HEC-6

Scour and Deposition In Rivers and Reservoirs

Users Manual

August 1993

WEST Consultants, Inc.
Water • Environmental • Sedimentation • Technology
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US Army Corps
of Engineers
Hydrologic Engineering Center

GENERALIZED COMPUTER PROGRAM

HEC-6

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User's Manual

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CPD-6

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	5/9*	degrees Celsius or Kelvin
feet	0.3048	meters
inches	2.54	centimeters
miles (US statute)	1.609347	kilometers
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C=(5/9)(F-32). To obtain Kelvin (K) readings, use: K=(5/9)(F-32)+273.15.

Foreword

HEC-6 development was initiated by William A. (Tony) Thomas at the Little Rock District of the Corps of Engineers. That program evolved into Version 2.7 in 1976 while Mr. Thomas was at the Hydrologic Engineering Center (HEC). Since then, program development by Mr. Thomas and his staff has continued at the Waterways Experiment Station (WES). Version 3.2 was released by HEC in 1986. That version was ported to MS-DOS by HEC, and was the HEC "Library Version" of HEC-6 until replaced by Version 4.0 in 1991.

Version 4.0 was developed at HEC from the 1988 "Network Version" of HEC-6 (sometimes called TABS-1) developed at WES. Mr. Thomas had added stream network capability, as well as additional transport functions and a more complete computation of cohesive sediment resuspension, and modified the movable bed width computation (see Section 2.2.4). Ms. Joan Tinios, working at HEC under the direction of Dr. Michael Gee upgraded the source code to FORTRAN 77 Standard. Miscellaneous changes to program output and minor error corrections were also performed at that time. Because of these changes, some computed results may differ from earlier versions.

In 1993, further modifications were made to Version 4.0. Version 4.1 will compute sediment transport of grain sizes up to 2048 mm. While several new records have been added to facilitate data input, we have tried to maintain the capability to use input data from earlier program versions. HEC-6 output has also been improved.

Current information regarding availability of this and other programs is available from HEC. While the U.S. Government is not responsible for the results obtained from this program, identified errors will be eliminated to the extent that time and funds are available. HEC-6 users are encouraged to notify HEC of any suspected errors.

This manual documents Version 4.1 of the HEC-6 computer program, "Scour and Deposition in Rivers and Reservoirs." The first draft was written in 1989 by Mr. David Williams, under contract with HEC. HEC staff edited and revised the draft and added the Input Description (Appendix A), the Glossary (Appendix B), and an index. The manual was released with Version 4.0 of HEC-6 in June of 1991. Since then, minor errors and discrepancies have been corrected and those corrections have been incorporated into this update of the manual and program.

Chapter 1

Introduction

1.1 Model Purpose and Philosophy

HEC-6 is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and/or deposition over moderate time periods (typically years, although applications to single flood events are possible). A continuous flow record is partitioned into a series of steady flows of variable discharges and durations. For each flow a water surface profile is calculated thereby providing energy slope, velocity, depth, etc. at each cross section. Potential sediment transport rates are then computed at each section. These rates, combined with the duration of the flow, permit a volumetric accounting of sediment within each reach. The amount of scour or deposition at each section is then computed and the cross section adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. The sediment calculations are performed by grain size fraction thereby allowing the simulation of hydraulic sorting and armoring. Features of HEC-6 include: capability to analyze networks of streams, channel dredging, various levee and encroachment alternatives, and to use several methods for computation of sediment transport rates.

Separation of sediment deposition from the hydraulics of flow is valid in some circumstances; for example, deposition in deep reservoirs can usually be characterized as a progressive reduction in storage capacity if the material is rarely entrained once it is deposited. Prediction of sediment behavior in shallow reservoirs and most rivers, however, requires that the interactions between the flow hydraulics, sediment transport, channel roughness and related changes in boundary geometry be considered. HEC-6 is designed to incorporate these interactions into the simulation.

HEC-6 simulates the capability of a stream to transport sediment, given the yield from upstream sources. This computation of transport includes both bed and suspended load as described by Einstein's Bed-Load Function (1950)[1]. A reach of river with a bed composed of the same type of sediment material as that moving in the stream is termed an "alluvial" reach (Einstein 1950). Einstein recognized that an alluvial reach provides a record of the sediment that the stream has, and does, transport. That record is reflected in the materials that form the stream boundaries. Using the hydraulic properties of the flow and the characteristics of the sediment material (which can be determined by analyzing samples of the riverbed sediment particles), one can compute the rate of sediment transport. HEC-6 implements similar concepts to compute the movement of sediment materials for a temporal sequence of flows and, through volume conservation of bed material, changes in channel dimensions. The transport, deposition, and erosion of silts and clays may also be calculated. Effects of the creation and removal of an armor layer are also simulated.

[1] Although Einstein's Bed-Load Function is not included in this version of HEC-6, his concepts of particle movement and interchange have guided development of the algorithms used in HEC-6 to describe the dynamic interactions between bed material composition and bed material transport.

1.2 Applications of HEC-6

A dynamic balance exists between the sediment moving in a natural stream, the size and gradation of sediment material in the stream's boundaries and the flow hydraulics. When a reservoir is constructed, flood damage reduction measures are implemented, or a minimum depth of flow is maintained for navigation, that balance may be changed. HEC-6 can be used to predict the impact of making one or more of those changes on the river hydraulics, sediment transport rates, and channel geometry.

HEC-6 is designed to simulate long-term trends of scour and/or deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and/or stage, or from modifying the channel geometry (e.g., encroaching on the floodplains). HEC-6 can be used to evaluate deposition in reservoirs (both the volume and location of deposits), design channel contractions required to maintain navigation depths or decrease the volume of maintenance dredging, predict the influence that dredging has on the rate of deposition, estimate possible maximum scour during large flood events, and evaluate sedimentation in fixed channels. Some early applications of HEC-6 were described by Thomas and Prasuhn (1977) and more recent application advice is provided by HEC (1992). Guidelines for performing sedimentation studies is given in USACE (1989) and river hydraulics studies in USACE (1993).

1.3 Overview of Manual

This manual describes the fundamental concepts, numerical model limitations and capabilities, computational procedures, input requirements and output of HEC-6. A brief description of model capabilities and the organization of this manual is presented below.

Theoretical Basis For Movable Boundary Calculations (Chapter 2)

This chapter describes the theoretical basis for hydraulic and sediment computations used in the computer program HEC-6. It presents the general capabilities of the program and describes how the computations are performed.

General Input Requirements (Chapter 3)

This chapter describes the general data requirements of HEC-6. It describes the input data required for implementation of specific HEC-6 capabilities.

Program Output (Chapter 4)

This chapter provides information on the various output levels available for displaying the geometric, sediment, and hydrologic data; and for listing the initial and boundary conditions. It also describes how to save desired information at selected times during a simulation.

Modeling Guidelines (Chapter 5)

General modeling guidelines and additional information on how HEC-6 performs its computations are presented in this chapter.

Example Problems (Chapter 6)

This chapter gives example applications of HEC-6. It covers single river and network situations and some commonly used features of the program.

1.4 Summary of HEC-6 Capabilities

1.4.1 Geometry

A river system consisting of a main stem, tributaries and local inflow/outflow points can be simulated. Such a system in which tributary sediment transport is calculated is referred to in this document as a **network model**. Sediment transport is calculated by HEC-6 in primary rivers and tributaries. There will be upper limits on the number of network branches, number of cross sections, etc., due to computer memory limitations. As these may change among HEC-6 implementations on various computer systems, the user should check the header on the output file to determine the limits of the particular version being used.

1.4.2 Hydraulics

The one-dimensional energy equation (USACE 1959) is used by HEC-6 for water surface profile computations. Manning's equation and *n* values for overbank and channel areas may be specified by discharge or elevation. Manning's *n* for the channel can also be varied by Limerinos' (1970) method using the bed gradation of each cross section. Expansion and contraction losses are included in the determination of energy losses. The energy loss coefficients may be changed at any cross section.

For each discharge in a hydrograph, the downstream water surface elevation can be determined by either a user-specified rating curve or a time dependent water surface elevation. Internal boundary conditions can be imposed on the solution. The downstream rating curve can be changed at any time. Internal boundary conditions can also be changed at any time.

Flow conveyance limits, containment of the flow by levees, ineffective flow areas, and overtopping of levees are simulated in a manner similar to HEC-2. Split flow computations are not done and no special capability for computing energy losses through bridges is available. Supercritical flow, should it occur, is approximated by normal depth; therefore, sediment transport phenomena occurring in supercritical reaches are simplified in HEC-6.

