps of Engineers, 1960) computes the outflow hydrograph as an average of the current and previous inflow ordinates.

$$Q(I) = \frac{(QIN(I) + QIN(I - 1))}{2} \qquad (3.107)$$

where QIN is the inflow hydrograph ordinate, and Q is the routed hydrograph ordinate. This averaging is repeated NSTPS times to produce the outflow hydrograph.

3.6.8 Calculated Reservoir Storage and Elevation from Inflow and Outflow

HEC-1 can compute changes in reservoir storage using the current hydrograph as inflow and a user-defined hydrograph as outflow. The HS record is used to tell the program to compute storage from the inflow and outflow. The outflow hydrograph is read from QO records, and is used in downstream calculations.

Initial storage at the beginning of the simulation is set on the HS record in the first field. Subsequent storage values are calculated from the following formula:

$$\mathrm{SRT(I)} \; = \; \mathrm{C} \times [\frac{\mathrm{(QI(I) + QI(I-1)}}{2} - \frac{\mathrm{(QO(I) + QO(I-1)}}{2}] \times \mathrm{DT} + \mathrm{STR(I-1)} \tag{3.108}$$

where:

STR(I)	=	storage at time I in acre-feet
QI(I)	=	inflow at time I in cfs
QO(I)	=	outflow at time I in cfs
DT	=	time interval between time I-1 and I in seconds
C	=	factor for converting from cubic feet to acre-feet

If an inflow or outflow value is missing, subsequent values will be undefined.

Known reservoir storage values maybe read from DSS using ZR=HS. In this case storages will be calculated starting with the last valid entry from DSS. If no valid storage value is found, initial storage will be set to zero, and the computed values will be changed in storage relative to the initial value.

An optional storage-elevation relationship can be entered on SV and SE records. If this information is present, reservoir elevations will be interpolated for each storage value and printed in the output. An example of how to calculate reservoir storages from inflow and outflow is given in Example Problem #14, Section 12.

3.6.9 Kinematic Wave

Kinematic wave routing was described in detail in Section 3.4.1. The channel routing computation can be utilized independently of the other elements of the subbasin runoff. In this case, an upstream inflow is routed through a reach (independent of lateral inflows) using the previously described numerical methods. The kinematic wave method in HEC-1 does not allow for explicit separation of main channel and overbank areas. The cross-sectional geometry is limited to the shapes shown in Figure 3.6. Theoretically a flood wave routed by the kinematic wave technique through these channel sections is translated, but does not attenuate (although a degree of attenuation is introduced by the finite difference solution). Consequently, the kinematic wave routing technique is most appropriate in channels where flood wave attenuation is not significant, as is typically the case in urban areas. Otherwise, flood wave attenuation can be modeled using the Muskingum-Cunge method or empirically by using the storage routing methods, modified Puls or working R and D.

3.6.10 Muskingum-Cunge vs. Kinematic Wave Routing

The Muskingum-Cunge and kinematic wave techniques (see Section 3.4) can be used to route an upstream hydrograph independent of lateral inflow. The conditions for which each technique is appropriate has been discussed extensively in the literature (e.g., Ponce et al., 1978). As discussed previously, neither method is applicable when the channel hydraulics are affected by backwater conditions. This limitation exists for all routing methods incorporated into HEC-1 because of the headwater nature of the model.

In general, the Muskingum-Cunge method (an approximate diffusion router) is a superior and more preferable technique than the kinematic wave method for channel routing, particularly when there is no lateral inflow to the channel. However, if applied, the kinematic wave channel routing method should be used for relatively short routing reaches (e.g., those encountered in urban watershed studies) in headwater areas. Routed hydrographs produced under these circumstances should show at most five percent peak discharge attenuation due to numerical errors in solving the kinematic wave equations. Peak attenuation greater than this amount probably indicates the formation of a kinematic "shock" which is not desireable. Under these circumstance the user should either reformulate the watershed model so that lateral inflow exists in the routing reach, or more preferably, utilize the Muskingum-Cunge method.

3.7 Diversions

Flow diversions may be simulated by linear interpolation from input tables of inflow versus diverted flow. The inflow DINFLO(I) corresponds to an amount of flow DIVFLO(I) to be diverted to a designated point in or out of the river basin. The diverted hydrograph can be retrieved and routed and combined with other flows anywhere in the system network downstream of the point of diversion or to a parallel drainage system. A diversion is illustrated in the first example problem, Section 12.1.

3.8 Pumping Plants

Pumping plants may be simulated for interior flooding problems where runoff ponds in low areas or behind levees, flood walls, etc. Multiple pumps may be used, each with different on and off elevations. Pumps are simulated using the level-pool reservoir routing option described in Section 3.6.6. The program checks the reservoir stage at the beginning of each time period. If the stage exceeds the "pump-on" elevation the pump is turned on and the pump output is included as an additional outflow term in the routing equation. When the reservoir stage drops below a "pump-off" elevation, the pump is turned off. Several pumps with different on and off elevations may be used.

Each pump discharges at a constant rate. It is either on or off. There is no variation of discharge with head. The average discharge for a time period is set to the pump capacity, so it is assumed that the pump is turned on immediately after the end of the previous period.

Pumped flow may be retrieved at any point after the pump location in the same manner as a diverted hydrograph.

Section 4

Parameter Calibration

Calibration and verification are essential parts of the modeling process. Rough estimates for the parameters in the HEC-1 model can be obtained from the description of the methods in Section 3; however, the model should be calibrated to observed flood data whenever possible. HEC-1 provides a powerful optimization technique for the estimation of some of the parameters when gaged precipitation and runoff data are available. By using this technique and regionalizing the results, rainfall-runoff parameters for ungaged areas can also be estimated (HEC, 1981). Examples of the use of the optimization option are given in Example Problems #4 and #5. A summary of the HEC's experience with automatic calibration of rainfall-runoff models is given by Ford et al. (1980).

4.1 Unit Hydrograph and Loss Rate Parameters

4.1.1 Optimization Methodology

The parameter calibration option has the capability to automatically determine a set of unit hydrograph and loss rate parameters that "best" reconstitute an observed runoff hydrograph for a subbasin. The data which must be provided to the model are: basin average precipitation; basin area; starting flow and base flow parameters STRTQ, QRCSN and RTIOR; and the outflow hydrograph. Means for estimating these data and their use in the model are described in Section 3. Unit hydrograph and loss rate parameters can be determined individually or in combination. Parameters that are not to be determined from the optimization process must be estimated and provided to the model. Initial estimates of the parameters to be determined can be input by the user or chosen by the program's optimization procedure.

The runoff parameters that can be determined in the calibration are the unit hydrograph parameters of the Snyder, Clark and SCS methods and the loss rate parameters of the exponential, Holtan, SCS, Green and Ampt, and initial/constant methods. The melt rate and threshold melt temperature can also be optimized for snow hydrology studies. If the Snyder method is employed, the Clark coefficients will be determined and converted to the Snyder parameters.

The "best" reconstitution is considered to be that which minimizes an objective function, STDER. The objective function is the square root of the weighted squared difference between the observed hydrograph and the computed hydrograph. Presumably, this difference will be a minimum for the optimal parameter estimates. STDER is depicted in Figure 4.1 and computed as follows.

$$STDER = \left[\sum_{i=1}^{n} (QOBS_i - QCOMP_i)^2 \times \frac{WT_i}{n}\right]^{\frac{1}{2}} \qquad \text{(4.1)}$$

where $QCOMP_i$ is the runoff hydrograph ordinate for time period i computed by HEC-1, $QOBS_i$ is the observed runoff hydrograph ordinate i, n is the total number of hydrograph ordinates, and WT_i is the weight for the hydrograph ordinate i computed from the following equation.

$$WT_i = \frac{(QOBS_i + QAVE)}{(2 \times QAVE)} \qquad \text{(4.2)}$$

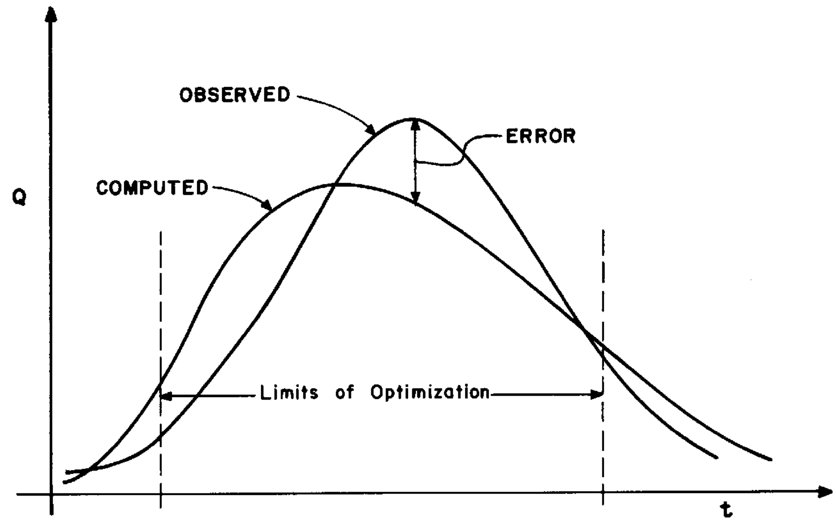


Figure 4.1 Error Calculation for Hydrologic Optimization

where QAVE is the average observed discharge. This weighting function emphasizes accurate reproduction of peak flows rather than low flows by biasing the objective function. Any errors for computed discharges that exceed the average discharge will be weighted more heavily, and hence the optimization scheme should focus on reduction of these errors.

The minimum of the objective function is found by employing the univariate search technique (Ford et al., 1980). The univariate search method computes values of the objective function for various values of the optimization parameters. The values of the parameters are systematically altered until STDER is minimized.

The range of feasible values of the parameters is bounded because of physical limitations on the values that the various unit hydrograph, loss rate, and snowmelt parameters may have, and also because of numerical limitations imposed by the mathematical functions. In addition to bounds on the maximum and minimum values of certain parameters, the interaction of some parameters is also restricted because of physical or numerical limitations. These constraints are summarized in Table 4.1. The constraints shown here are limited to those imposed explicitly by the program. Additional constraints may be appropriate in certain circumstances; however, these must be imposed externally to the program when the user must decide whether to accept, modify, or reject a given parameter set, based on engineering judgment.

The optimization procedure does not guarantee that a "global" optimum (or a global minimum of the objective function) will be found for the runoff parameter; a local minimum of the objective function might be found by the procedure. To help assess the results of the optimization, HEC-1 provides graphical and statistical comparisons of the observed and computed hydrographs. From this, the user can then judge the accuracy of the optimization result. It is possible that the computed hydrograph will not

Table 4.1

Constraints on Unit Graph and Loss Rate Parameters

Clark Unit Graph Parameters:

$TC \geq 1.03\Delta t$
$R \geq .52$
Δt = Computation Interval

Loss Rate Parameters

Exponential	**SCS**
ERAIN ≤ 1.0 RTIOL ≥ 1.0	0 ≤ CN ≤ 100
Snowmelt	**Green and Ampt**
RTIOK ≥ 1.0 - 1.11°C ≤ FRZTP ≤ 3.33°C	IA ≥ 0 DTHETA ≥ 0 PSIF ≥ 0 xKSAT ≥ 0
Uniform	**Holtan**
STRTL ≥ 0 CNSTL ≥ 0	FC ≥ 0 GIA ≥ 1.0 BEXP ≥ 0

meet with the criteria established by the user. An improvement in the reconstitution might be affected by specifying different starting values for the parameters to be optimized. This can be accomplished by varying the starting values in a number of optimization runs in order to better sample the objective function and find a global optimum.

4.1.2 Analysis of Optimization Results

The computed output resulting from an optimization run describes some of the initial and intermediate computations performed to obtain optimal precipitation-runoff parameters. It is instructive to relate the optimization algorithm to the example output shown in Table 4.2 (see Section 12.4, for the complete example application of this parameter calibration). The algorithm proceeds as follows:

(1) Initial values are assigned for all parameters. These values may be assigned by the user or program-assigned default values, Table 4.3, may be used. In the example output, four parameters are optimized: unit hydrograph parameters TC and R, and exponential loss infiltration parameters STRKR and DLTKR (ERAIN and RTIOL are constant). In this case, initial values were chosen by the user, STRKR = 0.20, etc. Note that the unit hydrograph parameters TC, R are displayed as the sum (TC + R) and ratio R/(TC + R) which are adjusted by the program during the optimization process.

(2) The response of the river basin as simulated with the initial parameter estimates and the initial value of the objective function is calculated. The volume of the simulated hydrograph is adjusted to within one percent of the observed hydrograph if the option to adjust infiltration parameters has been selected. This is demonstrated by the asterisked (*) values of STRKR (= 0.448*) and DLTKR (= 1.119*) in the example output. The asterisk (*) denotes which variable was changed and its "optimum" value. The value of the objective function at this point equals $3.4957\text{x}10^2$.

(3) In the order shown in Tables 4.2 and 4.3, each parameter to be estimated is decreased by one percent and then by two percent, the system response is evaluated, and the objective function calculated for each change, respectively. This gives three separate system evaluations at equally-spaced values of the parameter with all other parameters held constant. The "best" value of the parameter is then estimated using Newton's method. This is demonstrated in the example by the asterisked values of each of the optimization variables (e.g., TC + R = 6.895*, R/(TC + R) = 0.522*, etc.). A parameter which does not improve the objective function under this procedure is maintained at its original value. This is indicated by a plus (+) in place of an asterisk (*) in the computed output; this circumstance does not occur in the example.

(4) Step 3 is repeated four times. This results in adjustments to all four of the optimization parameters, four separate times. In this example, the resulting final values of the variables are: TC + R = 7.101*, R/(TC + R) = 0.551*, STRKR = 0.465*, DLTKR = 0.362*.

(5) Step 3 is then repeated for the parameter that most improved the value of the objective function in its last change. This is continued until no single change in any parameter yields a reduction of the objective function of more than one percent. In the example this leads to changes to STRKR and DLTKR.

Table 4.2

HEC-1 Unit Hydrograph and Loss Rate Optimization Output

INITIAL ESTIMATES FOR OPTIMIZATION VARIABLES

TC+R	R/(TC+R)	STRKR	DLTKR	RTIOL	ERAIN
6.16	0.50	0.20	0.50	1.00	0.50

INTERMEDIATE VALUES OF OPTIMIZATION VARIABLES
(*INDICATES CHANGE FROM PREVIOUS VALUE)
(+INDICATES VARIABLE WAS NOT CHANGED)

OBJECTIVE FUNCTION	TC+R	R/(TC+R)	STRKR	DLTKR	RTIOL	ERAIN
VOL. ADJ.	6.156	0.500	0.448*	1.119*	1.000	0.500
349.3	6.890*	0.500	0.448	1.119	1.000	0.500
346.8	6.890	0.521*	0.448	1.119	1.000	0.500
344.4	6.890	0.521	0.438*	1.119	1.000	0.500
339.3	6.890	0.521	0.438	0.984*	1.000	0.500
339.1	6.920*	0.521	0.438	0.984	1.000	0.500
335.8	6.920	0.546*	0.438	0.984	1.000	0.500
335.1	6.920	0.546	0.443*	0.984	1.000	0.500
328.3	6.920	0.546	0.443	0.812*	1.000	0.500
327.0	7.014*	0.546	0.443	0.812	1.000	0.500
326.8	7.014	0.550*	0.443	0.812	1.000	0.500
324.6	7.014	0.550	0.453*	0.812	1.000	0.500
311.1	7.014	0.550	0.453	0.541*	1.000	0.500
309.9	7.100*	0.550	0.453	0.541	1.000	0.500
309.9	7.100	0.551*	0.453	0.541	1.000	0.500
305.6	7.100	0.551	0.465*	0.541	1.000	0.500
293.4	7.100	0.551	0.465	0.361*	1.000	0.500
288.2	7.100	0.551	0.465	0.241*	1.000	0.500
286.2	7.100	0.551	0.465	0.160*	1.000	0.500
281.7	7.100	0.551	0.478*	0.160	1.000	0.500
281.7	7.100	0.551	0.477*	0.160	1.000	0.500
281.2	7.044*	0.551	0.477	0.160	1.000	0.500
VOL. ADJ.	7.044	0.551	0.487*	0.164*	1.000	0.500

OPTIMIZATION RESULTS

CLARK UNITGRAPH PARAMETERS

TC	3.16
R	3.88

SNYDER STANDARD UNITGRAPH PARAMETERS

TP	2.99
CP	0.52

LAG FROM CENTER OF MASS OF EXCESS TO CENTER OF MASS OF UNITGRAPH 5.36

UNITGRAPH PEAK	4333.
TIME OF PEAK	3.000

EXPONENTIAL LOSS RATE PARAMETERS

STRKR	0.49
DLTKR	0.16
RTIOL	1.00
ERAIN	0.50

EQUIVALENT UNIFORM LOSS RATE 0.444

COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS

STATISTICS BASED ON OPTIMIZATION REGION
(ORDINATES 1 THROUGH 61)

	SUM OF FLOWS	EQUIV DEPTH	MEAN FLOW	TIME TO CENTER OF MASS	LAG C.M. TO C.M.	PEAK FLOW	TIME OF PEAK
PRECIPITATION EXCESS		0.937		4.13			
COMPUTED HYDROGRAPH	84787.	0.867	1390.	8.51	4.38	3621.	7.00
OBSERVED HYDROGRAPH	84787.	0.867	1390.	8.16	4.03	3540.	7.00
DIFFERENCE	0.	0.000	0.	0.35	0.35	81.	0.00
PERCENT DIFFERENCE	0.00				8.66	2.30	

STANDARD ERROR	270.	AVERAGE ABSOLUTE ERROR	207.
OBJECTIVE FUNCTION	283.	AVERAGE PERCENT ABSOLUTE ERROR	27.24

Table 4.3

HEC-1 Default Initial Estimates for Unit Hydrograph and Loss Rate Parameters

Unit Graph

	Parameter	**Initial Value**
Clark	TC+R	$(TAREA)^{1/2}$
	R/(TC+R)	0.50

Loss Rates

	Parameter	**Initial Value**
Exponential	COEF	0.07
	STRKR	0.20
	STRKS	0.20
	RTIOK	2.00
	ERAIN	0.50
	FRZTP	0.00
	DLTKR	0.50
	RTIOL	2.00
Initial & Uniform	STRTL	1.00
	CNSTL	0.10
Holtan	FC	0.01
	GIA	0.50
	SA	1.00
	BEXP	1.40
Curve Number	STRTL	1.08
	CRVNBR	65.00
Green and Ampt	IA	0.10
	DTHETA	0.50
	PSIF	10.00
	XKSAT	0.10

TAREA = Drainage area, in square miles

(6) One more complete search of all parameters is made. This leads to a change in TC + R = 7.046*, leading to a final minimum objective function value of $2.8134x10^2$.

(7) A final adjustment to the infiltration parameters is made to adjust the computed hydrograph volume to within one percent of the observed hydrograph volume. Note that this leads to a small change in the objective function from optimal.

The final results of the optimization are also summarized in Table 4.2, TC = 3.16, R = 3.88, etc. Additional information is displayed comparing computed and observed hydrograph statistics, which are defined as follows:

Standard Error -	the root mean squared sum of the difference between observed and computed hydrographs.
Objective Function -	the weighted root mean squared sum of the difference between observed and computed hydrographs.
Average Absolute Error -	the average of the absolute value of the differences between observed and computed hydrographs.
Average Percent Absolute Error -	the average of absolute value of percent difference between computed and observed hydrograph ordinates.

The definition of the remaining statistics in Table 4.2 is self evident. As can be seen from the final statistics, the optimization results are very acceptable in this case.

4.1.3 Application of the Calibration Capability (from Ford et al., 1980)

Due to the varying quantity and form of data available for precipitation- runoff analysis, the exact sequence of steps in application of the automatic calibration capability of HEC-1 varies from study to study. An often-used strategy employs the following steps when using the complete exponential loss rate equation:

(1) For each storm selected, determine the base flow and recession parameters that are event dependent. These are not included in the set of parameters that can be estimated automatically. These parameters are the recession flow for antecedent runoff (STRTQ), the discharge at which recession flow begins (QRCSN), and the recession coefficient that is the ratio of flow at some time to the flow one hour later (RTIOR).

(2) For each storm at each gage, determine the optimal estimates of all unknown unit hydrograph and loss rate parameters using automatic calibration.

(3) If ERAIN is to be estimated, select a regional value of ERAIN, based on analysis of the results of Step 2 for all storms for the representative gages.

(4) Using the optimization scheme, estimate the unknown parameters with ERAIN now fixed at the selected value. Select an appropriate regional value of RTIOL if RTIOL is unknown. If the temporal and spatial distribution of precipitation is not well defined, an initial loss, followed by a uniform loss rate may be appropriate. (In this case, ERAIN = 0 and RTIOL = 1; or the initial and uniform loss rate parameters may be used.) If these values are used, as they often are in studies accomplished at HEC, Steps 2, 3, and 4 are omitted.

(5) With ERAIN and RTIOL fixed, estimate the remaining unknown parameters using the optimization scheme. Select a value of STRKR for each storm being used for calibration. If parameter values for adjacent basins have been determined, check the selected value for regional consistency.

(6) With ERAIN, RTIOL, and STRKR fixed, use the parameter estimation algorithm to compute all remaining unknown parameters. DLTKR can be generalized and fixed if desired at this point, although this parameter is considered to be relatively event-dependent.

(7) Using the calibration capability of HEC-1, determine values of TC + R and R/(TC + R). Select appropriate values of TC + R for each gage. In order to determine TC and R, an average value of R/(TC + R) is typically selected for the region.

(8) Once all parameters have been selected, the values should be verified by simulating the response of the gaged basins to other events not included in the calibration process.

4.2 Routing Parameters

HEC-1 may also be used to automatically derive routing criteria for certain hydrologic routing techniques. Criteria can be derived for the Tatum, straddle-stagger and Muskingum routing methods only.

Inputs to this method are observed inflow and outflow hydrographs and a pattern local inflow hydrograph for the river reach. The pattern hydrograph is used to compensate for the difference between observed inflow and outflow hydrographs. The assumed pattern hydrograph can have a significant effect on the optimized routing criteria.

Observed hydrographs are reconstituted to minimize the squared sum of the deviations between the observed hydrograph and the reconstituted hydrograph. The procedure used is essentially the same as in the unit hydrograph and loss rate parameters case.

Section 5

MultiPlan-MultiFlood Analysis

The multiplan-multiflood simulation option allows a user to investigate a series of floods for a number of different characterizations (plans) of the watershed in a single computer run. The advantage in this option is that multiple storms and flood control projects can be simulated efficiently and the results can be compared with a minimum of effort by the user.

The multiflood simulation allows the user to analyze several different floods in the same computer run. The multifloods are computed as ratios of a base event (e.g., .5, 1.0, 1.5, etc.) which may be either precipitation or runoff. The ratio hydrographs are computed for every component of the river basin. In the case of rainfall, each ordinate of the input base-event hyetograph is multiplied by a ratio and a stream network rainfall-runoff simulation carried out for each ratio. This is done for every ratio of the base event. In the case of runoff ratios, the ratios are applied to the computed or direct-input hydrograph and no rainfall-runoff calculations are made for individual ratios.

The multiplan option allows a user to conveniently modify a basin model to reflect desired flood control projects and changes in the basin's runoff response characteristics. This is useful when, for example, a comparison of flood control options or the effects of urbanization are being analyzed. The user designates PLAN 1 as the existing river basin model, and then modifies the existing plan data to reflect basin changes (such as reservoirs, channel improvements, or changes in land use) in PLANS 2, 3, etc.

If the basin's rainfall-runoff response characteristics are modified in one of the plans, then precipitation ratios and not runoff ratios must be used. Otherwise, ratios of hydrographs should be used. The program performs a stream network analysis, or multiflood analysis, for each plan, Figure 5.1. The results of the analysis provide flood hydrograph data for each plan and each ratio of the base event. The summary of the results at the end of the program output provides the user with a convenient method for comparing the differences between plans and the differences between different flood ratios for the same plan.

The input conventions for the use of this option are described in the input description. Section 10 gives specific examples on the use of data set update techniques for the multiplan option. Example Problems #9 and #10, Section 12, illustrate the use of this HEC-1 option.

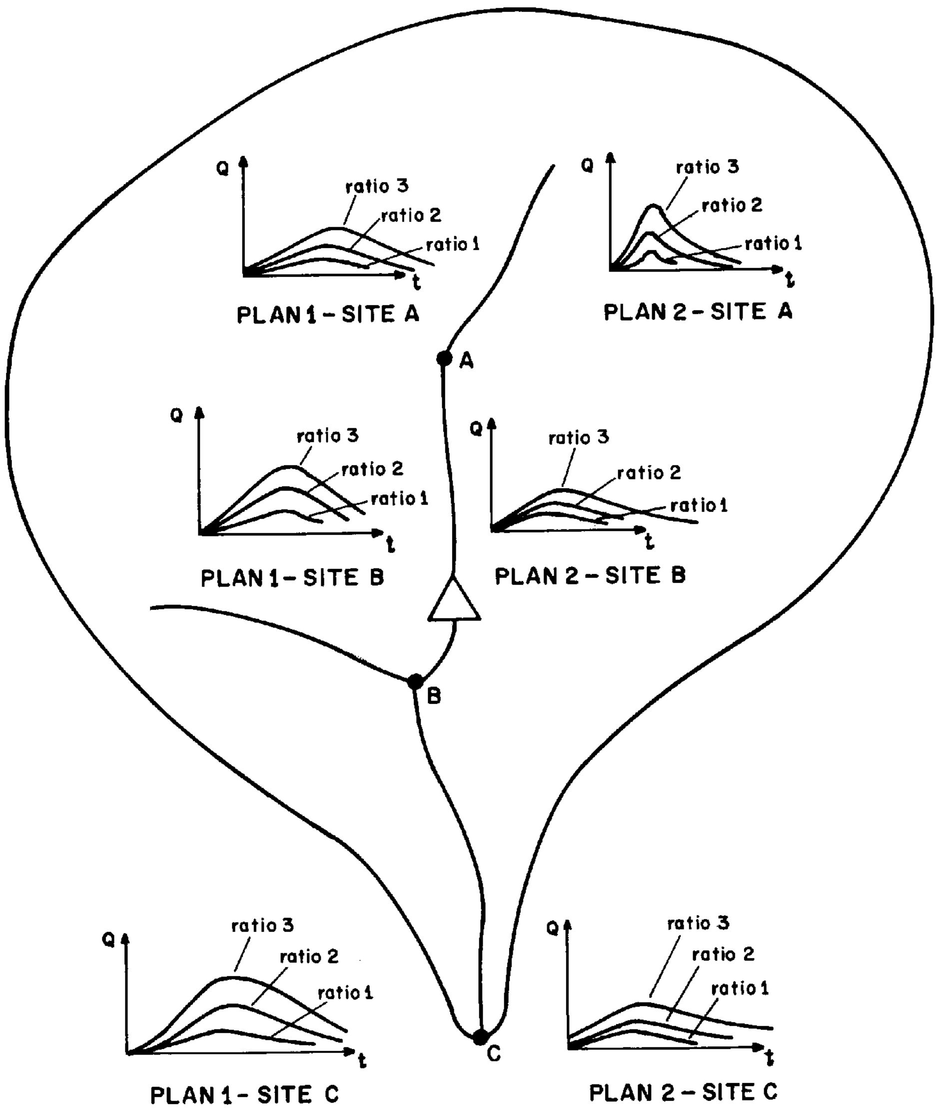


Figure 5.1 Multiflood and Multiplan Hydrographs

Section 6

Dam Safety Analysis

The dam safety analysis capability was added to the HEC-1 model to assist in studies required for the National Non-Federal Dam Safety Inspection Program. This option uses simplified hydraulic techniques to estimate the potential for and consequences of dam overtopping or structural failures on downstream areas in a river basin. Subsequent paragraphs describe dam overtopping analysis, dam-break model formulation, the methodology used to simulate dam failures, and the limitations of the method. An example of dam overtopping analysis with HEC-1 is given in Example Problem #7, Section 12. Example Problem #8 simulates dam failures.

6.1 Model Formulation

The reservoir component (described in Section 2) is employed in a stream network model to simulate a dam failure. In this case, the procedure for developing the stream network model is essentially the same as in precipitation-runoff analysis. However, the model emphasis is likely to be different. Most of the modeling effort is spent in characterizing the inflows to the dam under investigation, specifying the characteristics of the dam failure, and routing the dam failure hydrograph to a desired location in the river basin. Lateral inflows to the stream below the dam are usually small compared to the flows resulting from the dam failure and thus of less importance.

6.2 Dam Safety Analysis Methodology

The dam safety simulation differs from the previously described reservoir routing in that the elevation-outflow relation is computed by determining the flow over the top of the dam (dam overtopping) and/or through the dam breach (dam break) as well as through other reservoir outlet works. The elevation-outflow characteristics are then combined with the level-pool storage routing (see Section 3) to simulate a dam failure.

6.2.1 Dam Overtopping (Level Crest)

The discharge over the top of the dam is computed by the weir flow equation

$$Q_{od} = COQW \times DAMWID \times h_1^{EXPD} \qquad (6.1)$$

Where h_1 is the depth of water over the top of dam, COQW is the weir discharge coefficient, DAMWID is the effective width of top-of-dam weir overflow, and EXPD is the exponent of head. These variables are illustrated in Figure 6.1. The top-of-dam **weir crest length, DAMWID, must not include the spillway**. Spillway discharges continue to be computed by the spillway equation (see Section 3) even as the water surface elevation exceeds the top of the dam. The weir flow for dam overtopping is added to the spillway and low level-outlet discharges.

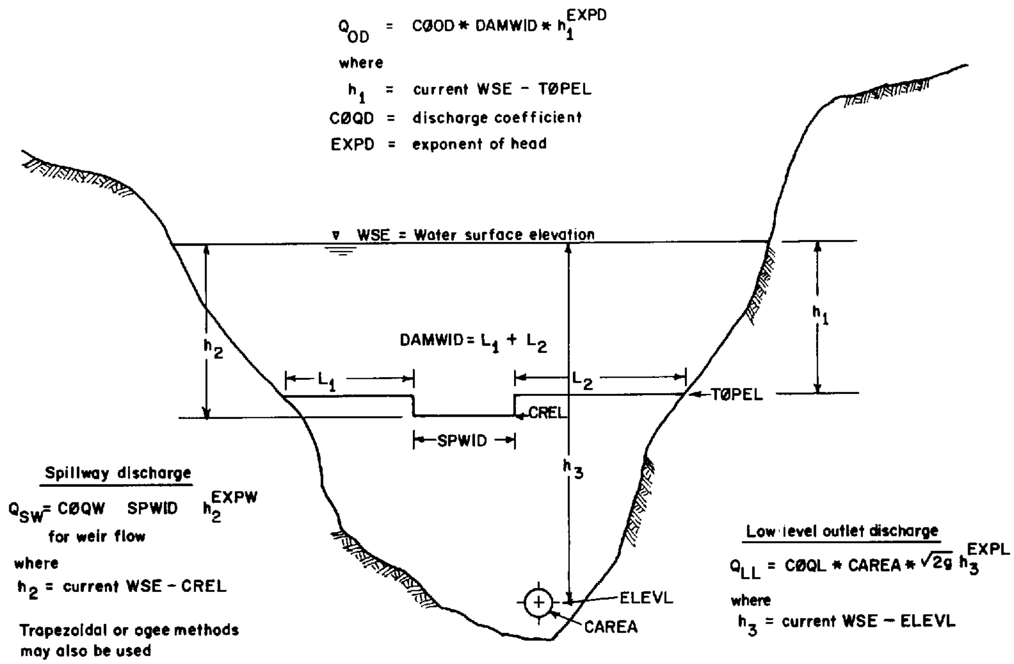


Figure 6.1 Spillway Adequacy and Dam Overtopping Variables in HEC-1

6.2.2 Dam Overtopping (Non-Level Crest)

Critical flow over a non-level dam crest is computed from crest length and elevation data. A dam crest such as shown in Figure 6.2a is transformed (for use by the program) to an equivalent section shown in Figure 6.2b. This crest is divided into rectangular and trapezoidal sections and the flow is computed through each section.

For a rectangular section (Figure 6.2c), critical depth, d_c, is

$$d_c = \frac{2H_m}{3} \qquad (6.2)$$

where H_m is the available specific energy which is taken to be the depth of the water above the bottom of the section.

For a trapezoidal section (Figure 6.2d), the critical depth is

$$d_c = \frac{2}{3} \times (H_m + \frac{1}{4} \times \Delta y) \qquad (6.3)$$

where Δy is the change in elevation across the section (ELVW(I + 1) - ELVW(I)). Flow area, A, is computed as T * d_c for rectangular sections and as ½T(2d_c - Δy) for trapezoidal sections, where T is top width [WIDTH(I + 1) - WIDTH(I)].

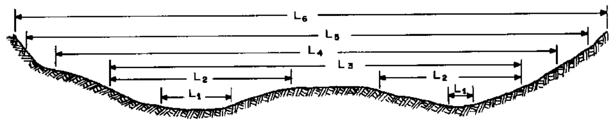


Figure 6.2a Non-Level Dam Crest

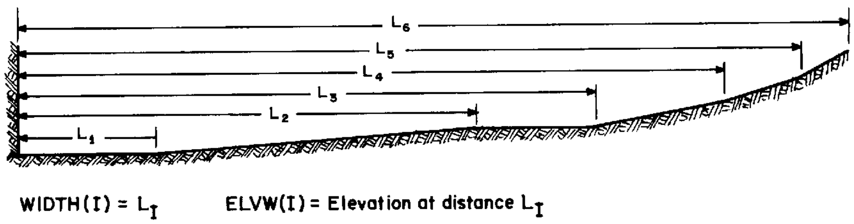


Figure 6.2b Equivalent Sections

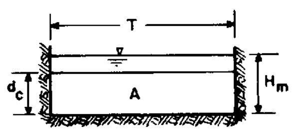


Figure 6.2c Rectangular Section

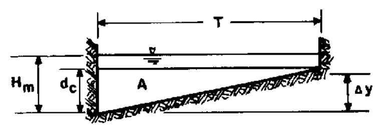


Figure 6.2d Trapezoidal Section

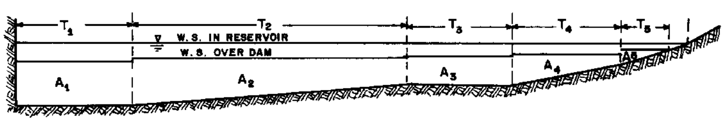


Figure 6.2e Flow Computations for Sections

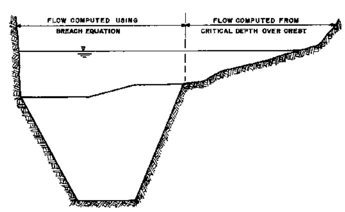


Figure 6.2f Breach Analysis

Figure 6.2 Non-Level Dam Crest

The flow through the section is computed from

$$Q = \frac{\sqrt{(A^3 \times g)}}{T} \qquad (6.4)$$

where g is acceleration due to gravity. The total flow over the top of dam is then the sum of flows through each section (Figure 6.2e). When a dam is being breached the width of the breach is subtracted from the crest length beginning at the lowest portion of the dam (Figure 6.2f).

6.2.3 Dam Breaks

Dam breaks are simulated using the methodology proposed by Fread (National Weather Service, 1979). Structural failures are modeled by assuming certain geometrical shapes for the dam breach. The variables used in the analysis, as well as the dam breach shapes available in the program, are shown in Figure 6.3.

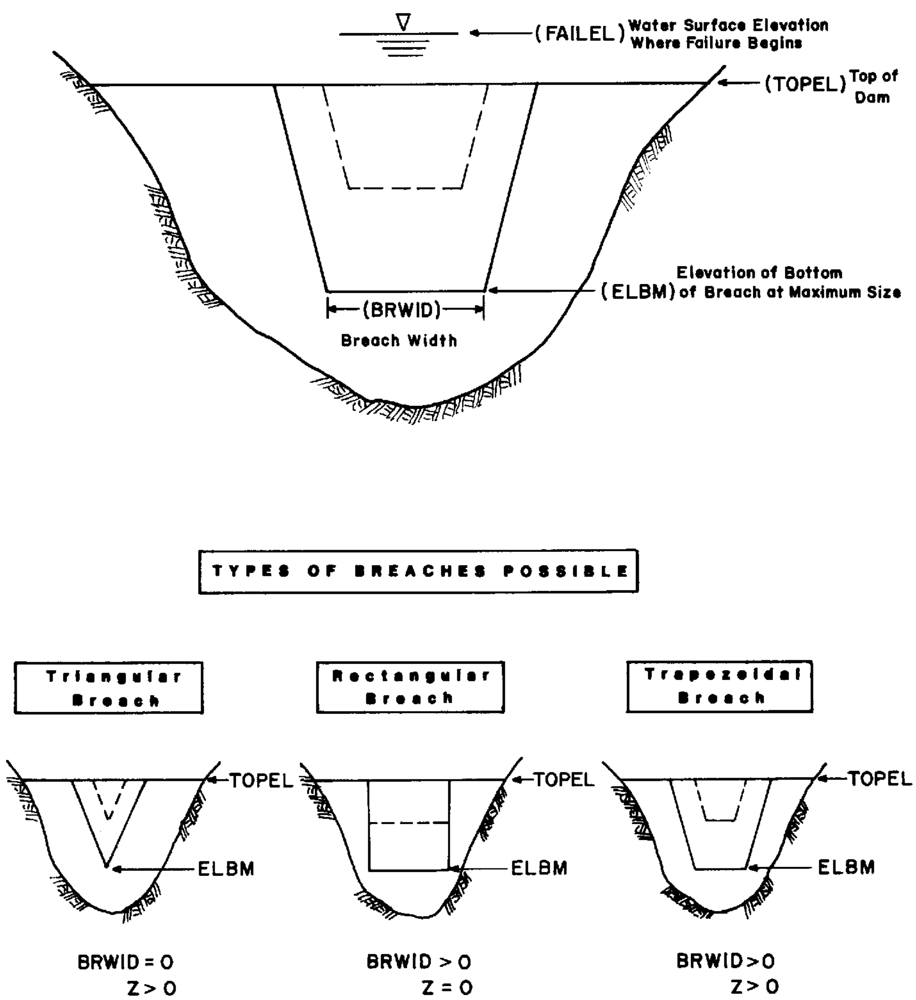


Figure 6.3 HEC-1 Dam-Breach Parameters

Flow Q through a dam breach is computed as

$$Q = C1 \times BRWID \times (WSEL - BREL)^{1.5} + C2 \times (WSEL - BREL)^{2.5} \qquad (6.5)$$

where WSEL is the reservoir water surface elevation, BREL is the elevation at base of breach, BRWID is the breach width, C1 is the broad-crested rectangular weir coefficient, and C2 is the V-notch weir coefficient.

The discharge coefficients are dynamically adjusted for **submergence effects** if the characteristics of the downstream channel are specified by a rating curve or an eight point channel cross section (see Section 3.6.3) using the following formulas:

$$C1 = 3.1k_S \quad \text{(English)} \qquad C1 = 1.70k_S \quad \text{(Metric)} \qquad (6.6)$$

$$C2 = 2.45Zk_S \quad \text{(English)} \qquad C2 = 1.35k_S \quad \text{(Metric)} \qquad (6.7)$$

where Z is the side slope horizontal to vertical, and k_s is a submergence factor defined as (see Brater, 1959):

$$k_S = 1.0 \quad \text{if} \quad \frac{TWEL - BREL}{WSEL - BREL} \le 0.67 \qquad (6.8)$$

otherwise

$$k_S = 1.0 - 27.8\left[\frac{TWEL - BREL}{WSEL - BREL} - 0.67\right]^3 \qquad (6.9)$$

where TWEL is downstream channel water surface elevation.

The breach is initiated when the water surface in the reservoir reaches a given elevation (FAILEL). The breach begins at the top of the dam and expands linearly to the bottom elevation of the breach (ELBM) and to its full width in a given time (TFAIL). Note that the top-of-dam elevation must be specified to fully determine the breach geometry.

The failure duration (TFAIL) is divided into 50 computation intervals. These short intervals are used to minimize routing errors during the period of rapidly changing flows when the breach is forming. Downstream routing methods in HEC-1 use a time interval which is usually greater than the time interval used during breach development. **Errors may be introduced into the downstream routing of the failure hydrograph if the HEC-1 standard time interval is too large compared to the duration of the breach**. That is, if the HEC-1 time interval is larger than the breach duration, the entire breach hydrograph may occur within a single HEC-1 time interval. Because HEC-1 computes and displays only end-of-period discharges, the peaks occurring within a time interval are not known.

This potential problem of loss of volume and peak is apparent in the program output which shows the short interval failure hydrograph and the location of the regular HEC-1 time intervals. It is important to be sure that the breach hydrograph is adequately described by the HEC-1 end-of-period intervals or else the downstream routings will be erroneous.

6.2.4 Tailwater Submergence

The outflow from a dam breach may be reduced by backwater from downstream constrictions or other flow resistances. HEC-1 allows a tailwater rating curve or a single cross section (and a calculated normal-depth rating curve) to be used to reflect such flow resistance. Submergence effects are calculated in the same manner as in the DAMBRK (Natural Weather Service, 1979) program.

6.3 Limitations

The dam-break simulation assumes that the reservoir pool remains level and that HEC-1 hydrologic routing methods are assumed appropriate for the dynamic flood wave. Under the appropriate conditions, these assumptions will be approximately true and the analysis will give answers which are sufficiently accurate for the purpose of the study. However, care should be taken in interpreting the results of the dam-break analysis. If a higher order of accuracy is needed, then an unsteady flow model, such as the National Weather Service's DAMBRK (1979), should be used.

Section 7

Precipitation Depth-Area Relationship Simulation

One of the more difficult problems of hydrologic evaluation is that of determining the effect that a project on a remote tributary has on floods at a downstream location. A similar problem is that of deriving flood hydrographs, such as for standard project floods or 100-year exceedance interval floods, at a series of locations throughout a complex river basin. Both problems could require the successive evaluation of many storm centerings upstream of each location of interest.

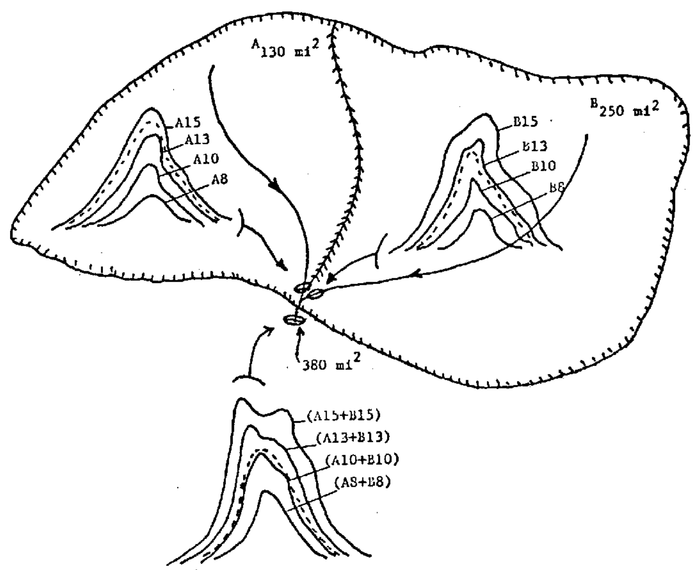
Precipitation must be distributed throughout the basin in such a manner that the runoff generated by each subbasin tributary to the location of interest is consistent with the runoff contributed by the other subbasins, including the subbasin on which a project may be located. Consistency between successive downstream hydrographs can be maintained by generating each from rainfall quantities that correspond to a specific subbasin size and a specific precipitation depth-drainage area relationship. The precipitation depth-drainage area relationship should correspond to the desired runoff event to be evaluated (e.g. standard project flood).

7.1 General Concept

The average depth of precipitation over a tributary area for a storm generally decreases with the size of contributing area. Thus, it is ordinarily necessary to recompute a decreasingly consistent flood quantity contributed by each subbasin to successive downstream points. In order to avoid the proliferation of hydrographs that would ensue, the depth area calculation of HEC-1 makes use of a number of hydrographs (termed "index hydrographs") computed from a range of precipitation depths throughout the river basin complex. The index hydrographs are computed from a set of precipitation depth-drainage area (index area) values, a time distribution of rainfall pattern, and appropriate loss rate and unit hydrograph parameters. Figure 7.1 is a schematic of a basin for which consistent hydrographs are desired for subbasins A, B, and the stream confluence of A and B. The precipitation depth-drainage area relationship is tabulated on the figure.

The computation procedure is identical for subbasins A and B. Four index runoff hydrographs for each subbasin are computed for precipitation quantities of 15, 13, 10 and 8 inches (for the subbasin's tributary area) and are labeled A15, A13, etc., and B15, B13, etc. The consistent hydrograph is that which corresponds to the appropriate precipitation depth for the subbasin's drainage area. The consistent hydrographs are determined by interpolating between the two index hydrographs bracketing the subbasin's drainage area and are shown dashed on the figure.

The consistent hydrograph for the confluence of A and B must be representative of runoff contributed by both upstream tributary areas A and B. The sum of the two consistent hydrographs would not be representative of both areas combined because the runoff volume would not be consistent with the precipitation depth-drainage area relationship. As shown on the figure, the index hydrographs for the confluence are the sum of the index hydrographs from subbasins A and B and are labeled (A15 + B15), (A13 + B13), etc., to so indicate. The consistent hydrograph for the confluence of A and B is then determined by interpolating between the two combined index hydrographs that bracket the sum of drainage areas A and B, as shown on the Figure 7.1.



Precipitation Depth-Drainage Area Function

Area - mi²	Precip - In.
100	15
200	13
500	10
1000	8

Legend

- Desired location for consistent hydrograph
- Stream channel
- Drainage boundary
- $A_{130\ mi^2}$ etc. - Subarea label and drainage area

Figure 7.1 Two-Subbasin Precipitation Depth-Area Simulation

The depth-area procedure of generating index hydrographs, interpolating, adding them to other index hydrographs and interpolating, routing and interpolating, is repeated throughout a river basin for as many locations as are desired. Figure 7.2 shows the precipitation depth-area calculation procedure for all locations in a complex river basin.

7.2 Interpolation Formula

An interpolation formula is applied to discharge ordinates for the two index hydrographs corresponding to areas which bracket the tributary drainage area. The interpolation is based on the index area and the actual tributary area.

The formula may be deduced from the following:

(1) The runoff transformation used (unit hydrograph) is a linear process.

(2) Precipitation depth varies approximately in proportion to the logarithm of the index drainage area.

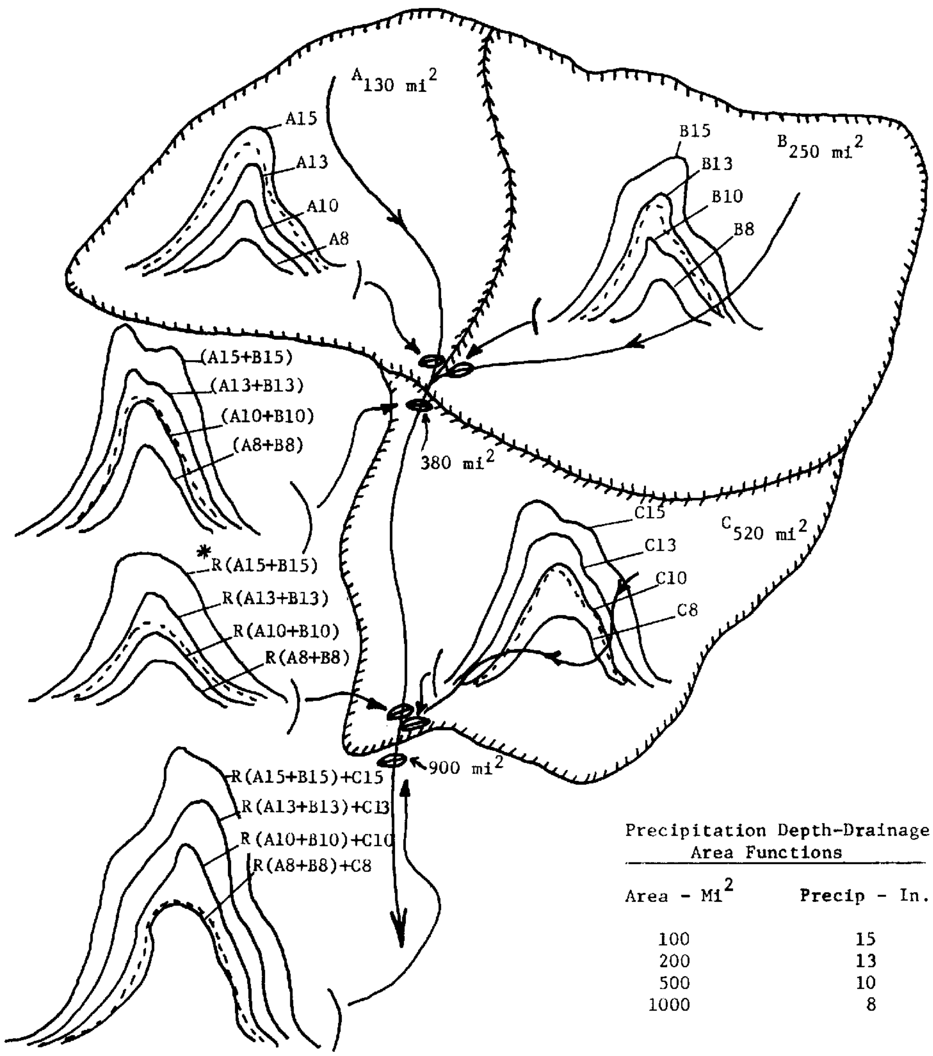
The interpolation formula can thus be derived assuming a linear discharge-log drainage area relationship as follows:

$$Q = \left[Q1 \times \left(\frac{\log \frac{A2}{Ax}}{\log \frac{A2}{A1}}\right)\right] + \left[Q2 \times \left(\frac{\log \frac{Ax}{A1}}{\log \frac{A2}{A1}}\right)\right] \qquad \text{. . . . . (7.1)}$$

where Q is the instantaneous flow of the consistent hydrograph, Ax is the tributary area for stream location, A1 is the next smaller index area, A2 is the next larger index area, Q1 is the instantaneous flow for index hydrograph 1, Q2 is the instantaneous flow for index hydrograph 2.

The interpolation formula would be exact if the loss function applied was uniform and if the precipitation depth-drainage area relationship was in fact a straight line on semi-logarithmic paper. Because the interpolation formula is not exact, the computer program insures that the peak of the interpolated hydrographs below all confluences are not smaller than any of the interpolated hydrographs above the confluence.

Operation of HEC-1 for the depth-area computation requires that the basin be modeled (Section 2) and that the desired precipitation depth-drainage area relationship be defined by up to nine pairs of values that include the range of tributary areas to be encountered. A different temporal pattern may be specified for each depth-area point. Successive runs of the depth-area feature with and without a proposed project will provide a balanced evaluation of that project on downstream flood hydrographs. A single run will provide a set of hydrographs at all locations within the basin that conform consistently with the precipitation depth-drainage area function.



Precipitation Depth-Drainage Area Functions

Area - Mi^2	Precip - In.
100	15
200	13
500	10
1000	8

Legend

* Routed
Desired location for consistent hydrograph
Stream channel
Drainage Boundary
$A_{130\ mi^2}$ etc. - Subarea label and drainage area

Figure 7.2 Multi-Subbasin Precipitation Depth-Area Simulation

Section 8

Flood Damage Analysis

Flood loss mitigation planning requires the ability to rationally assess the economic consequences of flood inundation damage. The flood damage analysis option provides the capability to assess flood inundation damage and determine flood damage reduction benefits provided by alternative flood loss mitigation measures. The subsequent sections discuss the basic concepts and methodologies employed in performing a flood damage analysis. Example problem 11, Section 12, shows the input data and output for a flood damage analysis.

8.1 Basic Principle

The damage reduction accrued due to the implementation of a flood loss mitigation plan is determined by computing the difference between damage values occurring in a river basin with and without the measures. **Damage is assumed to be only a function of peak discharge or stage** and does not depend on the duration of flooding. Total damage is determined by summing the damage computed for individual damage reaches within the river basin. The damage in each reach is calculated as the sum of damage for individual land use categories (e.g. agricultural, commercial, industrial, etc.).

HEC-1 computes expected annual damage (EAD) as the integral of the damage-exceedence frequency curve. EAD is the average-year damage that can be expected to occur in the reach over an extended period of time.

The basic technique used in the EAD analysis is to form the damage frequency curve by combining damage versus flow (stage) and flow (stage) versus frequency relations which are characteristic of the area that the damage reach represents. The damage versus flow (stage) relation ascribes a dollar damage that occurs in an area to a level of flood flow. The flow (stage) versus exceedence frequency relation ascribes an exceedence frequency to the magnitude of flood flow. By combining this information, the damage versus frequency curve and, hence, the EAD for a reach can be determined.

Consequently, the EAD is the measure of flood damage occurring in a river basin. By comparing river basin EAD with and without flood loss mitigation measures, damage reduction benefits are computed.

8.2 Model Formulation

In the flood damage analysis, the conceptual model of the river basin developed for a multiplan-multiflood analysis (Example Problems #9 and #10, Section 12) is extended to include damage computations. Damage reaches are designated by providing economic data, consisting of flow (stage) versus frequency and flow (stage) versus damage data, for each damage reach in the multiplan-multiflood model.

In the extended multiplan-multiflood analysis, PLAN 1 represents the base condition. Subsequent plans represent alternative flood loss mitigation plans. The difference between the EAD computed for PLAN 1 and subsequent plans is the damage reduction accrued by the flood loss mitigation measure(s).

The development of the conceptual model for the flood damage analysis is based on the interrelated requirements for the stream network and damage calculations. This relationship is shown on Figure 8.1 where subbasins, routing reaches, and damage reaches are delineated for an example river basin. The definition of the subbasins and routing reaches for the stream network calculations is determined in part by criteria outlined in Section 2, and in part by the requirements of the damage calculations.

The damage reaches in each area of interest are determined by isolating river reaches which have consistent flood profiles. (Consistent flood profiles occur when the stage profile along the reach is of similar shape for a range of flood frequencies. For example, similar profiles are indicated when the difference between the stages due to the 10- and 20-year flood is approximately the same throughout the entire reach.) Data used in the damage calculation are developed for an index location within each damage reach.

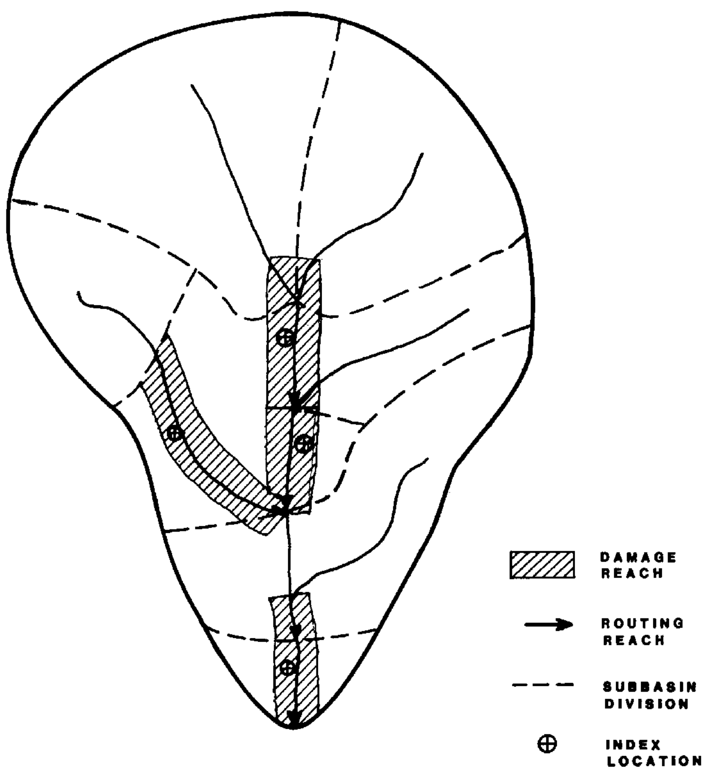


Figure 8.1 Flood-Damage Reduction Model

Note that the damage reach may encompass parts of a number of routing reaches. The flows used in the damage calculation are based on the outflows from the most downstream of these routing reaches. The flows combined with damage data for the index location result in the appropriate damage for the entire damage reach.

8.3 Damage Reach Data

The input data for damage computations follow the multiplan-multiflood stream network data in the input data set as shown in test example 11 and can be supplied in a number of forms.

Damage data can be provided as stage-damage or flow-damage tables. These data can be provided for a number of different damage categories for each reach.

Frequency data can be provided as stage-frequency or flow-frequency tables. In the case that the damage data are given in terms of flows and frequency data in terms of stages (or vice versa), a rating curve for the reach must be provided to relate stages and flows.

Damage reach location information may be specified in order to summarize damage in a river basin. Two locational descriptors (e.g., river and county names) are provided for each damage reach. A damage summary table is developed in which damage is summed and cross tabulated by the rivers and counties (or any other locational descriptors) in which they occurred.

8.4 Flood Damage Computation Methodology

There are two basic computations in a flood damage analysis: exceedence frequency curve modification and EAD calculation. Structural flood control measures (e.g., reservoirs and channel improvements) affect the flow-frequency relationship. Nonstructural measures (e.g., flood proofing and warning) do not usually have much impact on the flood-frequency relationship but do modify the flow (stage) damage relationship.

8.4.1 Frequency Curve Modification

The flow-exceedence frequency data provided for damage reaches refer to PLAN 1 or the base plan of the multiplan-multiflood model. Implementation of structural flood control measures or changes in watershed response will change this exceedence frequency relation. HEC-1 computes modified frequency relationships using the following methodology.

(1) A multiflood analysis is performed for PLAN 1 to establish the frequency of the peak discharge of each ratio of the pattern event. The peak-flow frequency for each ratio of the pattern event is interpolated from the input flow-frequency data tables for a damage reach. Since the flow-frequency data are generally highly non-linear, the interpolation is done with a cubic spline fit of the data as shown in Figure 8.2.

A stage frequency curve is established in essentially the same manner as for flows if stage-frequency data are specified for a damage reach. However, since the stage-frequency data are generally more uniform than the flow-frequency data, a linear interpolation scheme is used to determine frequencies for peak stage of each ratio of the multiflood.

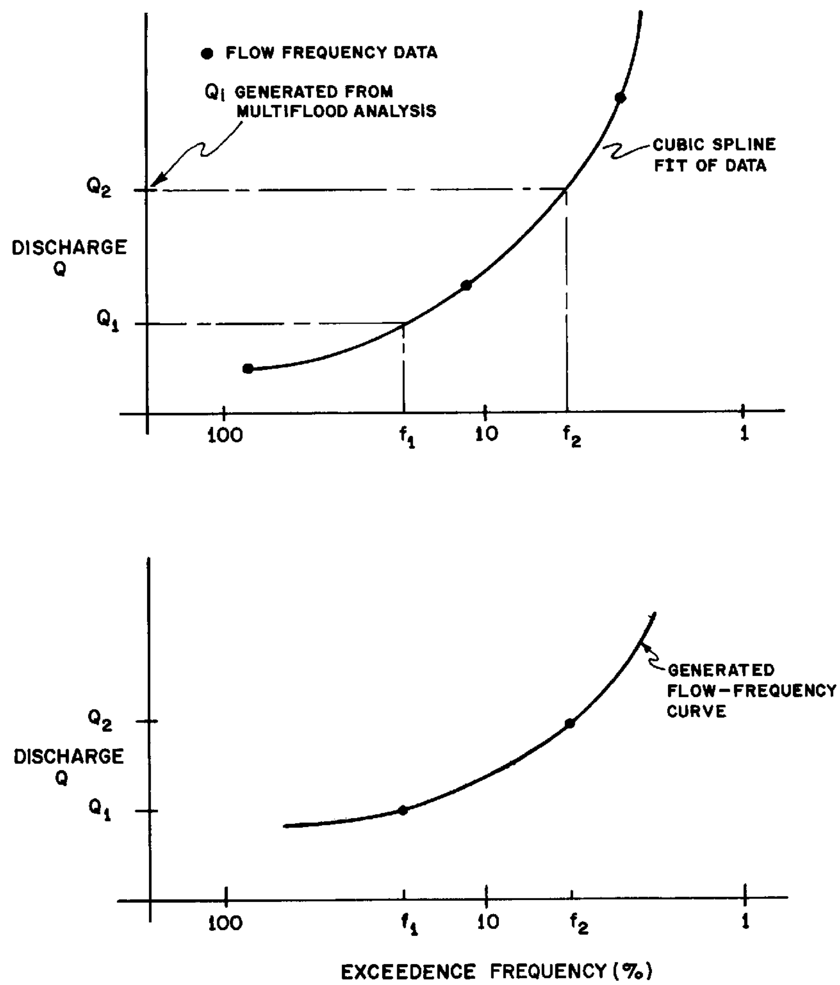


Figure 8.2 Flow Frequency Curve

(2) A multiflood simulation is performed for the flood control plans. The peak discharges (stages) are computed at each damage reach for each ratio of the design event. It is assumed that the frequency of each ratio remains the same as computed for the base case in (1) above; and only the peak flows associated with each ratio change for different plans. In this manner, the modified flow-frequency curve is computed for all ratios as shown in Figure 8.3. Thus, for example, the peak flow of RATIO 3 of PLAN 2 has the same frequency as the peak flow of RATIO 3 of PLAN 1. The assumption inherent in this procedure is that the event ratio-frequency relation is not affected by basin configuration. Care should be taken in interpreting the results of the model when this assumption is not warranted.

8.4.2 Expected Annual Damage (EAD) Calculation

EAD is calculated by combining the flow-frequency curve and the flow-damage data for each PLAN and damage reach (HEC, 1984b) using the following methodology.

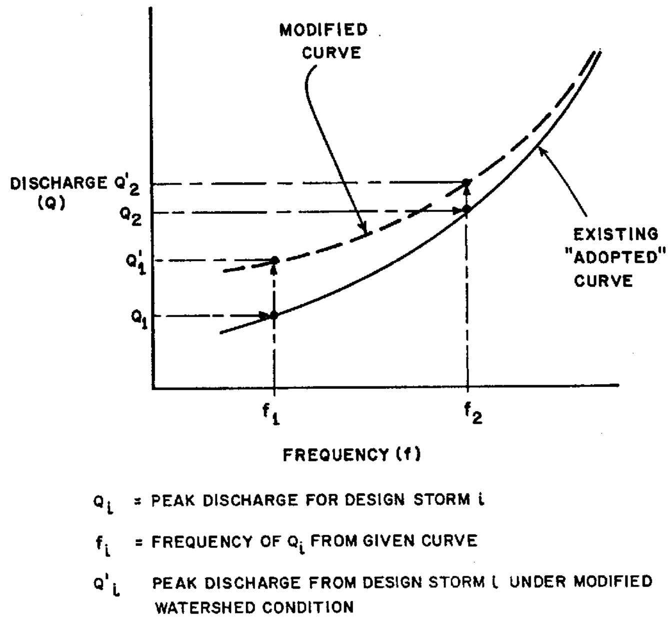


Figure 8.3 Flow-Frequency-Curve Modification

(1) The flow-frequency curve is used in conjunction with the flow-damage data to produce a damage-frequency curve as shown in Figure 8.4. The frequency interval between each pair of RATIOS is divided into ten equal increments. A cubic spline fit procedure is used to define the flow-frequency curve and interpolate the value of the flows for each of the ten frequency increments. Damage for each flow, and hence, the corresponding frequency, is found from the damage-flow data by linear interpolation, thus defining the damage frequency curve.

In the case that stages are used, the procedure is the same except that the stages for generated frequencies are determined using a linear interpolation procedure. If stages are specified for the damage data and flows for the frequency data (or vice versa), a rating curve is used to relate the stages and flows before determining the appropriate damage.

(2) The damage-frequency curve, at its extreme points, must include a zero damage (and corresponding frequency) and a zero exceedence frequency (and corresponding damage). The program does not extrapolate to zero damage. Consequently, a simulated peak flow in the multiflood analysis must be small enough to correspond to zero damage in the flow-damage table. Otherwise, an error in the expected annual damage calculation will be introduced. A zero exceedence frequency event cannot be

specified in the program, even if one could be defined. However, the program does extrapolate to the zero exceedence frequency as shown in Figure 8.4. This extrapolation will not severely affect the accuracy of the result if the peak flows generated result in a relatively small exceedence frequency.

(3) The integral of the damage-frequency curve is the EAD for the reach. This area is computed using a three point Gaussian Quadrature formula.

(4) If more than one damage category is specified for a reach, the above steps are repeated for each category. The EAD is summed for all the categories to produce the EAD for the reach.

The damage reduction accrued due to the employment of a flood loss mitigation plan is equal to the difference between the PLAN 1 EAD and the flood control EAD. The model performs this computation for all plans in the multiplan-multiflood analysis.

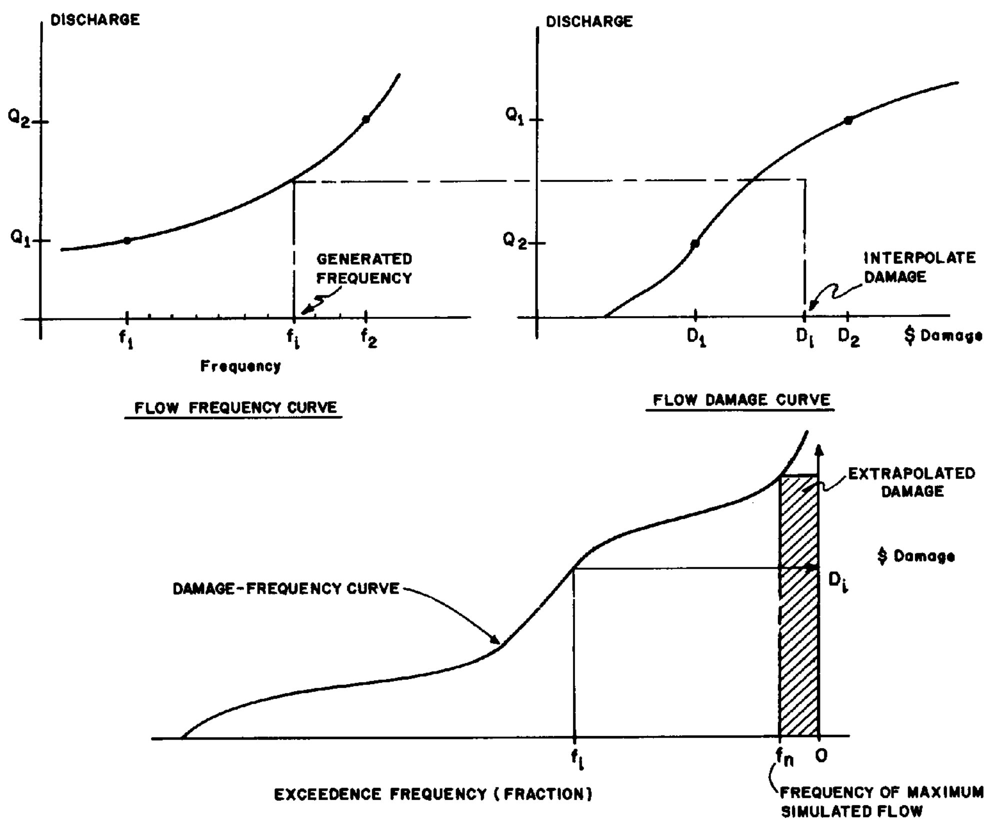


Figure 8.4 Damage Frequency Curve

8.5 Single Event Damage Computation

The option exists to compute damage for a single event (see JP record in Input Description Section). This option may be useful for calibrating damage functions to observed event damages.

8.6 Frequency-Curve Modification

The modified frequency curves can be computed in the absence of damage data. These modified frequency curves may be useful in other application programs (e.g., the Flood Damage Analysis Package, HEC, 1986). The modified frequency curve can be written to HECDSS, see Appendix B.

Section 9

Flood Control System Optimization

The flood control system optimization option is used to determine optimal sizes for the flood loss mitigation measures in a river basin flood control plan (Davis, 1974). The subsequent sections discuss the formulation of an optimization model, the measures (components) that can be optimized, data requirements, and the optimization methodology used. Example problem 12, Section 12, illustrates the application of this capability.

9.1 Optimization Model Formulation

The flood control system optimization capability is an extension of the flood damage analysis described in Section 8. The optimization model utilizes a two-plan damage analysis: PLAN 1 is the base condition of the existing river basin and PLAN 2 is the flood control plan being optimized. Data on the costs of various sizes of flood control projects are required, otherwise the formulation of the optimization model is essentially the same as in the flood damage model case. The flood control components that can be optimized as part of the flood control system are as follows:

Reservoir Component. The storage of an uncontrolled spillway-type reservoir is optimized by determining the elevation of the reservoir spillway, thus defining the point at which the reservoir begins to spill. The low-level outlet characteristics of the reservoir are fixed by input.

Diversion Component. Flow diversions, such as described for the stream network simulation, may have their channel capacity optimized. The diverted flow may be returned to another branch of the stream network or simply lost from the system.

Pumping Plant Component. Pumping plants may be located virtually anywhere in a stream network and their capacity may be optimized. The pumped water may be returned to another branch of the stream network or simply lost from the system.

Local Protection Project. A local protection project can be used to model a channel improvement or a levee. This component can only be used in conjunction with the damage analysis of a reach. Consequently, the optimization data are included in the economic data portion of the simulation input data set and are described in the economic input data description section. The local protection project analysis requires capacity and cost data together with pattern damage tables for maximum and minimum sizes of the project. Damage functions are interpolated for project sizes between these maximum and minimum design values. The difference between the channel improvement and the levee option is specified in the pattern damage tables. The channel improvement damage tables represent a reduction in the damage function specified for PLAN 1. On the other hand, the damage pattern tables for the levee indicate zero damage for flows below the design capacity and preserves the existing flow-damage relationships for flows exceeding the design capacity. Consequently, the pattern damage functions are equal to the existing damage functions for all non-zero damage values.

Uniform Level of Protection. A flood control plan may require that, as part of the flood control system, levees (local protection projects) provide the same level or a uniform level of protection at a number of locations (damage reaches). In this instance, the level of protection refers to the flood exceedence frequency at which the capacity of the project is surpassed. The flood control system optimization option can be used to determine the uniform level of protection that, in conjunction with the structural flood control components, leads to the maximum net flood loss reduction benefits in the river basin.

9.2 Data Requirements

The flood control component optimization model requires data as described for the flood damage model plus information about the capital and operating costs of the projects and about the objective function for the flood control scheme. The data for the various types of flood control components are essentially the same and may be separated into cost and capacity data, and optimization criteria as follows.

Cost and Capacity Data. Two types of data are required to calculate the total annual cost of a flood control component. First, capacity versus capital cost tables are required to determine the capital cost for any capacity of the flood control component. A capital recovery factor is also required so that equivalent annual costs for the capital investments can be computed. Second, operation and maintenance costs are computed as a proportion of the capital cost. For pumping plants, average annual power costs for various pump capacities are required. Pump operation costs are computed in proportion to the volume pumped. Capital and operating costs for non-optimized components of the system may also be considered.

Optimization Criteria. The optimization methodology operates on maximum net benefit and/or flow targets criteria. Maximum net benefits are computed using the cost and flood damage data previously described. Desired streamflow limitations may also be specified at any point downstream of a flood control project. These streamflow limitations, referred to as "flow targets" are specified as the flow (stage) which is desired to occur with a given exceedence frequency. For example, it may be desired to have the 5% flood at a particular location be 5,000 cfs. The input data for flow targets are the discharge or stage and the exceedence frequency.

9.3 Optimization Methodology

9.3.1 General Procedure

The model determines an optimal flood control system by minimizing a system objective function. The system objective function is the sum of flood control system total annual cost and the expected annual damage occurring in the basin. If flow targets are specified, then the previous sum is multiplied by a penalty factor which increases the objective function proportionately to deviations from the target. Note that the minimization of the objective function leads to the maximization of the net benefits accrued due to the employment of the flood loss mitigation measures. Net benefits are equal to the difference between the EAD occurring in PLAN 1 and the sum of the system costs and EAD occurring in PLAN 2.

The optimization procedure can be generally described as follows:

(1) An initial system configuration is analyzed by the program based on capacities specified by the user. The model performs a stream network simulation and expected annual damage calculation for the base condition, PLAN 1, without the proposed flood control measures. The base condition need only be simulated once because it will not change and serves as the reference point for computation of net benefits accruing to the proposed flood control plan. The stream network and expected annual damage calculations for the initial sizes of the proposed flood control system are then performed and the initial value of the objective function is determined. The program computes and displays the net benefit that is accrued due to the employment of the initial flood control system.

(2) The model then uses the univariate search procedure to find a minimum value for the objective function. (The optimization algorithm is the same as used for parameter optimization, Section 4.) The procedure finds a minimum by systematically altering flood control component capacities in order to calculate various values of the system objective function. Each time a flood control system capacity is changed, stream network calculation and EAD calculations are performed giving a value for the system objective function.

(3) Once the optimization procedure is completed, the costs, damage and net benefits accrued to the optimized system are computed and displayed.

An important point to note is that the optimization procedure does not guarantee a global minimum for the objective function. Local minimum points may be found by the procedure. This can be tested by trying different initial capacities for the flood control system optimization run. If the optimal system found each time is the same, then there is strong evidence that the minimum found is global. The optimization results and the steps in the optimization process should be reviewed carefully to see that they are reasonable. Other component sizes not analyzed by the search procedure should also be analyzed to see if better results can be obtained.

9.3.2 Computation Equations

The system objective function STDER is calculated as follows:

$$\mathrm{STDER} = (\mathrm{TANCST} + \mathrm{ANDMG}) \times (\mathrm{ODEV} + \mathrm{CONST}) \qquad (9.1)$$

where TANCST is the flood control system total annual cost, ANDMG is the river basin expected annual damage, ODEV is the sum of the weighted deviations from the target flow or stage, and CONST is a term representing the importance of the target penalty (default value equal to 1.0). As CONST increases, the target penalty has less importance in determining STDER.

The total annual cost TANCST is computed by the following formula:

$$\mathrm{TANCST} = \mathrm{CAPCST} + \mathrm{ANOMPR} + \mathrm{FDCNT} + \mathrm{FAN} \qquad (9.2)$$

where ANFCST is the sum of the equivalent annual capital costs for the flood control components, ANOMPR is the sum of the annual operation, maintenance, power and replacement costs for the flood control components, FDCNT is the equivalent annual capital cost for non-optimized components, and FAN is the annual operation, maintenance, power and replacement cost for non-optimized components.

The annualized capital and operation and maintenance costs are computed as follows.

$$\mathrm{ANFCST} = (\mathrm{CAPCST} \times \mathrm{CRF}) \quad \text{for all projects} \qquad (9.3)$$

$$\mathrm{ANOMPR} = (\mathrm{CAPCST} \times \mathrm{ANCSTF}) \quad \text{for all projects} \qquad (9.4)$$

$$\mathrm{FDCNT} = \mathrm{FCAP} \times \mathrm{CRF} \qquad (9.5)$$

$$\mathrm{FAN} = \mathrm{FCAP} \times \mathrm{ANCSTF} \qquad (9.6)$$

where CAPCST is the capital cost of a flood control project, CRF is the capital recovery factor for a specified project life and interest rate, and FCAP is the total capital cost of the non-optimized components of the system. FDCNT may be computed as shown above or the equivalent annual capital cost may be specified as direct input.

The expected annual damage, ANDMG, is calculated as described in Section 8.

The **target penalty** is a sum of weighted deviations from the conditions specified at designated reaches where damage is being calculated. The penalty at a single reach is a function of the deviation DEV from the target.

$$\mathrm{DEV} = \mathrm{TRGT} - \mathrm{TMP} \qquad (9.7)$$

where TRGT is the target flow specified by the user for a given exceedence frequency, and TMP is the computed flow for the given exceedence frequency with the flood control projects in operation, i.e., PLAN 2. The exceedence frequency specified for the target penalty is used to interpolate a value of TMP from the PLAN 2 flow-frequency curve computed for a reach. The interpolation is accomplished by using the cubic-spline fit procedure.

The penalty, PEN, for deviations from the target conditions are calculated for stages as:

$$\mathrm{PEN} = \left(\frac{\mathrm{DEV}}{\mathrm{ANORM}}\right)^4 \qquad (9.8)$$

and for flows:

$$\mathrm{PEN} = \left[\frac{\mathrm{DEV}}{(\mathrm{ANORM} \times \mathrm{TRGT})}\right]^4 \qquad (9.9)$$

where ANORM is a normalizing factor (default value of 0.1).

The sum of the penalties for all reaches is equal to the deviation penalty ODEV in Equation (9.1). The factors CONST (Equation (9.1)) and ANORM can be adjusted by the user (ANORM should be greater than or equal to .02) until satisfactory compliance with the target constraints are met by the optimization procedure. The default values for these parameters should suffice for most purposes.

Section 10

Input Data Overview

This section describes: the general organization of the input data, special features for specifying data, and groupings of data to accomplish specific simulation options. A detailed description of the individual input data records and their contents is given in the Appendix A: Input Description.

10.1 Organization of Input Data

There are two general types of data records for HEC-1: input control and river basin simulation data. The input control records tell the program the format of the river basin data as well as controlling certain diagnostic output. All input control records begin with an asterisk (*) in column one followed by a command. These input controls are discussed in the next subsection and a detailed explanation is given in Appendix A.

The river basin simulation data are all identified by a unique two-character alphabetic code in columns one and two of each record. These codes serve two functions: they identify the data to be read from the record; and they activate various simulation options. The first character of the code identifies the general category and the second character identifies a specific type of data within a category. An overview of these data categories and codes is shown in Table 10.1. The flood damage data, beginning with the EC record is placed at the end of the river basin simulation data. These data are not all labeled as E records because the record code and format were taken from the Expected Annual Flood Damage (HEC, 1984b) program. Thus these same data records may be used directly in both programs.

The river basin simulation data records are structured by the user to reflect the topology of the basin. **The sequence of the input data prescribes how the river basin is simulated.** There are three general subdivisions of these data as shown in Table 10.2: job control; hydrology and hydraulics; and economics. Example input data for a simple river basin are discussed in Section 10.3. The data model of a river basin can be thought of as a series of building blocks, each block beginning with a KK record. The data following each KK record identifies the type of operation to be performed, e.g., BA signifies subbasin runoff and R_ signifies a routing. Section 12 gives examples of input data structures to accomplish various program options.

10.2 Special Features for Input Data

10.2.1 Input Control

There are six input control commands: *FREE, *FIX, *LIST, *NOLIST, *MESSAGE, and *DIAGRAM. Data can be input to the HEC-1 model in a fixed and/or free format as noted in the Input Data Description. The traditional HEC fixed-format input structure (ten 8-column fields) is the default option of the program. The program also provides the capability to enter data in a free format. All records following a *FREE record in the data will be considered as being in free format. Free format data fields are separated by commas or one or more spaces, and successive commas represent blank fields. The fixed format can be returned to at any point in the data set by providing a *FIX record. The *FIX will be in control until another *FREE record is encountered, etc.

Table 10.1
HEC-1 Input Data Identification Scheme

Data Category	Record Identification	Description of Data
Job Initialization	ID	Job IDentification
	IT	Job Time Control
	IM	Metric Units
	IO	General Output Controls
	IN	Time Control for Input Data Arrays
Variable Output Summary	VS	Stations to be summarized
	VV	Variables to be summarized
Optimization	OU	Unit Graph and Loss Rate Controls
	OR	Routing Controls
	OS	Flood Control System Optimization
	OO	System Optimization Objective Function
Job Type	JP	Multi-Plan Data
	JR	Multi-Ratio Data
	JD	Depth-Area Data
Job Step Control	KK	Stream Station Identification
	KM	Alphanumeric Message Record
	KO	Output Control for This Station
	KF	Format for Punched Output
	KP	Plan Number
Hydrograph Transformation	HC	Combine Hydrographs
	HQ/HE	Stage(Elevation)/Discharge Rating Curve
	HL	Local flow computation option
	HS	Initial Storage for Given Reservoir Releases
	HB	Hydrograph Balance Option
Hydrograph Data	QO	Observed Hydrograph
	QI	Direct Input Hydrograph
	QS	Stage Hydrograph
	QP	Pattern Hydrograph
Basin Data	BA	Basin Area
	BF	Base Flow Characteristics
	BR	Retrieve Runoff Data from ATODTA File
	BI	Input Hydrograph from Prior Job
Precipitation Data	PB	Basin-Average Total Precipitation
	PI	Incremental Precipitation Time Series
	PC	Cumulative Precipitation Time Series
	PG	Gage Storm Total Precipitation
	PI/PC	Incremental/Cumulative Precipitation Time Series for Recording Gage
	PR	Recording Gages to be Weighted
	PT	Storm Total Gages to be Weighted
	PW	Weightings for Precipitation Gages
	PH	Hypothetical Storm's Return Period
	PM	Probable Maximum Precipitation Option
	PS	Standard Project Precipitation Option
Loss Rate Data Function	LE	HEC's Exponential Rainfall Loss Rate Function
	LM	HEC's Exponential SnowMelt Function
	LU	Initial and Uniform Rates
	LS	SCS Curve Number

Table 10.1
HEC-1 Input Data Identification Scheme (continued)

Data Category	Record Identification	Description of Data
	LH	Holtan's Function
	LG	Green and Ampt Loss Rate
Unit Hydrograph Data	UI	Direct Input Unit Hydrograph
	UC	Clark Unit Hydrograph
	US	Snyder Unit Hydrograph
	UD	SCS Dimensionless Unit Hydrograph
	UA	Time-Area Data
	UK	Kinematic Overland
	RK	Kinematic Wave Channel (collector, main)
	RD	Muskingum-Cunge "Diffusion" channel (collector, main)
Melt Data	MA	Zone Area and Snow Content Data
	MC	Melt Coefficient
	MD	Dewpoint Data
	MS	Solar Radiation Data
	MT	Temperature Data
	MW	Wind Data
Routing Data	RN	No Routing for Current Plan
	RL	Channel Loss Rates
	RD	Muskingum-Cunge "Diffusion" channel
	RK	Kinematic Wave Channel
	RM	Muskingum Parameters
	RT	Straddle/Stagger Parameters
	RS	Storage Routing Option, follow with SV and SQ records if Modified Puls is used
	RC	Channel Characteristics for Normal Depth Storage Routing
	RX	Cross-Section X Coordinates
	RY	Cross-Section Y Coordinates
Storage Routing Data	SL	Low-Level Outlet Characteristics
	ST	Top of Dam Characteristics
	SW	Width/Elevation for Non-Level Top of Dam
	SE	Geometry
	SS	Spillway Characteristics
	SGO	Gee or Trapezoidal Spillway Option
	SQ	Discharge/Elevation Tailwater Rating
	SE	Curve for SG record
	SV	Reservoir Volume
	SQ	Discharge,
	SA	Surface Area, and
	SE	Water Surface Elevation Data
	SB	Dam Breach Characteristics
	SO	Optimization Parameters
	SD	Cost $ Function Corresponding to SV Data
Diversion Data	DR	Retrieve Diverted Flow
	DT	Flow Diversion Characteristics
	DI	Variable Diversion Q as Function of
	DQ	Inflow
	DO	Diversion Size Optimization Data
	DD	Cost $ Function for Diversion
Pumping Withdrawal Data	WP	Pump Characteristics

Table 10.1
HEC-1 Input Data Identification Scheme (continued)

	WR	Pump flow Retrieval
	WO	Pump Size Optimization Data
	WC	Capacity Function for Pump
	WD	Cost $ Function for Pump
Flood Damage Data	EC	Identifies Flood Damage Option
	CN	Damage Category Names
	PN	Plan Names
	WN	Watershed Name
	TN	Township Name
	WT	Watershed and Township Location
	FR	Frequency Data
	QF	Discharges for FR data
For Each	SF	Stages for Rating Curve with QS
Damage Reach	QS	Discharges for SQ data
	SD	Stages for Damage Data, DG
	QD	Discharges for Damage Data, DG
	DG	Damage Data
	EP	End of Plan Identifier
End of Job	ZZ	Required to end job

Table 10.2
Subdivisions of Simulation Data

Job Control	**Hydrology & Hydraulics**	**Economics & End of Job**
I_, Job Initialization	K_, Job step control	E_, etc., Economics, data
V_, Variable Output Summary	H_, Hydrograph transformation	ZZ, End of Job
O_, Optimization	Q_, Hydrograph data	
J_, Job Type	B_, Basin data	
	P_, Precipitation data	
	L_, Loss (infiltration) data	
	U_, Unit Graph data	
	M_, Melt data	
	R_, Routing data	
	S_, Storage data	
	D_, Diversion data	
	W_, Pump Withdrawal data	

A preprocessor in the program converts free-format data to the standard 8-character field structure and prints the reformatted data. This "echo print" may be turned off and on with *NOLIST and *LIST records.

Messages, notes, explanations of data, etc., can be inserted anywhere in the data set by using the *MESSAGE record. These records are printed with the *LIST option but are not shown on any further output.

The stream network structure can be portrayed diagrammatically by using the *DIAGRAM record at the beginning of the data set. This option causes the program to search the input data set for KK records and determine the job step computation associated with each KK record group. A flow chart of the stream network simulation as recognized from the KK-record sequences is printed. The user should verify that this flow chart conforms to the intended network of subbasins and routing reaches.

10.2.2 Time Series Input

The **IN record** allows the user to enter time-series data, either hyetographs or hydrographs, at time steps other than the computation interval specified on the **IT record**. This option is convenient when entering data generated by another program or in a separate HEC-1 simulation. Note that if direct input unit hydrograph ordinates is used (UI record), they must be at the same time step as the simulation computation interval and **cannot** be input with the **IN record.**

10.2.3 Data Repetition Conventions

In many instances, certain physical characteristics are the same for a number of subbasins in the stream network model (for instance, infiltration characteristics). Further, in a multiplan analysis, much of the PLAN 1 subbasin data remains unchanged in subsequent plans. The HEC-1 program input conventions make it unnecessary to repeat much of this information in the data set.

Data groups for subbasin runoff simulation which need not be repeated (if they are the same as input for the previous subbasin) are shown in Table 10.3. HEC-1 automatically uses the previous subbasin's input data for these data types unless new data are provided for the current subbasin. The source of the data used as identified by the input record number is printed in the left hand margin. If a zero is printed as the input record number, this means no data records have been provided, up to that point, which contain the required information. **Great care should be taken to verify that the input data used was so intended**. No data are repeatable for routing reaches.