HEC-6 can be executed in "fixed bed" mode, which is similar to an HEC-2 application, in that only water surface profiles are computed. Sediment information such as inflowing sediment load and bed gradations are not needed to run HEC-6 in fixed-bed mode.

1.4.3 Sediment

Sediment transport rates are calculated for grain sizes up to 2048 mm. Sediment sizes larger than 2048 mm, that may exist in the bed, are used for sorting computations but are not transported. For deposition and erosion of clay and silt sizes up to 0.0625 mm, Krone's (1962) method is used for deposition and Ariathurai and Krone's (1976) adaptation of Parthenaides' (1965) method is used for scour. The default procedure for clay and silt computations allows only deposition using a method based on settling velocity.

The sediment transport function for bed material load is selected by the user. Transport functions available in the program are the following:

a. Toffaleti's (1966) transport function
b. Madden's (1963) modification of Laursen's (1958) relationship
c. Yang's (1973) stream power for sands
d. DuBoys' transport function (Vanoni 1975)
e. Ackers-White (1973) transport function
f. Colby (1964) transport function
g. Toffaleti (1966) and Schoklitsch (1930) combination
h. Meyer-Peter and Müller (1948)
i. Toffaleti and Meyer-Peter and Müller combination
j. Madden's (1985, unpublished) modification of Laursen's (1958) relationship
k. Modification by Ariathurai and Krone (1976) of Parthenaides' (1965) method for scour and Krone's (1962) method for deposition of cohesive sediments
l. Copeland's (1990) modification of Laursen's relationship (Copeland and Thomas 1989)
m. User specification of transport coefficients based upon observed data

The above methods (except for method a.), utilize the Colby (1964) method for adjusting the sediment transport potential when the wash load concentration is high. Armoring and destruction of the armor layer are simulated based upon Gessler's (1970) approach. Deposition or scour is modeled by moving each cross section point within the movable bed (i.e., the area which is shifted vertically each time step due to sediment movement).

The movable bed limits may extend beyond the channel bank "limits". Deposition is allowed to occur in all wetted areas, even if the wetted areas are beyond the conveyance or movable bed limits. Scour occurs only within the movable bed limits. Sediment transport potential is based upon the hydraulic and sediment characteristics of the channel alone. Simulation of geological controls such as bedrock or a clay layer may be done by specifying a minimum elevation for the movable bed at any particular cross section.

The sediment boundary conditions (inflowing sediment load as a function of water discharge) for the main river channel, its tributaries and local inflow/outflow points can be changed with time. HEC-6 has the capability to simulate the diversion of water and sediment by grain size. A transmissive boundary condition is available at each downstream boundary; this boundary condition forces all sediment entering that section to pass it, resulting in no scour or deposition at that section.

1.4.4 General

Computed information includes the total sediment discharge passing each cross section and the volume of deposits (or scour) accumulated at each cross section from the beginning of the simulation. HEC-6 also has the ability to simulate the effects of dredging activities. Dredging can be initiated when a depth of deposition is exceeded or can occur on a periodic basis. Dredging can also be based upon a required minimum depth for navigation.

Should a river network of a main stem and tributaries be simulated, HEC-6 uses the same data that previous versions had used if each river and tributary segment were being analyzed independently. Control point data must be supplied to link the geometric segments together into a complete stream network. Data sets from earlier versions of HEC-6 that include local inflows can be used if all **$TRIB** records are replaced by **$LOCAL** records and a water temperature is entered for each local inflow point.

1.5 Theoretical Assumptions and Limitations

HEC-6 is a one-dimensional continuous simulation model that uses a sequence of steady flows to represent discharge hydrographs. There is no provision for simulating the development of meanders or specifying a lateral distribution of sediment load across a cross section. The cross section is subdivided into two parts with input data; that part which has a movable bed, and that which does not. The movable bed is constrained within the limits of the wetted perimeter and other limitations that are explained later. The entire wetted part of the cross section is normally moved uniformly up or down; an option is available, however, which causes the bed elevation to be adjusted in horizontal layers when deposition occurs. Bed forms are not simulated; however, *n* values can be input as functions of discharge, which indirectly permits consideration of the effects of bed forms if the user can determine those effects from measured data. Limerinos' (1970) method is available as an option for computation of bed roughness. Density and secondary currents are not simulated.

There are three restrictions on the description of a network system within which sediment transport can be calculated with HEC-6:

a. Sediment transport in distributaries is not possible.
b. Flow around islands; i.e., closed loops, cannot be directly accommodated.
c. Only one junction or local inflow point is allowed between any two cross sections.

1.6 Single Event Analysis

HEC-6 is designed to analyze long-term scour and/or deposition. Single flood event analyses must be performed with **caution**. HEC-6 bed material transport algorithms assume that equilibrium conditions are reached within each time step (with certain restrictions that will be explained later); however, the prototype is often influenced by unsteady non-equilibrium conditions during flood events. Equilibrium may not occur under these conditions because of the continuously changing hydraulic and sediment dynamics. If such situations predominate, single event analyses should be performed only on a qualitative basis. For gradually changing sediment and hydraulic conditions, such as for large rivers with slow rising and falling hydrographs, single event analyses may be performed with confidence.

Chapter 2

Theoretical Basis for Movable Boundary Calculations

2.1 Overview of Approach and Capabilities

This chapter presents the theories and concepts embodied in HEC-6. Information regarding implementation of these theories and concepts in HEC-6 is presented in Chapter 3.

2.1.1 General

HEC-6 processes a discharge hydrograph as a sequence of steady flows of variable durations. Using continuity of sediment, changes are calculated with respect to time and distance along the study reach for the following: total sediment load, volume and gradation of sediment that is scoured or deposited, armoring of the bed surface, and the cross section elevations. In addition, sediment outflow at the downstream end of the study reach is calculated. The location and amount of material to be dredged can be obtained if desired.

2.1.2 Geometry

Geometry of the river system is represented by cross sections which are specified by coordinate points (stations and elevations) and the distances between cross sections. HEC-6 raises or lowers cross section elevations to reflect deposition and scour. The horizontal locations of the channel banks are considered fixed and the floodplains on each side of the channel are considered as having fixed ground locations; however, they will be moved vertically if they are within the movable bed limits specified by the user.

2.1.3 Hydraulics and Hydrology

The water discharge hydrograph is approximated by a sequence of steady flow discharges, each of which continues for a specified period of time. Water surface profiles are calculated for each flow using the standard-step method to solve the energy and continuity equations. Friction loss is calculated by Manning's equation and expansion and contraction losses are calculated if the loss coefficients are specified. Hydraulic roughness is described by Manning's n values and can vary from cross section to cross section. At each cross section n values may vary vertically or with discharge.

The downstream water surface elevation must be specified for subcritical water surface profile calculations. In the case of a reservoir the operating rule may be utilized, but if open river conditions exist, a stage-discharge rating curve is usually specified as the downstream boundary condition. A boundary condition or operating rule may be used at any location along the main stem or tributaries.

2.1.4 Sediment Transport

Inflowing sediment loads are related to water discharge by sediment-discharge curves for the upstream boundaries of the main stem, tributaries and local inflow points. For realistic computation of stream behavior, particularly scour and stable conditions, the gradation of the material forming the stream bed must be measured. HEC-6 allows a different gradation at each cross section. If only deposition is expected, the gradation of material in the bed is less important.

Sediment gradations are classified by grain size using the American Geophysical Union scale. HEC-6 will compute transport potential for clay (particles less than 0.004 mm diameter), four classes of silt (0.004-0.0625 mm), five classes of sand (from very fine sand, 0.0625 mm, to very coarse sand, 2.0 mm), five classes of gravel (from very fine gravel, 2.0 mm, to very coarse gravel, 64 mm), two class of cobbles (from small, 64mm, to large cobbles, 256mm) and three classes of boulders (from small, 256mm, to large boulders, 2048mm).

Transport potential is calculated at each cross section using hydraulic information from the water surface profile calculation (e.g., width, depth, energy slope, and flow velocity) and the gradation of bed material. Sediment is routed downstream after the backwater computations are made for each successive discharge (time step).

2.2 Theoretical Basis for Hydraulic Calculations

The basis for water surface profile calculations is essentially Method II, which is described in "Backwater Curves in River Channels," EM 1110-2-1409 (USACE 1959). Conveyance is calculated from average areas and average hydraulic radii for adjacent cross sections.

2.2.1 Equations for Water Surface Profile Calculations

The hydraulic parameters needed to calculate sediment transport potential are velocity, depth, width and energy slope - all of which are obtained from water surface profile calculations. The one-dimensional energy equation (Equation 2-1) is solved using the standard step method and the hydraulic parameters are calculated at each cross section for each successive discharge. Figure 2-1 shows a representation of the terms in the energy equation.