Table 10.3

Data Repetition Options

Data Types which are Automatically Repeated	Record Identification
Rainfall	P
Infiltration	L
Base Flow	BF
Snowmelt	M
*Unit Hydrograph	US, UC, UD
*Kinematic Wave	** UK, RK

* Not recommended
** Only if all records remain unchanged

In the multiplan analysis, data may be supplied for a number of plans for the same subbasin. Data need not be repeated for each plan by following two conventions:

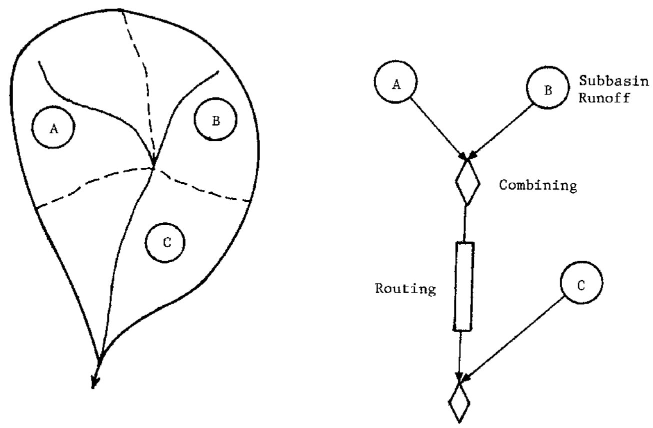
(1) Plans not specified in the data set by a **KP record** are assumed to be the same as the first plan in the KK record group. (Data for a particular plan follows a KP record in the data set.)

(2) Data specified subsequent to a **KP record** are considered to update previous plan data. If **no data** follows a KP record, then the indicated plan will be considered to be equivalent to the immediately preceding plan in the data set. See example problem 10 for an application of this program input convention.

10.3 Hydrologic/Hydraulic Simulation Options

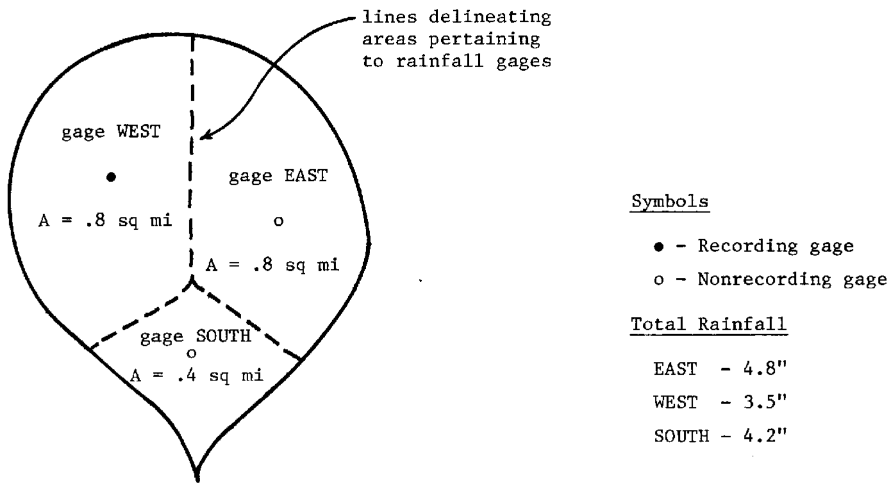
The HEC-1 program has a number of alternative methods available for simulating some aspects of the hydrologic/hydraulic processes (as referred to in the center column of Table 10.2). The different methods were also noted in the several data types available for one data category. For example, loss rates may be calculated by any of 5 different methods: exponential, initial/constant, SCS, Green and Ampt or Holtan. The general sequence of model building operations was shown in Figure 10.1.

There are a number of methods available for specifying rainfall hyetographs in the stream network computation as described in Section 3 and Table 10.4. Historical gage data can be input to the subbasin runoff computation as shown in Figure 10.2. The gage data consists of PG records for nonrecording gages and PG and PI or PC records for recording gages. These data are usually grouped toward the beginning of the data set before the first KK-record runoff computation. Within each KK-record group, the (PR, PW) and (PT, PW) records are used to specify which gages and corresponding weightings are to be used for computation of that subbasin's average precipitation. **Note that a recording gage can be used as both a storm total and a recording gage station**. This is indicated by using gage WEST of PT and PW records in Figure 10.2. If the storm total value is not specified on the PG record for the recording station (as is the case for the Figure 10.2 example), the program sums the incremental values on the PI records to compute that value.



Card ID		Description
	ID	Title
	IT	Time interval and beginning time
	IO	Output Control option for whole job
	KK	Subbasin A
Runoff	BA	Area
from	BF	Baseflow
Subbasin	P_	Select precipitation method, use IN if necessary
A	L_	Select one loss rate method
	U_	Select one rainfall excess transformation method
	KK	
Subbasin	BA	Similar to above for Subbasin A
runoff B	BF	
	P_,L_,U_	
	KK	Station Name
Combine	KM	Combine runoff from A and B (message option)
A + B	HC	Indicate 2 hydrographs are to be combined
Route	KK	Station name
(A+B)	RL	Channel loss optional
to C	R_	Select one routing method
	KK	
Subbasin	BA	Similar to above for Subbasin A
C runoff	BF	
	P_,L_,U_	
Combine Routed	KK	Station name
(A+B) with C	HC	Indicate 2 hydrographs are to be combined
	KK	
	IN	Compare computed and observed flows
	QO	
	ZZ	

Figure 10.1 Example Input Data Organization for a River Basin



DATA INPUT

	Card ID	Data			
	ID				
	IT				
	PG	EAST	4.8		
Rainfall gage data	PG	SOUTH	4.2		
	PG	WEST			
	PI	.02	.05	etc.	recording gage
	.				
	.	readings for storm			
	.				
	KK	3-gage basin			
	BA	2.0			
Gage weightings for	PT	WEST	EAST	SOUTH	
basin-average total	PW	.4	.4	.2	
Gage weightings for	PR	WEST			
basin-average recorder	PW	1			
	L_				
	U_				

Figure 10.2 Precipitation Gage Data for Subbasin-Average Computation

In order to facilitate the selection of data for the various simulation options, the following set of tables have been prepared.

Table 10.4	Precipitation Data Input Options
Table 10.5	Hydrograph Derivation Input Options
Table 10.6	Hydrograph Optimization Input Data Options
Table 10.7	Channel and Reservoir Routing Input Data Options
Table 10.8	Spillway Routing, Dam Overtopping and Dam Failure Input Data Options
Table 10.9	Net Benefit Analysis Input Data
Table 10.10	Flood Control Project Optimization Input Data Options
Table 10.11	Hydrograph Transformation, Comparison and I/O

These tables identify alternative methods for inputting data and simulating basin hydrology, hydraulics and flood damage. The example test problems in Section 12 further illustrate the input data structures for the various capabilities of HEC-1.

10.4 Input Data Retrieval from the HEC Data Storage System (DSS)

The HEC Data Storage System, DSS (HEC, 1994), may be used to retrieve and/or save certain catchment characteristics and time-series data. The options are: retrieve runoff parameters stored by program HYDPAR (Corps of Engineers, 1978); retrieve and/or store time-series data; and store flow-frequency curves. The input connections used to retrieve and store data are given in the overview of HEC-1 usage with DSS in Appendix B.

Table 10.4

Precipitation Data Input Options

Type of Storm Data	Record Identification
Basin-Average Storm Depth and Time Series	PB and/or (PI or PC)
Recording and Nonrecording Gages	PG for all nonrecording gages PG and (PI or PC) for all recording gages PR, PW, PT, PW for each subbasin
Synthetic Storm from Depth-Duration Data	PH
Probable Maximum Storm	PM
Standard Project Storm	PS
Depth-Area with Synthetic Storm	JD, PH, or PI/PC

Table 10.5

Hydrograph Input or Computation Options

		Hydrograph Derivation Options and Records		
Type of Data	**Input Hydrograph**	**SAM***	**Unit Graph**	**Kinematic Wave**
Inflows or Precipitation	QI	P_, M_	P_, M_	P_, M_
Basin Area	BA	BR	BA	BA
Base Flow	--	--	BF	BF
Loss Rate			LE, LM, LU, LS, LG or LH	LE, LM, LU, LS, LG or LH
Overland Flow Routing			UI, UC, US, UA or UD	UK, RK or RD

* Spatial data management and analysis files

Table 10.6

Runoff and Routing Optimization Input Data Options

Type of Data	**Runoff Optimization**	**Routing Optimization**
Optimization Control	OU	OR
Basin Characteristics	BA, L_, U_, and BF	
Pattern Hydrograph		QP
Observed Data	P_, M_, QO	QI, QO

Table 10.7

Channel and Reservoir Routing Methods Input Data Options
(without spillway and overtopping analysis)

		Modified Puls		
Type of Data	**Muskingum/ Muskingum-Cunge**	**Given Storage Outflow**	**Normal-Depth Storage Outflow**	**Kinematic Wave**
Routing Control	RM/RD	RS	RS	RK
Storage Discharge Relationships	--	SV/SQ*	--	--
Rating-Curve	--	SQ/SE*	--	--
Channel Hydraulic Characteristics	/RC, RX, RY**	--	RC, RX, RY	RK

* These data may be computed from options listed in Table 10.8

**Optional for Muskingum-Cunge

Table 10.8

Spillway Routing, Dam Overtopping, and Dam Failure
Input Data Options

		Type of Spillway Analysis		
Type of Data	**Given Rating Curve**	**Weir Coefficients**	**Trapezoid**	**Ogee**
Routing control	RS	RS, SS	RS, SG	RS, SG
Rating curve input	SQ, SE	--	--	--
Reservoir Area-Storage-Elevation	SA or SV, SE	SA or SV, SE	SA or SV, SE	SA or SV, SE
Spillway and Low Level Outlet Specs	SS (first field only)	SS, SL	SS	SS
Trapezoidal and Ogee Specs & Tailwater	--	--	SG, SQ, SE	SG, SQ, SE
Dam Overtopping Data	ST** SW, SE***	ST** SW, SE	ST** SW, SE	ST** SW, SE
Dam Failure Data	SB*	SB*	SB*	SB*
+Breach Outflow Submergence	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY

* Used for dam failure only, SB and ST Records required for dam failure.

** Required to obtain special summary printout for spillway adequacy and dam overtopping (ID only).

*** The SW, SE are used for non-level top of dam. The discharges computed with this option are added to discharges computed with the above options.

+ Must follow SB record, specifies downstream channel rating curve.

Table 10.9

Flood Damage Analysis Input Data Options

Type of Data	Record Identification
Economic Analysis Delimiter	EC
Damage Reach ID	KK
Damage Category	CN, WN*, PN*, TN*
Flow Frequency & Flow Damage Data	FR, QF, DG, QD, or FR, QF, SQ, QS, DG, SQ
Stage Frequency & Stage Damage Data	FR, SR, DG, SD or FR, SF, SQ, QS, DG, QD

* Optional records

Table 10.10

Flood Control Project Optimization
Input Data Options

	Stream Network Data			Economic Data
Type of Data	Pump	Reservoir	Diversion	Local Protection Project
Optimization		OS		
Target Penalty		OO		
Discount Factor + Size Constraint	WO	SO	DO	LO
Cost	WC, WD	SD*	DC, DD	LC, LD
Damage Pattern				DU, DL
Degree of Protection				DP

* Used with SE, SA or SV records for storage routing

Table 10.11

Hydrograph Transformation, Comparisons and I/O

	Transformation	Comparison	I/O
Combination	HC		
Adjust Hydrograph Ordinates	BA or HB		
Local Flow	HL, QO		
Compute Storage, Given Reservoir Releases	HS, QO		
Compute Stage	*HQ, HE		
Compare with Observations		QO or HL	
Write to Disk			*KO, KF
Read or Write from Scratch Files			*KO or BI

* The use of these options must be in combination with some other hydrograph computation

Section 11

Program Output

A large variety and degree of detail of output are available from HEC-1. This section describes the output in terms of input data feedback, intermediate simulation results, summary results, and error messages. The degree of detail of virtually all of the program output can be controlled by the user.

Several of the summary outputs are printed from scratch files generated during the simulation. If the user desires to save these scratch files for use in other jobs (say, for a plotting device), their location can be found in the definition of Input/Output Fortran logical units in Table 13.1 of Section 13.

11.1 Input Data Feedback

The input data file for each job are read and copied to a working file. As the data are copied to the working file they are converted from free format to fixed format (see Section 10.2.1) and a sequence number is assigned to each line. The reformatted data are printed so the user can see the data which are going into the main part of the program.

If a *DIAGRAM record is included in the input set, HEC-1 will plot a diagram of the stream network. The program scans the record identification codes to produce this diagram. B_ records (indicating subbasin runoff) cause a new branch to be added to the diagram. R_ records cause a 'V' to be printed indicating a routing reach. HC records cause a number of branches to be combined indicating a confluence of rivers. DT and DR cause right and left arrows to be printed showing diversion hydrographs leaving and returning to the network, respectively. The stream network diagram also shows how HEC-1 stores hydrographs in the computer memory. As a new branch is added to the diagram a new hydrograph is added to storage. Moving down the page, each hydrograph replaces in the computer memory the one printed above it. Diversion hydrographs are stored on a separate file.

11.2 Intermediate Simulation Results

The data used in each hydrograph computation (KK-record group) can be printed as well as the computed hydrograph, rainfall, storage, etc. as applicable. This output can be controlled by the IO record in general or overridden by the KO record for this specific KK-record group. The KK-record group of data which the program will use in its calculations are printed prior to the calculations. The sources of these data are indicated by the record identification code and line number printed on the left side of the page. The line numbers are keyed to the input data listing printed at the beginning of the job. The line number 'O' indicates that no data were provided and default values are being used. **Great care should be taken to verify that the intended data are being used in the calculation**.

Hydrographs may be printed in tabular form and/or graphed (printer plot or DSS DSPLAY) with the date, time, and sequence number for each ordinate. For runoff calculations, rainfall, losses, and excesses are included in the table and plot. For snowmelt calculations, separate values of loss and excess are printed for rainfall and snowmelt. For storage routings, storage and stage (if stage data are given) are printed/plotted along with discharge.

For optimization jobs (unit graph and loss rate, routing, or flood control project sizing), the program prints values for the variables and objective function for each iteration of the process. This output should be carefully reviewed to understand why changes are being made in the variables and to verify (using engineering judgment and comparison with similar results) that the results are reasonable.

11.3 Summary Results

The program produces hydrologic and economic summaries of the computations throughout the river basin. Users can also design their own special summaries using the VS and VV data. The standard program hydrologic summary shows the peak flow (stage) and accumulated drainage area for every hydrograph computation (KK-record group) in the simulation. The summaries may also include peak flows for each plan and ratio in multiplan-multiflood analysis or the peak flows for various durations in the basic stream network analysis. Flood damage summary data show the flood damages and damage reduction benefits (also costs for project optimization) for each damage reach and for the river basin. The river basin damage reduction results may also be summarized by two locational descriptors (say river name and county name) if desired.

11.4 Output to HEC Data Storage System (DSS)

The HEC Data Storage System, DSS (HEC, 1994), may be used to save HEC-1 output information for use in another HEC-1 simulation or by other HEC computer programs. Time-series data, streamflow or stage, as well as paired-function data, flow-frequency curves, can be output to DSS. The means by which this data can be stored is given in the overview of HEC-1 usage with DSS in Appendix B.

11.5 Error Messages

Table 11.1 lists error messages (in capital letters) which HEC-1 will print along with an explanation of the message. Some errors will not cause the program to stop execution, so the user should always check the output for possible errors or warnings.

The computer operating system may also print error messages. When an error occurs, the user should first ascertain if it is generated by HEC-1 or by the system. If it is generated by HEC-1, i.e., in the format given in Table 11.1, that table should be referred to and the indicated actions taken. If the error is system generated, the computer center user service and/or the in-house computer systems personnel should be contacted to ascertain the meaning of the error. These errors may be due to incorrectly input or read data or errors in HEC-1 or the computer system. If these system errors cannot be resolved in-house or if there is an error in the HEC-1 program, contact your distributor or the HEC.

Table 11.1

HEC-1 Error Messages

Error No.	Message	Subroutine
1	INVALID RECORD IDENTIFICATION CODE, OR RECORD OUT OF SEQUENCE Program does not recognize the record identification code in columns 1 and 2. Some records must be read in a designated sequence. Refer to Input Description and Section 10 of Users Manual. Program allows up to 30 input errors before terminating.	INPUT
2	NUMBER OF ORDINATES CANNOT EXCEED xxx. Number of ordinates, NQ, on IT record must be reduced to the stated limit.	OUTPUT
3	(NPLAN*NTRIO) CANNOT EXCEED xxx AND (NPLAN*NTRIO*NQ) CANNOT EXCEED xxx. Number of plans, ratios, or hydrograph ordinates must be reduced to stated limit.	OUTPUT
4	NO HYDROGRAPH AVAILABLE TO ROUTE. No hydrograph has been given to initiate network diagram.	PREVU
5	TOO MANY HYDROGRAPHS. COMBINE MORE OFTEN. Space for stream network diagram is limited, so maximum number of branches is limited to 9.	PREVU
6	TRIED TO COMBINE MORE HYDROGRAPHS THAN AVAILABLE. Network diagram has fewer branches than are to be combined at this point.	PREVU
7	DIMENSION EXCEEDED ON RECORD NO. nn **xx RECORD **. Too many values were read from given record. Check input description.	ECONO
8	xx RECORD ENCOUNTERED WHEN yy RECORD WAS EXPECTED FOLLOWING RECORD NO. nnn. Record No. nnn indicated that the next record would be a yy record, but an xx record was read instead. A record may be missing or out of sequence.	ECONO
9	QF OR SF RECORD MISSING. New flow- or stage-frequency data are required for each damage reach.	ECONO
10	QD OR SD RECORD MISSING. New flow- or stage-damage data are required for each damage reach.	ECONO
11	SQ RECORD MUST PRECEDE QS RECORD. See Input Description.	ECONO
12	SQ AND/OR QS MISSING. A stage-flow curve is required to convert flows to stages or vice versa.	ECONO
13	FIRST PLAN AT EACH STATION MUST BE PLAN 1. (EP-RECORD MAY BE MISSING). Damage calculations assume that PLAN 1 is the existing condition. Frequencies are given for PLAN 1 and flows for the other plans produced by the same ratio are assumed to have the same frequencies. See Section 8 of Users Manual.	ECONO
14	PEAK FLOW/STAGE DATA FOR LOCATION xxxxx NOT FOUND. Station name on KK record is not the same as station name used in hydrologic calculations. When an SF record is used, peak stages must have been calculated in the hydrologic portion of HEC-1.	ECONO
15	INSUFFICIENT DATA FOR STORAGE ROUTING. May also indicate redundant data. Storage routing requires storage and outflow data. With some options stages are required. See Input Description.	RESOUT

Table 11.1
HEC-1 Error Messages (continued)

Error No.	Message	Subroutine
16	ARRAY ON RECORD NO. nnn (xx) EXCEEDS DIMENSION OF KK. Attempted to read more data from xx record than was dimensioned in program.	REDARY
17	NUMBER OF PUMPS EXCEEDS nn--RECORD NO. ***** IGNORED. Attempted to read more pump data than dimensioned. For multiplan runs, number of pumps can be reset to zero by reading a blank WP record.	INPUT
18	NO TOTAL-STORM STATION WEIGHTS. Weighting factors are required to average total storm precipitation.	BASIN
19	NO RECORDING STATION WEIGHTS. Weighting factors are required to average temporal distribution of precipitation.	BASIN
20	PRECIPITATION STATION xxxxx NOT FOUND. Station name given on PR or PT record does not match names given on PG records.	BASIN
21	TIME INTERVAL TOO SMALL FOR DURATION OF PMS OR SPS. Standard project storm has a duration of 96 hours. Probable maximum storm duration varies from 24 to 96 hours, depending on given data. The given combination of time interval and storm duration causes the number of ordinates to exceed the program dimensions. Use a larger time interval or shorter storm.	BASIN
22	NO PREVIOUS DIVERSION HYDROGRAPHS HAVE BEEN SAVED. Attempted to retrieve a diversion hydrograph before the diversion has been computed.	DIVERT
23	DIVERSION HYDROGRAPH NOT FOUND FOR STATION xxxxx. Station name on DR record does not match names given on previous DT records.	DIVERT
24	INITIAL VALUES OF TC AND R. For optimization run, given values of TC and R on UC record must both be positive or both negative.	INVAR
25	STATION xxxxx NOT FOUND ON UNIT nn. Station name on BI record does not match names of hydrographs stored on unit nn.	READQ
26	SPILLWAY CREST IS ABOVE MAXIMUM RESERVOIR ELEVATION. Program cannot compute spillway discharge. Maximum reservoir elevation is assumed to be highest stage given with storage data.	RESOUT
27	VARIABLE NUMBER (nn) EXCEEDS SIZE OF VAR ARRAY. Variable numbers given on DO, SO, WO, and LO records must be in the range 1-10.	SETOPT
28	HYDROGRAPH STACK FULL. COMBINE MORE OFTEN. Storage space for hydrographs is full. Required storage can be reduced by using more combining points in the stream network.	STACK
29	ONLY ONE DATA POINT FOR INTERPOLATION. Program cannot interpolate from one piece of data. More ratios or frequencies are required for damage calculations.	AKIMAI

Table 11.1
HEC-1 Error Messages (continued)

30 X VALUES ARE NOT UNIQUE AND/OR INCREASING FOR CUBIC SPLINE INTERPOLATION. — AKIMA

The cubic spline interpolation routine requires that the independent variable be unique and monotonically increasing, i.e., X_J X_{J-1} for all j.

31 xx RECORD MUST FOLLOW yy RECORD (INPUT LINE NO. nn). — INPUT

An xx record was expected to be after the yy record. See Input Description for xx and yy records. nn is sequence number of yy record.

32 NUMBER OF STORAGE VALUES AND NUMBER OF OUTFLOW VALUES ARE NOT EQUAL. — RESOUT

Number of values given on SA or SV records must be the same as the number of flows on the SQ record unless elevations (SE record) are given for both storage and outflow. The number of values is determined by the last non-zero value on the record.

33 PLAN NUMBER (nn) ON KP-RECORD (NO. ii) IS GREATER THAN NUMBER OF PLANS (mm) DECLARED ON JP-RECORD. — INPUT

Number of plans for this run is declared on JP record. Plan number must be a positive integer less or than equal to value on JP record.

34 HYDROGRAPH STACK IS EMPTY. — STACK

Attempted to combine more hydrographs than have been saved (HC record), or attempted to route an upstream hydrograph when no hydrographs have been saved (e.g., RK record with "yes" option in kinematic wave runoff). Use *DIAGRAM record to check stream network.

35 PLAN NUMBER nn (ON KP-RECORD NO. iii) HAS ALREADY BEEN COMPUTED FOR STATION xxxxxxxxx. — INPUT

Duplicate plan numbers may not be used within a KK record segment of the input set. The plan number is set to 1 when a KK record is read. Only K_ or I_ record may be present between the KK record and a KP record for PLAN 1. This does not preclude the first KP record from being for any other plan (see Input Description for KP record).

36 ACCUMULATED AREA IS ZERO. ENTER AREA FOR COMBINED HYDROGRAPH IN FIELD 2 OF HC-RECORD. — MANE2

Basin area for a combined hydrograph was calculated as zero. This will result in an error when computing an interpolated hydrograph for the depth area option (JD-Record). Basin area to be used to calculate the interpolated hydrograph should be entered in Field 2 of the HC Record.

37 OPERATION CANNOT BE DETERMINED FROM RECORDS IN KK-RECORD GROUP BEGINNING WITH RECORD NO. XXX. — HEC1

The records specified in a KK-record group were not complete and it is likely that data needs to be specified on additional records.

38 X-COORDINATE **** IS NEGATIVE

The station distance values on the RX record must be greater than zero.

39 CROSS-SECTION X-COORDINATES ARE NOT INCREASING ****,****

The station distances on the RX record must increase from the beginning station (left overbank) to the ending station (right overbank).

40 CATEGORY NUMBER ON DG-RECORD IS NOT IN RANGE 1 TO XXX

Number of categories, ICAT, must be less than or equal to ten.

Section 12

Example Problems

This section contains several problems which serve as illustrative examples of various capabilities of HEC-1. The first three example problems illustrate the most basic river basin modeling capabilities. Following these, specialized capabilities of HEC-1 are added to the basic model. Examples 9, 10, 11 and 12 are a sequence of steps necessary to perform multiflood, multiplan, flood damage, and flood control project optimization analyses.

12.1 Example Problem #1: Stream Network Model

A stream network model was developed for the Red River watershed shown in Figure 12.1. The development of this type of model for a watershed is basic to the use of the HEC-1 program. The example demonstrates the following features of the program:

(1) Data input conventions.

(2) Rainfall specification by non-recording gage, recording gage and gage weighting data.

(3) Calculation of runoff hydrographs utilizing loss rate, base flow and unit graph data.

(4) Flood hydrograph routing by the channel storage method.

(5) Reservoir routing using the spillway and low-level outlet options.

(6) Channel bifurcations (man-made or natural) using the diversion option.

(7) Input of time-series data at time increments different than the computational time step.

Tables 12.1a - 12.1c display data for the watershed model; note that the data record identifiers used to input each type of data are also indicated in the tables. **Important points to note** about the stream network model data are as follows:

(1) Both recording and non-recording gage stations can be used as total-storm stations for a subbasin as specified on the PT, PW cards. (The total depth associated with incremental or cumulative rainfall data is automatically calculated for each recording gage.) In this example, gage 400 is used only for the temporal pattern. The subbasin storm pattern is calculated as a weighted average of the recording gage storm patterns indicated on the PR, PW cards.

(2) The various unit hydrograph options available can be used with any of the loss rate options. The data in the appropriate HEC-1 format and the results of the computer simulation are displayed in the Table 12.1d computer output.

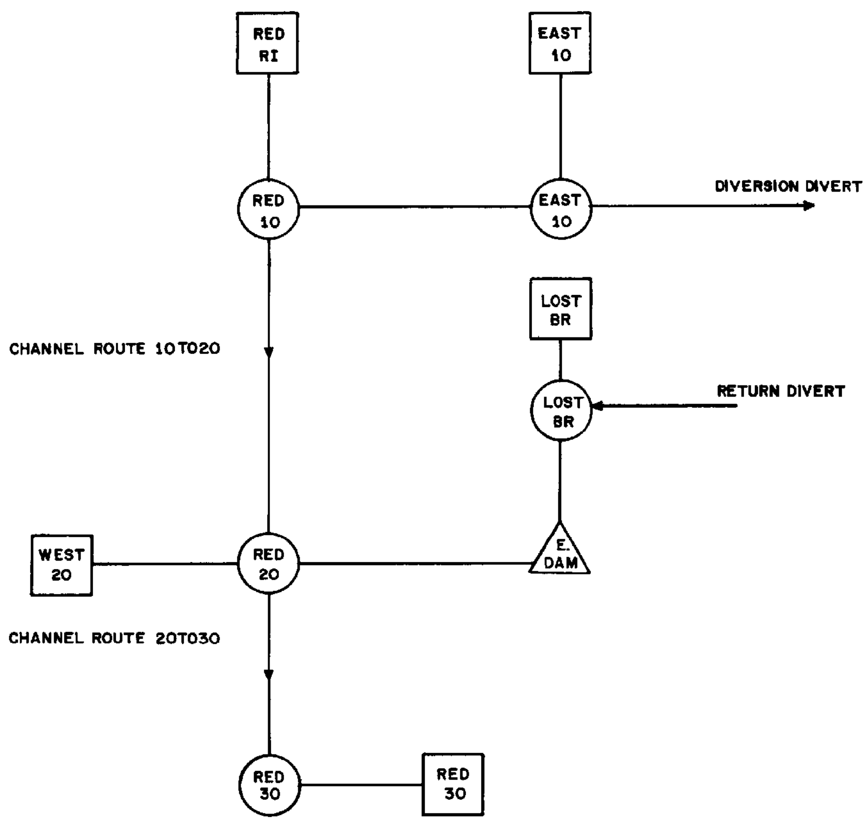


Figure 12.1 Stream Network Model Schematic

Table 12.1a

Red River Watershed: Rainfall and Observed Hydrograph Data

RAINFALL DATA

		Record Identifier
Total Storm Data:		PG
Gage #	Storm Depth (inches)	
60	4.68	
61	4.65	
62	4.85	
63	4.90	
64	5.10	
Hourly Precipitation Data:		
Starting Time: 7:15 AM Date: June 12, 1968		IN
Station #: 400		
Hourly incremental rainfall:		
04, .35, .01, .03, .73, .21, .02, .01, .03, .01		PG, PI

OBSERVED HYDROGRAPH DATA

	Record Identifier
Station RED30	KK
Observed flow beginning at same time simulation starts, see input data listing. IN card is required preceding the flow data because the data tabulation interval is different than the previous IN card for rainfall.	IN QO

Table 12.1b

Subbasin Physical Parameters (Test 1)

Subbasin Name (KK Record)	Basin Area (sq mi) (BA Record)	Precipitation Gage Weights (PT, PW Records) Gage No.	NT.	Loss Rate (Method)	Loss Rate (Record)	Unit Graph (Method)	Unit Graph (Record)	Base Flow Parameters (BF Record) STRTQ	QRCSN	RTIOR
RED RI	.82 61	400 60 .25	1 .75	SCS CN=80	LS	SCS LAG=1.47	UD	10.0	-2.5	1.2
EAST10	.66	400 61 62 63	1 .6 .3 .1	EXPON. STRKR=0.6 DLTKR=1.0 RTIOR=1.0 ERAIN=0.0	LE	SNYDER TP=1.3 CP=0.8	US	10.0	-.25	1.2
LOSTBR	.36	400 62 63	1 .5 .5	UNIFORM STRTL=0.3 CNSTL=.04	LU	CLARK TC=0.8 R=1.2	UC	10.0	-.25	1.2
WEST20	.80	400 63 64	1 .6 .4	HOLTAN GIA=0.4 SA=0.3 EXP=1.4 FC=.04	LH	SCS LAG=.94	UD	10.0	-.25	1.2
RED30	.19	400 64 63	1 .65 .35	SCS CN=79	LS	SCS LAG=1.04	UD	10.0	-.25	1.2

Table 12.1c
Channel Storage Routing and Diversion Data

CHANNEL STORAGE ROUTING

											Record Identifier
Reach: 10 to 20											KK
Volume-Outflow Data											RS
Volume:	0	18	36	54	84	110	138	174	228	444	SV
Outflow:	0	500	1000	1500	2150	2600	3000	3450	4000	6000	SQ
Reach: 20 to 30											KK
Volume-Outflow Data											RS
Volume:	0	17	42	67	100	184	274	386	620		SV
Outflow:	0	500	1000	1500	2000	3000	4000	5000	7000		SQ

RESERVOIR ROUTING DATA

	Record Identifier
Reservoir: E.DAM	KK
Initial WSEL: 851.2	RS
Low Level Outlet	SL
Invert elevation = 851.2 m.s.l.	
Cross-sectional area = 12 sq. ft.	
Discharge coefficient = .6	
Head exponent = .5	
Spillway	SS
Crest elevation = 856 m.s.l.	
Width = 60 feet	
Weir coefficient = 2.7	
Head exponent = 1.5	
Volume-Elevation Data	
Volume: 21 100 205 325 955	SV
Elevation: 850 851.5 853.3 856.5 858.0	SE

DIVERSION DATA

	Record Identifier
Location: EAST10	KK
Diversion Designation	
DT	
Diverted flows labeled: DIVERT	
Diverted Flow Data	
Channel Inflow: 0 100 300 600 900	DT
Diverted Flow: 0 25 100 180 270	DQ

Table 12.1d

Example Problem #1

Input

```
ID      EXAMPLE PROBLEM NO. 1
ID      STREAM NETWORK MODEL
*DIAGRAM
IT    15 12JUN68     715      58
IO     5
PG    60    4.68
PG    61    4.65
PG    62    4.85
PG    63    4.90
PG    64    5.10
PG   400       0
IN    60 12JUN68     715
PI   .04     .35     .01     .03     .73     .21     .02     .01     .03     .01
KKRED RI
KM      SCS RUNOFF COMPUTATION
BA   .82
BF  10.0    -.25     1.2
PR   400
PW     1
PT    60      61
PW   .75     .25
LS            80
UD  1.47
KKEAST10
KO     4       2
KM      SNYDER UNIT GRAPH COMPUTATION-EXPONENTIAL LOSS RATE
BA   .66
BF  10.0    -.25     1.2
PR   400
PW     1
PT    61      62      63
PW    .6      .3      .1
LE    .6     1.0     1.0       0
US   1.3      .8
KKEAST10
KO     4
KM      DIVERT FLOW TO LOSTBR
DTDIVERT
DI     0     100     300     600     900
DQ     0      25     100     180     270
KK RED10
KO     4
KM      COMBINE HYDROGRAPHS FROM SUBBASINS EAST10 AND RED RI
HC     2
KK10TO20
KO     4       2
KM      ROUTE FLOWS FROM STATION RED10 TO RED 20
RS     1    FLOW      -1
SV     0      18      36      54      84     110     138     174     228     444
SQ     0     500    1000    1500    2150    2600    3000    3450    4000    6000
KKLOSTBR
KM      RETRIEVE DIVERSION FROM EAST10
DRDIVERT
KKLOSTBR
KM      CLARK UNIT GRAPH COMPUTATION-INITIAL AND UNIFORM LOSS RATES
BA   .36
BF  10.0    -.25     1.2
PR   400
PW     1
PT    62      63
PW    .5      .5
LU    .3     .04
UC   .80     1.2
```

```
KKLOSTBR
KM      COMBINE RUNOFF FROM LOSTBR WITH DIVERTED FLOW
HC     2
KK E.DAM
KM      ROUTE FLOWS THROUGH DAM
RS     1    ELEV   851.2
SV    21     100     205     325     955
SE   850   851.5   853.3   856.5   858.0
SL 851.2      12      .6      .5
SS   856      60     2.7     1.5
KKWEST20
KM      SCS RUNOFF COMPUTATION-HOLTAN LOSS RATE
KO     1
BA   .80
BF  10.0    -.25     1.2
PR   400
PW     1
PT    63      64
PW    .6      .4
LH   .04      .4      .3     1.4
UD   .94
KK RED20
KM      COMBINE RUNOFF FROM WEST20,OUTFLOW FROM E.DAM AND REACH 1020
HC     3
KK20TO30
KM      ROUTE FLOWS FROM RED20 TO RED30
RS     1    FLOW      -1
SV     0      17      42      67     100     184     274     386     620
SQ     0     500    1000    1500    2000    3000    4000    5000    7000
KK RED30
KM      RUNOFF BY THE SCS METHOD
BA   .19
BF  10.0    -.25     1.2
PR   400
PW     1
PT    64      63
PW   .65     .35
LS            79
UD  1.03
KK RED30
KM      COMBINE RUNOFF FROM RED30 AND OUTFLOW FROM REACH 20TO30
HC     2
KK  GAGE
KO     1
KM      COMPARE COMPUTED AND OBSERVED HYDROGRAPHS AT RED30
IN    15 12JUN68     715
QO    10      13      16      20      25      30      51      92     159     241
QO   332     399     412     393     348     291     255     229     235     321
QO   472     705     921    1120    1255    1345    1373    1314    1228    1122
QO   996     900     817     742     668     614     549     500     444     409
QO   388     372     359     348     338     328     321     310     300     291
QO   282     274     267     277     252     240     231     224
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*            JUN   1998                 *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:37:53   *
*                                       *
*****************************************
```

```
                                         HEC-1 INPUT                                         PAGE  1

  LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

     1          ID        EXAMPLE PROBLEM NO. 1
     2          ID        STREAM NETWORK MODEL
                *DIAGRAM
     3          IT      15 12JUN68     715      58
     4          IO       5
     5          PG      60    4.68
     6          PG      61    4.65
     7          PG      62    4.85
     8          PG      63    4.90
     9          PG      64    5.10
    10          PG     400       0
    11          IN      60 12JUN68     715
    12          PI     .04     .35     .01     .03     .73     .21     .02     .01     .03     .01

    13          KK  RED RI
    14          KM        SCS RUNOFF COMPUTATION
    15          BA     .82
    16          BF    10.0    -.25     1.2
    17          PR     400
    18          PW       1
    19          PT      60      61
    20          PW     .75     .25
    21          LS              80
    22          UD    1.47

    23          KK  EAST10
    24          KO       4       2
    25          KM        SNYDER UNIT GRAPH COMPUTATION-EXPONENTIAL LOSS RATE
    26          BA     .66
    27          BF    10.0    -.25     1.2
    28          PR     400
    29          PW       1
    30          PT      61      62      63
    31          PW      .6      .3      .1
    32          LE      .6     1.0     1.0       0
    33          US     1.3      .8

    34          KK  EAST10
    35          KO       4
    36          KM        DIVERT FLOW TO LOSTBR
    37          DT  DIVERT
    38          DI       0     100     300     600     900
    39          DQ       0      25     100     180     270

    40          KK   RED10
    41          KO       4
    42          KM        COMBINE HYDROGRAPHS FROM SUBBASINS EAST10 AND RED RI
    43          HC       2

    44          KK  10TO20
    45          KO       4       2
    46          KM        ROUTE FLOWS FROM STATION RED10 TO RED 20
    47          RS       1    FLOW      -1
    48          SV       0      18      36      54      84     110     138     174     228     444
    49          SQ       0     500    1000    1500    2150    2600    3000    3450    4000    6000
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 50           KK  LOSTBR
 51           KM        RETRIEVE DIVERSION FROM EAST10
 52           DR  DIVERT

 53           KK  LOSTBR
 54           KM        CLARK UNIT GRAPH COMPUTATION-INITIAL AND UNIFORM LOSS RATES
 55           BA     .36
 56           BF    10.0    -.25     1.2
 57           PR     400
 58           PW       1
 59           PT      62      63
 60           PW      .5      .5
 61           LU      .3     .04
 62           UC     .80     1.2

 63           KK  LOSTBR
 64           KM        COMBINE RUNOFF FROM LOSTBR WITH DIVERTED FLOW
 65           HC       2

 66           KK   E.DAM
 67           KM        ROUTE FLOWS THROUGH DAM
 68           RS       1    ELEV   851.2
 69           SV      21     100     205     325     955
 70           SE     850   851.5   853.3   856.5   858.0
 71           SL   851.2      12      .6      .5
 72           SS     856      60     2.7     1.5

 73           KK  WEST20
 74           KM        SCS RUNOFF COMPUTATION-HOLTAN LOSS RATE
 75           KO       1
 76           BA     .80
 77           BF    10.0    -.25     1.2
 78           PR     400
 79           PW       1
 80           PT      63      64
 81           PW      .6      .4
 82           LH     .04      .4      .3     1.4
 83           UD     .94

 84           KK   RED20
 85           KM        COMBINE RUNOFF FROM WEST20,OUTFLOW FROM E.DAM AND REACH 1020
 86           HC       3

 87           KK  20TO30
 88           KM        ROUTE FLOWS FROM RED20 TO RED30
 89           RS       1    FLOW      -1
 90           SV       0      17      42      67     100     184     274     386     620
 91           SQ       0     500    1000    1500    2000    3000    4000    5000    7000

 92           KK   RED30
 93           KM        RUNOFF BY THE SCS METHOD
 94           BA     .19
 95           BF    10.0    -.25     1.2
 96           PR     400
 97           PW       1
 98           PT      64      63
 99           PW     .65     .35
100           LS              79
101           UD    1.03

102           KK   RED30
103           KM        COMBINE RUNOFF FROM RED30 AND OUTFLOW FROM REACH 20TO30
104           HC       2

105           KK    GAGE
106           KO       1
107           KM        COMPARE COMPUTED AND OBSERVED HYDROGRAPHS AT RED30
108           IN      15 12JUN68     715
109           QO      10      13      16      20      25      30      51      92     159     241
110           QO     332     399     412     393     348     291     255     229     235     321
111           QO     472     705     921    1120    1255    1345    1373    1314    1228    1122
112           QO     996     900     817     742     668     614     549     500     444     409
113           QO     388     372     359     348     338     328     321     310     300     291
114           QO     282     274     267     277     252     240     231     224
115           ZZ
```

```
                SCHEMATIC DIAGRAM OF STREAM NETWORK
INPUT
 LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

  NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

   13      RED RI
                .
                .
   23           .      EAST10
                .           .
                .           .
   37           .           .------->  DIVERT
   34           .      EAST10
                .           .
                .           .
   40       RED10............
                V
                V
   44      10TO20
                .
                .
   52           .           .<-------  DIVERT
   50           .      LOSTBR
                .           .
                .           .
   53           .           .      LOSTBR
                .           .           .
                .           .           .
   63           .      LOSTBR............
                .           V
                .           V
   66           .       E.DAM
                .           .
                .           .
   73           .           .      WEST20
                .           .           .
                .           .           .
   84       RED20........................
                V
                V
   87      20TO30
                .
                .
   92           .       RED30
                .           .
                .           .
  102       RED30............
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:37:53   *
*                                       *
*****************************************



                                 EXAMPLE PROBLEM NO. 1
                                 STREAM NETWORK MODEL

    4 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          15  MINUTES IN COMPUTATION INTERVAL
                        IDATE     12JUN68  STARTING DATE
                        ITIME        0715  STARTING TIME
                           NQ          58  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     12JUN68  ENDING DATE
                       NDTIME        2130  ENDING TIME
                       ICENT           19  CENTURY MARK

                    COMPUTATION INTERVAL     .25 HOURS
                         TOTAL TIME BASE   14.25 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 


             **************
             *            *
   23 KK     *    EAST10  *
             *            *
             **************

   24 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           4  PRINT CONTROL
                        IPLOT           2  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
                                 SNYDER UNIT GRAPH COMPUTATION-EXPONENTIAL LOSS RATE

                SUBBASIN RUNOFF DATA

   26 BA          SUBBASIN CHARACTERISTICS
                        TAREA         .66  SUBBASIN AREA

   27 BF          BASE FLOW CHARACTERISTICS
                        STRTQ       10.00  INITIAL FLOW
                        QRCSN        -.25  BEGIN BASE FLOW RECESSION
                        RTIOR     1.20000  RECESSION CONSTANT

                  PRECIPITATION DATA

   30 PT           TOTAL STORM STATIONS        61        62        63
   31 PW                        WEIGHTS       .60       .30       .10

   28 PR             RECORDING STATIONS       400
   29 PW                        WEIGHTS      1.00
```

```
32 LE          EXPONENTIAL LOSS RATE
                     STRKR         .60  INITIAL VALUE OF LOSS COEFFICIENT
                     DLTKR        1.00  INITIAL LOSS
                     RTIOL        1.00  LOSS COEFFICIENT RECESSION CONSTANT
                     ERAIN         .00  EXPONENT OF PRECIPITATION
                     RTIMP         .00  PERCENT IMPERVIOUS AREA

33 US          SNYDER UNITGRAPH
                        TP        1.30  LAG
                        CP         .80  PEAKING COEFFICIENT

               SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                     ***

             PRECIPITATION STATION DATA

                    STATION    TOTAL    AVG. ANNUAL    WEIGHT
                         61     4.65         .00          .60
                         62     4.85         .00          .30
                         63     4.90         .00          .10

               TEMPORAL DISTRIBUTIONS

               STATION      400,  WEIGHT =   1.00
                     .01      .01      .01      .01      .09      .09      .09      .09      .00      .00
                     .00      .00      .01      .01      .01      .01      .18      .18      .18      .18
                     .05      .05      .05      .05      .00      .00      .00      .00      .00      .00
                     .00      .00      .01      .01      .01      .01      .00      .00      .00      .00

                                                   UNIT HYDROGRAPH PARAMETERS
                                             CLARK   TC=  1.81 HR,       R=   .55 HR
                                            SNYDER   TP=  1.29 HR,      CP=   .79

                                                        UNIT HYDROGRAPH
                                                   16 END-OF-PERIOD ORDINATES
                     23.      79.     146.     210.     252.     261.     238.     181.     116.      73.
                     46.      29.      18.      12.       7.       5.
```

```
                                                        STATION   EAST10

                        (O) OUTFLOW
         0.        50.      100.      150.      200.      250.      300.      350.      400.      450.        0.        0.        0.
                                                                                                      (L) PRECIP,   (X) EXCESS
         .0        .0        .0        .0        .0        .0        .0        .0        .0        .6        .4        .2        .0
DAHRMN PER
120715   1.-O-------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
120730   2. O       .         .         .         .         .         .         .         .         .         .         .       LL.
120745   3. O       .         .         .         .         .         .         .         .         .         .         .       LL.
120800   4. O       .         .         .         .         .         .         .         .         .         .         .       LL.
120815   5. O       .         .         .         .         .         .         .         .         .         .         .       LL.
120830   6. O       .         .         .         .         .         .         .         .         .         .     LLLLLLLLLXXXXX.
120845   7.   O     .         .         .         .         .         .         .         .         .         .     LLLLLLLLXXXXXX.
120900   8.      O  .         .         .         .         .         .         .         .         .         .     LLLLLLLLXXXXXX.
120915   9.         . O       .         .         .         .         .         .         .         .         .     LLLLLLLXXXXXXX.
120930  10.         .      O  .         .         .         .         .         .         .         .         .         .         .
120945  11. . . . . . . . . . O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121000  12.         .         .   O     .         .         .         .         .         .         .         .         .         .
121015  13.         .         .  O      .         .         .         .         .         .         .         .         .         .
121030  14.         .         O         .         .         .         .         .         .         .         .         .        L.
121045  15.         .     O   .         .         .         .         .         .         .         .         .         .        L.
121100  16.         .O        .         .         .         .         .         .         .         .         .         .        L.
121115  17.      O  .         .         .         .         .         .         .         .         .         .         .        L.
121130  18.      O  .         .         .         .         .         .         .         .         LLLLLLLLXXXXXXXXXXXXXXXXXXXXXX.
121145  19.         .  O      .         .         .         .         .         .         .         LLLLLLLXXXXXXXXXXXXXXXXXXXXXXX.
121200  20.         .         .    O    .         .         .         .         .         .         LLLLLLLXXXXXXXXXXXXXXXXXXXXXXX.
121215  21. . . . . . . . . . . . . . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . LLLLLLLXXXXXXXXXXXXXXXXXXXXXXX.
121230  22.         .         .         .         .         .         .  O      .         .         .         .         .LLLLLLLLX.
121245  23.         .         .         .         .         .         .         .         O         .         .         .LLLLLLLLX.
121300  24.         .         .         .         .         .         .         .         .       O .         .         .LLLLLLLLX.
121315  25.         .         .         .         .         .         .         .         .      O  .         .         .LLLLLLLLX.
121330  26.         .         .         .         .         .         .         .    O    .         .         .         .        L.
121345  27.         .         .         .         .         .        O.         .         .         .         .         .        L.
121400  28.         .         .         .         . O       .         .         .         .         .         .         .        L.
121415  29.         .         .        O.         .         .         .         .         .         .         .         .        L.
121430  30.         .         . O       .         .         .         .         .         .         .         .         .         .
121445  31. . . . . . . . . . O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121500  32.         .         O         .         .         .         .         .         .         .         .         .         .
121515  33.         .        O.         .         .         .         .         .         .         .         .         .         .
121530  34.         .       O .         .         .         .         .         .         .         .         .         .        L.
121545  35.         .      O  .         .         .         .         .         .         .         .         .         .        L.
121600  36.         .      O  .         .         .         .         .         .         .         .         .         .        L.
121615  37.         .     O   .         .         .         .         .         .         .         .         .         .        L.
121630  38.         .    O    .         .         .         .         .         .         .         .         .         .         .
121645  39.         .   O     .         .         .         .         .         .         .         .         .         .         .
121700  40.         .   O     .         .         .         .         .         .         .         .         .         .         .
121715  41. . . . . . O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121730  42.         .  O      .         .         .         .         .         .         .         .         .         .         .
121745  43.         . O       .         .         .         .         .         .         .         .         .         .         .
121800  44.         . O       .         .         .         .         .         .         .         .         .         .         .
121815  45.         .O        .         .         .         .         .         .         .         .         .         .         .
121830  46.         .O        .         .         .         .         .         .         .         .         .         .         .
121845  47.         O         .         .         .         .         .         .         .         .         .         .         .
121900  48.         O         .         .         .         .         .         .         .         .         .         .         .
121915  49.        O.         .         .         .         .         .         .         .         .         .         .         .
121930  50.        O.         .         .         .         .         .         .         .         .         .         .         .
121945  51. . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
122000  52.       O .         .         .         .         .         .         .         .         .         .         .         .
122015  53.       O .         .         .         .         .         .         .         .         .         .         .         .
122030  54.      O  .         .         .         .         .         .         .         .         .         .         .         .
122045  55.      O  .         .         .         .         .         .         .         .         .         .         .         .
122100  56.      O  .         .         .         .         .         .         .         .         .         .         .         .
122115  57.     O   .         .         .         .         .         .         .         .         .         .         .         .
122130  58.-----O---.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
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*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

              **************
              *            *
   34 KK      *    EAST10  *
              *            *
              **************

   35 KO           OUTPUT CONTROL VARIABLES
                         IPRNT           4  PRINT CONTROL
                         IPLOT           0  PLOT CONTROL
                         QSCAL          0.  HYDROGRAPH PLOT SCALE
                                  DIVERT FLOW TO LOSTBR

      DT           DIVERSION
                         ISTAD      DIVERT  DIVERSION HYDROGRAPH IDENTIFICATION

      DI              INFLOW         .00    100.00    300.00    600.00    900.00

      DQ       DIVERTED FLOW         .00     25.00    100.00    180.00    270.00

                                                                   ***


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

              **************
              *            *
   40 KK      *     RED10  *
              *            *
              **************

   41 KO           OUTPUT CONTROL VARIABLES
                         IPRNT           4  PRINT CONTROL
                         IPLOT           0  PLOT CONTROL
                         QSCAL          0.  HYDROGRAPH PLOT SCALE
                                  COMBINE HYDROGRAPHS FROM SUBBASINS EAST10 AND RED RI

   43 HC           HYDROGRAPH COMBINATION
                         ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                                   ***


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

              **************
              *            *
   44 KK      *    10TO20  *
              *            *
              **************

   45 KO           OUTPUT CONTROL VARIABLES
                         IPRNT           4  PRINT CONTROL
                         IPLOT           2  PLOT CONTROL
                         QSCAL          0.  HYDROGRAPH PLOT SCALE
                                  ROUTE FLOWS FROM STATION RED10 TO RED 20

                 HYDROGRAPH ROUTING DATA

   47 RS           STORAGE ROUTING
                         NSTPS           1  NUMBER OF SUBREACHES
                          ITYP        FLOW  TYPE OF INITIAL CONDITION
                        RSVRIC       -1.00  INITIAL CONDITION
                             X         .00 WORKING R AND D COEFFICIENT

   48 SV             STORAGE       .0   18.0   36.0   54.0   84.0  110.0  138.0  174.0  228.0   444.0


   49 SQ           DISCHARGE       0.   500.  1000.  1500.  2150.  2600.  3000.  3450.  4000.   6000.

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                                                         STATION   10TO20

                         (I) INFLOW,   (O) OUTFLOW
         0.      100.      200.      300.      400.      500.      600.      700.      800.        0.        0.        0.        0.
                                                                                (S) STORAGE
         0.        0.        0.        0.        0.        0.        0.       10.       20.       30.        0.        0.        0.
DAHRMN PER
120715   1.-I-------.---------.---------.---------.---------.---------.S--------.---------.---------.---------.---------.---------.
120730   2. I       .         .         .         .         .         .S        .         .         .         .         .         .
120745   3. I       .         .         .         .         .         .S        .         .         .         .         .         .
120800   4. I       .         .         .         .         .         .S        .         .         .         .         .         .
120815   5.IO       .         .         .         .         .         .S        .         .         .         .         .         .
120830   6. I       .         .         .         .         .         .S        .         .         .         .         .         .
120845   7. I       .         .         .         .         .         .S        .         .         .         .         .         .
120900   8. OI      .         .         .         .         .         .S        .         .         .         .         .         .
120915   9.  O  I   .         .         .         .         .         .S        .         .         .         .         .         .
120930  10.    O  I .         .         .         .         .         . S       .         .         .         .         .         .
120945  11. . . .O. .I. . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . . . . . . . . . . . . .
121000  12.        O.  I      .         .         .         .         .  S      .         .         .         .         .         .
121015  13.         .O I      .         .         .         .         .   S     .         .         .         .         .         .
121030  14.         . OI      .         .         .         .         .   S     .         .         .         .         .         .
121045  15.         .IO       .         .         .         .         .   S     .         .         .         .         .         .
121100  16.        I.O        .         .         .         .         .   S     .         .         .         .         .         .
121115  17.      I  O         .         .         .         .         .  S      .         .         .         .         .         .
121130  18.      IO .         .         .         .         .         .  S      .         .         .         .         .         .
121145  19.        OI         .         .         .         .         .  S      .         .         .         .         .         .
121200  20.         .O      I .         .         .         .         .   S     .         .         .         .         .         .
121215  21. . . . . . . . .O. . . . . . I . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . . . . . . . . . . . . .
121230  22.         .         .     O   .         .    I    .         .        S.         .         .         .         .         .
121245  23.         .         .         .       O .         .        I.         .   S     .         .         .         .         .
121300  24.         .         .         .         .         O         .         I       S .         .         .         .         .
121315  25.         .         .         .         .         .         O         .   I     .S        .         .         .         .
121330  26.         .         .         .         .         .         .    O    . I       .   S     .         .         .         .
121345  27.         .         .         .         .         .         .    I O  .         .   S     .         .         .         .
121400  28.         .         .         .         .         .     I   .   O     .         .  S      .         .         .         .
121415  29.         .         .         .         .      I  .       O .         .         .S        .         .         .         .
121430  30.         .         .         .        I.         . O       .         .        S.         .         .         .         .
121445  31. . . . . . . . . . . . . . . . . I . . . . .O. . . . . . . . . . . . . . S . . . . . . . . . . . . . . . . . . . . . .
121500  32.         .         .        I.        O.         .         .         .   S     .         .         .         .         .
121515  33.         .         .    I    .  O      .         .         .         . S       .         .         .         .         .
121530  34.         .         .I       O.         .         .         .         S         .         .         .         .         .
121545  35.         .       I .    O    .         .         .         .        S.         .         .         .         .         .
121600  36.         .      I  .O        .         .         .         .       S .         .         .         .         .         .
121615  37.         .     I  O.         .         .         .         .      S  .         .         .         .         .         .
121630  38.         .     I O .         .         .         .         .     S   .         .         .         .         .         .
121645  39.         .    I O  .         .         .         .         .     S   .         .         .         .         .         .
121700  40.         .   I O   .         .         .         .         .     S   .         .         .         .         .         .
121715  41. . . . . . . IO. . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . . . . . . . . . . . .
121730  42.         .  IO     .         .         .         .         .    S    .         .         .         .         .         .
121745  43.         . I O     .         .         .         .         .    S    .         .         .         .         .         .
121800  44.         . IO      .         .         .         .         .    S    .         .         .         .         .         .
121815  45.         .IO       .         .         .         .         .   S     .         .         .         .         .         .
121830  46.         .IO       .         .         .         .         .   S     .         .         .         .         .         .
121845  47.         IO        .         .         .         .         .   S     .         .         .         .         .         .
121900  48.         IO        .         .         .         .         .   S     .         .         .         .         .         .
121915  49.        IO         .         .         .         .         .   S     .         .         .         .         .         .
121930  50.        IO         .         .         .         .         .   S     .         .         .         .         .         .
121945  51. . . . .I. . . . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . . . . . . . . . . . . .
122000  52.       IO.         .         .         .         .         .  S      .         .         .         .         .         .
122015  53.       IO.         .         .         .         .         .  S      .         .         .         .         .         .
122030  54.       I .         .         .         .         .         .  S      .         .         .         .         .         .
122045  55.      IO .         .         .         .         .         .  S      .         .         .         .         .         .
122100  56.      I  .         .         .         .         .         .  S      .         .         .         .         .         .
122115  57.      I  .         .         .         .         .         .  S      .         .         .         .         .         .
122130  58.-----IO--.---------.---------.---------.---------.---------.-S-------.---------.---------.---------.---------.---------.
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          *            *
  73 KK   *   WEST20   *
          *            *
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  75 KO         OUTPUT CONTROL VARIABLES
                      IPRNT           1  PRINT CONTROL
                      IPLOT           0  PLOT CONTROL
                      QSCAL          0.  HYDROGRAPH PLOT SCALE

              SUBBASIN RUNOFF DATA

  76 BA         SUBBASIN CHARACTERISTICS
                      TAREA         .80  SUBBASIN AREA

  77 BF         BASE FLOW CHARACTERISTICS
                      STRTQ       10.00  INITIAL FLOW
                      QRCSN        -.25  BEGIN BASE FLOW RECESSION
                      RTIOR     1.20000  RECESSION CONSTANT

                PRECIPITATION DATA

  80 PT          TOTAL STORM STATIONS        63       64
  81 PW                       WEIGHTS       .60      .40

  78 PR            RECORDING STATIONS       400
  79 PW                       WEIGHTS      1.00

  82 LH         HOLTAN LOSS RATE
                      FC            .04  DEEP PERCOLATION RATE
                      GIA           .40  COEFFICIENT OF SA
                      SA            .30  DEPTH OF AVAILABLE STORAGE
                      BEXP         1.40  EXPONENT OF SA
                      RTIMP         .00  PERCENT IMPERVIOUS AREA

  83 UD         SCS DIMENSIONLESS UNITGRAPH
                       TLAG         .94  LAG

                                                     ***

              PRECIPITATION STATION DATA

                       STATION    TOTAL    AVG. ANNUAL    WEIGHT
                            63     4.90         .00          .60
                            64     5.10         .00          .40

                TEMPORAL DISTRIBUTIONS

                STATION      400,  WEIGHT =   1.00
                    .01     .01     .01     .01     .09     .09     .09     .09     .00     .00
                    .00     .00     .01     .01     .01     .01     .18     .18     .18     .18
                    .05     .05     .05     .05     .00     .00     .00     .00     .00     .00
                    .00     .00     .01     .01     .01     .01     .00     .00     .00     .00

                                                          UNIT HYDROGRAPH
                                                     21 END-OF-PERIOD ORDINATES
              48.     153.     299.     361.     343.     280.     188.     125.      87.      59.
              40.      27.      19.      13.       9.       6.       4.       3.       2.       1.
               0.
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                                                 HYDROGRAPH AT STATION   WEST20

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DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
12 JUN 0715	1	.00	.00	.00	10.	12 JUN 1430	30	.01	.01	.00	211.
12 JUN 0730	2	.03	.02	.01	10.	12 JUN 1445	31	.01	.01	.00	200.
12 JUN 0745	3	.03	.02	.01	11.	12 JUN 1500	32	.01	.01	.00	192.
12 JUN 0800	4	.03	.02	.01	15.	12 JUN 1515	33	.01	.01	.00	183.
12 JUN 0815	5	.03	.02	.01	19.	12 JUN 1530	34	.03	.01	.01	175.
12 JUN 0830	6	.30	.02	.28	36.	12 JUN 1545	35	.03	.01	.01	167.
12 JUN 0845	7	.30	.02	.28	81.	12 JUN 1600	36	.03	.01	.01	160.
12 JUN 0900	8	.30	.02	.28	164.	12 JUN 1615	37	.03	.01	.01	152.
12 JUN 0915	9	.30	.02	.29	263.	12 JUN 1630	38	.01	.01	.00	146.
12 JUN 0930	10	.01	.01	.00	344.	12 JUN 1645	39	.01	.01	.00	139.
12 JUN 0945	11	.01	.01	.00	377.	12 JUN 1700	40	.01	.01	.00	133.
12 JUN 1000	12	.01	.01	.00	343.	12 JUN 1715	41	.01	.01	.00	127.
12 JUN 1015	13	.01	.01	.00	275.	12 JUN 1730	42	.00	.00	.00	121.
12 JUN 1030	14	.03	.02	.01	201.	12 JUN 1745	43	.00	.00	.00	116.
12 JUN 1045	15	.03	.02	.01	139.	12 JUN 1800	44	.00	.00	.00	111.
12 JUN 1100	16	.03	.02	.01	99.	12 JUN 1815	45	.00	.00	.00	106.
12 JUN 1115	17	.03	.02	.01	91.	12 JUN 1830	46	.00	.00	.00	101.
12 JUN 1130	18	.63	.02	.62	87.	12 JUN 1845	47	.00	.00	.00	97.
12 JUN 1145	19	.63	.01	.62	168.	12 JUN 1900	48	.00	.00	.00	92.
12 JUN 1200	20	.63	.01	.62	343.	12 JUN 1915	49	.00	.00	.00	88.
12 JUN 1215	21	.63	.01	.62	556.	12 JUN 1930	50	.00	.00	.00	84.
12 JUN 1230	22	.18	.01	.17	740.	12 JUN 1945	51	.00	.00	.00	81.
12 JUN 1245	23	.18	.01	.17	839.	12 JUN 2000	52	.00	.00	.00	77.
12 JUN 1300	24	.18	.01	.17	817.	12 JUN 2015	53	.00	.00	.00	74.
12 JUN 1315	25	.18	.01	.17	729.	12 JUN 2030	54	.00	.00	.00	70.
12 JUN 1330	26	.02	.02	.00	619.	12 JUN 2045	55	.00	.00	.00	67.
12 JUN 1345	27	.02	.01	.00	503.	12 JUN 2100	56	.00	.00	.00	64.
12 JUN 1400	28	.02	.01	.00	393.	12 JUN 2115	57	.00	.00	.00	61.
12 JUN 1415	29	.02	.01	.01	294.	12 JUN 2130	58	.00	.00	.00	59.

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       TOTAL RAINFALL =    4.98, TOTAL LOSS =     .55, TOTAL EXCESS =    4.43

   PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR        24-HR       72-HR     14.25-HR
     (CFS)      (HR)
       839.     5.50        (CFS)     367.         210.        210.         210.
                          (INCHES)   4.265        5.803       5.803        5.803
                           (AC-FT)    182.         248.        248.         248.

                           CUMULATIVE AREA =     .80 SQ MI



 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


              **************
              *            *
   105 KK     *     GAGE   *
              *            *
              **************

   106 KO          OUTPUT CONTROL VARIABLES
                         IPRNT           1  PRINT CONTROL
                         IPLOT           0  PLOT CONTROL
                         QSCAL          0.  HYDROGRAPH PLOT SCALE
                                   COMPARE COMPUTED AND OBSERVED HYDROGRAPHS AT RED30

   108 IN          TIME DATA FOR INPUT TIME SERIES
                         JXMIN          15  TIME INTERVAL IN MINUTES
                        JXDATE     12JUN68  STARTING DATE
                        JXTIME         715  STARTING TIME

                                                                                 ***
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COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS

	SUM OF FLOWS	EQUIV DEPTH	MEAN FLOW	TIME TO CENTER OF MASS	LAG C.M. TO C.M.	PEAK FLOW	TIME OF PEAK
COMPUTED HYDROGRAPH	27066.	3.705	467.	7.63	7.63	1331.	6.50
OBSERVED HYDROGRAPH	26768.	3.664	462.	7.75	7.75	1373.	6.50
DIFFERENCE	298.	.041	5.	-.12	-.12	-42.	.00
PERCENT DIFFERENCE	1.11				-1.59	-3.09	

STANDARD ERROR 21. AVERAGE ABSOLUTE ERROR 18.

OBJECTIVE FUNCTION 22. AVERAGE PERCENT ABSOLUTE ERROR 18.56

HYDROGRAPH AT STATION GAGE

DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL	DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL	DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL
12	JUN	0715	1	38.	10.	28.	12	JUN	1215	21	536.	472.	64.	12	JUN	1715	41	401.	388.	13.
12	JUN	0730	2	37.	13.	24.	12	JUN	1230	22	731.	705.	26.	12	JUN	1730	42	382.	372.	10.
12	JUN	0745	3	37.	16.	21.	12	JUN	1245	23	937.	921.	16.	12	JUN	1745	43	365.	359.	6.
12	JUN	0800	4	38.	20.	18.	12	JUN	1300	24	1119.	1120.	-1.	12	JUN	1800	44	350.	348.	2.
12	JUN	0815	5	40.	25.	15.	12	JUN	1315	25	1249.	1255.	-6.	12	JUN	1815	45	336.	338.	-2.
12	JUN	0830	6	46.	30.	16.	12	JUN	1330	26	1318.	1345.	-27.	12	JUN	1830	46	324.	328.	-4.
12	JUN	0845	7	64.	51.	13.	12	JUN	1345	27	1331.	1373.	-42.	12	JUN	1845	47	312.	321.	-9.
12	JUN	0900	8	106.	92.	14.	12	JUN	1400	28	1290.	1314.	-24.	12	JUN	1900	48	301.	310.	-9.
12	JUN	0915	9	178.	159.	19.	12	JUN	1415	29	1210.	1228.	-18.	12	JUN	1915	49	290.	300.	-10.
12	JUN	0930	10	270.	241.	29.	12	JUN	1430	30	1100.	1122.	-22.	12	JUN	1930	50	280.	291.	-11.
12	JUN	0945	11	359.	332.	27.	12	JUN	1445	31	987.	996.	-9.	12	JUN	1945	51	270.	282.	-12.
12	JUN	1000	12	418.	399.	19.	12	JUN	1500	32	890.	900.	-10.	12	JUN	2000	52	261.	274.	-13.
12	JUN	1015	13	435.	412.	23.	12	JUN	1515	33	806.	817.	-11.	12	JUN	2015	53	252.	267.	-15.
12	JUN	1030	14	417.	393.	24.	12	JUN	1530	34	731.	742.	-11.	12	JUN	2030	54	243.	277.	-34.
12	JUN	1045	15	378.	348.	30.	12	JUN	1545	35	662.	668.	-6.	12	JUN	2045	55	235.	252.	-17.
12	JUN	1100	16	330.	291.	39.	12	JUN	1600	36	602.	614.	-12.	12	JUN	2100	56	227.	240.	-13.
12	JUN	1115	17	289.	255.	34.	12	JUN	1615	37	551.	549.	2.	12	JUN	2115	57	220.	231.	-11.
12	JUN	1130	18	261.	229.	32.	12	JUN	1630	38	502.	500.	2.	12	JUN	2130	58	213.	224.	-11.
12	JUN	1145	19	270.	235.	35.	12	JUN	1645	39	458.	444.	14.							
12	JUN	1200	20	358.	321.	37.	12	JUN	1700	40	426.	409.	17.							

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                                                         STATION     GAGE

                         (I) INFLOW,   (O) OUTFLOW,   (*) OBSERVED FLOW
         0.      200.      400.      600.      800.     1000.     1200.     1400.        0.        0.        0.        0.        0.
DAHRMN PER
120715   1I*O-------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
120730   2I*O       .         .         .         .         .         .         .         .         .         .         .         .
120745   3I*O       .         .         .         .         .         .         .         .         .         .         .         .
120800   4I*O       .         .         .         .         .         .         .         .         .         .         .         .
120815   5I*O       .         .         .         .         .         .         .         .         .         .         .         .
120830   6I *       .         .         .         .         .         .         .         .         .         .         .         .
120845   7I  *      .         .         .         .         .         .         .         .         .         .         .         .
120900   8I    *    .         .         .         .         .         .         .         .         .         .         .         .
120915   9I       *O.         .         .         .         .         .         .         .         .         .         .         .
120930  10I         . *O      .         .         .         .         .         .         .         .         .         .         .
120945  11I . . . . . . . .*O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121000  12I         .         *O        .         .         .         .         .         .         .         .         .         .
121015  13I         .         .*O       .         .         .         .         .         .         .         .         .         .
121030  14I         .         *O        .         .         .         .         .         .         .         .         .         .
121045  15I         .      * O.         .         .         .         .         .         .         .         .         .         .
121100  16I         .    * O  .         .         .         .         .         .         .         .         .         .         .
121115  17I         .  *O     .         .         .         .         .         .         .         .         .         .         .
121130  18I         .* O      .         .         .         .         .         .         .         .         .         .         .
121145  19I         . * O     .         .         .         .         .         .         .         .         .         .         .
121200  20I         .     * O .         .         .         .         .         .         .         .         .         .         .
121215  21I . . . . . . . . . . . * .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121230  22I         .         .         .    * O  .         .         .         .         .         .         .         .         .
121245  23I         .         .         .         .     *O  .         .         .         .         .         .         .         .
121300  24I         .         .         .         .         .     *   .         .         .         .         .         .         .
121315  25I         .         .         .         .         .         . O*      .         .         .         .         .         .
121330  26I         .         .         .         .         .         .     O*  .         .         .         .         .         .
121345  27I         .         .         .         .         .         .      O *.         .         .         .         .         .
121400  28I         .         .         .         .         .         .    O*   .         .         .         .         .         .
121415  29I         .         .         .         .         .         O*        .         .         .         .         .         .
121430  30I         .         .         .         .         .    O*   .         .         .         .         .         .         .
121445  31I . . . . . . . . . . . . . . . . . . . . . . . .O* . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121500  32I         .         .         .         .    *    .         .         .         .         .         .         .         .
121515  33I         .         .         .         O*        .         .         .         .         .         .         .         .
121530  34I         .         .         .      *  .         .         .         .         .         .         .         .         .
121545  35I         .         .         .  *      .         .         .         .         .         .         .         .         .
121600  36I         .         .         O*        .         .         .         .         .         .         .         .         .
121615  37I         .         .      *O .         .         .         .         .         .         .         .         .         .
121630  38I         .         .    *    .         .         .         .         .         .         .         .         .         .
121645  39I         .         . *O      .         .         .         .         .         .         .         .         .         .
121700  40I         .         *O        .         .         .         .         .         .         .         .         .         .
121715  41I . . . . . . . . .*O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121730  42I         .        *.         .         .         .         .         .         .         .         .         .         .
121745  43I         .       * .         .         .         .         .         .         .         .         .         .         .
121800  44I         .      *  .         .         .         .         .         .         .         .         .         .         .
121815  45I         .      *  .         .         .         .         .         .         .         .         .         .         .
121830  46I         .     *   .         .         .         .         .         .         .         .         .         .         .
121845  47I         .     *   .         .         .         .         .         .         .         .         .         .         .
121900  48I         .    O*   .         .         .         .         .         .         .         .         .         .         .
121915  49I         .    *    .         .         .         .         .         .         .         .         .         .         .
121930  50I         .   O*    .         .         .         .         .         .         .         .         .         .         .
121945  51I . . . . . . * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
122000  52I         .  O*     .         .         .         .         .         .         .         .         .         .         .
122015  53I         .  *      .         .         .         .         .         .         .         .         .         .         .
122030  54I         . O *     .         .         .         .         .         .         .         .         .         .         .
122045  55I         . O*      .         .         .         .         .         .         .         .         .         .         .
122100  56I         .O*       .         .         .         .         .         .         .         .         .         .         .
122115  57I         .O*       .         .         .         .         .         .         .         .         .         .         .
122130  58I---------.*--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	RED RI	460.	6.25	221.	116.	116.	.82		
HYDROGRAPH AT	EAST10	442.	5.75	174.	100.	100.	.66		
DIVERSION TO	DIVERT	138.	5.75	52.	29.	29.	.66		
HYDROGRAPH AT	EAST10	304.	5.75	122.	71.	71.	.66		
2 COMBINED AT	RED10	740.	6.00	341.	188.	188.	1.48		
ROUTED TO	10TO20	667.	6.50	339.	186.	186.	1.48		
HYDROGRAPH AT	LOSTBR	138.	5.75	52.	29.	29.	.00		
HYDROGRAPH AT	LOSTBR	309.	5.50	149.	85.	85.	.36		
2 COMBINED AT	LOSTBR	436.	5.50	200.	114.	114.	.36		
ROUTED TO	E.DAM	68.	10.00	67.	47.	47.	.36	852.69	10.00
HYDROGRAPH AT	WEST20	839.	5.50	367.	210.	210.	.80		
3 COMBINED AT	RED20	1378.	6.00	733.	444.	444.	2.64		
ROUTED TO	20TO30	1224.	6.50	729.	439.	439.	2.64		
HYDROGRAPH AT	RED30	143.	5.75	61.	34.	34.	.19		
2 COMBINED AT	RED30	1331.	6.50	789.	473.	473.	2.83		

*** NORMAL END OF HEC-1 ***

12.2 Example Problem #2: Kinematic Wave Watershed Model

The use of the kinematic wave option is demonstrated in the development of a model for the Smith River Watershed. A schematic diagram of the watershed model is shown in Figure 12.2.

The input data for the watershed are displayed in Tables 12.2a - 12.2c. The HEC-1 data model for the basin is shown in Table 12.2d. There are a number of important points to note about the data:

(1) Each subbasin has data for two overland flow elements (only one is required) which is specified on the **UK record**. The two elements represent separately the impervious and pervious areas of a subbasin.

(2) Subcollector, collector, and main channel data are specified on the **RK record** for each subbasin. At a minimum the user must provide at least one RK record, which would represent a main channel only. A maximum of three RK records can be entered for each subbasin. Three RK records would represent three levels of channel order: a main channel; a representative collector channel; and a representative subcollector channel. Data for collectors and subcollectors are taken as average values that are representative of the collectors and subcollectors within that particular subbasin.

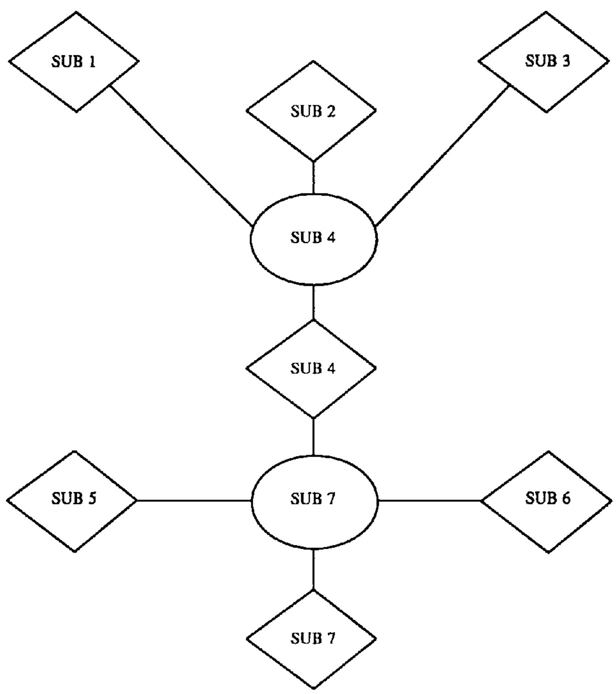

Figure 12.2 Kinematic Wave Model Schematic

(3) The infiltration data is specified only once, on the **LS record**, for subbasin sub 1. The infiltration data on this card is assumed to apply for all subsequent runoff computations by program input convention.

The simulation results are displayed in Table 12.2d following the input listing. The user should note the table entitled "SUMMARY OF KINEMATIC WAVE -MUSKINGUM-CUNGE ROUTING" (page 134) which is provided in addition to the "RUNOFF SUMMARY" (page 134) in the example output. The user should always

Table 12.2a

Subbasin Characteristics
Overland Flow Plane Data
(UK RECORD)

Subbasin Data	**O.F. Length (ft.)**	**O.F. Slope (ft/ft)**	**Manning N**	**% Subbasin Area**	**Drain Area (sq. mi.)**	**Loss Rate (LS Record) SCS Curve Number**
SUB 1						
Imp Catchment	100	.03	.15	15	1.43	98
Perv Catchment	190	.02	.35	85		85
SUB 2						
Imp Catchment	100	.05	.15	15	.67	98
Perv Catchment	190	.03	.35	85		85
SUB 3						
Imp Catchment	100	.05	.15	15	.56	98
Perv Catchment	190	.03	.35	85		85
SUB 4						
Imp Catchment	100	.03	.15	15	1.83	98
Perv Catchment	190	.015	.35	85		85
SUB 5						
Imp Catchment	100	.05	.15	20	.67	98
Perv Catchment	220	.028	.35	80		85
SUB 6						
Imp Catchment	100	.03	.15	20	1.43	98
Perv Catchment	200	.02	.35	80		85
SUB 7						
Imp Catchment	100	.06	.15	15	.96	98
Perv Catchment	190	.03	.35	85		85

examine the difference between the peak discharge, time to peak discharge and volume of the hydrograph computed using an internal variable computation step and that of the hydrograph interpolated to the user-specified computation interval (see Section 3.4 for further discussion). Consider, for example, the results summarized for subbasin SUB1. The peak discharge, time to peak and hydrograph volume, displayed for the minimum internal computation interval of 5.00 minutes, are respectively 704.84 (cfs), 208.51 (min) and 1.57 (in) versus 698.18 (cfs), 210.0 (min) and 1.57 (in). Note that although in this instance the minimum computation interval and the user specified computation interval are the same value of 5.00 minutes, hydrographs are not equivalent because the internal computations use a "variable time step".

Table 12.2b

Channel Data (Test 2)
(RK RECORD)

Subbasin	Length (ft)	Slope (ft/ft)	Manning N	Area (sq mi)	Shape	Width (ft)	Side Slope (ft/ft)	Upstream Inflow
SUB 1								
Collector Channel	2000	.008	.02	.45	TRAP	0	1	---
Main Channel	13500	.004	.03		TRAP	2	2	no
SUB 2								
Collector Channel	2400	.01	.02	.39	TRAP	0	1	---
Main Channel	6500	.008	.03	---	TRAP	2	2	no
SUB 3								
Collector Channel	1600	.019	.02	.35	TRAP	0	1	---
Main Channel	6500	.012	.03	---	TRAP	2	2	no
SUB 4								
Collector Channel	2500	.01	.02	.79	TRAP	0	1	---
Main Channel	12000	.007	.03	---	TRAP	50	2	yes
SUB 5								
SubCollector Channel	800	.020	.02	.10	TRAP	0	1	---
Collector Channel	2000	.013	.02	.42	TRAP	0	1	---
Main Channel	8000	.01	.03	---	TRAP	8	3	no
SUB 6								
Collector Channel	2200	.024	.02	.55	TRAP	0	1	---
Main Channel	14000	.011	.03	---	TRAP	2	2	no
SUB 7								
Collector Channel	2100	.011	.02	.74	TRAP	0	1	---
Main Channel	7000	.003	.03		TRAP	50	3	yes

The differences between the results are due to the difference between using a variable internal time step and the constant user specified time step. The difference becomes more noticeable for the results given for other subbasins in the example. If the difference between the results given for the internal and user-specified computation interval are **larger than the user finds acceptable,** then additional simulations should be performed with **smaller user-specified computation interval** (IT record) until an acceptable difference is obtained.

Table 12.2c

Precipitation Data

10% Chance Hypothetical Storm Event

The purpose of this simulation is to develop a runoff hydrograph, due to the 10% chance storm, at the outlet of the watershed. The contributing area at the outlet is 7.55 square miles. Therefore, the desired storm area size is also 7.55 square miles. Precipitation data were obtained from HYDRO-35 (National Weather Service, 1977) and TP-40 (National Weather Service, 1961). Listed below are the depth-duration data obtained for this example:

HYDRO-35	Duration	Depth (in.)
	5 min.	0.40
	15 min.	0.65
	1 hr.	1.00

TP-40	Duration	Depth (in.)
	2 hr.	1.50
	3 hr.	1.90
	6 hr.	2.90

Table 12.2d

Example Problem #2

Input

```
ID      EXAMPLE PROBLEM NO. 2
ID      KINEMATIC WAVE WATERSHED MODEL
IT     5 21SEP89    1200     100
IO     5
*
KK  SUB1
KM      RUNOFF FROM SUBBASIN 1
KO     1
BA  1.43
PH    10    7.55    0.40    0.65     1.0     1.5     1.9     2.9
LS            98                      85
UK   100     .03     .15      15
UK   190     .02     .35      85
RK  2000    .008     .02     .45    TRAP       0       1
RK 13500    .004     .03            TRAP       2       2
*
KK  SUB2
KM      RUNOFF FROM SUBBASIN 2
BA   .67
UK   100     .05     .15      15
UK   190     .03     .35      85
RK  2400     .01     .02     .39    TRAP       0       1
RK  6500    .008     .03            TRAP       2       2
*
KK  SUB3
KM      RUNOFF FROM SUBBASIN 3
BA   .56
UK   100     .05     .15      15
UK   190     .03     .35      85
RK  1600    .019     .02     .35    TRAP       0       1
RK  6500    .012     .03            TRAP       2       2
*
KK  SUB4
KM      COMBINE RUNOFF FROM SUB1, SUB2 AND SUB3
HC     3
*
KK  SUB4
KM      RUNOFF FROM SUBBASIN 4
BA  1.83
UK   100     .03     .15      15
UK   190    .015     .35      85
RK  2500     .01     .02     .79    TRAP       0       1
RK 12000    .007     .03            TRAP      50       2     YES
*
KK  SUB5
KO     1
KM      RUNOFF FROM SUBBASIN 5
BA   .67
UK   100     .05     .15      20
UK   220    .028     .35      80
RK   800    .020     .02     .10    TRAP       0       1
RK  2000    .013     .02     .42    TRAP       0       1
RK  8000     .01     .03            TRAP       8       3
*
KK  SUB6
KM      RUNOFF FROM SUBBASIN 6
BA  1.43
UK   100     .03     .15      20
UK   200     .02     .35      80
RK  2200    .024     .02     .55    TRAP       0       1
RK 14000    .011     .03            TRAP       2       2
*
KK  SUB7
KM      COMBINE RUNOFF FROM SUB4, SUB5, AND SUB6
HC     3
KK  SUB7
KM      RUNOFF FROM SUB7 AND UPSTREAM INFLOW
BA   .96
UK   100     .06     .15      15
UK   190     .03     .35      85
RK  2100    .011     .02     .74    TRAP       0       1
RK  7000    .005     .03            TRAP      50       3     YES
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:12   *
*                                       *
*****************************************


                                              HEC-1 INPUT                                        PAGE 1

 LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

    1          ID        EXAMPLE PROBLEM NO. 2
    2          ID        KINEMATIC WAVE WATERSHED MODEL
    3          IT       5 21SEP89    1200     100
    4          IO       5
               *

    5          KK    SUB1
    6          KM        RUNOFF FROM SUBBASIN 1
    7          KO       1
    8          BA    1.43
    9          PH      10    7.55    0.40    0.65     1.0     1.5     1.9     2.9
   10          LS              98                      85
   11          UK     100     .03     .15      15
   12          UK     190     .02     .35      85
   13          RK    2000    .008     .02     .45    TRAP       0       1
   14          RK   13500    .004     .03            TRAP       2       2
               *

   15          KK    SUB2
   16          KM        RUNOFF FROM SUBBASIN 2
   17          BA     .67
   18          UK     100     .05     .15      15
   19          UK     190     .03     .35      85
   20          RK    2400     .01     .02     .39    TRAP       0       1
   21          RK    6500    .008     .03            TRAP       2       2
               *

   22          KK    SUB3
   23          KM        RUNOFF FROM SUBBASIN 3
   24          BA     .56
   25          UK     100     .05     .15      15
   26          UK     190     .03     .35      85
   27          RK    1600    .019     .02     .35    TRAP       0       1
   28          RK    6500    .012     .03            TRAP       2       2
               *

   29          KK    SUB4
   30          KM        COMBINE RUNOFF FROM SUB1, SUB2 AND SUB3
   31          HC       3
               *

   32          KK    SUB4
   33          KM        RUNOFF FROM SUBBASIN 4
   34          BA    1.83
   35          UK     100     .03     .15      15
   36          UK     190    .015     .35      85
   37          RK    2500     .01     .02     .79    TRAP       0       1
   38          RK   12000    .007     .03            TRAP      50       2     YES
               *

   39          KK    SUB5
   40          KO       1
   41          KM        RUNOFF FROM SUBBASIN 5
   42          BA     .67
   43          UK     100     .05     .15      20
   44          UK     220    .028     .35      80
   45          RK     800    .020     .02     .10    TRAP       0       1
   46          RK    2000    .013     .02     .42    TRAP       0       1
   47          RK    8000     .01     .03            TRAP       8       3
               *
```

```
 LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   48           KK    SUB6
   49           KM        RUNOFF FROM SUBBASIN 6
   50           BA    1.43
   51           UK     100     .03     .15      20
   52           UK     200     .02     .35      80
   53           RK    2200    .024     .02     .55    TRAP       0       1
   54           RK   14000    .011     .03            TRAP       2       2
                *

   55           KK    SUB7
   56           KM        COMBINE RUNOFF FROM SUB4, SUB5, AND SUB6
   57           HC       3

   58           KK    SUB7
   59           KM        RUNOFF FROM SUB7 AND UPSTREAM INFLOW
   60           BA     .96
   61           UK     100     .06     .15      15
   62           UK     190     .03     .35      85
   63           RK    2100    .011     .02     .74    TRAP       0       1
   64           RK    7000    .005     .03            TRAP      50       3     YES
   65           ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:12   *
*                                       *
*****************************************
```

```
                                EXAMPLE PROBLEM NO. 2
                                KINEMATIC WAVE WATERSHED MODEL

    4 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN           5  MINUTES IN COMPUTATION INTERVAL
                        IDATE     21SEP89  STARTING DATE
                        ITIME        1200  STARTING TIME
                           NQ         100  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     21SEP89  ENDING DATE
                       NDTIME        2015  ENDING TIME
                        ICENT          19  CENTURY MARK

                    COMPUTATION INTERVAL     .08 HOURS
                         TOTAL TIME BASE    8.25 HOURS

           ENGLISH UNITS
                DRAINAGE AREA          SQUARE MILES
                PRECIPITATION DEPTH    INCHES
                LENGTH, ELEVATION      FEET
                FLOW                   CUBIC FEET PER SECOND
                STORAGE VOLUME         ACRE-FEET
                SURFACE AREA           ACRES
                TEMPERATURE            DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
```

```
          **************
          *            *
   5 KK   *     SUB1   *
          *            *
          **************

   7 KO        OUTPUT CONTROL VARIABLES
                     IPRNT           1  PRINT CONTROL
                     IPLOT           0  PLOT CONTROL
                     QSCAL          0.  HYDROGRAPH PLOT SCALE

             SUBBASIN RUNOFF DATA

   8 BA        SUBBASIN CHARACTERISTICS
                     TAREA        1.43  SUBBASIN AREA

             PRECIPITATION DATA

   9 PH                           DEPTHS FOR  10-PERCENT HYPOTHETICAL STORM
             ..... HYDRO-35 ......  ............... TP-40 ..............   ........... TP-49 ...........
             5-MIN  15-MIN  60-MIN   2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
               .40     .65    1.00   1.50    1.90    2.90     .00     .00     .00     .00     .00     .00

                                                STORM AREA =    7.55

  10 LS        SCS LOSS RATE
                     STRTL         .04  INITIAL ABSTRACTION
                    CRVNBR       98.00  CURVE NUMBER
                     RTIMP         .00  PERCENT IMPERVIOUS AREA

                 LOSS RATE VARIABLES FOR SECOND OVERLAND FLOW ELEMENT
                     STRTL         .35  INITIAL ABSTRACTION
                    CRVNBR       85.00  CURVE NUMBER
                     RTIMP         .00  PERCENT IMPERVIOUS AREA

               KINEMATIC WAVE
  11 UK          OVERLAND-FLOW ELEMENT NO. 1
                         L        100.  OVERLAND FLOW LENGTH
                         S       .0300  SLOPE
                         N        .150  ROUGHNESS COEFFICIENT
                        PA        15.0  PERCENT OF SUBBASIN
                     DXMIN           5  MINIMUM NUMBER OF DX INTERVALS
  12 UK          OVERLAND-FLOW ELEMENT NO. 2
                         L        190.  OVERLAND FLOW LENGTH
                         S       .0200  SLOPE
                         N        .350  ROUGHNESS COEFFICIENT
                        PA        85.0  PERCENT OF SUBBASIN
                     DXMIN           5  MINIMUM NUMBER OF DX INTERVALS
  13 RK          COLLECTOR CHANNEL
                         L       2000.  CHANNEL LENGTH
                         S       .0080  SLOPE
                         N        .020  CHANNEL ROUGHNESS COEFFICIENT
                        CA         .45  CONTRIBUTING AREA
                     SHAPE        TRAP  CHANNEL SHAPE
                        WD         .00  BOTTOM WIDTH OR DIAMETER
                         Z        1.00  SIDE SLOPE
                     DXMIN           2  MINIMUM NUMBER OF DX INTERVALS
  14 RK          MAIN CHANNEL
                         L      13500.  CHANNEL LENGTH
                         S       .0040  SLOPE
                         N        .030  CHANNEL ROUGHNESS COEFFICIENT
                        CA        1.43  CONTRIBUTING AREA
                     SHAPE        TRAP  CHANNEL SHAPE
                        WD        2.00  BOTTOM WIDTH OR DIAMETER
                         Z        2.00  SIDE SLOPE
                     DXMIN           2  MINIMUM NUMBER OF DX INTERVALS
                    RUPSTQ          NO  ROUTE UPSTREAM HYDROGRAPH

                                                             ***
                                  COMPUTED KINEMATIC PARAMETERS
                                        VARIABLE TIME STEP
                                      (DT SHOWN IS A MINIMUM)
               ELEMENT    ALPHA       M          DT         DX        PEAK     TIME TO      VOLUME    MAXIMUM
                                                                                PEAK                 CELERITY
                                               (MIN)       (FT)      (CFS)      (MIN)        (IN)      (FPS)

                  1        1.72     1.67        .93      20.00     514.87     185.07        2.58        .36
                  2         .60     1.67       4.73      38.00     641.04     197.01        1.41        .13
                  3        3.34     1.33        .76     666.67     965.20     187.60        1.59      14.71
                  4        1.36     1.35       5.00    3375.00     704.84     208.51        1.57       9.75



CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00  EXCESS= .1228E+03 OUTFLOW= .1199E+03 BASIN STORAGE= .1393E+01 PERCENT
ERROR=   1.2
```

INTERPOLATED TO SPECIFIED COMPUTATION INTERVAL

4	1.36	1.35	5.00	698.18	210.00	1.57

****

HYDROGRAPH AT STATION SUB1

****

DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
21	SEP	1200	1	.00	.00	.00	0.	*	21	SEP	1610	51	.03	.01	.03	385.
21	SEP	1205	2	.02	.02	.00	0.	*	21	SEP	1615	52	.03	.01	.03	368.
21	SEP	1210	3	.02	.02	.00	0.	*	21	SEP	1620	53	.03	.01	.03	353.
21	SEP	1215	4	.02	.02	.00	0.	*	21	SEP	1625	54	.03	.01	.03	341.
21	SEP	1220	5	.03	.02	.00	0.	*	21	SEP	1630	55	.03	.01	.02	331.
21	SEP	1225	6	.03	.02	.00	0.	*	21	SEP	1635	56	.03	.01	.03	323.
21	SEP	1230	7	.03	.02	.00	0.	*	21	SEP	1640	57	.03	.01	.03	315.
21	SEP	1235	8	.03	.02	.00	0.	*	21	SEP	1645	58	.03	.01	.02	308.
21	SEP	1240	9	.03	.02	.00	0.	*	21	SEP	1650	59	.03	.01	.02	302.
21	SEP	1245	10	.03	.02	.00	2.	*	21	SEP	1655	60	.03	.01	.02	296.
21	SEP	1250	11	.03	.02	.00	3.	*	21	SEP	1700	61	.03	.00	.02	291.
21	SEP	1255	12	.03	.02	.00	4.	*	21	SEP	1705	62	.03	.00	.02	286.
21	SEP	1300	13	.03	.02	.00	5.	*	21	SEP	1710	63	.03	.00	.02	282.
21	SEP	1305	14	.03	.02	.00	8.	*	21	SEP	1715	64	.03	.00	.02	278.
21	SEP	1310	15	.03	.03	.00	10.	*	21	SEP	1720	65	.03	.00	.02	274.
21	SEP	1315	16	.03	.02	.00	13.	*	21	SEP	1725	66	.03	.00	.02	271.
21	SEP	1320	17	.03	.02	.01	16.	*	21	SEP	1730	67	.03	.00	.02	267.
21	SEP	1325	18	.03	.02	.01	19.	*	21	SEP	1735	68	.03	.00	.02	264.
21	SEP	1330	19	.03	.02	.01	23.	*	21	SEP	1740	69	.03	.00	.02	261.
21	SEP	1335	20	.03	.02	.01	27.	*	21	SEP	1745	70	.03	.00	.02	257.
21	SEP	1340	21	.03	.02	.01	31.	*	21	SEP	1750	71	.02	.00	.02	254.
21	SEP	1345	22	.03	.02	.01	35.	*	21	SEP	1755	72	.02	.00	.02	251.
21	SEP	1350	23	.03	.02	.01	39.	*	21	SEP	1800	73	.02	.00	.02	248.
21	SEP	1355	24	.03	.02	.01	42.	*	21	SEP	1805	74	.00	.00	.00	243.
21	SEP	1400	25	.03	.02	.01	46.	*	21	SEP	1810	75	.00	.00	.00	234.
21	SEP	1405	26	.04	.02	.01	49.	*	21	SEP	1815	76	.00	.00	.00	222.
21	SEP	1410	27	.04	.02	.02	53.	*	21	SEP	1820	77	.00	.00	.00	207.
21	SEP	1415	28	.04	.02	.02	58.	*	21	SEP	1825	78	.00	.00	.00	190.
21	SEP	1420	29	.04	.02	.02	62.	*	21	SEP	1830	79	.00	.00	.00	172.
21	SEP	1425	30	.04	.02	.02	69.	*	21	SEP	1835	80	.00	.00	.00	155.
21	SEP	1430	31	.05	.02	.02	76.	*	21	SEP	1840	81	.00	.00	.00	137.
21	SEP	1435	32	.02	.01	.01	85.	*	21	SEP	1845	82	.00	.00	.00	122.
21	SEP	1440	33	.03	.01	.02	94.	*	21	SEP	1850	83	.00	.00	.00	108.
21	SEP	1445	34	.03	.02	.02	103.	*	21	SEP	1855	84	.00	.00	.00	96.
21	SEP	1450	35	.05	.02	.03	114.	*	21	SEP	1900	85	.00	.00	.00	85.
21	SEP	1455	36	.06	.03	.04	130.	*	21	SEP	1905	86	.00	.00	.00	75.
21	SEP	1500	37	.14	.05	.08	156.	*	21	SEP	1910	87	.00	.00	.00	67.
21	SEP	1505	38	.38	.12	.25	230.	*	21	SEP	1915	88	.00	.00	.00	60.
21	SEP	1510	39	.10	.03	.07	352.	*	21	SEP	1920	89	.00	.00	.00	53.
21	SEP	1515	40	.05	.01	.04	473.	*	21	SEP	1925	90	.00	.00	.00	48.
21	SEP	1520	41	.04	.01	.03	583.	*	21	SEP	1930	91	.00	.00	.00	43.
21	SEP	1525	42	.03	.01	.02	664.	*	21	SEP	1935	92	.00	.00	.00	39.
21	SEP	1530	43	.03	.01	.02	698.	*	21	SEP	1940	93	.00	.00	.00	35.
21	SEP	1535	44	.05	.01	.04	671.	*	21	SEP	1945	94	.00	.00	.00	32.
21	SEP	1540	45	.04	.01	.03	612.	*	21	SEP	1950	95	.00	.00	.00	29.
21	SEP	1545	46	.04	.01	.03	555.	*	21	SEP	1955	96	.00	.00	.00	26.
21	SEP	1550	47	.04	.01	.03	507.	*	21	SEP	2000	97	.00	.00	.00	24.
21	SEP	1555	48	.04	.01	.03	467.	*	21	SEP	2005	98	.00	.00	.00	22.
21	SEP	1600	49	.04	.01	.03	432.	*	21	SEP	2010	99	.00	.00	.00	20.
21	SEP	1605	50	.04	.01	.03	404.	*	21	SEP	2015	100	.00	.00	.00	18.

****

TOTAL RAINFALL = 2.82, TOTAL LOSS = 1.21, TOTAL EXCESS = 1.61

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	8.25-HR
698.	3.50	(CFS)	237.	176.	176.	176.
		(INCHES)	1.540	1.570	1.570	1.570
		(AC-FT)	117.	120.	120.	120.

CUMULATIVE AREA = 1.43 SQ MI

*** ***

```
          **************
          *            *
39 KK     *      SUB5  *
          *            *
          **************

40 KO          OUTPUT CONTROL VARIABLES
                     IPRNT           1  PRINT CONTROL
                     IPLOT           0  PLOT CONTROL
                     QSCAL          0.  HYDROGRAPH PLOT SCALE
                              RUNOFF FROM SUBBASIN 5

             SUBBASIN RUNOFF DATA

42 BA          SUBBASIN CHARACTERISTICS
                     TAREA         .67  SUBBASIN AREA

               PRECIPITATION DATA

 9 PH                                 DEPTHS FOR  10-PERCENT HYPOTHETICAL STORM
             ..... HYDRO-35 ......  ............... TP-40 ..............   ........... TP-49 ...........
             5-MIN  15-MIN  60-MIN   2-HR    3-HR    6-HR   12-HR   24-HR   2-DAY   4-DAY   7-DAY  10-DAY
              .40     .65    1.00   1.50    1.90    2.90     .00     .00     .00     .00     .00     .00

                                                STORM AREA =     7.55

10 LS          SCS LOSS RATE
                     STRTL         .04  INITIAL ABSTRACTION
                    CRVNBR       98.00  CURVE NUMBER
                     RTIMP         .00  PERCENT IMPERVIOUS AREA

                 LOSS RATE VARIABLES FOR SECOND OVERLAND FLOW ELEMENT
                     STRTL         .35  INITIAL ABSTRACTION
                    CRVNBR       85.00  CURVE NUMBER
                     RTIMP         .00  PERCENT IMPERVIOUS AREA

               KINEMATIC WAVE
43 UK            OVERLAND-FLOW ELEMENT NO. 1
                         L        100.  OVERLAND FLOW LENGTH
                         S       .0500  SLOPE
                         N        .150  ROUGHNESS COEFFICIENT
                        PA        20.0  PERCENT OF SUBBASIN
                     DXMIN           5  MINIMUM NUMBER OF DX INTERVALS
44 UK            OVERLAND-FLOW ELEMENT NO. 2
                         L        220.  OVERLAND FLOW LENGTH
                         S       .0280  SLOPE
                         N        .350  ROUGHNESS COEFFICIENT
                        PA        80.0  PERCENT OF SUBBASIN
                     DXMIN           5  MINIMUM NUMBER OF DX INTERVALS
45 RK            COLLECTOR CHANNEL
                         L        800.  CHANNEL LENGTH
                         S       .0200  SLOPE
                         N        .020  CHANNEL ROUGHNESS COEFFICIENT
                        CA         .10  CONTRIBUTING AREA
                     SHAPE        TRAP  CHANNEL SHAPE
                        WD         .00  BOTTOM WIDTH OR DIAMETER
                         Z        1.00  SIDE SLOPE
                     DXMIN           2  MINIMUM NUMBER OF DX INTERVALS
46 RK            COLLECTOR CHANNEL
                         L       2000.  CHANNEL LENGTH
                         S       .0130  SLOPE
                         N        .020  CHANNEL ROUGHNESS COEFFICIENT
                        CA         .42  CONTRIBUTING AREA
                     SHAPE        TRAP  CHANNEL SHAPE
                        WD         .00  BOTTOM WIDTH OR DIAMETER
                         Z        1.00  SIDE SLOPE
                     DXMIN           2  MINIMUM NUMBER OF DX INTERVALS
47 RK            MAIN CHANNEL
                         L       8000.  CHANNEL LENGTH
                         S       .0100  SLOPE
                         N        .030  CHANNEL ROUGHNESS COEFFICIENT
                        CA         .67  CONTRIBUTING AREA
                     SHAPE        TRAP  CHANNEL SHAPE
                        WD        8.00  BOTTOM WIDTH OR DIAMETER
                         Z        3.00  SIDE SLOPE
                     DXMIN           2  MINIMUM NUMBER OF DX INTERVALS
                    RUPSTQ          NO  ROUTE UPSTREAM HYDROGRAPH

                                                         ***
```

COMPUTED KINEMATIC PARAMETERS
VARIABLE TIME STEP
(DT SHOWN IS A MINIMUM)

ELEMENT	ALPHA	M	DT (MIN)	DX (FT)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)	MAXIMUM CELERITY (FPS)
1	2.22	1.67	.77	20.00	337.46	185.24	2.58	.43
2	.71	1.67	4.65	44.00	288.10	193.16	1.42	.16
3	5.28	1.33	.30	266.67	532.74	186.83	1.65	14.86
4	4.25	1.33	.62	666.67	523.95	187.01	1.65	17.99
5	1.50	1.40	3.97	2666.67	403.43	199.57	1.64	11.19

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .5958E+02 OUTFLOW= .5860E+02 BASIN STORAGE= .2966E+00 PERCENT ERROR= 1.1

INTERPOLATED TO SPECIFIED COMPUTATION INTERVAL

5	1.50	1.40	5.00		400.09	200.00	1.64

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HYDROGRAPH AT STATION SUB5

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DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
21 SEP 1200	1	.00	.00	.00	0.	*	21 SEP 1610	51	.03	.01	.03	169.
21 SEP 1205	2	.02	.02	.00	0.	*	21 SEP 1615	52	.03	.01	.03	163.
21 SEP 1210	3	.02	.02	.00	0.	*	21 SEP 1620	53	.03	.01	.03	158.
21 SEP 1215	4	.02	.02	.00	0.	*	21 SEP 1625	54	.03	.01	.03	154.
21 SEP 1220	5	.03	.02	.00	0.	*	21 SEP 1630	55	.03	.01	.03	150.
21 SEP 1225	6	.03	.02	.00	0.	*	21 SEP 1635	56	.03	.01	.03	146.
21 SEP 1230	7	.03	.02	.00	0.	*	21 SEP 1640	57	.03	.01	.03	143.
21 SEP 1235	8	.03	.02	.00	0.	*	21 SEP 1645	58	.03	.01	.02	141.
21 SEP 1240	9	.03	.02	.00	1.	*	21 SEP 1650	59	.03	.01	.02	138.
21 SEP 1245	10	.03	.02	.00	2.	*	21 SEP 1655	60	.03	.00	.02	136.
21 SEP 1250	11	.03	.02	.00	3.	*	21 SEP 1700	61	.03	.00	.02	134.
21 SEP 1255	12	.03	.02	.00	5.	*	21 SEP 1705	62	.03	.00	.02	132.
21 SEP 1300	13	.03	.02	.00	8.	*	21 SEP 1710	63	.03	.00	.02	130.
21 SEP 1305	14	.03	.02	.00	10.	*	21 SEP 1715	64	.03	.00	.02	129.
21 SEP 1310	15	.03	.02	.00	13.	*	21 SEP 1720	65	.03	.00	.02	127.
21 SEP 1315	16	.03	.02	.01	17.	*	21 SEP 1725	66	.03	.00	.02	125.
21 SEP 1320	17	.03	.02	.01	20.	*	21 SEP 1730	67	.03	.00	.02	124.
21 SEP 1325	18	.03	.02	.01	22.	*	21 SEP 1735	68	.03	.00	.02	122.
21 SEP 1330	19	.03	.02	.01	24.	*	21 SEP 1740	69	.03	.00	.02	121.
21 SEP 1335	20	.03	.02	.01	25.	*	21 SEP 1745	70	.03	.00	.02	119.
21 SEP 1340	21	.03	.02	.01	27.	*	21 SEP 1750	71	.02	.00	.02	118.
21 SEP 1345	22	.03	.02	.01	28.	*	21 SEP 1755	72	.02	.00	.02	117.
21 SEP 1350	23	.03	.02	.01	29.	*	21 SEP 1800	73	.02	.00	.02	115.
21 SEP 1355	24	.03	.02	.01	30.	*	21 SEP 1805	74	.00	.00	.00	112.
21 SEP 1400	25	.03	.02	.01	32.	*	21 SEP 1810	75	.00	.00	.00	106.
21 SEP 1405	26	.04	.02	.02	34.	*	21 SEP 1815	76	.00	.00	.00	96.
21 SEP 1410	27	.04	.02	.02	36.	*	21 SEP 1820	77	.00	.00	.00	86.
21 SEP 1415	28	.04	.02	.02	39.	*	21 SEP 1825	78	.00	.00	.00	75.
21 SEP 1420	29	.04	.02	.02	42.	*	21 SEP 1830	79	.00	.00	.00	65.
21 SEP 1425	30	.04	.02	.02	47.	*	21 SEP 1835	80	.00	.00	.00	57.
21 SEP 1430	31	.05	.02	.02	51.	*	21 SEP 1840	81	.00	.00	.00	49.
21 SEP 1435	32	.02	.01	.01	57.	*	21 SEP 1845	82	.00	.00	.00	43.
21 SEP 1440	33	.03	.01	.02	62.	*	21 SEP 1850	83	.00	.00	.00	37.
21 SEP 1445	34	.03	.01	.02	66.	*	21 SEP 1855	84	.00	.00	.00	32.
21 SEP 1450	35	.05	.02	.03	70.	*	21 SEP 1900	85	.00	.00	.00	29.
21 SEP 1455	36	.06	.03	.04	78.	*	21 SEP 1905	86	.00	.00	.00	26.
21 SEP 1500	37	.14	.05	.09	98.	*	21 SEP 1910	87	.00	.00	.00	22.
21 SEP 1505	38	.38	.12	.26	167.	*	21 SEP 1915	88	.00	.00	.00	20.
21 SEP 1510	39	.10	.03	.07	284.	*	21 SEP 1920	89	.00	.00	.00	18.
21 SEP 1515	40	.05	.01	.04	382.	*	21 SEP 1925	90	.00	.00	.00	16.
21 SEP 1520	41	.04	.01	.03	400.	*	21 SEP 1930	91	.00	.00	.00	14.
21 SEP 1525	42	.03	.01	.02	361.	*	21 SEP 1935	92	.00	.00	.00	13.
21 SEP 1530	43	.03	.01	.02	319.	*	21 SEP 1940	93	.00	.00	.00	12.
21 SEP 1535	44	.05	.01	.04	280.	*	21 SEP 1945	94	.00	.00	.00	11.
21 SEP 1540	45	.04	.01	.03	248.	*	21 SEP 1950	95	.00	.00	.00	10.
21 SEP 1545	46	.04	.01	.03	225.	*	21 SEP 1955	96	.00	.00	.00	9.
21 SEP 1550	47	.04	.01	.03	208.	*	21 SEP 2000	97	.00	.00	.00	8.
21 SEP 1555	48	.04	.01	.03	195.	*	21 SEP 2005	98	.00	.00	.00	7.
21 SEP 1600	49	.04	.01	.03	185.	*	21 SEP 2010	99	.00	.00	.00	7.
21 SEP 1605	50	.04	.01	.03	176.	*	21 SEP 2015	100	.00	.00	.00	6.

****

TOTAL RAINFALL = 2.82, TOTAL LOSS = 1.15, TOTAL EXCESS = 1.67

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	8.25-HR
400.	3.33	(CFS)	115.	86.	86.	86.
		(INCHES)	1.602	1.639	1.639	1.639
		(AC-FT)	57.	59.	59.	59.

CUMULATIVE AREA = .67 SQ MI

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SUB1	698.	3.50	237.	176.	176.	1.43		
HYDROGRAPH AT	SUB2	418.	3.25	112.	83.	83.	.67		
HYDROGRAPH AT	SUB3	368.	3.25	94.	70.	70.	.56		
3 COMBINED AT	SUB4	1326.	3.33	442.	328.	328.	2.66		
HYDROGRAPH AT	SUB4	2163.	3.50	744.	548.	548.	4.49		
HYDROGRAPH AT	SUB5	400.	3.33	115.	86.	86.	.67		
HYDROGRAPH AT	SUB6	799.	3.33	246.	183.	183.	1.43		
3 COMBINED AT	SUB7	3292.	3.42	1102.	817.	817.	6.59		
HYDROGRAPH AT	SUB7	3645.	3.50	1260.	929.	929.	7.55		

SUMMARY OF KINEMATIC WAVE - MUSKINGUM-CUNGE ROUTING
(FLOW IS DIRECT RUNOFF WITHOUT BASE FLOW)

						INTERPOLATED TO COMPUTATION INTERVAL			
ISTAQ	ELEMENT	DT (MIN)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)	DT (MIN)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)
SUB1	4	5.00	704.84	208.51	1.57	5.00	698.18	210.00	1.57

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .1228E+03 OUTFLOW= .1199E+03 BASIN STORAGE= .1393E+01 PERCENT ERROR= 1.2

SUB2	4	3.20	430.35	196.02	1.59	5.00	418.05	195.00	1.59

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .5752E+02 OUTFLOW= .5673E+02 BASIN STORAGE= .3887E+00 PERCENT ERROR= .7

SUB3	4	2.86	372.00	194.16	1.59	5.00	367.88	195.00	1.59

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .4808E+02 OUTFLOW= .4743E+02 BASIN STORAGE= .3294E+00 PERCENT ERROR= .7

SUB4	4	4.38	2178.04	208.87	1.57	5.00	2162.68	210.00	1.56

CONTINUITY SUMMARY (AC-FT) - INFLOW= .2238E+03 EXCESS= .1571E+03 OUTFLOW= .3748E+03 BASIN STORAGE= .4497E+01 PERCENT ERROR= .4

SUB5	5	3.97	403.43	199.57	1.64	5.00	400.09	200.00	1.64

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .5958E+02 OUTFLOW= .5860E+02 BASIN STORAGE= .2966E+00 PERCENT ERROR= 1.1

SUB6	4	5.21	800.35	199.10	1.64	5.00	798.59	200.00	1.64

CONTINUITY SUMMARY (AC-FT) - INFLOW= .0000E+00 EXCESS= .1272E+03 OUTFLOW= .1248E+03 BASIN STORAGE= .1099E+01 PERCENT ERROR= 1.0

SUB7	4	2.57	3650.23	209.04	1.58	5.00	3645.07	210.00	1.57

CONTINUITY SUMMARY (AC-FT) - INFLOW= .5570E+03 EXCESS= .8242E+02 OUTFLOW= .6346E+03 BASIN STORAGE= .4441E+01 PERCENT ERROR= .1

*** NORMAL END OF HEC-1 ***

12.3 Example Problem #3: Snowmelt Runoff Simulation

This example demonstrates the degree-day method of deriving a runoff hydrograph due to snowmelt. The example basin configuration and data are shown in Figure 12.3 and Table 12.3a. The general procedure used in this case is as follows:

(1) Determine total precipitation based on melt coefficients, initial available snowpack, rainfall and temperature data.

(2) Compute excess from exponential loss equations.

(3) Use the Clark unit hydrograph to route the excess to the basin outlet.

The input data and results of the analysis are displayed in the computer printout in Table 12.3b.

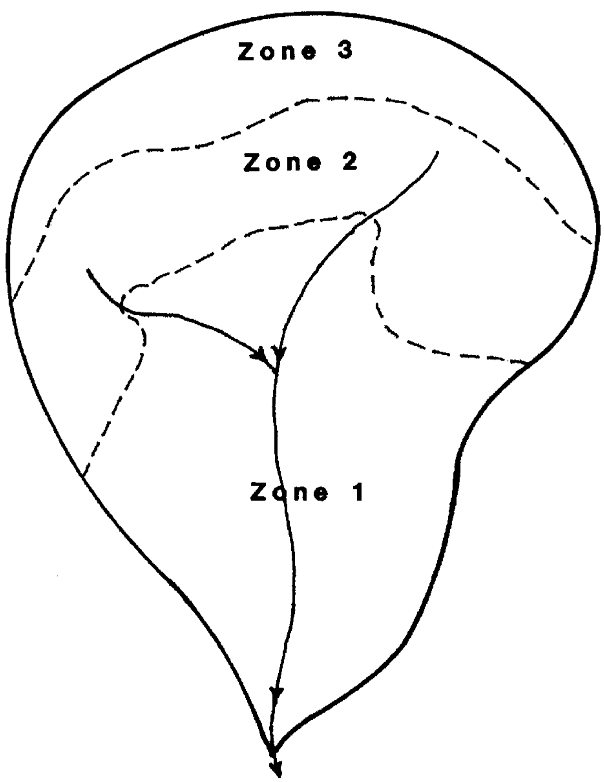

Figure 12.3 Snowmelt Basin

Table 12.3a

Snowmelt Data

	Record Identifier
INFILTRATION	
Rainfall - Exponential Loss Rate	LE
STRKR = 0.24 DLTKR = 0.00 RTIOL = 1.00 ERAIN = 0.70	
Snowmelt - Exponential Loss Rate	LM
STRKS = 0.24 RTIOK = 1.00	
UNIT HYDROGRAPH	UC
TC = 46 R = 183	
ZONE DATA	NA
MELT COEFFICIENTS	MC
TLAPS = 3.3 COEF = .08 FRZTP = 33	

ZONE DATA

Zone	Area (sq miles)	Snowpack (in water)
1	1,000	7.5
2	500	6.2
3	370	8.4

Table 12.3b

Example Problem #3: Input and Output

Input

```
ID      EXAMPLE PROBLEM NO. 3
ID      SNOWMELT RUNOFF SIMULATION
IT   720 04APR75    0800      90
IO     0       2
KK     7
KM   MINNESOTA RIVER BASIN
BA  1870
BF     8    1500  1.0022
IN  1440 04APR75    0800
PI     0       0       0       0       0       0    0.26    0.04       0       0
PI   .01       0       0       0       0       0       0      .2     .67     .36
PI   .01     .02      .3     .07     .09     .04       0       0       0     .01
PI   .02       0       0       0     .02     .03     .58     .56       0       0
PI   .32     .27       0     .48     .46     .21       0     .07     .01     .06
UC    46     183
LE   .24       0     1.0      .7
LM   .24     1.0
* ******************** ZONE1 DATA (LOWEST ZONE)
MA  1000     7.5
* ********************* DATA FOR ZONES AT HIGHER ELEVATIONS (1000 FT INCREMENTS)
MA   500     6.2
MA   370     8.4
MC   3.3     .08      33
IN  1440 04APR75    0800
MT    18      30      35      31      27      22      32      14       0       2
MT    17      37      28      37      38      34      37      48      51      47
MT    42      45      55      60      54      53      52      47      45      50
MT    55      51      50      49      50      60      55      50      41      46
MT    54      57      57      54      64      65      63      58      52      47
ZZ
```

Output

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*            VERSION 4.1               *
*                                      *
*  RUN DATE   10JUN98  TIME  20:38:17  *
*                                      *
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                                              HEC-1 INPUT                                      PAGE  1

         LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1           ID        EXAMPLE PROBLEM NO. 3
           2           ID        SNOWMELT RUNOFF SIMULATION
*** FREE ***
           3           IT     720 04APR75    0800      90
           4           IO       0       2

           5           KK       7
           6           KM     MINNESOTA RIVER BASIN
           7           BA    1870
           8           BF       8    1500  1.0022
           9           IN    1440 04APR75    0800
          10           PI       0       0       0       0       0       0    0.26    0.04       0       0
          11           PI     .01      .0       0       0       0       0       0      .2     .67     .36
          12           PI     .01     .02      .3     .07     .09     .04       0       0       0     .01
          13           PI     .02       0       0       0     .02     .03     .58     .56       0       0
          14           PI     .32     .27       0     .48     .46     .21       0     .07     .01     .06
          15           UC      46     183
          16           LE     .24       0     1.0      .7
          17           LM     .24     1.0
                       * ******************** ZONE1 DATA (LOWEST ZONE)
          18           MA    1000     7.5
                       * ********************* DATA FOR ZONES AT HIGHER ELEVATIONS (1000 FT INCREMENTS)
          19           MA     500     6.2
          20           MA     370     8.4
          21           MC     3.3     .08      33
          22           IN    1440 04APR75    0800
          23           MT      18      30      35      31      27      22      32      14       0       2
          24           MT      17      37      28      37      38      34      37      48      51      47
          25           MT      42      45      55      60      54      53      52      47      45      50
          26           MT      55      51      50      49      50      60      55      50      41      46
          27           MT      54      57      57      54      64      65      63      58      52      47
          28           ZZ
```

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*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:17   *
*                                       *
*****************************************




                                 EXAMPLE PROBLEM NO. 3
                                 SNOWMELT RUNOFF SIMULATION

    4 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           0  PRINT CONTROL
                        IPLOT           2  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN         720  MINUTES IN COMPUTATION INTERVAL
                        IDATE      4APR75  STARTING DATE
                        ITIME        0800  STARTING TIME
                           NQ          90  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     18MAY75  ENDING DATE
                       NDTIME        2000  ENDING TIME
                       ICENT           19  CENTURY MARK

                    COMPUTATION INTERVAL   12.00 HOURS
                         TOTAL TIME BASE 1068.00 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


             **************
             *            *
    5 KK     *         7  *
             *            *
             **************
                              MINNESOTA RIVER BASIN

    9 IN          TIME DATA FOR INPUT TIME SERIES
                        JXMIN        1440  TIME INTERVAL IN MINUTES
                       JXDATE      4APR75  STARTING DATE
                       JXTIME         800  STARTING TIME

   22 IN          TIME DATA FOR INPUT TIME SERIES
                        JXMIN        1440  TIME INTERVAL IN MINUTES
                       JXDATE      4APR75  STARTING DATE
                       JXTIME         800  STARTING TIME

                SUBBASIN RUNOFF DATA

    7 BA          SUBBASIN CHARACTERISTICS
                        TAREA     1870.00  SUBBASIN AREA

    8 BF          BASE FLOW CHARACTERISTICS
                        STRTQ        8.00  INITIAL FLOW
                        QRCSN     1500.00  BEGIN BASE FLOW RECESSION
                        RTIOR     1.00220  RECESSION CONSTANT

                  PRECIPITATION DATA

   10 PB                STORM        4.59  BASIN TOTAL PRECIPITATION
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10 PI          INCREMENTAL PRECIPITATION PATTERN
                   .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                   .00      .00      .13      .13      .02      .02      .00      .00      .00      .00
                   .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                   .00      .00      .00      .00      .10      .10      .34      .34      .18      .18
                   .00      .00      .01      .01      .15      .15      .04      .03      .05      .04
                   .02      .02      .00      .00      .00      .00      .00      .00      .01      .00
                   .01      .01      .00      .00      .00      .00      .00      .00      .01      .01
                   .02      .01      .29      .29      .28      .28      .00      .00      .00      .00
                   .16      .16      .13      .13      .00      .00      .24      .24      .23

   MC        SNOWMELT DATA
                   TLAPS        3.30  TEMPERATURE LAPSE RATE
                    COEF         .08  SNOWMELT COEFFICIENT
                   FRZTP       33.00  MELT TEMPERATURE

   MA          ELEVATION ZONE DATA
                  ZONE   AREA   SNOWPACK   ANNUAL PRECIP
                     1  1000.      7.50          .00
                     2   500.      6.20          .00
                     3   370.      8.40          .00

   MT          TEMPERATURE DATA
                  18.0     24.0     30.0     32.5     35.0     33.0     31.0     29.0     27.0     24.5
                  22.0     27.0     32.0     23.0     14.0      7.0       .0      1.0      2.0      9.5
                  17.0     27.0     37.0     32.5     28.0     32.5     37.0     37.5     38.0     36.0
                  34.0     35.5     37.0     42.5     48.0     49.5     51.0     49.0     47.0     44.5
                  42.0     43.5     45.0     50.0     55.0     57.5     60.0     57.0     54.0     53.5
                  53.0     52.5     52.0     49.5     47.0     46.0     45.0     47.5     50.0     52.5
                  55.0     53.0     51.0     50.5     50.0     49.5     49.0     49.5     50.0     55.0
                  60.0     57.5     55.0     52.5     50.0     45.5     41.0     43.5     46.0     50.0
                  54.0     55.5     57.0     57.0     57.0     55.5     54.0     59.0     64.0     64.5

16 LE        EXPONENTIAL LOSS RATE
                   STRKR         .24  INITIAL VALUE OF LOSS COEFFICIENT
                   DLTKR         .00  INITIAL LOSS
                   RTIOL        1.00  LOSS COEFFICIENT RECESSION CONSTANT
                   ERAIN         .70  EXPONENT OF PRECIPITATION
                   RTIMP         .00  PERCENT IMPERVIOUS AREA

   LM        MELTWATER LOSS RATE
                   STRKS         .24  INITIAL VALUE OF LOSS COEFFICIENT
                   RTIOK        1.00  LOSS COEFFICIENT RECESSION CONSTANT

15 UC        CLARK UNITGRAPH
                      TC       46.00  TIME OF CONCENTRATION
                       R      183.00  STORAGE COEFFICIENT

             SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                       ***

                                             UNIT HYDROGRAPH PARAMETERS
                                       CLARK   TC= 46.00 HR,       R=183.00 HR
                                      SNYDER   TP= 49.11 HR,      CP=   .23

                                                  UNIT HYDROGRAPH
                                             83 END-OF-PERIOD ORDINATES
          602.    2263.    4252.   5476.    5586.    5231.    4899.    4588.    4296.    4024.
         3768.    3529.    3305.   3095.    2899.    2715.    2542.    2381.    2230.    2088.
         1955.    1831.    1715.   1606.    1504.    1409.    1319.    1235.    1157.    1084.
         1015.     950.     890.    833.     781.     731.     685.     641.     600.     562.
          527.     493.     462.    433.     405.     379.     355.     333.     312.     292.
          273.     256.     240.    224.     210.     197.     184.     173.     162.     151.
          142.     133.     124.    116.     109.     102.      96.      90.      84.      79.
           74.      69.      65.     60.      57.      53.      50.      46.      44.      41.
           38.      36.      33.
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HYDROGRAPH AT STATION 7

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DA	MON	HRMN	ORD	PRECIP	TEMP	SNOMELT	SNOLOSS	SNOEXCS	RAIN	RAINLOS	RAINEXS	SNO+RAIN	LOSS	EXCESS	COMP Q
4	APR	0800	1	.00	18.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.
4	APR	2000	2	.00	24.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.
5	APR	0800	3	.00	30.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.
5	APR	2000	4	.00	32.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.
6	APR	0800	5	.00	35.0	.01	.01	.00	.00	.00	.00	.01	.01	.00	7.
6	APR	2000	6	.00	33.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.
7	APR	0800	7	.00	31.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.
7	APR	2000	8	.00	29.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.
8	APR	0800	9	.00	27.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
8	APR	2000	10	.00	24.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
9	APR	0800	11	.00	22.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
9	APR	2000	12	.00	27.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
10	APR	0800	13	.00	32.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
10	APR	2000	14	.13	23.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
11	APR	0800	15	.13	14.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.
11	APR	2000	16	.02	7.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
12	APR	0800	17	.02	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
12	APR	2000	18	.00	1.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
13	APR	0800	19	.00	2.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
13	APR	2000	20	.00	9.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
14	APR	0800	21	.00	17.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
14	APR	2000	22	.00	27.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.
15	APR	0800	23	.00	37.0	.05	.05	.00	.00	.00	.00	.05	.05	.00	4.
15	APR	2000	24	.00	32.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.
16	APR	0800	25	.00	28.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.
16	APR	2000	26	.00	32.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.
17	APR	0800	27	.00	37.0	.05	.05	.00	.00	.00	.00	.05	.05	.00	4.
17	APR	2000	28	.00	37.5	.06	.06	.00	.00	.00	.00	.06	.06	.00	5.
18	APR	0800	29	.00	38.0	.07	.07	.01	.00	.00	.00	.07	.07	.01	11.
18	APR	2000	30	.00	36.0	.03	.03	.00	.00	.00	.00	.03	.03	.00	24.
19	APR	0800	31	.00	34.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	37.
19	APR	2000	32	.00	35.5	.02	.02	.00	.00	.00	.00	.02	.02	.00	43.
20	APR	0800	33	.00	37.0	.05	.05	.00	.00	.00	.00	.05	.05	.00	43.
20	APR	2000	34	.00	42.5	.23	.17	.06	.00	.00	.00	.23	.17	.06	74.
21	APR	0800	35	.00	48.0	.45	.29	.16	.00	.00	.00	.45	.29	.16	260.
21	APR	2000	36	.10	49.5	.51	.30	.21	.10	.06	.04	.61	.36	.25	786.
22	APR	0800	37	.10	51.0	.57	.32	.24	.10	.06	.04	.67	.38	.29	1761.
22	APR	2000	38	.34	49.0	.49	.26	.23	.34	.18	.15	.82	.44	.38	3167.
23	APR	0800	39	.34	47.0	.41	.22	.18	.34	.19	.15	.74	.41	.33	4875.
23	APR	2000	40	.18	44.5	.31	.19	.12	.18	.11	.07	.49	.30	.18	6597.
24	APR	0800	41	.18	42.0	.21	.14	.07	.14	.09	.05	.35	.23	.12	7970.
24	APR	2000	42	.00	43.5	.27	.19	.07	.00	.00	.00	.27	.20	.07	8773.
25	APR	0800	43	.00	45.0	.33	.23	.10	.00	.00	.00	.33	.23	.10	9083.
25	APR	2000	44	.01	50.0	.53	.32	.21	.01	.01	.00	.54	.33	.21	9223.
26	APR	0800	45	.01	55.0	.73	.40	.32	.01	.01	.00	.74	.41	.33	9573.
26	APR	2000	46	.15	57.5	.83	.42	.41	.15	.08	.07	.98	.50	.48	10446.
27	APR	0800	47	.15	60.0	.50	.27	.22	.15	.09	.06	.65	.36	.28	11831.
27	APR	2000	48	.04	57.0	.23	.14	.09	.04	.03	.01	.26	.17	.09	13230.
28	APR	0800	49	.03	54.0	.10	.06	.04	.03	.03	.00	.14	.09	.04	14047.
28	APR	2000	50	.05	53.5	.10	.06	.04	.05	.04	.00	.14	.10	.04	14095.
29	APR	0800	51	.04	53.0	.09	.06	.04	.04	.04	.00	.14	.10	.04	13655.

29 APR 2000	52	.02	52.5	.09	.06	.03	.02	.02	.00	.11	.08	.03	13069.
30 APR 0800	53	.02	52.0	.09	.05	.03	.02	.02	.00	.11	.07	.03	12481.
30 APR 2000	54	.00	49.5	.07	.05	.02	.00	.00	.00	.07	.05	.02	11904.
1 MAY 0800	55	.00	47.0	.05	.04	.01	.00	.00	.00	.05	.04	.01	11323.
1 MAY 2000	56	.00	46.0	.04	.03	.01	.00	.00	.00	.04	.03	.01	10729.
2 MAY 0800	57	.00	45.0	.03	.03	.00	.00	.00	.00	.03	.03	.00	10124.
2 MAY 2000	58	.00	47.5	.05	.04	.01	.00	.00	.00	.05	.04	.01	9530.
3 MAY 0800	59	.00	50.0	.07	.05	.02	.00	.00	.00	.07	.05	.02	8978.
3 MAY 2000	60	.01	52.5	.03	.02	.00	.01	.00	.00	.03	.03	.00	8478.
4 MAY 0800	61	.00	55.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	8007.
4 MAY 2000	62	.01	53.0	.00	.00	.00	.01	.01	.00	.01	.01	.00	7541.
5 MAY 0800	63	.01	51.0	.00	.00	.00	.01	.01	.00	.01	.01	.00	7075.
5 MAY 2000	64	.00	50.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	6626.
6 MAY 0800	65	.00	50.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	6206.
6 MAY 2000	66	.00	49.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	5812.
7 MAY 0800	67	.00	49.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	5443.
7 MAY 2000	68	.00	49.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	5097.
8 MAY 0800	69	.00	50.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	4774.
8 MAY 2000	70	.01	55.0	.00	.00	.00	.01	.01	.00	.01	.01	.00	4471.
9 MAY 0800	71	.01	60.0	.00	.00	.00	.01	.01	.00	.01	.01	.00	4187.
9 MAY 2000	72	.02	57.5	.00	.00	.00	.02	.02	.00	.02	.02	.00	3921.
10 MAY 0800	73	.01	55.0	.00	.00	.00	.01	.01	.00	.01	.01	.00	3672.
10 MAY 2000	74	.29	52.5	.00	.00	.00	.29	.29	.00	.29	.29	.00	3440.
11 MAY 0800	75	.29	50.0	.00	.00	.00	.29	.29	.00	.29	.29	.00	3225.
11 MAY 2000	76	.28	45.5	.00	.00	.00	.28	.28	.00	.28	.28	.00	3026.
12 MAY 0800	77	.28	41.0	.00	.00	.00	.22	.22	.00	.22	.22	.00	2838.
12 MAY 2000	78	.00	43.5	.02	.02	.00	.00	.00	.00	.02	.02	.00	2660.
13 MAY 0800	79	.00	46.0	.04	.03	.01	.00	.00	.00	.04	.03	.01	2496.
13 MAY 2000	80	.00	50.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	2348.
14 MAY 0800	81	.00	54.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	2212.
14 MAY 2000	82	.16	55.5	.00	.00	.00	.16	.16	.00	.16	.16	.00	2081.
15 MAY 0800	83	.16	57.0	.00	.00	.00	.16	.16	.00	.16	.16	.00	1952.
15 MAY 2000	84	.13	57.0	.00	.00	.00	.13	.13	.00	.13	.13	.00	1828.
16 MAY 0800	85	.13	57.0	.00	.00	.00	.13	.13	.00	.13	.13	.00	1712.
16 MAY 2000	86	.00	55.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	1603.
17 MAY 0800	87	.00	54.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	1502.
17 MAY 2000	88	.24	59.0	.00	.00	.00	.24	.24	.00	.24	.24	.00	1462.
18 MAY 0800	89	.24	64.0	.00	.00	.00	.24	.24	.00	.24	.24	.00	1424.
18 MAY 2000	90	.23	64.5	.00	.00	.00	.23	.23	.00	.23	.23	.00	1387.

****

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 10-DAY	30-DAY	90-DAY	44.5-DAY
14095.	588.00	(CFS)	10928.	5759.	3884.	3884.
		(INCHES)	2.173	3.436	3.438	3.438
		(AC-FT)	216756.	342675.	342854.	342854.

CUMULATIVE AREA = 1870.00 SQ MI

```
                                                        STATION        7

                         (O) OUTFLOW
         0.     2000.     4000.     6000.     8000.    10000.    12000.    14000.    16000.        0.        0.        0.        0.
                                                                     (T) TEMPERATURE
         0.        0.        0.        0.        0.        0.        0.       20.       40.       60.       80.        0.        0.
                                                                                                       (L) PRECIP,   (X) EXCESS
        .0        .0        .0        .0        .0        .0        .0        .0        .0       1.2        .8        .4        .0
DAHRMN PER
 40800   10---------.---------.---------.---------.---------.---------.--------T.---------.---------.---------.---------.---------.
 42000   20         .         .         .         .         .         .         . T       .         .         .         .         .
 50800   30         .         .         .         .         .         .         .    T    .         .         .         .         .
 52000   40         .         .         .         .         .         .         .     T   .         .         .         .         .
 60800   50         .         .         .         .         .         .         .       T .         .         .         .         .
 62000   60         .         .         .         .         .         .         .      T  .         .         .         .         .
 70800   70         .         .         .         .         .         .         .     T   .         .         .         .         .
 72000   80         .         .         .         .         .         .         .    T    .         .         .         .         .
 80800   90         .         .         .         .         .         .         .   T     .         .         .         .         .
 82000  100         .         .         .         .         .         .         . T       .         .         .         .         .
 90800  110 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .T. . . . . . . . . . . . . . . . . . . . . . . .
 92000  120         .         .         .         .         .         .         .   T     .         .         .         .         .
100800  130         .         .         .         .         .         .         .     T   .         .         .         .         .
102000  140         .         .         .         .         .         .         . T       .         .         .         .         .
110800  150         .         .         .         .         .         .      T  .         .         .         .         .         .
112000  160         .         .         .         .         .         .   T     .         .         .         .         .         .
120800  170         .         .         .         .         .         T         .         .         .         .         .         .
122000  180         .         .         .         .         .         .T        .         .         .         .         .         .
130800  190         .         .         .         .         .         .T        .         .         .         .         .         .
132000  200         .         .         .         .         .         .    T    .         .         .         .         .         .
140800  210 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .T. . . . . . . . . . . . . . . . . . . . . . . . .
142000  220         .         .         .         .         .         .         .   T     .         .         .         .         .
150800  230         .         .         .         .         .         .         .        T.         .         .         .        L.
152000  240         .         .         .         .         .         .         .     T   .         .         .         .         .
160800  250         .         .         .         .         .         .         .   T     .         .         .         .         .
162000  260         .         .         .         .         .         .         .     T   .         .         .         .         .
170800  270         .         .         .         .         .         .         .        T.         .         .         .        L.
172000  280         .         .         .         .         .         .         .        T.         .         .         .       LL.
180800  290         .         .         .         .         .         .         .        T.         .         .         .       LL.
182000  300         .         .         .         .         .         .         .       T .         .         .         .        L.
190800  310 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .T. . . . . . . . . . . . . . . . . . . . .
192000  320         .         .         .         .         .         .         .       T .         .         .         .         .
200800  330         .         .         .         .         .         .         .        T.         .         .         .        L.
202000  340         .         .         .         .         .         .         .         .T        .         .         .   LLLLLX.
210800  35.O        .         .         .         .         .         .         .         .   T     .         .        LLLLLLLXXXX.
212000  36.   O     .         .         .         .         .         .         .         .    T    .         .    LLLLLLLLLXXXXXX.
220800  37.        O.         .         .         .         .         .         .         .     T   .         .  LLLLLLLLLLXXXXXXX.
222000  38.         .     O   .         .         .         .         .         .         .    T    .        LLLLLLLLLLLXXXXXXXXXX.
230800  39.         .         .   O     .         .         .         .         .         .   T     .         .LLLLLLLLLLLXXXXXXXX.
232000  40.         .         .         .  O      .         .         .         .         . T       .         .      LLLLLLLLXXXXX.
240800  41. . . . . . . . . . . . . . . . . . . . O . . . . . . . . . . . . . . . . . . . .T. . . . . . . . . . . . . .LLLLLLXXX.
242000  42.         .         .         .         .   O     .         .         .         . T       .         .         .  LLLLLXX.
250800  43.         .         .         .         .    O    .         .         .         .  T      .         .         . LLLLLXXX.
252000  44.         .         .         .         .     O   .         .         .         .    T    .         .     LLLLLLLLLXXXXX.
260800  45.         .         .         .         .       O .         .         .         .       T .         . LLLLLLLLLLXXXXXXXX.
262000  46.         .         .         .         .         . O       .         .         .        T.    LLLLLLLLLLLLXXXXXXXXXXXX.
270800  47.         .         .         .         .         .        O.         .         .         T         .  LLLLLLLLLLXXXXXXX.
272000  48.         .         .         .         .         .         .     O   .         .        T.         .         .  LLLLLXX.
280800  49.         .         .         .         .         .         .         O         .      T  .         .         .      LLX.
```

```
282000  50.         .         .         .         .         .         .         O         .      T  .         .         .     LLLX.
290800  51. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . O . . . . . . . . .T. . . . . . . . . . . . . . .LLX.
292000  52.         .         .         .         .         .         .    O    .         .     T   .         .         .      LLX.
300800  53.         .         .         .         .         .         . O       .         .     T   .         .         .      LLX.
302000  54.         .         .         .         .         .         O         .         .    T    .         .         .       LL.
 10800  55.         .         .         .         .         .      O  .         .         .   T     .         .         .        L.
 12000  56.         .         .         .         .         .   O     .         .         .  T      .         .         .        L.
 20800  57.         .         .         .         .         .O        .         .         .  T      .         .         .        L.
 22000  58.         .         .         .         .       O .         .         .         .   T     .         .         .        L.
 30800  59.         .         .         .         .    O    .         .         .         .    T    .         .         .       LX.
 32000  60.         .         .         .         .  O      .         .         .         .     T   .         .         .        L.
 40800  61. . . . . . . . . . . . . . . . . . . O . . . . . . . . . . . . . . . . . . . . . . . T . . . . . . . . . . . . . . . .
 42000  62.         .         .         .       O .         .         .         .         .      T  .         .         .         .
 50800  63.         .         .         .    O    .         .         .         .         .     T   .         .         .         .
 52000  64.         .         .         .  O      .         .         .         .         .    T    .         .         .         .
 60800  65.         .         .         .O        .         .         .         .         .    T    .         .         .         .
 62000  66.         .         .        O.         .         .         .         .         .    T    .         .         .         .
 70800  67.         .         .      O  .         .         .         .         .         .    T    .         .         .         .
 72000  68.         .         .    O    .         .         .         .         .         .    T    .         .         .         .
 80800  69.         .         .   O     .         .         .         .         .         .    T    .         .         .         .
 82000  70.         .         . O       .         .         .         .         .         .       T .         .         .         .
 90800  71. . . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . T . . . . . . . . . . . . . . .
 92000  72.         .         O         .         .         .         .         .         .        T.         .         .         .
100800  73.         .       O .         .         .         .         .         .         .       T .         .         .         .
102000  74.         .      O  .         .         .         .         .         .         .     T   .         .         .  LLLLLLL.
110800  75.         .     O   .         .         .         .         .         .         .    T    .         .         .  LLLLLLL.
112000  76.         .    O    .         .         .         .         .         .         .  T      .         .         .  LLLLLLL.
120800  77.         .   O     .         .         .         .         .         .         .T        .         .         .   LLLLLL.
122000  78.         .  O      .         .         .         .         .         .         . T       .         .         .         .
130800  79.         . O       .         .         .         .         .         .         .  T      .         .         .        L.
132000  80.         . O       .         .         .         .         .         .         .    T    .         .         .         .
140800  81. . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .T. . . . . . . . . . . . . . . .
142000  82.         O         .         .         .         .         .         .         .       T .         .         .     LLLL.
150800  83.         O         .         .         .         .         .         .         .        T.         .         .     LLLL.
152000  84.        O.         .         .         .         .         .         .         .        T.         .         .      LLL.
160800  85.        O.         .         .         .         .         .         .         .        T.         .         .      LLL.
162000  86.       O .         .         .         .         .         .         .         .       T .         .         .         .
170800  87.       O .         .         .         .         .         .         .         .      T  .         .         .         .
172000  88.      O  .         .         .         .         .         .         .         .         T         .         .   LLLLLL.
180800  89.      O  .         .         .         .         .         .         .         .         . T       .         .   LLLLLL.
182000  90.------O--.---------.---------.---------.---------.---------.---------.---------.---------.-T-------.---------.---LLLLLL.
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 10-DAY	30-DAY	90-DAY	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	7	14095.	588.00	10928.	5759.	3884.	1870.00		

*** NORMAL END OF HEC-1 ***

12.4 Example Problem #4: Unit Graph and Loss Rate Parameter Optimization

This example demonstrates the optimization of Clark UNit Hydrograph parameters TC and R, and the loss rate parameters for the HEC-1 exponential loss function. Note that unit graph and loss rate parameters can be fixed at a desired value; in this example, the exponential loss rate parameter ERAIN was fixed at 0.7, leaving the remaining loss rate and unit graph parameters to be optimized. The example input data in the appropriate HEC-1 format and the optimization results are shown in Table 12.4.

Table 12.4
Example Problem #4: Input and Output

Input

```
ID       EXAMPLE TEST NO. 4
ID       UNIT GRAPH AND LOSS RATE OPTIMIZATION
IT    15 27AUG67    1145      61
IO     1       2
OU
PG467042    2.39    1.00
PG   100
PI     0       0     .03     .06     .45     .42     .29     .14     .08     .04
PI   .03     .02     .02     .02     .01     .01     .01     .01     .01     .02
PI   .01     .01     .02     .01     .01     .01     .01     .01     .01       0
PI   .01     .01       0       0     .01     .02     .01     .01     .01       0
PI   .01     .01     .01     .01       0       0       0     .01       0       0
PG   300
PI     0       0       0       0       0       0       0       0       0       0
PI     0       0       0     .10     .45    1.45     .73     .02     .80     .50
PI   .25     .05       0       0       0       0       0       0       0       0
PG  5000
PI     0       0       0       0       0       0       0       0       0       0
PI     0       0       0       0       0       0       0       0       0       0
PI     0       0       0       0       0       0       0       0     .04     .23
PI   .39     .18     .56       0       0       0     .19     .08     .20     .20
PI   .11     .03       0       0       0       0       0       0       0       0
KK467042
QO    57      57      59      61      63      65      67      69      71      73
QO   130     250     370     520     720     920    1170    1470    1720    1900
QO  2060    2250    2400    2570    2720    2860    3090    3390    3540    3520
QO  3480    3330    3290    3230    3100    2900    2720    2520    2270    2050
QO  1800    1570    1430    1300    1200    1100     980     890     800     745
QO   690     650     610     570     540     510     490     475     460     445
QO   430       0       0       0       0       0       0       0       0       0
PT467042
PW  1.00
PR   100     300    5000
PW   .45     .45     .10
BA 37.90      0.
BF   57.    -.25  1.3195
UC -1.00   -1.00
LE   -1.     -1.      1.      .5
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*            JUN   1998                 *
*         VERSION 4.1                   *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:21   *
*                                       *
*****************************************
```

```
                                        HEC-1 INPUT                                          PAGE  1

 LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   1           ID        EXAMPLE TEST NO. 4
   2           ID        UNIT GRAPH AND LOSS RATE OPTIMIZATION
   3           IT      15 27AUG67    1145      61
   4           IO       1       2
   5           OU
   6           PG  467042    2.39    1.00
   7           PG     100
   8           PI       0       0     .03     .06     .45     .42     .29     .14     .08     .04
   9           PI     .03     .02     .02     .02     .01     .01     .01     .01     .01     .02
  10           PI     .01     .01     .02     .01     .01     .01     .01     .01     .01       0
  11           PI     .01     .01       0       0     .01     .02     .01     .01     .01       0
  12           PI     .01     .01     .01     .01       0       0       0     .01       0       0
  13           PG     300
  14           PI       0       0       0       0       0       0       0       0       0       0
  15           PI       0       0       0     .10     .45    1.45     .73     .02     .80     .50
  16           PI     .25     .05       0       0       0       0       0       0       0       0
  17           PG    5000
  18           PI       0       0       0       0       0       0       0       0       0       0
  19           PI       0       0       0       0       0       0       0       0       0       0
  20           PI       0       0       0       0       0       0       0       0     .04     .23
  21           PI     .39     .18     .56       0       0       0     .19     .08     .20     .20
  22           PI     .11     .03       0       0       0       0       0       0       0       0

  23           KK  467042
  24           QO      57      57      59      61      63      65      67      69      71      73
  25           QO     130     250     370     520     720     920    1170    1470    1720    1900
  26           QO    2060    2250    2400    2570    2720    2860    3090    3390    3540    3520
  27           QO    3480    3330    3290    3230    3100    2900    2720    2520    2270    2050
  28           QO    1800    1570    1430    1300    1200    1100     980     890     800     745
  29           QO     690     650     610     570     540     510     490     475     460     445
  30           QO     430       0       0       0       0       0       0       0       0       0
  31           PT  467042
  32           PW    1.00
  33           PR     100     300    5000
  34           PW     .45     .45     .10
  35           BA   37.90      0.
  36           BF     57.    -.25  1.3195
  37           UC   -1.00   -1.00
  38           LE     -1.     -1.      1.      .5
  39           ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN  1998                *
*           VERSION 4.1                 *
*                                       *
* RUN DATE  10JUN98  TIME  20:38:21     *
*                                       *
*****************************************
                                 EXAMPLE TEST NO. 4
                                 UNIT GRAPH AND LOSS RATE OPTIMIZATION

    4 IO         OUTPUT CONTROL VARIABLES
                       IPRNT          1  PRINT CONTROL
                       IPLOT          2  PLOT CONTROL
                       QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT         HYDROGRAPH TIME DATA
                        NMIN         15  MINUTES IN COMPUTATION INTERVAL
                       IDATE    27AUG67  STARTING DATE
                       ITIME       1145  STARTING TIME
                          NQ         61  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE    28AUG67  ENDING DATE
                      NDTIME       0245  ENDING TIME
                      ICENT          19  CENTURY MARK

                   COMPUTATION INTERVAL     .25 HOURS
                        TOTAL TIME BASE   15.00 HOURS

          ENGLISH UNITS
               DRAINAGE AREA         SQUARE MILES
               PRECIPITATION DEPTH   INCHES
               LENGTH, ELEVATION     FEET
               FLOW                  CUBIC FEET PER SECOND
               STORAGE VOLUME        ACRE-FEET
               SURFACE AREA          ACRES
               TEMPERATURE           DEGREES FAHRENHEIT

      OU         OPTIMIZATION OF UNITGRAPH AND LOSS RATE PARAMETERS
                       IFORD          1  FIRST ORDINATE OF OPTIMIZATION REGION
                       ILORD         61  LAST ORDINATE OF OPTIMIZATION REGION
 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
            **************
            *            *
   23 KK    *    467042  *
            *            *
            **************

               SUBBASIN RUNOFF DATA

   35 BA         SUBBASIN CHARACTERISTICS
                       TAREA      37.90  SUBBASIN AREA

   36 BF         BASE FLOW CHARACTERISTICS
                       STRTQ      57.00  INITIAL FLOW
                       QRCSN       -.25  BEGIN BASE FLOW RECESSION
                       RTIOR    1.31950  RECESSION CONSTANT

                 PRECIPITATION DATA

   31 PT          TOTAL STORM STATIONS    467042
   32 PW                       WEIGHTS      1.00

   33 PR            RECORDING STATIONS       100       300      5000
   34 PW                       WEIGHTS       .45       .45       .10
```

```
 38 LE          EXPONENTIAL LOSS RATE
                      STRKR       -1.00  INITIAL VALUE OF LOSS COEFFICIENT
                      DLTKR       -1.00  INITIAL LOSS
                      RTIOL        1.00  LOSS COEFFICIENT RECESSION CONSTANT
                      ERAIN         .50  EXPONENT OF PRECIPITATION
                      RTIMP         .00  PERCENT IMPERVIOUS AREA

 37 UC          CLARK UNITGRAPH
                         TC       -1.00  TIME OF CONCENTRATION
                          R       -1.00  STORAGE COEFFICIENT

                SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED
                                                         ***
              PRECIPITATION STATION DATA

                     STATION    TOTAL    AVG. ANNUAL    WEIGHT
                      467042     2.39        1.00        1.00

                TEMPORAL DISTRIBUTIONS

                STATION      100,  WEIGHT =    .45
                     .00      .00      .03      .06      .45      .42      .29      .14      .08      .04
                     .03      .02      .02      .02      .01      .01      .01      .01      .01      .02
                     .01      .01      .02      .01      .01      .01      .01      .01      .01      .00
                     .01      .01      .00      .00      .01      .02      .01      .01      .01      .00
                     .01      .01      .01      .01      .00      .00      .00      .01

                STATION      300,  WEIGHT =    .45
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .10      .45     1.45      .73      .02      .80      .50
                     .25      .05      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00

                STATION     5000,  WEIGHT =    .10
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .04      .23
                     .39      .18      .56      .00      .00      .00      .19      .08      .20      .20
                     .11      .03      .00      .00      .00      .00      .00      .00

                                           INITIAL ESTIMATES FOR OPTIMIZATION VARIABLES
                    TC+R  R/(TC+R)     STRKR     DLTKR     RTIOL     ERAIN
                    6.16       .50       .20       .50      1.00       .50

                                           INTERMEDIATE VALUES OF OPTIMIZATION VARIABLES
                                              (*INDICATES CHANGE FROM PREVIOUS VALUE)
                                              (+INDICATES VARIABLE WAS NOT CHANGED)
 OBJECTIVE
  FUNCTION        TC+R  R/(TC+R)      STRKR      DLTKR      RTIOL      ERAIN
VOL. ADJ.        6.156      .500      .448*     1.119*     1.000       .500

     349.3       6.890*     .500      .448      1.119      1.000       .500
     346.8       6.890      .521*     .448      1.119      1.000       .500
     344.4       6.890      .521      .438*     1.119      1.000       .500
     339.3       6.890      .521      .438       .984*     1.000       .500

     339.1       6.920*     .521      .438       .984      1.000       .500
     335.8       6.920      .546*     .438       .984      1.000       .500
     335.1       6.920      .546      .443*      .984      1.000       .500
     328.4       6.920      .546      .443       .812*     1.000       .500

     327.0       7.014*     .546      .443       .812      1.000       .500
     326.8       7.014      .550*     .443       .812      1.000       .500
     324.6       7.014      .550      .453*      .812      1.000       .500
     311.1       7.014      .550      .453       .541*     1.000       .500

     309.9       7.100*     .550      .453       .541      1.000       .500
     309.9       7.100      .551*     .453       .541      1.000       .500
     305.6       7.100      .551      .465*      .541      1.000       .500
     293.4       7.100      .551      .465       .361*     1.000       .500

     288.2       7.100      .551      .465       .241*     1.000       .500
     286.2       7.100      .551      .465       .160*     1.000       .500
     281.7       7.100      .551      .478*      .160      1.000       .500
     281.7       7.100      .551      .477*      .160      1.000       .500

     281.2       7.044*     .551      .477       .160      1.000       .500
VOL. ADJ.        7.044      .551      .487*      .164*     1.000       .500
```

```
                                   ***************************************************
                                   *                                                 *
                                   *              OPTIMIZATION RESULTS               *
                                   *                                                 *
                                   ***************************************************
                                   *                                                 *
                                   *     CLARK UNITGRAPH PARAMETERS                  *
                                   *           TC    3.16                            *
                                   *            R    3.88                            *
                                   *                                                 *
                                   *     SNYDER STANDARD UNITGRAPH PARAMETERS        *
                                   *           TP    2.99                            *
                                   *           CP     .52                            *
                                   *                                                 *
                                   *     LAG FROM CENTER OF MASS OF EXCESS           *
                                   *     TO CENTER OF MASS OF UNITGRAPH    5.36      *
                                   *                                                 *
                                   *     UNITGRAPH PEAK     4333.                    *
                                   *     TIME OF PEAK       3.00                     *
                                   *                                                 *
                                   ***************************************************
                                   *                                                 *
                                   *     EXPONENTIAL LOSS RATE PARAMETERS            *
                                   *        STRKR     .49                            *
                                   *        DLTKR     .16                            *
                                   *        RTIOL    1.00                            *
                                   *        ERAIN     .50                            *
                                   *                                                 *
                                   *     EQUIVALENT UNIFORM LOSS RATE     .444       *
                                   *                                                 *
                                   ***************************************************


***********************************************************************************************************
*                                                                                                         *
*                                 COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS                         *
*                                                                                                         *
***********************************************************************************************************
*                                                                                                         *
*                                     STATISTICS BASED ON OPTIMIZATION REGION                             *
*                                           (ORDINATES   1 THROUGH  61)                                   *
*                                                                                                         *
***********************************************************************************************************
*                                                                                                         *
*                                                              TIME TO      LAG                           *
*                             SUM OF     EQUIV       MEAN      CENTER      C.M. TO     PEAK    TIME OF    *
*                              FLOWS     DEPTH       FLOW      OF MASS      C.M.       FLOW       PEAK    *
*                                                                                                         *
*   PRECIPITATION EXCESS                  .937                  4.13                                      *
*                                                                                                         *
*   COMPUTED HYDROGRAPH       84787.      .867       1390.      8.51        4.38      3621.      7.00     *
*   OBSERVED HYDROGRAPH       84787.      .867       1390.      8.16        4.03      3540.      7.00     *
*                                                                                                         *
*   DIFFERENCE                    0.      .000          0.       .35         .35        81.       .00     *
*   PERCENT DIFFERENCE           .00                                        8.66       2.30               *
*                                                                                                         *
*                  STANDARD ERROR      270.                  AVERAGE ABSOLUTE ERROR      207.             *
*              OBJECTIVE FUNCTION      283.          AVERAGE PERCENT ABSOLUTE ERROR     27.24             *
*                                                                                                         *
***********************************************************************************************************

                                                        UNIT HYDROGRAPH
                                                   89 END-OF-PERIOD ORDINATES
                    96.      361.      741.     1191.     1690.     2227.     2779.     3285.     3700.     4018.
                  4233.     4333.     4267.     4052.     3799.     3562.     3340.     3131.     2936.     2753.
                  2581.     2420.     2269.     2127.     1994.     1870.     1753.     1644.     1541.     1445.
                  1355.     1270.     1191.     1116.     1047.      981.      920.      863.      809.      758.
                   711.      667.      625.      586.      549.      515.      483.      453.      424.      398.
                   373.      350.      328.      308.      288.      270.      253.      238.      223.      209.
                   196.      184.      172.      161.      151.      142.      133.      125.      117.      110.
                   103.       96.       90.       85.       79.       74.       70.       65.       61.       58.
                    54.       51.       47.       44.       42.       39.       37.       34.       32.
```

HYDROGRAPH AT STATION 467042

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	OBS Q	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	OBS Q
27 AUG 1145	1	.00	.00	.00	57.	57.	27 AUG 1930	32	.03	.03	.00	3312.	3330.
27 AUG 1200	2	.00	.00	.00	53.	57.	27 AUG 1945	33	.02	.02	.00	3136.	3290.
27 AUG 1215	3	.00	.00	.00	50.	59.	27 AUG 2000	34	.04	.04	.00	2948.	3230.
27 AUG 1230	4	.01	.01	.00	46.	61.	27 AUG 2015	35	.00	.00	.00	2765.	3100.
27 AUG 1245	5	.02	.02	.00	43.	63.	27 AUG 2030	36	.00	.00	.00	2592.	2900.
27 AUG 1300	6	.16	.10	.06	46.	65.	27 AUG 2045	37	.01	.01	.00	2430.	2720.
27 AUG 1315	7	.15	.09	.05	64.	67.	27 AUG 2100	38	.02	.02	.00	2279.	2520.
27 AUG 1330	8	.10	.08	.02	100.	69.	27 AUG 2115	39	.01	.01	.00	2136.	2270.
27 AUG 1345	9	.05	.05	.00	151.	71.	27 AUG 2130	40	.02	.02	.00	2003.	2050.
27 AUG 1400	10	.03	.03	.00	212.	73.	27 AUG 2145	41	.02	.02	.00	1878.	1800.
27 AUG 1415	11	.01	.01	.00	280.	130.	27 AUG 2200	42	.01	.01	.00	1761.	1570.
27 AUG 1430	12	.01	.01	.00	352.	250.	27 AUG 2215	43	.01	.01	.00	1651.	1430.
27 AUG 1445	13	.01	.01	.00	423.	370.	27 AUG 2230	44	.00	.00	.00	1548.	1300.
27 AUG 1500	14	.01	.01	.00	487.	520.	27 AUG 2245	45	.00	.00	.00	1451.	1200.
27 AUG 1515	15	.04	.04	.00	539.	720.	27 AUG 2300	46	.00	.00	.00	1360.	1100.
27 AUG 1530	16	.16	.10	.06	584.	920.	27 AUG 2315	47	.00	.00	.00	1276.	980.
27 AUG 1545	17	.52	.18	.34	658.	1170.	27 AUG 2330	48	.00	.00	.00	1196.	890.
27 AUG 1600	18	.26	.12	.14	792.	1470.	27 AUG 2345	49	.00	.00	.00	1121.	800.
27 AUG 1615	19	.01	.01	.00	973.	1720.	28 AUG 0000	50	.00	.00	.00	1051.	745.
27 AUG 1630	20	.29	.13	.16	1198.	1900.	28 AUG 0015	51	.00	.00	.00	986.	690.
27 AUG 1645	21	.18	.10	.08	1481.	2060.	28 AUG 0030	52	.00	.00	.00	924.	650.
27 AUG 1700	22	.09	.07	.02	1818.	2250.	28 AUG 0045	53	.00	.00	.00	866.	610.
27 AUG 1715	23	.02	.02	.00	2189.	2400.	28 AUG 0100	54	.00	.00	.00	812.	570.
27 AUG 1730	24	.01	.01	.00	2557.	2570.	28 AUG 0115	55	.00	.00	.00	762.	540.
27 AUG 1745	25	.00	.00	.00	2894.	2720.	28 AUG 0130	56	.00	.00	.00	714.	510.
27 AUG 1800	26	.00	.00	.00	3187.	2860.	28 AUG 0145	57	.00	.00	.00	669.	490.
27 AUG 1815	27	.00	.00	.00	3420.	3090.	28 AUG 0200	58	.00	.00	.00	628.	475.
27 AUG 1830	28	.00	.00	.00	3573.	3390.	28 AUG 0215	59	.00	.00	.00	588.	460.
27 AUG 1845	29	.00	.00	.00	3621.	3540.	28 AUG 0230	60	.00	.00	.00	552.	445.
27 AUG 1900	30	.01	.01	.00	3569.	3520.	28 AUG 0245	61	.00	.00	.00	517.	430.
27 AUG 1915	31	.02	.02	.00	3458.	3480.							

TOTAL RAINFALL = 2.39, TOTAL LOSS = 1.45, TOTAL EXCESS = .94

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	15.00-HR
3621.	7.00	(CFS)	2591.	1408.	1408.	1408.
		(INCHES)	.636	.864	.864	.864
		(AC-FT)	1285.	1746.	1746.	1746.

CUMULATIVE AREA = 37.90 SQ MI

STATION 467042

(O) OUTFLOW, (*) OBSERVED FLOW

0. 400. 800. 1200. 1600. 2000. 2400. 2800. 3200. 3600. 4000. 0. 0.

```
                                                                                                       (L) PRECIP,   (X) EXCESS
         .0        .0        .0        .0        .0        .0        .0        .0        .0        .6        .4        .2        .0
DAHRMN PER
271145   1.*--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
271200   2.*        .         .         .         .         .         .         .         .         .         .         .         .
271215   3.*        .         .         .         .         .         .         .         .         .         .         .         .
271230   4.O*       .         .         .         .         .         .         .         .         .         .         .        L.
271245   5.O*       .         .         .         .         .         .         .         .         .         .         .        L.
271300   6.O*       .         .         .         .         .         .         .         .         .         .         . LLLLLXXX.
271315   7. *       .         .         .         .         .         .         .         .         .         .         .  LLLLXXX.
271330   8. *O      .         .         .         .         .         .         .         .         .         .         .    LLLLX.
271345   9. * O     .         .         .         .         .         .         .         .         .         .         .       LL.
271400  10. *  O    .         .         .         .         .         .         .         .         .         .         .        L.
271415  11. .*. .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .L.
271430  12.     *  O.         .         .         .         .         .         .         .         .         .         .        L.
271445  13.        *.O        .         .         .         .         .         .         .         .         .         .         .
271500  14.         . O*      .         .         .         .         .         .         .         .         .         .         .
271515  15.         .  O    * .         .         .         .         .         .         .         .         .         .       LL.
271530  16.         .    O    .  *      .         .         .         .         .         .         .         .         . LLLLLXXX.
271545  17.         .     O   .        *.         .         .         .         .         .         .   LLLLLLLLLXXXXXXXXXXXXXXXXX.
271600  18.         .         O         .      *  .         .         .         .         .         .         .      LLLLLLXXXXXXX.
271615  19.         .         .   O     .         .  *      .         .         .         .         .         .         .        L.
271630  20.         .         .         O         .       * .         .         .         .         .         .     LLLLLLXXXXXXXX.
271645  21. . . . . . . . . . . . . . . . . . .O. . . . . . * . . . . . . . . . . . . . . . . . . . . . . . . . . . . .LLLLLXXXX.
271700  22.         .         .         .         .    O    .     *   .         .         .         .         .         .    LLLLX.
271715  23.         .         .         .         .         .    O    *         .         .         .         .         .        L.
271730  24.         .         .         .         .         .         .   *     .         .         .         .         .         .
271745  25.         .         .         .         .         .         .       * . O       .         .         .         .         .
271800  26.         .         .         .         .         .         .         . *       O         .         .         .         .
271815  27.         .         .         .         .         .         .         .      *  .     O   .         .         .         .
271830  28.         .         .         .         .         .         .         .         .    *   O.         .         .         .
271845  29.         .         .         .         .         .         .         .         .        *.O        .         .         .
271900  30.         .         .         .         .         .         .         .         .       *O.         .         .         .
271915  31. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . O*. . . . . . . . . . . . . . . .L.
271930  32.         .         .         .         .         .         .         .         .  *      .         .         .       LL.
271945  33.         .         .         .         .         .         .         .       O . *       .         .         .        L.
272000  34.         .         .         .         .         .         .         .   O     .*        .         .         .       LL.
272015  35.         .         .         .         .         .         .        O.       * .         .         .         .         .
272030  36.         .         .         .         .         .         .    O    .  *      .         .         .         .         .
272045  37.         .         .         .         .         .         .O      * .         .         .         .         .         .
272100  38.         .         .         .         .         .      O  .  *      .         .         .         .         .        L.
272115  39.         .         .         .         .         .  O   *  .         .         .         .         .         .         .
272130  40.         .         .         .         .         O*        .         .         .         .         .         .        L.
272145  41. . . . . . . . . . . . . . . . . . . . . . .*.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .L.
272200  42.         .         .         .        *.   O     .         .         .         .         .         .         .        L.
272215  43.         .         .         .     *   .O        .         .         .         .         .         .         .         .
272230  44.         .         .         .  *     O.         .         .         .         .         .         .         .         .
272245  45.         .         .         *     O   .         .         .         .         .         .         .         .         .
272300  46.         .         .       * .   O     .         .         .         .         .         .         .         .         .
272315  47.         .         .    *    . O       .         .         .         .         .         .         .         .         .
272330  48.         .         . *       O         .         .         .         .         .         .         .         .         .
272345  49.         .         *       O .         .         .         .         .         .         .         .         .         .
280000  50.         .        *.     O   .         .         .         .         .         .         .         .         .         .
280015  51. . . . . . . . .*. . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
280030  52.         .     *   .  O      .         .         .         .         .         .         .         .         .         .
280045  53.         .    *    . O       .         .         .         .         .         .         .         .         .         .
280100  54.         .   *     O         .         .         .         .         .         .         .         .         .         .
280115  55.         .   *    O.         .         .         .         .         .         .         .         .         .         .
280130  56.         .  *    O .         .         .         .         .         .         .         .         .         .         .
280145  57.         . *    O  .         .         .         .         .         .         .         .         .         .         .
280200  58.         . *   O   .         .         .         .         .         .         .         .         .         .         .
280215  59.         . *  O    .         .         .         .         .         .         .         .         .         .         .
280230  60.         .*  O     .         .         .         .         .         .         .         .         .         .         .
280245  61.---------.*-O------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.

                    (-) LIMITS OF OPTIMIZATION
```

** STATION 467042 ** DRAINAGE AREA = 37.90

...DATE...			...PERCENT ERROR...				.... OPTIMIZATION RESULTS											
DA	MON	YR	AVG	VOL	LAG	PEAK	TC	R	TC+R	R/(TC+R)	TP	CP	QP	STRKR	DLTKR	RTIOL	ERAIN
27	AUG	67	27.2	.0	8.7	2.3	3.16	3.88	7.04	.55	2.99	.52	111.	.49	.16	1.00	.50

*** NORMAL END OF HEC-1 ***

12.5 Example Problem #5: Routing Parameter Optimization

Input data requirements for the routing parameter optimization are observed inflow and outflow hydrographs and a pattern lateral inflow hydrograph for the routing reach. The routing parameters optimized in this example are the Muskingum K and X, and the number of subreaches, NSTEPS. The example input data and optimization results are shown in Table 12.5.

Table 12.5

Example Problem #5: Input and Output

Input

```
ID      EXAMPLE PROBLEM NO. 5
ID      STREAMFLOW ROUTING OPTIMIZATION
ID      MUSKINGUM METHOD
IT   720  600000       0      16
IO     1       2
OR     2
KK     1
QP  2000    2000    7000   11700   16500   24000   29100   28400   23800   19400
QP 15300   11200    8200    6400    5200    4600       0       0       0       0
QI  2200    2200   14500   28400   31800   29700   25300   20400   16300   12600
QI  9300    6700    5000    4100    3600    2400       0       0       0       0
QO  2000    2000    7000   11700   16500   24000   29100   28400   23800   19400
QO 15300   11200    8200    6400    5200    4600       0       0       0       0
RL  0.      0.
RM    -1   -1.00   -1.00
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:31   *
*                                       *
*****************************************


                                                  HEC-1 INPUT                                         PAGE  1

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1           ID        EXAMPLE PROBLEM NO. 5
            2           ID        STREAMFLOW ROUTING OPTIMIZATION
            3           ID        MUSKINGUM METHOD
            4           IT     720  600000       0      16
            5           IO       1       2
            6           OR       2

            7           KK       1
            8           QP    2000    2000    7000   11700   16500   24000   29100   28400   23800   19400
            9           QP   15300   11200    8200    6400    5200    4600       0       0       0       0
           10           QI    2200    2200   14500   28400   31800   29700   25300   20400   16300   12600
           11           QI    9300    6700    5000    4100    3600    2400       0       0       0       0
           12           QO    2000    2000    7000   11700   16500   24000   29100   28400   23800   19400
           13           QO   15300   11200    8200    6400    5200    4600       0       0       0       0
           14           RL    0.      0.
           15           RM      -1   -1.00   -1.00
           16           ZZ


*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:31   *
*                                       *
*****************************************


                                EXAMPLE PROBLEM NO. 5
                                STREAMFLOW ROUTING OPTIMIZATION
                                MUSKINGUM METHOD

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           1  PRINT CONTROL
                        IPLOT           2  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN         720  MINUTES IN COMPUTATION INTERVAL
                        IDATE      6000 0  STARTING DATE
                        ITIME        0000  STARTING TIME
                           NQ          16  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     13    0  ENDING DATE
                       NDTIME        1200  ENDING TIME
                       ICENT           19  CENTURY MARK

                    COMPUTATION INTERVAL   12.00 HOURS
                         TOTAL TIME BASE  180.00 HOURS
```

```
      ENGLISH UNITS
          DRAINAGE AREA         SQUARE MILES
          PRECIPITATION DEPTH   INCHES
          LENGTH, ELEVATION     FEET
          FLOW                  CUBIC FEET PER SECOND
          STORAGE VOLUME        ACRE-FEET
          SURFACE AREA          ACRES
          TEMPERATURE           DEGREES FAHRENHEIT

 OR          OPTIMIZATION OF ROUTING PARAMETERS
                   IFORD           2  FIRST ORDINATE OF OPTIMIZATION REGION
                   ILORD          16  LAST ORDINATE OF OPTIMIZATION REGION


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


        **************
        *            *
  7 KK  *         1  *
        *            *
        **************

          HYDROGRAPH ROUTING DATA

 14 RL       ROUTING LOSSES
                   QLOSS         .00  INITIAL LOSS
                   CLOSS         .00  ADDITIONAL FRACTION LOST

 15 RM       MUSKINGUM ROUTING
                   NSTPS        -1 NUMBER OF SUBREACHES
                   AMSKK     -1.00 MUSKINGUM K
                       X     -1.00 MUSKINGUM X

                                                                   ***

                                               INITIAL ESTIMATES FOR OPTIMIZATION VARIABLES
                AMSKK         X
                12.00       .20

                                               INTERMEDIATE VALUES OF OPTIMIZATION VARIABLES
                                                  (*INDICATES CHANGE FROM PREVIOUS VALUE)
                                                   (+INDICATES VARIABLE WAS NOT CHANGED)
 OBJECTIVE
  FUNCTION        AMSKK          X
        NUMBER OF ROUTING STEPS =  1
    2192.6       18.000*      .200
    2153.2       18.000       .136*

    1785.4       23.146*      .136
    1738.3       23.146       .203*

    1723.5       22.355*      .203
    1721.7       22.355       .192*

    1721.6       22.317*      .192
    1721.6       22.317       .191*


    1721.6       22.316*      .191
        NUMBER OF ROUTING STEPS =  2
    1533.1       21.939*      .191
    1415.2       21.939       .127*

    1414.5       21.813*      .127
    1368.4       21.813       .085*

    1368.1       21.719*      .085
    1350.6       21.719       .057*

    1350.4       21.653*      .057
    1344.1       21.653       .038*


    1344.0       21.608*      .038
        NUMBER OF ROUTING STEPS =  3
    1403.6       21.692*      .038
    1386.6       21.692       .025*
```

```
1386.6       21.675*      .025
1375.9       21.675       .017*

1375.9       21.664*      .017
1369.1       21.664       .011*

1369.1       21.656*      .011
1364.6       21.656       .007*


1364.6       21.651*      .007
       NUMBER OF ROUTING STEPS =  2
1344.0       21.607*      .038
1342.1       21.607       .025*

1342.1       21.577*      .025
1341.8       21.577       .019*

1341.8       21.562*      .019
1341.7       21.562       .018*

1341.7       21.562+      .018
1341.7       21.562       .018*


1341.7       21.558*      .018
```

DERIVED COEFFICIENTS

NSTPS	NSTDL	LAG	AMSKK	X	TSK
2	0	0	21.56	.02	.00

DAY MON	HRMN	ORD	INFLOW	LOCAL	OUTFLOW	ACTUAL
6	0000	1	2200.	3.	2203.	2000.
6	1200	2	2200.	3.	2203.	2000.
7	0000	3	14500.	10.	3719.	7000.
7	1200	4	28400.	16.	9480.	11700.
8	0000	5	31800.	23.	18318.	16500.
8	1200	6	29700.	34.	25339.	24000.
9	0000	7	25300.	41.	27934.	29100.
9	1200	8	20400.	40.	26786.	28400.
10	0000	9	16300.	33.	23550.	23800.
10	1200	10	12600.	27.	19638.	19400.
11	0000	11	9300.	21.	15775.	15300.
11	1200	12	6700.	16.	12238.	11200.
12	0000	13	5000.	11.	9227.	8200.
12	1200	14	4100.	9.	6915.	6400.
13	0000	15	3600.	7.	5332.	5200.
13	1200	16	2400.	6.	4230.	4600.
		SUM	214500.	300.	212887.	214800.

```
                                                          STATION        1

                         (I) INFLOW,   (O) OUTFLOW,   (*) OBSERVED FLOW
         0.     4000.     8000.    12000.    16000.    20000.    24000.    28000.    32000.        0.        0.        0.        0.
DAHRMN PER
 60000   1. . .*I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 61200   2.----*I---.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
 70000   3.        O.       * .         .     I   .         .         .         .         .         .         .         .         .
 71200   4.         .         .   O    *.         .         .         .         .I        .         .         .         .         .
 80000   5.         .         .         .         .*    O   .         .         .         I         .         .         .         .
 81200   6.         .         .         .         .         .         *  O      .   I     .         .         .         .         .
 90000   7.         .         .         .         .         .         .  I      O  *      .         .         .         .         .
 91200   8.         .         .         .         .         .I        .      O  .*        .         .         .         .         .
100000   9.         .         .         .         .I        .        O*         .         .         .         .         .         .
101200  10.         .         .         . I       .        *.         .         .         .         .         .         .         .
110000  11. . . . . . . . . . . .I. . . . . . . *O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
111200  12.         .      I  .       * .O        .         .         .         .         .         .         .         .         .
120000  13.         .  I      .* O      .         .         .         .         .         .         .         .         .         .
121200  14.        I     *O  .         .         .         .         .         .         .         .         .         .         .
130000  15.        I.  *      .         .         .         .         .         .         .         .         .         .         .
131200  16.-----I---.O*-------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.