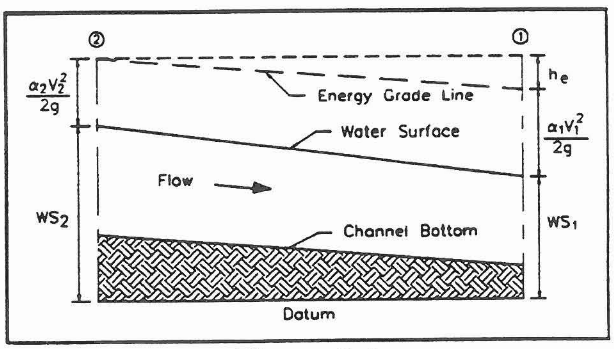

Figure 2-1
Energy Equation Terms

$$WS_2 + \frac{\alpha_2 V_2^2}{2g} = WS_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad (2\text{-}1)$$

where:

- g = acceleration of gravity
- h_e = energy loss
- V_1, V_2 = average velocities (total discharge ÷ total flow area) at ends of reach
- WS_1, WS_2 = water surface elevations at ends of reach
- α_1, α_2 = velocity distribution coefficients for flow at ends of reach.

2.2.2 Hydraulic Losses

2.2.2.1 Friction Losses

River geometry is specified by cross sections and reach lengths; friction losses are calculated by Method II (USACE 1959). The energy loss term, h_e, in Equation 2-1 is composed of friction loss, h_f, and form losses, h_o, as shown in Equation 2-2. Only contraction and expansion losses are considered in the geometric form loss term.

$$h_e = h_f + h_o \qquad (2\text{-}2)$$

To approximate the transverse distribution of flow, the river is divided into strips having similar hydraulic properties in the direction of flow. Each cross section is subdivided into portions that are referred to as subsections. Friction, h_f, loss is calculated as shown below:

$$h_f = \left[\frac{Q}{K_t'}\right]^2 \qquad (2\text{-}3)$$

in which:

$$K_t' = \sum_{j=1}^{NSS}\left[\frac{1.49}{n_j}\right]\frac{\frac{(A_2 + A_1)_j}{2}\left[\frac{R_2 + R_1}{2}\right]_j^{2/3}}{L_j^{1/2}} \qquad (2\text{-}4)$$

where:

A_1, A_2	=	downstream and upstream area, respectively, of the flow normal to the cross sections
NSS	=	total number of subsections across each cross section
K'_t	=	length-weighted subsection conveyance
L_j	=	length of the j^{th} strip between subsections
n	=	Manning's roughness coefficient
Q	=	water discharge
R_1, R_2	=	downstream and upstream hydraulic radius, respectively.

2.2.2.2 Other Losses

Energy losses due to contractions and expansions are computed by the following equation:

$$h_o = C_L\left|\frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g}\right| \qquad (2\text{-}5)$$

where: C_L = loss coefficient for expansion or contraction

If the quantity within the absolute value notation is negative, flow is contracting and C_L is the coefficient of contraction; if it is positive, flow is expanding and C_L is the coefficient of expansion.

2.2.3 Computation of Hydraulic Elements

Each cross section is defined by coordinates (X,Y) as shown in Figure 2-2. For convenience of assigning *n* values, reach lengths, etc., each cross section is divided into subsections, usually consisting of a main channel, with left and right overbanks.

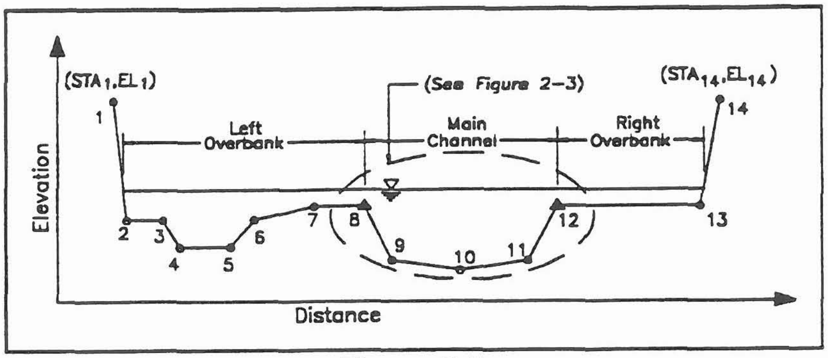

Figure 2-2
Typical Representation of a Cross Section

2.2.3.1 Subsection Area

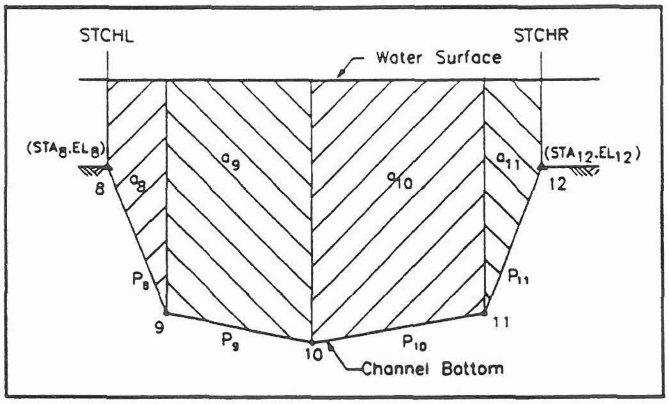

Figure 2-3
Incremental Areas in Channel Subsection

The area of each subsection is computed by summing incremental areas below the water surface between consecutive coordinates of the cross section. Figure 2-3 illustrates the technique with a subsection of Figure 2-2 where STCHL and STCHR are the lateral boundaries of the subsection.

The area of the channel subsection is:

$$A_j = a_8 + a_9 + a_{10} + a_{11} \tag{2-6}$$

where: a_i = incremental area.

The equation for an incremental area, a_i, is:

$$a_i = \frac{(d_i + d_{i+1})\,W}{2} \tag{2-7}$$

where: d_i, d_{i+1} = the left and right depth of each incremental area, respectively (see Figure 2-4)

W = width of an incremental area.

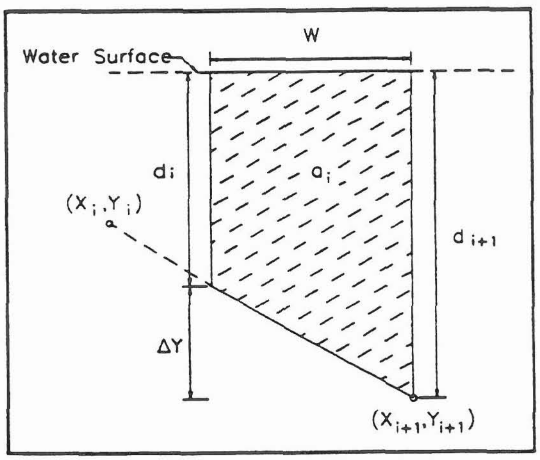

Figure 2-4
Incremental Area

Normally, d_i, d_{i+1} and W are defined by two consecutive cross section coordinate points, as shown in Figure 2-4. However at the first and last increments in each subsection, a subsection station defines one side of the incremental area. If the subsection station does not coincide with an X coordinate, straight line interpolation is used to compute the length of either, d_i, d_{i+1}, or both.

2.2.3.2 Wetted Perimeter

The wetted perimeter, P, is computed as the length of the cross section below the water surface. In the case of Figure 2-3, this is:

$$P = P_8 + P_9 + P_{10} + P_{11} \tag{2-8}$$

where: P_i = incremental wetted perimeter.

The equation for the wetted perimeter of the incremental area in Figure 2-4 is:

$$P_i = (\Delta Y^2 + W^2)^{1/2} \tag{2-9}$$

where: ΔY and W are as shown in Figure 2-4.

Note that only the distance between coordinate points is considered in p_i, not the depths d_i and d_{i+1}. In other words, friction due to shear forces between subsections is not considered.

2.2.3.3 Hydraulic Radius

The hydraulic radius, R, is calculated for each subsection, $_j$, by:

$$R_j = \frac{A_j}{P_j} \tag{2-10}$$

where: A_j = area of subsection
P_j = wetted perimeter of subsection
R_j = hydraulic radius of subsection.

2.2.3.4 Conveyance

The conveyance, K_j, is computed for each subsection, $_j$, by:

$$K_j = \frac{1.49}{n_j} A_j R_j^{2/3} \tag{2-11}$$

The total conveyance, K_t, in the cross section is:

$$K_t = \sum_{j=1}^{NSS} K_j \tag{2-12}$$

where: NSS = total number of subsections.