                    (-) LIMITS OF OPTIMIZATION


*** NORMAL END OF HEC-1 ***
```

12.6 Example Problem #6: Precipitation Depth-Area Simulation for a Basin

In this example, runoff in the river basin shown in Figure 12.4 is to be simulated using the precipitation depth-area relationship given in Table12.6a. The storm pattern, to be used for all drainage basin sizes in this case, is also shown in Table 12.6a.

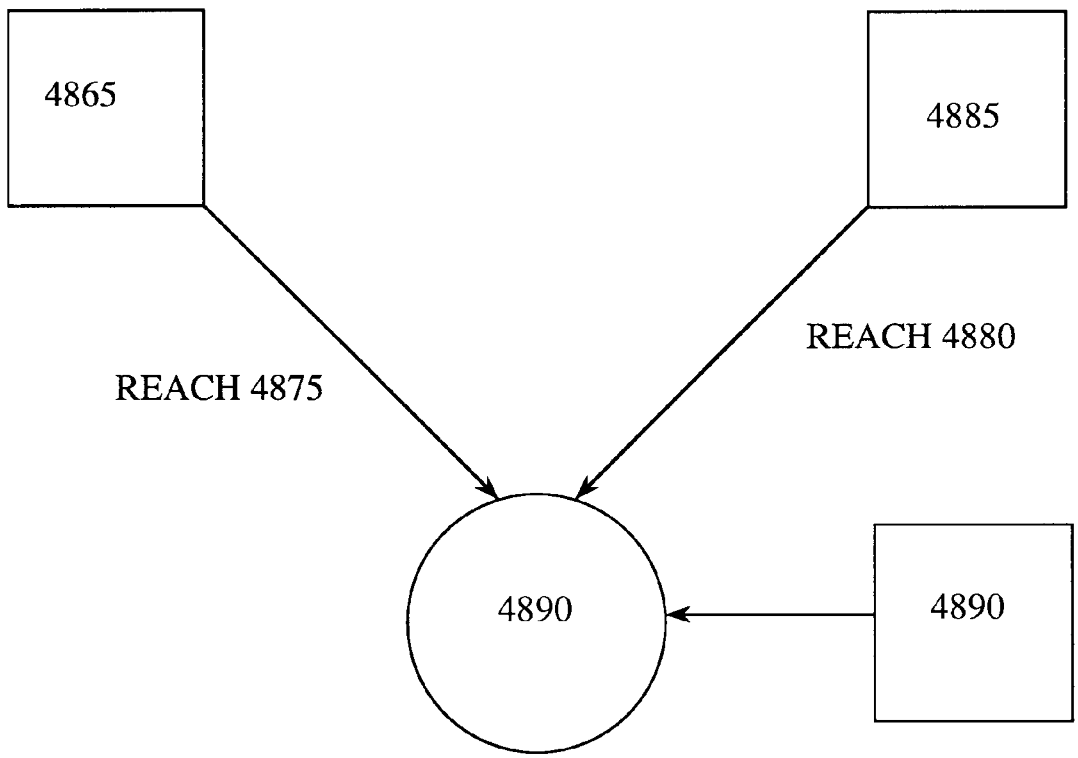

Figure 12.4 Precipitation Depth-Area Analysis Basin

All subbasin system hydrographs are routed and combined as in a stream network computation. However, the resulting hydrograph at any control point is interpolated from the system hydrographs based on the cumulative area to that point. The listing of the input data deck and the resulting depth-area simulation is shown in Table 12.6b.

Table 12.6a

Depth Area Simulation Data
Rainfall Data

Transposition Area (sq mi)	Storm Depth (in)	Record Identifier
1000	9.08	JD
3000	8.93	
5000	8.70	
7000	8.57	
9000	8.43	

Please see data input listing for pattern hyetograph (PI records)

Table 12.6b

Example Problem #6: Input and Output

Input

```
ID       EXAMPLE PROBLEM NO. 6
ID      PRECIPITATION DEPTH-AREA SIMULATION
ID      FOR A RIVER BASIN
ID                          AND INTERPOLATION ROUTINE
IT   120       0       0      97
IO     5
JD  9.08 1000.00
PI0.      0.      0.       .0014   .0015   .0048   .0092   .0048   .0048   .0063
PI .0131   .0141   .0189   .0237   .0189   .0141   .0092   .0048   .0029   .0015
PI .0029  0.      0.      0.       .0087   .0175   .0175   .0175   .0039   .0087
PI0.      0.       .0140  0.       .0097   .0184  0.      0.       .0310  0.
PI0.       .0209   .0179   .0155   .0155   .0058   .0131   .0155   .0063   .0097
PI .0087   .0126   .0175   .0146   .0121   .0141   .0141   .0136   .0126   .0155
PI .0170   .0233   .0209   .0276   .0340   .0660   .0209   .0184   .0170   .0155
PI .0146   .0126   .0073   .0107   .0049   .0073   .0034   .0024  0.      0.
PI .0107  0.       .0107   .0310   .0048   .0281   .0141   .0048   .0039   .0087
PI0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
JD  8.93 3000.00
JD  8.70 5000.00
JD  8.57 7000.00
JD  8.43 9000.00
KK  4865
KO     3
BA 3503.    0.
LE   .40    0.      4.00     .70    0.
UC 12.30    8.60
BF 1200.   3000.  1.0132
KK  4890
RL    0.    0.
RT    24       2       0
KK  4885
BA 1750.    0.
LE   .33    0.      4.00     .70    0.
UC  6.60    4.60
BF  280.    700.  1.0147
KK  4890
RL    0.    0.
RT    12       2       0
KK  4890
BA 3296.    0.
LE   .39    0.      4.00     .70    0.
UC 13.20    9.20
BF  400.   1000.  1.0147
KK  4890
HC     3
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*            JUN   1998                 *
*         VERSION 4.1                   *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:41   *
*                                       *
*****************************************

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1           ID         EXAMPLE PROBLEM NO. 6
            2           ID        PRECIPITATION DEPTH-AREA SIMULATION
            3           ID        FOR A RIVER BASIN
            4           ID                          AND INTERPOLATION ROUTINE
            5           IT     120       0       0      97
            6           IO       5
            7           JD    9.08 1000.00
            8           PI  0.      0.      0.       .0014   .0015   .0048   .0092   .0048   .0048   .0063
            9           PI   .0131   .0141   .0189   .0237   .0189   .0141   .0092   .0048   .0029   .0015
           10           PI   .0029  0.      0.      0.       .0087   .0175   .0175   .0175   .0039   .0087
           11           PI  0.      0.       .0140  0.       .0097   .0184  0.      0.       .0310  0.
           12           PI  0.       .0209   .0179   .0155   .0155   .0058   .0131   .0155   .0063   .0097
           13           PI   .0087   .0126   .0175   .0146   .0121   .0141   .0141   .0136   .0126   .0155
           14           PI   .0170   .0233   .0209   .0276   .0340   .0660   .0209   .0184   .0170   .0155
           15           PI   .0146   .0126   .0073   .0107   .0049   .0073   .0034   .0024  0.      0.
           16           PI   .0107  0.       .0107   .0310   .0048   .0281   .0141   .0048   .0039   .0087
           17           PI  0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
           18           JD    8.93 3000.00
           19           JD    8.70 5000.00
           20           JD    8.57 7000.00
           21           JD    8.43 9000.00

           22           KK    4865
           23           KO       3
           24           BA   3503.     0.
           25           LE     .40     0.      4.00     .70     0.
           26           UC   12.30    8.60
           27           BF   1200.   3000.  1.0132

           28           KK    4890
           29           RL      0.      0.
           30           RT      24       2       0

           31           KK    4885
           32           BA   1750.     0.
           33           LE     .33     0.      4.00     .70     0.
           34           UC    6.60    4.60
           35           BF    280.    700.  1.0147

           36           KK    4890
           37           RL      0.      0.
           38           RT      12       2       0

           39           KK    4890
           40           BA   3296.     0.
           41           LE     .39     0.      4.00     .70     0.
           42           UC   13.20    9.20
           43           BF    400.   1000.  1.0147

           44           KK    4890
           45           HC       3
           46           ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:38:41   *
*                                       *
*****************************************


                                 EXAMPLE PROBLEM NO. 6
                                 PRECIPITATION DEPTH-AREA SIMULATION
                                 FOR A RIVER BASIN
                                                    AND INTERPOLATION ROUTINE
    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN         120  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1    0  STARTING DATE
                        ITIME        0000  STARTING TIME
                           NQ          97  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      9    0  ENDING DATE
                       NDTIME        0000  ENDING TIME
                       ICENT           19  CENTURY MARK

                      COMPUTATION INTERVAL    2.00 HOURS
                           TOTAL TIME BASE  192.00 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT

    7 JD          INDEX STORM NO. 1
                         STRM        9.08  PRECIPITATION DEPTH
                         TRDA     1000.00  TRANSPOSITION DRAINAGE AREA

    8 PI            PRECIPITATION PATTERN
               .00      .00      .00      .00      .00      .00      .01      .00      .00      .01
               .01      .01      .02      .02      .02      .01      .01      .00      .00      .00
                    .00      .00               .00      .00      .00      .00      .01      .02      .02
 .02       .00      .01
               .00      .00      .01      .00      .01      .02      .00      .00      .03      .00
               .00      .02      .02      .02      .02      .01      .01      .02      .01      .01
               .01      .01      .02      .01      .01      .01      .01      .01      .01      .02
               .02      .02      .02      .03      .03      .07      .02      .02      .02      .02
               .01      .01      .01      .01      .00      .01      .00      .00      .00      .00
               .01      .00      .01      .03      .00      .03      .01      .00      .00      .01

   18 JD          INDEX STORM NO. 2
                         STRM        8.93  PRECIPITATION DEPTH
                         TRDA     3000.00  TRANSPOSITION DRAINAGE AREA

    0 PI            PRECIPITATION PATTERN
                      .00      .00      .00      .00      .00      .00      .01      .00      .00      .01
                      .01      .01      .02      .02      .02      .01      .01      .00      .00      .00
                      .00      .00      .00      .00      .01      .02      .02      .02      .00      .01
                      .00      .00      .01      .00      .01      .02      .00      .00      .03      .00
                      .00      .02      .02      .02      .02      .01      .01      .02      .01      .01
                      .01      .01      .02      .01      .01      .01      .01      .01      .01      .02
                      .02      .02      .02      .03      .03      .07      .02      .02      .02      .02
                      .01      .01      .01      .01      .00      .01      .00      .00      .00      .00
                      .01      .00      .01      .03      .00      .03      .01      .00      .00      .01

   19 JD          INDEX STORM NO. 3
                         STRM        8.70  PRECIPITATION DEPTH
                         TRDA     5000.00  TRANSPOSITION DRAINAGE AREA

    0 PI            PRECIPITATION PATTERN
                      .00      .00      .00      .00      .00      .00      .01      .00      .00      .01
                      .01      .01      .02      .02      .02      .01      .01      .00      .00      .00
                      .00      .00      .00      .00      .01      .02      .02      .02      .00      .01
```

```
                    .00       .00       .01       .00       .01       .02       .00       .00       .03       .00
                    .00       .02       .02       .02       .02       .01       .01       .02       .01       .01
                    .01       .01       .02       .01       .01       .01       .01       .01       .01       .02
                    .02       .02       .02       .03       .03       .07       .02       .02       .02       .02
                    .01       .01       .01       .01       .00       .01       .00       .00       .00       .00
                    .01       .00       .01       .03       .00       .03       .01       .00       .00       .01

  20 JD        INDEX STORM NO. 4
                      STRM       8.57  PRECIPITATION DEPTH
                      TRDA    7000.00  TRANSPOSITION DRAINAGE AREA

   0 PI          PRECIPITATION PATTERN
                    .00       .00       .00       .00       .00       .00       .01       .00       .00       .01
                    .01       .01       .02       .02       .02       .01       .01       .00       .00       .00
                    .00       .00       .00       .00       .01       .02       .02       .02       .00       .01
                    .00       .00       .01       .00       .01       .02       .00       .00       .03       .00
                    .00       .02       .02       .02       .02       .01       .01       .02       .01       .01
                    .01       .01       .02       .01       .01       .01       .01       .01       .01       .02
                    .02       .02       .02       .03       .03       .07       .02       .02       .02       .02
                    .01       .01       .01       .01       .00       .01       .00       .00       .00       .00
                    .01       .00       .01       .03       .00       .03       .01       .00       .00       .01

  21 JD        INDEX STORM NO. 5
                      STRM       8.43  PRECIPITATION DEPTH
                      TRDA    9000.00  TRANSPOSITION DRAINAGE AREA

   0 PI          PRECIPITATION PATTERN
                    .00       .00       .00       .00       .00       .00       .01       .00       .00       .01
                    .01       .01       .02       .02       .02       .01       .01       .00       .00       .00
                    .00       .00       .00       .00       .01       .02       .02       .02       .00       .01
                    .00       .00       .01       .00       .01       .02       .00       .00       .03       .00
                    .00       .02       .02       .02       .02       .01       .01       .02       .01       .01
                    .01       .01       .02       .01       .01       .01       .01       .01       .01       .02
                    .02       .02       .02       .03       .03       .07       .02       .02       .02       .02
                    .01       .01       .01       .01       .00       .01       .00       .00       .00       .00
                    .01       .00       .01       .03       .00       .03       .01       .00       .00       .01


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

          **************
          *            *
  22 KK   *      4865  *
          *            *
          **************

  23 KO        OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
                     IPLOT          0  PLOT CONTROL
                     QSCAL         0.  HYDROGRAPH PLOT SCALE

             SUBBASIN RUNOFF DATA

  24 BA        SUBBASIN CHARACTERISTICS
                     TAREA    3503.00  SUBBASIN AREA

  27 BF        BASE FLOW CHARACTERISTICS
                     STRTQ    1200.00  INITIAL FLOW
                     QRCSN    3000.00  BEGIN BASE FLOW RECESSION
                     RTIOR    1.01320  RECESSION CONSTANT

  25 LE        EXPONENTIAL LOSS RATE
                     STRKR        .40  INITIAL VALUE OF LOSS COEFFICIENT
                     DLTKR        .00  INITIAL LOSS
                     RTIOL       4.00  LOSS COEFFICIENT RECESSION CONSTANT
                     ERAIN        .70  EXPONENT OF PRECIPITATION
                     RTIMP        .00  PERCENT IMPERVIOUS AREA

  26 UC        CLARK UNITGRAPH
                        TC      12.30  TIME OF CONCENTRATION
                         R       8.60  STORAGE COEFFICIENT

               SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                           ***

                                                  UNIT HYDROGRAPH PARAMETERS
                                            CLARK   TC= 12.30 HR,       R=  8.60 HR
                                           SNYDER   TP= 10.29 HR,      CP=   .65
```

```
                                               UNIT HYDROGRAPH
                                            27 END-OF-PERIOD ORDINATES
       10918.   39523.   77100.  113480.  137385.  142547.  126313.  100632.   79667.   63070.
       49930.   39528.   31293.   24774.   19613.   15527.   12292.    9731.    7704.    6099.
        4828.    3822.    3026.    2396.    1897.    1501.    1189.

  ***             ***             ***             ***             ***

                    HYDROGRAPH AT STATION     4865
                  TRANSPOSITION AREA   1000.0 SQ MI

   TOTAL RAINFALL =    9.08, TOTAL LOSS =    5.37, TOTAL EXCESS =    3.71

PEAK FLOW     TIME                         MAXIMUM AVERAGE FLOW
 (CFS)        (HR)                   6-HR       24-HR       72-HR    192.00-HR

 158251.   140.00      (CFS)      155074.     124589.      78467.       42735.
                    (INCHES)         .412       1.323       2.499        3.630
                     (AC-FT)       76896.     247119.     466913.      678114.

                     CUMULATIVE AREA = 3503.00 SQ MI


  ***             ***             ***             ***             ***

                    HYDROGRAPH AT STATION     4865
                  TRANSPOSITION AREA   3000.0 SQ MI

   TOTAL RAINFALL =    8.93, TOTAL LOSS =    5.32, TOTAL EXCESS =    3.61

PEAK FLOW     TIME                         MAXIMUM AVERAGE FLOW
 (CFS)        (HR)                   6-HR       24-HR       72-HR    192.00-HR

 154475.   140.00      (CFS)      151369.     121524.      76450.       41543.
                    (INCHES)         .402       1.290       2.435        3.528
                     (AC-FT)       75059.     241039.     454908.      659196.

                     CUMULATIVE AREA = 3503.00 SQ MI


  ***             ***             ***             ***             ***

                    HYDROGRAPH AT STATION     4865
                  TRANSPOSITION AREA   5000.0 SQ MI

   TOTAL RAINFALL =    8.70, TOTAL LOSS =    5.25, TOTAL EXCESS =    3.45

PEAK FLOW     TIME                         MAXIMUM AVERAGE FLOW
 (CFS)        (HR)                   6-HR       24-HR       72-HR    192.00-HR

 148710.   140.00      (CFS)      145712.     116845.      73371.       39726.
                    (INCHES)         .387       1.241       2.337        3.374
                     (AC-FT)       72254.     231758.     436588.      630363.

                     CUMULATIVE AREA = 3503.00 SQ MI


  ***             ***             ***             ***             ***

                    HYDROGRAPH AT STATION     4865
                  TRANSPOSITION AREA   7000.0 SQ MI

   TOTAL RAINFALL =    8.57, TOTAL LOSS =    5.21, TOTAL EXCESS =    3.36

PEAK FLOW     TIME                         MAXIMUM AVERAGE FLOW
 (CFS)        (HR)                   6-HR       24-HR       72-HR    192.00-HR

145464.   140.00      (CFS)      142527.     114212.      71639.       38705.
                    (INCHES)         .378       1.213       2.282        3.287
                     (AC-FT)       70675.     226536.     426282.      614162.

                     CUMULATIVE AREA = 3503.00 SQ MI


  ***             ***             ***             ***             ***
```

HYDROGRAPH AT STATION 4865
TRANSPOSITION AREA 9000.0 SQ MI

TOTAL RAINFALL = 8.43, TOTAL LOSS = 5.16, TOTAL EXCESS = 3.27

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	192.00-HR
141980.	140.00	(CFS)	139109.	111386.	69780.	37611.
		(INCHES)	.369	1.183	2.223	3.194
		(AC-FT)	68979.	220930.	415223.	596796.

CUMULATIVE AREA = 3503.00 SQ MI

*** *** *** *** ***

INTERPOLATED HYDROGRAPH AT 4865

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	192.00-HR
152726.	140.00	(CFS)	149653.	120104.	75516.	40992.
		(INCHES)	.397	1.275	2.405	3.482
		(AC-FT)	74208.	238223.	449349.	650447.

CUMULATIVE AREA = 3503.00 SQ MI

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	4865	152726.	140.00	149653.	120104.	75516.	3503.00		
ROUTED TO	4890	134678.	166.00	132570.	114463.	72205.	3503.00		
HYDROGRAPH AT	4885	112011.	136.00	103306.	72302.	43669.	1750.00		
ROUTED TO	4890	93847.	148.00	91223.	70648.	43403.	1750.00		
HYDROGRAPH AT	4890	142090.	142.00	138339.	113338.	72159.	3296.00		
3 COMBINED AT	4890	249934.	146.00	247715.	227713.	172326.	8549.00		

*** NORMAL END OF HEC-1 ***

12.7 Example Problem #7: Dam Safety Analysis

Two examples of dam analysis are included in these example problems: Test 7 illustrates evaluations of overtopping of the dam, and Test 8 shows the analysis of the downstream consequences resulting from various assumed dam breaches. The desired hydrologic analysis includes evaluations of overtopping the dam and of various types of structural failures. Figure 12.5 illustrates the schematic of the Bear Creek system and associated hydrologic data. Table 12.7a gives pertinent reservoir data.

Problem Description. Test 7 analyzes the overtopping potential of the Bear Creek Dam. Ratios of the PMF were generated and routed through the reservoir to determine the event (expressed as percent of the PMF) that would overtop the structure. The general procedure used in the analysis was:

Develop the PMP for area above the reservoir from input index rainfall parameters.

- Determine average basin loss rates and probable maximum rainfall excess.
- Develop a unit hydrograph using the Snyder method.
- Generate the runoff hydrograph and add base flow to get probable maximum inflow hydrograph to the reservoir.
- Apply ratios to the PMF to obtain a series of proportional inflow hydrographs.
- Develop reservoir storage-outflow functions from elevation-area relationship and characteristics of reservoir outlet works and dam.
- Route hydrographs through the reservoir and determine the ratio of the PMP that overtops the dam.

The input data and output from the HEC-1 program are shown in Table 12.7b.

Discussion of Results. The last page of the HEC-1 output (Table 12.7b) provides a "SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION DAM" which illustrates the potential of the dam to overtop as a ratio of the PMF. Also, data on duration of overtopping and maximum water surface elevations, for use in determining possible dam failure due to erosion are shown. Interpolation of the information provided in that summary indicates that a flood of about thirty percent of the PMF would overtop the dam.

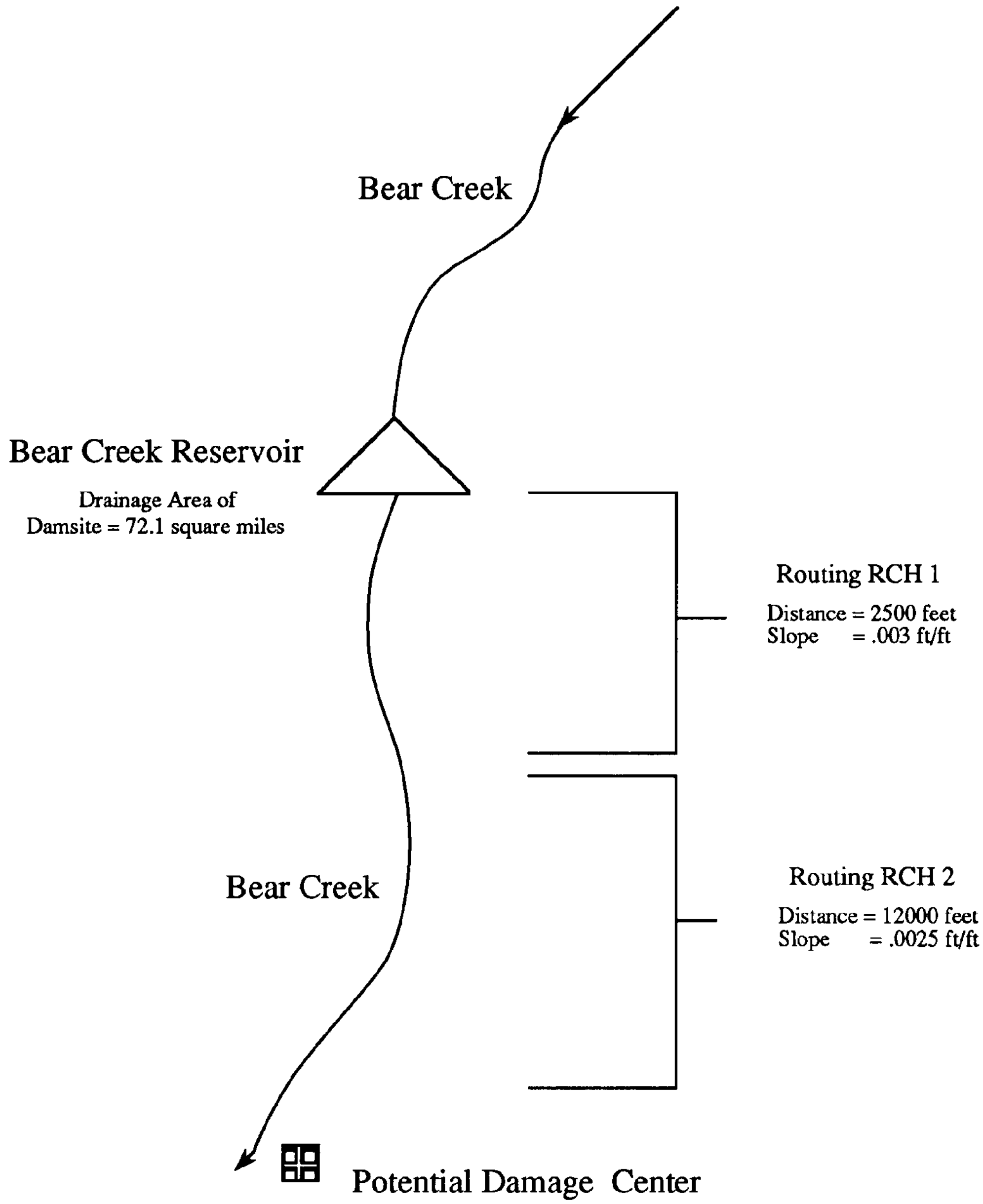

Figure 12.5 Schematic Bear Creek Basin

Table 12.7a

Reservoir Data

			Record Identifier
Outflow characteristics of the Bear Creek Reservoir			
Low level outlet			SL
• Diameter	=	4 feet	
• Coefficient of discharge	=	.7	
• Downstream centerline elevation of outlet	=	380.0 m.s.l.	
• Exponent of head	=	.5	
Spillway			SS
• Crest elevation	=	420.0 m.s.l.	
• Length	=	200 feet	
• Weir coefficient	=	3.1	
• Exponent of head	=	1.5	
Dam			ST
• Crest elevation	=	432.0 m.s.l.	
• Length	=	900 feet	
• Weir coefficient	=	3.1	
• Exponent of head	=	1.5	

Reservoir elevation-area relationship for the Bear Creek Reservoir

Elevation (m.s.l.)	**Area (acres)**	SE, SA
340	0	
380	100	
410	250	
420	300	
424	320	
428	350	
432	380	
436	410	
440	450	
444	500	

Table 12.7b

Example Problem #7: Input and Output

Input

```
ID       EXAMPLE PROBLEM NO. 7
ID       DAM SAFETY ANALYSIS
ID            ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
IT    15       0       0     121
IO     5
JR  FLOW     .20     .35     .50     .65     .80     1.0
KKINFLOW   INFLOW TO BEAR CREEK RESERVOIR
BA  72.1
BF  -1.0    -.05     2.0
PM    25       0       0              82      97     110
LU   1.0     .04
US   4.8     .60
KK   DAM      BEAR CREEK DAM
KO     1
RS     1    STOR   10000
SA     0     100     250     300     320     350     380     410     450     500
SE   340     380     410     420     424     428     432     436     440     444
SS   420     200     3.1     1.5
SL   380    12.6      .7      .5
ST   432     900     3.1     1.5
KK  RCH1
KM     ROUTE OUTFLOW FROM RESERVOIR THROUGH FIRST CHANNEL REACH DOWNSTREAM
RS     1    STOR      -1
RC   .04     .05     .04   15000   .0033     312
RX     0     500    1400    1425    1450    1475    2500    3000
RY   400     350     290     280     280     290     350     400
ZZ
```

Output

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*             JUN   1998               *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   10JUN98  TIME  20:38:55  *
*                                      *
****************************************
```

```
                                         HEC-1 INPUT                                      PAGE  1

       LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

         1            ID        EXAMPLE PROBLEM NO. 7
         2            ID        DAM SAFETY ANALYSIS
         3            ID              ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
 *** FREE ***
         4            IT      15       0       0     121
         5            IO       5
         6            JR    FLOW     .20     .35     .50     .65     .80     1.0

         7            KK  INFLOW   INFLOW TO BEAR CREEK RESERVOIR
         8            BA    72.1
         9            BF    -1.0    -.05     2.0
        10            PM      25       0       0              82      97     110
        11            LU     1.0     .04
        12            US     4.8     .60

        13            KK     DAM      BEAR CREEK DAM
        14            KO       1
        15            RS       1    STOR   10000
        16            SA       0     100     250     300     320     350     380     410     450     500
        17            SE     340     380     410     420     424     428     432     436     440     444
        18            SS     420     200     3.1     1.5
        19            SL     380    12.6      .7      .5
        20            ST     432     900     3.1     1.5

        21            KK    RCH1
        22            KM       ROUTE OUTFLOW FROM RESERVOIR THROUGH FIRST CHANNEL REACH DOWNSTREAM
        23            RS       1    STOR      -1
        24            RC     .04     .05     .04   15000   .0033     312
        25            RX       0     500    1400    1425    1450    1475    2500    3000
        26            RY     400     350     290     280     280     290     350     400
        27            ZZ
```


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****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*             JUN   1998               *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   10JUN98  TIME  20:38:55  *
*                                      *
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                              EXAMPLE PROBLEM NO. 7
                              DAM SAFETY ANALYSIS
                                    ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
```

```
   IT         HYDROGRAPH TIME DATA
                    NMIN          15  MINUTES IN COMPUTATION INTERVAL
                   IDATE       1    0  STARTING DATE
                   ITIME        0000  STARTING TIME
                      NQ         121  NUMBER OF HYDROGRAPH ORDINATES
                  NDDATE       2    0  ENDING DATE
                  NDTIME        0600  ENDING TIME
                  ICENT           19  CENTURY MARK

              COMPUTATION INTERVAL     .25 HOURS
                   TOTAL TIME BASE   30.00 HOURS

        ENGLISH UNITS
             DRAINAGE AREA         SQUARE MILES
             PRECIPITATION DEPTH   INCHES
             LENGTH, ELEVATION     FEET
             FLOW                  CUBIC FEET PER SECOND
             STORAGE VOLUME        ACRE-FEET
             SURFACE AREA          ACRES
             TEMPERATURE           DEGREES FAHRENHEIT

   JP         MULTI-PLAN OPTION
                   NPLAN           1  NUMBER OF PLANS

   JR         MULTI-RATIO OPTION
                 RATIOS OF RUNOFF
                 .20       .35       .50       .65       .80      1.00
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*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
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          **************
          *            *
  13 KK   *       DAM  *          BEAR CREEK DAM
          *            *
          **************

  14 KO         OUTPUT CONTROL VARIABLES
                      IPRNT           1  PRINT CONTROL
                      IPLOT           0  PLOT CONTROL
                      QSCAL          0.  HYDROGRAPH PLOT SCALE

              HYDROGRAPH ROUTING DATA

  15 RS         STORAGE ROUTING
                      NSTPS           1  NUMBER OF SUBREACHES
                       ITYP        STOR  TYPE OF INITIAL CONDITION
                     RSVRIC    10000.00  INITIAL CONDITION
                          X         .00 WORKING R AND D COEFFICIENT

  16 SA              AREA       .0   100.0   250.0   300.0   320.0   350.0   380.0   410.0   450.0   500.0


  17 SE         ELEVATION   340.00  380.00  410.00  420.00  424.00  428.00  432.00  436.00  440.00  444.00


  19 SL         LOW-LEVEL OUTLET
                      ELEVL      380.00  ELEVATION AT CENTER OF OUTLET
                      CAREA       12.60  CROSS-SECTIONAL AREA
                       COQL         .70  COEFFICIENT
                       EXPL         .50  EXPONENT OF HEAD

  18 SS         SPILLWAY
                       CREL      420.00  SPILLWAY CREST ELEVATION
                      SPWID      200.00  SPILLWAY WIDTH
                       COQW        3.10  WEIR COEFFICIENT
                       EXPW        1.50  EXPONENT OF HEAD

  20 ST         TOP OF DAM
                      TOPEL      432.00  ELEVATION AT TOP OF DAM
                     DAMWID      900.00  DAM WIDTH
                       COQD        3.10  WEIR COEFFICIENT
                       EXPD        1.50  EXPONENT OF HEAD

                                                   ***
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COMPUTED STORAGE-ELEVATION DATA

STORAGE	.00	1333.33	6414.47	9160.68	10400.46	11740.01	13199.60	14779.22	16498.60	18397.72
ELEVATION	340.00	380.00	410.00	420.00	424.00	428.00	432.00	436.00	440.00	444.00

COMPUTED OUTFLOW-ELEVATION DATA

(EXCLUDING FLOW OVER DAM)

OUTFLOW	.00	.00	102.19	114.85	131.09	152.68	182.78	227.66	301.76	447.38
ELEVATION	340.00	380.00	382.09	382.64	383.43	384.66	386.68	390.36	398.20	420.00
OUTFLOW	524.09	1044.57	2444.54	5159.65	9625.54	16277.80	25552.04	37883.85	53708.95	73462.70
ELEVATION	420.25	420.97	422.17	423.85	426.01	428.65	431.77	435.37	439.45	444.00

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

(INCLUDING FLOW OVER DAM)

STORAGE	.00	1333.33	1550.58	1610.64	1700.12	1842.50	2091.06	2590.89	3870.13	6414.47
OUTFLOW	.00	.00	102.19	114.85	131.09	152.68	182.78	227.66	301.76	387.44
ELEVATION	340.00	380.00	382.09	382.64	383.43	384.66	386.68	390.36	398.20	410.00
STORAGE	9160.68	9234.42	9453.83	9824.07	10353.85	10400.46	11060.17	11740.01	11970.54	13113.30
OUTFLOW	447.38	524.09	1044.57	2444.54	5159.65	5429.21	9625.54	14519.08	16277.80	25552.04
ELEVATION	420.00	420.25	420.97	422.17	423.85	424.00	426.01	428.00	428.65	431.77
STORAGE	13199.60	14522.20	14779.22	16250.56	16498.60	18397.72				
OUTFLOW	26283.00	55139.68	62529.34	110388.80	119132.90	189440.80				
ELEVATION	432.00	435.37	436.00	439.45	440.00	444.00				

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = .20

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	1		1015	42	578.	9266.2	420.4	1		2030	83	16151.	11954.1	428.6
1		0015	2	2921.	9928.0	422.5	1		1030	43	612.	9283.9	420.4	1		2045	84	16534.	12003.6	428.7
1		0030	3	2654.	9870.7	422.3	1		1045	44	653.	9303.8	420.5	1		2100	85	16808.	12039.0	428.8
1		0045	4	2420.	9818.4	422.2	1		1100	45	702.	9325.8	420.5	1		2115	86	16974.	12060.3	428.9
1		0100	5	2213.	9770.8	422.0	1		1115	46	758.	9349.6	420.6	1		2130	87	17040.	12068.7	428.9
1		0115	6	2030.	9727.1	421.9	1		1130	47	822.	9375.0	420.7	1		2145	88	17016.	12065.6	428.9
1		0130	7	1867.	9686.9	421.7	1		1145	48	894.	9401.7	420.8	1		2200	89	16910.	12052.1	428.9
1		0145	8	1722.	9649.9	421.6	1		1200	49	972.	9429.3	420.9	1		2215	90	16735.	12029.5	428.8
1		0200	9	1593.	9615.8	421.5	1		1215	50	1057.	9457.8	421.0	1		2230	91	16498.	11999.0	428.7
1		0215	10	1477.	9584.1	421.4	1		1230	51	1147.	9487.0	421.1	1		2245	92	16210.	11961.7	428.6
1		0230	11	1373.	9554.7	421.3	1		1245	52	1245.	9516.9	421.2	1		2300	93	15878.	11918.7	428.5
1		0245	12	1280.	9527.4	421.2	1		1300	53	1349.	9547.7	421.3	1		2315	94	15513.	11871.0	428.4
1		0300	13	1195.	9501.9	421.1	1		1315	54	1461.	9579.6	421.4	1		2330	95	15122.	11819.6	428.2
1		0315	14	1119.	9478.0	421.0	1		1330	55	1582.	9612.9	421.5	1		2345	96	14713.	11765.7	428.1
1		0330	15	1050.	9455.6	421.0	1		1345	56	1714.	9647.9	421.6	2		0000	97	14293.	11709.9	427.9
1		0345	16	987.	9434.6	420.9	1		1400	57	1859.	9684.9	421.7	2		0015	98	13867.	11653.0	427.8
1		0400	17	930.	9414.8	420.8	1		1415	58	2018.	9724.2	421.9	2		0030	99	13440.	11595.5	427.6
1		0415	18	879.	9396.1	420.8	1		1430	59	2194.	9766.4	422.0	2		0045	100	13015.	11537.8	427.4
1		0430	19	832.	9378.5	420.7	1		1445	60	2391.	9811.9	422.1	2		0100	101	12594.	11480.3	427.3
1		0445	20	788.	9361.7	420.7	1		1500	61	2610.	9860.9	422.3	2		0115	102	12178.	11423.0	427.1
1		0500	21	749.	9345.9	420.6	1		1515	62	2855.	9914.0	422.5	2		0130	103	11770.	11366.3	426.9
1		0515	22	713.	9330.8	420.6	1		1530	63	3128.	9971.3	422.6	2		0145	104	11369.	11310.2	426.8
1		0530	23	681.	9316.4	420.5	1		1545	64	3436.	10033.9	422.8	2		0200	105	10977.	11254.8	426.6
1		0545	24	651.	9302.6	420.5	1		1600	65	3789.	10103.1	423.1	2		0215	106	10593.	11200.2	426.4
1		0600	25	623.	9289.5	420.4	1		1615	66	4195.	10180.1	423.3	2		0230	107	10219.	11146.4	426.3
1		0615	26	599.	9277.1	420.4	1		1630	67	4661.	10265.4	423.6	2		0245	108	9853.	11093.4	426.1
1		0630	27	576.	9265.3	420.3	1		1645	68	5189.	10359.0	423.9	2		0300	109	9496.	11041.2	426.0
1		0645	28	557.	9254.3	420.3	1		1700	69	5781.	10460.2	424.2	2		0315	110	9149.	10989.8	425.8
1		0700	29	540.	9244.2	420.3	1		1715	70	6433.	10568.4	424.5	2		0330	111	8809.	10939.2	425.7
1		0715	30	525.	9235.1	420.2	1		1730	71	7142.	10682.5	424.9	2		0345	112	8479.	10889.4	425.5
1		0730	31	513.	9227.2	420.2	1		1745	72	7902.	10801.3	425.2	2		0400	113	8156.	10840.4	425.4
1		0745	32	504.	9220.7	420.2	1		1800	73	8705.	10923.6	425.6	2		0415	114	7843.	10792.1	425.2
1		0800	33	497.	9215.7	420.2	1		1815	74	9543.	11048.0	426.0	2		0430	115	7537.	10744.7	425.1
1		0815	34	493.	9212.4	420.2	1		1830	75	10401.	11172.7	426.3	2		0445	116	7241.	10698.0	424.9
1		0830	35	491.	9211.1	420.2	1		1845	76	11265.	11295.6	426.7	2		0500	117	6952.	10652.3	424.8
1		0845	36	492.	9211.8	420.2	1		1900	77	12117.	11414.6	427.1	2		0515	118	6673.	10607.3	424.6
1		0900	37	496.	9214.7	420.2	1		1915	78	12941.	11527.7	427.4	2		0530	119	6402.	10563.3	424.5
1		0915	38	503.	9220.1	420.2	1		1930	79	13720.	11633.3	427.7	2		0545	120	6140.	10520.2	424.4
1		0930	39	514.	9227.8	420.2	1		1945	80	14443.	11729.8	428.0	2		0600	121	5888.	10478.2	424.2
1		0945	40	530.	9238.1	420.3	1		2000	81	15095.	11816.2	428.2							
1		1000	41	551.	9250.9	420.3	1		2015	82	15668.	11891.3	428.4							

PEAK OUTFLOW IS 17040. AT TIME 21.50 HOURS

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
17040.	21.50	(CFS)	15289.	7102.	5965.	5965.
		(INCHES)	1.972	3.663	3.846	3.846
		(AC-FT)	7581.	14087.	14790.	14790.

PEAK STORAGE (AC-FT)	TIME (HR)	MAXIMUM AVERAGE STORAGE 6-HR	24-HR	72-HR	30.00-HR
12069.	21.50	11840.	10516.	10322.	10322.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	30.00-HR
428.93	21.50	428.28	424.26	423.66	423.66

CUMULATIVE AREA = 72.10 SQ MI

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = .35

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	1		1015	42	812.	9371.0	420.7	1		2030	83	30687.	13494.1	432.8
1		0015	2	2922.	9928.2	422.5	1		1030	43	905.	9405.7	420.8	1		2045	84	31357.	13530.5	432.9
1		0030	3	2656.	9871.0	422.3	1		1045	44	1014.	9443.7	420.9	1		2100	85	31622.	13544.5	432.9
1		0045	4	2422.	9818.9	422.2	1		1100	45	1139.	9484.5	421.1	1		2115	86	31543.	13540.4	432.9
1		0100	5	2215.	9771.3	422.0	1		1115	46	1281.	9527.7	421.2	1		2130	87	31205.	13522.3	432.8
1		0115	6	2032.	9727.6	421.9	1		1130	47	1436.	9572.7	421.4	1		2145	88	30681.	13493.8	432.8
1		0130	7	1870.	9687.5	421.7	1		1145	48	1605.	9619.0	421.5	1		2200	89	30027.	13457.1	432.7
1		0145	8	1725.	9650.6	421.6	1		1200	49	1786.	9666.3	421.7	1		2215	90	29287.	13414.0	432.6
1		0200	9	1595.	9616.4	421.5	1		1215	50	1976.	9714.0	421.8	1		2230	91	28497.	13365.4	432.4
1		0215	10	1479.	9584.8	421.4	1		1230	51	2176.	9762.0	422.0	1		2245	92	27690.	13312.2	432.3
1		0230	11	1375.	9555.4	421.3	1		1245	52	2385.	9810.6	422.1	1		2300	93	26904.	13254.6	432.1
1		0245	12	1282.	9528.0	421.2	1		1300	53	2605.	9860.0	422.3	1		2315	94	26197.	13189.5	432.0
1		0300	13	1197.	9502.5	421.1	1		1315	54	2838.	9910.5	422.4	1		2330	95	25589.	13117.7	431.8
1		0315	14	1121.	9478.6	421.1	1		1330	55	3086.	9962.6	422.6	1		2345	96	24933.	13039.9	431.6
1		0330	15	1052.	9456.2	421.0	1		1345	56	3352.	10017.0	422.8	2		0000	97	24252.	12958.7	431.4
1		0345	16	989.	9435.2	420.9	1		1400	57	3641.	10074.2	423.0	2		0015	98	23547.	12874.3	431.1
1		0400	17	932.	9415.3	420.8	1		1415	58	3955.	10134.9	423.2	2		0030	99	22832.	12788.1	430.9
1		0415	18	880.	9396.7	420.8	1		1430	59	4301.	10199.8	423.4	2		0045	100	22113.	12701.0	430.7
1		0430	19	833.	9379.0	420.7	1		1445	60	4683.	10269.5	423.6	2		0100	101	21397.	12613.6	430.4
1		0445	20	790.	9362.2	420.7	1		1500	61	5107.	10344.7	423.8	2		0115	102	20686.	12526.4	430.2
1		0500	21	750.	9346.3	420.6	1		1515	62	5579.	10426.0	424.1	2		0130	103	19985.	12439.8	430.0
1		0515	22	714.	9331.2	420.6	1		1530	63	6103.	10514.0	424.4	2		0145	104	19296.	12354.1	429.7
1		0530	23	682.	9316.8	420.5	1		1545	64	6690.	10610.1	424.7	2		0200	105	18620.	12269.3	429.5
1		0545	24	652.	9303.1	420.5	1		1600	65	7360.	10716.8	425.0	2		0215	106	17958.	12185.7	429.3
1		0600	25	624.	9290.0	420.4	1		1615	66	8129.	10836.1	425.3	2		0230	107	17311.	12103.4	429.0
1		0615	26	600.	9277.7	420.4	1		1630	67	9007.	10968.8	425.7	2		0245	108	16678.	12022.3	428.8
1		0630	27	578.	9266.1	420.4	1		1645	68	9998.	11114.5	426.2	2		0300	109	16061.	11942.4	428.6
1		0645	28	559.	9255.6	420.3	1		1700	69	11101.	11272.4	426.6	2		0315	110	15458.	11863.8	428.4
1		0700	29	543.	9246.3	420.3	1		1715	70	12309.	11441.1	427.1	2		0330	111	14870.	11786.5	428.1
1		0715	30	531.	9238.6	420.3	1		1730	71	13614.	11618.9	427.7	2		0345	112	14297.	11710.4	427.9
1		0730	31	521.	9232.7	420.2	1		1745	72	15001.	11803.7	428.2	2		0400	113	13738.	11635.6	427.7
1		0745	32	516.	9228.9	420.2	1		1800	73	16456.	11993.5	428.7	2		0415	114	13194.	11562.1	427.5
1		0800	33	514.	9227.6	420.2	1		1815	74	17961.	12186.1	429.3	2		0430	115	12664.	11490.0	427.3
1		0815	34	516.	9229.2	420.2	1		1830	75	19492.	12378.4	429.8	2		0445	116	12150.	11419.1	427.1
1		0830	35	523.	9233.8	420.2	1		1845	76	21018.	12567.2	430.3	2		0500	117	11650.	11349.6	426.9
1		0845	36	536.	9241.8	420.3	1		1900	77	22508.	12748.9	430.8	2		0515	118	11165.	11281.5	426.7
1		0900	37	555.	9253.5	420.3	1		1915	78	23932.	12920.4	431.3	2		0530	119	10696.	11214.9	426.5
1		0915	38	584.	9269.2	420.4	1		1930	79	25265.	13079.3	431.7	2		0545	120	10243.	11150.0	426.3
1		0930	39	622.	9288.9	420.4	1		1945	80	26509.	13221.6	432.1	2		0600	121	9806.	11086.6	426.1
1		0945	40	672.	9312.4	420.5	1		2000	81	28125.	13341.5	432.4							
1		1000	41	735.	9339.8	420.6	1		2015	82	29594.	13432.1	432.6							

PEAK OUTFLOW IS 31622. AT TIME 21.00 HOURS

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
31622.	21.00	(CFS)	27265.	12575.	10344.	10344.
		(INCHES)	3.516	6.487	6.670	6.670
		(AC-FT)	13520.	24943.	25647.	25647.

PEAK STORAGE (AC-FT)	TIME (HR)	MAXIMUM AVERAGE STORAGE 6-HR	24-HR	72-HR	30.00-HR
13545.	21.00	13220.	11242.	10902.	10902.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	30.00-HR
432.90	21.00	432.05	426.34	425.33	425.33

CUMULATIVE AREA = 72.10 SQ MI

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = .50

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	*	1		1015	42	1100.	9471.8	421.0	*	1		2030	83	46845.	14214.2	434.6
1		0015	2	2923.	9928.4	422.5	*	1		1030	43	1263.	9522.4	421.2	*	1		2045	84	46857.	14214.6	434.6
1		0030	3	2657.	9871.4	422.3	*	1		1045	44	1452.	9577.0	421.4	*	1		2100	85	46489.	14200.4	434.6
1		0045	4	2424.	9819.3	422.2	*	1		1100	45	1665.	9635.0	421.6	*	1		2115	86	45802.	14173.5	434.5
1		0100	5	2217.	9771.8	422.0	*	1		1115	46	1902.	9695.6	421.8	*	1		2130	87	44877.	14137.0	434.4
1		0115	6	2035.	9728.2	421.9	*	1		1130	47	2159.	9758.1	422.0	*	1		2145	88	43785.	14093.4	434.3
1		0130	7	1872.	9688.2	421.7	*	1		1145	48	2435.	9821.9	422.2	*	1		2200	89	42577.	14044.4	434.2
1		0145	8	1727.	9651.2	421.6	*	1		1200	49	2725.	9886.2	422.4	*	1		2215	90	41287.	13991.1	434.0
1		0200	9	1598.	9617.1	421.5	*	1		1215	50	3028.	9950.5	422.6	*	1		2230	91	39944.	13934.4	433.9
1		0215	10	1482.	9585.4	421.4	*	1		1230	51	3341.	10014.7	422.8	*	1		2245	92	38573.	13875.2	433.7
1		0230	11	1378.	9556.1	421.3	*	1		1245	52	3666.	10079.1	423.0	*	1		2300	93	37194.	13814.1	433.6
1		0245	12	1284.	9528.7	421.2	*	1		1300	53	4004.	10144.1	423.2	*	1		2315	94	35825.	13751.6	433.4
1		0300	13	1199.	9503.1	421.1	*	1		1315	54	4358.	10210.3	423.4	*	1		2330	95	34486.	13688.4	433.3
1		0315	14	1123.	9479.2	421.1	*	1		1330	55	4733.	10278.4	423.6	*	1		2345	96	33194.	13625.2	433.1
1		0330	15	1054.	9456.8	421.0	*	1		1345	56	5134.	10349.3	423.8	*	2		0000	97	31957.	13562.2	432.9
1		0345	16	991.	9435.7	420.9	*	1		1400	57	5565.	10423.7	424.1	*	2		0015	98	30783.	13499.4	432.8
1		0400	17	934.	9415.9	420.8	*	1		1415	58	6035.	10502.7	424.3	*	2		0030	99	29674.	13436.8	432.6
1		0415	18	882.	9397.2	420.8	*	1		1430	59	6549.	10587.2	424.6	*	2		0045	100	28634.	13374.0	432.5
1		0430	19	834.	9379.5	420.7	*	1		1445	60	7116.	10678.2	424.9	*	2		0100	101	27668.	13310.7	432.3
1		0445	20	791.	9362.8	420.7	*	1		1500	61	7744.	10776.8	425.2	*	2		0115	102	26768.	13243.7	432.1
1		0500	21	752.	9346.8	420.6	*	1		1515	62	8440.	10883.6	425.5	*	2		0130	103	26061.	13173.4	431.9
1		0515	22	716.	9331.7	420.6	*	1		1530	63	9214.	10999.5	425.8	*	2		0145	104	25420.	13097.7	431.7
1		0530	23	683.	9317.3	420.5	*	1		1545	64	10081.	11126.4	426.2	*	2		0200	105	24755.	13018.7	431.5
1		0545	24	653.	9303.5	420.5	*	1		1600	65	11069.	11268.0	426.6	*	2		0215	106	24051.	12934.6	431.3
1		0600	25	625.	9290.5	420.4	*	1		1615	66	12206.	11426.8	427.1	*	2		0230	107	23327.	12847.7	431.1
1		0615	26	601.	9278.3	420.4	*	1		1630	67	13503.	11603.9	427.6	*	2		0245	108	22590.	12758.9	430.8
1		0630	27	580.	9267.0	420.4	*	1		1645	68	14963.	11798.8	428.2	*	2		0300	109	21847.	12668.7	430.6
1		0645	28	561.	9256.9	420.3	*	1		1700	69	16585.	12010.2	428.8	*	2		0315	110	21103.	12577.6	430.3
1		0700	29	547.	9248.5	420.3	*	1		1715	70	18357.	12236.2	429.4	*	2		0330	111	20360.	12486.2	430.1
1		0715	30	536.	9242.1	420.3	*	1		1730	71	20263.	12474.2	430.1	*	2		0345	112	19623.	12394.8	429.8
1		0730	31	530.	9238.2	420.3	*	1		1745	72	22281.	12721.4	430.7	*	2		0400	113	18893.	12303.6	429.6
1		0745	32	528.	9237.2	420.3	*	1		1800	73	24389.	12975.1	431.4	*	2		0415	114	18174.	12213.0	429.3
1		0800	33	532.	9239.5	420.3	*	1		1815	74	26629.	13232.1	432.1	*	2		0430	115	17466.	12123.2	429.1
1		0815	34	542.	9245.8	420.3	*	1		1830	75	30308.	13473.0	432.7	*	2		0445	116	16772.	12034.3	428.8
1		0830	35	560.	9256.3	420.3	*	1		1845	76	34192.	13674.3	433.2	*	2		0500	117	16093.	11946.6	428.6
1		0845	36	588.	9271.5	420.4	*	1		1900	77	37632.	13833.7	433.6	*	2		0515	118	15431.	11860.3	428.3
1		0900	37	628.	9291.9	420.4	*	1		1915	78	40470.	13956.8	434.0	*	2		0530	119	14787.	11775.6	428.1
1		0915	38	683.	9317.4	420.5	*	1		1930	79	42712.	14049.9	434.2	*	2		0545	120	14163.	11692.6	427.9
1		0930	39	755.	9348.2	420.6	*	1		1945	80	44416.	14118.7	434.4	*	2		0600	121	13559.	11611.5	427.6
1		0945	40	847.	9384.4	420.7	*	1		2000	81	45644.	14167.3	434.5	*							
1		1000	41	961.	9425.7	420.9	*	1		2015	82	46444.	14198.6	434.6	*							

PEAK OUTFLOW IS 46857. AT TIME 20.75 HOURS

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
46857.	20.75	(CFS)	40082.	18093.	14759.	14759.
		(INCHES)	5.169	9.333	9.516	9.516
		(AC-FT)	19876.	35888.	36593.	36593.

PEAK STORAGE (AC-FT)	TIME (HR)	MAXIMUM AVERAGE STORAGE 6-HR	24-HR	72-HR	30.00-HR
14215.	20.75	13928.	11736.	11298.	11298.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	30.00-HR
434.60	20.75	433.88	427.71	426.42	426.42

CUMULATIVE AREA = 72.10 SQ MI

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = .65

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	1		1015	42	1427.	9570.1	421.3	1		2030	83	61272.	14736.4	435.9
1		0015	2	2924.	9928.6	422.5	1		1030	43	1668.	9635.7	421.6	1		2045	84	61116.	14731.1	435.9
1		0030	3	2659.	9871.7	422.3	1		1045	44	1943.	9705.9	421.8	1		2100	85	60498.	14709.9	435.8
1		0045	4	2426.	9819.8	422.2	1		1100	45	2252.	9779.8	422.0	1		2115	86	59483.	14674.9	435.7
1		0100	5	2220.	9772.3	422.0	1		1115	46	2590.	9856.6	422.3	1		2130	87	58181.	14629.7	435.6
1		0115	6	2037.	9728.8	421.9	1		1130	47	2955.	9935.2	422.5	1		2145	88	56680.	14576.9	435.5
1		0130	7	1875.	9688.8	421.7	1		1145	48	3341.	10014.8	422.8	1		2200	89	55041.	14518.7	435.4
1		0145	8	1730.	9651.9	421.6	1		1200	49	3745.	10094.6	423.0	1		2215	90	53305.	14456.1	435.2
1		0200	9	1600.	9617.7	421.5	1		1215	50	4161.	10173.8	423.3	1		2230	91	51508.	14390.3	435.0
1		0215	10	1484.	9586.1	421.4	1		1230	51	4589.	10252.5	423.5	1		2245	92	49678.	14322.2	434.9
1		0230	11	1380.	9556.7	421.3	1		1245	52	5029.	10331.0	423.8	1		2300	93	47839.	14252.4	434.7
1		0245	12	1286.	9529.3	421.2	1		1300	53	5485.	10409.9	424.0	1		2315	94	46014.	14181.8	434.5
1		0300	13	1201.	9503.8	421.1	1		1315	54	5959.	10490.1	424.3	1		2330	95	44229.	14111.2	434.3
1		0315	14	1125.	9479.8	421.1	1		1330	55	6458.	10572.4	424.5	1		2345	96	42503.	14041.4	434.2
1		0330	15	1055.	9457.4	421.0	1		1345	56	6990.	10658.2	424.8	2		0000	97	40848.	13972.7	434.0
1		0345	16	992.	9436.3	420.9	1		1400	57	7561.	10748.4	425.1	2		0015	98	39266.	13905.3	433.8
1		0400	17	935.	9416.5	420.8	1		1415	58	8182.	10844.3	425.4	2		0030	99	37758.	13839.3	433.7
1		0415	18	883.	9397.7	420.8	1		1430	59	8862.	10947.2	425.7	2		0045	100	36321.	13774.5	433.5
1		0430	19	836.	9380.0	420.7	1		1445	60	9613.	11058.3	426.0	2		0100	101	34950.	13710.6	433.3
1		0445	20	792.	9363.3	420.7	1		1500	61	10445.	11178.9	426.4	2		0115	102	33642.	13647.4	433.2
1		0500	21	753.	9347.3	420.6	1		1515	62	11367.	11310.0	426.8	2		0130	103	32393.	13584.7	433.0
1		0515	22	717.	9332.2	420.6	1		1530	63	12391.	11452.4	427.2	2		0145	104	31203.	13522.2	432.8
1		0530	23	684.	9317.7	420.5	1		1545	64	13539.	11608.9	427.6	2		0200	105	30069.	13459.5	432.7
1		0545	24	654.	9304.0	420.5	1		1600	65	14850.	11783.8	428.1	2		0215	106	28994.	13396.3	432.5
1		0600	25	626.	9291.0	420.4	1		1615	66	16357.	11980.8	428.7	2		0230	107	27983.	13332.0	432.3
1		0615	26	602.	9278.8	420.4	1		1630	67	18077.	12200.8	429.3	2		0245	108	27051.	13266.0	432.2
1		0630	27	581.	9267.8	420.4	1		1645	68	20014.	12443.3	430.0	2		0300	109	26236.	13194.1	432.0
1		0645	28	564.	9258.2	420.3	1		1700	69	22159.	12706.5	430.7	2		0315	110	25577.	13116.2	431.8
1		0700	29	551.	9250.7	420.3	1		1715	70	24497.	12988.0	431.4	2		0330	111	24867.	13032.0	431.6
1		0715	30	542.	9245.6	420.3	1		1730	71	27298.	13284.4	432.2	2		0345	112	24127.	12943.8	431.3
1		0730	31	539.	9243.7	420.3	1		1745	72	32042.	13566.6	433.0	2		0400	113	23360.	12851.7	431.1
1		0745	32	542.	9245.4	420.3	1		1800	73	37087.	13809.3	433.6	2		0415	114	22575.	12757.0	430.8
1		0800	33	552.	9251.4	420.3	1		1815	74	41794.	14012.2	434.1	2		0430	115	21780.	12660.4	430.6
1		0815	34	571.	9262.3	420.3	1		1830	75	45984.	14180.6	434.5	2		0445	116	20982.	12562.8	430.3
1		0830	35	602.	9278.8	420.4	1		1845	76	49621.	14320.0	434.9	2		0500	117	20187.	12464.7	430.0
1		0845	36	648.	9301.2	420.5	1		1900	77	52717.	14434.7	435.2	2		0515	118	19398.	12366.8	429.8
1		0900	37	711.	9329.9	420.6	1		1915	78	55300.	14527.9	435.4	2		0530	119	18622.	12269.6	429.5
1		0915	38	797.	9365.1	420.7	1		1930	79	57399.	14602.3	435.6	2		0545	120	17861.	12173.4	429.2
1		0930	39	908.	9406.9	420.8	1		1945	80	59033.	14659.3	435.7	2		0600	121	17119.	12078.9	429.0
1		0945	40	1049.	9455.2	421.0	1		2000	81	60219.	14700.3	435.8							
1		1000	41	1221.	9509.7	421.2	1		2015	82	60966.	14726.0	435.9							

PEAK OUTFLOW IS 61272. AT TIME 20.50 HOURS

PEAK FLOW (CFS)	TIME (HR)		6-HR	24-HR	72-HR	30.00-HR
			MAXIMUM AVERAGE FLOW			
61272.	20.50	(CFS)	52915.	23638.	19195.	19195.
		(INCHES)	6.824	12.193	12.376	12.376
		(AC-FT)	26239.	46885.	47591.	47591.

PEAK STORAGE (AC-FT)	TIME (HR)	6-HR	24-HR	72-HR	30.00-HR
		MAXIMUM AVERAGE STORAGE			
14736.	20.50	14434.	12118.	11604.	11604.

PEAK STAGE (FEET)	TIME (HR)	6-HR	24-HR	72-HR	30.00-HR
		MAXIMUM AVERAGE STAGE			
435.90	20.50	435.15	428.75	427.25	427.25

CUMULATIVE AREA = 72.10 SQ MI

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = .80

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	1		1015	42	1784.	9665.9	421.7	1		2030	83	75545.	15205.6	437.0
1		0015	2	2924.	9928.8	422.5	1		1030	43	2108.	9745.9	421.9	1		2045	84	75278.	15197.1	437.0
1		0030	3	2660.	9872.0	422.3	1		1045	44	2475.	9830.9	422.2	1		2100	85	74444.	15170.5	436.9
1		0045	4	2428.	9820.3	422.2	1		1100	45	2882.	9919.9	422.5	1		2115	86	73130.	15128.5	436.8
1		0100	5	2222.	9772.9	422.0	1		1115	46	3327.	10011.9	422.8	1		2130	87	71470.	15075.0	436.7
1		0115	6	2039.	9729.4	421.9	1		1130	47	3802.	10105.6	423.1	1		2145	88	69576.	15013.5	436.6
1		0130	7	1877.	9689.4	421.7	1		1145	48	4302.	10200.0	423.4	1		2200	89	67517.	14945.9	436.4
1		0145	8	1732.	9652.5	421.6	1		1200	49	4820.	10294.0	423.7	1		2215	90	65346.	14873.9	436.2
1		0200	9	1603.	9618.4	421.5	1		1215	50	5351.	10387.1	424.0	1		2230	91	63103.	14798.6	436.0
1		0215	10	1487.	9586.7	421.4	1		1230	51	5893.	10479.1	424.2	1		2245	92	60822.	14721.0	435.9
1		0230	11	1382.	9557.3	421.3	1		1245	52	6446.	10570.5	424.5	1		2300	93	58532.	14641.9	435.7
1		0245	12	1288.	9529.9	421.2	1		1300	53	7015.	10662.3	424.8	1		2315	94	56262.	14562.2	435.5
1		0300	13	1203.	9504.4	421.1	1		1315	54	7606.	10755.4	425.1	1		2330	95	54045.	14482.9	435.3
1		0315	14	1127.	9480.4	421.1	1		1330	55	8227.	10851.2	425.4	1		2345	96	51903.	14404.9	435.1
1		0330	15	1057.	9458.0	421.0	1		1345	56	8888.	10951.0	425.7	2		0000	97	49850.	14328.6	434.9
1		0345	16	994.	9436.9	420.9	1		1400	57	9598.	11056.1	426.0	2		0015	98	47889.	14254.4	434.7
1		0400	17	937.	9417.0	420.8	1		1415	58	10370.	11168.2	426.3	2		0030	99	46018.	14182.0	434.5
1		0415	18	885.	9398.3	420.8	1		1430	59	11215.	11288.6	426.7	2		0045	100	44232.	14111.3	434.3
1		0430	19	837.	9380.6	420.7	1		1445	60	12149.	11419.0	427.1	2		0100	101	42524.	14042.2	434.2
1		0445	20	794.	9363.8	420.7	1		1500	61	13185.	11560.9	427.5	2		0115	102	40890.	13974.4	434.0
1		0500	21	754.	9347.8	420.6	1		1515	62	14334.	11715.4	427.9	2		0130	103	39322.	13907.8	433.8
1		0515	22	718.	9332.6	420.6	1		1530	63	15609.	11883.6	428.4	2		0145	104	37818.	13841.9	433.7
1		0530	23	685.	9318.2	420.5	1		1545	64	17040.	12068.7	428.9	2		0200	105	36371.	13776.8	433.5
1		0545	24	655.	9304.5	420.5	1		1600	65	18675.	12276.2	429.5	2		0215	106	34980.	13712.0	433.3
1		0600	25	627.	9291.5	420.4	1		1615	66	20556.	12510.4	430.2	2		0230	107	33642.	13647.4	433.2
1		0615	26	603.	9279.4	420.4	1		1630	67	22702.	12772.4	430.9	2		0245	108	32354.	13582.7	433.0
1		0630	27	583.	9268.6	420.4	1		1645	68	25115.	13061.5	431.6	2		0300	109	31116.	13517.5	432.8
1		0645	28	566.	9259.5	420.3	1		1700	69	28516.	13366.7	432.4	2		0315	110	29930.	13451.6	432.7
1		0700	29	554.	9252.8	420.3	1		1715	70	33961.	13663.1	433.2	2		0330	111	28803.	13384.6	432.5
1		0715	30	548.	9249.1	420.3	1		1730	71	39661.	13922.3	433.9	2		0345	112	27744.	13315.9	432.3
1		0730	31	548.	9249.1	420.3	1		1745	72	45084.	14145.2	434.4	2		0400	113	26752.	13242.4	432.1
1		0745	32	555.	9253.5	420.3	1		1800	73	50104.	14338.1	434.9	2		0415	114	25981.	13164.0	431.9
1		0800	33	573.	9263.2	420.3	1		1815	74	54725.	14507.4	435.3	2		0430	115	25260.	13078.7	431.7
1		0815	34	602.	9278.7	420.4	1		1830	75	58949.	14656.4	435.7	2		0445	116	24505.	12988.9	431.4
1		0830	35	647.	9300.8	420.5	1		1845	76	62744.	14786.5	436.0	2		0500	117	23706.	12893.3	431.2
1		0845	36	712.	9330.1	420.6	1		1900	77	66073.	14898.1	436.3	2		0515	118	22885.	12794.5	430.9
1		0900	37	802.	9367.0	420.7	1		1915	78	68917.	14991.9	436.5	2		0530	119	22054.	12693.8	430.7
1		0915	38	922.	9411.7	420.8	1		1930	79	71262.	15068.3	436.7	2		0545	120	21221.	12592.2	430.4
1		0930	39	1076.	9464.3	421.0	1		1945	80	73103.	15127.6	436.8	2		0600	121	20394.	12490.4	430.1
1		0945	40	1270.	9524.4	421.2	1		2000	81	74435.	15170.2	436.9							
1		1000	41	1505.	9591.8	421.4	1		2015	82	75253.	15196.3	437.0							

PEAK OUTFLOW IS 75545. AT TIME 20.50 HOURS

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
75545.	20.50	(CFS)	65517.	29205.	23649.	23649.
		(INCHES)	8.449	15.064	15.248	15.248
		(AC-FT)	32488.	57927.	58634.	58634.

PEAK STORAGE (AC-FT)	TIME (HR)	MAXIMUM AVERAGE STORAGE 6-HR	24-HR	72-HR	30.00-HR
15206.	20.50	14873.	12437.	11859.	11859.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	30.00-HR
437.03	20.50	436.22	429.60	427.93	427.93

CUMULATIVE AREA = 72.10 SQ MI

HYDROGRAPH AT STATION DAM
PLAN 1, RATIO = 1.00

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	3225.	9991.2	422.7	1		1015	42	2300.	9791.0	422.1	1		2030	83	94537.	15788.3	438.4
1		0015	2	2926.	9929.1	422.5	1		1030	43	2739.	9889.2	422.4	1		2045	84	94132.	15776.3	438.4
1		0030	3	2662.	9872.5	422.3	1		1045	44	3234.	9993.1	422.7	1		2100	85	93019.	15743.1	438.3
1		0045	4	2430.	9820.9	422.2	1		1100	45	3779.	10101.2	423.1	1		2115	86	91310.	15691.8	438.2
1		0100	5	2225.	9773.6	422.0	1		1115	46	4369.	10212.2	423.4	1		2130	87	89179.	15627.6	438.0
1		0115	6	2043.	9730.2	421.9	1		1130	47	4994.	10324.8	423.8	1		2145	88	86764.	15554.3	437.8
1		0130	7	1880.	9690.2	421.7	1		1145	48	5647.	10437.6	424.1	1		2200	89	84154.	15474.4	437.7
1		0145	8	1736.	9653.4	421.6	1		1200	49	6317.	10549.4	424.5	1		2215	90	81408.	15389.6	437.5
1		0200	9	1606.	9619.3	421.5	1		1215	50	6998.	10659.6	424.8	1		2230	91	78577.	15301.3	437.3
1		0215	10	1490.	9587.6	421.4	1		1230	51	7688.	10768.1	425.1	1		2245	92	75702.	15210.6	437.0
1		0230	11	1385.	9558.2	421.3	1		1245	52	8389.	10875.8	425.5	1		2300	93	72819.	15118.5	436.8
1		0245	12	1291.	9530.8	421.2	1		1300	53	9107.	10983.7	425.8	1		2315	94	69964.	15026.1	436.6
1		0300	13	1206.	9505.2	421.1	1		1315	54	9852.	11093.2	426.1	1		2330	95	67175.	14934.6	436.4
1		0315	14	1129.	9481.3	421.1	1		1330	55	10632.	11205.8	426.4	1		2345	96	64484.	14845.1	436.2
1		0330	15	1060.	9458.8	421.0	1		1345	56	11463.	11323.4	426.8	2		0000	97	61905.	14758.0	435.9
1		0345	16	996.	9437.7	420.9	1		1400	57	12356.	11447.6	427.2	2		0015	98	59443.	14673.5	435.7
1		0400	17	939.	9417.8	420.9	1		1415	58	13328.	11580.3	427.5	2		0030	99	57094.	14591.5	435.5
1		0415	18	887.	9399.0	420.8	1		1430	59	14394.	11723.3	428.0	2		0045	100	54852.	14511.9	435.3
1		0430	19	839.	9381.3	420.7	1		1445	60	15572.	11878.7	428.4	2		0100	101	52708.	14434.4	435.2
1		0445	20	795.	9364.5	420.7	1		1500	61	16879.	12048.1	428.9	2		0115	102	50654.	14358.7	435.0
1		0500	21	756.	9348.5	420.6	1		1515	62	18331.	12232.9	429.4	2		0130	103	48682.	14284.6	434.8
1		0515	22	719.	9333.3	420.6	1		1530	63	19944.	12434.7	429.9	2		0145	104	46785.	14211.8	434.6
1		0530	23	686.	9318.8	420.5	1		1545	64	21753.	12657.2	430.6	2		0200	105	44958.	14140.2	434.4
1		0545	24	656.	9305.1	420.5	1		1600	65	23822.	12907.2	431.2	2		0215	106	43195.	14069.6	434.2
1		0600	25	629.	9292.1	420.4	1		1615	66	26202.	13190.1	432.0	2		0230	107	41491.	13999.6	434.1
1		0615	26	605.	9280.2	420.4	1		1630	67	30588.	13488.7	432.8	2		0245	108	39843.	13930.1	433.9
1		0630	27	585.	9269.7	420.4	1		1645	68	36378.	13777.1	433.5	2		0300	109	38246.	13860.9	433.7
1		0645	28	569.	9261.3	420.3	1		1700	69	42431.	14038.4	434.2	2		0315	110	36701.	13791.8	433.5
1		0700	29	559.	9255.7	420.3	1		1715	70	48399.	14273.8	434.8	2		0330	111	35206.	13722.7	433.4
1		0715	30	556.	9253.8	420.3	1		1730	71	54170.	14487.4	435.3	2		0345	112	33762.	13653.3	433.2
1		0730	31	560.	9256.4	420.3	1		1745	72	59722.	14683.2	435.8	2		0400	113	32372.	13583.6	433.0
1		0745	32	575.	9264.4	420.3	1		1800	73	65058.	14864.3	436.2	2		0415	114	31038.	13513.3	432.8
1		0800	33	602.	9278.9	420.4	1		1815	74	70164.	15032.6	436.6	2		0430	115	29766.	13442.2	432.6
1		0815	34	646.	9300.6	420.5	1		1830	75	74978.	15187.6	437.0	2		0445	116	28566.	13369.8	432.4
1		0830	35	712.	9330.3	420.6	1		1845	76	79398.	15327.0	437.3	2		0500	117	27423.	13293.4	432.2
1		0845	36	806.	9368.8	420.7	1		1900	77	83331.	15449.1	437.6	2		0515	118	26428.	13214.2	432.0
1		0900	37	935.	9416.5	420.8	1		1915	78	86719.	15553.0	437.8	2		0530	119	25685.	13129.1	431.8
1		0915	38	1105.	9473.6	421.0	1		1930	79	89524.	15638.0	438.0	2		0545	120	24909.	13037.0	431.6
1		0930	39	1323.	9540.0	421.3	1		1945	80	91722.	15704.2	438.2	2		0600	121	24103.	12940.8	431.3
1		0945	40	1592.	9615.5	421.5	1		2000	81	93299.	15751.4	438.3							
1		1000	41	1917.	9699.4	421.8	1		2015	82	94244.	15779.6	438.4							

PEAK OUTFLOW IS 94537. AT TIME 20.50 HOURS

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	30.00-HR
94537.	20.50	(CFS)	82087.	36679.	29629.	29629.
		(INCHES)	10.585	18.919	19.104	19.104
		(AC-FT)	40704.	72751.	73459.	73459.

PEAK STORAGE (AC-FT)	TIME (HR)	MAXIMUM AVERAGE STORAGE 6-HR	24-HR	72-HR	30.00-HR
15788.	20.50	15405.	12806.	12155.	12155.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	30.00-HR
438.39	20.50	437.49	430.56	428.70	428.70

CUMULATIVE AREA = 72.10 SQ MI

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN		RATIO 1 .20	RATIO 2 .35	RATIO 3 .50	RATIO 4 .65	RATIO 5 .80	RATIO 6 1.00
HYDROGRAPH AT	INFLOW	72.10	1	FLOW	19032.	33305.	47579.	61853.	76126.	95158.
				TIME	20.25	20.25	20.25	20.25	20.25	20.25
ROUTED TO	DAM	72.10	1	FLOW	17040.	31622.	46857.	61272.	75545.	94537.
				TIME	21.50	21.00	20.75	20.50	20.50	20.50
			** PEAK STAGES IN FEET **							
			1	STAGE	428.93	432.90	434.60	435.90	437.03	438.39
				TIME	21.50	21.00	20.75	20.50	20.50	20.50
ROUTED TO	RCH1	72.10	1	FLOW	16886.	31224.	46515.	60842.	75115.	94074.
				TIME	22.00	21.50	21.00	20.75	20.75	20.75
			** PEAK STAGES IN FEET **							
			1	STAGE	298.11	301.71	304.37	306.39	308.10	310.07
				TIME	22.00	21.50	21.00	20.75	20.75	20.75

(RATIOS APPLIED TO FLOWS)

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION DAM

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	422.71	420.00	432.00
	STORAGE	9991.	9161.	13200.
	OUTFLOW	3225.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	428.93	.00	12069.	17040.	.00	21.50	.00
.35	432.90	.90	13545.	31622.	3.50	21.00	.00
.50	434.60	2.60	14215.	46857.	7.25	20.75	.00
.65	435.90	3.90	14736.	61272.	9.50	20.50	.00
.80	437.03	5.03	15206.	75545.	11.25	20.50	.00
1.00	438.39	6.39	15788.	94537.	13.00	20.50	.00

*** NORMAL END OF HEC-1 ***

12.8 Example Problem #8: Dam Failure Analysis

Test 8 involves evaluation of the downstream hydrologic-hydraulic consequences in the Bear Creek system (Figure 12.5) resulting from different assumed structural failures of the dam (Table 12.7a). The test uses the multiplan capability of the program to evaluate five different types of dam breaches in a single computer run. The user designed output option was also used in this test. The computation sequence performed by the program was:

- Compute the PMF inflow hydrograph for the reservoir.
- Route the hydrograph through the reservoir. The outflow hydrograph is based on the specified breach criteria and normal releases of the outlet works.
- Route hydrographs through channel reaches RCH 1 and RCH 2 using the cross-sectional data shown in Figure 12.6.

A summary of the HEC-1 results are shown in Table 12.8a. The input format and computation results for this test are shown in Table 12.8b.

Discussion of Results. The failure analysis performed provides insight into the sensitivity of various breach dimensions on downstream water surface elevations. The downstream peak discharges and corresponding stages are given in Table 12.8a. The HEC-1 summary output, Table 12.8b, contains these results (input and output listing as well as line printer plots of the breach hydrographs).

The plots illustrate how well the hydrograph depicted by normal time steps represents the breach hydrograph generated using smaller time steps. PLAN 1 has a volume gain of 2330 acre-feet from the peak portion of the hydrograph indicating that a smaller time step should be used. The plot for PLAN 3 indicates that the peak flow from the dam occurs after the breach is fully formed. Characterization of the outflow hydrograph and peak discharge will depend on the specified time step as in a standard storage routing.

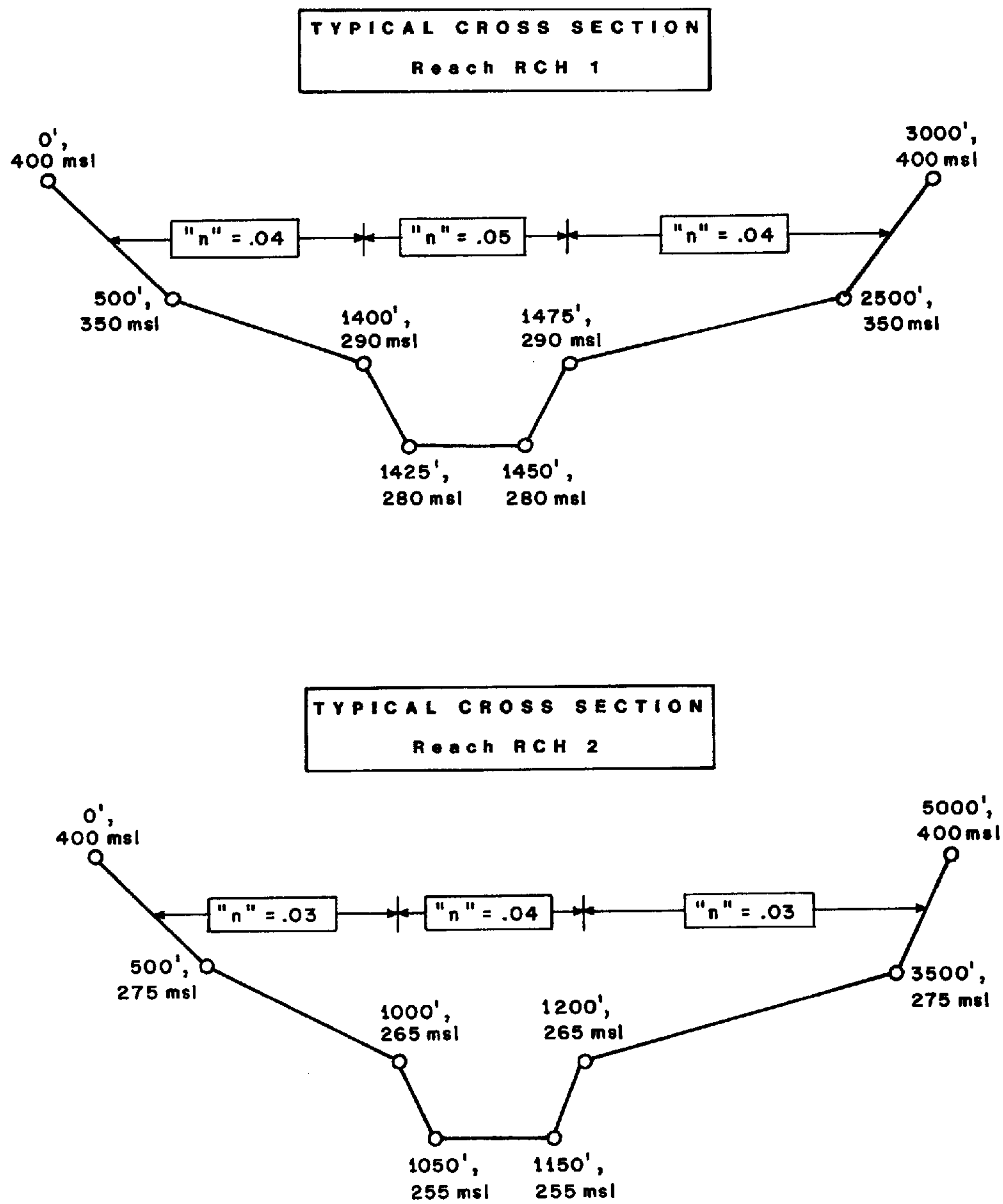

Figure 12.6 Bear Creek Downstream Cross Sections

Table 12.8a

Dam Failure Analysis Results

	RESERVOIR		REACH 1		REACH 2	
	Peak Q	Peak WSEL	Peak Q	Peak WSEL	Peak Q	Peak WSEL
PLAN 1 fail time = 15 min. total dam	1,244,000	433.5	610,000	334.1	422,000	280.7
PLAN 2 fail time = 3 hrs. total dam	209,000	434.1	197,000	317.7	184,000	276.0
PLAN 3 fail time = 3 hrs breach depth = 50 ft. b.w. = 50 ft. s.s. = 2:1	135,000	435.4	127,000	312.9	122,000	274.2
PLAN 4 fail time = 3 hrs breach depth = 70 ft. b.w. = 200 ft. s.s. = 2:1	180,000	434.6	175,000	316.3	171,000	275.6
PLAN 5 fail time = 10 hrs breach depth = 70 ft. b.w. = 200 ft. s.s. = 2:1	109,000	436.6	109,000	311.4	108,000	273.7

Table 12.8b

Example Problem #8

Input

```
ID      EXAMPLE PROBLEM NO. 8
ID      DAM FAILURE ANALYSIS
*FIX
IT    15                     140
IO     5
JP     5
VS  RCH1    RCH1    RCH1    RCH1    RCH2    RCH2    RCH2    RCH2
VV  2.11    2.51    7.11    7.51    2.11    2.51    7.11    7.51
KK    IN        BEAR CREEK RESERVOIR
KM    CALCULATION OF INFLOW TO BEAR CREEK RESERVOIR
BA  72.1
PM    25       0       0       0      82      97     110
LU    1.     .04
US   4.8     .60
BF    -1    -.05   1.319
KK  OUT        BEAR CREEK DAM
KM      ROUTED FLOWS THROUGH BEAR CREEK RESERVOIR
KO     1
KP     1
RS     1    ELEV     420
SA     0     100     250     300     320     350     380     410     450     500
SE   340     380     410     420     424     428     432     436     440     444
SS   420     200     3.1     1.5
ST   432     900     3.1     1.5
SL   380    12.6      .7      .5
SB   340     900       0     .25     433
KP     2
KO     5
SB   340     900       0       3     433
KP     3
SB   382      50       2       3     433
KP     4
SB   362     200       2       3     433
KP     5
SB   362     200       2      10     433
KK  RCH1
KO     1
KM      CHANNEL ROUTING   REACH 2-3
RS     1    STOR       0
RC   .04     .05     .04   15000   .0033     335
RX     0     500    1400    1425    1450    1475    2500    3000
RY   400     350     290     280     280     290     350     400
KP     2
KO     5
KK  RCH2
KM      CHANNEL ROUTING   REACH 3-4
RS     1    STOR       0
RC   .03     .04     .03   12000   .0025     280
RX     0     500    1000    1050    1150    1200    3500    5000
RY   400     275     265     255     255     265     275     400
ZZ
```