2.2.3.5 Velocity Distribution Factor, Alpha

Alpha is an energy correction factor to account for the transverse distribution of velocity across the floodplains and channel. Large values of alpha (>2) will occur if the depth of flow on the overbanks is shallow, the conveyance is small, and the area is large. Alpha is computed as follows:

$$\alpha = \frac{\sum_{j=1}^{NSS} \left[\frac{K_j^3}{A_j^2}\right]}{\left[\frac{K_t^3}{A_t^2}\right]} \tag{2-13}$$

2.2.3.6 Effective Depth and Width

The sediment transport capacity for non-rectangular sections is calculated using a weighted depth, EFD, called the effective depth. The corresponding effective width, EFW, is calculated from the effective depth to preserve $A(D^{2/3})$ for the cross section.

$$EFD = \frac{\sum_{i=1}^{i_t} D_{avg} \cdot a_i \cdot D_{avg}^{2/3}}{\sum_{i=1}^{i_t} a_i \cdot D_{avg}^{2/3}} \qquad (2\text{-}14)$$

$$EFW = \frac{\sum_{i=1}^{i_t} a_i \cdot D_{avg}^{2/3}}{EFD^{5/3}} \qquad (2\text{-}15)$$

where: a_i = flow area of each trapezoidal element
D_{avg} = average water depth of each trapezoidal element
i_t = the total number of trapezoidal elements in a subsection

The sediment transport computation is based upon hydraulics of the main channel only; therefore, the hydraulic elements are from the geometry within the channel limits only.

2.2.3.7 Critical Depth Calculations

To assess if the backwater profiles remain above critical depth, the critical section factor, CRT, is computed using Equation 2-16, and compared with the computed section factor at each cross section.

$$CRT = \frac{Q}{\left(\frac{g}{\alpha}\right)^{1/2}} \qquad (2\text{-}16)$$

A computed section factor, ZSQ, is calculated for comparison to CRT.

$$ZSQ = A_t \left(\frac{A_t}{W_t}\right)^{1/2} \qquad (2\text{-}17)$$

where: A_t = total area of cross section
W_t = total water surface width

If CRT is less than ZSQ, subcritical flow exists and computations continue. Otherwise, critical depth is calculated by tracing the specific energy curve to the elevation of minimum total energy and the resulting water surface elevation is compared with the water surface elevation calculated by Equation 2-1 to decide if flow is supercritical. If supercritical flow is indicated, flow depth is determined as described in the following section.

2.2.3.8 Supercritical Flow

In the standard step method for water surface profile computations, calculations proceed from downstream to upstream based upon the reach's starting water surface elevation. At each cross section, HEC-6 examines the appropriate hydraulic parameters to determine if the reach is a subcritical or supercritical flow reach. If flow is subcritical, computations proceed upstream in the manner described in Section 2.2.1. If it is supercritical, HEC-6 approximates the channel geometry using the effective depth and width as described in Section 2.2.3.6 and determines the water surface elevation based upon the supercritical normal depth.

If a subcritical reach is eventually encountered, the downstream cross section of the reach is assumed to be at critical depth and backwater computations proceed upstream for assumed subcritical flow conditions. Note that for subcritical flow, M1 and M2 curves are possible in HEC-6 but under supercritical flow, S1 and S2 curves are not computed because only supercritical normal flow depths are calculated. An example of such a series of profiles is shown in Figure 2-5.

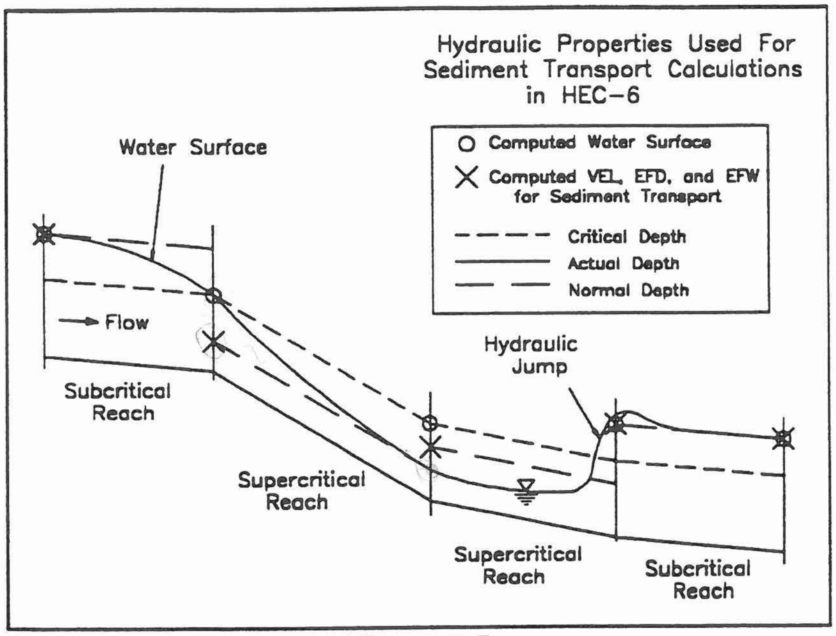

Figure 2-5
Examples of Subcritical, Critical, and Supercritical Flow Simulations in HEC-6

2.2.3.9 Convergence Equations

Three major steps are used to converge computational trials in computing the upstream cross section water surface elevation. Figure 2-6 demonstrates the sequence of successive trials to converge the standard step method.

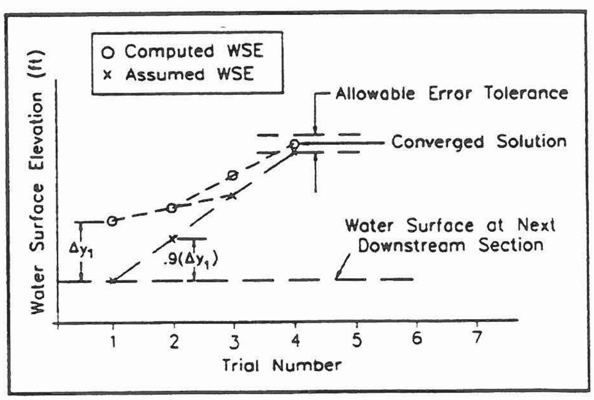

Figure 2-6
Convergence of Assumed and Computed Water Surface Elevations

Computational Procedure:

Trial 1: Based on the previous water surface elevation.

Trial 2: Assumed change is ninety percent of ΔY_1

Trial 3: Trial 1 and 2 elevations assumed are connected with a straight line and the computed Trial 1 and 2 solutions are also connected with a straight line. The intersection of these lines becomes Trial 3's assumed value.

Trial 4, etc.: This process continues until the assumed and computed values of water surface elevation are within the allowable error tolerance. If they are, the computed water surface elevation becomes the converged solution.

Oscillation between positive and negative "error" is permitted. A note is printed in the event a solution is "forced" (after 20 trials) even though the "error" is greater than the allowable error. In this case, the last computed water surface elevation is used.

2.2.4 Representative Hydraulic Parameters Used in Sediment Calculations

Hydraulic parameters are converted into representative (weighted) values for each reach prior to calculating transport capacity. General equations are shown below. These weighting factors can be modified with input data.

Interior Point (section)

$$VEL = XID \cdot VEL(K-1) + XIN \cdot VEL(K) + XIU \cdot VEL(K+1) \tag{2-18}$$

$$EFD = XID \cdot EFD(K-1) + XIN \cdot EFD(K) + XIU \cdot EFD(K+1) \tag{2-19}$$

$$EFW = XID \cdot EFW(K-1) + XIN \cdot EFW(K) + XIU \cdot EFW(K+1) \tag{2-20}$$

$$SLO = 0.5 \cdot [SLO(K) + SLO(K+1)] \tag{2-21}$$

Upstream Point (section)

$$VEL = UBN \cdot VEL(K) + UBI \cdot VEL(K-1) \tag{2-22}$$

$$EFD = UBN \cdot EFD(K) + UBI \cdot EFD(K-1) \tag{2-23}$$

$$EFW = UBN \cdot EFW(K) + UBI \cdot EFW(K-1) \tag{2-24}$$

$$SLO = SLO(K) \tag{2-25}$$

Downstream Point (section)

$$VEL = DBN \cdot VEL(K) + DBI \cdot VEL(K+1) \tag{2-26}$$

$$EFD = DBN \cdot EFD(K) + DBI \cdot EFD(K+1) \tag{2-27}$$

$$EFW = DBN \cdot EFW(K) + DBI \cdot EFW(K+1) \tag{2-28}$$

$$SLO = SLO(K) \tag{2-29}$$

where:

DBN, DBI	=	coefficients for downstream reach boundary
K-1, K, K+1	=	downstream, midpoint, and upstream locations, respectively, of a reach
SLO	=	friction slope
UBN, UBI	=	coefficients for upstream reach boundary
VEL	=	weighted velocity of the reach
XID, XIN, XIU	=	downstream, interior, and upstream coefficients, respectively, for interior points.