Output

```
 *****************************************
 *                                       *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
 *              JUN   1998               *
 *           VERSION 4.1                 *
 *                                       *
 *  RUN DATE   10JUN98  TIME  20:39:04   *
 *                                       *
 *****************************************
```

```
                                          HEC-1 INPUT                                       PAGE  1

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1          ID        EXAMPLE PROBLEM NO. 8
           2          ID        DAM FAILURE ANALYSIS
*** FIX ***
           3          IT      15                   140
           4          IO       5
           5          JP       5
           6          VS    RCH1    RCH1    RCH1    RCH1    RCH2    RCH2    RCH2    RCH2
           7          VV    2.11    2.51    7.11    7.51    2.11    2.51    7.11    7.51

           8          KK      IN        BEAR CREEK RESERVOIR
           9          KM      CALCULATION OF INFLOW TO BEAR CREEK RESERVOIR
          10          BA    72.1
          11          PM      25       0       0       0      82      97     110
          12          LU      1.     .04
          13          US     4.8     .60
          14          BF      -1    -.05   1.319

          15          KK    OUT        BEAR CREEK DAM
          16          KM        ROUTED FLOWS THROUGH BEAR CREEK RESERVOIR
          17          KO       1
          18          KP       1
          19          RS       1    ELEV     420
          20          SA       0     100     250     300     320     350     380     410     450     500
          21          SE     340     380     410     420     424     428     432     436     440     444
          22          SS     420     200     3.1     1.5
          23          ST     432     900     3.1     1.5
          24          SL     380    12.6      .7      .5
          25          SB     340     900       0     .25     433
          26          KP       2
          27          KO       5
          28          SB     340     900       0       3     433
          29          KP       3
          30          SB     382      50       2       3     433
          31          KP       4
          32          SB     362     200       2       3     433
          33          KP       5
          34          SB     362     200       2      10     433

          35          KK    RCH1
          36          KO       1
          37          KM        CHANNEL ROUTING   REACH 2-3
          38          RS       1    STOR       0
          39          RC     .04     .05     .04   15000   .0033     335
          40          RX       0     500    1400    1425    1450    1475    2500    3000
          41          RY     400     350     290     280     280     290     350     400
          42          KP       2
          43          KO       5

          44          KK    RCH2
          45          KM        CHANNEL ROUTING   REACH 3-4
          46          RS       1    STOR       0
          47          RC     .03     .04     .03   12000   .0025     280
          48          RX       0     500    1000    1050    1150    1200    3500    5000
          49          RY     400     275     265     255     255     265     275     400
          50          ZZ
```

```
 *****************************************
 *                                       *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
 *              JUN   1998               *
 *           VERSION 4.1                 *
 *                                       *
 *  RUN DATE   10JUN98  TIME  20:39:04   *
 *                                       *
 *****************************************



                        EXAMPLE PROBLEM NO. 8
                        DAM FAILURE ANALYSIS

  4 IO         OUTPUT CONTROL VARIABLES
                     IPRNT           5  PRINT CONTROL
                     IPLOT           0  PLOT CONTROL
                     QSCAL          0.  HYDROGRAPH PLOT SCALE

    IT         HYDROGRAPH TIME DATA
                      NMIN          15  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME        0000  STARTING TIME
                        NQ         140  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      2    0  ENDING DATE
                    NDTIME        1045  ENDING TIME
                    ICENT           19  CENTURY MARK

                 COMPUTATION INTERVAL     .25 HOURS
                      TOTAL TIME BASE   34.75 HOURS

        ENGLISH UNITS
             DRAINAGE AREA         SQUARE MILES
             PRECIPITATION DEPTH   INCHES
             LENGTH, ELEVATION     FEET
             FLOW                  CUBIC FEET PER SECOND
             STORAGE VOLUME        ACRE-FEET
             SURFACE AREA          ACRES
             TEMPERATURE           DEGREES FAHRENHEIT

               USER-DEFINED OUTPUT SPECIFICATIONS

       TABLE 1
    VS       STATION    RCH1    RCH1    RCH1    RCH1    RCH2    RCH2    RCH2    RCH2
    VV VARIABLE CODE    2.11    2.51    7.11    7.51    2.11    2.51    7.11    7.51     .00     .00

    JP         MULTI-PLAN OPTION
                     NPLAN           5  NUMBER OF PLANS

    JR         MULTI-RATIO OPTION
                   RATIOS OF RUNOFF
                  1.00


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 


             **************
             *            *
  15 KK      *     OUT    *            BEAR CREEK DAM
             *            *
             **************

  17 KO        OUTPUT CONTROL VARIABLES
                     IPRNT           1  PRINT CONTROL
                     IPLOT           0  PLOT CONTROL
                     QSCAL          0.  HYDROGRAPH PLOT SCALE


***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***
```

```
  18 KP        PLAN  1 FOR STATION     OUT                  BEAR CREEK DAM

               HYDROGRAPH ROUTING DATA

  19 RS          STORAGE ROUTING
                       NSTPS          1  NUMBER OF SUBREACHES
                        ITYP       ELEV  TYPE OF INITIAL CONDITION
                      RSVRIC     420.00  INITIAL CONDITION
                           X        .00 WORKING R AND D COEFFICIENT

  20 SA                 AREA       .0   100.0   250.0   300.0   320.0   350.0   380.0   410.0   450.0   500.0


  21 SE          ELEVATION   340.00  380.00  410.00  420.00  424.00  428.00  432.00  436.00  440.00  444.00


  24 SL          LOW-LEVEL OUTLET
                       ELEVL     380.00  ELEVATION AT CENTER OF OUTLET
                       CAREA      12.60  CROSS-SECTIONAL AREA
                        COQL        .70  COEFFICIENT
                        EXPL        .50  EXPONENT OF HEAD

  22 SS          SPILLWAY
                        CREL     420.00  SPILLWAY CREST ELEVATION
                       SPWID     200.00  SPILLWAY WIDTH
                        COQW       3.10  WEIR COEFFICIENT
                        EXPW       1.50  EXPONENT OF HEAD

  23 ST          TOP OF DAM
                       TOPEL     432.00  ELEVATION AT TOP OF DAM
                      DAMWID     900.00  DAM WIDTH
                        COQD       3.10  WEIR COEFFICIENT
                        EXPD       1.50  EXPONENT OF HEAD

  25 SB          BREACH DATA
                        ELBM     340.00  ELEVATION AT BOTTOM OF BREACH
                       BRWID     900.00  WIDTH OF BREACH BOTTOM
                           Z        .00  BREACH SIDE SLOPE
                       TFAIL        .25  TIME FOR BREACH TO DEVELOP
                      FAILEL     433.00  W.S. ELEVATION TO TRIGGER FAILURE

                                                                            ***

                                                        COMPUTED STORAGE-ELEVATION DATA

   STORAGE      .00   1333.33   6414.47   9160.68  10400.46  11740.01  13199.60  14779.22  16498.60  18397.72
 ELEVATION   340.00    380.00    410.00    420.00    424.00    428.00    432.00    436.00    440.00    444.00


                                                        COMPUTED OUTFLOW-ELEVATION DATA
                                                          (EXCLUDING FLOW OVER DAM)

   OUTFLOW      .00       .00    102.19    114.85    131.09    152.68    182.78    227.66    301.76    447.38
 ELEVATION   340.00    380.00    382.09    382.64    383.43    384.66    386.68    390.36    398.20    420.00

   OUTFLOW   524.09   1044.57   2444.54   5159.65   9625.54  16277.80  25552.04  37883.85  53708.95  73462.70
 ELEVATION   420.25    420.97    422.17    423.85    426.01    428.65    431.77    435.37    439.45    444.00


                                                    COMPUTED STORAGE-OUTFLOW-ELEVATION DATA
                                                          (INCLUDING FLOW OVER DAM)

   STORAGE      .00   1333.33   1550.58   1610.64   1700.12   1842.50   2091.06   2590.89   3870.13   6414.47
   OUTFLOW      .00       .00    102.19    114.85    131.09    152.68    182.78    227.66    301.76    387.44
 ELEVATION   340.00    380.00    382.09    382.64    383.43    384.66    386.68    390.36    398.20    410.00

   STORAGE  9160.68   9234.42   9453.83   9824.07  10353.85  10400.46  11060.17  11740.01  11970.54  13113.30
   OUTFLOW   447.38    524.09   1044.57   2444.54   5159.65   5429.21   9625.54  14519.08  16277.80  25552.04
 ELEVATION   420.00    420.25    420.97    422.17    423.85    424.00    426.01    428.00    428.65    431.77

   STORAGE 13199.60  14522.20  14779.22  16250.56  16498.60  18397.72
   OUTFLOW 26283.00  55139.68  62529.34 110388.80 119132.90 189440.80
 ELEVATION   432.00    435.37    436.00    439.45    440.00    444.00

  BEGIN DAM FAILURE AT 16.75 HOURS
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HYDROGRAPH AT STATION OUT
PLAN 1, RATIO = 1.00

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DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	447.	9160.7	420.0	1		1145	48	4989.	10324.0	423.8	1		2330	95	62753.	10.7	348.0
1		0015	2	447.	9152.9	420.0	1		1200	49	5714.	10449.0	424.2	1		2345	96	60170.	9.8	347.8
1		0030	3	447.	9145.0	419.9	1		1215	50	6450.	10571.1	424.5	2		0000	97	57717.	9.0	347.6
1		0045	4	447.	9137.0	419.9	1		1230	51	7193.	10690.5	424.9	2		0015	98	55382.	8.3	347.4
1		0100	5	447.	9128.9	419.9	1		1245	52	7945.	10808.0	425.3	2		0030	99	53153.	7.7	347.2
1		0115	6	447.	9120.8	419.9	1		1300	53	8712.	10924.6	425.6	2		0045	100	51017.	7.1	347.0
1		0130	7	446.	9112.6	419.8	1		1315	54	9501.	11041.9	426.0	2		0100	101	48966.	6.5	346.8
1		0145	8	446.	9104.3	419.8	1		1330	55	10323.	11161.4	426.3	2		0115	102	46993.	6.0	346.6
1		0200	9	446.	9096.0	419.8	1		1345	56	11190.	11285.0	426.7	2		0130	103	45091.	5.5	346.4
1		0215	10	446.	9087.6	419.8	1		1400	57	12117.	11414.6	427.1	2		0145	104	43253.	5.1	346.2
1		0230	11	446.	9079.2	419.7	1		1415	58	13119.	11551.9	427.5	2		0200	105	41474.	4.7	346.1
1		0245	12	446.	9070.7	419.7	1		1430	59	14211.	11699.1	427.9	2		0215	106	39748.	4.3	345.9
1		0300	13	446.	9062.1	419.7	1		1445	60	15413.	11858.0	428.3	2		0230	107	38071.	3.9	345.7
1		0315	14	445.	9053.6	419.6	1		1500	61	16742.	12030.5	428.8	2		0245	108	36438.	3.6	345.6
1		0330	15	445.	9045.0	419.6	1		1515	62	18213.	12218.0	429.3	2		0300	109	34848.	3.3	345.4
1		0345	16	445.	9036.3	419.6	1		1530	63	19842.	12422.0	429.9	2		0315	110	33300.	3.0	345.2
1		0400	17	445.	9027.6	419.6	1		1545	64	21666.	12646.6	430.5	2		0330	111	31795.	2.7	345.1
1		0415	18	445.	9018.9	419.5	1		1600	65	23747.	12898.3	431.2	2		0345	112	30333.	2.5	344.9
1		0430	19	445.	9010.2	419.5	1		1615	66	26139.	13182.6	432.0	2		0400	113	28914.	2.3	344.8
1		0445	20	444.	9001.4	419.5	1		1630	67	30485.	13482.9	432.7	2		0415	114	27539.	2.1	344.6
1		0500	21	444.	8992.6	419.4	1		1645	68	36297.	13773.4	433.5	2		0430	115	26208.	1.9	344.5
1		0515	22	444.	8983.8	419.4	1		1700	69	1244166.	3946.2	398.6	2		0445	116	24924.	1.7	344.3
1		0530	23	444.	8974.9	419.4	1		1715	70	59117.	9.5	347.7	2		0500	117	23688.	1.5	344.2
1		0545	24	444.	8966.2	419.3	1		1730	71	63945.	11.1	348.1	2		0515	118	22506.	1.4	344.0
1		0600	25	444.	8957.6	419.3	1		1745	72	68727.	12.8	348.5	2		0530	119	21381.	1.2	343.9
1		0615	26	443.	8949.5	419.3	1		1800	73	73426.	14.6	348.9	2		0545	120	20311.	1.1	343.8
1		0630	27	443.	8942.4	419.3	1		1815	74	77934.	16.5	349.2	2		0600	121	19296.	1.0	343.6
1		0645	28	443.	8937.0	419.2	1		1830	75	82065.	18.3	349.6	2		0615	122	18331.	.9	343.5
1		0700	29	443.	8934.1	419.2	1		1845	76	85687.	19.9	349.8	2		0630	123	17414.	.8	343.4
1		0715	30	443.	8934.7	419.2	1		1900	77	88762.	21.4	350.1	2		0645	124	16543.	.7	343.3
1		0730	31	443.	8939.9	419.3	1		1915	78	91262.	22.6	350.3	2		0700	125	15716.	.7	343.2
1		0745	32	443.	8950.7	419.3	1		1930	79	93164.	23.5	350.4	2		0715	126	14930.	.6	343.1
1		0800	33	444.	8968.3	419.4	1		1945	80	94455.	24.2	350.5	2		0730	127	14184.	.5	343.0
1		0815	34	444.	8994.0	419.4	1		2000	81	95125.	24.5	350.6	2		0745	128	13474.	.5	342.9
1		0830	35	445.	9028.8	419.6	1		2015	82	95158.	24.6	350.6	2		0800	129	12801.	.4	342.8
1		0845	36	446.	9074.0	419.7	1		2030	83	94495.	24.2	350.5	2		0815	130	12161.	.4	342.7
1		0900	37	447.	9130.9	419.9	1		2045	84	93048.	23.5	350.4	2		0830	131	11552.	.4	342.6
1		0915	38	477.	9199.9	420.1	1		2100	85	90939.	22.4	350.2	2		0845	132	10975.	.3	342.5
1		0930	39	605.	9280.2	420.4	1		2115	86	88476.	21.2	350.1	2		0900	133	10426.	.3	342.4
1		0945	40	813.	9371.2	420.7	1		2130	87	85827.	20.0	349.9	2		0915	134	9905.	.3	342.3
1		1000	41	1099.	9471.7	421.0	1		2145	88	83040.	18.7	349.6	2		0930	135	9410.	.2	342.3
1		1015	42	1464.	9580.5	421.4	1		2200	89	80149.	17.4	349.4	2		0945	136	8939.	.2	342.2
1		1030	43	1904.	9696.1	421.8	1		2215	90	77195.	16.2	349.2	2		1000	137	8492.	.2	342.1
1		1045	44	2414.	9817.2	422.2	1		2230	91	74218.	14.9	348.9	2		1015	138	8067.	.2	342.0
1		1100	45	2987.	9942.1	422.6	1		2245	92	71248.	13.8	348.7	2		1030	139	7662.	.2	342.0
1		1115	46	3615.	10069.2	423.0	1		2300	93	68317.	12.7	348.5	2		1045	140	7277.	.1	341.9
1		1130	47	4286.	10197.0	423.4	1		2315	94	65471.	11.6	348.2							

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PEAK OUTFLOW IS 1244166. AT TIME 17.00 HOURS

THE DAM BREACH HYDROGRAPH WAS DEVELOPED USING A TIME INTERVAL OF .005 HOURS DURING BREACH FORMATION.
DOWNSTREAM CALCULATIONS WILL USE A TIME INTERVAL OF .250 HOURS.
THIS TABLE COMPARES THE HYDROGRAPH FOR DOWNSTREAM CALCULATIONS WITH THE COMPUTED BREACH HYDROGRAPH.
INTERMEDIATE FLOWS ARE INTERPOLATED FROM END-OF-PERIOD VALUES.

TIME (HOURS)	TIME FROM BEGINNING OF BREACH (HOURS)	INTERPOLATED BREACH HYDROGRAPH (CFS)	-	COMPUTED BREACH HYDROGRAPH (CFS)	=	ERROR (CFS)	ACCUMULATED ERROR (CFS)	ACCUMULATED ERROR (AC-FT)
16.750	.000	36297.		36297.		0.	0.	0.
16.755	.005	60454.		36651.		23803.	23803.	10.
16.760	.010	84612.		37634.		46978.	70781.	29.
16.765	.015	108769.		39427.		69343.	140124.	58.
16.770	.020	132927.		42173.		90753.	230877.	95.
16.775	.025	157084.		45994.		111090.	341967.	141.
16.780	.030	181241.		50991.		130251.	472218.	195.
16.785	.035	205399.		57253.		148146.	620364.	256.
16.790	.040	229556.		64858.		164698.	785062.	324.
16.795	.045	253713.		73874.		179839.	964901.	399.
16.800	.050	277871.		84359.		193512.	1158413.	479.
16.805	.055	302028.		96362.		205666.	1364079.	564.
16.810	.060	326186.		109923.		216263.	1580342.	653.
16.815	.065	350343.		125076.		225267.	1805609.	746.
16.820	.070	374500.		141848.		232652.	2038261.	842.
16.825	.075	398658.		160259.		238399.	2276660.	941.
16.830	.080	422815.		180321.		242494.	2519154.	1041.
16.835	.085	446972.		202041.		244931.	2764086.	1142.
16.840	.090	471130.		225421.		245708.	3009794.	1244.
16.845	.095	495287.		250462.		244825.	3254619.	1345.
16.850	.100	519445.		277168.		242276.	3496896.	1445.
16.855	.105	543602.		305595.		238007.	3734902.	1543.
16.860	.110	567759.		335716.		232043.	3966946.	1639.
16.865	.115	591917.		367272.		224645.	4191591.	1732.
16.870	.120	616074.		400189.		215885.	4407476.	1821.
16.875	.125	640231.		434385.		205847.	4613323.	1906.
16.880	.130	664389.		469764.		194625.	4807948.	1987.
16.885	.135	688546.		506222.		182324.	4990272.	2062.
16.890	.140	712703.		543644.		169059.	5159331.	2132.
16.895	.145	736861.		581905.		154956.	5314287.	2196.
16.900	.150	761018.		620868.		140150.	5454437.	2254.
16.905	.155	785176.		660381.		124794.	5579232.	2305.
16.910	.160	809333.		700282.		109051.	5688282.	2351.
16.915	.165	833490.		740402.		93088.	5781370.	2389.
16.920	.170	857648.		780562.		77086.	5858456.	2421.
16.925	.175	881805.		820583.		61222.	5919678.	2446.
16.930	.180	905962.		860405.		45558.	5965235.	2465.
16.935	.185	930120.		899948.		30172.	5995407.	2477.
16.940	.190	954277.		939175.		15102.	6010509.	2484.
16.945	.195	978435.		978312.		123.	6010632.	2484.
16.950	.200	1002592.		1016305.		-13713.	5996919.	2478.
16.955	.205	1026749.		1052710.		-25960.	5970958.	2467.
16.960	.210	1050907.		1087236.		-36329.	5934629.	2452.
16.965	.215	1075064.		1119565.		-44501.	5890128.	2434.
16.970	.220	1099221.		1149388.		-50167.	5839961.	2413.
16.975	.225	1123379.		1176366.		-52988.	5786974.	2391.
16.980	.230	1147536.		1199786.		-52250.	5734724.	2370.
16.985	.235	1171694.		1218912.		-47218.	5687505.	2350.
16.990	.240	1195851.		1233143.		-37292.	5650213.	2335.
16.995	.245	1220008.		1241811.		-21803.	5628411.	2326.
17.000	.250	1244166.		1244166.		0.	5628411.	2326.

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                                                    STATION     OUT
TIME                       (O) INTERPOLATED BREACH HYDROGRAPH           (*) POINTS AT NORMAL TIME INTERVAL
(HRS)                      (B) COMPUTED BREACH HYDROGRAPH
         0.   200000.   400000.   600000.   800000.  1000000.  1200000.  1400000.        0.        0.        0.        0.        0.
16.75   1 .-*-------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
16.75   2 . BO      .         .         .         .         .         .         .         .         .         .         .
16.76   3 . B O     .         .         .         .         .         .         .         .         .         .         .
16.76   4 . B  O    .         .         .         .         .         .         .         .         .         .         .
16.77   5 . B    O  .         .         .         .         .         .         .         .         .         .         .
16.77   6 . B     O .         .         .         .         .         .         .         .         .         .         .
16.78   7 .  B     O.         .         .         .         .         .         .         .         .         .         .
16.78   8 .  B      O         .         .         .         .         .         .         .         .         .         .
16.79   9 .  B      .O        .         .         .         .         .         .         .         .         .         .
16.79  10 .   B     .  O      .         .         .         .         .         .         .         .         .         .
16.80  11 . . B . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
16.80  12 .    B    .    O    .         .         .         .         .         .         .         .         .         .
16.81  13 .    B    .     O   .         .         .         .         .         .         .         .         .         .
16.81  14 .     B   .       O .         .         .         .         .         .         .         .         .         .
16.82  15 .      B  .        O.         .         .         .         .         .         .         .         .         .
16.82  16 .       B .         O         .         .         .         .         .         .         .         .         .
16.83  17 .        B.         .O        .         .         .         .         .         .         .         .         .
16.83  18 .         B         . O       .         .         .         .         .         .         .         .         .
16.84  19 .         .B        .   O     .         .         .         .         .         .         .         .         .
16.84  20 .         .  B      .    O    .         .         .         .         .         .         .         .         .
16.85  21 . . . . . . . B . . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
16.85  22 .         .    B    .      O  .         .         .         .         .         .         .         .         .
16.86  23 .         .      B  .       O .         .         .         .         .         .         .         .         .
16.86  24 .         .       B .         O         .         .         .         .         .         .         .         .
16.87  25 .         .         B         .O        .         .         .         .         .         .         .         .
16.87  26 .         .         . B       . O       .         .         .         .         .         .         .         .
16.88  27 .         .         .  B      .  O      .         .         .         .         .         .         .         .
16.88  28 .         .         .    B    .   O     .         .         .         .         .         .         .         .
16.89  29 .         .         .      B  .     O   .         .         .         .         .         .         .         .
16.89  30 .         .         .        B.      O  .         .         .         .         .         .         .         .
16.90  31 . . . . . . . . . . . . . . . .B. . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
16.90  32 .         .         .         .  B     O.         .         .         .         .         .         .         .
16.91  33 .         .         .         .    B    O         .         .         .         .         .         .         .
16.91  34 .         .         .         .      B  . O       .         .         .         .         .         .         .
16.92  35 .         .         .         .        B.  O      .         .         .         .         .         .         .
16.92  36 .         .         .         .         .B  O     .         .         .         .         .         .         .
16.93  37 .         .         .         .         .  B O    .         .         .         .         .         .         .
16.93  38 .         .         .         .         .    B O  .         .         .         .         .         .         .
16.94  39 .         .         .         .         .      BO .         .         .         .         .         .         .
16.94  40 .         .         .         .         .        B.         .         .         .         .         .         .
16.95  41 . . . . . . . . . . . . . . . . . . . . . . . . . OB. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
16.95  42 .         .         .         .         .         .O B      .         .         .         .         .         .
16.96  43 .         .         .         .         .         .  OB     .         .         .         .         .         .
16.96  44 .         .         .         .         .         .   O B   .         .         .         .         .         .
16.97  45 .         .         .         .         .         .    O B  .         .         .         .         .         .
16.97  46 .         .         .         .         .         .     O  B.         .         .         .         .         .
16.98  47 .         .         .         .         .         .      O  B         .         .         .         .         .
16.98  48 .         .         .         .         .         .        O.B        .         .         .         .         .
16.99  49 .         .         .         .         .         .         O B       .         .         .         .         .
16.99  50 .         .         .         .         .         .         .OB       .         .         .         .         .
17.00  51 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . * . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
    (CFS)       (HR)                 6-HR       24-HR       72-HR     34.75-HR

  1244166.     17.00       (CFS)  130590.      50702.      35189.       35189.
                        (INCHES)   16.840      26.153      26.281       26.281
                         (AC-FT)   64755.     100566.     101058.      101058.

 PEAK STORAGE   TIME                         MAXIMUM AVERAGE STORAGE
   (AC-FT)      (HR)                 6-HR       24-HR       72-HR     34.75-HR

    13796.     16.78               11444.       7054.       4873.        4873.

  PEAK STAGE    TIME                          MAXIMUM AVERAGE STAGE
    (FEET)      (HR)                 6-HR       24-HR       72-HR     34.75-HR

    433.54     16.78               427.05      401.28      383.63       383.63

                        CUMULATIVE AREA =   72.10 SQ MI

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

   26 KP        PLAN  2 FOR STATION     OUT                 BEAR CREEK DAM

   27 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

            **************
            *            *
   35 KK    *      RCH1  *
            *            *
            **************

   36 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           1  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
                                 CHANNEL ROUTING   REACH 2-3

              HYDROGRAPH ROUTING DATA

   38 RS          STORAGE ROUTING
                        NSTPS           1  NUMBER OF SUBREACHES
                         ITYP        STOR  TYPE OF INITIAL CONDITION
                       RSVRIC         .00  INITIAL CONDITION
                            X         .00 WORKING R AND D COEFFICIENT

   39 RC          NORMAL DEPTH CHANNEL
                          ANL        .040  LEFT OVERBANK N-VALUE
                         ANCH        .050  MAIN CHANNEL N-VALUE
                          ANR        .040  RIGHT OVERBANK N-VALUE
                        RLNTH      15000.  REACH LENGTH
                          SEL       .0033  ENERGY SLOPE
                        ELMAX       335.0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                               CROSS-SECTION DATA
                             --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
   41 RY        ELEVATION   400.00    350.00    290.00    280.00    280.00    290.00    350.00    400.00
   40 RX        DISTANCE       .00    500.00   1400.00   1425.00   1450.00   1475.00   2500.00   3000.00

                                                                            ***

                                                COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

  STORAGE      .00     32.13     78.70    139.69    226.73    398.27    662.40   1019.10   1468.38   2010.23
  OUTFLOW      .00    278.28    996.96   2203.46   4252.05   8073.86  14580.63  24604.21  38871.36  58044.76
ELEVATION   280.00    282.89    285.79    288.68    291.58    294.47    297.37    300.26    303.16    306.05

  STORAGE  2644.67   3371.68   4191.26   5103.43   6108.17   7205.48   8395.38   9677.85  11052.90  12520.53
  OUTFLOW 82741.75 113545.00 151009.60 195667.30 248030.70 308595.30 377841.80 456237.60 544238.60 642289.60
ELEVATION   308.95    311.84    314.74    317.63    320.53    323.42    326.32    329.21    332.11    335.00
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HYDROGRAPH AT STATION RCH1
PLAN 1, RATIO = 1.00

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	0.	.0	280.0	1		1145	48	3637.	200.6	290.7	1		2330	95	66220.	2220.2	307.0
1		0015	2	73.	8.5	280.8	1		1200	49	4305.	229.1	291.6	1		2345	96	63490.	2150.1	306.7
1		0030	3	135.	15.6	281.4	1		1215	50	4970.	259.0	292.1	2		0000	97	60882.	2083.1	306.4
1		0045	4	186.	21.5	281.9	1		1230	51	5663.	290.1	292.6	2		0015	98	58397.	2019.3	306.1
1		0100	5	229.	26.4	282.4	1		1245	52	6376.	322.1	293.2	2		0030	99	56162.	1957.0	305.8
1		0115	6	265.	30.6	282.8	1		1300	53	7107.	354.9	293.7	2		0045	100	53979.	1895.3	305.4
1		0130	7	306.	33.9	283.0	1		1315	54	7855.	388.4	294.3	2		0100	101	51844.	1835.0	305.1
1		0145	8	344.	36.4	283.2	1		1330	55	8671.	422.5	294.7	2		0115	102	49775.	1776.5	304.8
1		0200	9	372.	38.2	283.3	1		1345	56	9517.	456.9	295.1	2		0130	103	47777.	1720.1	304.5
1		0215	10	393.	39.5	283.4	1		1400	57	10384.	492.0	295.5	2		0145	104	45847.	1665.5	304.2
1		0230	11	407.	40.5	283.4	1		1415	58	11290.	528.8	295.9	2		0200	105	43982.	1612.8	303.9
1		0245	12	418.	41.2	283.5	1		1430	59	12254.	568.0	296.3	2		0215	106	42177.	1561.8	303.7
1		0300	13	425.	41.7	283.5	1		1445	60	13292.	610.1	296.8	2		0230	107	40428.	1512.4	303.4
1		0315	14	431.	42.0	283.5	1		1500	61	14422.	656.0	297.3	2		0245	108	38740.	1464.2	303.1
1		0330	15	435.	42.3	283.5	1		1515	62	15780.	705.1	297.7	2		0300	109	37210.	1416.1	302.8
1		0345	16	438.	42.5	283.5	1		1530	63	17241.	757.1	298.1	2		0315	110	35660.	1367.3	302.5
1		0400	17	440.	42.6	283.5	1		1545	64	18822.	813.3	298.6	2		0330	111	34122.	1318.8	302.2
1		0415	18	441.	42.7	283.6	1		1600	65	20570.	875.5	299.1	2		0345	112	32611.	1271.2	301.9
1		0430	19	442.	42.7	283.6	1		1615	66	22538.	945.6	299.7	2		0400	113	31135.	1224.8	301.6
1		0445	20	443.	42.8	283.6	1		1630	67	25188.	1037.5	300.4	2		0415	114	29698.	1179.5	301.3
1		0500	21	443.	42.8	283.6	1		1645	68	29240.	1165.1	301.2	2		0430	115	28302.	1135.6	301.0
1		0515	22	443.	42.8	283.6	1		1700	69	444993.	9493.9	328.8	2		0445	116	26951.	1093.0	300.7
1		0530	23	444.	42.8	283.6	1		1715	70	610856.	12050.0	334.1	2		0500	117	25644.	1051.9	300.5
1		0545	24	444.	42.8	283.6	1		1730	71	191963.	5027.8	317.4	2		0515	118	24405.	1012.0	300.2
1		0600	25	444.	42.8	283.6	1		1745	72	109731.	3281.7	311.5	2		0530	119	23298.	972.6	299.9
1		0615	26	444.	42.8	283.6	1		1800	73	86195.	2726.2	309.3	2		0545	120	22194.	933.3	299.6
1		0630	27	444.	42.8	283.6	1		1815	74	79963.	2573.3	308.6	2		0600	121	21119.	895.1	299.3
1		0645	28	443.	42.8	283.6	1		1830	75	79984.	2573.8	308.6	2		0615	122	20081.	858.1	299.0
1		0700	29	443.	42.8	283.6	1		1845	76	82216.	2631.2	308.9	2		0630	123	19087.	822.8	298.7
1		0715	30	443.	42.8	283.6	1		1900	77	85234.	2703.5	309.2	2		0645	124	18138.	789.0	298.4
1		0730	31	443.	42.8	283.6	1		1915	78	88143.	2772.2	309.5	2		0700	125	17235.	756.8	298.1
1		0745	32	443.	42.8	283.6	1		1930	79	90622.	2830.6	309.7	2		0715	126	16374.	726.2	297.9
1		0800	33	443.	42.8	283.6	1		1945	80	92563.	2876.5	309.9	2		0730	127	15557.	697.1	297.7
1		0815	34	444.	42.8	283.6	1		2000	81	93919.	2908.5	310.0	2		0745	128	14779.	669.5	297.4
1		0830	35	444.	42.9	283.6	1		2015	82	94663.	2926.0	310.1	2		0800	129	14094.	642.6	297.2
1		0845	36	444.	42.9	283.6	1		2030	83	94763.	2928.4	310.1	2		0815	130	13439.	616.1	296.9
1		0900	37	445.	42.9	283.6	1		2045	84	94159.	2914.1	310.0	2		0830	131	12797.	590.0	296.6
1		0915	38	450.	43.2	283.6	1		2100	85	92840.	2883.0	309.9	2		0845	132	12175.	564.7	296.3
1		0930	39	475.	44.9	283.7	1		2115	86	90933.	2838.0	309.7	2		0900	133	11577.	540.5	296.0
1		0945	40	539.	49.0	283.9	1		2130	87	88631.	2783.7	309.5	2		0915	134	11004.	517.2	295.8
1		1000	41	654.	56.5	284.4	1		2145	88	86075.	2723.3	309.3	2		0930	135	10458.	495.0	295.5
1		1015	42	826.	67.7	285.1	1		2200	89	83347.	2659.0	309.0	2		0945	136	9937.	473.9	295.3
1		1030	43	1078.	82.8	286.0	1		2215	90	80630.	2590.4	308.7	2		1000	137	9441.	453.8	295.1
1		1045	44	1445.	101.3	286.9	1		2230	91	77806.	2517.9	308.4	2		1015	138	8970.	434.6	294.9
1		1100	45	1871.	122.9	287.9	1		2245	92	74896.	2443.1	308.0	2		1030	139	8521.	416.4	294.7
1		1115	46	2380.	147.2	288.9	1		2300	93	71963.	2367.8	307.7	2		1045	140	8095.	399.1	294.5
1		1130	47	2994.	173.3	289.8	1		2315	94	69055.	2293.1	307.3							

```
  PEAK FLOW     TIME                             MAXIMUM AVERAGE FLOW
   (CFS)        (HR)                  6-HR       24-HR        72-HR     34.75-HR

   610856.     17.25        (CFS)   128012.      50552.      35050.       35050.
                         (INCHES)    16.508      26.075      26.177       26.177
                          (AC-FT)    63477.     100269.     100659.      100659.

 PEAK STORAGE   TIME                            MAXIMUM AVERAGE STORAGE
   (AC-FT)      (HR)                 6-HR       24-HR       72-HR     34.75-HR

    12050.     17.25                  3501.       1599.       1117.        1117.

  PEAK STAGE    TIME                             MAXIMUM AVERAGE STAGE
    (FEET)      (HR)                  6-HR       24-HR        72-HR     34.75-HR

    334.07     17.25                 311.44      301.98      296.24       296.24

                          CUMULATIVE AREA =   72.10 SQ MI


***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

   42 KP        PLAN  2 FOR STATION     RCH1

   43 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

 WARNING --- ROUTED OUTFLOW ( 422100.) IS GREATER THAN MAXIMUM OUTFLOW ( 386821.) IN STORAGE-OUTFLOW TABLE

 WARNING --- ROUTED OUTFLOW ( 405334.) IS GREATER THAN MAXIMUM OUTFLOW ( 386821.) IN STORAGE-OUTFLOW TABLE
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PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN		RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	IN	72.10	1	FLOW	95158.
				TIME	20.25
			2	FLOW	95158.
				TIME	20.25
			3	FLOW	95158.
				TIME	20.25
			4	FLOW	95158.
				TIME	20.25
			5	FLOW	95158.
				TIME	20.25
ROUTED TO	OUT	72.10	1	FLOW	1244166.
				TIME	17.00
			2	FLOW	208217.
				TIME	18.25
			3	FLOW	135679.
				TIME	19.75
			4	FLOW	179532.
				TIME	19.50
			5	FLOW	109207.
				TIME	21.75
			** PEAK STAGES IN FEET **		
			1	STAGE	433.54
				TIME	16.78
			2	STAGE	434.13
				TIME	17.13
			3	STAGE	435.35
				TIME	17.94
			4	STAGE	434.61
				TIME	17.38
			5	STAGE	436.63
				TIME	19.00
ROUTED TO	RCH1	72.10	1	FLOW	610856.
				TIME	17.25
			2	FLOW	197055.
				TIME	18.50
			3	FLOW	127387.
				TIME	20.00
			4	FLOW	175177.
				TIME	19.75
			5	FLOW	108708.
				TIME	22.00
			** PEAK STAGES IN FEET **		
			1	STAGE	334.07
				TIME	17.25
			2	STAGE	317.71
				TIME	18.50
			3	STAGE	312.91
				TIME	20.00
			4	STAGE	316.30
				TIME	19.75
			5	STAGE	311.39
				TIME	22.00
ROUTED TO	RCH2	72.10	1	FLOW	422100.
				TIME	17.25
			2	FLOW	184431.
				TIME	18.75
			3	FLOW	122201.
				TIME	20.25
			4	FLOW	170547.
				TIME	19.75
			5	FLOW	108251.
				TIME	22.25
			** PEAK STAGES IN FEET **		
			1	STAGE	280.63
				TIME	17.25
			2	STAGE	275.97
				TIME	18.75
			3	STAGE	274.18
				TIME	20.25
			4	STAGE	275.61
				TIME	19.75
			5	STAGE	273.67
				TIME	22.25

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION OUT

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	420.00	420.00	432.00
STORAGE	9161.	9161.	13200.
OUTFLOW	447.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	433.54	1.54	13796.	1244166.	.60	17.00	16.75

PLAN 2 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	420.00	420.00	432.00
STORAGE	9161.	9161.	13200.
OUTFLOW	447.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	434.13	2.13	14025.	209653.	1.25	18.31	16.75

PLAN 3 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	420.00	420.00	432.00
STORAGE	9161.	9161.	13200.
OUTFLOW	447.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	435.35	3.35	14516.	135679.	3.00	19.75	16.75

PLAN 4 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	420.00	420.00	432.00
STORAGE	9161.	9161.	13200.
OUTFLOW	447.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	434.61	2.61	14218.	180309.	1.88	19.38	16.75

PLAN 5 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	420.00	420.00	432.00
STORAGE	9161.	9161.	13200.
OUTFLOW	447.	447.	26283.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	436.63	4.63	15040.	109207.	5.00	21.75	16.75

TABLE 1		STATION	RCH1	RCH1	RCH1	RCH1	RCH2	RCH2	RCH2	RCH2
			FLOW	FLOW	STAGE	STAGE	FLOW	FLOW	STAGE	STAGE
		PLAN	1	5	1	5	1	5	1	5
		RATIO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PER	DAY MON	HRMN								
1	1	0000	.00	.00	280.00	280.00	.00	.00	255.00	255.00
2	1	0015	73.46	73.46	280.76	280.76	5.47	5.47	255.02	255.02
3	1	0030	134.83	134.83	281.40	281.40	20.17	20.17	255.09	255.09
4	1	0045	186.10	186.10	281.94	281.94	41.06	41.06	255.18	255.18
5	1	0100	228.93	228.93	282.38	282.38	65.85	65.85	255.29	255.29
6	1	0115	264.69	264.69	282.75	282.75	92.80	92.80	255.41	255.41
7	1	0130	305.55	305.55	283.00	283.00	121.45	121.45	255.53	255.53
8	1	0145	344.29	344.29	283.16	283.16	151.75	151.75	255.66	255.66
9	1	0200	372.33	372.33	283.27	283.27	182.51	182.51	255.80	255.80
10	1	0215	392.62	392.62	283.36	283.36	212.30	212.30	255.93	255.93
11	1	0230	407.28	407.28	283.41	283.41	240.24	240.24	256.05	256.05
12	1	0245	417.87	417.87	283.46	283.46	265.91	265.91	256.16	256.16
13	1	0300	425.50	425.50	283.49	283.49	289.11	289.11	256.26	256.26
14	1	0315	430.99	430.99	283.51	283.51	317.59	317.59	256.35	256.35
15	1	0330	434.92	434.92	283.53	283.53	349.69	349.69	256.41	256.41
16	1	0345	437.73	437.73	283.54	283.54	373.79	373.79	256.46	256.46
17	1	0400	439.72	439.72	283.55	283.55	391.85	391.85	256.49	256.49
18	1	0415	441.11	441.11	283.55	283.55	405.36	405.36	256.52	256.52
19	1	0430	442.08	442.08	283.55	283.55	415.44	415.44	256.54	256.54
20	1	0445	442.74	442.74	283.56	283.56	422.95	422.95	256.55	256.55
21	1	0500	443.17	443.17	283.56	283.56	428.51	428.51	256.56	256.56
22	1	0515	443.43	443.43	283.56	283.56	432.63	432.63	256.57	256.57
23	1	0530	443.58	443.58	283.56	283.56	435.65	435.65	256.58	256.58
24	1	0545	443.64	443.64	283.56	283.56	437.87	437.87	256.58	256.58
25	1	0600	443.64	443.64	283.56	283.56	439.47	439.47	256.58	256.58
26	1	0615	443.59	443.59	283.56	283.56	440.63	440.63	256.59	256.59
27	1	0630	443.52	443.52	283.56	283.56	441.44	441.44	256.59	256.59
28	1	0645	443.44	443.44	283.56	283.56	442.01	442.01	256.59	256.59
29	1	0700	443.35	443.35	283.56	283.56	442.39	442.39	256.59	256.59
30	1	0715	443.29	443.29	283.56	283.56	442.65	442.65	256.59	256.59
31	1	0730	443.25	443.25	283.56	283.56	442.82	442.82	256.59	256.59
32	1	0745	443.27	443.27	283.56	283.56	442.94	442.94	256.59	256.59
33	1	0800	443.36	443.36	283.56	283.56	443.05	443.05	256.59	256.59
34	1	0815	443.53	443.53	283.56	283.56	443.16	443.16	256.59	256.59
35	1	0830	443.82	443.82	283.56	283.56	443.30	443.30	256.59	256.59
36	1	0845	444.23	444.23	283.56	283.56	443.50	443.50	256.59	256.59
37	1	0900	444.80	444.80	283.57	283.57	443.79	443.79	256.59	256.59
38	1	0915	449.56	449.56	283.58	283.58	444.73	444.73	256.59	256.59
39	1	0930	474.74	474.74	283.69	283.69	449.57	449.57	256.60	256.60
40	1	0945	539.10	539.10	283.95	283.95	465.53	465.53	256.63	256.63
41	1	1000	653.77	653.77	284.41	284.41	501.95	501.95	256.71	256.71
42	1	1015	826.47	826.47	285.10	285.10	568.21	568.21	256.83	256.83
43	1	1030	1077.60	1077.60	285.98	285.98	674.99	674.99	257.04	257.04
44	1	1045	1444.57	1444.57	286.86	286.86	838.04	838.04	257.36	257.36
45	1	1100	1870.85	1870.85	287.89	287.89	1089.25	1089.25	257.78	257.78
46	1	1115	2379.56	2379.56	288.93	288.93	1454.81	1454.81	258.26	258.26
47	1	1130	2994.03	2994.03	289.80	289.80	1889.54	1889.54	258.83	258.83
48	1	1145	3636.99	3636.99	290.71	290.71	2456.10	2456.10	259.43	259.43
49	1	1200	4305.33	4305.33	291.62	291.62	3072.56	3072.56	260.05	260.05
50	1	1215	4970.13	4970.13	292.12	292.12	3753.79	3753.79	260.64	260.64
51	1	1230	5662.88	5662.88	292.65	292.65	4456.53	4456.53	261.21	261.21
52	1	1245	6376.19	6376.19	293.19	293.19	5179.41	5179.41	261.76	261.76
53	1	1300	7106.74	7106.74	293.74	293.74	5937.76	5937.76	262.28	262.28
54	1	1315	7854.94	7854.94	294.31	294.31	6686.90	6686.90	262.79	262.79
55	1	1330	8670.97	8670.97	294.74	294.74	7490.69	7490.69	263.27	263.27
56	1	1345	9517.10	9517.10	295.12	295.12	8318.78	8318.78	263.75	263.75
57	1	1400	10384.00	10384.00	295.50	295.50	9162.31	9162.31	264.23	264.23
58	1	1415	11290.42	11290.42	295.90	295.90	10041.01	10041.01	264.64	264.64
59	1	1430	12253.92	12253.92	296.33	296.33	10949.22	10949.22	265.06	265.06
60	1	1445	13291.98	13291.98	296.80	296.80	11906.00	11906.00	265.51	265.51
61	1	1500	14422.28	14422.28	297.30	297.30	12675.67	12675.67	265.74	265.74
62	1	1515	15779.84	15779.84	297.71	297.71	13619.38	13619.38	266.01	266.01
63	1	1530	17241.21	17241.21	298.14	298.14	14744.32	14744.32	266.34	266.34
64	1	1545	18821.90	18821.90	298.59	298.59	16023.37	16023.37	266.72	266.72
65	1	1600	20569.95	20569.95	299.10	299.10	17422.87	17422.87	267.02	267.02
66	1	1615	22537.65	22537.65	299.67	299.67	18982.83	18982.83	267.30	267.30
67	1	1630	25187.82	25187.82	300.38	300.38	20825.63	20825.63	267.63	267.63
68	1	1645	29240.43	29240.43	301.20	301.20	23238.12	23238.12	268.06	268.06
69	1	1700	444993.40	34257.40	328.80	302.22	126295.60	26641.82	274.33	268.49
70	1	1715	610856.40	39968.23	334.07	303.32	422100.00	30879.19	280.63	268.98
71	1	1730	191962.70	46376.13	317.39	304.29	405333.70	35919.15	280.33	269.54
72	1	1745	109731.30	52690.27	311.48	305.24	207893.70	41900.64	276.51	270.03
73	1	1800	86194.58	58962.32	309.27	306.16	135232.30	48019.05	274.66	270.53
74	1	1815	79963.27	65445.61	308.62	306.92	107021.60	54491.89	273.62	270.98
75	1	1830	79983.99	71517.87	308.62	307.63	92937.07	61133.02	273.02	271.38

TABLE 1 (CONT.)		STATION	RCH1 FLOW	RCH1 FLOW	RCH1 STAGE	RCH1 STAGE	RCH2 FLOW	RCH2 FLOW	RCH2 STAGE	RCH2 STAGE
		PLAN	1	5	1	5	1	5	1	5
		RATIO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PER	DAY MON	HRMN								
76	1	1845	82216.41	77240.15	308.89	308.30	86915.11	67421.03	272.74	271.76
77	1	1900	85233.57	82577.64	309.18	308.93	85292.14	73362.71	272.67	272.11
78	1	1915	88143.26	87761.18	309.46	309.42	86002.48	79369.33	272.70	272.39
79	1	1930	90621.52	92248.80	309.69	309.84	87722.00	84780.18	272.78	272.64
80	1	1945	92562.77	96109.24	309.87	310.20	89690.92	89561.80	272.87	272.86
81	1	2000	93918.88	99371.59	310.00	310.51	91496.91	93722.64	272.95	273.06
82	1	2015	94663.20	102046.70	310.07	310.76	92918.41	97276.98	273.02	273.22
83	1	2030	94762.55	104143.40	310.08	310.96	93831.34	100236.90	273.06	273.36
84	1	2045	94159.09	105672.00	310.02	311.10	94151.59	102678.90	273.08	273.46
85	1	2100	92840.46	106595.80	309.90	311.19	93819.98	104547.80	273.06	273.53
86	1	2115	90932.93	107051.50	309.72	311.23	92836.43	105778.80	273.02	273.58
87	1	2130	88630.60	107639.80	309.50	311.29	91282.38	106626.30	272.94	273.61
88	1	2145	86075.10	108417.90	309.26	311.36	89283.25	107385.00	272.85	273.64
89	1	2200	83346.98	108707.50	309.00	311.39	86957.16	108022.00	272.74	273.66
90	1	2215	80630.49	108182.80	308.70	311.34	84429.49	108250.90	272.63	273.67
91	1	2230	77806.21	106917.10	308.37	311.22	81778.34	107871.80	272.50	273.65
92	1	2245	74896.29	105126.80	308.03	311.05	79017.33	106871.20	272.38	273.62
93	1	2300	71963.03	103155.90	307.68	310.87	76174.63	105394.60	272.24	273.56
94	1	2315	69055.46	101552.70	307.34	310.72	73292.38	103750.00	272.11	273.50
95	1	2330	66219.80	100143.10	307.01	310.58	70599.16	102180.20	271.95	273.44
96	1	2345	63490.26	98221.21	306.69	310.40	67872.36	100618.90	271.79	273.38
97	2	0000	60882.07	95610.77	306.39	310.16	65173.07	98735.07	271.63	273.29
98	2	0015	58396.71	92393.98	306.09	309.85	62546.18	96327.33	271.47	273.18
99	2	0030	56162.39	88681.73	305.77	309.51	60046.05	93381.96	271.32	273.04
100	2	0045	53979.27	84603.34	305.44	309.12	57684.27	89953.30	271.18	272.88
101	2	0100	51844.37	80455.82	305.12	308.68	55418.73	86176.51	271.04	272.71
102	2	0115	49775.43	76269.48	304.80	308.19	53230.87	82201.24	270.91	272.52
103	2	0130	47776.77	72021.30	304.50	307.69	51126.98	78102.85	270.78	272.33
104	2	0145	45846.91	67842.30	304.21	307.20	49231.07	73945.85	270.62	272.14
105	2	0200	43981.95	63806.78	303.93	306.73	47334.50	70038.01	270.47	271.92
106	2	0215	42177.16	59953.82	303.66	306.28	45465.04	66165.46	270.32	271.69
107	2	0230	40427.68	56415.21	303.39	305.81	43636.14	62376.82	270.17	271.46
108	2	0245	38739.71	53122.19	303.13	305.31	41855.65	58765.16	270.02	271.24
109	2	0300	37209.69	48370.89	302.82	304.59	40150.51	54958.63	269.89	271.01
110	2	0315	35660.41	42747.24	302.51	303.74	38518.08	50553.53	269.75	270.73
111	2	0330	34122.43	38505.16	302.19	303.08	36924.66	46191.84	269.62	270.38
112	2	0345	32611.32	35673.25	301.89	302.51	35361.51	42192.48	269.50	270.05
113	2	0400	31135.03	33428.37	301.59	302.05	33928.62	38835.03	269.34	269.78
114	2	0415	29697.89	31553.82	301.30	301.67	32507.33	36047.74	269.17	269.55
115	2	0430	28302.46	29905.92	301.01	301.34	31088.06	33820.30	269.01	269.33
116	2	0445	26950.66	28400.77	300.74	301.03	29687.27	31931.69	268.84	269.11
117	2	0500	25644.29	26992.66	300.47	300.75	28315.50	30217.89	268.68	268.91
118	2	0515	24405.42	25658.26	300.21	300.48	26983.85	28642.72	268.53	268.72
119	2	0530	23297.54	24406.31	299.89	300.21	25716.25	27181.66	268.38	268.55
120	2	0545	22194.44	23293.45	299.57	299.88	24514.25	25833.36	268.24	268.39
121	2	0600	21118.60	22188.13	299.26	299.57	23387.52	24581.87	268.08	268.25
122	2	0615	20081.22	21111.47	298.96	299.25	22334.84	23422.55	267.90	268.09
123	2	0630	19087.32	20074.05	298.67	298.95	21296.14	22353.93	267.71	267.90
124	2	0645	18138.46	19080.57	298.40	298.67	20282.86	21305.39	267.53	267.71
125	2	0700	17234.55	18132.54	298.13	298.39	19302.40	20286.23	267.35	267.53
126	2	0715	16374.48	17229.69	297.89	298.13	18359.12	19302.46	267.18	267.35
127	2	0730	15556.63	16370.86	297.65	297.89	17455.24	18357.56	267.02	267.18
128	2	0745	14779.22	15554.43	297.43	297.65	16591.48	17453.17	266.87	267.02
129	2	0800	14093.59	14778.61	297.15	297.43	15757.18	16589.66	266.64	266.87
130	2	0815	13439.18	14094.52	296.86	297.15	14982.57	15756.08	266.41	266.64
131	2	0830	12797.04	13441.65	296.57	296.86	14257.12	14982.56	266.20	266.41
132	2	0845	12174.91	12801.23	296.30	296.58	13567.97	14258.41	266.00	266.20
133	2	0900	11576.72	12180.85	296.03	296.30	12909.56	13570.73	265.81	266.00
134	2	0915	11004.12	11584.41	295.78	296.04	12279.56	12913.90	265.62	265.81
135	2	0930	10457.61	11013.61	295.53	295.78	11583.03	12285.55	265.36	265.63
136	2	0945	9936.96	10468.89	295.30	295.54	10856.03	11593.42	265.02	265.36
137	2	1000	9441.42	9949.96	295.08	295.31	10243.87	10867.34	264.74	265.03
138	2	1015	8969.94	9456.07	294.87	295.09	9699.21	10256.50	264.48	264.74
139	2	1030	8521.32	8986.16	294.67	294.88	9198.94	9713.31	264.25	264.49
140	2	1045	8094.54	8539.11	294.48	294.68	8737.42	9214.56	263.99	264.26
		MAX	610856.40	108707.50	334.07	311.39	422100.00	108250.90	280.63	273.67
		MIN	.00	.00	280.00	280.00	.00	.00	255.00	255.00
		AVE	34828.21	31008.90	296.18	296.19	34706.25	30882.18	264.74	264.72

*** NORMAL END OF HEC-1 ***

12.9 Example Problem #9: Multiflood Analysis

12.9.1 Introduction to Example Problems #9, #10, #11 and #12

The next four problems demonstrate the multiflood, multiplan, flood damage and flood control system optimization analysis capabilities of HEC-1. The watershed being analyzed has been experiencing severe flooding problems. To evaluate flood control measures proposed to mitigate existing problems, the HEC-1 model is to be employed. Problem 9 describes the use of the HEC-1 multiflood analysis capabilities in evaluating flooding potential of the subject watershed. Problem 10 continues the analysis begun in problem 9 by utilizing the HEC-1 multiplan-multiflood analysis capabilities to investigate various flood control scenarios for the watershed. In problem 11, the flood loss reduction benefits of proposed flood control measures are evaluated by adding flood damage data to the watershed model developed in problems 9 and 10. Problem 12 utilizes the HEC-1 optimization scheme to determine the optimal size of one of the flood control systems proposed in problem 11.

The Rockbed Watershed is the location of a small but expanding community. A diagram of the watershed is given in Figure 12.7. In the past, the area has experienced flooding in the low land area near the Black Water estuary. This flooding has generally been caused by the ponding at the 48" culvert, which drains runoff from the watershed through a protective embankment into the estuary. Recently, however, flooding in the area has had more serious consequences due to the residential and commercial development in the low lands. In addition, urbanization in the upper reaches of the watershed has caused increases in storm water runoff which further impacts on the flooding problems in the low land areas.

12.9.2 Multiflood Analysis

The hydrologic-hydraulic analysis of the Rockbed watershed with HEC-1 will focus on the two special problem areas shown in Figure 12.7, flood damage areas in reaches RCH1 and RCH2. The hydrologic effects of a series of floods on these damage reaches will be determined by using the multiflood analysis capabilities of HEC-1. In this example, ratios of a design flood will be used to simulate the effects of a number of different events at the damage centers. The **ratios are taken of the flow** (see JR card) and not of the precipitation because the rainfall-runoff response is assumed to be the same for current and future conditions.

The input data and program output are shown in Table 12.9a. In this case, the runoff from the design flood is input directly; these data would have been obtained from previous rainfall-runoff simulations. The RCH1 channel routing data are for the modified Puls method in which previous water surface profile studies have determined the storage-outflow characteristics of the reach. The RCH2 routing is from the ponding area, through the levee culvert, and into the main river. Two important points should be made about the input and output for this example:

(1) The multiflood analysis data deck differs from a stream network data by the addition of a JR record (see problem 1 for an example of a stream network analysis).

(2) The resulting peak flows and stages for each ratio of the design flood are displayed in the summary output at the end of the exhibited printout.

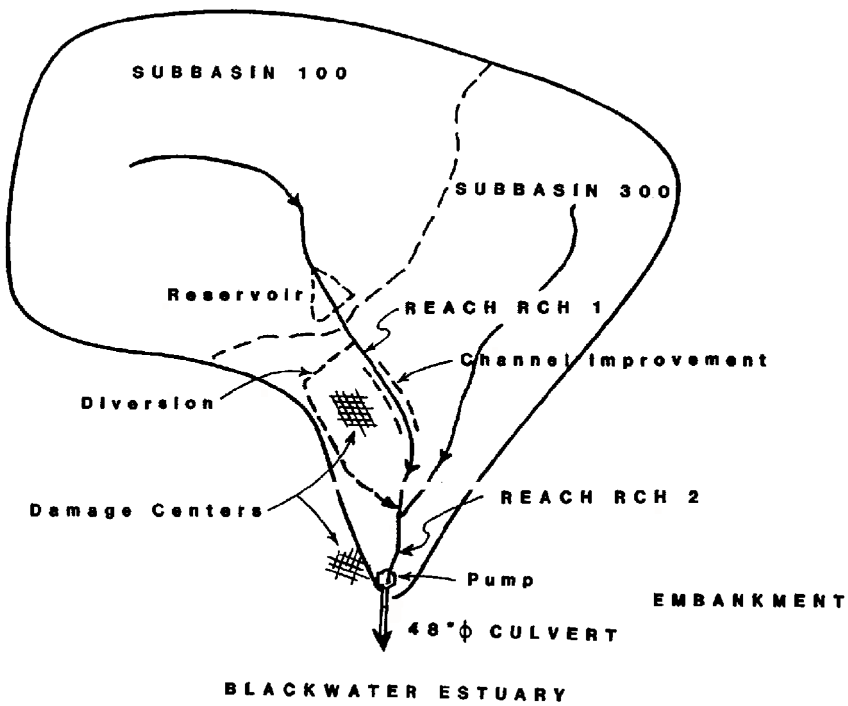

Figure 12.7a Rockbed Basin and Potential Flood Control Projects

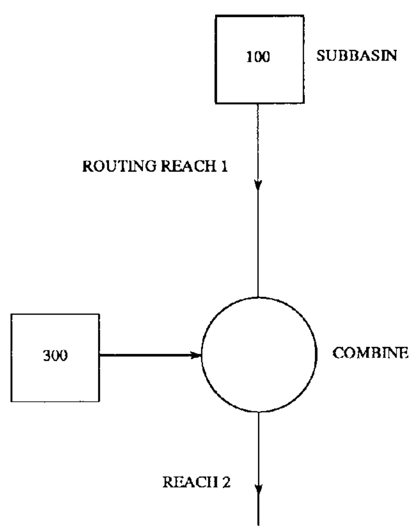

Figure 12.7b Rockbed Basin Schematic of Multiflood Analysis

Figure 12.7 Rockbed River Basin

Table 12.9

Example Problem #9

Input

```
ID      EXAMPLE PROBLEM NO. 9
ID      MULTIFLOOD ANALYSIS
ID      ROCKBED WATERSHED
*DIAGRAM
IT    60       0       0     130
IO     4
* ***************************   MULTIFLOOD RATIOS
JR  FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50
KK   100
KM     DESIGN FLOOD FOR SUBBASIN 100
BA  35.1
QI    24      24      24      26      33      50      86     189     376     516
QI   594     657     710     760     801     839     910    1044    1287    1921
QI  2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
QI  2719    2200    1844    1540    1251     994     777     605     471     365
QI   281       0       0       0       0       0       0       0       0       0
KK  RCH1
KM     LOCATION OF EXISTING FLOOD HAZARD
RS     1    STOR     -1.    0.
SV    0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
SQ    0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
KK   300
KM      RUNOFF FROM SUBBASIN 300
BA  49.1
QI    32      32      32      35      44      67     114     252     501     688
QI   789     877     940    1013    1068    1119    1214    1392    1717    2561
QI  3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
QI  3622    2930    2458    2053    1665    1325    1032     806     628     487
QI   374
KK   300
KM      COMBINED UPSTREAM INFLOWS
HC     2
KK  RCH2
KM     DAMAGE CENTER LOCATED IN THIS REACH, LOWLAND FLOODING
RS     1    STOR     -1.    0.
SV    0.    400.  30000.  35000.  40000.
SE   840     845     855     857     859
SQ     0    1250    1500    1800    2000
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:13   *
*                                       *
*****************************************
```

```
                                          HEC-1 INPUT                                         PAGE  1

 LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

    1          ID        EXAMPLE PROBLEM NO. 9
    2          ID        MULTIFLOOD ANALYSIS
    3          ID        ROCKBED WATERSHED
               *DIAGRAM
    4          IT      60       0       0     130
    5          IO       4
               * ***************************  MULTIFLOOD RATIOS
    6          JR    FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50

    7          KK     100
    8          KM       DESIGN FLOOD FOR SUBBASIN 100
    9          BA    35.1
   10          QI      24      24      24      26      33      50      86     189     376     516
   11          QI     594     657     710     760     801     839     910    1044    1287    1921
   12          QI    2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
   13          QI    2719    2200    1844    1540    1251     994     777     605     471     365
   14          QI     281       0       0       0       0       0       0       0       0       0

   15          KK    RCH1
   16          KM       LOCATION OF EXISTING FLOOD HAZARD
   17          RS       1    STOR     -1.      0.
   18          SV      0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
   19          SQ      0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.

   20          KK     300
   21          KM        RUNOFF FROM SUBBASIN 300
   22          BA    49.1
   23          QI      32      32      32      35      44      67     114     252     501     688
   24          QI     789     877     940    1013    1068    1119    1214    1392    1717    2561
   25          QI    3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
   26          QI    3622    2930    2458    2053    1665    1325    1032     806     628     487
   27          QI     374

   28          KK     300
   29          KM        COMBINED UPSTREAM INFLOWS
   30          HC       2

   31          KK    RCH2
   32          KM       DAMAGE CENTER LOCATED IN THIS REACH, LOWLAND FLOODING
   33          RS       1    STOR     -1.      0.
   34          SV      0.    400.  30000.  35000.  40000.
   35          SE     840     845     855     857     859
   36          SQ       0    1250    1500    1800    2000
   37          ZZ
```

```
                          SCHEMATIC DIAGRAM OF STREAM NETWORK
                INPUT
                 LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

                  NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

                    7         100
                               V
                               V
                   15        RCH1
                               .
                               .
                   20          .         300
                               .           .
                               .           .
                   28         300............
                               V
                               V
                   31        RCH2

                (***) RUNOFF ALSO COMPUTED AT THIS LOCATION
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:13   *
*                                       *
*****************************************
```

```
                                 EXAMPLE PROBLEM NO. 9
                                 MULTIFLOOD ANALYSIS
                                 ROCKBED WATERSHED

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           4  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          60  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1    0  STARTING DATE
                        ITIME        0000  STARTING TIME
                           NQ         130  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      6    0  ENDING DATE
                       NDTIME        0900  ENDING TIME
                       ICENT           19  CENTURY MARK

                  COMPUTATION INTERVAL    1.00 HOURS
                       TOTAL TIME BASE  129.00 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT

      JP          MULTI-PLAN OPTION
                        NPLAN           1  NUMBER OF PLANS

      JR          MULTI-RATIO OPTION
                      RATIOS OF RUNOFF
                      .11       .26       .45       .65       .86      1.00      1.20      1.40      1.50


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
```

```
             **************
             *            *
   7 KK      *       100  *
             *            *
             **************
                                  DESIGN FLOOD FOR SUBBASIN 100

                SUBBASIN RUNOFF DATA

   9 BA           SUBBASIN CHARACTERISTICS
                        TAREA       35.10  SUBBASIN AREA

                                                                   ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
  15 KK      *      RCH1  *
             *            *
             **************
                                  LOCATION OF EXISTING FLOOD HAZARD

                HYDROGRAPH ROUTING DATA

  17 RS           STORAGE ROUTING
                        NSTPS           1  NUMBER OF SUBREACHES
                         ITYP        STOR  TYPE OF INITIAL CONDITION
                       RSVRIC       -1.00  INITIAL CONDITION
                            X         .00 WORKING R AND D COEFFICIENT

  18 SV             STORAGE          .0      50.0     475.0     940.0    2135.0    3080.0

  19 SQ           DISCHARGE          0.      200.     1020.     2050.     6100.    10250.

                                                                   ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
  20 KK      *       300  *
             *            *
             **************
                                   RUNOFF FROM SUBBASIN 300

                SUBBASIN RUNOFF DATA

  22 BA           SUBBASIN CHARACTERISTICS
                        TAREA       49.10  SUBBASIN AREA

                                                                   ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
  28 KK      *       300  *
             *            *
             **************
                                   COMBINED UPSTREAM INFLOWS

  30 HC           HYDROGRAPH COMBINATION
                        ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                                   ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
```

```
              **************
              *            *
   31 KK      *     RCH2   *
              *            *
              **************
                                   DAMAGE CENTER LOCATED IN THIS REACH, LOWLAND FLOODING

                 HYDROGRAPH ROUTING DATA

   33 RS          STORAGE ROUTING
                        NSTPS          1  NUMBER OF SUBREACHES
                         ITYP       STOR  TYPE OF INITIAL CONDITION
                       RSVRIC      -1.00  INITIAL CONDITION
                            X        .00 WORKING R AND D COEFFICIENT

   34 SV            STORAGE          .0      400.0    30000.0    35000.0    40000.0

   35 SE          ELEVATION      840.00     845.00     855.00     857.00     859.00

   36 SQ          DISCHARGE          0.      1250.      1500.      1800.      2000.

                                                                     ***
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

					RATIOS APPLIED TO FLOWS								
OPERATION	STATION	AREA	PLAN		RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8	RATIO 9
					.11	.26	.45	.65	.86	1.00	1.20	1.40	1.50
HYDROGRAPH AT	100	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	RCH1	35.10	1	FLOW	429.	978.	1742.	2680.	3668.	4313.	5232.	6156.	6701.
				TIME	28.00	28.00	28.00	28.00	28.00	27.00	27.00	27.00	27.00
HYDROGRAPH AT	300	49.10	1	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
2 COMBINED AT	300	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	RCH2	84.20	1	FLOW	964.	1257.	1273.	1291.	1312.	1326.	1347.	1369.	1379.
				TIME	28.00	33.00	37.00	39.00	40.00	41.00	43.00	45.00	46.00
					** PEAK STAGES IN FEET **								
			1	STAGE	843.86	845.27	845.90	846.65	847.48	848.05	848.89	849.74	850.17
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00

*** NORMAL END OF HEC-1 ***

12.10 Example Problem #10: Multiplan, Multiflood Analysis

In the previous example, the existing flooding problems of Rockbed Watershed were quantified. Using the multiplan analysis capability of HEC-1, a number of flood protection scenarios for the subject area can be investigated in one run. In this case, two alternatives have been proposed to provide flood protection. The first alternative is to provide a reservoir upstream of damage reach RCH1 to reduce peak discharges in lower lying areas. A second alternative is to reduce flood hazard at reach RCH1 by providing a diversion channel upstream of the reach. In both alternatives, a pump will be used at damage reach RCH2 to reduce stages in the low land area. Fig. 12.7 shows these projects. A schematic of the PLAN 2 and PLAN 3 watershed models is given in Figures 12.8 and 12.9, respectively.

HEC-1 Multiplan Input Data Convention Examples. The data needed to update the multiflood model (Problem 9) to the desired multiplan model are displayed in Table 12.10a. Two routing reaches must be added to the Problem 9 model: one for the reservoir, and one for the diversion. The inclusion of this data in the multiflood data deck is clearly shown in the Table 12.10b data deck listing which is part of the computer output. In particular, note that the **multiplan option requires** the use of the **JP record**, and that the **KP** and **RN** records are also employed.

Preparation of the multiplan data for input into the required HEC-1 format can be simplified by following input conventions described in Section 10. Examples which demonstrate these conventions in the problem 10 data set are as follows:

(1) Inflows from subareas 100 and 300 are only specified once for all three plans; same as for problem 9. Because the rainfall-runoff response is assumed constant in all three plans, ratios are taken of the runoff.

(2) Routing reach RCH2 specifies data for a storage routing in PLAN 1; a KP record specifying PLAN 2 updates the storage routing with pump information; and lastly, a KP record specifying PLAN 3, not followed by any data, indicates PLAN 2 and PLAN 3 data for reach RCH2 are equivalent.

(3) Note the use of the **RN record** for routing reach 200. In the existing plan, PLAN 1, a reservoir is not included, and this is indicated with an RN record. The PLAN 2 flood control scenario includes a reservoir at station 200, which is indicated by the appropriate KP record and routing data. There is no data specified for PLAN 3 in this case (the KP record is absent) and hence the program defaults to the PLAN 1 data and prints a message to that effect. This is appropriate since there is no reservoir at station 200 for PLAN 3.

(4) Only PLAN 3 calls for a diversion as part of the flood control system. However, diversion data are included in all three plans. By program input convention, the data for PLANS 1 and 2 specify a diversion of zero capacity which has the intended effect of omitting a diversion for these plans.

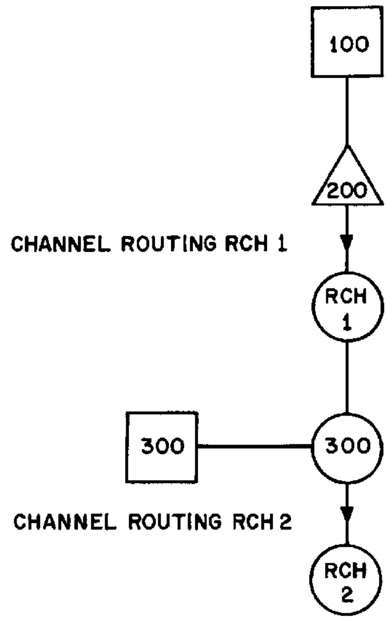

Figure 12.8 "PLAN 2" Rockbed Basin Schematic

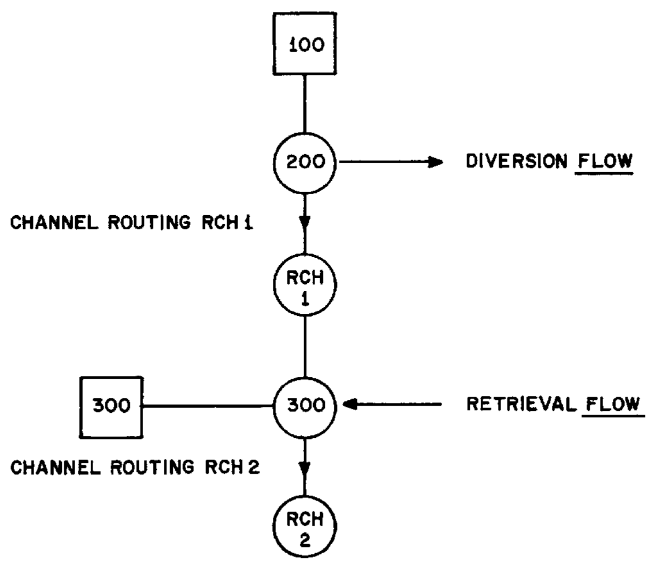

Figure 12.9 "PLAN 3" Rockbed Basin Schematic

Multiplan Analysis Results. The computer output for the multiplan analysis run is shown in Table 12.10b. A summary table at the end of that output shows the results of the analysis for each reach, flood ratio, and plan. Note that the peak flows are reduced at RCH1 and RCH2 by the reservoir and pump in PLAN 2. In PLAN 3, peak flows are reduced at RCH1 by diverting a portion of the flow at reach 325 to RCH2. However this has the result of increasing the flows at RCH2 to the point where it exceeds PLAN 1 conditions.

Table 12.10a

Multiplan Analysis - Rockbed Watershed Flood Control Data

Record Identifier

Flood Control Reservoir, PLAN 2

Reach ID: 200 — KK

Storage Routing — RS

NSTPS = 1
ITYP = STOR
RSVRIC = -1

Low Level Outlet — SL

Invert Elevation = 975 (m.s.l.)
Cross section Area = 35 (sq.ft.)
Discharge Coefficient = .7
Exponent of Head = .5

Spillway — SS

Crest Elevation = 1105 (m.s.l.)
Width = 35 (ft.)
Weir Coefficient = 2.8
Exponent of Head = 1.5

Volume-Elevation Data

Volume:	0,	2500,	4000,	5200,	6800,	9000,	11500,	15500,	21000,	30000	SV
Elevation:	965,	1000,	1015,	1030,	1045,	1060,	1075,	1090,	1105,	1120	SE

Channel Diversion, PLAN 3

Reach ID: 325 — KK

Diversion ID: Flow — DT

Inflow:	0,	2300,	4100,	6300,	8800,	14300,	20200,	30400,	33250,	38000	DI
Diversion:	0,	1400,	2000,	3400,	4800,	8000,	12200,	16200,	18550,	20000	DT

Pump, PLANS 2 and 3:

Reach ID: RCH2

Pump Data — WP

Threshold Reservoir Elevation = 843.5 (ft.)
Pump Capacity = 3000 (cfs)

Table 12.10b

Example Problem #10

Input

```
ID      EXAMPLE PROBLEM NO. 10
ID      MULTIPLAN ANALYSIS
ID      ROCKBED WATERSHED
*DIAGRAM
IT    60       0       0     130
IO     4
* ***************************************  MULTI PLAN AND RATIO DATA
JP     3
JR  FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50
KK   100
KM       POTENTIAL RESERVOIR INFLOW
BA  35.1
QI    24      24      24      26      33      50      86     189     376     516
QI   594     657     710     760     801     839     910    1044    1287    1921
QI  2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
QI  2719    2200    1844    1540    1251     994     777     605     471     365
QI   281       0       0       0       0       0       0       0       0       0
* ***************************************  PROPOSED RESERVOIR DATA
KK   200
KM       PROPOSED RESERVOIR
RN
KP     2
RS     1    STOR     -1.      0.
SL   975      35      .7      .5
SS  1105      35     2.8     1.5
SV     0    2500    4000    5200    6800    9000   11500   15500   21000   30000
SE   965    1000    1015    1030    1045    1060    1075    1090    1105    1120
* ***************************************  NO RESERVOIR PLAN 3
KP     3
RN
KK   325
KM      DIVERT FLOW PLAN 3
* ***************************************  DUMMY DIVERSION
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250
DQ
KP     2
* ***************************************  DUMMY DIVERSION
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250
DQ
KP     3
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250   38000
DQ     0    1400    2000    3400    4800    8000   12200   16200   18550   20000
KK  RCH1
KM       POTENTIAL CHANNEL MODIFICATION REACH
RS     1    STOR     -1.      0.
SV    0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
SQ    0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
KK   300
KM      RUNOFF FROM SUBBASIN 300
BA  49.1
QI    32      32      32      35      44      67     114     252     501     688
QI   789     877     940    1013    1068    1119    1214    1392    1717    2561
QI  3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
QI  3622    2930    2458    2053    1665    1325    1032     806     628     487
QI   374
KK   300
KM      COMBINED UPSTREAM INFLOWS
HC     2
KK   350
KM      RETRIEVE DIVERTED FLOW
DR  FLOW
KK   400
KM      COMBINE UPSTREAM AND DIVERTED INFLOWS
HC     2
KK  RCH2
KM       PROPOSED PUMPING PLANT SITE
RS     1    STOR     -1.      0.
SV    0.    400.  30000.  35000.  40000.
SE   840     845     855     857     859
SQ     0    1250    1500    1800    2000
* ***************************************  PLAN 2 PUMP DATA
KP     2
WP 843.5    3000
KP     3
ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:21   *
*                                       *
*****************************************




                                   HEC-1 INPUT                                        PAGE  1

  LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

    1           ID        EXAMPLE PROBLEM NO. 10
    2           ID        MULTIPLAN ANALYSIS
    3           ID        ROCKBED WATERSHED
                *DIAGRAM
    4           IT      60       0       0     130
    5           IO       4
                * **************************************  MULTI PLAN AND RATIO DATA
    6           JP       3
    7           JR    FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50

    8           KK     100
    9           KM         POTENTIAL RESERVOIR INFLOW
   10           BA    35.1
   11           QI      24      24      24      26      33      50      86     189     376     516
   12           QI     594     657     710     760     801     839     910    1044    1287    1921
   13           QI    2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
   14           QI    2719    2200    1844    1540    1251     994     777     605     471     365
   15           QI     281       0       0       0       0       0       0       0       0       0
                * **************************************  PROPOSED RESERVOIR DATA

   16           KK     200
   17           KM         PROPOSED RESERVOIR
   18           RN
   19           KP       2
   20           RS       1    STOR     -1.      0.
   21           SL     975      35      .7      .5
   22           SS    1105      35     2.8     1.5
   23           SV       0    2500    4000    5200    6800    9000   11500   15500   21000   30000
   24           SE     965    1000    1015    1030    1045    1060    1075    1090    1105    1120
                * **************************************  NO RESERVOIR PLAN 3
   25           KP       3
   26           RN

   27           KK     325
   28           KM        DIVERT FLOW PLAN 3
                * **************************************  DUMMY DIVERSION
   29           DT    FLOW   20000
   30           DI       0    2300    4100    6300    8800   14300   20200   30400   33250
   31           DQ
   32           KP       2
                * **************************************  DUMMY DIVERSION
   33           DT    FLOW   20000
   34           DI       0    2300    4100    6300    8800   14300   20200   30400   33250
   35           DQ
   36           KP       3
   37           DT    FLOW   20000
   38           DI       0    2300    4100    6300    8800   14300   20200   30400   33250   38000
   39           DQ       0    1400    2000    3400    4800    8000   12200   16200   18550   20000

   40           KK    RCH1
   41           KM         POTENTIAL CHANNEL MODIFICATION REACH
   42           RS       1    STOR     -1.      0.
   43           SV      0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
   44           SQ      0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
```

```
                                        HEC-1 INPUT                                                        PAGE  2

LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  45         KK     300
  46         KM        RUNOFF FROM SUBBASIN 300
  47         BA    49.1
  48         QI      32      32      32      35      44      67     114     252     501     688
  49         QI     789     877     940    1013    1068    1119    1214    1392    1717    2561
  50         QI    3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
  51         QI    3622    2930    2458    2053    1665    1325    1032     806     628     487
  52         QI     374

  53         KK     300
  54         KM        COMBINED UPSTREAM INFLOWS
  55         HC       2

  56         KK     350
  57         KM        RETRIEVE DIVERTED FLOW
  58         DR    FLOW

  59         KK     400
  60         KM        COMBINE UPSTREAM AND DIVERTED INFLOWS
  61         HC       2

  62         KK    RCH2
  63         KM         PROPOSED PUMPING PLANT SITE
  64         RS       1    STOR     -1.     0.
  65         SV      0.    400.  30000.  35000.  40000.
  66         SE     840     845     855     857     859
  67         SQ       0    1250    1500    1800    2000
             * **************************************  PLAN 2 PUMP DATA
  68         KP       2
  69         WP   843.5    3000
  70         KP       3
  71         ZZ
```

```
                  SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

     8         100
                 V
                 V
    16         200
                 .
                 .
    29           .------->    FLOW
    27         325
                 V
                 V
    40        RCH1
                 .
                 .
    45           .         300
                 .           .
                 .           .
    53         300............
                 .
                 .
    58           .           .<-------    FLOW
    56           .         350
                 .           .
                 .           .
    59         400............
                 V
                 V
    69           .------->
    62        RCH2

 (***) RUNOFF ALSO COMPUTED AT THIS LOCATION
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:21   *
*                                       *
*****************************************


                                 EXAMPLE PROBLEM NO. 10
                                 MULTIPLAN ANALYSIS
                                 ROCKBED WATERSHED

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          4  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN         60  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1    0  STARTING DATE
                        ITIME       0000  STARTING TIME
                           NQ        130  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      6    0  ENDING DATE
                       NDTIME       0000  ENDING TIME
                       ICENT          19  CENTURY MARK

                    COMPUTATION INTERVAL    1.00 HOURS
                         TOTAL TIME BASE  129.00 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT

      JP          MULTI-PLAN OPTION
                        NPLAN          3  NUMBER OF PLANS

      JR          MULTI-RATIO OPTION
                      RATIOS OF RUNOFF
                      .11       .26       .45       .65       .86      1.00      1.20      1.40      1.50


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
    8 KK     *       100  *
             *            *
             **************
                                  POTENTIAL RESERVOIR INFLOW

                SUBBASIN RUNOFF DATA

   10 BA          SUBBASIN CHARACTERISTICS
                        TAREA       35.10  SUBBASIN AREA

                                                                   ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                PLAN  2 INPUT DATA FOR STATION      100 ARE SAME AS FOR PLAN  1

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                PLAN  3 INPUT DATA FOR STATION      100 ARE SAME AS FOR PLAN  1


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
```

```
            **************
            *            *
  16 KK     *       200  *
            *            *
            **************
                              PROPOSED RESERVOIR

               HYDROGRAPH ROUTING DATA

  18 RN          NO ROUTING

                                                                        ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

  19 KP        PLAN  2 FOR STATION      200

               HYDROGRAPH ROUTING DATA

  20 RS          STORAGE ROUTING
                       NSTPS           1  NUMBER OF SUBREACHES
                        ITYP        STOR  TYPE OF INITIAL CONDITION
                      RSVRIC       -1.00  INITIAL CONDITION
                           X         .00 WORKING R AND D COEFFICIENT

  23 SV            STORAGE          .0    2500.0    4000.0    5200.0    6800.0    9000.0   11500.0   15500.0   21000.0   30000.0


  24 SE          ELEVATION      965.00   1000.00   1015.00   1030.00   1045.00   1060.00   1075.00   1090.00   1105.00   1120.00


  21 SL          LOW-LEVEL OUTLET
                       ELEVL      975.00  ELEVATION AT CENTER OF OUTLET
                       CAREA       35.00  CROSS-SECTIONAL AREA
                        COQL         .70  COEFFICIENT
                        EXPL         .50  EXPONENT OF HEAD

  22 SS          SPILLWAY
                        CREL     1105.00  SPILLWAY CREST ELEVATION
                       SPWID       35.00  SPILLWAY WIDTH
                        COQW        2.80  WEIR COEFFICIENT
                        EXPW        1.50  EXPONENT OF HEAD

                                                                        ***

                                                COMPUTED OUTFLOW-ELEVATION DATA

             OUTFLOW        .00        .00     369.46     419.50     485.23     575.38     706.68     915.61    1299.94    2240.33
           ELEVATION     965.00     975.00     978.54     979.56     981.10     983.57     987.93     996.71    1018.77    1105.00

             OUTFLOW    2250.35    2300.46    2423.35    2651.62    3017.85    3554.66    4294.65    5270.33    6514.41    8059.34
           ELEVATION    1105.19    1105.67    1106.45    1107.51    1108.86    1110.51    1112.45    1114.67    1117.19    1120.00
```

```
                                        COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

          STORAGE        .00    714.29    966.82   1039.86   1149.88   1326.78   1638.21   2265.28   2500.00   4000.00
          OUTFLOW        .00       .00    369.46    419.50    485.23    575.38    706.68    915.61    982.45   1242.71
        ELEVATION     965.00    975.00    978.54    979.56    981.10    983.57    987.93    996.71   1000.00   1015.00

          STORAGE    4301.52   5200.00   6800.00   9000.00  11500.00  15500.00  21000.00  21116.16  21404.88  21868.21
          OUTFLOW    1299.94   1457.21   1643.95   1811.55   1964.90   2107.12   2240.33   2250.35   2300.46   2423.35
        ELEVATION    1018.77   1030.00   1045.00   1060.00   1075.00   1090.00   1105.00   1105.19   1105.67   1106.45

          STORAGE   22506.15  23318.63  24305.71  25467.41  26803.64  28314.55  30000.00
          OUTFLOW    2651.62   3017.85   3554.66   4294.65   5270.33   6514.41   8059.34
        ELEVATION    1107.51   1108.86   1110.51   1112.45   1114.67   1117.19   1120.00


***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

  25 KP        PLAN  3 FOR STATION      200

               HYDROGRAPH ROUTING DATA

  26 RN          NO ROUTING

                                                                ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

            **************
            *            *
  27 KK     *       325  *
            *            *
            **************
                                DIVERT FLOW PLAN 3

     DT          DIVERSION
                       ISTAD        FLOW  DIVERSION HYDROGRAPH IDENTIFICATION
                      DSTRMX    20000.00  MAXIMUM VOLUME TO BE DIVERTED

     DI             INFLOW         .00   2300.00   4100.00   6300.00   8800.00  14300.00  20200.00  30400.00  33250.00

     DQ      DIVERTED FLOW         .00       .00       .00       .00       .00       .00       .00       .00       .00

                                                                ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

  32 KP        PLAN  2 FOR STATION      325

     DT          DIVERSION
                       ISTAD        FLOW  DIVERSION HYDROGRAPH IDENTIFICATION
                      DSTRMX    20000.00  MAXIMUM VOLUME TO BE DIVERTED

     DI             INFLOW         .00   2300.00   4100.00   6300.00   8800.00  14300.00  20200.00  30400.00  33250.00

     DQ      DIVERTED FLOW         .00       .00       .00       .00       .00       .00       .00       .00       .00

                                                                ***
```

```
***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

   36 KP        PLAN  3 FOR STATION      325

      DT          DIVERSION
                        ISTAD        FLOW  DIVERSION HYDROGRAPH IDENTIFICATION
                       DSTRMX    20000.00  MAXIMUM VOLUME TO BE DIVERTED

      DI             INFLOW         .00   2300.00   4100.00   6300.00   8800.00  14300.00  20200.00  30400.00  33250.00  38000.00


      DQ      DIVERTED FLOW         .00   1400.00   2000.00   3400.00   4800.00   8000.00  12200.00  16200.00  18550.00  20000.00

                                                                ***

 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


             **************
             *            *
   40 KK     *      RCH1  *
             *            *
             **************
                                POTENTIAL CHANNEL MODIFICATION REACH

                HYDROGRAPH ROUTING DATA

   42 RS          STORAGE ROUTING
                        NSTPS           1  NUMBER OF SUBREACHES
                         ITYP        STOR  TYPE OF INITIAL CONDITION
                       RSVRIC       -1.00  INITIAL CONDITION
                            X         .00 WORKING R AND D COEFFICIENT

   43 SV            STORAGE          .0      50.0     475.0     940.0    2135.0    3080.0

   44 SQ          DISCHARGE          0.      200.     1020.     2050.     6100.    10250.
                                                                ***


 ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                PLAN  2 INPUT DATA FOR STATION     RCH1 ARE SAME AS FOR PLAN  1


 ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                PLAN  3 INPUT DATA FOR STATION     RCH1 ARE SAME AS FOR PLAN  1


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
```

```
              **************
              *            *
   45 KK      *       300  *
              *            *
              **************
                                 RUNOFF FROM SUBBASIN 300

                 SUBBASIN RUNOFF DATA

   47 BA           SUBBASIN CHARACTERISTICS
                         TAREA       49.10  SUBBASIN AREA

                                                                 ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                 PLAN  2 INPUT DATA FOR STATION      300 ARE SAME AS FOR PLAN  1

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

                 PLAN  3 INPUT DATA FOR STATION      300 ARE SAME AS FOR PLAN  1

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 

              **************
              *            *
   53 KK      *       300  *
              *            *
              **************
                                 COMBINED UPSTREAM INFLOWS

   55 HC           HYDROGRAPH COMBINATION
                         ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                                 ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 

              **************
              *            *
   56 KK      *       350  *
              *            *
              **************
                                 RETRIEVE DIVERTED FLOW

   58 DR           RETRIEVE DIVERSION HYDROGRAPH
                         ISTAD        FLOW  DIVERSION HYDROGRAPH IDENTIFICATION

                                                                 ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 

              **************
              *            *
   59 KK      *       400  *
              *            *
              **************
                                 COMBINE UPSTREAM AND DIVERTED INFLOWS

   61 HC           HYDROGRAPH COMBINATION
                         ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                                 ***

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** 
```

```
                 **************
                 *            *
   62 KK         *      RCH2  *
                 *            *
                 **************
                                    PROPOSED PUMPING PLANT SITE

                    HYDROGRAPH ROUTING DATA

   64 RS              STORAGE ROUTING
                            NSTPS            1  NUMBER OF SUBREACHES
                             ITYP         STOR  TYPE OF INITIAL CONDITION
                           RSVRIC        -1.00  INITIAL CONDITION
                                X          .00 WORKING R AND D COEFFICIENT

   65 SV                STORAGE          .0      400.0   30000.0   35000.0   40000.0

   66 SE              ELEVATION      840.00     845.00    855.00    857.00    859.00

   67 SQ              DISCHARGE          0.      1250.     1500.     1800.     2000.

                                                                       ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

   68 KP            PLAN  2 FOR STATION     RCH2

                    HYDROGRAPH ROUTING DATA

   64 RS              STORAGE ROUTING
                            NSTPS            1  NUMBER OF SUBREACHES
                             ITYP         STOR  TYPE OF INITIAL CONDITION
                           RSVRIC        -1.00  INITIAL CONDITION
                                X          .00 WORKING R AND D COEFFICIENT

   65 SV                STORAGE          .0      400.0   30000.0   35000.0   40000.0

   66 SE              ELEVATION      840.00     845.00    855.00    857.00    859.00

   67 SQ              DISCHARGE          0.      1250.     1500.     1800.     2000.

   69 WP              PUMPING DATA

                         PUMP ON    PUMPING    PUMP OFF
                        ELEVATION     RATE    ELEVATION

                           843.5     3000.       843.5

                            ISTAD              PUMP FLOW HYDROGRAPH IDENTIFICATION

                                                                       ***

***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***     ***

   70 KP            PLAN  3 FOR STATION     RCH2

                    HYDROGRAPH ROUTING DATA

   64 RS              STORAGE ROUTING
                            NSTPS            1  NUMBER OF SUBREACHES
                             ITYP         STOR  TYPE OF INITIAL CONDITION
                           RSVRIC        -1.00  INITIAL CONDITION
                                X          .00 WORKING R AND D COEFFICIENT

   65 SV                STORAGE          .0      400.0   30000.0   35000.0   40000.0

   66 SE              ELEVATION      840.00     845.00    855.00    857.00    859.00

   67 SQ              DISCHARGE          0.      1250.     1500.     1800.     2000.

   69 WP              PUMPING DATA

                         PUMP ON    PUMPING    PUMP OFF
                        ELEVATION     RATE    ELEVATION

                           843.5     3000.       843.5

                            ISTAD              PUMP FLOW HYDROGRAPH IDENTIFICATION

                                                                       ***
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN		RATIO 1 .11	RATIO 2 .26	RATIO 3 .45	RATIO 4 .65	RATIO 5 .86	RATIO 6 1.00	RATIO 7 1.20	RATIO 8 1.40	RATIO 9 1.50
HYDROGRAPH AT	100	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	200	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	617.	864.	1052.	1206.	1317.	1467.	1573.	1627.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			** PEAK STAGES IN FEET **										
			1	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	STAGE	978.51	984.95	994.56	1003.99	1012.91	1020.02	1030.80	1039.32	1043.67
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
DIVERSION TO	FLOW	35.10	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			2	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			3	FLOW	360.	850.	1439.	1798.	2332.	2811.	3483.	4085.	4386.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
HYDROGRAPH AT	325	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	617.	864.	1052.	1206.	1317.	1467.	1573.	1627.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	FLOW	231.	547.	979.	1695.	2290.	2563.	2965.	3438.	3675.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	RCH1	35.10	1	FLOW	429.	978.	1742.	2680.	3668.	4313.	5232.	6156.	6701.
				TIME	28.00	28.00	28.00	28.00	28.00	27.00	27.00	27.00	27.00
			2	FLOW	305.	551.	784.	980.	1135.	1241.	1389.	1504.	1557.
				TIME	34.00	38.00	39.00	41.00	41.00	41.00	42.00	43.00	43.00
			3	FLOW	199.	399.	675.	1129.	1626.	1868.	2225.	2646.	2853.
				TIME	27.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
HYDROGRAPH AT	300	49.10	1	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00

2 COMBINED AT	300	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	979.	2176.	3649.	5181.	6777.	7833.	9332.	10825.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	974.	2215.	3805.	5597.	7500.	8712.	10420.	12175.	13108.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
HYDROGRAPH AT	350	.00	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			2	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			3	FLOW	360.	850.	1439.	1798.	2332.	2811.	3483.	4085.	4386.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
2 COMBINED AT	400	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	979.	2176.	3649.	5181.	6777.	7833.	9332.	10825.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	1333.	3065.	5244.	7395.	9832.	11523.	13903.	16261.	17494.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
PUMP FLOW TO		84.20	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	FLOW	0.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
				TIME	1.00	23.00	21.00	19.00	17.00	16.00	14.00	13.00	13.00
			3	FLOW	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
				TIME	26.00	22.00	20.00	16.00	14.00	13.00	12.00	12.00	12.00
HYDROGRAPH AT	RCH2	84.20	1	FLOW	964.	1257.	1273.	1291.	1312.	1326.	1347.	1369.	1379.
				TIME	28.00	33.00	37.00	39.00	40.00	41.00	43.00	45.00	46.00
			2	FLOW	802.	1127.	1251.	1252.	1260.	1265.	1274.	1284.	1290.
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00
			3	FLOW	935.	1250.	1252.	1263.	1278.	1289.	1306.	1323.	1333.
				TIME	25.00	25.00	28.00	30.00	32.00	33.00	34.00	35.00	35.00
			** PEAK STAGES IN FEET **										
			1	STAGE	843.86	845.27	845.90	846.65	847.48	848.05	848.89	849.74	850.17
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00
			2	STAGE	843.21	844.51	845.02	845.09	845.41	845.62	845.97	846.36	846.60
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00
			3	STAGE	843.74	845.01	845.09	845.51	846.14	846.57	847.23	847.93	848.32
				TIME	25.00	25.00	28.00	30.00	32.00	33.00	34.00	35.00	35.00

*** NORMAL END OF HEC-1 ***

12.11 Example Problem #11: Flood Damage Analysis

The flood damage reduction analysis is useful in evaluating the economic viability of various flood control plans. In this example, the multiplan watershed model of Problem 10 is updated with economic data for each damage center as depicted in Figure 12.7. The resulting model is used to calculate the expected annual damage for each plan and the inundation reduction benefit accrued due to the employment of any flood control scenario.

The data for the flood damage analysis is shown in Table 12.11a. The listing of the input data deck and a summary of the analysis results is given in Table 12.11b. **Note** that the economic data (beginning with the EC record) is added at the end of the multiplan-multiflood data deck (no changes are made to the multiplan-multiflood data).

Discussion of Results. An important point to note in the computer output (Table 12.11b) concerns the calculation of the damage frequency curve discussed in Section 8. The program outputs the interpolated flow-damage and flow-frequency data based on the input data and simulated flows. It is important that the damage-frequency curve calculated from this data cover the entire range of frequencies intended (including rare frequencies) for an accurate estimate of EAD. See Section 8 for a more detailed discussion of this point.