Several different weighting factors were investigated during the formulation of the computation scheme. Table 2-1 shows the set of factors which appeared to give the most stable calculation and thereby permits the longest time steps (Scheme 1) and the set which is the most sensitive to changes in bed elevation but requires shorter time steps to be stable (Scheme 2). Scheme 1 is often the best choice because the computed energy slope may vary drastically from section-to-section whereas the actual river's behavior may be dependent upon reach properties. HEC-6 defaults to Scheme 2 but this can be changed by entering other values for the weighting factors on the **I5** record.

Table 2-1.
Representative Hydraulic Parameter Weighting Factors

	DBI	DBN	XID	XIN	XIU	UBI	UBN	
Scheme 1	0.5	0.5	0.25	0.5	0.25	0.0	1.0	Most Stable
Scheme 2	0.0	1.0	0.0	1.0	0.0	0.0	1.0	Most Sensitive

2.2.5 Hydraulic Roughness

Boundary roughness of an alluvial stream is closely tied to sediment transport and the movement of bed material. Energy losses for water surface profile calculations must include the effects of all losses: grain roughness of the movable bed, drag losses from bed forms such as ripples and dunes, bank irregularities, vegetation, contraction/expansion losses, bend losses, and junction losses. All these losses except the contraction/expansion losses are embodied in a single roughness parameter, Manning's *n*.

2.3 Theoretical Basis for Sediment Calculations

Sediment transport rates are calculated for each flow in the hydrograph for each grain size. The transport potential is calculated for each grain size class in the bed as though that size comprised 100% of the bed material. Transport **potential** is then multiplied by the fraction of each size class present in the bed at that time to yield the transport **capacity** for that size class. These fractions often change significantly during a time step, therefore an iteration technique is used to permit these changes to effect the transport capacity. The basis for adjusting bed elevations for scour or deposition is the Exner equation (see Section 2.3.1.3).

2.3.1 Equation for Continuity of Sediment Material

2.3.1.1 Control Volume

Each cross section represents a control volume. The control volume width is usually equal to the movable bed width and its depth extends from the water surface to the top of bedrock or other geological control beneath the bed surface. In areas where no bedrock exists, an arbitrary limit (called the "model bottom") is assigned (see Figure 2-7).

The control volume for cross section 2 is represented by the heavy dashed lines. The control volumes for cross sections 1 and 3 join that for cross section 2, etc.

The sediment continuity equation is written for this control volume; however, the energy equation is written between cross sections. Because descriptions of both sediment continuity and conservation of energy should enclose the same space; and because the averaging of two cross sections tends to smooth numerical results, the shape of the control volume is conceptually deformed.

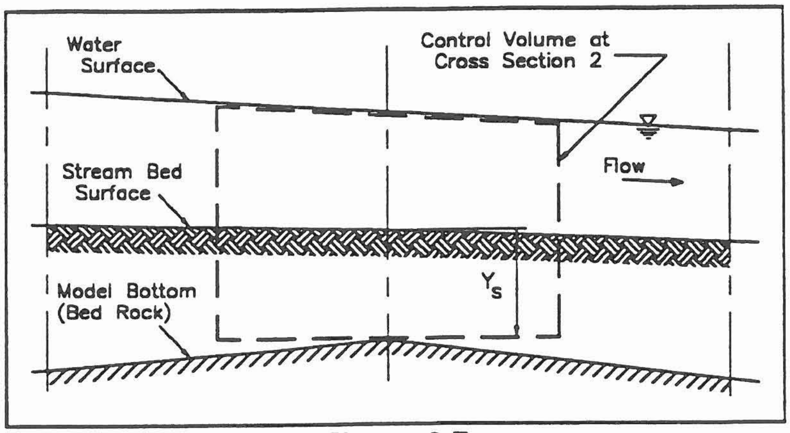

Figure 2-7
Control Volume for Bed Material

The amount of sediment in the stream bed, using an average end area approximation, is:

$$V_{sed} = B_o \cdot Y_s \cdot \frac{L_u + L_d}{2} \tag{2-30}$$

where: B_o = width of the movable bed
L_u, L_d = length of the upstream and downstream reach, respectively, used in control volume computation
V_{sed} = volume of sediment in control volume
Y_s = depth of sediment in control volume.

For a water depth, D, the volume of fluid in the water column is:

$$V_f = B_o \cdot D \cdot \frac{L_u + L_d}{2} \tag{2-31}$$

B_o and D are hydraulic parameters, width and depth, which are calculated by averaging over the same space used in solving the energy equation as described in Sections 2.2.1 and 2.2.4.

The solution of the continuity of sediment equation assumes that the initial concentration of suspended bed material is negligible. That is, all bed material is contained in the sediment reservoir at the start of the computation interval and is returned to the sediment reservoir at the end of the computation interval. Therefore, no initial concentration of bed material load need be specified in the control volume.

The hydraulic parameters, bed material gradation and calculated transport capacity are assumed to be uniform throughout the control volume. The inflowing sediment load is assumed to be mixed uniformly with sediment existing in the control volume. HEC-6 assumes instantaneous diffusion of all grain size classes on a control volume basis.

2.3.1.2 Concepts of the Control Volume

The control volume concept employed in HEC-6 represents the alluvium of a natural river. Over time, the river will exchange sediment with its boundaries both vertically and laterally, changing its shape by forming channels, natural levees, meanders, islands, and other plan forms. HEC-6, however, only models vertical sediment exchange with the bed; the width and depth of which are user defined. Correct reproduction of the natural river system depends on modeling the proper exchange of sediment between the flow field and the bed sediment. The physics of that exchange process are not well understood.

HEC-6 accounts for two sediment sources; the sediment in the inflowing water and the bed sediment. The inflowing sediment load is a boundary condition and is prescribed with input data. The bed sediment control volume provides the source-sink component and is also prescribed with input data.

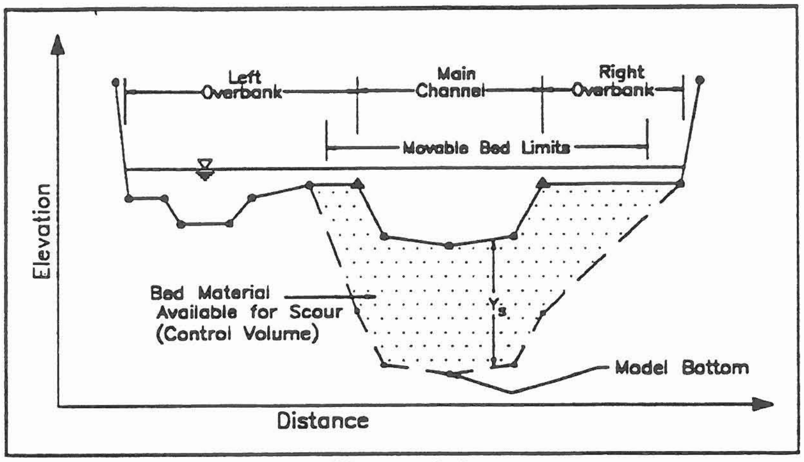

Figure 2-8
Sediment Material in the Streambed

Transport theory for sand and larger sizes relates the transport rate to the gradation of sediment particles on the bed surface and the flow hydraulics. Armor calculations require the gradation of material beneath the bed surface. The depth to bedrock or some other material that might prevent degradation should also be identified to limit the scour process. These requirements are addressed in HEC-6 by separately computing the bed surface gradation and the sub-surface gradation.

The coordinates connected by the solid line in Figure 2-8 define the initial cross section shape at the beginning of a simulation. For scour conditions, the difference between the inflowing sediment load and the reach's transport capacity is converted to a scour volume. After each time step, the coordinates within the "movable bed" are lowered by an amount which, when multiplied by the movable bed width and the representative reach length, equals the required scour volume. If a model bottom elevation is not specified in the initial conditions, a default value of 10 ft is used, which then becomes the maximum depth of bed material available for scour.