Table 12.11a

Flood Damage Reduction Analysis Economic Data

Record Identifiers

1. **Land Use Categories:** CN

Category	**Category ID**	**Category No.**
Residential	RESID	1
Industrial/Commercial	IND/COM	2
Agricultural	AGRIC	3

2. **Frequency-Flow, Flow-Damage Data, Damage Reach RCH1:** QF, FR DG, PD

Hydrologic Data			**Damage Data**		
	Frequency (% Exceedence)	Flow (cfs)		Flow (cfs)	AGRIC (THOUS $)
1.	700	400	1.	400	0
2.	600	490	2.	600	1
3.	550	530	3.	730	2
4.	450	640	4.	960	3
5.	350	800	5.	1230	5
6.	250	1070	6.	1530	7
7.	150	1480	7.	1970	28
8.	90	1690	8.	2500	49
9.	70	1920	9.	3100	111
10.	50	2170	10.	3490	314
11.	35	2480	11.	3780	516
12.	25	2850	12.	4290	619
13.	16.5	3240	13.	5120	723
14.	10.0	3640	14.	6020	728
15.	5.0	4090	15.	7100	830
16.	2.0	4900			
17.	.5	5900			
18.	.1	7100			

3. **Frequency-Stage, Stage-Damage Data, Damage Reach RCH1:** SF, FR SD, DG

Hydrologic Data			**Damage Data**			
	Frequency (% Exceedence)	Stage (ft)		Stage (ft)	RESID (THOUS $)	IND/COM (THOUS $)
1.	95	843.6	1.	845.0	0	0
2.	81	844.8	2.	845.5	5720	10.5
3.	60	846.6	3.	847.0	1380	15.0
4.	45	846.0	4.	847.6	2710	52.5
5.	25	846.6	5.	848.3	5200	105.0
6.	11	847.3	6.	849.0	8000	202.5
7.	5	857.9	7.	849.8	10050	540.0
8.	2.5	848.4	8.	851.0	11250	585.0
9.	1	849.1				
10.	.5	849.5				
11.	.2					

Table 12.11b

Example Problem #11

Input

```
ID      EXAMPLE PROBLEM NO. 11
ID      FLOOD DAMAGE ANALYSIS
ID      ROCKBED WATERSHED
*DIAGRAM
IT    60       0       0     130
IO     5
* **************************************  MULTI PLAN AND RATIO DATA
JP     3
JR  FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50
KK   100
KM      DESIGN FLOOD SUBBASIN 100
BA  35.1
QI    24      24      24      26      33      50      86     189     376     516
QI   594     657     710     760     801     839     910    1044    1287    1921
QI  2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
QI  2719    2200    1844    1540    1251     994     777     605     471     365
QI   281       0       0       0       0       0       0       0       0       0
* **************************************  PROPOSED RESERVOIR DATA
KK   200
KM       PROPOSED RESERVOIR
RN
KP     2
RS     1    STOR     -1.     0.
SL   975      35      .7      .5
SS  1105      35     2.8     1.5
SV     0    2500    4000    5200    6800    9000   11500   15500   21000   30000
SE   965    1000    1015    1030    1045    1060    1075    1090    1105    1120
* **************************************  NO RESERVOIR PLAN 3
KK   325
KM      DIVERT FLOW PLAN 3
* **************************************  DUMMY DIVERSION
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250
DQ
KP     2
* **************************************  DUMMY DIVERSION
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250
DQ
KP     3
DT  FLOW   20000
DI     0    2300    4100    6300    8800   14300   20200   30400   33250   38000
DQ     0    1400    2000    3400    4800    8000   12200   16200   18550   20000
KK  RCH1
KM      LOCAL PROTECTION PROJECT PROJECT FOR REACH RCH1
RS     1    STOR     -1.     0.
SV    0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
SQ    0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
KK   300
KM      DESIGN FLOOD SUBBASIN 300
KM      RUNOFF FROM SUBBASIN 300
BA  49.1
QI    32      32      32      35      44      67     114     252     501     688
QI   789     877     940    1013    1068    1119    1214    1392    1717    2561
QI  3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
QI  3622    2930    2458    2053    1665    1325    1032     806     628     487
QI   374
KK   300
KM      COMBINED UPSTREAM INFLOWS
HC     2
KK   350
KM      RETRIEVE DIVERTED FLOW
DR  FLOW
```

```
KK   400
KM      COMBINE UPSTREAM AND DIVERTED INFLOWS
HC     2
KK  RCH2
KM      DAMAGE REACH LOWLAND FLOODING PROBLEMS
KM       PROPOSED PUMPING PLANT SITE
RS     1    STOR     -1.    0.
SV    0.    400.  30000.  35000.  40000.
SE   840     845     855     857     859
SQ     0    1250    1500    1800    2000
* **************************************  PLAN 2 PUMP DATA
KP     2
WP 843.5    3000
KP     3
* **************************************  ECONOMICS DATA
EC
KK  RCH1
CN     3   RESID IND/COM   AGRIC
FR            18   700.0   600.0   550.0   450.0   350.0   250.0   150.0    90.0
FR  70.0    50.0    35.0    25.0    16.5    10.0     5.0     2.0      .5      .1
QF                   400     490     530     640     800    1070    1480    1690
QF  1920    2170    2480    2850    3240    3640    4090    4900    5900    7100
QD            15     400     600     730     960    1230    1530    1970    2500
QD  3100    3490    3780    4290    5120    6020    7100
DG           1 3       0       1       2       3       5       7      28      49
DG   111     314     516     619     723     728     830
KK  RCH2
CN     3   RESID IND/COM   AGRIC
FR            12      95      81      60      45      25      11       5     2.5
FR     1      .5      .2      .1
SF                 843.6   844.8   845.6   846.0   846.6   847.3   847.9   848.4
SF 849.1   849.5   850.0   850.3
SD             8   845.0   845.5   847.0   847.6   848.3   849.0   849.8   851.0
DG           1 1       0     720    1380    2710    5200    8000   10050   11250
DG           1 2       0    10.5    15.0    52.5   105.0   202.5     540     585
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*            VERSION 4.1                *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:31   *
*                                       *
*****************************************


                                         HEC-1 INPUT                                        PAGE  1

  LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

    1           ID        EXAMPLE PROBLEM NO. 11
    2           ID        FLOOD DAMAGE ANALYSIS
    3           ID        ROCKBED WATERSHED
                *DIAGRAM
    4           IT      60       0       0     130
    5           IO       5
                * ************************************** MULTI PLAN AND RATIO DATA
    6           JP       3
    7           JR    FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40    1.50

    8           KK     100
    9           KM        DESIGN FLOOD SUBBASIN 100
   10           BA    35.1
   11           QI      24      24      24      26      33      50      86     189     376     516
   12           QI     594     657     710     760     801     839     910    1044    1287    1921
   13           QI    2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
   14           QI    2719    2200    1844    1540    1251     994     777     605     471     365
   15           QI     281       0       0       0       0       0       0       0       0       0
                * ************************************** PROPOSED RESERVOIR DATA

   16           KK     200
   17           KM         PROPOSED RESERVOIR
   18           RN
   19           KP       2
   20           RS       1    STOR     -1.     0.
   21           SL     975      35      .7      .5
   22           SS    1105      35     2.8     1.5
   23           SV       0    2500    4000    5200    6800    9000   11500   15500   21000   30000
   24           SE     965    1000    1015    1030    1045    1060    1075    1090    1105    1120
                * ************************************** NO RESERVOIR PLAN 3

   25           KK     325
   26           KM        DIVERT FLOW PLAN 3
                * ************************************** DUMMY DIVERSION
   27           DT    FLOW   20000
   28           DI       0    2300    4100    6300    8800   14300   20200   30400   33250
   29           DQ
   30           KP       2
                * ************************************** DUMMY DIVERSION
   31           DT    FLOW   20000
   32           DI       0    2300    4100    6300    8800   14300   20200   30400   33250
   33           DQ
   34           KP       3
   35           DT    FLOW   20000
   36           DI       0    2300    4100    6300    8800   14300   20200   30400   33250   38000
   37           DQ       0    1400    2000    3400    4800    8000   12200   16200   18550   20000

   38           KK    RCH1
   39           KM        LOCAL PROTECTION PROJECT PROJECT FOR REACH RCH1
   40           RS       1    STOR     -1.     0.
   41           SV      0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
   42           SQ      0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  43          KK     300
  44          KM        DESIGN FLOOD SUBBASIN 300
  45          KM        RUNOFF FROM SUBBASIN 300
  46          BA    49.1
  47          QI      32      32      32      35      44      67     114     252     501     688
  48          QI     789     877     940    1013    1068    1119    1214    1392    1717    2561
  49          QI    3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
  50          QI    3622    2930    2458    2053    1665    1325    1032     806     628     487
  51          QI     374

  52          KK     300
  53          KM        COMBINED UPSTREAM INFLOWS
  54          HC       2

  55          KK     350
  56          KM        RETRIEVE DIVERTED FLOW
  57          DR    FLOW

  58          KK     400
  59          KM        COMBINE UPSTREAM AND DIVERTED INFLOWS
  60          HC       2

  61          KK    RCH2
  62          KM        DAMAGE REACH LOWLAND FLOODING PROBLEMS
  63          KM         PROPOSED PUMPING PLANT SITE
  64          RS       1    STOR     -1.      0.
  65          SV      0.    400.  30000.  35000.  40000.
  66          SE     840     845     855     857     859
  67          SQ       0    1250    1500    1800    2000
              * ***************************************  PLAN 2 PUMP DATA
  68          KP       2
  69          WP   843.5    3000
  70          KP       3
              * ***************************************  ECONOMICS DATA

  71          EC

  72          KK    RCH1
  73          CN       3   RESID IND/COM   AGRIC
  74          FR              18   700.0   600.0   550.0   450.0   350.0   250.0   150.0    90.0
  75          FR    70.0    50.0    35.0    25.0    16.5    10.0     5.0     2.0      .5      .1
  76          QF                     400     490     530     640     800    1070    1480    1690
  77          QF    1920    2170    2480    2850    3240    3640    4090    4900    5900    7100
  78          QD              15     400     600     730     960    1230    1530    1970    2500
  79          QD    3100    3490    3780    4290    5120    6020    7100
  80          DG             1 3       0       1       2       3       5       7      28      49
  81          DG     111     314     516     619     723     728     830

  82          KK    RCH2
  83          CN       3   RESID IND/COM   AGRIC
  84          FR              12      95      81      60      45      25      11       5     2.5
  85          FR       1      .5      .2      .1
  86          SF                   843.6   844.8   845.6   846.0   846.6   847.3   847.9   848.4
  87          SF   849.1   849.5   850.0   850.3

  88          SD               8   845.0   845.5   847.0   847.6   848.3   849.0   849.8   851.0
  89          DG             1 1       0     720    1380    2710    5200    8000   10050   11250
  90          DG             1 2       0    10.5    15.0    52.5   105.0   202.5     540     585
  91          ZZ
```

```
                    SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

    8         100
                V
                V
   16         200
                .
                .
   27           .------->    FLOW
   25         325
                V
                V
   38        RCH1
                .
                .
   43           .         300
                .           .
                .           .
   52         300............
                .
                .
   57           .           .<-------    FLOW
   55           .         350
                .           .
                .           .
   58         400............
                V
                V
   69           .------->
   61        RCH2
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:31   *
*                                       *
*****************************************
```

```
                                 EXAMPLE PROBLEM NO. 11
                                 FLOOD DAMAGE ANALYSIS
                                 ROCKBED WATERSHED

    5 IO         OUTPUT CONTROL VARIABLES
                       IPRNT           5  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT         HYDROGRAPH TIME DATA
                       NMIN           60  MINUTES IN COMPUTATION INTERVAL
                       IDATE      1    0  STARTING DATE
                       ITIME        0000  STARTING TIME
                          NQ         130  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE      6    0  ENDING DATE
                      NDTIME        0900  ENDING TIME
                      ICENT           19  CENTURY MARK

                   COMPUTATION INTERVAL    1.00 HOURS
                        TOTAL TIME BASE  129.00 HOURS

          ENGLISH UNITS
               DRAINAGE AREA         SQUARE MILES
               PRECIPITATION DEPTH   INCHES
               LENGTH, ELEVATION     FEET
               FLOW                  CUBIC FEET PER SECOND
               STORAGE VOLUME        ACRE-FEET
               SURFACE AREA          ACRES
               TEMPERATURE           DEGREES FAHRENHEIT

      JP         MULTI-PLAN OPTION
                       NPLAN           3  NUMBER OF PLANS

      JR         MULTI-RATIO OPTION
                     RATIOS OF RUNOFF
                     .11       .26       .45       .65       .86      1.00      1.20      1.40      1.50
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

					RATIOS APPLIED TO FLOWS								
OPERATION	STATION	AREA	PLAN		RATIO 1 .11	RATIO 2 .26	RATIO 3 .45	RATIO 4 .65	RATIO 5 .86	RATIO 6 1.00	RATIO 7 1.20	RATIO 8 1.40	RATIO 9 1.50
HYDROGRAPH AT	100	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	200	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	617.	864.	1052.	1206.	1317.	1467.	1573.	1627.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			** PEAK STAGES IN FEET **										
			1	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	STAGE	978.51	984.95	994.56	1003.99	1012.91	1020.02	1030.80	1039.32	1043.67
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
DIVERSION TO	FLOW	35.10	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			2	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			3	FLOW	360.	850.	1439.	1798.	2332.	2811.	3483.	4085.	4386.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
HYDROGRAPH AT	325	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	617.	864.	1052.	1206.	1317.	1467.	1573.	1627.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			3	FLOW	231.	547.	979.	1695.	2290.	2563.	2965.	3438.	3675.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	RCH1	35.10	1	FLOW	429.	978.	1742.	2680.	3668.	4313.	5232.	6156.	6701.
				TIME	28.00	28.00	28.00	28.00	28.00	27.00	27.00	27.00	27.00
			2	FLOW	305.	551.	784.	980.	1135.	1241.	1389.	1504.	1557.
				TIME	34.00	38.00	39.00	41.00	41.00	41.00	42.00	43.00	43.00
			3	FLOW	199.	399.	675.	1129.	1626.	1868.	2225.	2646.	2853.
				TIME	27.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
HYDROGRAPH AT	300	49.10	1	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
2 COMBINED AT	300	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	979.	2176.	3649.	5181.	6777.	7833.	9332.	10825.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	974.	2215.	3805.	5597.	7500.	8712.	10420.	12175.	13108.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
HYDROGRAPH AT	350	.00	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			2	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			3	FLOW	360.	850.	1439.	1798.	2332.	2811.	3483.	4085.	4386.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00

2 COMBINED AT	400	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	979.	2176.	3649.	5181.	6777.	7833.	9332.	10825.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			3	FLOW	1333.	3065.	5244.	7395.	9832.	11523.	13903.	16261.	17494.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
PUMP FLOW TO		84.20	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	FLOW	0.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
				TIME	1.00	23.00	21.00	19.00	17.00	16.00	14.00	13.00	13.00
			3	FLOW	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
				TIME	26.00	22.00	20.00	16.00	14.00	13.00	12.00	12.00	12.00
HYDROGRAPH AT	RCH2	84.20	1	FLOW	964.	1257.	1273.	1291.	1312.	1326.	1347.	1369.	1379.
				TIME	28.00	33.00	37.00	39.00	40.00	41.00	43.00	45.00	46.00
			2	FLOW	802.	1127.	1251.	1252.	1260.	1265.	1274.	1284.	1290.
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00
			3	FLOW	935.	1250.	1252.	1263.	1278.	1289.	1306.	1323.	1333.
				TIME	25.00	25.00	28.00	30.00	32.00	33.00	34.00	35.00	35.00
			** PEAK STAGES IN FEET **										
			1	STAGE	843.86	845.27	845.90	846.65	847.48	848.05	848.89	849.74	850.17
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00
			2	STAGE	843.21	844.51	845.02	845.09	845.41	845.62	845.97	846.36	846.60
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00
			3	STAGE	843.74	845.01	845.09	845.51	846.14	846.57	847.23	847.93	848.32
				TIME	25.00	25.00	28.00	30.00	32.00	33.00	34.00	35.00	35.00

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           **************
           *            *
  72 KK    *     RCH1   *
           *            *
           **************

     FR         PERCENT EXCEEDANCE
                                               700.0    600.0    550.0    450.0    350.0    250.0    150.0     90.0
                              70.0      50.0    35.0     25.0     16.5     10.0      5.0      2.0       .5       .1

     QF         PEAK FLOW
                                               400.     490.     530.     640.     800.    1070.    1480.    1690.
                             1920.     2170.   2480.    2850.    3240.    3640.    4090.    4900.    5900.    7100.

                           DAMAGE DATA
      FLOW      RESID     IND/COM     AGRIC       TOTAL
     400.0       .000       .000       .000        .000
     600.0       .000       .000      1.000       1.000
     730.0       .000       .000      2.000       2.000
     960.0       .000       .000      3.000       3.000
    1230.0       .000       .000      5.000       5.000
    1530.0       .000       .000      7.000       7.000
    1970.0       .000       .000     28.000      28.000
    2500.0       .000       .000     49.000      49.000
    3100.0       .000       .000    111.000     111.000
    3490.0       .000       .000    314.000     314.000
    3780.0       .000       .000    516.000     516.000
    4290.0       .000       .000    619.000     619.000
    5120.0       .000       .000    723.000     723.000
    6020.0       .000       .000    728.000     728.000
    7100.0       .000       .000    830.000     830.000

* DAMAGE DATA FOR PLAN 1 *

  FREQ    FLOW  STAGE     RESID   IND/COM     AGRIC     TOTAL
668.87    429.     .0       .00       .00       .15       .15
279.57    978.     .0       .00       .00      3.14      3.14
 85.07   1742.     .0       .00       .00     17.11     17.11
 29.26   2680.     .0       .00       .00     67.65     67.65
  9.60   3668.     .0       .00       .00    438.01    438.01
  3.77   4313.     .0       .00       .00    621.86    621.86
  1.38   5232.     .0       .00       .00    723.62    723.62
   .33   6156.     .0       .00       .00    740.82    740.82
   .11   6701.     .0       .00       .00    792.28    792.28

EXP ANNUAL DAMAGE           .00       .00    129.22    129.22

* DAMAGE DATA FOR PLAN 2 *

  FREQ    FLOW  STAGE     RESID   IND/COM     AGRIC     TOTAL
668.87    305.     .0       .00       .00       .00       .00
279.57    551.     .0       .00       .00       .75       .75
 85.07    784.     .0       .00       .00      2.23      2.23
 29.26    980.     .0       .00       .00      3.15      3.15
  9.60   1135.     .0       .00       .00      4.30      4.30
  3.77   1241.     .0       .00       .00      5.07      5.07
  1.38   1389.     .0       .00       .00      6.06      6.06
   .33   1504.     .0       .00       .00      6.83      6.83
   .11   1557.     .0       .00       .00      8.31      8.31

EXP ANNUAL DAMAGE           .00       .00      6.22      6.22

AVE ANNUAL BENEFITS         .00       .00    123.00    123.00

* DAMAGE DATA FOR PLAN 3 *

  FREQ    FLOW  STAGE     RESID   IND/COM     AGRIC     TOTAL
668.87    199.     .0       .00       .00       .00       .00
279.57    399.     .0       .00       .00       .00       .00
 85.07    675.     .0       .00       .00      1.58      1.58
 29.26   1129.     .0       .00       .00      4.25      4.25
  9.60   1626.     .0       .00       .00     11.58     11.58
  3.77   1868.     .0       .00       .00     23.13     23.13
  1.38   2225.     .0       .00       .00     38.10     38.10
   .33   2646.     .0       .00       .00     64.10     64.10
   .11   2853.     .0       .00       .00     85.43     85.43

EXP ANNUAL DAMAGE           .00       .00      6.27      6.27

AVE ANNUAL BENEFITS         .00       .00    122.95    122.95
```

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          **************
          *            *
  82 KK   *      RCH2  *
          *            *
          **************
```

FR	PERCENT EXCEEDANCE											
				95.0	81.0	60.0	45.0	25.0	11.0	5.0	2.5
		1.0	.5	.2	.1						

SF	PEAK STAGE										
				843.6	844.8	845.6	846.0	846.6	847.3	847.9	848.4
		849.1	849.5	850.0	850.3						

DAMAGE DATA

STAGE	RESID	IND/COM	AGRIC	TOTAL
845.0	.000	.000	.000	.000
845.5	720.000	10.500	.000	730.500
847.0	1380.000	15.000	.000	1395.000
847.6	2710.000	52.500	.000	2762.500
848.3	5200.000	105.000	.000	5305.000
849.0	8000.000	202.500	.000	8202.500
849.8	10050.000	540.000	.000	10590.000
851.0	11250.000	585.000	.000	11835.000

* DAMAGE DATA FOR PLAN 1 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
93.53	0.	843.9	.00	.00	.00	.00
70.19	0.	845.3	387.69	5.65	.00	393.34
48.51	0.	845.9	898.05	11.71	.00	909.77
23.49	0.	846.7	1227.46	13.96	.00	1241.42
8.77	0.	847.5	2451.85	45.22	.00	2497.07
4.07	0.	848.1	4327.45	86.60	.00	4414.05
1.36	0.	848.9	7559.58	187.16	.00	7746.74
.33	0.	849.7	9899.23	515.18	.00	10414.40
.13	0.	850.2	10422.49	553.97	.00	10976.46
EXP ANNUAL DAMAGE			1099.95	20.21	.00	1120.16

* DAMAGE DATA FOR PLAN 2 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
93.53	0.	843.2	.00	.00	.00	.00
70.19	0.	844.5	.00	.00	.00	.00
48.51	0.	845.0	33.40	.49	.00	33.89
23.49	0.	845.1	132.89	1.94	.00	134.83
8.77	0.	845.4	595.37	8.68	.00	604.05
4.07	0.	845.6	772.07	10.86	.00	782.93
1.36	0.	846.0	928.80	11.92	.00	940.72
.33	0.	846.4	1099.60	13.09	.00	1112.69
.13	0.	846.6	1204.07	13.80	.00	1217.87
EXP ANNUAL DAMAGE			139.82	1.98	.00	141.80
AVE ANNUAL BENEFITS			960.13	18.23	.00	978.36

* DAMAGE DATA FOR PLAN 3 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
93.53	0.	843.7	.00	.00	.00	.00
70.19	0.	845.0	13.01	.19	.00	13.20
48.51	0.	845.1	134.30	1.96	.00	136.26
23.49	0.	845.5	726.58	10.54	.00	737.12
8.77	0.	846.1	1000.80	12.41	.00	1013.22
4.07	0.	846.6	1192.31	13.72	.00	1206.03
1.36	0.	847.2	1900.91	29.69	.00	1930.59
.33	0.	847.9	3870.65	76.97	.00	3947.63
.13	0.	848.3	5283.49	107.91	.00	5391.40
EXP ANNUAL DAMAGE			375.42	5.29	.00	380.71
AVE ANNUAL BENEFITS			724.53	14.92	.00	739.44

EXPECTED ANNUAL FLOOD DAMAGE SUMMARY

STREAM STATION	DAMAGE REACH	WATERSHED	TOWNSHIP	*		DAMAGE CATEGORY	EXPECTED ANNUAL DAMAGE PLAN 1	PLAN 2	PLAN 3
RCH1	1			*	1	RESID	.00	.00	.00
				*	2	IND/COM	.00	.00	.00
				*	3	AGRIC	129.22	6.22	6.27
				*					
				*		TOTAL	129.22	6.22	6.27
			DAMAGE CHANGE (BENEFITS)				BASE	123.00	122.95
RCH2	2			*	1	RESID	1099.95	139.82	375.42
				*	2	IND/COM	20.21	1.98	5.29
				*	3	AGRIC	.00	.00	.00
				*					
				*		TOTAL	1120.16	141.80	380.71
			DAMAGE CHANGE (BENEFITS)				BASE	978.36	739.44
BASIN TOTAL				*	1	RESID	1099.95	139.82	375.42
				*	2	IND/COM	20.21	1.98	5.29
				*	3	AGRIC	129.22	6.22	6.27
				*					
				*		TOTAL	1249.37	148.02	386.98
			DAMAGE CHANGE (BENEFITS)				BASE	1101.36	862.39

*** NORMAL END OF HEC-1 ***

12.12 Example Problem #12: Flood Control System Optimization

Two flood control plans for Rockbed Watershed were presented in previous tests. In each plan, a single capacity for the flood control system was explored. The flood control system optimization option of HEC-1 allows the user to determine the flood control system capacity that is optimal for the proposed project (e.g., the system capacity that leads to the greatest net benefit). For example purposes, the flood control system outlined in PLAN 2 of the previous test has been chosen to demonstrate the optimization capabilities of HEC-1. In order to further demonstrate the capabilities of HEC-1, a local protection project (a channel improvement) has been added to the flood control measures for the damage center in reach RCH1, Figure 12.7.

The data for the optimization model is shown in Table 12.12a. A number of points should be noted about the data:

(1) Optimization runs are specified by an **OS record**. The initial capacity of the flood control components to be optimized are indicated as negative numbers on this card.

(2) Basic optimization data consists of maximum and minimum allowable capacity, and cost versus capacity tables for the project.

(3) The channel improvement data requires the addition of upper and lower pattern damage information for the reach **(DU, DL records)**.

(4) A degree of protection can be specified for any damage reach (**DP record**). In this example, a maximum stage of 846.9 feet at the 1% exceedence level has been specified as the protection level for damage reach RCH2.

The input data in the appropriate HEC-1 format and the output from the model are shown in Table 12.12b. Note that the cost and optimization data for the reservoir and pump are located in the stream network portion of the input data deck, whereas, the local protection and degree of protection data are located in the economic analysis portion of the data deck. The results of the optimization analysis are shown in the output summaries at the end of the computer output (Table 12.12b).

Table 12.12a

Flood Control System Optimization Data

Record Identifiers

Reservoir Data

Initial Size	=	15000 (ac-ft)	OS
Maximum Capacity	=	29000 (ac-ft)	SO
Minimum Capacity	=	0 (ac-ft)	
O+M Factor	=	.023	
Discount Factor	=	.0504	

Cost Data (Thousands of dollars)
(corresponding to elevation data on SE card)

0, 1500, 2400, 2000, 3600, 4350, 4450, 5550, 6000, 7200	SD

Pump Data

Initial Size	=	8000 (cfs)	OS
Maximum Capacity	=	10000 (cfs)	WO
Minimum Capacity	=	100 (cfs)	
O+M Factor	=	.023	
Discount Factor	=	.0504	

Capacity-Cost Data

Capacity (cfs)	0, 250, 500, 1000, 2000, 6000, 8000, 10000	WC
Cost (Thousands of dollars)	0, 670, 1000, 16000, 2300, 6000, 7860, 8670	WD

Local Protection Project Data

Initial Size	=	17000 (cfs)	OS
Maximum Capacity	=	21000 (cfs)	LO
Minimum Capacity	=	0 (cfs)	
O+M Factor	=	.023	
Discount Factor	=	.0504	

Capacity-Cost Data

Capacity (cfs)	0,	5000,	5500,	7000,	8300,	9300,	12000,	15000,	21000	LC
Cost (Thousands of dollars)	0,	103,	149,	122,	283,	340,	600,	1000,	3000	LD

Upper Pattern-Lower Pattern Damage Table
Agricultural Land Use
(corresponds to flows on QD Card for damage reach RCH1) DU,DL

Upper Pattern	0,	1,	2,	3,	5,	7,	28,	49,	111,	314,	516,	619,	723,	728,	830
Lower Pattern	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	.44,	3.5,	7.15

Table 12.12b

Example Problem #12

Input

```
NOTE: The results of this test are dependent on
      the machine word size.  Results are likely
      to be within five percent of the answers
      shown.
```

```
ID      EXAMPLE PROBLEM _ 12
ID      FLOOD CONTROL SYSTEM OPTIMIZATION
ID      ROCKBED WATERSHED
*DIAGRAM
IT    60       0       0     130
IO     4
OS-15000   -8000  -17000
* ***************************************  MULTI PLAN AND RATIO DATA
JP     2
JR  FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40     1.5
KK   100
KM       POTENTIAL RESERVOIR INFLOW
BA  35.1
QI    24      24      24      26      33      50      86     189     376     516
QI   594     657     710     760     801     839     910    1044    1287    1921
QI  2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
QI  2719    2200    1844    1540    1251     994     777     605     471     365
QI   281       0       0       0       0       0       0       0       0       0
* ***************************************  PROPOSED RESERVOIR DATA
KK   200
KM       PROPOSED RESERVOIR
RN
KP     2
RS     1    STOR     -1.    0.
SO     1    .023   .0504   29000       0
SL   975      35      .7      .5
SS  1105      35     2.8     1.5
SV     0    2500    4000    5200    6800    9000   11500   15500   21000   30000
SE   965    1000    1015    1030    1045    1060    1075    1090    1105    1120
SD     0    1500    2400    3000    3600    4350    4950    5550    6000    7200
KK  RCH1
KM       POTENTIAL CHANNEL MODIFICATION REACH
RS     1    STOR     -1.    0.
SV    0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
SQ    0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.
KK   300
KM      RUNOFF FROM SUBBASIN 300
BA  49.1
QI    32      32      32      35      44      67     114     252     501     688
QI   789     877     940    1013    1068    1119    1214    1392    1717    2561
QI  3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
QI  3622    2930    2458    2053    1665    1325    1032     806     628     487
QI   374
KK   300
KM      COMBINED UPSTREAM INFLOWS
HC     2
KK  RCH2
KM       PROPOSED PUMPING PLANT SITE
RS     1    STOR     -1.    0.
SV    0.    400.  30000.
SE   840     845     855
SQ     0    1250    1500
```

```
* *************************************  PLAN 2 PUMP DATA
KP     2
WO     2    .023   .0504     100   10000
WP 843.5    3000
WC     0     250     500    1000    2000    6000    8000   10000
WD     0     670    1000    1600    2300    6000    7860    8670
* *************************************  ECONOMICS DATA
EC
KK  RCH1
CN     3   RESID IND/COM   AGRIC
FR            18   700.0   600.0   550.0   450.0   350.0   250.0   150.0    90.0
FR  70.0    50.0    35.0    25.0    16.5    10.0     5.0     2.0      .5      .1
QF                   400     490     530     640     800    1070    1480    1690
QF  1920    2170    2480    2850    3240    3640    4090    4900    5900    7100
QD            15     400     600     730     960    1230    1530    1970    2500
QD  3100    3490    3780    4290    5120    6020    7100
DG           1 3       0       1       2       3       5       7      28      49
DG   111     314     516     619     723     728     830
LO     3    .023   .0504   21000       0
LC     0    5000    5500    7000    8300    9300   12000   15000   21000
LD     0     103     149     222     283     340     600    1000    3000
DU             3       0       1       2       3       5       7      28      49
DU   111     314     516     619     723     728     830
DL             3      0.      0.      0.      0.      0.      0.      0.      0.
DL    0.      0.      0.      0.    0.44     3.5    7.15
KK  RCH2
CN     3   RESID IND/COM   AGRIC
FR            12      95      81      60      45      25      11       5     2.5
FR     1      .5      .2      .1
SF                 843.6   844.8   845.6   846.0   846.6   847.3   847.9   848.4
SF 849.1   849.5   850.0   850.3
SD             8   845.0   845.5   847.0   847.6   848.3   849.0   849.8   851.0
DG           1 1       0     720    1380    2710    5200    8000   10050   11250
DG           1 2       0    10.5    15.0    52.5   105.0   202.5     540     585
DP     1   846.9
ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:39   *
*                                       *
*****************************************


                                     HEC-1 INPUT                                          PAGE  1

 LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   1            ID        EXAMPLE PROBLEM _ 12
   2            ID        FLOOD CONTROL SYSTEM OPTIMIZATION
   3            ID        ROCKBED WATERSHED
                *DIAGRAM
   4            IT      60       0       0     130
   5            IO       4
   6            OS  -15000   -8000  -17000
                * **************************************  MULTI PLAN AND RATIO DATA
   7            JP       2
   8            JR    FLOW     .11     .26     .45     .65     .86    1.00    1.20    1.40     1.5

   9            KK     100
  10            KM         POTENTIAL RESERVOIR INFLOW
  11            BA    35.1
  12            QI      24      24      24      26      33      50      86     189     376     516
  13            QI     594     657     710     760     801     839     910    1044    1287    1921
  14            QI    2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
  15            QI    2719    2200    1844    1540    1251     994     777     605     471     365
  16            QI     281       0       0       0       0       0       0       0       0       0
                * **************************************  PROPOSED RESERVOIR DATA

  17            KK     200
  18            KM         PROPOSED RESERVOIR
  19            RN
  20            KP       2
  21            RS       1    STOR     -1.     0.
  22            SO       1    .023   .0504   29000       0
  23            SL     975      35      .7      .5
  24            SS    1105      35     2.8     1.5
  25            SV       0    2500    4000    5200    6800    9000   11500   15500   21000   30000
  26            SE     965    1000    1015    1030    1045    1060    1075    1090    1105    1120
  27            SD       0    1500    2400    3000    3600    4350    4950    5550    6000    7200

  28            KK    RCH1
  29            KM         POTENTIAL CHANNEL MODIFICATION REACH
  30            RS       1    STOR     -1.     0.
  31            SV      0.     50.    475.    940.   2135.   3080.      0.      0.      0.      0.
  32            SQ      0.    200.   1020.   2050.   6100.  10250.      0.      0.      0.      0.

  33            KK     300
  34            KM        RUNOFF FROM SUBBASIN 300
  35            BA    49.1
  36            QI      32      32      32      35      44      67     114     252     501     688
  37            QI     789     877     940    1013    1068    1119    1214    1392    1717    2561
  38            QI    3993    4273    6139    6727    7163    7179    6789    6137    5308    4433
  39            QI    3622    2930    2458    2053    1665    1325    1032     806     628     487
  40            QI     374

  41            KK     300
  42            KM        COMBINED UPSTREAM INFLOWS
  43            HC       2
```

```
LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


  44           KK    RCH2
  45           KM         PROPOSED PUMPING PLANT SITE
  46           RS       1    STOR     -1.    0.
  47           SV      0.    400.  30000.
  48           SE     840     845     855
  49           SQ       0    1250    1500
               * **************************************  PLAN 2 PUMP DATA
  50           KP       2
  51           WO       2    .023   .0504     100   10000
  52           WP   843.5    3000
  53           WC       0     250     500    1000    2000    6000    8000   10000
  54           WD       0     670    1000    1600    2300    6000    7860    8670
               * **************************************  ECONOMICS DATA

  55           EC

  56           KK    RCH1
  57           CN       3   RESID IND/COM   AGRIC
  58           FR              18   700.0   600.0   550.0   450.0   350.0   250.0   150.0    90.0
  59           FR    70.0    50.0    35.0    25.0    16.5    10.0     5.0     2.0      .5      .1
  60           QF                     400     490     530     640     800    1070    1480    1690
  61           QF    1920    2170    2480    2850    3240    3640    4090    4900    5900    7100
  62           QD              15     400     600     730     960    1230    1530    1970    2500
  63           QD    3100    3490    3780    4290    5120    6020    7100
  64           DG             1 3       0       1       2       3       5       7      28      49
  65           DG     111     314     516     619     723     728     830
  66           LO       3    .023   .0504   21000       0
  67           LC       0    5000    5500    7000    8300    9300   12000   15000   21000
  68           LD       0     103     149     222     283     340     600    1000    3000
  69           DU               3       0       1       2       3       5       7      28      49
  70           DU     111     314     516     619     723     728     830
  71           DL               3      0.      0.      0.      0.      0.      0.      0.      0.
  72           DL      0.      0.      0.      0.    0.44     3.5    7.15

  73           KK    RCH2
  74           CN       3   RESID IND/COM   AGRIC
  75           FR              12      95      81      60      45      25      11       5     2.5
  76           FR       1      .5      .2      .1
  77           SF                   843.6   844.8   845.6   846.0   846.6   847.3   847.9   848.4
  78           SF   849.1   849.5   850.0   850.3
  79           SD               8   845.0   845.5   847.0   847.6   848.3   849.0   849.8   851.0
  80           DG             1 1       0     720    1380    2710    5200    8000   10050   11250
  81           DG             1 2       0    10.5    15.0    52.5   105.0   202.5     540     585
  82           DP       1   846.9
  83           ZZ
```

```
                  SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

     9         100
                 V
                 V
    17         200
                 V
                 V
    28        RCH1
                 .
                 .
    33           .          300
                 .            .
                 .            .
    41         300............
                 V
                 V
    52           .------->
    44        RCH2
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:39   *
*                                       *
*****************************************




                               EXAMPLE PROBLEM _ 12
                               FLOOD CONTROL SYSTEM OPTIMIZATION
                               ROCKBED WATERSHED

    5 IO          OUTPUT CONTROL VARIABLES
                       IPRNT          10  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                       NMIN           60  MINUTES IN COMPUTATION INTERVAL
                       IDATE      1    0  STARTING DATE
                       ITIME        0000  STARTING TIME
                          NQ         130  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE      6    0  ENDING DATE
                      NDTIME        0900  ENDING TIME
                      ICENT           19  CENTURY MARK

                COMPUTATION INTERVAL    1.00 HOURS
                     TOTAL TIME BASE  129.00 HOURS

       ENGLISH UNITS
            DRAINAGE AREA         SQUARE MILES
            PRECIPITATION DEPTH   INCHES
            LENGTH, ELEVATION     FEET
            FLOW                  CUBIC FEET PER SECOND
            STORAGE VOLUME        ACRE-FEET
            SURFACE AREA          ACRES
            TEMPERATURE           DEGREES FAHRENHEIT

      JP          MULTI-PLAN OPTION
                       NPLAN           2  NUMBER OF PLANS

      JR          MULTI-RATIO OPTION
                    RATIOS OF RUNOFF
                      .11       .26       .45       .65       .86      1.00      1.20      1.40      1.50
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN		RATIO 1 .11	RATIO 2 .26	RATIO 3 .45	RATIO 4 .65	RATIO 5 .86	RATIO 6 1.00	RATIO 7 1.20	RATIO 8 1.40	RATIO 9 1.50
HYDROGRAPH AT	100	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	200	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	617.	866.	1052.	1206.	1315.	1467.	1573.	1627.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
			** PEAK STAGES IN FEET **										
			1	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	STAGE	978.51	984.95	994.55	1003.99	1012.91	1020.03	1030.80	1039.32	1043.67
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	34.00	34.00	35.00
ROUTED TO	RCH1	35.10	1	FLOW	429.	978.	1742.	2680.	3668.	4313.	5232.	6156.	6701.
				TIME	28.00	28.00	28.00	28.00	28.00	27.00	27.00	27.00	27.00
			2	FLOW	305.	551.	785.	980.	1135.	1239.	1389.	1504.	1557.
				TIME	34.00	38.00	39.00	41.00	41.00	41.00	42.00	43.00	43.00
HYDROGRAPH AT	300	49.10	1	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
2 COMBINED AT	300	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	980.	2176.	3649.	5181.	6777.	7833.	9332.	10825.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
PUMP FLOW TO		84.20	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	FLOW	0.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
				TIME	1.00	23.00	21.00	19.00	17.00	16.00	14.00	13.00	13.00
HYDROGRAPH AT	RCH2	84.20	1	FLOW	964.	1257.	1273.	1291.	1312.	1326.	1347.	1369.	1379.
				TIME	28.00	33.00	37.00	39.00	40.00	41.00	43.00	45.00	46.00
			2	FLOW	802.	1127.	1251.	1252.	1260.	1265.	1274.	1284.	1290.
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00
			** PEAK STAGES IN FEET **										
			1	STAGE	843.86	845.27	845.90	846.65	847.48	848.05	848.89	849.74	850.17
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00
			2	STAGE	843.21	844.51	845.02	845.09	845.41	845.62	845.97	846.36	846.60
				TIME	28.00	25.00	24.00	28.00	30.00	30.00	32.00	33.00	33.00

EXPECTED ANNUAL FLOOD DAMAGE SUMMARY

STREAM STATION	DAMAGE REACH	WATERSHED	TOWNSHIP	*	DAMAGE CATEGORY	EXPECTED ANNUAL DAMAGE PLAN 1	PLAN 2
RCH1	1			*	1 RESID	.00	.00
				*	2 IND/COM	.00	.00
				*	3 AGRIC	129.22	.00
				*			
				*	TOTAL	129.22	.00
			DAMAGE CHANGE (BENEFITS)			BASE	129.22
RCH2	2			*	1 RESID	1099.95	139.77
				*	2 IND/COM	20.21	1.97
				*	3 AGRIC	.00	.00
				*			
				*	TOTAL	1120.16	141.75
			DAMAGE CHANGE (BENEFITS)			BASE	978.41
BASIN TOTAL				*	1 RESID	1099.95	139.77
				*	2 IND/COM	20.21	1.97
				*	3 AGRIC	129.22	.00
				*			
				*	TOTAL	1249.37	141.75
			DAMAGE CHANGE (BENEFITS)			BASE	1107.63

SUMMARY OF COMPONENT COSTS

PROJECT	LOCATION	CAPACITY	CAPITAL COST	AMORTIZED CAPITAL COST	ANNUAL O+M COST	ANNUAL POWER COST	TOTAL ANNUAL COST
RESERVOIR	200	15000.0	5475.000	275.940	125.925	.000	401.865
PUMP	RCH2	8000.0	7860.000	396.144	180.780	100.000	676.924
LOCAL PROTECTION	RCH1	17000.0	1666.667	84.000	38.333	.000	122.333

INITIAL ESTIMATES OF COMPONENT SIZE

VAR 1	VAR 2	VAR 3
15000.00	8000.00	17000.00

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                              SYSTEM COST AND PERFORMANCE SUMMARY
                         (UNITS SAME AS INPUT - NORMALLY 1000"S OF DOLLARS)

          TOTAL SYSTEM CAPITAL COST * * * * * * * * * * * * * * *      15002.

          TOTAL SYSTEM AMORTIZED CAPITAL COST * * * * * * * * * *        756.

          TOTAL SYSTEM ANNUAL O,M,POWER AND REPLACEMENT COST  *          445.

          TOTAL SYSTEM ANNUAL COST  * * * * * * * * * * * * * * *       1201.


          AVERAGE ANNUAL DAMAGES -- EXISTING CONDITIONS * * * *         1249.

          AVERAGE ANNUAL DAMAGES -- OPTIMIZED SYSTEM  * * * * *          142.

          AVERAGE ANNUAL DAMAGE REDUCTION (BENEFITS)  * * * * *                    1108.


          AVERAGE ANNUAL SYSTEM NET BENEFITS  * * * * * * * * *                     -93.


                                       INTERMEDIATE VALUES OF OPTIMIZATION VARIABLES
OBJECTIVE
FUNCTION      VAR  1     VAR  2     VAR  3

             15000.000   8000.000  17000.000
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4962.007  1201.122   141.748   6.6647E+06

             14850.000*  8000.000  17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4962.01
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4962.007  1199.471   141.748   6.6565E+06

             14700.000*  8000.000  17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4962.01
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4962.007  1197.819   141.748   6.6483E+06

             10000.000*  8000.000  17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4950.47
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4950.470  1136.163   141.822   6.3279E+06
6327907.5    10000.000*  8000.000  17000.000

             10000.000   7920.000* 17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4950.47
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4950.470  1130.702   141.822   6.3009E+06

             10000.000   7840.000* 17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4950.47
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4950.470  1125.241   141.822   6.2738E+06

             10000.000   5333.336* 17000.000
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4950.47
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4950.470   954.376   141.822   5.4278E+06
5427794.0    10000.000   5333.336* 17000.000

             10000.000   5333.336  16830.000*
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2   846.90    846.06      .84  4950.47
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                             4950.470   950.217   141.822   5.4072E+06
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            10000.000   5333.336  16660.000*
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   946.057   141.822   5.3866E+06

            10000.000   5333.336  11333.340*
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   871.371   141.822   5.0168E+06
5016795.1   10000.000   5333.336  11333.340*

             9900.005*  5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4962.01
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4962.007   869.609   141.822   5.0197E+06

             9800.005*  5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4962.01
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4962.007   867.848   141.822   5.0110E+06

            15000.010*  5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4962.01
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4962.007   936.330   141.748   5.3505E+06

            11500.010*  5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4962.01
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4962.007   897.795   141.815   5.1596E+06

            10450.000*  5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   879.298   141.814   5.0560E+06
5016795.1   10000.000+  5333.336  11333.340

            10000.000   5333.336  11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   871.371   141.822   5.0168E+06

            10000.000   5280.002* 11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   867.750   141.822   4.9989E+06

            10000.000   5226.669* 11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   864.129   141.822   4.9809E+06

            10000.000   3555.559* 11333.340
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   750.669   141.822   4.4191E+06
4419142.1   10000.000   3555.559* 11333.340

            10000.000   3555.559  11220.010*
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   749.868   141.822   4.4152E+06
         10000.000   3555.559  11106.670*
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.06      .84  4950.47
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                            4950.470   749.066   141.822   4.4112E+06
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          10000.000   3555.559   7555.563*
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4950.47
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4950.470   729.549   141.822   4.3146E+06
4314568.4 10000.000   3555.559   7555.563*

           9900.005*  3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4962.01
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4962.007   727.787   141.822   4.3159E+06
           9800.005*  3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4962.01
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4962.007   726.026   141.822   4.3071E+06
          15000.010*  3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4962.01
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4962.007   794.508   141.748   4.6466E+06
          11500.010*  3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4962.01
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4962.007   755.973   141.815   4.4557E+06
          10450.000*  3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4950.47
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4950.470   737.476   141.814   4.3538E+06
4314568.4 10000.000+  3555.559   7555.563
          10000.000   3555.559   7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4950.47
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4950.470   729.549   141.822   4.3146E+06
          10000.000   3520.003*  7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4950.47
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4950.470   727.135   141.822   4.3026E+06
          10000.000   3484.448*  7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.06       .84  4950.47
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              4950.470   724.721   141.822   4.2907E+06
          10000.000   2370.374*  7555.563
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.29       .61  1378.37
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              1378.366   649.081   165.578   1.1237E+06
1123712.0 10000.000   2370.374*  7555.563
          10000.000   2370.374   7480.007*
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.29       .61  1378.37
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              1378.366   648.821   165.578   1.1234E+06
          10000.000   2370.374   7404.452*
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.29       .61  1378.37
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              1378.366   648.560   165.578   1.1230E+06
          10000.000   2370.374   5037.044*
                                                          LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                              RCH2  846.90    846.29       .61  1378.37
                                                            TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              1378.366   638.683   165.578   1.1094E+06
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1109369.6   10000.000   2370.374   5037.044*

             9900.005*  2370.374   5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.29      .61  1378.37
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                     1378.366   636.921   165.578   1.1069E+06

             9800.005*  2370.374   5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.29      .61  1378.37
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                     1378.366   635.160   165.578   1.1045E+06

             6666.673*  2370.374   5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.29      .61  1378.37
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                     1378.366   562.347   165.625   1.0041E+06
1004140.1    6666.673*  2370.374   5037.044

             6666.673   2346.670*  5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.30      .60  1288.42
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                     1288.423   560.738   168.669   9.4051E+05

             6666.673   2322.966*  5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.31      .59  1206.45
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                     1206.450   559.129   171.338   8.8200E+05

             6666.673   2063.642*  5037.044
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.41      .49   554.63
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      554.635   541.522   224.474   4.2561E+05
 425613.7    6666.673   2063.642*  5037.044

             6666.673   2063.642   4986.674*
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.41      .49   554.63
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      554.635   541.251   224.474   4.2546E+05

             6666.673   2063.642   4936.304*
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.41      .49   554.63
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      554.635   541.175   224.474   4.2542E+05

             6666.673   2063.642   4941.726*
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.41      .49   554.63
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      554.635   541.183   224.474   4.2543E+05
 425425.8    6666.673   2063.642   4941.726*


             6666.673   2063.642   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.41      .49   554.63
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      554.635   541.183   224.474   4.2543E+05

             6666.673   2043.005*  4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.42      .48   511.32
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      511.320   539.782   226.816   3.9274E+05

             6666.673   2022.369*  4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.43      .47   472.57
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      472.570   538.381   229.165   3.6349E+05
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            6666.673   1856.417*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.51      .39   223.80
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      223.797   529.485   251.021   1.7546E+05
 175455.8   6666.673   1856.417*  4941.726

            6666.673   1856.417   4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.51      .39   223.80
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      223.797   529.485   251.021   1.7546E+05

            6666.673   1837.852*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.53      .37   197.11
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      197.111   528.531   253.958   1.5502E+05

            6666.673   1819.288*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.53      .37   180.10
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      180.096   527.577   256.898   1.4207E+05

            6666.673   1796.427*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.54      .36   159.99
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      159.993   526.403   273.383   1.2876E+05
 128759.8   6666.673   1796.427*  4941.726

            6666.673   1796.427   4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.54      .36   159.99
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      159.993   526.403   273.383   1.2876E+05

            6666.673   1778.463*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.55      .35   146.19
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      146.186   525.480   273.712   1.1763E+05

            6666.673   1760.499*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.56      .34   131.96
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                      131.957   524.557   274.390   1.0623E+05

            6666.673   1197.619*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.83      .07      .25
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .250   495.636   351.675   1.0588E+03
   1058.8   6666.673   1197.619*  4941.726

            6666.673   1197.619   4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.83      .07      .25
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .250   495.636   351.675   1.0588E+03

            6666.673   1185.642*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.84      .06      .17
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .170   495.021   353.826   9.9313E+02

            6666.673   1173.666*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.84      .06      .16
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .156   494.405   355.797   9.8249E+02

            6666.673   1177.336*  4941.726
                                                  LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                      RCH2   846.90    846.84      .06      .17
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .175   494.594   355.060   9.9796E+02
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998.0      6666.673   1177.336*  4941.726

           6666.673   1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.84      .06      .17
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .175   494.594   355.060   9.9796E+02

           6600.007*  1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.84      .06      .17
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .175   492.759   355.066   9.9581E+02

           6533.340*  1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.84      .06      .17
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .175   490.924   355.081   9.9367E+02

           4444.451*  1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    847.02     -.12     1.82
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                               1.824   426.495   364.555   2.2338E+03

           6000.007*  1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.83      .07      .19
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .185   476.244   355.572   9.8598E+02
986.0      6000.007*  1177.336   4941.726

           6000.007   1177.336   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.83      .07      .19
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .185   476.244   355.572   9.8598E+02

           6000.007   1165.563*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.84      .06      .13
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .126   475.639   357.795   9.3839E+02

           6000.007   1153.789*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.85      .05      .08
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .076   475.034   359.986   8.9870E+02

           6000.007   1100.625*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.88      .02      .00
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .001   472.303   370.874   8.4400E+02
844.0      6000.007   1100.625*  4941.726

           6000.007   1100.625   4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.88      .02      .00
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .001   472.303   370.874   8.4400E+02

           6000.007   1089.618*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.89      .01      .00
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .000   471.737   373.172   8.4504E+02

           6000.007   1078.612*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.89      .01      .00
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .000   471.172   375.545   8.4672E+02

           6000.007   1112.754*  4941.726
                                                        LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                            RCH2  846.90    846.87      .03      .01
                                                          TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                .008   472.926   368.354   8.4790E+02
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          6000.007   1104.263*  4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.87      .03      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .004   472.490   370.067   8.4593E+02

          6000.007   1101.716*  4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.88      .02      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .003   472.359   370.591   8.4563E+02
 844.0    6000.007   1100.625+  4941.726

          6000.007   1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.88      .02      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .001   472.303   370.874   8.4400E+02

          5940.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.88      .02      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .001   470.651   370.997   8.4232E+02

          5880.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.88      .02      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .001   469.000   371.124   8.4066E+02

          4000.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    847.20     -.30    78.90
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                               78.898   406.242   386.881   6.3369E+04

          5400.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.90      .00      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .000   455.788   372.791   8.2858E+02
 828.6    5400.007*  1100.625   4941.726

          5400.007   1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.90      .00      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .000   455.788   372.791   8.2858E+02

          5346.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.90      .00      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .000   454.301   373.022   8.2732E+02

          5292.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.90      .00      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .000   452.815   373.257   8.2607E+02

          3600.006*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    847.30     -.40   245.15
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                              245.146   388.626   393.292   1.9247E+05

          4860.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.97     -.07      .21
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .212   437.805   376.526   9.8713E+02

          5238.007*  1100.625   4941.726
                                                         LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                             RCH2  846.90    846.90     -.00      .00
                                                           TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                                 .000   451.328   373.509   8.2484E+02
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824.8     5238.007*  1100.625   4941.726

          5238.007   1100.625   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.90     -.00      .00
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .000   451.328   373.509   8.2484E+02

          5185.627*  1100.625   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.91     -.01      .00
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .000   449.755   373.805   8.2360E+02

          5133.247*  1100.625   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.92     -.02      .00
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .001   447.832   374.202   8.2249E+02

          4697.633*  1100.625   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    847.00     -.10     1.18
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                        1.176   431.845   378.005   1.7619E+03

          5075.895*  1100.625   4941.726
                                                 LOCATION   TARGET  COMP VAL  DEVIATN  PENALTY
                                                     RCH2   846.90    846.92     -.02      .00
                                                   TRGT PNLTY  ANN COST  ANN DAMG  OBJCT FNCTN
                                                         .003   445.728   374.660   8.2319E+02
823.2     5075.895*  1100.625   4941.726
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN		RATIO 1 .11	RATIO 2 .26	RATIO 3 .45	RATIO 4 .65	RATIO 5 .86	RATIO 6 1.00	RATIO 7 1.20	RATIO 8 1.40	RATIO 9 1.50
HYDROGRAPH AT	100	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
ROUTED TO	200	35.10	1	FLOW	591.	1397.	2418.	3493.	4622.	5374.	6449.	7524.	8061.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	367.	618.	863.	1054.	1207.	1315.	1726.	3089.	3733.
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	33.00	31.00	30.00
			** PEAK STAGES IN FEET **										
			1	STAGE	.00	.00	.00	.00	.00	.00	.00	.00	.00
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00
			2	STAGE	978.49	984.94	994.54	1003.97	1012.89	1020.02	1030.31	1034.59	1036.29
				TIME	29.00	31.00	32.00	33.00	33.00	34.00	33.00	31.00	30.00
ROUTED TO	RCH1	35.10	1	FLOW	429.	978.	1742.	2680.	3668.	4313.	5232.	6156.	6701.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	306.	551.	785.	982.	1136.	1239.	1457.	2350.	2871.
				TIME	34.00	38.00	39.00	41.00	41.00	41.00	37.00	35.00	34.00
HYDROGRAPH AT	300	49.10	1	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	790.	1867.	3231.	4666.	6174.	7179.	8615.	10051.	10769.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
2 COMBINED AT	300	84.20	1	FLOW	1162.	2688.	4687.	6892.	9339.	10959.	13250.	15529.	16663.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	981.	2176.	3649.	5182.	6777.	7833.	9333.	10826.	11571.
				TIME	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
PUMP FLOW TO		84.20	1	FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.
				TIME	.00	.00	.00	.00	.00	.00	.00	.00	.00
			2	FLOW	0.	1101.	1101.	1101.	1101.	1101.	1101.	1101.	1101.
				TIME	1.00	23.00	21.00	19.00	17.00	16.00	14.00	13.00	13.00
HYDROGRAPH AT	RCH2	84.20	1	FLOW	964.	1257.	1273.	1291.	1312.	1326.	1347.	1369.	1379.
				TIME	25.00	25.00	25.00	26.00	25.00	25.00	25.00	25.00	25.00
			2	FLOW	803.	991.	1254.	1264.	1275.	1282.	1295.	1311.	1320.
				TIME	28.00	30.00	30.00	32.00	34.00	35.00	37.00	41.00	42.00
			** PEAK STAGES IN FEET **										
			1	STAGE	843.86	845.27	845.90	846.65	847.48	848.05	848.89	849.74	850.17
				TIME	28.00	33.00	37.00	39.00	40.00	42.00	43.00	45.00	46.00
			2	STAGE	843.21	843.96	845.17	845.55	845.99	846.30	846.79	847.43	847.82
				TIME	28.00	30.00	30.00	32.00	34.00	35.00	37.00	41.00	42.00

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          **************
          *            *
 56 KK    *      RCH1  *
          *            *
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FR	PERCENT EXCEEDANCE									
			700.0	600.0	550.0	450.0	350.0	250.0	150.0	90.0
	70.0	50.0	35.0	25.0	16.5	10.0	5.0	2.0	.5	.1

QF	PEAK FLOW									
			400.	490.	530.	640.	800.	1070.	1480.	1690.
	1920.	2170.	2480.	2850.	3240.	3640.	4090.	4900.	5900.	7100.

DAMAGE DATA

FLOW	RESID	IND/COM	AGRIC	TOTAL
400.0	.000	.000	.000	.000
600.0	.000	.000	1.000	1.000
730.0	.000	.000	2.000	2.000
960.0	.000	.000	3.000	3.000
1230.0	.000	.000	5.000	5.000
1530.0	.000	.000	7.000	7.000
1970.0	.000	.000	28.000	28.000
2500.0	.000	.000	49.000	49.000
3100.0	.000	.000	111.000	111.000
3490.0	.000	.000	314.000	314.000
3780.0	.000	.000	516.000	516.000
4290.0	.000	.000	619.000	619.000
5120.0	.000	.000	723.000	723.000
6020.0	.000	.000	728.000	728.000
7100.0	.000	.000	830.000	830.000

* DAMAGE DATA FOR PLAN 1 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
668.87	429.	.0	.00	.00	.15	.15
279.57	978.	.0	.00	.00	3.14	3.14
85.07	1742.	.0	.00	.00	17.11	17.11
29.26	2680.	.0	.00	.00	67.65	67.65
9.60	3668.	.0	.00	.00	438.01	438.01
3.77	4313.	.0	.00	.00	621.86	621.86
1.38	5232.	.0	.00	.00	723.62	723.62
.33	6156.	.0	.00	.00	740.82	740.82
.11	6701.	.0	.00	.00	792.28	792.28
EXP ANNUAL DAMAGE			.00	.00	129.22	129.22

* DAMAGE DATA FOR PLAN 2 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
668.87	306.	.0	.00	.00	.00	.00
279.57	551.	.0	.00	.00	.00	.00
85.07	785.	.0	.00	.00	.00	.00
29.26	982.	.0	.00	.00	.00	.00
9.60	1136.	.0	.00	.00	.00	.00
3.77	1239.	.0	.00	.00	.00	.00
1.38	1457.	.0	.00	.00	.00	.00
.33	2350.	.0	.00	.00	.00	.00
.11	2871.	.0	.00	.00	.00	.00
EXP ANNUAL DAMAGE			.00	.00	.00	.00
AVE ANNUAL BENEFITS			.00	.00	129.22	129.22

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          **************
          *            *
 73 KK    *      RCH2  *
          *            *
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  FR        PERCENT EXCEEDANCE
                                             95.0    81.0    60.0    45.0    25.0    11.0     5.0     2.5
                         1.0       .5         .2      .1

  SF        PEAK STAGE
                                            843.6   844.8   845.6   846.0   846.6   847.3   847.9   848.4
                       849.1     849.5      850.0   850.3
```

DAMAGE DATA

STAGE	RESID	IND/COM	AGRIC	TOTAL
845.0	.000	.000	.000	.000
845.5	720.000	10.500	.000	730.500
847.0	1380.000	15.000	.000	1395.000
847.6	2710.000	52.500	.000	2762.500
848.3	5200.000	105.000	.000	5305.000
849.0	8000.000	202.500	.000	8202.500
849.8	10050.000	540.000	.000	10590.000
851.0	11250.000	585.000	.000	11835.000

* DAMAGE DATA FOR PLAN 1 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
93.53	0.	843.9	.00	.00	.00	.00
70.19	0.	845.3	387.69	5.65	.00	393.34
48.51	0.	845.9	898.05	11.71	.00	909.77
23.49	0.	846.7	1227.46	13.96	.00	1241.42
8.77	0.	847.5	2451.85	45.22	.00	2497.07
4.07	0.	848.1	4327.45	86.60	.00	4414.05
1.36	0.	848.9	7559.58	187.16	.00	7746.74
.33	0.	849.7	9899.23	515.18	.00	10414.40
.13	0.	850.2	10422.49	553.97	.00	10976.46
EXP ANNUAL DAMAGE			1099.95	20.21	.00	1120.16

* DAMAGE DATA FOR PLAN 2 *

FREQ	FLOW	STAGE	RESID	IND/COM	AGRIC	TOTAL
93.53	0.	843.2	.00	.00	.00	.00
70.19	0.	844.0	.00	.00	.00	.00
48.51	0.	845.2	251.54	3.67	.00	255.21
23.49	0.	845.6	744.17	10.66	.00	754.83
8.77	0.	846.0	933.42	11.96	.00	945.38
4.07	0.	846.3	1070.87	12.89	.00	1083.76
1.36	0.	846.8	1287.29	14.37	.00	1301.66
.33	0.	847.4	2336.30	41.96	.00	2378.26
.13	0.	847.8	3477.69	68.69	.00	3546.38
EXP ANNUAL DAMAGE			369.56	5.10	.00	374.66
AVE ANNUAL BENEFITS			730.38	15.11	.00	745.50

EXPECTED ANNUAL FLOOD DAMAGE SUMMARY

STREAM STATION	DAMAGE REACH	WATERSHED	TOWNSHIP	*	DAMAGE CATEGORY	EXPECTED ANNUAL DAMAGE PLAN 1	PLAN 2
RCH1	1			*	1 RESID	.00	.00
				*	2 IND/COM	.00	.00
				*	3 AGRIC	129.22	.00
				*			
				*	TOTAL	129.22	.00
			DAMAGE CHANGE (BENEFITS)			BASE	129.22
RCH2	2			*	1 RESID	1099.95	369.56
				*	2 IND/COM	20.21	5.10
				*	3 AGRIC	.00	.00
				*			
				*	TOTAL	1120.16	374.66
			DAMAGE CHANGE (BENEFITS)			BASE	745.50
BASIN TOTAL				*	1 RESID	1099.95	369.56
				*	2 IND/COM	20.21	5.10
				*	3 AGRIC	129.22	.00
				*			
				*	TOTAL	1249.37	374.66
			DAMAGE CHANGE (BENEFITS)			BASE	874.71

SUMMARY OF COMPONENT COSTS

PROJECT	LOCATION	CAPACITY	CAPITAL COST	AMORTIZED CAPITAL COST	ANNUAL O+M COST	ANNUAL POWER COST	TOTAL ANNUAL COST
RESERVOIR	200	5075.9	2937.949	148.073	67.573	.000	215.645
PUMP	RCH2	1100.6	1670.437	84.190	38.420	100.000	222.610
LOCAL PROTECTION	RCH1	4941.7	101.800	5.131	2.341	.000	7.472

OPTIMIZATION RESULTS

VAR 1	VAR 2	VAR 3
5075.89	1100.62	4941.73

SYSTEM COST AND PERFORMANCE SUMMARY
(UNITS SAME AS INPUT - NORMALLY 1000"S OF DOLLARS)

TOTAL SYSTEM CAPITAL COST * * * * * * * * * * * * * * 4710.

TOTAL SYSTEM AMORTIZED CAPITAL COST * * * * * * * * * 237.

TOTAL SYSTEM ANNUAL O,M,POWER AND REPLACEMENT COST * 208.

TOTAL SYSTEM ANNUAL COST * * * * * * * * * * * * * * 446.

AVERAGE ANNUAL DAMAGES -- EXISTING CONDITIONS * * * * 1249.

AVERAGE ANNUAL DAMAGES -- OPTIMIZED SYSTEM * * * * * 375.

AVERAGE ANNUAL DAMAGE REDUCTION (BENEFITS) * * * * * 875.

AVERAGE ANNUAL SYSTEM NET BENEFITS * * * * * * * * * 429.

***** OPTIMIZATION OBJECTIVE - MAXIMIZE SYSTEM NET BENEFITS FOR TARGET PROTECTION LEVEL *****

*** NORMAL END OF HEC-1 ***

12.13 Example Problem #13: Using the HEC Data Storage System with HEC-1

This example demonstrates how to read and write data using the HEC Data Storage System (DSS). In general, HEC-1 can read or write data to a DSS file by inserting a "ZR" and/or "ZW" record into the input file.

Reading data is accomplished by placing a ZR record at the point in the data file where the data would have normally been read. Time-series data that can be retrieved with the ZR record are cumulative or incremental precipitation and discharge hydrographs, corresponding to data which can be specified on PC, PI, QI or QO records.

Flow, storage or stage time-series data computed in HEC-1 may be stored in DSS using the ZW record. The ZW record can be placed in the input file wherever a hydrograph is being computed. For more information about DSS, Pathnames, and the use of ZR and ZW records, see appendix B.

For this example assume that observed precipitation and flow data, for a single subbasin, are stored in a DSS file. The task is to compute the runoff for this subbasin and to compare it to the observed flows for this particular event. A listing of the input data and the resulting output is shown in table 12.13.

The first ZR record is used to read in incremental rainfall that would normally be placed on PI records, as noted by "ZR =PI". The second ZR record is used to read in observed flows to be compared against the computed hydrograph. When entered by hand, observed flows are placed on QO records ("ZR =QO"). Also, a ZW record was placed in the section of data where the hydrograph at location SUB1 is being computed. This ZW record instructs the program to write the computed hydrograph at this location to the DSS file.

Notice that not all pathname parts are specified on the ZR and ZW records. In general, if the B part is missing from the pathname it will be taken as the station location from field one of the previous KK record. The D part of the pathname is derived from the starting date and time of the simulation, which is located in fields 2 and 3 of the IT record. The E part of the pathname, which is used to specify the time interval of data read from DSS, will default to the computation interval in field one of the IT record. If the data being read from the DSS file are in a different time interval than what is specified as the computation interval (field one, IT record), then that data's time interval must be specified as a standard DSS time interval on part E of the pathname (e.g. E=15MIN, E=1HOUR, etc...) on the ZR record. Time series data is always written at the interval specified on the IT record. Consequently, if a ZW record is used to write time series data, then the computation interval on the IT record must be a standard DSS time interval (see Appendix B, page B-4). Pathname parts A and C must be specified at least once, PART F being optional. Subsequent ZR and ZW records only require these portions of the pathname if they are different from the previous ZR or ZW record.

Table 12.13

Example Problem #13

Input

```
ID  TEST EXAMPLE NO. 13
ID USE OF DSS TO READ AND WRITE DATA
ID USE OF THE DSPLAY PROGRAM TO PLOT RESULTS
IT    15 14SEP88    1200     100
KK  SUB1
BA   5.7
BF   100    -.20   1.020
PB
ZR=PI A=EXAMPLE13 B=SUB1 C=PRECIP-INC E=1HOUR F=OBS
LU   0.3    0.15
UC   2.0     5.5
ZW  A=EXAMPLE13 C=FLOW F=COMP
KK   CMP
ZR=QO A=EXAMPLE13 B=SUB1 C=FLOW E=10MIN F=OBS
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*               JUN   1998              *
*            VERSION 4.1                *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:56   *
*                                       *
*****************************************


                                                    HEC-1 INPUT                                          PAGE  1

  LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

     1           ID    TEST EXAMPLE NO. 13
     2           ID   USE OF DSS TO READ AND WRITE DATA
     3           ID   USE OF THE DSPLAY PROGRAM TO PLOT RESULTS
     4           IT      15 14SEP88    1200     100

     5           KK    SUB1
     6           BA     5.7
     7           BF     100    -.20   1.020
     8           PB
     9           ZR  =PI A=EXAMPLE13 B=SUB1 C=PRECIP-INC E=1HOUR F=OBS
    10           LU     0.3    0.15
    11           UC     2.0     5.5
    12           ZW    A=EXAMPLE13 C=FLOW F=COMP

    13           KK     CMP
    14           ZR  =QO A=EXAMPLE13 B=SUB1 C=FLOW E=10MIN F=OBS
    15           ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*            JUN   1998                 *
*         VERSION 4.1                   *
*                                       *
*  RUN DATE   10JUN98  TIME  20:39:56   *
*                                       *
*****************************************

                          TEST EXAMPLE NO. 13
                         USE OF DSS TO READ AND WRITE DATA
                         USE OF THE DSPLAY PROGRAM TO PLOT RESULTS

      IT          HYDROGRAPH TIME DATA
                        NMIN          15  MINUTES IN COMPUTATION INTERVAL
                       IDATE     14SEP88  STARTING DATE
                       ITIME        1200  STARTING TIME
                          NQ         100  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE     15SEP88  ENDING DATE
                      NDTIME        1245  ENDING TIME
                      ICENT           19  CENTURY MARK

                   COMPUTATION INTERVAL     .25 HOURS
                        TOTAL TIME BASE   24.75 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
    5 KK     *      SUB1  *
             *            *
             **************

    -----DSS---ZOPEN; Existing File Opened - Unit:  71  File: HEC113.DSS
  -----DSS--- ZREAD Unit  71; Vers.    3:  /EXAMPLE13/SUB1/PRECIP-INC/01SEP1988/1HOUR/OBS/
  -----DSS--- ZREAD Unit  71; Vers.    3:  /EXAMPLE13/SUB1/PRECIP-INC/01SEP1988/1HOUR/OBS/

**** WARNING RDTIMS - MISSING PRECIPITATION   IN DSS FILE - READ AND INTERPOLATED VALUES SET TO ZERO ****


                SUBBASIN RUNOFF DATA

    6 BA          SUBBASIN CHARACTERISTICS
                        TAREA        5.70  SUBBASIN AREA

    7 BF          BASE FLOW CHARACTERISTICS
                        STRTQ      100.00  INITIAL FLOW
                        QRCSN        -.20  BEGIN BASE FLOW RECESSION
                        RTIOR     1.02000  RECESSION CONSTANT

                  PRECIPITATION DATA

    9 PB                STORM        3.85  BASIN TOTAL PRECIPITATION

    9 PI            INCREMENTAL PRECIPITATION PATTERN
                        .05      .05      .05      .05      .15      .15      .15      .15      .00      .00
                        .00      .00      .00      .00      .00      .00      .05      .05      .05      .05
                        .13      .13      .13      .13      .30      .30      .30      .30      .17      .18
                        .17      .17      .08      .08      .07      .08      .02      .03      .03      .02
                        .01      .01      .01      .01

   10 LU          UNIFORM LOSS RATE
                        STRTL         .30  INITIAL LOSS
                        CNSTL         .15  UNIFORM LOSS RATE
                        RTIMP         .00  PERCENT IMPERVIOUS AREA

   11 UC          CLARK UNITGRAPH
                           TC        2.00  TIME OF CONCENTRATION
                            R        5.50  STORAGE COEFFICIENT

                  SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                                             ***

                                                                UNIT HYDROGRAPH PARAMETERS
                                                          CLARK   TC=  2.00 HR,        R=  5.50 HR
                                                         SNYDER   TP=  2.02 HR,       CP=   .30

                                                                     UNIT HYDROGRAPH
                                                             121 END-OF-PERIOD ORDINATES
              20.       77.      160.      258.      361.      451.      517.      552.      547.      523.
             500.      478.      456.      436.      417.      398.      381.      364.      347.      332.
             317.      303.      290.      277.      265.      253.      242.      231.      221.      211.
             201.      192.      184.      176.      168.      160.      153.      146.      140.      134.
             128.      122.      117.      112.      107.      102.       97.       93.       89.       85.
              81.       78.       74.       71.       68.       65.       62.       59.       56.       54.
              51.       49.       47.       45.       43.       41.       39.       37.       36.       34.
              33.       31.       30.       29.       27.       26.       25.       24.       23.       22.
              21.       20.       19.       18.       17.       17.       16.       15.       14.       14.
              13.       13.       12.       11.       11.       10.       10.       10.        9.        9.
               8.        8.        8.        7.        7.        7.        6.        6.        6.        6.
               5.        5.        5.        5.        4.        4.        4.        4.        4.        4.
               3.
```

HYDROGRAPH AT STATION SUB1

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
14 SEP 1200	1	.00	.00	.00	100.	*	15 SEP 0030	51	.00	.00	.00	730.
14 SEP 1215	2	.05	.05	.00	100.	*	15 SEP 0045	52	.00	.00	.00	700.
14 SEP 1230	3	.05	.05	.00	99.	*	15 SEP 0100	53	.00	.00	.00	672.
14 SEP 1245	4	.05	.05	.00	99.	*	15 SEP 0115	54	.00	.00	.00	645.
14 SEP 1300	5	.05	.05	.00	98.	*	15 SEP 0130	55	.00	.00	.00	620.
14 SEP 1315	6	.15	.11	.04	98.	*	15 SEP 0145	56	.00	.00	.00	595.
14 SEP 1330	7	.15	.04	.11	102.	*	15 SEP 0200	57	.00	.00	.00	572.
14 SEP 1345	8	.15	.04	.11	114.	*	15 SEP 0215	58	.00	.00	.00	549.
14 SEP 1400	9	.15	.04	.11	135.	*	15 SEP 0230	59	.00	.00	.00	528.
14 SEP 1415	10	.00	.00	.00	165.	*	15 SEP 0245	60	.00	.00	.00	507.
14 SEP 1430	11	.00	.00	.00	200.	*	15 SEP 0300	61	.00	.00	.00	488.
14 SEP 1445	12	.00	.00	.00	235.	*	15 SEP 0315	62	.00	.00	.00	469.
14 SEP 1500	13	.00	.00	.00	264.	*	15 SEP 0330	63	.00	.00	.00	451.
14 SEP 1515	14	.00	.00	.00	285.	*	15 SEP 0345	64	.00	.00	.00	434.
14 SEP 1530	15	.00	.00	.00	295.	*	15 SEP 0400	65	.00	.00	.00	418.
14 SEP 1545	16	.00	.00	.00	294.	*	15 SEP 0415	66	.00	.00	.00	402.
14 SEP 1600	17	.00	.00	.00	287.	*	15 SEP 0430	67	.00	.00	.00	387.
14 SEP 1615	18	.05	.04	.01	278.	*	15 SEP 0445	68	.00	.00	.00	373.
14 SEP 1630	19	.05	.04	.01	270.	*	15 SEP 0500	69	.00	.00	.00	359.
14 SEP 1645	20	.05	.04	.01	264.	*	15 SEP 0515	70	.00	.00	.00	346.
14 SEP 1700	21	.05	.04	.01	259.	*	15 SEP 0530	71	.00	.00	.00	333.
14 SEP 1715	22	.13	.04	.09	258.	*	15 SEP 0545	72	.00	.00	.00	321.
14 SEP 1730	23	.13	.04	.09	262.	*	15 SEP 0600	73	.00	.00	.00	310.
14 SEP 1745	24	.13	.04	.09	273.	*	15 SEP 0615	74	.00	.00	.00	299.
14 SEP 1800	25	.13	.04	.09	293.	*	15 SEP 0630	75	.00	.00	.00	288.
14 SEP 1815	26	.30	.04	.26	324.	*	15 SEP 0645	76	.00	.00	.00	278.
14 SEP 1830	27	.30	.04	.26	371.	*	15 SEP 0700	77	.00	.00	.00	268.
14 SEP 1845	28	.30	.04	.26	438.	*	15 SEP 0715	78	.00	.00	.00	259.
14 SEP 1900	29	.30	.04	.26	525.	*	15 SEP 0730	79	.00	.00	.00	250.
14 SEP 1915	30	.17	.04	.14	627.	*	15 SEP 0745	80	.00	.00	.00	242.
14 SEP 1930	31	.18	.04	.14	736.	*	15 SEP 0800	81	.00	.00	.00	234.
14 SEP 1945	32	.17	.04	.14	844.	*	15 SEP 0815	82	.00	.00	.00	229.
14 SEP 2000	33	.17	.04	.14	944.	*	15 SEP 0830	83	.00	.00	.00	228.
14 SEP 2015	34	.08	.04	.04	027.	*	15 SEP 0845	84	.00	.00	.00	227.
14 SEP 2030	35	.08	.04	.04	1088.	*	15 SEP 0900	85	.00	.00	.00	226.
14 SEP 2045	36	.07	.04	.04	1126.	*	15 SEP 0915	86	.00	.00	.00	225.
14 SEP 2100	37	.08	.04	.04	1145.	*	15 SEP 0930	87	.00	.00	.00	223.
14 SEP 2115	38	.02	.02	.00	1148.	*	15 SEP 0945	88	.00	.00	.00	222.
14 SEP 2130	39	.03	.03	.00	1138.	*	15 SEP 1000	89	.00	.00	.00	221.
14 SEP 2145	40	.03	.03	.00	1117.	*	15 SEP 1015	90	.00	.00	.00	220.
14 SEP 2200	41	.02	.02	.00	1087.	*	15 SEP 1030	91	.00	.00	.00	219.
14 SEP 2215	42	.01	.01	.00	1052.	*	15 SEP 1045	92	.00	.00	.00	218.
14 SEP 2230	43	.01	.01	.00	1015.	*	15 SEP 1100	93	.00	.00	.00	217.
14 SEP 2245	44	.01	.01	.00	976.	*	15 SEP 1115	94	.00	.00	.00	216.
14 SEP 2300	45	.01	.01	.00	936.	*	15 SEP 1130	95	.00	.00	.00	215.
14 SEP 2315	46	.00	.00	.00	898.	*	15 SEP 1145	96	.00	.00	.00	214.
14 SEP 2330	47	.00	.00	.00	861.	*	15 SEP 1200	97	.00	.00	.00	213.
14 SEP 2345	48	.00	.00	.00	826.	*	15 SEP 1215	98	.00	.00	.00	212.
15 SEP 0000	49	.00	.00	.00	793.	*	15 SEP 1230	99	.00	.00	.00	211.
15 SEP 0015	50	.00	.00	.00	760.	*	15 SEP 1245	100	.00	.00	.00	210.

TOTAL RAINFALL = 3.85, TOTAL LOSS = 1.32, TOTAL EXCESS = 2.53

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	24.75-HR
1148.	9.25	(CFS)	927.	458.	447.	447.
		(INCHES)	1.513	2.988	3.009	3.009
		(AC-FT)	460.	908.	915.	915.

CUMULATIVE AREA = 5.70 SQ MI

```
-----DSS---ZWRITE Unit  71; Vers.    9:  /EXAMPLE13/SUB1/FLOW/14SEP1988/15MIN/COMP/
-----DSS---ZWRITE Unit  71; Vers.    9:  /EXAMPLE13/SUB1/FLOW/15SEP1988/15MIN/COMP/
```

```
              **************
              *            *
  13 KK       *       CMP  *
              *            *
              **************

-----DSS--- ZREAD Unit  71; Vers.    2:  /EXAMPLE13/SUB1/FLOW/14SEP1988/10MIN/OBS/
-----DSS--- ZREAD Unit  71; Vers.    2:  /EXAMPLE13/SUB1/FLOW/14SEP1988/10MIN/OBS/
-----DSS--- ZREAD Unit  71; Vers.    2:  /EXAMPLE13/SUB1/FLOW/15SEP1988/10MIN/OBS/

                                                                   ***


     ************************************************************************************************************************
     *                                                                                                                      *
     *                                  COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS                                     *
     *                                                                                                                      *
     ************************************************************************************************************************
     *                                                                                                                      *
     *                                                            TIME TO       LAG                                         *
     *                              SUM OF       EQUIV       MEAN       CENTER      C.M. TO       PEAK       TIME OF     *
     *                               FLOWS       DEPTH       FLOW       OF MASS       C.M.        FLOW        PEAK      *
     *                                                                                                                      *
     *     COMPUTED HYDROGRAPH        44424.      3.019        444.      12.09       12.09       1148.        9.25      *
     *     OBSERVED HYDROGRAPH        45771.      3.111        458.      12.49       12.49       1104.        9.25      *
     *                                                                                                                      *
     *     DIFFERENCE                 -1348.      -.092        -13.       -.40        -.40         44.         .00      *
     *     PERCENT DIFFERENCE          -2.94                                          -3.23        3.98                 *
     *                                                                                                                      *
     *                  STANDARD ERROR       42.                    AVERAGE ABSOLUTE ERROR       35.                      *
     *              OBJECTIVE FUNCTION       43.            AVERAGE PERCENT ABSOLUTE ERROR      9.11                      *
     *                                                                                                                      *
     ************************************************************************************************************************
```

HYDROGRAPH AT STATION CMP

DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL	DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL	DA	MON	HRMN	ORD	COMP Q	OBS Q	RESIDUL
14	SEP	1200	1	100.	100.	0.	14	SEP	2030	35	1088.	1030.	58.	15	SEP	0500	69	359.	426.	-67.
14	SEP	1215	2	100.	100.	-0.	14	SEP	2045	36	1126.	1070.	56.	15	SEP	0515	70	346.	413.	-67.
14	SEP	1230	3	99.	100.	-0.	14	SEP	2100	37	1145.	1094.	50.	15	SEP	0530	71	333.	400.	-67.
14	SEP	1245	4	99.	99.	-1.	14	SEP	2115	38	1148.	1104.	44.	15	SEP	0545	72	321.	388.	-67.
14	SEP	1300	5	98.	99.	-1.	14	SEP	2130	39	1138.	1103.	35.	15	SEP	0600	73	310.	376.	-67.
14	SEP	1315	6	98.	99.	-0.	14	SEP	2145	40	1117.	1091.	26.	15	SEP	0615	74	299.	365.	-66.
14	SEP	1330	7	102.	99.	3.	14	SEP	2200	41	1087.	1070.	17.	15	SEP	0630	75	288.	354.	-66.
14	SEP	1345	8	114.	105.	9.	14	SEP	2215	42	1052.	1044.	8.	15	SEP	0645	76	278.	344.	-66.
14	SEP	1400	9	135.	118.	17.	14	SEP	2230	43	1015.	1014.	0.	15	SEP	0700	77	268.	334.	-65.
14	SEP	1415	10	165.	139.	26.	14	SEP	2245	44	976.	982.	-6.	15	SEP	0715	78	259.	324.	-65.
14	SEP	1430	11	200.	165.	34.	14	SEP	2300	45	936.	949.	-13.	15	SEP	0730	79	250.	315.	-64.
14	SEP	1445	12	235.	193.	41.	14	SEP	2315	46	898.	917.	-19.	15	SEP	0745	80	242.	306.	-64.
14	SEP	1500	13	264.	219.	46.	14	SEP	2330	47	861.	885.	-24.	15	SEP	0800	81	234.	297.	-63.
14	SEP	1515	14	285.	238.	47.	14	SEP	2345	48	826.	855.	-29.	15	SEP	0815	82	229.	289.	-60.
14	SEP	1530	15	295.	249.	45.	15	SEP	0000	49	793.	826.	-33.	15	SEP	0830	83	228.	281.	-53.
14	SEP	1545	16	294.	251.	43.	15	SEP	0015	50	760.	798.	-37.	15	SEP	0845	84	227.	273.	-46.
14	SEP	1600	17	287.	247.	40.	15	SEP	0030	51	730.	771.	-41.	15	SEP	0900	85	226.	266.	-40.
14	SEP	1615	18	278.	242.	36.	15	SEP	0045	52	700.	745.	-44.	15	SEP	0915	86	225.	259.	-34.
14	SEP	1630	19	270.	237.	33.	15	SEP	0100	53	672.	720.	-47.	15	SEP	0930	87	223.	252.	-28.
14	SEP	1645	20	264.	235.	29.	15	SEP	0115	54	645.	696.	-50.	15	SEP	0945	88	222.	245.	-23.
14	SEP	1700	21	259.	234.	25.	15	SEP	0130	55	620.	672.	-53.	15	SEP	1000	89	221.	239.	-17.
14	SEP	1715	22	258.	238.	20.	15	SEP	0145	56	595.	650.	-55.	15	SEP	1015	90	220.	232.	-12.
14	SEP	1730	23	262.	246.	16.	15	SEP	0200	57	572.	629.	-57.	15	SEP	1030	91	219.	226.	-7.
14	SEP	1745	24	273.	262.	11.	15	SEP	0215	58	549.	608.	-59.	15	SEP	1045	92	218.	222.	-4.
14	SEP	1800	25	293.	284.	8.	15	SEP	0230	59	528.	588.	-60.	15	SEP	1100	93	217.	221.	-4.
14	SEP	1815	26	324.	318.	6.	15	SEP	0245	60	507.	569.	-62.	15	SEP	1115	94	216.	220.	-4.
14	SEP	1830	27	371.	363.	8.	15	SEP	0300	61	488.	551.	-63.	15	SEP	1130	95	215.	219.	-5.
14	SEP	1845	28	438.	427.	11.	15	SEP	0315	62	469.	533.	-64.	15	SEP	1145	96	214.	219.	-5.
14	SEP	1900	29	525.	507.	19.	15	SEP	0330	63	451.	516.	-65.	15	SEP	1200	97	213.	218.	-6.
14	SEP	1915	30	627.	600.	27.	15	SEP	0345	64	434.	499.	-65.	15	SEP	1215	98	212.	218.	-6.
14	SEP	1930	31	736.	700.	36.	15	SEP	0400	65	418.	484.	-66.	15	SEP	1230	99	211.	217.	-7.
14	SEP	1945	32	844.	799.	45.	15	SEP	0415	66	402.	468.	-66.	15	SEP	1245	100	210.	217.	-7.
14	SEP	2000	33	944.	892.	52.	15	SEP	0430	67	387.	454.	-67.							
14	SEP	2015	34	1027.	970.	58.	15	SEP	0445	68	373.	440.	-67.							