2.3.1.3 Exner Equation

The above description of the processes of scour and deposition must be converted into numerical algorithms for computer simulation. The basis for simulating vertical movement of the bed is the continuity equation for sediment material (the Exner equation):

$$\frac{\partial G}{\partial x} + B_o \cdot \frac{\partial Y_s}{\partial t} = 0 \qquad (2\text{-}32)$$

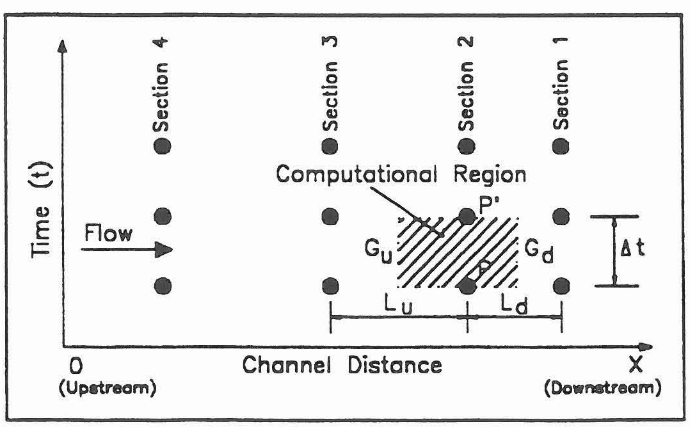

Figure 2-9
Computation Grid

where: B_o = width of movable bed
t = time
G = average sediment discharge (ft^3/sec) rate during time step Δt
x = distance along the channel
Y_s = depth of sediment in control volume.

Equations 2-33 and 2-34 represents the Exner Equation expressed in finite difference form for point P using the terms shown in Figure 2-9.

$$\frac{G_d - G_u}{0.5(L_d + L_u)} + \frac{B_{sp}(Y'_{sp} - Y_{sp})}{\Delta t} = 0 \qquad \textbf{(2-33)}$$

$$Y'_{sp} = Y_{sp} - \frac{\Delta t}{(0.5)B_{SP}} \cdot \frac{G_d - G_u}{L_d + L_u} \qquad \textbf{(2-34)}$$

where:
- B_{sp} = width of movable bed at point P
- G_u, G_d = sediment loads at the upstream and downstream cross sections, respectively
- L_u, L_d = upstream and downstream reach lengths, respectively, between cross sections
- Y_{sp}, Y'_{sp} = depth of sediment before and after time step, respectively, at point P
- 0.5 = the "volume shape factor" which weights the upstream and downstream reach lengths
- Δt = computational time step

The initial depth of bed material at point P defines the initial value of Y_{sp}. The sediment load, G_u, is the amount of sediment, by grain size, entering the control volume from the upstream control volume. For the upstream-most reach, this is the inflowing load boundary condition provided by the user. The sediment leaving the control volume, G_d, becomes the G_u for the next downstream control volume.

The sediment load, G_d, is calculated by considering the transport capacity at point P, the sediment inflow, availability of material in the bed, and armoring. The difference between G_d and G_u is the amount of material deposited or scoured in the reach labelled as "computational region" on Figure 2-9, and is converted to a change in bed elevation using Equation 2-34.

The transport **potential** of each grain size is calculated for the hydraulic conditions at the **beginning** of the time interval and is not recalculated during that interval. Therefore, it is important that each time interval be short enough so that changes in bed elevation due to scour or deposition during that time interval do not significantly influence the transport potential by the end of the time interval. Fractions of a day are typical time steps for large water discharges and several days or even months may be satisfactory for low flows. The amount of change in bed elevation that is acceptable in one time step is a matter of judgment. Good results have been achieved by using either 1 ft or 10% of the water depth, whichever is less, as the allowable bed change in a computational time interval. The gradation of the bed material, however, is recalculated during the time interval because the amount of material transported is very sensitive to the gradation of bed material.

2.3.1.4 Bed Gradation Recomputations

HEC-6 solves the Exner equation for continuity of sediment. If transport capacity is greater than the load entering the control volume, available sediment is removed from the bed to satisfy continuity. Since transport capacity for a given size depends upon the fraction of that size on the bed, it is necessary to frequently recalculate fractions present as sediment is exchanged with the bed. The number of exchange increments, **SPI**, during a time step is theoretically related to the time step length, Δt, velocity, and reach length in each reach by:

$$\text{NO. OF EXCHANGE INCREMENTS} = \frac{\Delta t \cdot \text{VELOCITY}}{\text{REACH LENGTH}} \tag{2-35}$$

Usually the number of exchange increments can be less than this without generating significant numerical problems. Specify SPI in field 2 of the I1 record. Initially, SPI should be set to zero (which invokes Equation 2-35) and an extreme hydrologic event simulated. This should be the most stable (and computationally intensive) case. Then, starting from SPI=50 or more, one should decrease it in increments of 10 until the results become significantly different from the results with SPI=0. Use the smallest SPI that gives a solution close to that obtained with SPI=0.

2.3.2 Determination of the Active and Inactive Layers

HEC-6 implements the concept of an active and an inactive bed layer. The active layer is assumed to be continually mixed by the flow, but it can have a surface of slow moving particles that shield the finer particles from being entrained in the flow. Two different processes are simulated: (1) Mixing that occurs between the bed sediment particles and the fluid-sediment mixture due to the energy in the moving fluid and, (2) Mixing that occurs between the active layer and the inactive layer due to the movement of the bed surface. The mixing mechanisms are attributed to large scale turbulence and bed shear stress from the moving water. The mixing depth (termed "equilibrium depth") is expressed as a function of flow intensity (unit discharge), energy slope, and particle size.

2.3.2.1 Equilibrium Depth

The minimum energy hydraulic condition at which a particular grain size will just be stationary on the bed surface can be calculated by combining Manning's, Strickler's, and Einstein's equations, respectively:

$$V = \frac{1.49}{n} R^{2/3} S_f^{1/2} \tag{2-36}$$

$$n = \frac{d^{1/6}}{29.3} \tag{2-37}$$

$$\psi = \frac{\rho_s - \rho_f}{\rho_f} \cdot \frac{d}{DS_f} \tag{2-38}$$

where:
- d = grain diameter
- D = water depth
- V = water velocity
- ρ_s = density of sand grains
- ρ_f = density of water
- ψ = transport intensity from Einstein's bed load function, related to the inverse of Shield's parameter
- S_f = friction slope

For negligible transport, ψ equals 30 or greater. Solving Equation 2-38 in terms of S_f for a specific gravity of sand of 2.65 and with ψ set at 30 yields:

$$S_f = \frac{d}{18.18D} \tag{2-39}$$

Combining this with the Manning and Strickler equations, in which R has been replaced with D, and multiplying velocity by depth to get unit discharge yields:

$$q = \frac{(1.49)(29.3)D^{5/3}}{d^{1/6}}\left[\frac{d}{18.18D}\right]^{1/2} \quad (2\text{-}40)$$

$$= 10.21 \cdot D^{7/6} \cdot D^{1/3}$$

where: q = water discharge per unit width of flow

The equilibrium depth for a given grain size and unit discharge is therefore:

$$D_e = D = \left[\frac{q}{10.21d^{1/3}}\right]^{6/7} \quad (2\text{-}41)$$

where: D_e = the minimum water depth for negligible sediment transport (i.e., equilibrium depth) for grain size d

2.3.3 Hydraulic Sorting of the Bed Material - Method 1

Two methods are available in HEC-6 for computing the changes in composition (gradation) of the bed material with time. These methods are presented below. Note that, because of the limitations of each, neither method will be appropriate for all conditions.

The primary restrictions on rate of scour are the thickness of the active bed layer and amount of surface area armored. The active bed is the layer of material between the bed surface and a hypothetical depth at which no transport occurs for the given gradation of bed material and flow conditions. The thickness of the active bed is calculated at the beginning of each interval. The amount of surface area armored is proportional to the amount of active bed removed by scour. The basis for stability of the armor layer is the work by Gessler (1970). It is assumed that the transport capacity can be satisfied, if the sediment is available, within each time step within each control volume. The depth of scour required to accumulate a sufficient amount of coarse surface material to armor the bed is calculated as follows: The number of grains times the surface area shielded by each grain equals the total surface area, SA, of a vertical column, as illustrated by Figure 2-10 and shown in Equations 2-42 and 2-43:

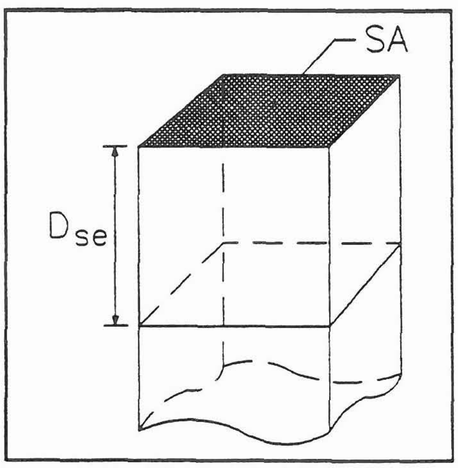

Figure 2-10
A Column of Bed Material Having Surface Area (SA)

$$SA = N\left[\frac{\pi d^2}{4}\right] \quad (2\text{-}42)$$

$$N = \frac{SA}{\left[\frac{\pi d^2}{4}\right]} \quad (2\text{-}43)$$

where: N = number of sediment grains on bed surface (assuming spherical particles)

SA = bed surface area.

The surface area of the column may be partially shielded by a rock outcrop or an armor layer such that the potential scour area is less than the total surface area of the column. This reduces the number of grains, N, exposed to scour as follows:

$$N = \frac{A \cdot SAE}{\left[\frac{\pi d^2}{4}\right]} \tag{2-44}$$

where: SAE = ratio of surface area of potential scour to total surface area

Assuming a mixture of grain sizes, the depth of scour required to produce the volume of a particular grain size that is sufficient to completely cover the bed to a thickness of one grain diameter is:

$$V_{se} = PC \cdot SA \cdot D_{se} = N \frac{\pi d_a^3}{6} \tag{2-45}$$

where: d_a = smallest stable grain size in armor layer
D_{se} = depth of bed material which must be removed to reach equilibrium in a time step
PC = fraction of bed material coarser than size d_a
V_{se} = volume of bed material which must be removed to reach equilibrium in a time step

Combining the surface area and volume equations and solving for the required depth of scour to fully develop the armor layer gives:

$$D_{se} = \left[\frac{SA \cdot SAE}{(\pi d^2/4)}\right] \cdot \left[\frac{(\pi d^3/6)}{PC \cdot SA}\right] = \left(\frac{2}{3}\right)\left[\frac{SAE \cdot d}{PC}\right] \tag{2-46}$$

This equation is used with Equation 2-41 to calculate an equilibrium depth for a mixture of grain sizes. In order to determine the PC to use in Equation 2-46, the proper segment on the bed gradation curve is found by approximating the functional relationship between d and PC with a sequence of straight line segments as shown in Figure 2-11. The first step in locating the proper segment on the gradation curve is to calculate the equilibrium depths, $D1_{eq}$ and $D2_{eq}$ for the grain sizes at points 1 and 2 (Figure 2-12) using Equation 2-41. If the actual water depth, D_W, is less than $D2_{eq}$, the straight line segment from 1 to 2 in Figure 2-11 defines the required functional relationship and the final equilibrium depth is calculated. If D_W is greater than the equilibrium depth for grain size at point 2, computations move down the gradation curve to points 2 to 3, 3 to 4, etc., until either the proper segment is located or the smallest grain size is sufficient to armor the bed in which case scour will not occur.

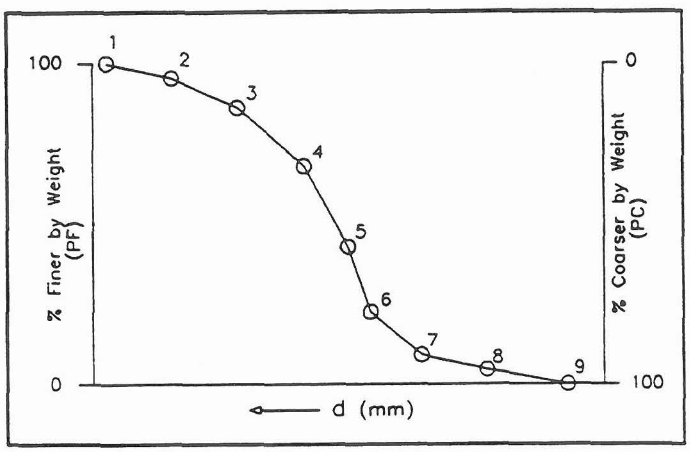

Figure 2-11
Gradation of Bed Material for Equilibrium Depth Computation

HEC-6 designates the zone of material between the bed surface and equilibrium depth as the active layer and the zone from equilibrium depth to the model bottom as the inactive layer. The active layer provides the source of material forming the bed surface. The inactive layer initially has the same gradation as the parent bed. That gradation changes as material is deposited on the active layer and is exchanged with the inactive layer. Material is moved from one layer to the other layer as the active layer thickness changes with water depth, velocity and slope. Only the material in the active layer is subject to scour. HEC-6 allows sorting by grain size during the solution of the Exner equation which requires continuous accounting of the percent of sediment in each size class within each time step. When all material is removed from the active layer, the bed is completely armored for that hydraulic condition.

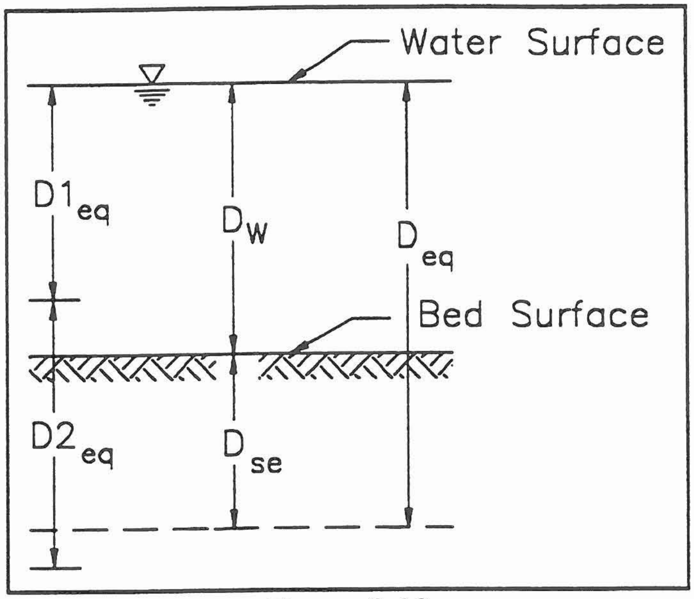

Figure 2-12
Equilibrium Depth Conditions

Assuming that the bed material is well mixed the rate of armoring is proportional to the volume of material removed, and the surface area exposed, **SAE**, for scour is:

$$SAE = \frac{VOL_A}{VOL_{SE}} \qquad (2\text{-}47)$$

where: VOL_A = volume remaining in active layer
VOL_{SE} = total volume in active layer

Leaching of the smaller particles from beneath the bed surface is prevented by adjusting the **SAE**. If a grain of bed sediment is smaller than the armor size, transport capacity is linearly decreased to zero as **SAE** decreases to 40% of the total bed surface (Harrison 1950). Thereafter, only the inflowing load of that grain size and smaller is transported through the reach. Particle sizes equal to and larger than the armor size are not constrained by this procedure.

2.3.3.1 Impact of the Active Layer on Depth of Erosion

After the depth of the active layer has been calculated, Method 1 completes the bed change calculation for that cross section. At each exchange increment (SPI), Method 1 checks the volume of sediment in the active layer. However, if all material has been removed before the last exchange increment of the time step, HEC-6 does not give a warning message. When this happens, the calculated erosion rates and depths will be too small.

To avoid such a condition, the duration of each computation time step must be tested and reduced until further reductions do not change the results. This procedure is similar to the calibration method described in HEC (1992).

2.3.3.2 Composition of the Active Layer

When computations begin, the gradation of the active layer defaults to the inactive layer gradation. At the beginning of each new time step, a new active layer gradation is calculated as follows. When the new depth of the active layer is greater than the existing depth, sediment is added to the active layer from the inactive layer. When the new depth of the active layer is less than the existing depth, sediment is removed from the active layer and added to the inactive layer. In either case, a new gradation is calculated for the new mixture in each layer.

2.3.3.3 Rate of Replenishing the Active Layer

A streambed having a gravel or cobble surface underlain by finer material is said to be armored. This condition does not reduce the stream's potential to transport sediment but rather limits the supply of sediment material so that transport theory cannot be used for grain sizes finer than those in the armor layer because their rate of movement is constrained by their availability, not the flow hydraulics. The armor layer forms when fines are transported away more rapidly than they are replaced by the inflowing load, allowing the coarser grain sizes to dominate the bed surface gradation and prevent further degradation.