```
                                                        STATION      CMP

                        (I) INFLOW,   (O) OUTFLOW,   (*) OBSERVED FLOW
         0.      200.      400.      600.      800.     1000.     1200.        0.        0.        0.        0.        0.        0.
DAHRMN PER
141200   1I----*----.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
141215   2I    *    .         .         .         .         .         .         .         .         .         .         .         .
141230   3I    *    .         .         .         .         .         .         .         .         .         .         .         .
141245   4I    *    .         .         .         .         .         .         .         .         .         .         .         .
141300   5I    *    .         .         .         .         .         .         .         .         .         .         .         .
141315   6I    *    .         .         .         .         .         .         .         .         .         .         .         .
141330   7I    *    .         .         .         .         .         .         .         .         .         .         .         .
141345   8I    *O   .         .         .         .         .         .         .         .         .         .         .         .
141400   9I     *O  .         .         .         .         .         .         .         .         .         .         .         .
141415  10I      *O .         .         .         .         .         .         .         .         .         .         .         .
141430  11I . . . * O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
141445  12I         * O       .         .         .         .         .         .         .         .         .         .         .
141500  13I         .* O      .         .         .         .         .         .         .         .         .         .         .
141515  14I         . * O     .         .         .         .         .         .         .         .         .         .         .
141530  15I         . *  O    .         .         .         .         .         .         .         .         .         .         .
141545  16I         .  * O    .         .         .         .         .         .         .         .         .         .         .
141600  17I         . * O     .         .         .         .         .         .         .         .         .         .         .
141615  18I         . * O     .         .         .         .         .         .         .         .         .         .         .
141630  19I         . * O     .         .         .         .         .         .         .         .         .         .         .
141645  20I         . *O      .         .         .         .         .         .         .         .         .         .         .
141700  21I . . . . . *O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
141715  22I         . *O      .         .         .         .         .         .         .         .         .         .         .
141730  23I         . *O      .         .         .         .         .         .         .         .         .         .         .
141745  24I         .  *O     .         .         .         .         .         .         .         .         .         .         .
141800  25I         .   *O    .         .         .         .         .         .         .         .         .         .         .
141815  26I         .     *   .         .         .         .         .         .         .         .         .         .         .
141830  27I         .       *O.         .         .         .         .         .         .         .         .         .         .
141845  28I         .         .*O       .         .         .         .         .         .         .         .         .         .
141900  29I         .         .    *O   .         .         .         .         .         .         .         .         .         .
141915  30I         .         .         *O        .         .         .         .         .         .         .         .         .
141930  31I . . . . . . . . . . . . . . . . .*.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
141945  32I         .         .         .         * O       .         .         .         .         .         .         .         .
142000  33I         .         .         .         .    * O  .         .         .         .         .         .         .         .
142015  34I         .         .         .         .       * .O        .         .         .         .         .         .         .
142030  35I         .         .         .         .         .*  O     .         .         .         .         .         .         .
142045  36I         .         .         .         .         .  *  O   .         .         .         .         .         .         .
142100  37I         .         .         .         .         .    * O  .         .         .         .         .         .         .
142115  38I         .         .         .         .         .    * O  .         .         .         .         .         .         .
142130  39I         .         .         .         .         .    * O  .         .         .         .         .         .         .
142145  40I         .         .         .         .         .    *O   .         .         .         .         .         .         .
142200  41I . . . . . . . . . . . . . . . . . . . . . . . . . . *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
142215  42I         .         .         .         .         . *O      .         .         .         .         .         .         .
142230  43I         .         .         .         .         .*        .         .         .         .         .         .         .
142245  44I         .         .         .         .        *.         .         .         .         .         .         .         .
142300  45I         .         .         .         .      *  .         .         .         .         .         .         .         .
142315  46I         .         .         .         .    O*   .         .         .         .         .         .         .         .
142330  47I         .         .         .         .  O*     .         .         .         .         .         .         .         .
142345  48I         .         .         .         .O *      .         .         .         .         .         .         .         .
150000  49I         .         .         .         O*        .         .         .         .         .         .         .         .
150015  50I         .         .         .       O *         .         .         .         .         .         .         .         .
150030  51I . . . . . . . . . . . . . . . . . O .*. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
150045  52I         .         .         .    O *  .         .         .         .         .         .         .         .         .
150100  53I         .         .         .   O *   .         .         .         .         .         .         .         .         .
```

```
150115  54I         .         .         . O  *    .         .         .         .         .         .         .         .         .
150130  55I         .         .         .O  *     .         .         .         .         .         .         .         .         .
150145  56I         .         .         O  *      .         .         .         .         .         .         .         .         .
150200  57I         .         .        O.*        .         .         .         .         .         .         .         .         .
150215  58I         .         .      O  *         .         .         .         .         .         .         .         .         .
150230  59I         .         .     O  *.         .         .         .         .         .         .         .         .         .
150245  60I         .         .    O  * .         .         .         .         .         .         .         .         .         .
150300  61I . . . . . . . . . . . O . * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
150315  62I         .         .  O   *  .         .         .         .         .         .         .         .         .         .
150330  63I         .         .  O  *   .         .         .         .         .         .         .         .         .         .
150345  64I         .         . O  *    .         .         .         .         .         .         .         .         .         .
150400  65I         .         .O  *     .         .         .         .         .         .         .         .         .         .
150415  66I         .         O  *      .         .         .         .         .         .         .         .         .         .
150430  67I         .        O.  *      .         .         .         .         .         .         .         .         .         .
150445  68I         .        O. *       .         .         .         .         .         .         .         .         .         .
150500  69I         .       O .*        .         .         .         .         .         .         .         .         .         .
150515  70I         .      O  .*        .         .         .         .         .         .         .         .         .         .
150530  71I . . . . . . . .O. * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
150545  72I         .     O  *.         .         .         .         .         .         .         .         .         .         .
150600  73I         .    O   *.         .         .         .         .         .         .         .         .         .         .
150615  74I         .    O  * .         .         .         .         .         .         .         .         .         .         .
150630  75I         .   O   * .         .         .         .         .         .         .         .         .         .         .
150645  76I         .   O  *  .         .         .         .         .         .         .         .         .         .         .
150700  77I         .  O   *  .         .         .         .         .         .         .         .         .         .         .
150715  78I         .  O  *   .         .         .         .         .         .         .         .         .         .         .
150730  79I         .  O  *   .         .         .         .         .         .         .         .         .         .         .
150745  80I         . O  *    .         .         .         .         .         .         .         .         .         .         .
150800  81I . . . . . O .*. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
150815  82I         .O  *     .         .         .         .         .         .         .         .         .         .         .
150830  83I         .O  *     .         .         .         .         .         .         .         .         .         .         .
150845  84I         .O  *     .         .         .         .         .         .         .         .         .         .         .
150900  85I         .O *      .         .         .         .         .         .         .         .         .         .         .
150915  86I         .O *      .         .         .         .         .         .         .         .         .         .         .
150930  87I         .O *      .         .         .         .         .         .         .         .         .         .         .
150945  88I         .O*       .         .         .         .         .         .         .         .         .         .         .
151000  89I         .O*       .         .         .         .         .         .         .         .         .         .         .
151015  90I         .O*       .         .         .         .         .         .         .         .         .         .         .
151030  91I . . . . .*. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
151045  92I         .*        .         .         .         .         .         .         .         .         .         .         .
151100  93I         .*        .         .         .         .         .         .         .         .         .         .         .
151115  94I         .*        .         .         .         .         .         .         .         .         .         .         .
151130  95I         .*        .         .         .         .         .         .         .         .         .         .         .
151145  96I         .*        .         .         .         .         .         .         .         .         .         .         .
151200  97I         .*        .         .         .         .         .         .         .         .         .         .         .
151215  98I         .*        .         .         .         .         .         .         .         .         .         .         .
151230  99I         .*        .         .         .         .         .         .         .         .         .         .         .
151245 100I---------O*--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

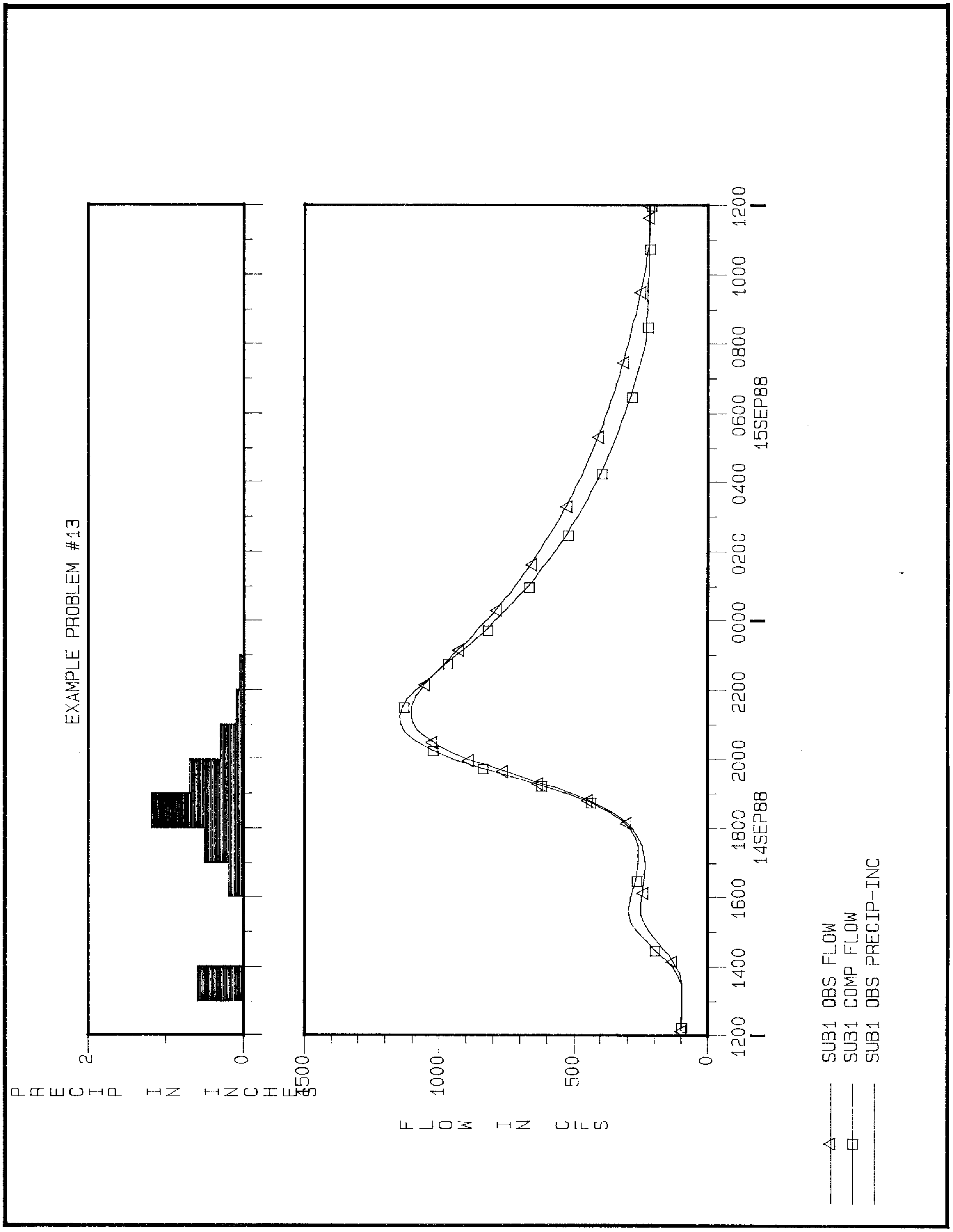
OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SUB1	1148.	9.25	927.	458.	447.	5.70		

```
 *** NORMAL END OF HEC-1 ***


    -----DSS---ZCLOSE Unit: 71
               Number of Records:      5
               File Size:     12.5  Kbytes
               Percent Inactive: 28.86
```

Besides the normal HEC-1 output, graphical plots can be generated through the use of the DSPLAY program. DSPLAY is a graphics package that allows the user to plot any data that is contained in the DSS file. In this example it was stated that the basin average precipitation and the observed flows for the historical event were stored in the DSS file. During execution of the HEC-1 program, the computed hydrograph was also written to the DSS file. Through the use of the DSPLAY program the plot on the following page was generated.

Command	**Description**
CA.NA	Develop a new catalog of all the data stored in the DSS file and display it in an abbreviated format on the screen.
TI 14SEP88 1215 15SEP88 1215	Establish a time window for retrieving and plotting data.
SH -1 -1 0	Use the shading command to establish that the first two lines will have no shading and the third line will be completely shaded.
SY 3 4 0	The SY command is used to establish point symbols for the data to be plotted.
PL 2 4 1	Plot on the screen (default device) the data referenced by pathnames 2, 4, and 1 in the DSS file catalog listing.
DEV PRINTER	Change plotting device option to printer.
PL	Send the previously defined plot (PL 2 4 1) to the printer.
DE SCREEN	Reset the current plotting device back to the screen.
FI	End the DSPLAY session and return to the main menu or DOS.



EXAMPLE PROBLEM #13
PRECIP IN INCHES
2
0
FLOW IN CFS
1500
1000
500
0
1200
1400
1600
1800
14SEP88
2000
2200
0000
0200
0400
0600
15SEP88
0800
1000
1200
SUB1 OBS FLOW
SUB1 COMP FLOW
SUB1 OBS PRECIP-INC

12.14 Example problem #14: Calculating Reservoir Storage and Elevation From Inflow and Outflow

This example demonstrates how to calculate reservoir storages and elevations from a known inflow hydrograph and a user defined outflow hydrograph. The user defined outflow hydrograph can be observed flows from a specific historical event, or it can be a hypothetical release schedule. The HS record is used to tell the program to compute storage from inflow and outflow. The outflow hydrograph is read from QO records, and is used in subsequent downstream calculations.

The initial storage in the reservoir at the beginning of the simulation is placed in the first field of the HS record. Subsequent storage values are calculated from the equation:

$$STR = C*D*((QI(I)+QI(I-1))/2 - (QO(I)+QO(I-1))/2) + STR(I-1)$$

where:

STR(I)	= Storage at time I in acre-ft.
QI(I)	= Inflow at time I in cfs.
QO(I)	= Outflow at time I in cfs.
DT	= Time interval between time I and I-1 in seconds.
C	= Factor for converting from cfs to acre-ft.

An "optional" storage-elevation table may be placed on SV and SE records. If this table is present, reservoir elevations will be interpolated for each storage value computed. A listing of the input data and output for this example is shown in Table 12.14.

Table 12.14

Example Problem #14

Input

```
ID TEST EXAMPLE NO. 14.  PROBLEM TO CALCULATE STORAGES AND STAGES
ID FROM KNOWN INFLOW AND OUTFLOW HYDROGRAPHS.
ID GARY W. BRUNNER  AUGUST 5, 1988
IT    60 05JAN62    0500     100
KKINFLOW
BA   383
PB   5.0
PI   0.2      0.3     1.0     1.2     1.0     0.5     0.4     0.2     0.2
BF   500     -.05    1.02
LU   0.5     0.10
UC  15.0     16.0
KK   RES
KM CALCULATE STORAGE AND ELEVATION FROM INFLOW AND OUTFLOW
HS139179
QO    80       66      52      50      48      43      39      37      35      40
QO    45       50      55      60      80     100     200     300     500     700
QO   900     1400    2400    3480    4260    5000    5500    5900    6000    2000
QO  2000
SV     8    14855  152218  181213  192238  213662  249108  287814  317123  319295
SV321487  323673  325878  330324  334818
SE 530.0    586.0   666.2   676.0   679.5   686.0   696.0   706.0   713.0   713.5
SE 714.0    714.5   715.0   716.0   717.0
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             JUN   1998                *
*          VERSION 4.1                  *
*                                       *
*  RUN DATE   10JUN98  TIME  20:40:04   *
*                                       *
*****************************************


                    TEST EXAMPLE NO. 14.  PROBLEM TO CALCULATE STORAGES AND STAGES
                    FROM KNOWN INFLOW AND OUTFLOW HYDROGRAPHS.
                    GARY W. BRUNNER  AUGUST 5, 1988

  IT          HYDROGRAPH TIME DATA
                     NMIN          60  MINUTES IN COMPUTATION INTERVAL
                    IDATE      5JAN62  STARTING DATE
                    ITIME        0500  STARTING TIME
                       NQ         100  NUMBER OF HYDROGRAPH ORDINATES
                   NDDATE      9JAN62  ENDING DATE
                   NDTIME        0800  ENDING TIME
                   ICENT           19  CENTURY MARK

                COMPUTATION INTERVAL    1.00 HOURS
                     TOTAL TIME BASE   99.00 HOURS
```

```
       ENGLISH UNITS
          DRAINAGE AREA         SQUARE MILES
          PRECIPITATION DEPTH   INCHES
          LENGTH, ELEVATION     FEET
          FLOW                  CUBIC FEET PER SECOND
          STORAGE VOLUME        ACRE-FEET
          SURFACE AREA          ACRES
          TEMPERATURE           DEGREES FAHRENHEIT

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


        **************
        *            *
   5 KK *   INFLOW   *
        *            *
        **************

          SUBBASIN RUNOFF DATA

   6 BA     SUBBASIN CHARACTERISTICS
                 TAREA      383.00  SUBBASIN AREA

   9 BF     BASE FLOW CHARACTERISTICS
                 STRTQ      500.00  INITIAL FLOW
                 QRCSN        -.05  BEGIN BASE FLOW RECESSION
                 RTIOR     1.02000  RECESSION CONSTANT

            PRECIPITATION DATA

   7 PB          STORM        5.00  BASIN TOTAL PRECIPITATION

   8 PI       INCREMENTAL PRECIPITATION PATTERN
                  .20       .30      1.00      1.20      1.00       .50       .40       .20       .20

  10 LU     UNIFORM LOSS RATE
                 STRTL         .50  INITIAL LOSS
                 CNSTL         .10  UNIFORM LOSS RATE
                 RTIMP         .00  PERCENT IMPERVIOUS AREA

  11 UC     CLARK UNITGRAPH
                    TC       15.00  TIME OF CONCENTRATION
                     R       16.00  STORAGE COEFFICIENT

            SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                           ***

                                                        UNIT HYDROGRAPH PARAMETERS
                                                  CLARK   TC= 15.00 HR,       R= 16.00 HR
                                                 SNYDER   TP= 14.09 HR,      CP=  .56

                                                             UNIT HYDROGRAPH
                                                        93 END-OF-PERIOD ORDINATES
        182.      687.     1410.     2268.     3221.     4247.     5328.     6439.     7482.     8367.
       9081.     9621.     9981.    10141.    10042.     9616.     9033.     8486.     7971.     7488.
       7035.     6608.     6208.     5831.     5478.     5146.     4834.     4541.     4266.     4007.
       3765.     3536.     3322.     3121.     2932.     2754.     2587.     2430.     2283.     2145.
       2015.     1893.     1778.     1670.     1569.     1474.     1384.     1301.     1222.     1148.
       1078.     1013.      951.      894.      840.      789.      741.      696.      654.      614.
        577.      542.      509.      478.      449.      422.      396.      372.      350.      329.
        309.      290.      272.      256.      240.      226.      212.      199.      187.      176.
        165.      155.      146.      137.      129.      121.      114.      107.      100.       94.
         88.       83.       78.
```

```
*****************************************************************************************************************

                                    HYDROGRAPH AT STATION   INFLOW

*****************************************************************************************************************
DA MON HRMN  ORD    RAIN    LOSS  EXCESS     COMP Q  *  DA MON HRMN  ORD    RAIN    LOSS  EXCESS     COMP Q
                                                     *
 5 JAN 0500    1     .00     .00     .00       500.  *   7 JAN 0700   51     .00     .00     .00      5701.
 5 JAN 0600    2     .20     .20     .00       490.  *   7 JAN 0800   52     .00     .00     .00      5363.
 5 JAN 0700    3     .30     .30     .00       481.  *   7 JAN 0900   53     .00     .00     .00      5046.
 5 JAN 0800    4    1.00     .10     .90       635.  *   7 JAN 1000   54     .00     .00     .00      4747.
 5 JAN 0900    5    1.20     .10    1.10      1281.  *   7 JAN 1100   55     .00     .00     .00      4467.
 5 JAN 1000    6    1.00     .10     .90      2642.  *   7 JAN 1200   56     .00     .00     .00      4203.
 5 JAN 1100    7     .50     .10     .40      4728.  *   7 JAN 1300   57     .00     .00     .00      3955.
 5 JAN 1200    8     .40     .10     .30      7428.  *   7 JAN 1400   58     .00     .00     .00      3722.
 5 JAN 1300    9     .20     .10     .10     10622.  *   7 JAN 1500   59     .00     .00     .00      3503.
 5 JAN 1400   10     .20     .10     .10     14202.  *   7 JAN 1600   60     .00     .00     .00      3297.
 5 JAN 1500   11     .00     .00     .00     18067.  *   7 JAN 1700   61     .00     .00     .00      3104.
 5 JAN 1600   12     .00     .00     .00     22047.  *   7 JAN 1800   62     .00     .00     .00      2922.
 5 JAN 1700   13     .00     .00     .00     25903.  *   7 JAN 1900   63     .00     .00     .00      2751.
 5 JAN 1800   14     .00     .00     .00     29417.  *   7 JAN 2000   64     .00     .00     .00      2590.
 5 JAN 1900   15     .00     .00     .00     32439.  *   7 JAN 2100   65     .00     .00     .00      2439.
 5 JAN 2000   16     .00     .00     .00     34878.  *   7 JAN 2200   66     .00     .00     .00      2297.
 5 JAN 2100   17     .00     .00     .00     36664.  *   7 JAN 2300   67     .00     .00     .00      2164.
 5 JAN 2200   18     .00     .00     .00     37691.  *   8 JAN 0000   68     .00     .00     .00      2038.
 5 JAN 2300   19     .00     .00     .00     37802.  *   8 JAN 0100   69     .00     .00     .00      1920.
 6 JAN 0000   20     .00     .00     .00     37010.  *   8 JAN 0200   70     .00     .00     .00      1863.
 6 JAN 0100   21     .00     .00     .00     35584.  *   8 JAN 0300   71     .00     .00     .00      1826.
 6 JAN 0200   22     .00     .00     .00     33840.  *   8 JAN 0400   72     .00     .00     .00      1791.
 6 JAN 0300   23     .00     .00     .00     31985.  *   8 JAN 0500   73     .00     .00     .00      1755.
 6 JAN 0400   24     .00     .00     .00     30130.  *   8 JAN 0600   74     .00     .00     .00      1721.
 6 JAN 0500   25     .00     .00     .00     28335.  *   8 JAN 0700   75     .00     .00     .00      1687.
 6 JAN 0600   26     .00     .00     .00     26630.  *   8 JAN 0800   76     .00     .00     .00      1654.
 6 JAN 0700   27     .00     .00     .00     25029.  *   8 JAN 0900   77     .00     .00     .00      1622.
 6 JAN 0800   28     .00     .00     .00     23524.  *   8 JAN 1000   78     .00     .00     .00      1590.
 6 JAN 0900   29     .00     .00     .00     22111.  *   8 JAN 1100   79     .00     .00     .00      1559.
 6 JAN 1000   30     .00     .00     .00     20782.  *   8 JAN 1200   80     .00     .00     .00      1528.
 6 JAN 1100   31     .00     .00     .00     19534.  *   8 JAN 1300   81     .00     .00     .00      1498.
 6 JAN 1200   32     .00     .00     .00     18362.  *   8 JAN 1400   82     .00     .00     .00      1469.
 6 JAN 1300   33     .00     .00     .00     17260.  *   8 JAN 1500   83     .00     .00     .00      1440.
 6 JAN 1400   34     .00     .00     .00     16225.  *   8 JAN 1600   84     .00     .00     .00      1412.
 6 JAN 1500   35     .00     .00     .00     15252.  *   8 JAN 1700   85     .00     .00     .00      1384.
 6 JAN 1600   36     .00     .00     .00     14338.  *   8 JAN 1800   86     .00     .00     .00      1357.
 6 JAN 1700   37     .00     .00     .00     13480.  *   8 JAN 1900   87     .00     .00     .00      1330.
 6 JAN 1800   38     .00     .00     .00     12673.  *   8 JAN 2000   88     .00     .00     .00      1304.
 6 JAN 1900   39     .00     .00     .00     11914.  *   8 JAN 2100   89     .00     .00     .00      1279.
 6 JAN 2000   40     .00     .00     .00     11202.  *   8 JAN 2200   90     .00     .00     .00      1254.
 6 JAN 2100   41     .00     .00     .00     10533.  *   8 JAN 2300   91     .00     .00     .00      1229.
 6 JAN 2200   42     .00     .00     .00      9904.  *   9 JAN 0000   92     .00     .00     .00      1205.
 6 JAN 2300   43     .00     .00     .00      9312.  *   9 JAN 0100   93     .00     .00     .00      1181.
 7 JAN 0000   44     .00     .00     .00      8757.  *   9 JAN 0200   94     .00     .00     .00      1158.
 7 JAN 0100   45     .00     .00     .00      8235.  *   9 JAN 0300   95     .00     .00     .00      1136.
 7 JAN 0200   46     .00     .00     .00      7744.  *   9 JAN 0400   96     .00     .00     .00      1113.
 7 JAN 0300   47     .00     .00     .00      7284.  *   9 JAN 0500   97     .00     .00     .00      1091.
 7 JAN 0400   48     .00     .00     .00      6850.  *   9 JAN 0600   98     .00     .00     .00      1070.
 7 JAN 0500   49     .00     .00     .00      6443.  *   9 JAN 0700   99     .00     .00     .00      1049.
 7 JAN 0600   50     .00     .00     .00      6061.  *   9 JAN 0800  100     .00     .00     .00      1028.
*****************************************************************************************************************

     TOTAL RAINFALL =    5.00, TOTAL LOSS =    1.20, TOTAL EXCESS =    3.80

   PEAK FLOW     TIME                              MAXIMUM AVERAGE FLOW
     (CFS)       (HR)                  6-HR        24-HR        72-HR      99.00-HR


     37802.     18.00       (CFS)     36518.      27510.       13067.        9831.
                         (INCHES)       .887       2.671        3.807        3.938
                          (AC-FT)     18108.      54565.       77755.       80437.

                          CUMULATIVE AREA =  383.00 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


             **************
             *            *
   12 KK     *      RES   *
             *            *
             **************
                                   CALCULATE STORAGE AND ELEVATION FROM INFLOW AND OUTFLOW

               HYDROGRAPH ROUTING DATA

   14 HS         COMPUTED STORAGE FROM INFLOW AND OUTFLOW
                      STR(1)    139179.0  INITIAL STORAGE

                                                                            ***
```

HYDROGRAPH AT STATION RES

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
5	JAN	0500	1	80.	139179.0	658.6	6	JAN	1500	35	2000.	193993.4	680.0	8	JAN	0100	69	2000.	206359.2	683.8
5	JAN	0600	2	66.	139213.9	658.6	6	JAN	1600	36	2000.	195050.9	680.4	8	JAN	0200	70	2000.	206350.2	683.8
5	JAN	0700	3	52.	139249.1	658.6	6	JAN	1700	37	2000.	196035.1	680.7	8	JAN	0300	71	2000.	206337.4	683.8
5	JAN	0800	4	50.	139291.0	658.7	6	JAN	1800	38	2000.	196950.4	680.9	8	JAN	0400	72	2000.	206321.6	683.8
5	JAN	0900	5	48.	139366.1	658.7	6	JAN	1900	39	2000.	197801.1	681.2	8	JAN	0500	73	2000.	206302.8	683.8
5	JAN	1000	6	43.	139524.5	658.8	6	JAN	2000	40	2000.	198591.1	681.4	8	JAN	0600	74	2000.	206281.2	683.8
5	JAN	1100	7	39.	139825.6	659.0	6	JAN	2100	41	2000.	199323.9	681.6	8	JAN	0700	75	2000.	206256.7	683.8
5	JAN	1200	8	37.	140324.8	659.3	6	JAN	2200	42	2000.	200003.1	681.9	8	JAN	0800	76	2000.	206229.5	683.7
5	JAN	1300	9	35.	141067.7	659.7	6	JAN	2300	43	2000.	200631.8	682.0	8	JAN	0900	77	2000.	206199.6	683.7
5	JAN	1400	10	40.	142090.4	660.3	7	JAN	0000	44	2000.	201213.2	682.2	8	JAN	1000	78	2000.	206167.0	683.7
5	JAN	1500	11	45.	143420.3	661.1	7	JAN	0100	45	2000.	201750.1	682.4	8	JAN	1100	79	2000.	206131.9	683.7
5	JAN	1600	12	50.	145074.0	662.0	7	JAN	0200	46	2000.	202245.1	682.5	8	JAN	1200	80	2000.	206094.1	683.7
5	JAN	1700	13	55.	147051.0	663.2	7	JAN	0300	47	2000.	202700.8	682.7	8	JAN	1300	81	2000.	206053.9	683.7
5	JAN	1800	14	60.	149332.2	664.5	7	JAN	0400	48	2000.	203119.5	682.8	8	JAN	1400	82	2000.	206011.3	683.7
5	JAN	1900	15	80.	151882.5	666.0	7	JAN	0500	49	2000.	203503.6	682.9	8	JAN	1500	83	2000.	205966.2	683.7
5	JAN	2000	16	100.	154656.7	667.0	7	JAN	0600	50	2000.	203855.0	683.0	8	JAN	1600	84	2000.	205918.7	683.7
5	JAN	2100	17	200.	157600.6	668.0	7	JAN	0700	51	2000.	204175.7	683.1	8	JAN	1700	85	2000.	205869.0	683.6
5	JAN	2200	18	300.	160652.5	669.1	7	JAN	0800	52	2000.	204467.6	683.2	8	JAN	1800	86	2000.	205817.0	683.6
5	JAN	2300	19	500.	163739.0	670.1	7	JAN	0900	53	2000.	204732.5	683.3	8	JAN	1900	87	2000.	205762.7	683.6
6	JAN	0000	20	700.	166780.8	671.1	7	JAN	1000	54	2000.	204971.8	683.4	8	JAN	2000	88	2000.	205706.3	683.6
6	JAN	0100	21	900.	169714.4	672.1	7	JAN	1100	55	2000.	205187.3	683.4	8	JAN	2100	89	2000.	205647.8	683.6
6	JAN	0200	22	1400.	172488.1	673.1	7	JAN	1200	56	2000.	205380.3	683.5	8	JAN	2200	90	2000.	205587.1	683.6
6	JAN	0300	23	2400.	175051.1	673.9	7	JAN	1300	57	2000.	205552.1	683.5	8	JAN	2300	91	2000.	205524.5	683.5
6	JAN	0400	24	3480.	177374.9	674.7	7	JAN	1400	58	2000.	205704.0	683.6	9	JAN	0000	92	2000.	205459.8	683.5
6	JAN	0500	25	4260.	179471.0	675.4	7	JAN	1500	59	2000.	205837.3	683.6	9	JAN	0100	93	2000.	205393.1	683.5
6	JAN	0600	26	5000.	181359.6	676.0	7	JAN	1600	60	2000.	205953.0	683.7	9	JAN	0200	94	2000.	205324.5	683.5
6	JAN	0700	27	5500.	183060.4	676.6	7	JAN	1700	61	2000.	206052.3	683.7	9	JAN	0300	95	2000.	205254.0	683.4
6	JAN	0800	28	5900.	184595.7	677.1	7	JAN	1800	62	2000.	206136.0	683.7	9	JAN	0400	96	2000.	205181.6	683.4
6	JAN	0900	29	6000.	185989.7	677.5	7	JAN	1900	63	2000.	206205.1	683.7	9	JAN	0500	97	2000.	205107.4	683.4
6	JAN	1000	30	2000.	187431.5	678.0	7	JAN	2000	64	2000.	206260.6	683.8	9	JAN	0600	98	2000.	205031.5	683.4
6	JAN	1100	31	2000.	188932.2	678.5	7	JAN	2100	65	2000.	206303.1	683.8	9	JAN	0700	99	2000.	204953.7	683.4
6	JAN	1200	32	2000.	190332.9	678.9	7	JAN	2200	66	2000.	206333.6	683.8	9	JAN	0800	100	2000.	204874.3	683.3
6	JAN	1300	33	2000.	191639.6	679.3	7	JAN	2300	67	2000.	206352.6	683.8							
6	JAN	1400	34	2000.	192858.0	679.7	8	JAN	0000	68	2000.	206360.9	683.8							

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	99.00-HR
6000.	28.00	(CFS)	4900.	2764.	2255.	1802.
		(INCHES)	.119	.268	.657	.722
		(AC-FT)	2430.	5483.	13417.	14742.

PEAK STAGE (FEET)	TIME (HR)	MAXIMUM AVERAGE STAGE 6-HR	24-HR	72-HR	99.00-HR
683.78	67.00	683.78	683.74	682.74	678.19

CUMULATIVE AREA = 383.00 SQ MI

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	INFLOW	37802.	18.00	36518.	27510.	13067.	383.00		
ROUTED TO	RES	6000.	28.00	4900.	2764.	2255.	383.00	683.78	67.00

*** NORMAL END OF HEC-1 ***

12.15 Example Problem #15: Muskingum-Cunge Channel Routing

The use of Muskingum-Cunge channel routing is demonstrated in the development of a rainfall-runoff model for Kempton Creek. The watershed has been subdivided into three separate catchments, as shown in Figure 12.10. Clark's unit hydrograph and the SCS Curve Number method were used to evaluate local runoff from each of the subbasins. Channel routing from control point CP1 to CP2 and from CP2 to CP3 was accomplished with Muskingum-Cunge routing.

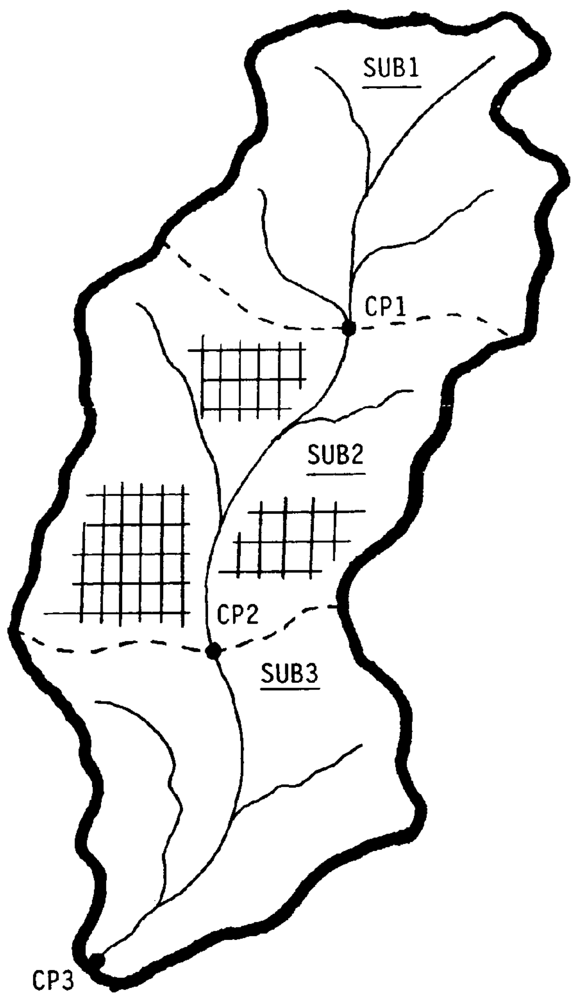


Figure 12.10 Kempton Creek Watershed for Muskingum-Cunge Channel Routing Example

Subbasin 2 (SUB2) is heavily urbanized with commercial and residential land use. The channel from CP1 to CP2 is a concrete lined trapezoidal channel with the following dimensions:

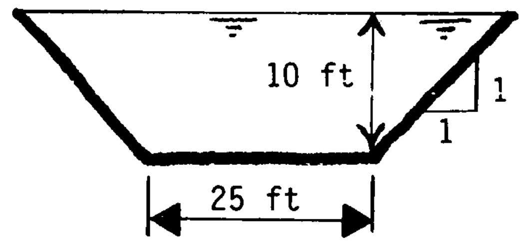


Figure 12.11 Trapezoidal Channel

Both subbasins 1 and 3 are completely undeveloped. The channel between CP2 and CP3 is in its natural state. A representative 8-point cross section has been fit to match the main channel and overbank flows through the reach as shown below:

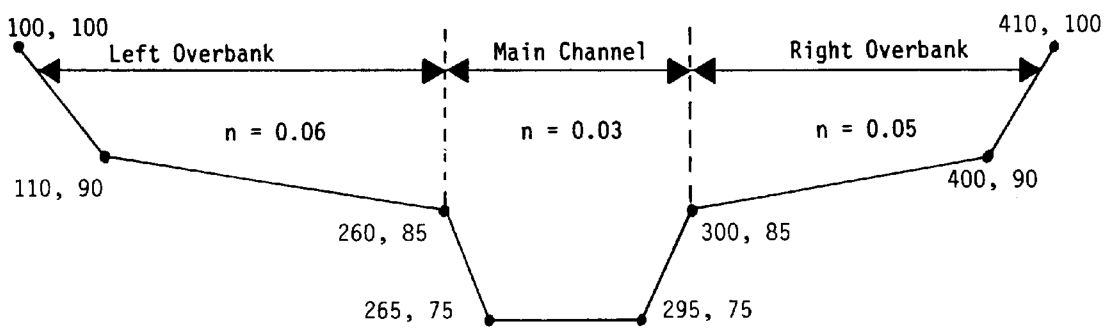


Figure 12.12 8-point Cross Section

Listings of the required input data and the resulting output are shown in Table 12.15. For the channel routing from CP1 to CP2, it is only necessary to have an RD record. Use of the RD record by itself means that the channel geometry can be described with a simple geometric element, such as a trapezoid. For the routing reach between CP2 and CP3, it is necessary to also include RC, RX, and RY records to describe the geometry through this reach. When using the 8-point cross-section option, the RD record only serves to indicate a Muskingum-Cunge channel routing is being performed. All of the necessary information is obtained from the RC, RX, and RY records.

Table 12.15

Example Problem #15

Input

```
ID TEST EXAMPLE NO. 15.  MUSKINGUM-CUNGE CHANNEL ROUTING EXAMPLE
ID GARY W. BRUNNER  APRIL 18, 1989
IT    15 18APR89    1100      60
IO     5
*
KK  SUB1
KM  RUNOFF CALCULATION FOR SUB1
BA  25.0
PB   3.5
PI   0.2     0.3     0.5     0.8     1.0     0.8     0.6     0.4     0.2     0.1
BF  -1.0    -.05    1.02
LS   0.5      65
UC   3.5     3.0
*
KK ROUT1
KM ROUTE SUB1 HYDROGRAPH FROM CP1 TO CP2
KO     1
RD 31680  0.0008   0.015            TRAP      25     1.0
*
KK  SUB2
KM  LOCAL RUNOFF FROM SUBBASIN SUB2
BA  35.0
PB   3.0
LS   0.5      75      35
UC   2.8     2.1
*
KK   CP2
KM  COMBINE LOCAL SUB2 AND ROUTED SUB1 HYDROGRAPHS
HC     2
*
KK ROUT2
KM ROUTE TOTAL FLOW AT SUB2 FROM CP2 TO CP3
KO     1       2
RD
RC  0.06    0.03    0.05   29040  0.0007      96
RX   100     110     260     265     295     300     400     410
RY   100      90      85      75      75      85      90     100
*
KK  SUB3
KM  LOCAL RUNOFF FROM SUBBASIN SUB3
BA  32.5
PB   2.9
LS   0.5      70
UC   4.0     3.5
*
KK   CP3
KM  COMBINE LOCAL SUB3 WITH ROUTED FROM SUB2
HC     2
*
ZZ
```

Output

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:40:12   *
*                                       *
*****************************************


                                                   HEC-1 INPUT                                      PAGE  1

         LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1            ID   TEST EXAMPLE NO. 15.  MUSKINGUM-CUNGE CHANNEL ROUTING EXAMPLE
           2            ID   GARY W. BRUNNER  APRIL 18, 1989
           3            IT      15 18APR89    1100      60
           4            IO       5
                        *

           5            KK    SUB1
           6            KM    RUNOFF CALCULATION FOR SUB1
           7            BA    25.0
           8            PB     3.5
           9            PI     0.2     0.3     0.5     0.8     1.0     0.8     0.6     0.4     0.2     0.1
          10            BF    -1.0    -.05    1.02
          11            LS     0.5      65
          12            UC     3.5     3.0
                        *

          13            KK   ROUT1
          14            KM   ROUTE SUB1 HYDROGRAPH FROM CP1 TO CP2
          15            KO       1
          16            RD   31680  0.0008   0.015            TRAP      25     1.0
                        *

          17            KK    SUB2
          18            KM    LOCAL RUNOFF FROM SUBBASIN SUB2
          19            BA    35.0
          20            PB     3.0
          21            LS     0.5      75      35
          22            UC     2.8     2.1
                        *

          23            KK     CP2
          24            KM    COMBINE LOCAL SUB2 AND ROUTED SUB1 HYDROGRAPHS
          25            HC       2
                        *

          26            KK   ROUT2
          27            KM   ROUTE TOTAL FLOW AT SUB2 FROM CP2 TO CP3
          28            KO       1       2
          29            RD
          30            RC    0.06    0.03    0.05   29040  0.0007      96
          31            RX     100     110     260     265     295     300     400     410
          32            RY     100      90      85      75      75      85      90     100
                        *

          33            KK    SUB3
          34            KM    LOCAL RUNOFF FROM SUBBASIN SUB3
          35            BA    32.5
          36            PB     2.9
          37            LS     0.5      70
          38            UC     4.0     3.5
                        *
          39            KK     CP3
          40            KM    COMBINE LOCAL SUB3 WITH ROUTED FROM SUB2
          41            HC       2
                        *
          42            ZZ
```

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   10JUN98  TIME  20:40:12   *
*                                       *
*****************************************


                            TEST EXAMPLE NO. 15.  MUSKINGUM-CUNGE CHANNEL ROUTING EXAMPLE
                            GARY W. BRUNNER  APRIL 18, 1989

    4 IO         OUTPUT CONTROL VARIABLES
                       IPRNT          5  PRINT CONTROL
                       IPLOT          0  PLOT CONTROL
                       QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT         HYDROGRAPH TIME DATA
                        NMIN         15  MINUTES IN COMPUTATION INTERVAL
                       IDATE    18APR89  STARTING DATE
                       ITIME       1100  STARTING TIME
                          NQ         60  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE    19APR89  ENDING DATE
                      NDTIME       0145  ENDING TIME
                      ICENT          19  CENTURY MARK

                   COMPUTATION INTERVAL     .25 HOURS
                        TOTAL TIME BASE   14.75 HOURS

          ENGLISH UNITS
               DRAINAGE AREA         SQUARE MILES
               PRECIPITATION DEPTH   INCHES
               LENGTH, ELEVATION     FEET
               FLOW                  CUBIC FEET PER SECOND
               STORAGE VOLUME        ACRE-FEET
               SURFACE AREA          ACRES
               TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


            **************
            *            *
   13 KK    *     ROUT1  *
            *            *
            **************

   15 KO         OUTPUT CONTROL VARIABLES
                       IPRNT          1  PRINT CONTROL
                       IPLOT          0  PLOT CONTROL
                       QSCAL         0.  HYDROGRAPH PLOT SCALE

               HYDROGRAPH ROUTING DATA

   16 RD         MUSKINGUM-CUNGE CHANNEL ROUTING
                          L      31680.  CHANNEL LENGTH
                          S       .0008  SLOPE
                          N        .015  CHANNEL ROUGHNESS COEFFICIENT
                         CA         .00  CONTRIBUTING AREA
                      SHAPE        TRAP  CHANNEL SHAPE
                         WD       25.00  BOTTOM WIDTH OR DIAMETER
                          Z        1.00  SIDE SLOPE

                                                                            ***
                                         COMPUTED MUSKINGUM-CUNGE PARAMETERS
                                                COMPUTATION TIME STEP
               ELEMENT    ALPHA       M          DT         DX        PEAK    TIME TO      VOLUME    MAXIMUM
                                                                               PEAK                 CELERITY
                                               (MIN)       (FT)      (CFS)    (MIN)        (IN)      (FPS)

                 MAIN       .42      1.56       12.00    6336.00   3330.12    300.00       1.05      12.85
```

```
                                  INTERPOLATED TO SPECIFIED COMPUTATION INTERVAL


              MAIN        .42      1.56     15.00           3330.12    300.00      1.05


CONTINUITY SUMMARY (AC-FT) - INFLOW= .1425E+04 EXCESS= .0000E+00 OUTFLOW= .1405E+04 BASIN STORAGE= .2808E+02
PERCENT ERROR=   -.5

*********************************************************************************************************

                                          HYDROGRAPH AT STATION    ROUT1

*********************************************************************************************************
                          *                            *                            *
DA MON HRMN  ORD     FLOW * DA MON HRMN  ORD    FLOW  * DA MON HRMN  ORD    FLOW   * DA MON HRMN  ORD    FLOW
                          *                            *                            *
 8 APR 1100    1      25. * 18 APR 1445   16    2064. * 18 APR 1830   31    1858.  * 18 APR 2215   46    607.
18 APR 1115    2      25. * 18 APR 1500   17    2481. * 18 APR 1845   32    1721.  * 18 APR 2230   47    565.
18 APR 1130    3      25. * 18 APR 1515   18    2818. * 18 APR 1900   33    1594.  * 18 APR 2245   48    526.
18 APR 1145    4      25. * 18 APR 1530   19    3077. * 18 APR 1915   34    1479.  * 18 APR 2300   49    489.
18 APR 1200    5      25. * 18 APR 1545   20    3248. * 18 APR 1930   35    1371.  * 18 APR 2315   50    456.
18 APR 1215    6      25. * 18 APR 1600   21    3330. * 18 APR 1945   36    1271.  * 18 APR 2330   51    425.
18 APR 1230    7      25. * 18 APR 1615   22    3315. * 18 APR 2000   37    1179.  * 18 APR 2345   52    396.
18 APR 1245    8      25. * 18 APR 1630   23    3228. * 18 APR 2015   38    1094.  * 19 APR 0000   53    369.
18 APR 1300    9      27. * 18 APR 1645   24    3084. * 18 APR 2030   39    1016.  * 19 APR 0015   54    344.
18 APR 1315   10      39. * 18 APR 1700   25    2907. * 18 APR 2045   40     943.  * 19 APR 0030   55    321.
18 APR 1330   11      78. * 18 APR 1715   26    2714. * 18 APR 2100   41     875.  * 19 APR 0045   56    300.
18 APR 1345   12     183. * 18 APR 1730   27    2522. * 18 APR 2115   42     813.  * 19 APR 0100   57    280.
18 APR 1400   13     533. * 18 APR 1745   28    2337. * 18 APR 2130   43     756.  * 19 APR 0115   58    262.
18 APR 1415   14    1067. * 18 APR 1800   29    2164. * 18 APR 2145   44     702.  * 19 APR 0130   59    243.
18 APR 1430   15    1589. * 18 APR 1815   30    2005. * 18 APR 2200   45     652.  * 19 APR 0145   60    236.
                          *                            *                            *
*********************************************************************************************************

  PEAK FLOW     TIME                           MAXIMUM AVERAGE FLOW
    (CFS)       (HR)                6-HR        24-HR       72-HR     14.75-HR

     3330.      5.00      (CFS)     2268.       1153.       1153.        1153.
                        (INCHES)     .844       1.054       1.054        1.054
                         (AC-FT)    1125.       1405.       1405.        1405.

                         CUMULATIVE AREA =   25.00 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

            **************
            *            *
  26 KK     *     ROUT2  *
            *            *
            **************

  28 KO          OUTPUT CONTROL VARIABLES
                       IPRNT           1  PRINT CONTROL
                       IPLOT           2  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

               HYDROGRAPH ROUTING DATA

  29 RD          MUSKINGUM-CUNGE CHANNEL ROUTING

  30 RC          NORMAL DEPTH CHANNEL
                         ANL        .060  LEFT OVERBANK N-VALUE
                        ANCH        .030  MAIN CHANNEL N-VALUE
                         ANR        .050  RIGHT OVERBANK N-VALUE
                       RLNTH      29040.  REACH LENGTH
                         SEL       .0007  ENERGY SLOPE
                       ELMAX        96.0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                               CROSS-SECTION DATA
                           --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
  32 RY        ELEVATION    100.00     90.00     85.00     75.00     75.00     85.00     90.00    100.00
  31 RX        DISTANCE     100.00    110.00    260.00    265.00    295.00    300.00    400.00    410.00

                                                                          ***
```

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

STORAGE	.00	22.51	45.84	69.98	94.94	120.71	147.29	174.69	202.90	231.93
OUTFLOW	.00	45.55	141.88	274.39	437.13	626.66	840.79	1078.04	1337.39	1618.12
ELEVATION	75.00	76.11	77.21	78.32	79.42	80.53	81.63	82.74	83.84	84.95
STORAGE	279.87	368.49	497.82	667.88	875.06	1090.26	1307.08	1525.54	1745.62	1967.33
OUTFLOW	1984.99	2443.41	3029.47	3774.70	4754.58	5986.67	7389.58	8951.15	10662.29	12515.79
ELEVATION	86.05	87.16	88.26	89.37	90.47	91.58	92.68	93.79	94.89	96.00

COMPUTED MUSKINGUM-CUNGE PARAMETERS

ELEMENT	ALPHA	M	COMPUTATION TIME STEP DT (MIN)	DX (FT)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)	MAXIMUM CELERITY (FPS)
MAIN			12.00	2904.00	10016.39	348.00	1.44	3.86
INTERPOLATED TO SPECIFIED COMPUTATION INTERVAL								
MAIN			15.00		10008.47	360.00	1.44	

CONTINUITY SUMMARY (AC-FT) - INFLOW= .4771E+04 EXCESS= .0000E+00 OUTFLOW= .4618E+04 BASIN STORAGE= .1125E+03
PERCENT ERROR= .9

****

HYDROGRAPH AT STATION ROUT2

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
18 APR 1100	1	60.	18 APR 1445	16	3090.	18 APR 1830	31	7877.	18 APR 2215	46	2298.
18 APR 1115	2	60.	18 APR 1500	17	3853.	18 APR 1845	32	7431.	18 APR 2230	47	1860.
18 APR 1130	3	60.	18 APR 1515	18	4914.	18 APR 1900	33	7000.	18 APR 2245	48	1567.
18 APR 1145	4	60.	18 APR 1530	19	6160.	18 APR 1915	34	6592.	18 APR 2300	49	1382.
18 APR 1200	5	60.	18 APR 1545	20	7401.	18 APR 1930	35	6207.	18 APR 2315	50	1264.
18 APR 1215	6	60.	18 APR 1600	21	8477.	18 APR 1945	36	5846.	18 APR 2330	51	1179.
18 APR 1230	7	60.	18 APR 1615	22	9250.	18 APR 2000	37	5507.	18 APR 2345	52	1112.
18 APR 1245	8	60.	18 APR 1630	23	9745.	18 APR 2015	38	5187.	19 APR 0000	53	1058.
18 APR 1300	9	60.	18 APR 1645	24	9985.	18 APR 2030	39	4876.	19 APR 0015	54	1014.
18 APR 1315	10	130.	18 APR 1700	25	10008.	18 APR 2045	40	4569.	19 APR 0030	55	974.
18 APR 1330	11	512.	18 APR 1715	26	9841.	18 APR 2100	41	4259.	19 APR 0045	56	938.
18 APR 1345	12	1106.	18 APR 1730	27	9556.	18 APR 2115	42	3937.	19 APR 0100	57	905.
18 APR 1400	13	1664.	18 APR 1745	28	9191.	18 APR 2130	43	3592.	19 APR 0115	58	875.
18 APR 1415	14	2093.	18 APR 1800	29	8775.	18 APR 2145	44	3209.	19 APR 0130	59	847.
18 APR 1430	15	2529.	18 APR 1815	30	8329.	18 APR 2200	45	2777.	19 APR 0145	60	836.

****

PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	14.75-HR
10008.	6.00	(CFS)	7366.	3791.	3791.	3791.
		(INCHES)	1.141	1.444	1.444	1.444
		(AC-FT)	3652.	4621.	4621.	4621.

CUMULATIVE AREA = 60.00 SQ MI

```
                                                         STATION    ROUT2

                         (I) INFLOW,   (O) OUTFLOW
         0.     2000.     4000.     6000.     8000.    10000.    12000.    14000.        0.        0.        0.        0.        0.
DAHRMN PER
181100   1I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
181115   2I         .         .         .         .         .         .         .         .         .         .         .         .
181130   3OI        .         .         .         .         .         .         .         .         .         .         .         .
181145   4OI        .         .         .         .         .         .         .         .         .         .         .         .
181200   5O I       .         .         .         .         .         .         .         .         .         .         .         .
181215   6O   I     .         .         .         .         .         .         .         .         .         .         .         .
181230   7O      I  .         .         .         .         .         .         .         .         .         .         .         .
181245   8O         .I        .         .         .         .         .         .         .         .         .         .         .
181300   9O         .      I  .         .         .         .         .         .         .         .         .         .         .
181315  10.O        .         .  I      .         .         .         .         .         .         .         .         .         .
181330  11. .O. . . . . . . . . . . . . I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
181345  12.     O   .         .         .      I  .         .         .         .         .         .         .         .         .
181400  13.       O .         .         .         .   I     .         .         .         .         .         .         .         .
181415  14.         O         .         .         .         .I        .         .         .         .         .         .         .
181430  15.         .  O      .         .         .         .     I   .         .         .         .         .         .         .
181445  16.         .    O    .         .         .         .         I         .         .         .         .         .         .
181500  17.         .        O.         .         .         .         .I        .         .         .         .         .         .
181515  18.         .         .    O    .         .         .         I         .         .         .         .         .         .
181530  19.         .         .         .O        .         .       I .         .         .         .         .         .         .
181545  20.         .         .         .      O  .         .   I     .         .         .         .         .         .         .
181600  21. . . . . . . . . . . . . . . . . . . . O . . . .I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
181615  22.         .         .         .         .     OI  .         .         .         .         .         .         .         .
181630  23.         .         .         .         .  I     O.         .         .         .         .         .         .         .
181645  24.         .         .         .        I.         O         .         .         .         .         .         .         .
181700  25.         .         .         .     I   .         O         .         .         .         .         .         .         .
181715  26.         .         .         .  I      .        O.         .         .         .         .         .         .         .
181730  27.         .         .        I.         .       O .         .         .         .         .         .         .         .
181745  28.         .         .      I  .         .     O   .         .         .         .         .         .         .         .
181800  29.         .         .   I     .         .   O     .         .         .         .         .         .         .         .
181815  30.         .         . I       .         . O       .         .         .         .         .         .         .         .
181830  31. . . . . . . . . . I . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
181845  32.         .       I .         .      O  .         .         .         .         .         .         .         .         .
181900  33.         .     I   .         .    O    .         .         .         .         .         .         .         .         .
181915  34.         .    I    .         .  O      .         .         .         .         .         .         .         .         .
181930  35.         .  I      .         .O        .         .         .         .         .         .         .         .         .
181945  36.         . I       .        O.         .         .         .         .         .         .         .         .         .
182000  37.         .I        .       O .         .         .         .         .         .         .         .         .         .
182015  38.         I         .     O   .         .         .         .         .         .         .         .         .         .
182030  39.        I.         .   O     .         .         .         .         .         .         .         .         .         .
182045  40.       I .         .  O      .         .         .         .         .         .         .         .         .         .
182100  41. . . . I . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
182115  42.      I  .         O         .         .         .         .         .         .         .         .         .         .
182130  43.     I   .       O .         .         .         .         .         .         .         .         .         .         .
182145  44.     I   .     O   .         .         .         .         .         .         .         .         .         .         .
182200  45.     I   .   O     .         .         .         .         .         .         .         .         .         .         .
182215  46.    I    .O        .         .         .         .         .         .         .         .         .         .         .
182230  47.    I   O.         .         .         .         .         .         .         .         .         .         .         .
182245  48.    I  O .         .         .         .         .         .         .         .         .         .         .         .
182300  49.    I O  .         .         .         .         .         .         .         .         .         .         .         .
182315  50.    IO   .         .         .         .         .         .         .         .         .         .         .         .
182330  51. . I O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
182345  52.   I O   .         .         .         .         .         .         .         .         .         .         .         .
190000  53.   IO    .         .         .         .         .         .         .         .         .         .         .         .
190015  54.   IO    .         .         .         .         .         .         .         .         .         .         .         .
190030  55.   IO    .         .         .         .         .         .         .         .         .         .         .         .
190045  56.   IO    .         .         .         .         .         .         .         .         .         .         .         .
190100  57.   IO    .         .         .         .         .         .         .         .         .         .         .         .
190115  58.   I     .         .         .         .         .         .         .         .         .         .         .         .
190130  59.   I     .         .         .         .         .         .         .         .         .         .         .         .
190145  60.--IO-----.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SUB1	3381.	4.50	2285.	1169.	1169.	25.00		
ROUTED TO	ROUT1	3330.	5.00	2268.	1153.	1153.	25.00		
HYDROGRAPH AT	SUB2	9862.	3.75	5816.	2763.	2763.	35.00		
2 COMBINED AT	CP2	12131.	4.00	7824.	3916.	3916.	60.00		
ROUTED TO	ROUT2	10008.	6.00	7366.	3791.	3791.	60.00		
HYDROGRAPH AT	SUB3	3091.	5.00	2225.	1202.	1202.	32.50		
2 COMBINED AT	CP3	12813.	5.75	9438.	4993.	4993.	92.50		

SUMMARY OF KINEMATIC WAVE - MUSKINGUM-CUNGE ROUTING
(FLOW IS DIRECT RUNOFF WITHOUT BASE FLOW)

ISTAQ	ELEMENT	DT (MIN)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)	DT (MIN)	PEAK (CFS)	INTERPOLATED TO COMPUTATION INTERVAL TIME TO PEAK (MIN)	VOLUME (IN)
ROUT1	MANE	12.00	3330.12	300.00	1.05	15.00	3330.12	300.00	1.05

CONTINUITY SUMMARY (AC-FT) - INFLOW= .1425E+04 EXCESS= .0000E+00 OUTFLOW= .1405E+04 BASIN STORAGE= .2808E+02
PERCENT ERROR= -.5

ISTAQ	ELEMENT	DT (MIN)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)	DT (MIN)	PEAK (CFS)	TIME TO PEAK (MIN)	VOLUME (IN)
ROUT2	MANE	12.00	10016.39	348.00	1.44	15.00	10008.47	360.00	1.44

CONTINUITY SUMMARY (AC-FT) - INFLOW= .4771E+04 EXCESS= .0000E+00 OUTFLOW= .4618E+04 BASIN STORAGE= .1125E+03
PERCENT ERROR= .9

*** NORMAL END OF HEC-1 ***

Section 13

Computer Requirements

13.1 Program Operations and File Structure

Figure 13.1 shows the sequence of operations for most jobs. HEC-1 uses up to 16 I/O and scratch files. These can be stored on disk, tape, or whatever medium is available. The program knows these files by their assigned unit numbers. Table 13.1 shows the unit numbers used by HEC-1. These numbers can be changed for a particular installation by changing their definition in the BLOCK DATA source code. All files are sequential.

13.2 Execution Times

Table 13.2 lists execution times of a range of computers for the example problems described in Section 12 of this manual.

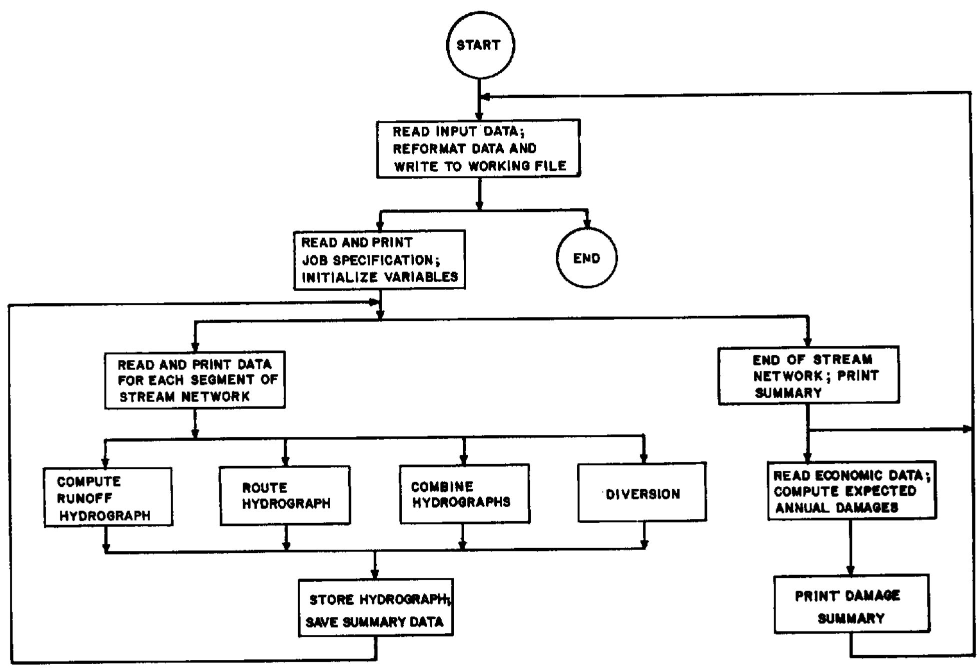


Figure 13.1 HEC-1 Program Operations Overview

Table 13.1

Input/Output and Scratch Files

Unit Number	Variable Name	Description	Formatted, F Unformatted, U	Max Record Length
5	INP[1]	Primary input	F	80 characters
6	IP[1]	Primary output file (printer)	F	132 characters
7	IPU	Output data for saved hydrographs	F	80 characters
23	IC	Working input file; reformatted input data with line number and next record ID appended to front of each record.	F	89 characters
24	IS[2]	Dam-overtopping summary report	F	132 characters
25	IU[2]	Runoff parameter optimization	F	132 characters
32	IDIV	Scratch, saves diversion hydrographs	U	4895 real + 3 integer words
33	IE	Scratch; expected annual damage Summary data	U	50 real + 6 integer words
34	IR	Scratch; data for first plan in multiplan run	U	61 real words
35	ISOP	Scratch; data for flood control system optimization	U	2400 real words
36	LSFIL	Scratch; data for user-defined output tables	U	301 real words
38	ND	Scratch; output summary data	U	91 real + 4 integer words
71	--	DSS file assigned automatically by DSS software		
**	IOUT	Output data; used to save hydrographs for a subsequent job	F	131 characters
**	IQIN	Input data; hydrographs from a previous job	F	131 characters

[1] Run time file assignments performed in subroutine OPHEC1, all other file assignments performed with standard FORTRAN open statements.

[2] File is copied to primary output file (IP) by subroutine PRT

** Unit number is defined by user on KO or BI records (The unit numbers specified should not conflict with

Table 13.2

HEC-1 Execution Times

Example Problem[1]	Job Type	XT[2]	386[3]	386/33[4]	486/66[5]	Pentium/90[6]
				Execution Time (Hr:Min:Sec)		
1	Stream Network Model	1:09	0:14	0:06	0:02	0:01
2	Kinematic Wave Watershed Model	4:23	1:00	0:19	0:04	0:02
3	Snowmelt Runoff	0:33	0:09	0:03	0:02	0:01
4	Unit Graph & Loss Rate Optimization	1:11	0:14	0:05	0:02	0:01
5	Routing Optimization	0:18	0:07	0:02	0:01	< 0:01
6	Precipitation Depth-Area	0:49	0:11	0:05	0:02	0:01
7	Dam Safety Analysis	1:11	0:14	0:05	0:02	< 0:01
8	Dam Failure Analysis	3:16	0:30	0:12	0:04	0:02
9	Multiflood Analysis	0:34	0:09	0:03	0:02	0:01
10	Multiplan, Multiflood Analysis	2:07	0:21	0:08	0:03	0:01
11	Flood Damage Analysis	2:30	0:25	0:10	0:03	0:02
12	Flood Control System Optimization	58:36	7:51	3:29	2:10	0:32
13	Using the HEC Data Storage System with HEC-1	0:26	0:08	0:05	0:02	0:01
14	Calculating Reservoir Storage Elevation from Inflow & Outflow	0:19	0:04	0:02	0:01	< 0:01
15	Muskingum-Cunge Channel Routing	1:52	0:18	0:06	0:2	0:01
	Total Time	1:19:14	11:55	5:00	2:42	0:49

[1]Example Problems are shown in Section 12.

[2] 1990 version of HEC-1 running on IBM PC/XT computer with an 8087 math coprocessor, 3.1 MS-DOS operating system, 4.77 MHz clock rate and 640Kb memory.

[3] 1990 version of HEC-1 running on COMPAQ Deskpro 386 with an 80387 math coprocessor, 3.2 MS-DOS operating system, 16 MHz clock rate.

[4] 1990 version of HEC-1 running on COMPAQ Deskpro 386 with an 80387 math coprocessor, 4.01 MS-DOS operating system, 33 MHz clock rate, "no caching".

[5] 1996 version of HEC-1 running on GATEWAY2000 4DX2-66V, 6.22 MS-DOS operating system/Pharlap extender, 16 mb memory, 66 MHz clock rate.

[6] 1996 version of HEC-1 running on GATEWAY2000 PS5-90, 6.22 MS-DOS operating system/Pharlap extender, 32mb memory, 90 MHz clock

Section 14

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Appendix A

HEC-1 Input Description

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HEC-1 Input Description

Introduction

1 Introduction

1.1 Organization of this Input Description

This input description is organized into three major types of data: 1) job description and initialization data, 2) hydrograph calculation data, and 3) economic analysis data. This corresponds to the general sequence of data necessary to build the digital model of a river basin as described in the next subsection on Input Data Structure.

The first group (pages A-6 through A-18), JOB DESCRIPTION AND INITIALIZATION DATA, begins with the I records and goes through the V records. The ID and IT records are required and are described first. The other records are optional and are described in a recommended input sequence, i.e., I, J, O, V records as desired.

The second group (pages A-19 through A-97), HYDROGRAPH CALCULATION DATA, comprises all of the data necessary to simulate the various river basin processes. The input data in this group are organized ALPHABETICALLY, beginning with the B records and ending with the W records. The required and recommended order to input these data are described in the next subsection, Input Data Structure.

The third group (pages A-98 through A-112), ECONOMIC ANALYSIS DATA, consists of data to be supplied after all of the hydrologic and hydraulic calculations are completed. These data are optional and begin with the EC record and are organized in the recommended sequence of input.

The last record described is the REQUIRED ZZ RECORD, page A-113, to end the job.

1.2 Input Data Structure

The input data set is divided into three sections - job description and initialization data, hydrograph calculation data, and economic analysis data.

The first section begins with an ID record. This section contains an alphanumeric description of the job, sets the job type, output control, time interval and time span, and the type of units to be used.

Section two contains data for calculating hydrographs. Each hydrograph calculation begins with a KK record, and the records following the KK record provide information on how the hydrograph is to be calculated.

The third section begins with an EC record. All data following the EC record are for calculation of expected annual damages.

Finally the job is terminated by a ZZ record. Data for a new job beginning with an ID record may follow immediately after the ZZ record.

The record sequence for a typical job is shown. A dash, -, is used to indicate the second character of a record identification which will be selected at the option of the user.

```
          ID          Job identification

          IT          Time specification

          I-*         Additional initialization data

          J-*         Job type

          O-*         Optimization

          VV*,VS*     Variable output summary tables

(         KK      Hydrograph computation identification        )
(                                                              )
(                 KK-record groups describing RUNOFF,          )
(         .       ROUTING, COMBINING, etc., components         )
(         .       are repeated as necessary to simulate        )
(         .       the processes and connectivity of a          )
(         .       river basin.  See following pages.           )

EC*       Economic data identification

.         (See section on economic data)

ZZ        End-of-job record
```

*Optional records

HEC-1 Input Description
Input Data Structure

Data input for RUNOFF calculations will be retained and used for subsequent runoff calculations until new data are read. Thus the data used in calculating runoff need only be read once, unless they are to be changed for a new basin. A typical record sequence for computing subbasin rainfall-runoff is:

(	KK	Hydrograph computation identification	)
(			)
(	BA	Basin area	)
(			)
(	BF*	Base flow data	)
(			)
(	P-	Precipitation data	)
(			)
(	L-	Loss data	)
(			)
(	U-	Unit graph or kinematic wave data	)

(	KK	Hydrograph computation identification	)
(			)
(	BA		)
(			)
(	BF*	If BF, P-, L-, U-records	)
(			)
(	P-*	do not appear, data from	)
(			)
(	L-*	previous calculation will	)
(			)
(	U-*	be used.	)

(	KK	Etc.	)
(			)

For hydrograph ROUTING the record sequence is:

(	KK	Hydrograph computation identification	)
(			)
(	R-	Routing option	)
(			)
(	S-*	Reservoir data or dam-break analysis	)

*Optional records

For DIVERSIONS the record sequence is:

```
(    KK    Hydrograph computation identification     )
(                                                    )
(    DT    Diversion identification                  )
(                                                    )
(    DI    Inflow to diversion point                 )
(                                                    )
(    DQ    Diverted flow                             )

(    KK    Etc., for other parts of stream network   )
.
.
.
(    KK    Hydrograph computation identification     )
(                                                    )
(    DR    Retrieve diversion hydrograph             )

(    KK    Etc., for routing/combining of return flow )
.
.
.
```

Each input record is described in detail on the following pages. Variable locations on each record are shown by field numbers which indicate the relative position of the data on the record.

When data are entered in FIXED FORMAT the record is divided into ten fields of eight columns each, except field one. Variables occurring in field one may only occupy columns 3-8 because columns 1 and 2 are reserved for the record identification characters. Integer and alphanumeric values must be right justified in their fields.

Data may also be entered in FREE FORMAT where fields are separated by a comma or one or more spaces. Successive commas are used to indicate blank fields. When entering time series data (flow, precipitation, etc.), more (or less) than 10 values can be placed on a record.

HEC-1 Input Description
Input Control Records

1.3 Input Control Records

The following records may be used to control the format and printing of the input data. An input comment record is also described which may be inserted anywhere in the input data stream.

RECORD IDENTIFICATION	DESCRIPTION OF INPUT CONTROL
*LIST	Causes echo print of input data following this record until a *NOLIST record is encountered. *LIST is the default assumption.
*NOLIST	Stops echo print listing of input data until a *LIST record is encountered.
*FREE	Indicates a free format will be used for the input following this record and before a *FIX record is encountered. Fields may be separated by a comma or by one or more spaces. Successive commas would indicate blank fields. When entering time-series data (flow, precipitation, etc.), more (or less) than 10 values may be placed on a record. Default is fixed format.
*FIX	Indicates a standard HEC fixed format (10 8-column fields) will be used for the data following this record and before a *FREE record is encountered. Default is fixed format.
*	This is a COMMENT record that is printed only with the input echo listing. The comment occupies columns 3 through 80. Any number of comment records may be inserted at any point in the input data stream.
*DIAGRAM	Causes a diagram of the stream network to be printed. In multiple job runs this option is reset so a diagram is generated only for those jobs which contain this record.

NOTE - The asterisk (*) must be in column 1 and followed by the remainder of the identification. If column 2 is blank, it is assumed to be a COMMENT record.

HEC-1 Input Description
Job Initialization (I Records)

2 Job Initialization (I Records)

The ID and IT records are required to begin the job. The other records (IM AND IO) are only used if those options are desired.

2.1 ID Record - Job Title Information**

At least one ID record is required but any number may be used as desired to title the output from this job. The title information is contained in columns 3-80 inclusive and any characters or symbols may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ID	Record identification.
1-10	ITLS	AN	Job title information.

**Required

2.2 IT Record - Time Specification**

The IT record is used to define time interval, starting date and time, and length of hydrographs calculated by the program.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	IT	Record identification.
1	NMIN	+	Integer number of minutes in tabulation interval. Minimum value is one minute.
2	IDATE1	+	Day, month, and year of the beginning of the first time interval (e.g., 17MAR78 is input for March 17, 1978). Required to specify pathname part D when using DSS.
3	ITIME1	+	Integer number for hour and minute of the beginning of the first time interval (e.g., 1645 is input for 4:45 pm).
4	NQ	+	Integer number of hydrograph ordinates to be computed (300 maximum). If end date and time are specified in Fields 5 and 6, NQ will be computed from the beginning and end dates and times.
5	NDDATE	+	Day, month, and year of last ordinate (used to compute NQ).
6	NDTIME	+	Integer number for time of last ordinate (used to compute NQ).
7	ICENT	+	Integer number for century of IDATE (e.g., 1800, default 1900).

[1]CAUTION **-** IDATE and ITIME are the time of initial flow conditions. No runoff calculations are made from precipitation preceding this time. The first runoff computation is for the end of the first period (ITIME+NMIN); thus, the first precipitation value specified should be for the precipitation that fell between ITIME and ITIME+NMIN.

Use 3-character code for month: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC. Use of any other code for month means this is not a date, and days will be numbered consecutively from the given day. Default is day = 1.

**Required

HEC-1 Input Description
Job Initialization (I Records)

2.3 IN Record - Time Interval for Input Data

The IN record is used to define time interval and starting time for time series data which are read into the program on PC, PI, QO, QI, QS, MD, MS, MT and MW records.

FIELD	VARIABLE	VALUE	DESCRIPTION
1	JXMIN	+	Integer number of minutes in tabulation interval.
2	JXDATE	+	Day, month, year at beginning of the first time interval (e.g., March 17, 1978 is input as 17MAR78).
3	JXTIME	+	Hour and minute at the beginning of the first time interval (e.g., 4:45 pm is input as 1645).

If an IN record is not used the time interval and starting time for all time series will be the values specified on the IT record.

IN records may appear anywhere (exception: not after JD and before PI) in the input stream. The same time interval and starting time will be used for all time series data until these values are reset by reading new values on an IN record.

When time series data are read from PC, PI, QO, QS, QP, MD, MS, MT, or MW records, values to be used by the program are computed using linear interpolation to match the tabulation interval specified on the IT record.

For times preceding or following the given ordinates, the first or last value is repeated as necessary to define NQ (IT-4) ordinates.

Data on PC, QI, QO, QP and QS records are **instantaneous** values. The first value will occur at JXDATE and JXTIME.

Data on PI, MD, MS, MT and MW records are **cumulative** or average values over a time interval. The first value on these records is for the time interval beginning at JXDATE, JXTIME and ending at JXTIME + JXMIN.

HEC-1 Input Description
Job Initialization (I Records)

2.4 IO Record - Output Control

The IO record is used to control output for the entire job. The KO record may be used to change output control for each hydrograph calculation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	IO	Record identification.
1	IPRT	0,1,2	Print all output.
		3	Print input data and intermediate and master summaries.
		4	Print input data and master summary.
		5	Print job specification and master summary only.
2	IPLT	0,1	No printer plots for entire job unless overridden temporarily by a KO record for any station operation.
		2	Plot every computed hydrograph for entire job unless overridden by a KO record for any station.
3	QSCAL	0 or, Blank	Program will choose scale for streamflow plots.
		+	Desired scale for streamflow plots in units per ten printer characters (e.g., one hundred for one hundred cfs per ten characters).

2.5 IM Record - Metric Units

This record is required if input is in metric units. Include one record with IM beginning in column 1. No other fields on the record are presently used.

HEC-1 Input Description
Job Type Option (J Records)

3 Job Type Option (J Records)

J records are required only if one of the following special jobs is desired.

3.1 JP Record - Multiplan

Required only if more than one plan is being analyzed or if performing single event damage.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JP	Record identification.
1	NPLAN [1]	+	Number of plans desired (NPLAN = 1 for single event damage calculation).

NOTE: The product NPLAN*NRATIO (NRATIO is the number of ratios as defined on JR record) cannot exceed forty-five. The product NPLAN*NRATIO*NQ (NQ defined on IT record) cannot exceed 4,800. These limits may be changed if the dimensions are changed as noted in the HEC-1 Programmers Manual.

[1] Must be greater than or equal two for economic analysis.

3.2 JR Record - Multiratio

Required only if multiple ratios are desired for each plan. If performing single event damage then a single ratio may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JR	Record identification.
1	IRTIO	PREC	Indicates ratios are to be taken of precipitation (default).
		FLOW	Indicates ratios are to be taken of runoff.
2	RTIO(1)	+	Ratio by which all hydrograph or precipitation ordinates of each subarea are to be multiplied for all plans.
3	RTIO(2)	+	Same as above for up to nine ratios as desired. Ratios **must** be in ascending order for use in economic calculations.

HEC-1 Input Description
Job Type Option (J Records)

3.3 JD Record - Depth/Area Storm

Required only if stream system is to be simulated using a consistent depth/area relationship. Each JD record may be followed by a set of PC or PI records giving the precipitation pattern to be used for that depth and area. If no pattern is given following any of the second through ninth JD records, the previous pattern will be used. A maximum of nine depth-area storms (maximum of nine JD records) may be used.

Precipitation patterns may be generated using the hypothetical storm option. The convention for specifying hypothetical storms with a JD, PH record combination is somewhat different than for gage rainfall (i.e. with PI or PC records). In this case only a single PH record following the first JD record is required for all depth area storms. The variable PNHR(I) on the PH record (see page A-52) specifies the depth duration data for point rainfall. This point rainfall may be adjusted for a partial to annual series correction (variable PFREQ on the PH record) and for a point to areal rainfall correction (see page 13 in this manual). The areal correction is made by using the value TRDA on the JD record in place of the variable TRSDA on the PH record. Consequently, a different storm is obtained by applying the areal correction for the area specified on the JD records to the point precipitation. The total storm depth is obtained from the adjusted rainfall on the PH record and need not be specified as STRM on the JD record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JD	Record identification.
1	STRM	+	Average precipitation in inches (mm). Not required with hypothetical storm.
2	TRDA	+	Area in square miles (sq km).

HEC-1 Input Description
Optimization Option (O Records)

4 Optimization Option (O Records)

4.1 OU Record - Unit Graph and Loss Rate Optimization[1]

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OU	Record identification.
1	IFORD	0,1 or Blank	Begin optimization at first simulated value.
		+I	Begin optimization at Ith simulated value.
2	ILORD	0, or Blank	End optimization at last simulated value.
		+I	End optimization at Ith simulated value.

4.2 OR Record - Routing Optimization

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OR	Record identification.
1	IFORD	0,1 or Blank	Begin optimization at first simulated value.
		+I	Begin optimization at Ith simulated value.
2	ILORD	0, or Blank	End optimization at last simulated value.
		+I	End optimization at Ith simulated value.

[1]ZZ record at the end of each optimization required if summary of multiple optimizations are desired.

HEC-1 Input Description
Optimization Option (O Records)

4.3 OS Record - Flood Control System Optimization

When HEC-1 is used to determine optimal sizes of flood control system components, initial estimates for sizes of the components are entered on the OS record. The following records are used later in the input set to refer to variables initialized on the OS record:

DO	Diversion
SO	Reservoir
WO	Pump
LO	Local protection projects and uniform degree of protection

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OS	Record identification.
1	VAR(1)	+	Size of flood control system component. Reservoir volume in acre-ft (1,000 cu m), diversion, and pump in cfs (cu m/sec), local protection in cfs (cu m/sec) or feet (meters), uniform degree of protection in percent. Size will not be optimized.
		0	Zero capacity indicates component will be ignored during simulation.
		S	Initial estimates of component; size will be optimized.
2-10	VAR(I)	+ or -	Similar to Field 1. Up to ten values.

4.4 OF Record - Fixed Facility Costs

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OF	Record identification.
1	FCAP	+	Capital cost of system facilities other than those to be optimized (fixed facilities). Same dollar units as system components.
2	FDCNT	+	Equivalent annual cost of FCAP. Same dollar units as system components.
		+.0000	Discount factor (capital recover factor) to compute equivalent annual cost from capital cost. (Example .05)
3	FAN	+	Equivalent annual cost of operation, maintenance power and replacement of FCAP system facilities.
		+.0000	Proportion of capital cost that will be required for annual operation, maintenance, power and replacement.

4.5 OO Record - System Optimization Objective Function

Used to modify objective function.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OO	Record identification.
1	ANORM	0	Default value of 0.1 will be used.
		+	Proportion of target flow for normalized objective function. May wish to reduce if target flow deviation is excessive. Do not reduce to below .02.
2	CNST	0	Default value of 1.0 will be used.
		+	Relative weight between net benefits and performance target deviation in objective function.

5 User-Defined Output Tables (V Records)

VS and VV records define tables which may be used to display selected time series output. Each table may contain up to ten columns of data as defined on one pair of VS/VV records. Up to five tables may be output by using five successive pairs of VS/VV records.

5.1 VS Record - Stations Desired

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	VS	Record identification.
1	ISTA(1)	AN	Station identification corresponding to ISTAQ on KK record where special output summary is desired. Variable to be printed is described by SMVAR(1) on the VV record.
2	ISTA(2)	AN	Same as above for up to ten stations; same station must be repeated in order to print several time series for the same station.

HEC-1 Input Description
User-Defined Output Tables (V Records)

5.2 VV Record - Information Desired

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	VV	Record identification.
1	SMVAR(1)	+	Numeric code describing the first column of output, identified as V.PR where V is the variable to be printed in the table, P is the plan number, and R is the ratio number (corresponding to ISTA(1) on a VS record). Values of V correspond to: 1. Observed flow 2. Calculated flow 3. Rainfall values 4. Rainfall loss values 5. Rainfall excess value 6. Storage values 7. Stage values
2	SMVAR(2)	+	Same as above corresponding to ISTA(2). Up to ten values.

6 Basin Runoff Data (B Records)

These records are required for direct input of a hydrograph or for computing runoff from precipitation on a basin/subbasin.

6.1 BA Record - Subbasin Area

Required for subbasin runoff computation or direct input of a hydrograph on QI records. If QI records are used, they should follow the BA record and an IN record if necessary. The next hydrograph computation specification record (KK) should follow the last QI record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BA	Record identification.
1	TAREA	+	Drainage area in square miles (sq km).
2	SNAP	+	Normal annual precipitation for the drainage area above. Will be overridden by computed normal annual for snowmelt zone, if used.
		0 or Blank	Weighting by basin normal annual precipitation will not be performed.
3	RATIO	+	Multiply each hydrograph ordinate by this value.

6.2 BF Record - Base Flow Characteristics

Base flow parameters (STRTQ, QRCSN, and RTIOR) will be assumed equal to zero unless this record is supplied. Once this record is supplied, all following subbasins will be assumed to have these values unless overridden by another BF record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BF	Record identification.
1	STRTQ	+	Flow at start of storm in cfs (cu m/s). Will be receded in same manner as QRCSN below.
		-	When negative, this is cfs/sq mi (cu m/s/sq km) which will be multiplied by subbasin area, TAREA, to determine STRTQ.
2	QRCSN	+	Flow in cfs (cu m/s) below which base flow recession occurs in accordance with the recession constant RTIOR. QRCSN is that flow where the straight line (in semilog paper) recession deviates from the falling limb of the hydrograph.
		-	When negative, it is the ratio by which the peak discharge is multiplied to compute QRCSN.
3	RTIOR	+	Ratio of recession flow, QRCSN to that flow occurring one hour later. Must be greater than or equal to one.

NOTE **-** The definition of RTIOR has been changed from the 1973 version of HEC-1. The old value is QA/QB in the following equation:

$$\text{New RTIOR} = \left(\frac{QA}{QB}\right)^{\left(\frac{1}{DT}\right)}$$

Where QB is a recession flow occurring DT hours after recession flow QA.

6.3 BI Record - Read Hydrograph from a File

A BI record is used to identify a hydrograph on a file created earlier by HEC-1. The hydrograph is read from this file and converted to the time interval and starting time for the current job.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BI	Record identification.
1	ISTA	AN	Station name for hydrograph to be read from file on unit IQIN (default is ISTAQ on KK record).
2	IQIN	21 or 22	Unit number (specify 21 or 22) for file which contains HEC-1 data to be retrieved from a previous simulation. This option allows HEC-1 to be restarted from the point where a previous simulation saved the HEC-1 data via the IOUT option on the KO record, Field 5.

HEC-1 Input Description
Diversion Data (D Records)

7 Diversion Data (D Records)

Streamflow may be diverted or retrieved at any stream station operation (KK record series).

7.1 DR Record - Retrieve Previously Diverted Flow

The DR record is used to retrieve a hydrograph which was created by a previous diversion. This hydrograph can then be treated like any other hydrograph in the system. Retrieval of a diversion hydrograph is a separate operation, so the DR record must be preceded by a KK record which identifies the hydrograph which has been retrieved.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DR	Record identification.
1	ISTAD	AN	Station name corresponding to the name given a previously diverted flow with a DT record.

7.2 DT/DI/DQ Records - Flow Diversion

Flow diversion is considered to be a separate operation, so the D records must be preceded by a KK record which identifies the hydrograph which remains after diversion. Diversions are specified as a function of main channel flow on the DI/DQ records.

For multiplan simulations (JP record), diversion data (DI and DQ records) must be supplied for all plans. If no water is be diverted for a particular plan, then the DQ record would contain only zeroes. Diversion hydrographs are saved for all plans using the name in Field 1 of the DT record.

7.2.1 DT Record - Diversion Identifier

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DT	Record identification.
1	ISTAD	AN	Name to be assigned to the diverted flow for future retrieval purposes with DR record.
2	DSTRMX	+	Maximum volume of diverted flow in acre-feet (1,000 cu m) (not used if zero or blank).
3	DVRSMX	+	Peak flow (cfs) that can be diverted in any computation period. (Default: 1×10^{10})

HEC-1 Input Description
Diversion Data (D Records)

7.2.2 DI Record - Diversion Inflow Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DI	Record identification.
1	DINFLO(1)	+	Inflow (cfs, cu m/s) to the diversion station, corresponding to DIVFLO(1) (DQ record), the flow to be diverted.
2-10	DINFLO(I)	+	Etc., up to twenty values (two records) corresponding to the amount of flow to be diverted on the DQ records.

7.2.3 DQ Record - Diversion Outflow Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DQ	Record identification.
1	DIVFLO(1)	+	Rate of flow (cfs, cu m/s) to be diverted, corresponding to the main channel flow rate (before diversion) on DINFLO, DI records.
2-10	DIVFLO(I)	+	Etc., up to twenty values (two records) corresponding to values on DI records.

7.3 DO Record - Diversion Optimization

Data required for optimization of diversion capacity are:

Diversion Identification	DT record
Diverted Flow vs. Inflow	DI, DQ records
Cost Factors, Range	DO record
Cost vs. Capacity	DC, DD records

Note: the order is important for these records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DO	Record identification.
1	IOPTD	+	Number of field on OS record which contains capacity of diversion (overrides DSTRMX on DT record).
		0, or Blank	Diversion capacity is not optimized.
2	DANCST	+	Proportion of capital cost of diversion that will be required for annual operation and maintenance.
3	DDSCNT	+	Discount factor (capital recovery factor) to compute equivalent annual cost from capital cost.
4	DVRMX	+	Maximum permissible capacity of diversion in cfs (cu m/sec). Used as a constraint on optimization.
5	DVRMN	+	Minimum permissible capacity of diversion cfs (cu m/sec). Used as a constraint on optimization.

HEC-1 Input Description
Diversion Data (D Records)

7.4 DC Record - Diversion Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DC	Record identification.
1	DCAP(1)	+	Diversion capacity in cfs (cu m/sec) corresponding to costs on DD record.
2-10	DCAP(I)	+	Etc., up to ten values.

7.5 DD Record - Diversion Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DD	Record identification.
1	DCST(1)	+	Diversion capital cost corresponding to capacity on DC record.
2-10	DCST(I)	+	Etc., up to ten values.

8 Hydrograph Transformation (H Records)

These records describe operations which combine or reshape hydrographs.

8.1 HB Record - Hydrograph Balance

This record is required only if it is desired to balance the current hydrograph according to these specified volumes/durations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HB	Record identification.
1	NQB(1)	+	Number of ordinates to be included in the shortest duration.
2	SUMB(1)	+	Sum of flows corresponding to duration NQB(1) shortest duration.
3	NQB(2)	+	Number of ordinates for the next larger duration (including the prior duration).
4	SUMB(2)	+	Sum of flows corresponding to duration NQB(2).
5-10			Pairs of numbers and sums, up to five durations.

HEC-1 Input Description
Hydrograph Transformation (H Records)

8.2 HC Record - Combine Hydrographs

Hydrograph combination is considered as a separate operation, so the HC record must be preceded by a KK record which identifies the resulting hydrograph. The HC record indicates the number of hydrographs which will be combined.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HC	Record identification.
1	ICOMP	2-5	Indicates ICOMP hydrographs will be combined at this stream station. Default is two.
2	TAREA	+	For depth-area jobs (JD records), this field may be used to set the cumulative basin area for the combined hydrograph. This option is useful **when combining diversion hydrographs**. The area associated with a diversion hydrograph is zero when combined with another hydrograph. This option may also be useful to set the area when combining a hydrograph brought in with a BI record.
		0	Use basin area calculated by program to compute interpolated hydrographs.

HEC-1 Input Description
Hydrograph Transformation (H Records)

8.3 HL Record - Local Flow

HL records are used in conjunction with observed QO records to compute local flow. The local flow is the difference between the last computed hydrograph and the observed flows. Note that the current hydrograph now corresponds to the observed flows. The last computed hydrograph is removed from the stack and is no longer available for computations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HL	Record identification.
1	TAREA	+	Basin area (sq mi) corresponding to observed hydrograph.

8.4 HQ/HE Records - Rating Table for Stage Hydrograph

HQ and HE records may be included in any hydrograph calculation to compute stages from the computed hydrograph.

8.4.1 HQ Record - Flows for Rating Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HQ	Record identification.
1-10	QSTG	+	Flows in cfs (cu m/sec) corresponding to stages on HE record. Up to twenty values on two records.

8.4.2 HE Record - Stages for Rating Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HE	Record identification.
1-10	STGQ	+	Stages in feet (meters) corresponding to flows on HQ record. Up to twenty values on two records.

HEC-1 Input Description
Hydrograph Transformation (H Records)

8.5 HS Record - Calculate Reservoir Storage frm Inflow and Outflow

The HS record must be followed by the desired reservoir releases on QO records. Reservoir storage is calculated as a result of the inflow to this location and the prescribed releases on QO records. Those QO records are then used as the hydrograph for the next downstream KK calculation. See Example Problem #14.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HS	Record identification.
1	STR	+	Initial storage in acre-feet at the beginning of the simulation.

HEC-1 Input Description
Job Step Control (K Records)

9 Job Step Control (K Records)

9.1 KK Record - Station Computation Identifier**

The KK record must be repeated at the beginning of each station computation (i.e., subbasin runoff, routing, combining, diversion, etc.).

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KK	Record identification.
1	ISTAQ	AN	Stream station location identification. Must be a unique identifier for entire run when used in conjunction with a damage reach in economic analysis.
2-10	NAME	AN	Station description.

9.2 KM Record - Message

The message on the KM record will be printed at the beginning of the output for each stations or plan. There is no limit on the number of KM records. KM records may not be interspersed in certain record sequences such as precipitation records or kinematic wave records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KM	Record identification.
1-10	ITLS	AN	Station- or computation-description message.

**Required

HEC-1 Input Description
Job Step Control (K Records)

9.3 KO Record - Output Control Option

Use this record to temporarily override output control specified on IO record until the next KK record is read.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KO	Record identification.
1	JPRT	0 or Blank	Use print control specified on IO record.
		1,2	Print all output for this station.
		3	Print input data and summaries for this computation.
		4	Print basin input data only for this computation.
		5	No printout for this computation.
2	JPLT	0 or Blank	Use plot control specified on IO record.
		1	No printer plots for this computation.
		2	Plot computed hydrograph for this computation.
3	QSCAL	0 or Blank	Use plot scale specified on IO record.
		+	Desired scale for streamflow plot in units per ten printer characters (e.g., one hundred for one hundred cfs per ten characters).
4	IPNCH	0	No hydrograph is to be saved on Unit 7 for this station.

9.3 KO Record - Output Control Option (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	Hydrograph computed at this station is to be saved on Unit 7. See Fields 6, 7, and 8 below for optional definition of beginning and ending ordinate and time interval. A KF record may be used to specify format for the Unit 7 file. Default format is (2HQI,I6,9I8). See Table 13.1.
5	IOUT	0	No hydrograph written to tape/disk file for this station.
		21 or 22	Unit number (specify 21 or 22) for tape/disk file on which to save HEC-1 data in order to restart the simulation at this location in a subsequent program execution. The program restart option is activated on the BI record. See Fields 6, 7, and 8 below for optional definition of beginning and ending ordinates and time interval. The file will be saved under the name "TAPE21" or "TAPE22", depending on the unit number specified.
6	ISAV1	+	First ordinate of hydrograph to be saved on Unit 7, 21, or 22. Default is 1.
7	ISAV2	+	Last ordinate of hydrograph to be saved on Unit 7, 21, or 22. Default is NQ (IT-4).
8	TIMINT	+	Time interval in hours for hydrograph to be saved on Unit 7, 21, or 22. Ordinates will be interpolated from current hydrograph. Default is time interval specified on IT record (IT-1).

HEC-1 Input Description
Job Step Control (K Records)

9.4 KF Record - Unit 7 Output Format

Use this record to specify format for the hydrographs on Unit 7. (See KO-4.) This format will be used until a new KF record is read. Default format is (2HQI,I6,9I8). KF record should not be used unless format is to be changed. This record can only be used in *FIX format.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KF	Record identification.
1	FLOTQ	YES	Convert hydrograph to floating point (decimal) numbers before writing.
		NO	Write hydrograph in integer format (default).
2-10	IFMT	AN	Alphanumeric format specification for output. This format must be consistent with the choice of integer or floating point indicated in Field 1. Parentheses must be included. Example: (2HQI,F6.2,9F8.2)

9.5 KP Record - Plan Label

This record is required to identify (number) a plan in a multiplan run. If hydrograph computation data is provided before (or without) a KP record, it is assumed to be plan 1. The data provided after a KP record need only be that required to change what was computed in the previous plan. All plans not specifically identified with a KP record are **assumed to be the same as the first plan processed**. See following example.

```
KK
KP 1
.
.       Data for PLAN 1
.
KP 3
.
.       Data for PLAN 3
.
        *Data for PLAN 2 is not provided and thus will be the same as
        PLAN 1
KK
```

FIELD	**VARIABLE**	**VALUE**	**DESCRIPTION**
Col 1+2	ID	KP	Record identification.
1	ISTM	+	Plan number identifier.

HEC-1 Input Description
Loss Rate Data (L Records)

10 Loss Rate Data (L Records)

One of four different rainfall loss rate procedures may be used for a subbasin runoff computation. A different loss rate may be used for each subbasin and/or plan. Snowmelt loss rate (LM record) may be used in conjunction with the exponential (LE record) or uniform (LU record) loss rates.

10.1 LU Record - Initial and Uniform Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LU	Record identification.
1	STRTL	0,+	Initial rainfall/snowmelt loss in inches (mm) for snow free ground. If operating in the optimization mode (OU record), this variable will be fixed at this value and not optimized.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	CNSTL	0,+ or - STRTL	Uniform rainfall/snowmelt loss in inches/hour (mm/hr) which is used after the starting loss is completely satisfied. See Field 1 for meaning of VALUE.
3	RTIMP	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin.
4-6			Specify loss rate variables similar to Fields 1-3 for second kinematic subcatchment.

10.2 LE Record - HEC Exponential Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LE	Record identification.
1	STRKR	+,0	Initial value of STRKR in inches/hour (mm/hr) for HEC's exponential rain loss rate function. If doing an optimization (OU record), this variable will not be optimized and will be fixed at this value.
		-1	For optimization only (OU record previously supplied), program assumes a starting value and then optimizes.
		–	For optimization only (OU record previously supplied), program uses this (after sign change) as the starting value for the optimization.
2	DLTKR	0,+ or -	DLTKR is the amount in inches (mm) of initial accumulated RAIN loss during which the loss coefficient is increased. See Field 1 for meaning of value.
3	RTIOL	0,+ or -	Rate of change of the rain loss-rate parameter computed as the ratio of STRKR to a value of STRKR after ten inches (ten mm) of accumulated loss. See Field 1 for an explanation of the values.
4	ERAIN	0,+ or -	Exponent of precipitation for loss rate function. See Field 1 for meaning of value.
5	RTIMP	+	Percent of subbasin which is impervious. 100 percent runoff will be computed for this portion of the subbasin.
6-10			Specify loss rate variables similar to Fields 1-5 above, for the second kinematic subcatchment. UK record is used. No optimization may be performed.

10.3 LM Record - HEC Exponential Snowmelt Loss Rate

This record is used in conjunction with the LE or LU records to compute the loss rate for snowmelt. Only the exponential loss can be used with the optimization option.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LM	Record identification.
1	STRKS	+,0	Initial value of STRKS in inches/hour (mm/hr) for HEC exponential snowmelt loss rate function. When used with LE record, or uniform meltwater loss rate, inches/hour (mm/hour) when used with LU record. If doing an optimization (OU record) this variable will not be optimized and will be fixed at this value.
		-1	For optimization of exponential loss only (OU record previously supplied), program assumes a starting VALUE and then optimizes.
		-	For optimization of exponential loss only (OU record previously supplied), program uses this (after sign change) as the starting VALUE for the optimization.
2	RTIOK	0,+ or -	Rate of change of the snowmelt loss-rate parameter computed as the ratio STRKS to a value of STRKS after ten inches (ten mm) of accumulated loss. See Field 1 for the meaning of VALUE. Not used for uniform meltwater loss rate.

10.4 LG Record - Green and Ampt Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LG	Record identification.
1	IA	0, +	Initial loss inches (mm).
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	DTHETA	+ or -	Volumetric moisture deficit. (If value equal to zero method reduces to initial loss equal to IA and constant loss, equal to XKSAT, see LU record.) See Field 1 for meaning of value.
3	PSIF	+ or -	Wetting front suction inches (mm). (If value equal to zero method reduces to initial loss equal to IA and constant loss equal XKSAT, see LU record.) See Field 1 for meaning of value.
4	XKSAT	+ or -	Hydraulic conductivity at natural saturation inches per hour (mm/hour). See Field 1 for meaning of value.
5	RTIMP	+	Percent of subbasin which is impervious. One hundred percent runoff will be computed for this portion of the subbasin.
6-10			Specify loss rate variables similar to Fields 1-5 above, for the second kinematic subcatchment. UK record is used. No optimization may be performed.

HEC-1 Input Description
Loss Rate Data (L Records)

10.5 LH Record - Holtan Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LG	Record identification.
1	FC	0, +	Holtans long term equilibrium loss rate in inches/hour (mm/hr) for rainfall/snowmelt losses on snowfree ground. If this is an optimization job (OU record supplied), this variable will be fixed at this value and not optimized.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	GIA	0, + or -	Infiltration rate in inches/hour per (inch**BEXP) or mm/hr per (mm**BEXP) of available soil moisture storage capacity (i.e., 1 - soil moisture). See Field 1 for meaning of VALUE.
3	SAI	0, + or -	Initial value and upper limit of SA avaliable soil moisture capacity in inches (mm). FC cannot cause the soil moisture capacity to grow above this value. See Field 1 for meaning of VALUE.
4	BEXP	0, + or -	Exponent of available soil moisture storage, SA. Default value is 1.4. See Field 1 for meaning of VALUE.
5	RTIMP	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin. This variable is not optimized.
6-10			Repeat Fields 1-5 for second kinematic subcatchment if used.

10.4 LS Record - SCS Curve Number Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LS	Record identification.
1	STRTL	+	Initial rainfall abstraction in inches (mm) for snow free ground. For an optimization job (OU record) this variable is fixed at the given value.
		0	Initial abstraction will be computed as 0.2*(1000-10*CRVNBR)/CRVNBR. For an optimization job, initial abstraction will vary with CRVNBR.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	CRVNBR	0,+	SCS curve number for rainfall/snowmelt losses on snow-free ground. If this is an optimization job (OU record supplied), this variable will be fixed at this value and not optimized.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
3	RTIMP[1]	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin.
4-6			Specify loss rate variables similar to Fields 1-3 for second kinematic subcatchment if used.

[1]This factor should only be used for directly connected impervious areas not already accounted for in the curve number land use.

HEC-1 Input Description
Snowmelt Data (M Records)

11 Snowmelt Data (M Records)

M records are required only if snowfall/melt computations are to be made. Snow computations are accomplished in separate, equally incremented, elevation zones within each subbasin. Melt may be computed by the degree-day or energy-budget method.

11.1 MA Record - Elevation Zone Data

These records are required for snowfall/melt simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MA	Record identification.
1	AREA(1)	+	Drainage area in sq mi (sq km) in Zone 1 (lowest zone).
2	SNO(1)	+	Average water equivalent in inches (mm) of snowpack at start of this job (first interval of NQ) in Zone 1, corresponding to AREA(1).
3	ANAP(1)	+	Normal annual precipitation in inches (mm) for Zone 1, corresponding to AREA (1).

NOTE - Up to ten records, one for each zone. Zones must be in equal elevation increments corresponding to lapse rate coefficient TLAPS (MC-1).

11.2 MC Record - Melt Coefficient

This record is required for any snowfall/melt simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MC	Record identification.
1	TLAPS	+	Temperature lapse in degrees F (°C) per elevation zone. All zones must have same increment of elevation.
2	COEF	+	Snowmelt coefficient, usually about 0.07 for degree-day method and 1.0 for energy-budget method.
		-1	For optimization only (OU record previously supplied), program assumes a starting value and then optimizes.
		-	For optimization only (OU record previously supplied), program uses this (after sign change) as the starting value for optimization.
3	FRZTP	+ or -	Index temperature at which snow will melt in degrees F (°C). Precipitation will be assumed to fall as snow at temperature of FRZTP+2°F (FRZTP+2°C) and below.

HEC-1 Input Description
Snowmelt Data (M Records)

11.3 MT Record - Temperature Time Series

These data are required for any snowfall/melt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MT	Record identification.
1	TEMPR(1)	+	Air temperature for first interval in degrees F (°C) at bottom of lowest elevation zone. Will be adjusted to each zone by use of TLAPS (MC-1).
2	TEMPR(2)	+	Air temperature as above for second interval.
3	TEMPR(3)	+	Etc.

11.4 MS Record - Energy Budget Shortwave Radiation

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MS	Record identification.
1	SOL(1)	+	Shortwave radiation in Langleys during first interval.
2	SOL(2)	+	Shortwave radiation during second interval.
3	SOL(3)	+	Etc.

HEC-1 Input Description
Snowmelt Data (M Records)

11.5 MD Record - Energy Budget Dew Point

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MD	Record identification.
1	DEWPT(1)	+	Dew point during first interval in degrees F (°C) at bottom of lowest elevation zone. Will be adjusted to each zone by use of 0.2 TLAPS (MC-1).
2	DEWPT(2)	+	Dew point as above for second interval.
3	DEWPT(3)	+	Etc.

11.6 MW Record - Energy Budget Wind Speed

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MW	Record identification.
1	WIND(1)	+	Wind speed in mi/hr (km/hr) at fifty feet (fifteen meters) above surface, average for basin during first interval.
2	WIND(2)	+	Wind speed as above for second interval.
3	WIND(3)	+	Etc.

12 Precipitation Data (P Records)

Precipitation data can be input as either precipitation gage data or subbasin-average precipitation.

Once precipitation data has been specified for a subbasin runoff computation, those data will be used for subsequent runoff calculations until changed by reading new precipitation data.

A typical record sequence for GAGE data is as follows:

	ID		
	IT	Etc., for job initialization	
	PG	Non-recording gage (total storm precipitation)	
	PG	Non-recording gage (total storm precipitation), etc.	
	PG	This is a recording gage if the PG record is followed by PI or PC records.	
	PI		
	.		
	.		
	KK	Subbasin runoff computation	
	BA		
	BF		
(	PT	Specification of stations and weightings for	)
(	PW	computation of the storm total precipitation	)
(	PR	and its time patter for this subbasin. If	)
(	PW	recording stations are to be used in the	)
(		computation of subbasin-average TOTAL	)
(		precipitation, their gage identification must	)
(		also be on the PT record.	)
	L-		
	U-		
	KK	Etc.	
	.		
	.		

PG and PG+PI/PC record combinations can be included at any point in the data set following the IT record. It is usually convenient to group them together as a precipitation data bank before the first KK record. Different storms can then be simulated by simply inserting different data banks, as long as the gage identification and weightings are the same.

HEC-1 Input Description
Precipitation Data (P Records)

Subbasin-average precipitation can be specified using historical storm data (PB and PI/PC records) or synthetic storm data (PM, PS or PH records).

12 Precipitation Data (P Records) (continued)

A typical record sequence is as follows:

ID
IT

KK
.
.
.
PB Subbasin-average precipitation specified as
PI part of this subbasin runoff computation.
.
.
.
KK
.
PM, PS or PH Synthetic storm data for this subbasin.
.
.
.
.

Once precipitation data has been specified for a subbasin runoff computation, those data will be used for subsequent runoff calculations until changed by reading new precipitation data.

HEC-1 Input Description
Precipitation Data (P Records)

12.1 PB/PI/PC Records - Storm Total and Distribution Option

These records are used if the basin-average, storm total precipitation is known along with a time pattern with which to distribute the storm total. They must be included in the KK record group for a runoff calculation.

12.1.1 PB Record - Basin Average Precipitation

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PB	Record identification.
1	STORM	0	Total storm, basin-average precipitation will be computed from values given on the following PI or PC records.
		+	Total storm, basin-average precipitation in inches (mm). If this value is given, the following PI or PC records' values for PRCPR will be used as a distribution pattern for the STORM amount.

12.1.2 PI Record - Incremental Precipitation Time Series

PI records contain an incremental precipitation time distribution. They are only used after a PG, PB or JD record which identifies the distribution. The interval length and starting time for the first interval will be as specified on the last IN record which has been read. The program reads all consecutive PI records and interpolates incremental precipitation values for the computation time interval and time period specified on the IT record. If an IN record is not specified the parameters on the IT record will be used. A maximum of 300 values can be specified on up to thirty records. A negative one may be used to signify missing data when using more than one recording gage in conjunction with PG records. The precipitation will be computed based on the weighted average of the remaining stations.

FIELD	**VARIABLE**	**VALUE**	**DESCRIPTION**
Col 1+2	ID	PI	Record identification.
1	PRCPR(1)	+	Precipitation in inches (mm) during the firs time interval identified on the preceding IN record, i.e. from JXTIME (IN record) to JXTIME+JXMIN.
2	PRCPR(2)	+	Etc.

HEC-1 Input Description
Precipitation Data (P Records)

12.1.3 PC Record - Cumulative Precipitation Time Series

PC records contain a cumulative precipitation distribution. They are only used after a PG, PB or JD record which identifies the distribution. The interval of ordinates and time of first mass curve ordinate are as specified on previous IN record. If an IN record is not specified the parameters on the IT recorded will be used. The program reads all consecutive PC records and interpolates incremental precipitation values for the computation time interval and time period specified on the IT record. A maximum of 300 values can be specified on up to thirty records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PC	Record identification.
1	PRCPR(1)	+	Cumulative precipitation at beginning of storm.
2	PRCPR(2)	+	Cumulative precipitation at end of first period.
3	PRCPR(3)	+	Cumulative precipitation at end of second period.
4	PRCPR(4)	+	Etc.

12.2 PG Record - Storm Total Precipitation for a Station (Gage)

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PG	Record identification.
1	ISTAN	AN	Station identification.
2	PRCPN	0	Total storm precipitation will be computed from following PI or PC records.
		+	Total storm precipitation in inches (mm) for above station.
3	ANAPN	+	Normal annual precipitation for above station. Used to compute basin mean precipitation by weighted average of station normal precipitation.
		0 or Blank	Weighting by normal annual precipitation will not be performed.
4	ISTANX	AN	Station to be replaced by station identified in Field 1.

All precipitation gages are total-storm stations. Some stations may also have temporal distributions associated with the storm-total precipitation. These stations are also called recording stations when referring to the temporal pattern. The temporal distribution is defined on PI or PC records immediately following a PG record.

Up to seventy stations may be entered on PG records. However, precipitation time series (PI or PC records) can be stored for only fifteen stations. If more stations are required, additional PG records may be entered later in the input stream and the data from those records will replace data for the station identified by ISTANX.

PR, PT and PW records are used within each KK, BA, etc., record series to specify weightings of precipitation station data to compute the subbasin- average precipitation distribution.

HEC-1 Input Description
Precipitation Data (P Records)

12.3 PH Record - Hypothetical Storms

These records are used to compute a hypothetical storm over a subbasin. The total storm will be automatically distributed according to the specified depth/duration data. A triangular precipitation distribution is constructed such that the depth specified for any duration occurs during the central part of the storm.

The duration of the storm will be the duration for the last non-zero depth which is specified. The first non-zero depth specified will be the most intense portion of the storm. Depths must be specified for all durations between these limits.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PH	Record identification.
1	PFREQ	50,20, 10	Storm frequency in percent. Rainfall will be converted to annual-series rainfall for fifty, twenty, and ten percent storms. No conversion is made for any other frequency (see Table 3.3, page 13).
		Blank	No conversion is made from partial-duration to annual series.
2	TRSDA	+	Storm area to be used in computing reduction of point rainfall depths per TP-40.
		0 or Blank	Basin area from BA record will be used to compute reduction of point rainfall depths, for the stream network option or from the JD record (TRDA) for the depth area option.
3	PNHR(1)	+	5-minute duration depth for PFREQ storm.
4	PNHR(2)	+	15-minute duration depth for PFREQ storm.
5	PNHR(3)	+	60-minute duration depth for PFREQ storm.
6	PNHR(4)	+	2-hour duration depth for PFREQ storm.
7	PNHR(5)	+	3-hour duration depth for PFREQ storm.

12.3 PH Record - Hypothetical Storms (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
8	PNHR(6)	+	6-hour duration depth for PFREQ storm.
9	PNHR(7)	+	12-hour duration depth for PFREQ storm.
10	PNHR(8)	+	24-hour duration depth for PFREQ storm.

Continue on second PH record (if needed).

FIELD	VARIABLE	VALUE	DESCRIPTION
1	PNHR(9)	+	2-day duration depth for PFREQ storm.
2	PNHR(10)	+	4-day duration depth for PFREQ storm.
3	PNHR(11)	+	7-day duration depth for PFREQ storm.
4	PNHR(12)	+	10-day duration depth for PFREQ storm.

HEC-1 Input Description
Precipitation Data (P Records)

12.4 PM Record - Probable Maximum Precipitation (Eastern United States)

This record is used for automatic computation of a Probable Maximum Storm (PMS) according to the outdated Hydrometeorological Report No. 33. This capability has been retained in HEC-1 to allow recomputation of hydrographs according to the old HMR No. 33 method.

NOTE - **Hydrometeorological Report No. 33 has been superseded by HMR No. 51 and No. 52.** Computer program HMR52 (HEC, 1984) may be used to calculate PMS hyetographs.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PM	Record identification.
1	PMS	+	Probable maximum index precipitation from HYDROMET Report 33.
2	TRSPC	0	TRSPC defaults to the Hop Brook factor (reference EC-1110-2-163). The adjustment is automatically made by the program. The precipitation is adjusted based on drainage area size using the following criteria.

HOP Brook Adjustment Factor

Drainage Area sq mi	**Precipitation Reduction**	**Adjustment Factor**
1000	10	.90
500	10	.90
200	10	.89
100	13	.87
50	15	.85
10 OR LESS	20	.80

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	Direct input of the transposition coefficient as desired (use 1.0 if no adjustment is desired).

12.4 PM Record - Probable Maximum Precipitation (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
3	TRSDA	0	Defaults to TAREA (BA-1).
		+	Drainage area in square miles (sq km) for which storm is transposed. Transposition drainage area is used to compute the storm reduction coefficient (TRSPC) for probable maximum storm. TRSDA may be different from the actual subbasin area TAREA (BA-1). Example: It is desired to center a PMS over a five hundred square miles watershed and calculate the corresponding runoff for a two hundred square mile subbasin of that watershed. For this condition TAREA=200 and TRSDA=500.
4	SWD	NO	Precipitation will be distributed according to EM 1110-2-1411 (default).
		YES	Precipitation will be distributed according to Southwestern Division criteria (see Table 3.1, page 11).
5	R6	+	Maximum 6-hour precipitation in percent of index PMS.
6	R12	+	Maximum 12-hour percentage of PMS.
7	R24	+	Maximum 24-hour percentage of PMS.
8	R48	+	Maximum 48-hour percentage of PMS (optional).
9	R72	+	Maximum 72-hour percentage of PMS (optional).
10	R96	+	Maximum 96-hour percentage of PMS (optional).

Duration of the computed PMS will correspond to the last non-zero percentage entered. Minimum duration is twenty-four hours.

HEC-1 Input Description
Precipitation Data (P Records)

12.5 PS Record - Standard Project Precipitation (SPS)

This record is used for automatic computation of the Standard Project Storm according to EM-1110-2-1411.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PS	Record identification.
1	SPFE	+	Standard project index precipitation from EM 1110-2-1411.
2	TRSPC	+	Storm reduction coefficient for standard project storm computations. This parameter is equal to the shape factor of the basin and should be input directly.
3	TRSDA	0	Default to TAREA (BA-1).
		+	Drainage area to be used in computing the peak twenty-four hour precipitation.
4	SWD	YES	Precipitation will be distributed according to Southwestern Division criteria (see Table 3.1, page 11).

12.6 PR/PT/PW Records - Precipitation Gage Weighting

These records are used to identify the gages and their relative weightings for computing this subbasin's average precipitation.

Both PR and PT records are required to compute a hyetograph. Rainfall for stations on the PT record are weighted to get the total rainfall for the storm, and hyetographs for stations on the PR record are weighted to get a temporal distribution for this total rainfall.

12.6.1 PR Record - Recording Stations to be Weighted

CAUTION - Weighting of two or more hyetographs may result in loss of detail for intense precipitation periods.

The recording precipitation distribution is computed as (WTR*PRCPR)/(SUM OF WTR) for all intervals. This precipitation distribution is used as the pattern to distribute the computed basin average total precipitation from the PT/PW records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PR	Record identification.
1	ISTR(1)	AN	Alphanumeric station identification of recording gage to be used and corresponding to weighting in Field 1 on the following PW record. Must correspond to a station name on a previous PG record.
2-5	ISTR(I)	AN	Etc., for up to five stations.

HEC-1 Input Description
Precipitation Data (P Records)

12.6.2 PT Record - Storm Total Stations to be Weighted

Basin-average total precipitation is computed as (WTR*PRCPN)/(SUM OF WTR) for all stations used. Recording gages can also be used in this computation of subbasin-average storm total precipitation; if used, their gage identification must be specified on the PT record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PT	Record identification.
1	ISTN(1)	AN	Alphanumeric station identification for total storm station. Must correspond to one of the station names on a previous PG record.
2-10	ISTN(I)	AN	Etc., up to ten stations corresponding to weightings on following PW record.

12.6.3 PW Record - Weightings for Precipitation Stations

This record is used to specify weights to be assigned to precipitation gages. If used, this record must follow immediately after a PR and/or PT record. If no PW record is used, each gage on the PR or PT record will have the same relative weight.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PW	Record identification.
1	WTR(1)	+	Relative weight in any units for the station name specified in Field 1 on the previous PR or PT record.
2-10	WTR(I)	+	Etc., corresponding to stations on previous PR record and/or PT record.

13 Hydrograph Time-Series Data (Q Records)

These records contain hydrograph time series data. The first value on the record is at the starting time specified on the previous IN record. Subsequent values are spaced at the time interval specified on the IN record. The program reads all consecutive Q records and interpolates values for the computation time interval and time period specified on the IT record. If the computation time period extends before or beyond the Q data supplied, the first or last value will be repeated as necessary to produce a hydrograph for the full time period.

13.1 QO Record - Observed Hydrograph

These records are used to input an observed hydrograph for an optimization job (OU or OR records) or for comparing the computed with an observed flow at any point in a river network. For optimization jobs, QO records are included in the data for runoff calculation. For comparison of hydrographs, QO records are separated from other data with a KK record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QO	Record identification.
1	QO(1)	+	Observed flow in cfs (cu m/s) at the beginning of the first period.
2	QO(2)	+	Etc.

HEC-1 Input Description
Hydrograph Time-Series Data (Q Records)

13.2 QI Record - Direct Input Hydrograph

These records are used to input a hydrograph directly (without rainfall-runoff computations) at any point in a river network.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QI	Record identification.
1	QI(1)	+	Hydrograph ordinate in cfs (cu m/s) at beginning of first period.
2	QI(2)	+	Etc.

13.3 QS Record - Stage Hydrograph

These records are used to input a stage hydrograph for comparison with the computed hydrograph. A rating table, on HQ and HE RECORDS, must also be supplied. Comparison of hydrographs is a distinct operation which must be separated from other operations with a KK RECORD.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QS	Record identification.
1	QS(1)	+	Stage in feet (m) at the beginning of the first time interval.
2	QS(2)	+	Etc.

13.4 QP Record - Pattern Hydrograph

These records are used to input a pattern hydrograph for which local inflow will be distributed in a routing optimization job (OR record) only.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QP	Record identification.
1	QP(1)	+	Pattern hydrograph for local inflow which will be adjusted for volume in routing coefficient derivation.
2	QP(2)	+	Etc.

14 Routing Data (R Records)

Routing of streamflows may be accomplished by several different methods. One of the following methods should be selected and put in the record set immediately after the streamflows to be routed have been computed. Also see Table 10.7 for input data requirements for alternative routing methods.

General information (use if desired)

RN indicates NO routing, **used only with multiPLAN**.
RL **channel losses**, may be used in conjunction with any of routing methods.

Routing Methods (choose one)

RD **Muskingum-Cunge** "diffusion" (RC, RX, RY optional)
RK **Kinematic Wave**
RM **Muskingum**
RT **Straddle/Stagger**
RS **Storage** (modified Puls, normal depth, or level pool, see summary of options on RS record)

Routing is considered to be a separate operation, so the R records must be preceded by a KK record which identifies the routed hydrograph.

14.1 RN Record - No Routing Option for this Plan

The RN record is used in a multiplan job to indicate that no routing occurs for this plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RN	Record identification.

HEC-1 Input Description
Routing Data (R Records)

14.2 RL Record - Channel Loss

Channel infiltration/percolation losses may be computed in conjunction with any of the routing methods. If desired, include the RL record with the desired routing method records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RL	Record identification.
1	QLOSS	+	Constant channel loss in entire routing in cfs (cu m/sec). This value is subtracted from every ordinate of the inflow hydrograph.
2	CLOSS	+	Ratio of remaining flow (after QLOSS) which is lost for entire routing. Each inflow hydrograph ordinate (after QLOSS is subtracted) is multiplied by (1-CLOSS).
3	PERCRT	+	Percolation rate cfs/acre (cu m/sec-acre) for wetted surface area of channel. This option is used in conjunction with storage routing and requires SA or SV/SE records.
4	ELVINV	+	Average invert elevation of channel L used to compute flow surface area for PERCRT.

14.3 RD Record - Muskingum-Cunge Routing

The RD record can be used by itself or in conjunction with RC, RX, and RY records to specify an eight point cross-section. When utilizing the eight-point cross-section option, fields 1-8 of the RD record do not need to be filled out. All of the necessary routing information is taken from the RC, RX, and RY records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RD	Record identification.
1	L	+	Channel length (feet or meters).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness (Manning's n).
4			Not used.
5	SHAPE	TRAP	Trapezoidal channel, includes triangular and rectangular (default).
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (feet or meters). Default value is zero.
7	Z	+	Side slopes, if required. Defaults equals one when WD, RD-6, is zero.
8			Not used. This field is only used in conjunction with kinematic wave subbasin runoff, see UK record.

14.4 RK Record - Kinematic Wave Channel Routing

This record is used for kinematic wave routing of a previously computed hydrograph. For channel routing in conjunction with runoff calculation, see the section on UK and RK records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RK	Record identification.
1	L	+	Channel length (feet or meters).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness.
4			Not used. This field is only used with the UK/RK record combination.
5	SHAPE	TRAP, 0, or Blank	Trapezoidal channel (including triangular and rectangular). (Default)
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (feet or meters). (Default value is zero.)
7	Z	+	Side slopes, if required (default value is 1.0 when WD, RK-6, is zero). (1 vertical to Z horizontal.)
8			Not used. This field is only used with kinematic wave subbasin runoff, see UK record.
9	NDXMIN	+	Integer number of routing increments (default five, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

HEC-1 Input Description
Routing Data (R Records)

14.5 RM Record - Muskingum Routing

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RM	Record identification.
1	NSTPS	+	Integer steps (equal to number of subreaches) for the Muskingum routing.
		-1	Number of steps will be optimized. OR record must have been previously supplied.
2	AMSKK	+	Muskingum K coefficient in hours for entire reach[1]. The program will automatically compute the subreach Muskingum K as AMSKK/NSTPS. AMSKK, etc., must be within the following limits: $$\frac{1}{2(1-X)} \le \frac{(AMSKK * 60)}{(NMIN * NSTPS)} \le \frac{1}{2X}$$ Where NMIN is the number of minutes in the computation interval.
		-1	Muskingum K coefficient will be optimized. OR record must have been previously supplied.
3	X	+	Muskingum X coefficient for Muskingum routing or working R&D routing.
		-1	Muskingum X coefficient will be optimized. OR records must have been previously supplied.

[1]NOTE - The Muskingum K coefficient input is DIFFERENT than in the pre-1981 versions of HEC-1. It is now input as the TOTAL K for the routing reach, not the K for the subreach.

14.6 RT Record - Straddle\Stagger Routing

NOTE - The variables used for this routing method are dependent on the computation time interval. The user should make proper adjustments when using different time intervals.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RT	Record identification.
1	NSTPS	+	Integer number of routing steps to be used for routing by Tatum method.
		0	LAG method.
		-1	If number of steps for Tatum method is to be derived by the program. OR record must have been previously supplied.
		1	If routing by Straddle-Stagger method.
2	NSTDL	+	Integer number of ordinates to be averaged in the Straddle-Stagger routing.
		-1	If straddle is to be derived by the program. OR record must have been previously supplied.
		2	If routing by the Tatum method with or without derivation.
3	LAG	+	Integer number of intervals hydrograph is to be lagged.
		-1	If lag is to be derived by the program. OR record must have been previously supplied.
		0	Tatum

HEC-1 Input Description
Routing Data (R Records)

14.7 RS Record - Storage Routing

This record is required to perform a storage-discharge routing. The record contains the starting conditions for the routing. A storage-discharge relation may be input directly on the SV and SQ records, or computed from surface area and elevation on SA and SE records and stage-discharge data on SE and SQ records, or computed from channel characteristics on RC, RX and RY records. Thus, storage routing may be accomplished by one of the following sequences of records:

Channel Routing: (choose one method)

RS, RC, RX, RY	Normal depth storage
RS, SV, SQ	Modified Puls

Reservoir Routing: RS + volume + outflow

Volume: (choose one method)

SV (SE optional)	Known volume
SA, SE	Compute volume

Outflow: (choose one method)

SQ (SE optional)	Known outflow (and rating)
SS, (SL and ST optional) requires SE record on outflow volume specifications.	Computed weir spillway
SS, (SL and ST optional) SG, SQ, SE	Computed ogee or trapezoidal spillway outflow

14.7 RS Record - Storage Routing (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RS	Record identification.
1	NSTPS	+	Number of steps to be used in the storage routing. Usually about equal to (reach length/ average velocity)/time interval (NMIN). NSTPS is usually equal to 1 for a reservoir.
2	ITYP	STOR	Storage (acre-feet or 1000 cu m) for the beginning of the first time period is specified in next field (default).
		FLOW	Discharge (cfs or cu m/s) for the beginning of the first time period is specified in the next field.
		ELEV	Elevation in (feet or meters) for the beginning of the first time period is specified in the next field.
3	RSVRIC	+	Storage (acre-ft or 1000 cu m), discharge (cfs or cu m/s), or elevation (ft or m), as indicated by previous field ITYP, corresponding to the desired starting condition at the beginning of the first time period IDATE/ITIME (IT-2/IT-3).
		-1	The initial outflow will be set to the initial inflow.
4	X	0	Working R&D method not used.
		+	Wedge storage coefficient (Muskingum X) to be used in a working R&D routing using a computed or given storage-discharge relationship.
5	y	0	Flow-through option ignored
		1	Outflow will be set equal to inflow for all time periods following time when reservoir elevation equals the spillway elevation. Used with diversion to model offline storage which achieves equilibrium with main channel flow.

14.8 RC Record - Normal-Depth Channel Routing

This record is used in combination with the RX and RY records to describe the channel in a routing reach. Manning's equation is used to compute a table of storage and outflow values for use in modified puls routing. These values are based on uniform subcritical flow in the reach. An RS record is required to provide initial conditions for modified puls routing.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RC	Record identification.
1	ANL	+	Left overbank Manning's n value.
2	ANCH	+	Channel Manning's n value.
3	ANR	+	Right overbank Manning's n value.
4	RLNTH	+	Reach length, in feet (m), for which computations are represented.
5	SEL	+	Energy grade line slope in ft/ft (m/m) for normal flow rate computations. If unknown, may be estimated as equal to channel or floodplain slope.
6	ELMAX	+	Maximum elevation for which storage and outflow values are to be computed (default is maximum elevation on RY record).

14.9 RX Record - Cross Section X Coordinates[1]

Left bank and right bank of channel are assumed to be located at points 3 and 6, respectively, of the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RX	Record identification.
1	X(1)	+	Horizontal station, in feet (m), of first point in cross section on the LEFT OVERBANK. Corresponds to first elevation Y(1) on RY record.
2	X(2)	+	Similar to above for another point on LEFT OVERBANK. Corresponds to second elevation Y(2) on RY record.
3	X(3)	+	Similar to above for LEFT BANK of CHANNEL.
4	X(4)	+	Similar to above for a point in CHANNEL.
5	X(5)	+	Similar to above for another point in CHANNEL.
6	X(6)	+	Similar to above for RIGHT BANK of CHANNEL.
7	X(7)	+	Similar to above for a point on RIGHT OVERBANK.
8	X(8)	+	Similar to above for another point on RIGHT OVERBANK.

[1]All eight points must be used. Stationing (x distance) must continuously increase.

HEC-1 Input Description
Routing Data (R Records)

14.10 RY Record - Cross Section Y Coordinates

Left bank and right bank of channel are assumed to be located at points 3 and 6, respectively, of the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RY	Record identification.
1	Y(1)	+	Vertical elevation, in feet (m), of first point in cross section on the LEFT OVERBANK. Corresponds to first station on RX record. Must be a positive value.
2	Y(2)	+	Similar to above for another point on the LEFT OVERBANK. Corresponds to second station on RX record.
3	Y(3)	+	Similar to above for LEFT BANK of CHANNEL.
4	Y(4)	+	Similar to above for a point in CHANNEL.
5	Y(5)	+	Similar to above for another point in CHANNEL.
6	Y(6)	+	Similar to above for RIGHT BANK of CHANNEL.
7	Y(7)	+	Similar to above for a point on RIGHT OVERBANK.
8	Y(8)	+	Similar to above for another point on RIGHT OVERBANK.

15 Storage Routing Data (S Records)

S records are used to provide storage and outflow data for storage routing.

STORAGE data can be input in two ways:

1. Storage volume on SV records
2. Surface area and elevation on SA and SE records

OUTFLOW data can be input in three ways:

1. Discharge on SQ records
2. Weir and orifice data on SS and SL records
3. Ogee spillway data on SL, SS, SG, SQ, and SE records

When spillway data (weir or ogee) are provided, the program computes a steady flow rating curve, then interpolates from that rating curve during the routing calculation. Elevation data may be input for storage or outflow by following SV or SQ records with SE records.

HEC-1 Input Description
Storage Routing Data (S Records)

15.1 SV/SA Records - Reservoir Storage Data

One of these sets of records is required in order to compute the storage relationship for a reservoir routing. If the storage volumes are not known, they may be computed by the conic method using surface area-elevation information.

15.1.1 SV Record - Reservoir Volume

These records are to be used if the reservoir volumes are known. Do not use if SA records are supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SV	Record identification.
1-10	RCAP(I)	+	Reservoir storage in acre-feet (1,000 cubic meters), up to twenty values on two records.

15.1.2 SA Record - Reservoir Surface Area Option

These records are used if the reservoir volumes (SV record) are not known. Do not use if SV records are supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SA	Record identification.
1-10	RAREA(I)	+	Reservoir surface area in acres (10,000 square meters), up to twenty values on two records.

HEC-1 Input Description
Storage Routing Data (S Records)

15.2 SE Record - Elevation

SE records may be used immediately after SV, SA, or SQ records to specify elevations for the values on those records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SE	Record identification.
1-10	ELEV(I)	+	Elevation in feet (m) corresponding to value in same field on preceding SV, SA, or SQ record (up to twenty values on two records). Note that the SE record must follow an SV or SA record.

15.3 SQ Record - Discharge

The SQ record gives outflow data for storage routing. Values should correspond to storage data, or if elevation data are provided for both storage and outflow, the program will interpolate discharges for the given storages.

The SQ and SE records are also used to specify tailwater data for the ogee spillway option.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SQ	Record identification.
1-10	DISQ(I)	+	Discharge in cfs (cu m/s) up to twenty values on two records.

15.4 SL Record - Low-Level Outlet

This record is necessary to describe flow through a low-level outlet. An SS record is also required if the SL record is used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SL	Record identification.
1	ELEVL	+	Centerline elevation, in feet (m), of downstream end of low-level outlet. This low-level outlet may be used with the weir, trapezoidal, or ogee spillways.
2	CAREA	+	Cross-sectional area, a, in square feet (sq m), in the low-level outlet orifice equation as described below for COQL.
3	COQL	+	Discharge coefficient, c, in orifice equation, $q=ca(2gh)^e$, for the low-level outlet.
4	EXPL	+	Exponent, e, of head h in orifice equation for low-level outlet as described in previous two fields. Usually equals 0.5.

15.5 SS Record - Spillway Characteristics

This record is used to compute flow for weir or ogee spillways. If the dam overtopping summary is requested (ST record), the spillway crest elevation should be provided on this record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SS	Record identification.
1	CREL	+	Spillway crest elevation, in feet (m). This crest elevation is also required in the weir, trapezoidal, and ogee spillway computations.
2	SPWID	+	Spillway length, in feet (m) corresponding to L in the WEIR equation as described below for COQW or the bottom width of the TRAPEZOIDAL spillway or the length of the OGEE spillway.
3	COQW	+	Discharge coefficient, c, in the spillway WEIR flow equation $q=clh^e$.
4	EXPW	+	Exponent, e, of head, h, in spillway WEIR flow equation. Usually equals 1.5.

HEC-1 Input Description
Storage Routing Data (S Records)

15.6 ST Record - Top-of-Dam Overflow

This record is used to compute flow over the top of a dam. Flow computed using the weir coefficients specified on this record is added to outflow computed from the spillway (SQ, SS, SL, or SG records). Use of this record calls for the dam overtopping summary (spillway crest elevation should be provided on SS record). This record is required if the non-level top-of-dam option (SW/SE records) is used. The discharge over the top of dam is added to the discharge elevation relationship generated by the program (SL, SS, SG options) or specified by the user (SQ, SE option).

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ST	Record identification.
1	TOPEL	+	Elevation, in feet (m), of the top of the dam at which overtopping begins.
2	DAMWID	+	Length, in feet (m), of the top-of-dam which is actively being overtopped - corresponds to one in the weir equation $q=clh^e$. Does not include spillway.
3	COQD	+	Discharge coefficient, c, in the above weir equation. If SQ/SE records include flow over top of dam, Field 3 should be zero.
4	EXPD	+	Exponent, e, in the above weir equation. Usually equals 1.5.

HEC-1 Input Description
Storage Routing Data (S Records)

15.7 SW/SE Records - Non-Level Top-of-Dam Option

If a non-level top-of-dam has a significant impact on the flow over the top of the dam, the following records should be used to describe the geometry of the top of the dam. These records are used in addition to the ST record.

15.7.1 SW Record - Non-Level Crest Lengths

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SW	Record identification.
1-10	WIDTH(I)	+	Accumulated dam crest length at or below corresponding elevation on SE record (up to ten values).

15.7.2 SE Record - Non-Level Crest Elevations

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SE	Record identification.
1-10	ELVW(I)	+	Elevation in feet (m) for corresponding crest length on SW record (up to 10 values).

15.8 SG Record - Trapezoidal and Ogee Spillway

This record is used only if a trapezoidal or ogee spillway is to be simulated in detail (see users manual for details). Tailwater rating curve must be provided on SQ and SE records which follow immediately after SG record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SG	Record identification.
1	IABCOA	0 or Blank	Abutment contraction coefficients are to be based on adjacent EARTH non-overflow section.
		10	Abutment contraction coefficients are to be based on adjacent CONCRETE non-overflow sections.
2	ISPITW	0	Spillway tailwater will be given on SQ/SE records.
		10	Spillway tailwater will be computed using specific energy equation. The low-level outlet tailwater will be on SQ/SE records in either case.
3	ISPCTW	0 or Blank	Both spillway and low-level outlet cause submergence of low level outlet.
		10	Low-level outlet discharges only shall be used in computing low-level outlet submergence.
4	NGATES	+	Number of spillway gates, i.e., spillway openings (or intermediate piers plus one). Used in computation of pier losses.
5	SS	0	For ogee spillway.
		+	Side slope of trapezoidal spillway. Slope is horizontal over vertical, e.g., 2.0 for two to one side slopes.

15.8 SG Record - Trapezoidal and Ogee Spillway (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
6	DESHD	+	Design head for ogee spillway, in feet (m).
7	APEL	+	Apron elevation, in feet (m), at base of spillway.
8	APWID	+	Spillway apron width, in feet (m).
9	APLOSS	+	Approach-channel head loss in feet (m), at the design head.
10	PDPTH	+	Approach depth for ogee spillway, in feet (minimum of ten percent of design head).

NOTE - SQ and SE records to define the tailwater must follow this SG record. If a low-level outlet is specified, it should precede the SG record to prevent error message.

15.9 SB Record - Dam-Breach Simulation

This record is required only to simulate a dam breach. Both an SB and an ST record are required for dam breach calculations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SB	Record identification.
1	ELBM	+	Elevation, in feet (m), of the bottom of the breach when breach is at maximum size.
2	BRWID	+	Width, in feet (m), of the bottom of the breach when breach is at maximum size.
3	Z	+	Side slope of breach (z horizontal to one vertical).
4	TFAIL	+	Time, in hours, for breach to develop to maximum size.
5	FAILEL	+	Elevation, in feet (m), of water surface which will cause dam to fail (begins breach computation).

NOTE - Tables and plots of dam-breach hydrographs for each plan are generated automatically when IPRNT (IO-1 or KO-1) is less than four. Those tables and plots show how well the breach hydrograph is represented by the normal time interval specified on the IT record.

Dam-breach outflow submergence. Tailwater submergence effects on outflow from the breach may be taken into account by inserting SQ/SE or RC/RX/RY records immediately after the SB record. The RC/RX/RY records depict a cross-section representative of the downstream flow restriction condition. A normal depth rating curve is calculated from the cross-section data for use in the submergence calculation.

15.10 SO Record - Reservoir Volume Optimization

Data required for determining optimum volume of a reservoir are:

Low-Level Outlet data	SL record
Spillway data	SS record
Volume vs. Elevation data	SV, SE records
Cost Factors, Range	SO record
Costs vs. Volume data	SD record

Note: the order is important for these records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SO	Record identification.
1	IOPTR	+	Number of field on OS record which contains reservoir volume (overrides CREL on SS record).
		0, or Blank	Reservoir volume is not to be optimized. To be used during initial data set testing and to fix size of the reservoir.
2	RANCST	+	Proportion (decimal) of capital cost of reservoir that will be required for annual operation and maintenance.
3	RDSCNT	+	Discount or capital recovery factor (decimal) to compute equivalent annual cost from capital cost.
4	CAPMX	+	Maximum permissible storage capacity of reservoir in acre-feet (1,000 cu m). Used as a constraint on optimization.
5	CAPMN	+	Minimum permissible storage capacity of reservoir in acre-feet (1,000 cu m). Used as a constraint on optimization.

HEC-1 Input Description
Storage Routing Data (S Records)

15.11 SD Record - Reservoir Cost

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SD	Record identification.
1	RCST(1)	+	Reservoir capital cost corresponding to storage on SV record.
2-10	RCST(I)	+	Etc., up to ten values.

16 Unit Graph/Kinematic Data (U Records)

Five different methods are available to transform rainfall/snowmelt excesses into runoff. Choose one technique for each subbasin.

16.1 UI Record - Given Unit Graph

The given unit hydrograph must have been derived for the time interval on the IT record (IT-1, IT-2). For example, if the time interval is fifteen minutes, then a fifteen minute unit hydrograph must be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UI	Record identification.
1	QUNGR(1)	+	Unit hydrograph flow in cfs (cu m/sec) at end of first interval.
2	QUNGR(2)	+	Same for second interval.
3	QUNGR(3)	+	Etc., up to one hundred and fifty values on successive UI records.

HEC-1 Input Description
Unit Graph/Kinematic Data (U Records)

16.2 UC Record - Clark Unit Graph

Clark's time-area data is supplied on UA records if desired or a synthetic time-area curve is used if the UA record is not supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UC	Record identification.
1	TC	+	TC is the time of concentration in hours for the Clark unit hydrograph. Neither TC nor R are to be optimized. The value of R, Field 2, must also be positive. Value of variable is fixed at the given value. TC must be greater than or equal to NMIN (IT-1).
		-1	TC and R will both be optimized and the value of R (Field 2) must also be -1. The program will supply the starting value for the optimization scheme. OU record must have been previously supplied.
		-2	Ratio R/(TC+R) is to be read in the next field (2) and held constant. TC and R will both be optimized but the specified ratio will not be changed. Field 2 must be a positive ratio R/(TC+R). OU record must have been supplied.
		-X	Where X is the desired starting value for TC in the optimization and the starting value of R, Field 2, must also be supplied as a negative number. Cannot be equal to -1 or -2. X (when converted to minutes) must be greater than or equal to NMIN (IT-1). OU record must have been supplied.

16.2 UC Record - Clark Unit Graph (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
2	R	+	R is the Clark storage coefficient in hours. No optimization of TC or R unless TC is equal to -2. If TC is -2, this field contains the constant value for the ratio R/(TC+R). R must be greater than or equal to 0.5 NMIN.
		-Y	Where Y is the desired starting value for R in the optimization and the starting value of TC must also be supplied as a negative number. Cannot be -1. R (when converted to minutes) must be greater than or equal to 0.5 NMIN.

HEC-1 Input Description
Unit Graph/Kinematic Data (U Records)

16.3 US Record - Snyder Unit Graph

A time-area curve may be supplied on UA records, following this record if desired.

If it is desired to optimize the Snyder coefficient, an OU record must have been previously supplied. Optimization is accomplished using the Clark function to compute a continuous unit graph and then estimate the Snyder parameters.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	US	Record identification.
1	TP	+	Snyder's standard lag in hours. If in the optimization mode (OU record previously supplied), this variable is fixed at the given value and not optimized.
		-1	For optimization only (OU record previously supplied). Program will assume a starting value and optimize.
		-	Same as (-1) above except program uses this value (after a sign change) as the starting point for the optimization.
2	CP	+ or -	Snyder's peaking coefficient, CP. See Field 1 for meaning of VALUE.

16.4 UA Record - Time-Area Data

This time-area data may be used with either the Clark or Snyder methods. This data may be in any units, since area is scaled to the subbasin area and time is scaled to time of concentration. The areas contribute to runoff at the basin outlet at equally spaced time intervals. A synthetic time-area curve will be used if the UA record is not supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UA	Record identification.
1	QCLK(1)	+	Area in any units, that contributes at time zero (usually area of reservoir, if any) at concentration point.
2	QCLK(2)	+	Total area contributing runoff during first time interval. The time intervals may be of any length, but the same equal interval must be used for all points on this time area relationship, QCLK(I).
3	QCLK(3)	+	Cumulative area contributing runoff during second such interval.
4	QCLK(4)	+	Etc., up to 150 values.

HEC-1 Input Description
Unit Graph/Kinematic Data (U Records)

16.5 UD Record - SCS Dimensionless Unit Graph

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UD	Record identification.
1	TLAG	+	SCS lag in hours. If in the optimization mode (OU record previously supplied), this variable is fixed at the given value and not optimized.
		-1	For optimization only (OU record previously supplied) program will assume a starting value and optimize.
		–	Same as (-1) above except program uses this value (after a sign change) as the starting point for the optimization.

16.6 UK/RK or UK/RD Records - Kinematic Wave or Muskingum-Cunge Excess Transformation

At least one UK record and one RK or RD record are required to define characteristics for kinematic wave routing of precipitation excess to the subbasin outlet. UK records may be used with RK or RD records, but RK and RD records cannot be intermixed. A maximum of two UK records and three RK or three RD records can be used.

16.6.1 UK Record - Kinematic Overland Flow

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UK	Record identification.
1	L	+	Overland flow length (ft) (m).
2	S	+	Representative slope (ft/ft) (m/m).
3	N	+	Roughness coefficient, see users manual.
4	A	+	Percentage of subbasin area that this element represents (percent).
5	NDXMIN	+	Integer number of routing increments for overland flow plane (default five, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

If the percentage in Field 4 is less than one hundred, a second UK record must be supplied to describe another subcatchment contributing to the same collector system (RK record). The percentages for two subcatchments must add up to one hundred. Two separate subcatchments are typically used to describe the pervious and impervious portions of a subbasin.

The first and second loss rates specified on a previous L record will be used for the first and second UK subcatchments, respectively.

16.6.2 RK/RD Record - Subcatchment Kinematic Wave or Muskingum-Cunge Collector/Main Channels

Overland flow (from the UK record) is routed to the subbasin outlet through channels described on RK or RD records. UK record(s) may be followed by up to two RK or two RD records representing successive collector channels and one RK or one RD record representing the main channel. **RK and RD records cannot be mixed**, one method must be used for all collector/main channels within the same subbasin. The outflow from the first collector channel is inflow to the second, etc. The RD record may be used in conjunction with the RC, RX, RY records to specify an eight point cross-section for **main** channel routing only.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RK or RD	Record identification.
1	L	+	Channel length (feet or meters).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness (Manning's n).
4	CA	+	Contributing area to a typical collector (sq mi or sq km). On the last RK record (main channel) the contributing area is assumed to be TAREA (BA-1).
5	SHAPE	TRAP	Trapezoidal channel, includes triangular and rectangular (default).
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (feet or meters). (Default value is zero.)
7	Z	+	Side slopes, if required. Default = 1 when WD, RK-6, is zero.

16.6.2 RK/RD Record - Subcatchment Kinematic Wave or Muskingum-Cunge Collector/Main Channels (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
8	UPSTQ		This field is only used for main channels.
		YES	Upstream hydrograph will be routed through main channel, in addition to lateral inflow from this subbasin.
		NO	Do not route upstream hydrograph (default).
9	NDXMIN	+	**Kinematic wave routing only**. Integer number of routing increments for collector/main channels (default two, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

NOTE: Fields 1-9 are not used for RD main channel routing with RC/RX/RY records.

17 Pump Data (W Records)

A pump may be included as a part of level-pool reservoir routing to withdraw water from the reach. Pumped water leaves the reach but can be retrieved in a subsequent computation (see WR record).

17.1 WP Record - Pump Operation

WP records are added to storage routing data to simulate operation of a pumping station. Up to 5 pumps may be used at different elevations for a pump station. Pumped water is removed from the current reach and can be retrieved at another location (see WR record).

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WP	Record identification.
1	PMPON	+	Elevation in feet (m) at which is turned on. The program checks the elevation at the end of the previous time interval to see if a pump should be turned on or off.
2	PUMPQ	+	Pump flow in cfs (cu m/sec).
		0	Number of pumps is reset to zero. This is used for multiplan runs where a plan has no pumps.
3	PMPOFF	+	Elevation in feet (m) at which pump turns off. See description for PMPON above.
4	ISTAD	AN	Name assigned to pumped flow for future retrieval with WR record. This name must be same on all the WP records in a KK group.

The **use of the WP record with the MULTIPLAN capability requires some special conventions**. A **single** WP record with a **non-zero** (can be set very small) pump flow is required (PUMPQ, Field 2) for PLAN 1. All other plans must specify first a WP record with **zero** PUMPQ and then a second WP record with desired pumping rate. Example:

Field	**1**	**2**	**3**	**4**
KK	PUMP	REACH		
KP				
RS,SV,SE,SQ	Storage Routing Data			
WP		0.001		PMPQ1
KP	2			
WP				PMPQ1
WP	843.5	3000	842.0	PMPQ1

17.2 WR Record - Retrieve Previously Pumped Flow

The WR record is used to retrieve a hydrograph which was created by a previous diversion. This hydrograph can then be treated like any other hydrograph in the system. Retrieval of a diversion hydrograph is a separate operation, so the WR record must be preceded by a KK record which identifies the hydrograph which will be retrieved.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WR	Record identification.
1	ISTAD	AN	Station name corresponding to the name given on a previous pump operation WP record.

HEC-1 Input Description
Pump Data (W Records)

17.3 WO Record - Pump Optimization

Data required for optimization of pump capacity are:

Storage Routing data	RS, S records
Pump Operation data	WP record
Cost Factors, Range	WO record
Cost vs. Capacity	WC, WD record

Note: the order is important for these records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WO	Record identification.
1	IOPTP	+	Number of field on OS record which contains pump capacity (overrides PUMPQ on WP record).
		0, or Blank	Pump capacity on WP record is used.
2	PANCST	+	Proportion of capital cost of pump that will be required for annual operation and maintenance.
3	PDSCNT	+	Discount or capital recovery factor (decimal) to compute equivalent annual cost from capital cost.
4	PWRCST	+	Average annual power cost for capacity on OS or WP record. Cost is computed as a function of volume pumped for each size pump during the optimization.
5	PMPMX	+	Maximum permissible capacity of pumping plant in cfs (cu m/sec). Used as a constraint on optimization.
6	PMPMN	+	Minimum permissible capacity of pumping plant in cfs (cu m/sec). Used as a constraint on optimization.

HEC-1 Input Description
Pump Data (W Records)

17.4 WC Record - Pump Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WC	Record identification.
1	PCAP(1)	+	Pump capacity in cfs (cu m/sec) corresponding to PCST(1) on following WD record.
2-10	PCAP(I)	+	Etc., up to ten values.

17.5 WD Record - Pumping Plant Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WD	Record identification.
1	PCST(1)	+	Pumping plant capital cost corresponding to capacity on WC record.
2-10	PCST(I)	+	Etc., up to ten values.

HEC-1 Input Description
Economic Data

18 Economic Data

Data for economic evaluation of flood damage is placed in the data set following the last hydrograph calculation and before the ZZ record. The first record in the economic data is an EC record, and all records between the EC and ZZ records are economic-data records. The economic data may be used to calculate expected annual damage, single event damage, or adjusted flow or stage frequency curves.

A typical sequence for economic data is:

EC	Identifies following records as containing economic data
CN	Damage category names
PN*	Plan names
WN*	Watershed names
TN*	Township names
KK	Station identification to a unique KK record station in the previous river network simulation data
WT*	Watershed and township identification
FR	Frequency data
QF,SF*	Flows for frequency data
SQ*	Stages for rating curve
QS*	Flows for rating curve
QD,SD*	Flows or stages for damage data (only required for damage calculations)
DG	Damage data (only required for damage calculations)
KK, Etc.	For other damage centers in the river network

*Optional records

HEC-1 Input Description
Economic Data

18.1 EC Record - Economic Data**

This record is required as the first record of economic data. It indicates that following records will contain data for calculation of expected annual damages.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	EC	Record identification.

18.2 CN Record - Damage Category Names**

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	CN	Record identification.
1	NCAT	+	The number of different damage categories (or types), e.g., urban, rural, utility, etc. Dimensioned for ten categories.
2	NMCAT	AN	Alphanumeric name for first damage category. Damage data (DG records) must be identified by the order input here.
3-10	NMCAT	AN	Repeat as required by NCAT (CN-1). If NCAT is 10, the tenth name must be in Field 2 of the next record.

**These records are REQUIRED for flood damage analysis.

HEC-1 Input Description
Economic Data

18.3 PN Record - Plan Names

This record is used for description of the plans. One record is used for each plan. A maximum of five plans (PN records) may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PN	Record identification.
1	IPLN	+	Plan number to which this description applies.
2-10	NMPLN	AN	Alphanumeric description of above plan number (may use remainder of record).

HEC-1 Input Description
Economic Data

18.4 WN Record - Watershed Name

WN, TN, and WT records may be used to identify damage reaches by watershed and township. If this option is used expected annual damages will be listed in summary tables according to watershed and township.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WN	Record identification.
1	NWAT	+	Number of watershed names to read. Dimensioned for fifteen watersheds.
2	WID	AN	Alphanumeric name for first watershed.
3-10	WID	AN	Repeat for each watershed as required by NWAT (WN-1). If NWAT is greater than nine, the tenth name must be in Field 3 of the next record.

18.5 TN Record - Township Name

See WN record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	TN	Record identification.
1	NTWN	+	Number of township names to read. Dimensioned for fifteen townships.
2	TID	AN	Alphanumeric name for first township.
3-10	TID	AN	Repeat for each township as required by NTWN (TN-1). If NTWN is greater than nine, the tenth name must be in Field 3 of the next record.

HEC-1 Input Description
Economic Data

18.6 KK Record - Station Computation Identifier**

The KK record must be repeated at the beginning of each damage reach.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KK	Record identification. Default value for pathname part B if FR record not used (DSS use only).
1	ISTAQ	AN	Stream station location identification. It must correspond identically to the station identification used on the KK record in the hydrologic calculations, see page A-32.
2-10	NAME	AN	Station description.

**Required

HEC-1 Input Description
Economic Data

18.7 WT Record - Watershed and Township Identification

This record is used to identify the watershed and township for the stream station given on the KK record. Watershed and township designations will be the same for all stations until a new WT record is read.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WT	Record identification.
1	IWAT	+	Integer corresponding to watershed name on WN record.
2	ITWN	+	Integer corresponding to township name on TN record.

18.8 FR Record - Frequency Data**

This record is required for the first station. These frequency values will be used until changed by a new FR record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	FR	Record identification.
1		+	Pathname part B (DSS use only).
2	NFRQ	+	Number of exceedence frequency values to be read on FR records. Dimensioned for eighteen.
3	PFREQ	+	Exceedance frequency values (in percent). Must be in descending order (99,90,.....,10, etc.).
4-10	PFREQ	+	Repeat as required by NFRQ (FR-2). If there are more than eight values, the ninth value must be in the first field of the next record.

**Required

HEC-1 Input Description
Economic Data

18.9 QF Record - Flows for Frequency Curve

This record is required for each station if SF record is not provided.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QF	Record identification.
1			Not used.
2			Not used.
3-10	QFRQ	+	Peak flow values corresponding to exceedence frequencies on FR record. Repeat as required by NFRQ (FR-2). If there are more than eight values the ninth value must be in the first field of the next record.

18.10 SF Record - Stages for Frequency Curve

This record should be used only if peak stage have been calculated in the hydrologic portion of HEC-1. This record is required for each station if QF record is not provided.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SF	Record identification.
1			Not used.
2			Not used.
3-10	SFRQ	+	Peak stages corresponding to exceedence frequencies on FR record. Repeat as required by NFRQ (FR-2). If there are more than eight values, the ninth value must be in the first field of the next record.

HEC-1 Input Description
Economic Data

18.11 SQ Record - Stages for Rating Curve

A stage-flow rating curve is required when stage-damage data are provided and stages are not computed in the river network simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SQ	Record identification.
1			Not used.
2	NSTG	+	Number of stage values to be read on SQ records. Dimensioned for eighteen.
3-10	STGQ	+	Stage values corresponding to flows on QS records. Values must be in ascending order. Repeat as required by NSTG (SQ-2). If there are more than eight values, the ninth value must be in the first field of the next record.

18.12 QS Record - Flows for Rating Curve

This record must be preceded by an SQ record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QS	Record identification.
1			Not used.
2			Not used.
3-10	QSTG	+	Flow values corresponding to stages on the SQ record. Repeat as required by NSTG (SQ-2). If there are more than eight values, the ninth value must be in the first field of the next record.

HEC-1 Input Description
Economic Data

18.13 SD Record - Stages for Damage Data

Do not use this record if flow-damage data are to be used or if damages are not to be computed. Provide one SD record for each station. If stage-damage data change for each plan, a new SD record must be provided for each plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SD	Record identification.
1			Not used.
2	NDMG	+	Number of stage values to be read. Dimensioned for eighteen.
3-10	SDMG	+	Stage values corresponding to damage on DG record. Values must be in ascending order. Repeat as required by NDMG (SD-2). If there are more than eight values, the ninth value must be in field one of the next record.

18.14 QD Record - Flows for Damage Data

This record is required if SD record is not provided and damages are to be calculated. If flow-damage data change for each plan, a new QD record must be provided for each plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QD	Record identification.
1			Not used.
2	NDMG	+	Number of flow values to be read, dimensioned for eighteen.
3-10	QDMG	+	Flow values corresponding to damages on DG record. Values must be in ascending order. Repeat as required by NDMG (QD-2). If more than eight values are to be read, the ninth value must be in field one of the next record.

HEC-1 Input Description
Economic Data

18.15 DG Record - Damage Data**

Damage data must be provided for each station if damages are to be calculated. One (two if NDMG is greater than eight) record is required for each damage category.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DG	Record identification.
1			Not used.
2			A **three digit number** containing the PLAN and damage category in columns 14-16. Do not leave imbedded blanks.
	IPLN	+	Column 14 contains the one digit PLAN number to which this data applies.
		0	If column 14 is zero, the same data is used for all plans.
	ICAT	+	Columns 15 and 16 contain the 2-digit damage category number, e.g., 01, 02, ... or 10.
3-10	DAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD). Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in field one of the next record.

**Required

HEC-1 Input Description
Economic Data

18.16 EP Record - End of Plan

This record is required to indicate the end of data for a plan. The current plan will be evaluated and new data will be read for the next plan. If there are no additional data, the last data set read will be used to compute expected annual damages for any plan which has not been evaluated.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	EP	Record identification.

The following data conventions must be followed in using the EP record:

- The frequency curve (FR and QF/SF records) **cannot** be changed.

- The stages for a rating curve (SQ record) **cannot** be changed.

- The discharges for a rating curve (QS record) **can** be changed.

- The damage data (SD/QD and DG records) **can** be changed.

- Labels such as Plan Name (PN) and Damage Category Name (CN) **can** be changed. Plan Names could be specified for all plans in the first group of data (for the first plan).

18.17 LO Record - Optimize Local-Protection Project

Data required for optimization of a local protection project or uniform degree of protection are:

Damage Data with Improvements	DU, DL records
Cost Factors, Range	LO record
Cost vs. Capacity Table	LC, LD records

Note: the order is important for these records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LO	Record identification.
1	IOPTLP	+	Number of field on OS record which contains capacity of local protection project.
		-	Number of field on OS record which contains uniform degree of protection.
2	XANCST	+	Proportion of local protection project capital cost that will be required for annual operation and maintenance.
3	XDSCNT	+	Discount factor (capital recovery factor) to compute equivalent annual cost from capital cost.
4	LPMX	+	Maximum permissible design capacity of local protection project in same units as QD or SD record. This is the design level associated with lower pattern damage function on DL records. Used as a constraint on optimization.
5	XLPMN	+	Minimum permissible design capacity of local protection project in same units as QD or SD record. This is the design level associated with upper pattern damage function on DU records. Used as a constraint on optimization.

HEC-1 Input Description
Economic Data

18.18 LC Record - Local-Protection Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LC	Record identification.
1	XLCAP(1)	+	Local project design capacity in same units as QD or SD record.
2-10	XLCAP(I)	+	Etc., up to ten values.

18.19 LD Record - Local-Protection Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LD	Record identification.
1	XLCST(1)	+	Capital cost of local protection project corresponding to capacity on LC record.
2-10	XLCST(I)	+	Etc., up to ten values.

HEC-1 Input Description
Economic Data

18.20 DU Record - Upper Pattern Damage Table

Pattern damage table for minimum design level (XLPMN) for local protection project.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DU	Record identification.
1			Not used.
2	ICAT	+	Damage category number.
3-10	TUDAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD) values. Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in Field 1 on the next record.

18.21 DL Record - Lower Pattern Damage Table

Pattern damage table for maximum design level (XLPMX) for local protection project.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DL	Record identification.
1			Not used.
2	ICAT	+	Damage category number.
3-10	TLDAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD) values. Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in Field 1 on the next record.

18.22 DP Record - Degree of Protection

Degree of protection and target level are used as performance constraints on optimization of a flood control system.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DP	Record identification.
1	DGPRT	+	Target degree of protection for this location in percent exceedence frequency.
2	TRGT	+	Target level for degree of protection corresponding to exceedence frequency, DGPRT, above. TRGT is elevation in feet (meters) if SF record is used, or TRGT is flow in cfs (cu m/sec) if QF record is used.

HEC-1 Input Description
End-of-Job Card (ZZ Record)

19 End-of-Job (ZZ Record)**

This record identifies the end of an HEC-1 job and causes summary computations and printout to occur. Another job may be started with another ID, IT, etc., record series if desired. If another job does not follow, the control is passed back to the computer operating system.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ZZ	Record identification.

**Required

HEC-1 Input Description
HEC-1 Input Record Summary

20 HEC-1 INPUT RECORD SUMMARY FIELD

ID	1	2	3	4	5	6	7	8	9	10	Page
*LIST											A-5
*NOLIST											A-5
*FREE											A-5
*FIX											A-5
* (comment beginning in Column 3)											A-5
*DIAGRAM											A-5
ID	ITLS										A-6
IT	NMIN	IDATE	ITIME	NQ	NDDATE	NDTIME	ICENT				A-7
IN	JXMIN	JXDATE	JXTIME								A-8
IO	IPRT	IPLT	QSCAL								A-9
IM											A-9
JP	NPLAN										A-10
JR	IRTIO	RTIO	. . .								A-11
JD	STRM	TRDA									A-12
OU	IFORD	ILORD									A-13
OR	IFORD	ILORD									A-13
OS	VAR	. . .									A-14
OF	FCAP	FDCNT	FAN								A-15
OO	ANORM	CNST									A-16
VS	ISTA	. . .									A-17
VV	SMVAR	. . .									A-18
BA	TAREA	SNAP	RATIO								A-19
BF	STRTQ	QRCSN	RTIOR								A-20
BI	ISTA	IQIN									A-21
DR	ISTAD										A-22
DT	ISTAD	DSTRMX	DVRSMX								A-23
DI	DINFLO	. . .									A-24
DQ	DIVFLO	. . .									A-24
DO	IOPTD	DANCST	DDSCNT	DVRMX	DVRMN						A-25
DC	DCAP	. . .									A-26
DD	DCST	. . .									A-26

20 **HEC-1 INPUT RECORD SUMMARY FIELD** (continued)

ID	1	2	3	4	5	6	7	8	9	10	Page
HB	NQB	SUMB	NQB	SUMB	. . .						A-27
HC	ICOMP	TAREA									A-28
HL	TAREA										A-29
HQ	QSTG	. . .									A-29
HE	STGQ	. . .									A-29
HS	STR										A-30
KK	ISTAQ	NAME	. . .								A-31
KM	ITLS	. . .									A-31
KO	JPRT	JPLT	QSCAL	IPNCH	IOUT	ISAV1	ISAV2	TIMINT			A-32
KF	FLOTQ	IFMT	. . .								A-34
KP	ISTM										A-35
LU	STRTL	CNSTL									
LE	STRKR	DLTKR	RTIOL	ERAIN	RTIMP	*					A-37
LM	STRKS	RTIOK									A-38
LS	STRTL	CRVNBR	RTIMP	*							A-39
LH	FC	GIA	SAI	BEXP	RTIMP	*					A-40
LG	IA	DTHETA	PSIF	XKSAT	RTIMP						A-41
MA	AREA	SNO	ANAP								A-42
MC	TLAPS	COEF	FRZTP								A-43
MT	TEMPR	. . .									A-44
MS	SOL	. . .									A-44
MD	DEWPT	. . .									A-45
MW	WIND	. . .									A-45
PB	STORM										A-48
PI	PRCPR	. . .									A-49
PC	PRCPR	. . .									A-50
PG	ISTAN	PRCPN	ANAPN	ISTANX							A-51
PH	PFREQ	TRSDA	PNHR	. . .							A-52
PM	PMS	TRSPC	TRSDA	SWD	R6	R12	R24	R48	R72	R96	A-54
PS	SPFE	TRSPC	TRSDA	SWD							A-56
PR	ISTR	. . .									A-57
PT	ISTN	. . .									A-58
PW	WTR	. . .									A-58
QO	QO	. . .									A-59
QI	QI	. . .									A-60
QS	QS	. . .									A-60
QP	QP	. . .									A-61

20 **HEC-1 INPUT RECORD SUMMARY FIELD** (continued)

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RL	QLOSS	CLOSS	PERCRT	ELVTNV							A-63
RD	L	S	N		SHAPE	WD	Z	UPSTQ			A-64
RM	NSTPS	AMSKK	X								A-65
RS	NSTPS	ITYP	RSVRIC	X	y						A-66
RC	ANL	ANCH	ANR	RLNTH	SEL	ELMAX					A-68
RX	X	. . .									A-69
RY	Y	. . .									A-70
RK	L	S	N	---	SHAPE	WD	Z	---	NDXMIN		A-71
RT	NSTPS	NSTDL	LAG								A-72
SV	RCAP	. . .									A-74
SA	RAREA	. . .									A-74
SE	ELEV	. . .									A-75
SQ	DISQ	. . .									A-75
SL	ELEVL	CAREA	COQL	EXPL							A-76
SS	CREL	SPWID	COQW	EXPW							A-77
ST	TOPEL	DAMWID	COQD	EXPD							A-78
SW	WIDTH	. . .									A-79
SE	ELVW	. . .									A-79
SG	IABCOA	ISPITW	ISPCTW	NGATES	SS	DESHD	APEL	APWID	APLOSS	PDPTH	A-80
SB	ELBM	BRWID	Z	TFAIL	FAILEL						A-82
SO	IOPTR	RANCST	RDSCNT	CAPMX	CAPMN						A-83
SD	RCST	. . .									A-84
UI	QUNGR	. . .									A-85
UC	TC	R									A-86
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UA	QCLK	. . .									A-89
UD	TLAG										A-90
UK	L	S	N	A	DX						A-91
RK	L	S	N	CA	SHAPE	WD	Z	UPSTQ	DX		A-92
WP	PMPON	PUMPQ	PMPOFF	ISTAD							A-94
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WO	IOPTP	PANCST	PDSCNT	PWRCST	PMPMX	PMPMN					A-96
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20 **HEC-1 INPUT RECORD SUMMARY FIELD** (continued)

ID	1	2	3	4	5	6	7	8	9	10	Page
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PN	IPLN	NMPLN									A-100
WN	NWAT	WID	. . .								A-101
TN	NTWN	TID	. . .								A-101
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WT	IWAT	ITWN									A-103
FR	---	NFRQ	PFREQ	. . .							A-103
QF	---	---	QFRQ	. . .							A-104
SF	---	---	SFRQ	. . .							A-104
SQ	---	NSTG	STGQ	. . .							A-105
QS	---	---	QSTG	. . .							A-105
SD	---	NDMG	SDMG	. . .							A-106
QD	---	NDMG	QDMG	. . .							A-106
DG	---	IPLN	DAMG	. . .							A-107
EP											A-108
LO	IOPTLP	XANCST	XDSCNT	LPMX	XLPMN						A-109
LC	XLCAP	. . .									A-110
LD	XLCST	. . .									A-110
DU	---	ICAT	TUDAMG	. . .							A-111
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Appendix B

HEC-1 Usage with HEC Data Storage System

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Appendix B

HEC-1 Usage with HEC Data Storage System

1 Introduction

The HEC Data Storage System (DSS) (HEC, 1994) has been developed to allow transfer of data between HEC programs. The data are identified by unique labels called PATHNAMEs which are specified when the data are created or retrieved. Thus, a hydrograph computed by HEC-1 can be labeled and stored in DSS for later retrieval as input data to HEC-5, for instance. The DSS has several utility programs for manipulating data. These programs enable editing of information, changing pathnames, purging unwanted data sets and insertion of other data sets. Graphic and tabular portrayal of DSS data are also available.

The interested user is encouraged to contact HEC for up-to-date information and documentation on the DSS and companion utility programs. It should be emphasized, however, that application of DSS does not require familiarity with all the intracacies of the general purpose DSS system.

1.1 Pathnames for Identifying Data

The pathname is separated into six different parts by a slash "/" delimiter so that each part refers to a specific, unique identifier. One convention that has been developed to simplify definition of pathname parts for typical hydrologic data is shown below:

Pathname Part	Description
A	General identifier (e.g., river basin or project name)
B	Location or gage number
C	Data time intervalsuch as FLOW, ELEV, PRECIP, etc.
D	Beginning date for data (blank for HEC-1 usage)
E	Data time interval. If left blank it defaults to the computation interval on the IT reccord.
F	Additional user-defined description to further define the data, such as PLAN A, FORECAST 1, etc.

In general, DSS software finds the data associated with a pathname by using each of the six parts to search the DSS file structure, which is hierarchical, or "tree-like." An example of a pathname for a time-series data record is:

/MISSISSIPPI/CAIRO/STAGE/01JAN1985/1HOUR/OBSERVED/

This pathname would represent a block of observed hourly stages on the Mississippi River at Cairo for all or part of 1985 beginning January 1.

1.2 Access to/from DSS

HEC-1 can interact with DSS as follows: retrieve runoff parameters stored in DSS by program HYDPAR (Corps of Engineers, 1978); retrieve and/or store time-series data; and store flow-frequency curves. The access to this data is accomplished using the BZ, ZR and ZW records in the HEC-1 input data set.

The ZR and ZW records are used in a somewhat different manner depending on which type of the above data is being manipulated. In each case, however, these records are used to specify the appropriate DSS pathname. The BZ record is used specifically for the retrieval of runoff parameters.

The HEC-1 input conventions do not require that information be specified for all parts of the pathname. In general, pathname part D is left blank and other parts are only used as required by the type of data being manipulated. Part D is obtained by requiring that the date in field 2 of the IT record be specified.

2 Retrieval of HYDPAR Runoff Parameters

Retrieval of runoff parameters is accomplished with a record sequence as shown in Table B.1. In this instance the BZ record is substituted for the record used to specify the basin area (BA record) and the ZR record is used to retrieve either the SCS loss rate and unit graph data (LS and UD records) or the Snyder unit graph data (US Record). If the Snyder unit graph is retrieved from DSS, the loss rate must be supplied separately in the HEC-1 input data.

The BZ and ZR records can be used in either fixed or free format modes independent of the input mode for the rest of the data. As an example of the BZ and ZR record formats, consider the pathname,

A B E F
/MISSISSIPPI/CAIRO///1985/PLAN A/

the BZ and ZR record would then have the following fixed form:

Table B.1

Record Sequence to Access HYDPAR Runoff Parameter Data from DSS

ID	
IT	
IO	
JP	(required for multiplan simulation)
JR	(required for multiratio simulation)
:	
KK	
KP	(only required if multiplan simulation)
ZR	
BZ	
L	(only required if Snyder unit graph is used)
KP	(only required if multiplan simulation)
ZR	
BZ	
:	
:	
KK	
:	
ZZ	

Field	**Variable Value**	
0	ID=BZ	
1	ISTA=CAIRO	(Part B)

Field	**Variable Value**	
0	ID=ZR	
1-2	PRNAME=MISSISSIPPI	(Part A)
3-5	PLNAME=PLAN A	(Part F)
6	IYR=1985	(Part E)
7	CODE=BZ	(right justified columns 55-56)
8	PLAN=1	(corresponds to appropriate plan)

or in free format:

ZR=BZ A=MISSISSIPPI B=CAIRO E=1985 F=PLAN A

Note, that parts C and D are left blank.

3 Retrieval of Time-Series Data

The time-series data that can be retrieved with the ZR record are cumulative or incremental precipitation and discharge hydrographs, corresponding to data which can be specified on PC, PI, QI or QO records. The record sequence needed to perform this operation is shown in Table B.2. This option is useful in either stream network or multiplan-multiratio simulations.

Table B.2
Record Sequence to Read or Write DSS Time-Series Data

ID	
IT	
IO	
JP	(required for multiplan simulation)
JR	(required for multiratio simulation)
:	
KK	
:	other input data
KP	(required for multiplan simulation)
ZR or ZW	
:	other input data
KK	
:	
ZZ	

Pathname part D is not used. The program uses information on the IT record in the place of information normally specified with part D. Pathname part E may be specified as standard DSS intervals to read DSS data at a different interval than the computation interval specified on the IT record. If no part E is specified then the **computation interval specified on the IT** record is used to create pathname part E. The standard PART E intervals are specified as 5MIN, 10MIN, 15MIN, 30MIN, 1HOUR, 2HOUR, 3HOUR, 4HOUR, 6HOUR, 12HOUR, 1DAY, 1WEEK, 1MON, 1YEAR. As an example application, consider the pathname needed to retrieve an observed hydrograph:

A B C E F
/MISSISSIPPI/CAIRO/FLOW//15MIN/OBS/

Retrieval of that data requires a ZR record as follows:

ZR=QO A=MISSISSIPPI B=CAIRO C=FLOW E=15MIN F=CALC

where all the pathname part descriptors and the type of time-series data is specified by the "=QO". Note that the additional parameter "=aa", must set the value "aa" equal to PC, PI, QI or QO to indicate the type of time-series data.

In contrast to the HYDPAR data retrieval, the ZR time series retrieval format is used with the fixed or free input for the rest of the data. Further, for multiplan simulations, a KP record must be used with each ZR record for each plan. The program will then retrieve a single time-series sequence with each plan and apply the ratios specified on the JR record. The retrieved time series data will be interpolated from any standard DSS time interval to the computation interval of the program.

4 Storing Time-Series Data

Flow, storage or stage time-series data may be stored in DSS using the ZW record. The ZW convention is similar to the use of the ZR record (see Table B.2). Using the previous example for the ZR record, the ZW record specifies the pathname as:

ZW A=MISSISSIPPI B=CAIRO C=FLOW F=CALC

The pathname part C dictates which type of data (flow, storage or stage) is written to DSS. If more than one type of data is to be written as part of a DSS command sequence, then only part B and C need be repeated. Using the above example, if an addition to flow, stage and storage are to be written, then the following records would be specified:

ZW B=CAIRO C=STOR
ZW B=CAIRO C=STAGE

Note that parts A and F need not be repeated. If part B were not used, then the station name on the KK record would be used for location name.

As in the case of the ZR record, the ZW data IS USED IN THE FREE **format mode**. However, the application of the ZW record differs slightly in that for each plan all ratios of the computed time series are saved (as opposed to a single time-series trace for the ZR record). The pathname part F need not be repeated for each plan, as the program automatically assumes the description given for plan 1. As in the case of the ZR record, a KP record must be used with each ZW record for each plan.

5 Storing Flow- or Stage-Frequency Curves

Flow- or stage-frequency curves may be stored in DSS using the ZW record (see Table B.3). This option is most useful with multiplan flood damage computations; however, flood damage computations are not required in order to write the flow-frequency curves to DSS. Although a single frequency curve may be stored using a single plan, it is probably easier to directly input a single frequency curve to the EAD program (Hydrologic Engineering Center, 1979a).

Flow or stage frequency data are stored for **each plan** as indicated by a PN, ZW, etc., record combination as noted in Table B.3. A frequency curve for plan 1 on the QF or SF, FR records is required. The economic calculation will be carried out so dummy data needs to be provided on CN, QD, and DG records if real economic computations are not being made. For frequency curve storage, the ZW record utilizes a **fixed or free field format to specify the pathname**. Either format mode may be used independently of the input mode for the rest of the data.

Table B.3

Record Sequence to Store Flow-Frequency Curves in DSS

```
IT
IO
JP
JR
:
KK                    (runoff computation KK Record sets)
:
EC                    (indicates economic computations)
KK                    (location for frequency curve computation)
CN        1           (dummy data for economics)
PN        1      Plan Name
ZW                    (this will write given frequency curve to DSS)
FR
QF or SF     }        (given frequency curve for Plan 1 conditions)
QD        1           2         10         10000     (dummy data for economics)
DG        1  1
EP
PN        2      Plan Name
ZW                    (this writes modified frequency curve for Plan 2 conditions to DSS)
EP
.
.                     repeat PN,ZW,EP for each plan
.
KK                    do similarly for other locations as needed
:
ZZ
```

HEC-1 Input Description
DSS Records

6 HEC Data Storage System (DSS) Records

6.1 BZ Record - HYDPAR Parameter Retrieval (Fixed Format Option)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BZ	Record identification.
1	ISTA	AN	Station name (part B of pathname). This must be identical to the station name used in the HYDPAR run. Alphanumeric data.

6.2 ZR Record

The ZR record has two types of retrieval, the HYDPAR parameter retrieval or the time-series data retrieval. Either type of retirieval can be in fixed format or free format. The follow sections describe each method.

6.2.1 ZR Record - HYDPAR Parameter Retrieval (Fixed Format Option)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ZR	Record identification.
1-2	PRNAME	AN	Study, basin, etc. name (part A of pathname).
3-5	PLNAME	AN	Alternative name or designation (part F of pathname).
6	IYR	+	Data year (part E of pathname) in columns 45-48.
7	CODE	BZ	Record type for DSS read; columns 55-56.
8	PLAN	+	Plan number. Enter a right-justified integer.

HEC-1 Input Description
DSS Records

6.2.2 ZR Record - HYDPAR Parameter Retrieval (Input in Free Format)

FIELD	VARIABLE	VALUE	DESCRIPTION
0		ZR	Record identification.
		=BZ	
		A=AN	Study, basin, etc. name, beginning or after column 4 (part A of pathname).
		B=AN	Station name (part B of pathname). This must be identical to the station name used in the HYDPAR run.
		E=AN	Data year (part E of pathname)
		F=AN	Alternative name or designation (part F of pathname).

6.2.3 ZR record - Retrieval of Time-Series Data (Input in Free Format)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	D	ZR	Record identification.
		=AN	HEC-1 record identifier. It must begin in or after column 4 and be identical to one of the following: =PC Cumulative precipitation. =PI Incremental precipitation. =QI Input hydrograph. =QO Observed hydrograph.
		A=AN	Pathname part A - usually the study, project, or river basin name.
		B=AN	Pathname part B - usually the location name. If only part B is not specified, it will be defined by the first field in the preceding KK record.

HEC-1 Input Description
DSS Records

6.2.3 ZR Record - Retrieval of Time-Series Data (Input in Free Format) (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
		C=AN	Parameter name (options are FLOW or PRECIP)
		E=AN	Time interval of DSS data (e.g., E=15MIN) computation interval specified on IT record. Must be a standard DSS time interval; 5MIN, 10MIN, 15MIN, 30MIN, 1HOUR, 2HOUR, 3HOUR, 4HOUR, 6HOUR, 1DAY (see HECDSS User's Guide and Utility Program Manuals, pg. C-3).
		F=AN	Additional parameter qualifier (e.g., OBS for observed flow).

6.3 ZW Record

This record allows the user to store time-series data in a free format mode. Also, the user can store flow frequency curves either using fixed format or free format. Each method is described in the following sections.

6.3.1 ZW record - Writing Time-Series Data to DSS (Input in Free Format)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ZW	Record identification.
		A=AN	Pathname part A - beginning in or after column 4.
		B=AN	Pathname part B - usually study, project or river basin name. If part B is not specified, it will be defined by the first field in the preceding KK record.
		C=AN	Parameter name - it must be identical to one of the following: C=FLOW C=STORE C=STAGE C=ELEV
		F=AN	Additional parameter qualifier (e.g., OBS for observed flow). Required for plan 1.

HEC-1 Input Description
DSS Records

6.3.2 ZW record - Writing Flow Frequency Curves to DSS (Fixed Format Option)

FIELD	VARIABLE	VALUE	DESCRIPTION
0		ZW	Record identification.
1-2	PRNAME	AN	Study, project or basin name (part A of the DSS pathname).
3-5	PLNAME	AN	Study or plan alternative (part F of the DSS pathname).
6	IYR	AN	Data year (part E of the DSS pathname). The data year must be entered in columns 45-48.

6.3.3 ZW record - Writing Flow Frequency Curves to DSS (Free Format Option)

This record must always follow a PN record in the economic data. The conventions for specifying this record are analogous to the reading of HYDPAR data.

FIELD	VARIABLE	VALUE	DESCRIPTION
0		ZW	Record identification.
		A=AN	Study, project or basin name (pathname part A) - beginning in or after column 4.
		E=AN	Data year (part E of the DSS pathname).
		F=AN	Study or plan alternative (part F of the DSS pathname).

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