The stability of the armor layer is based on a normal probability distribution function in which the ratio of critical to actual tractive force is the independent variable. Equations used for the two tractive forces are:

$$\tau_c = 0.047(\gamma_s - \gamma)d_m \qquad (2\text{-}48)$$

and

$$\tau_b = \gamma \cdot EFD \cdot S_f \qquad (2\text{-}49)$$

where:
- d_m = median grain diameter of the grain size class being tested for stability
- EFD = effective depth
- S_f = friction slope
- 0.047 = Y-intercept of empirical data, from Shields (Vanoni 1975)
- γ = unit weight of water
- γ_s = unit weight of sediment particles
- τ_b = bed shear stress
- τ_c = critical bed shear stress, after Meyer-Peter and Müller (1948)

According to Gessler (1970), the stability of sediment particles on the bed surface is a probability relationship as shown on Figure 2-13. Shields' deterministic curve for movement of sediment particles corresponds to a tractive force ratio (τ_c/τ_b) of 1.0 in Figure 2-13 and indicates a stability probability of 0.5. As the actual tractive force increases, the tractive force ratio decreases to reflect a lower probability that the grains will remain stationary. This does not guarantee particle movement, nor do tractive force

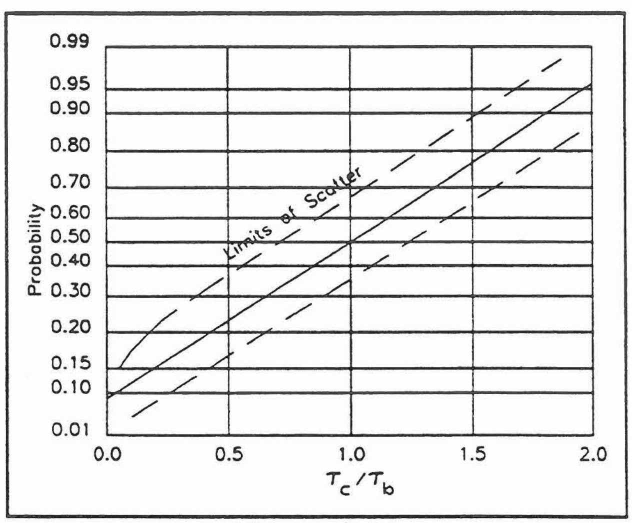

Figure 2-13
Probability of Grain Stability

ratios greater than one guarantee that sediment particles will remain stationary in the bed. This relationship is used to calculate a bed stability coefficient, BSF, which includes the particle size distribution of the active layer as follows:

$$BSF = \frac{\sum_{i=1}^{NGS} PROB \cdot PROB \cdot PI_i \cdot d_{mi}}{\sum_{i=1}^{NGS} PROB \cdot PI_i \cdot d_{mi}} \tag{2-50}$$

where:

d_{mi}	=	median grain diameter for grain size class i
i	=	grain size class analyzed
NGS	=	number of grain sizes present
PI	=	fraction of bed composed of a grain size class
PROB	=	probability that grains will stay in the bed

Gessler (1970) proposed that a stability factor equal to or greater than 0.65 indicates a stable armor layer. If a partially armored bed is stable for a given hydraulic condition, material is taken from the active layer until enough stable grains are left to cover the bed to the depth of one stable grain size. If the armored bed is not stable, the layer is destroyed and a completely new active bed is calculated.

The probability function could be used to determine the amount of armor layer destroyed; however, a simple linear relationship is used instead. The amount of armor layer destroyed is related to the magnitude of the bed stability coefficient, BSF, as:

$$SAE_{i+1} = 1.0 - \frac{BSF}{0.65}(1.0 - SAE_i) \tag{2-51}$$

where subscripts i and i+1 represent beginning and ending of an exchange increment (see Section 2.3.1.4). Material from the active layer is removed until the remaining stable grains are sufficient to cover the bed at the ending SAE.

2.3.3.4 Influence of Armoring on Transport Capacity

All grain sizes are analyzed in each exchange increment. Before the next increment, the surface area exposed for scour is calculated. In Einstein's relationship, the hiding factor adjusts transport capacity to account for armoring. In some other transport relationships, the transport capacity is corrected for armoring by a parabolic relationship which attempts to account for extra scour due to the presence of large individual sediment particles. The relationship used in HEC-6 is:

$$FSAE = CSAE + (1.0 - CSAE)\, SAE^{BSAE} \tag{2-52}$$

where:

BSAE	=	coefficient used in calculation of transport under armor conditions
CSAE	=	fraction of transport capacity sufficient to pass inflowing sediment discharge, used in armor layer calculations
FSAE	=	transport capacity correction due to armoring

The value of **CSAE** is the fraction of transport capacity just sufficient to pass the inflowing sediment discharge with no deposition. HEC-6 assigns the value of 0.5 for **BSAE** unless input data specifies otherwise. **FSAE** varies between 0.5 and 1.0 and applies equally to all grain sizes.

2.3.3.5 Some Limitations of Method 1

This method for computing hydraulic sorting and armoring has exhibited the following shortcomings:

(1) In rivers with large gradation coefficients it appeared that there was too much leaching of sands; i.e., insufficient "armoring".

(2) The active layer was too thick in many large sand bed rivers which dampened hydraulic sorting.

(3) A sediment continuity problem was observed when consolidated silts and clays were exchanged between the active and inactive layers.

2.3.4 Hydraulic Sorting of the Bed Material - Method 2

A second method of computing hydraulic sorting was developed to alleviate some of the limitations of Method 1. This algorithm is based on the concept that exchange of sediment particles occurs within a thin "cover layer" of bed material at the bed surface which is continually mixed by the flow. It is presumed that, as the bed progresses toward an equilibrium condition in which deposition and resuspension of each size class is balanced, the slow moving thin cover layer becomes coarser and serves as a shield, regulating the entrainment of finer particles below. If the cover layer is replenished by deposition from the water column, it will remain as a shield constraining the entrainment of finer material from below. Harrison (1950) observed that this shielding began to occur when as little as 40% of the bed surface was covered. If conditions change such that more material is scoured from, than deposited on, the cover layer; then the cover layer begins to disintegrate and more fine material can be removed from below. Eventually, the cover layer may be completely removed and the bed surface takes on the composition of the material below. This conceptual process replaces the concepts of "surface-area exposed," **SAE**, and "bed-stability factor," **BSF**, used in Method 1.

In Method 2 there are two components of the active layer; a cover layer that is retained from the previous time step and a sub-surface layer that is created at the beginning of the time step from the inactive layer. The sub-surface layer material is returned to the inactive layer at the end of the time step. The cover layer from the previous time step is limited to an arbitrary maximum thickness 2 ft. If the previous cover layer thickness is 2 ft or greater, the new cover layer is assigned a thickness of 0.2 ft (This is approximately equal to the sampling depth of a standard US BM-54 Bed Material Sampler). The residual material is mixed with the inactive layer. The initial thickness of the sub-surface layer is calculated using the equilibrium depth concept presented in Section 2.3.2.1. The maximum thickness, however, is constrained by an estimated maximum scour that could occur during the exchange increment. The estimated maximum scour is calculated from the hydraulics, inactive bed gradation, and selected transport function. This constraint will almost always override the thickness calculated using equilibrium depth. A minimum thickness of two times the largest grain size in transport is also imposed. The computation of bed layer adjustments during a time step using Method 2 is depicted on Figures 2-14 through 2-16.

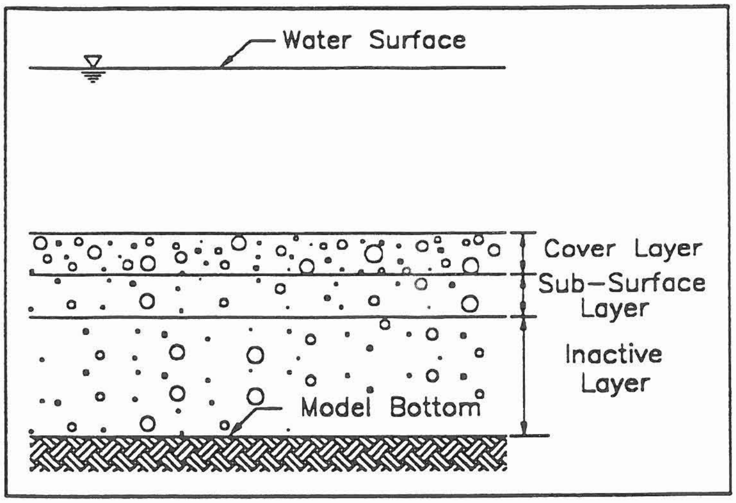

Figure 2-14
Bed Layers at Beginning of Time Step.

- cover layer composition and thickness are left over from the previous computational time step (maximum 2 ft).
- Sub-surface layer is created from the inactive layer with identical composition. Thickness is based on equilibrium depth and an estimate of maximum possible erosion during the time step (minimum $2 \cdot D_{max}$).

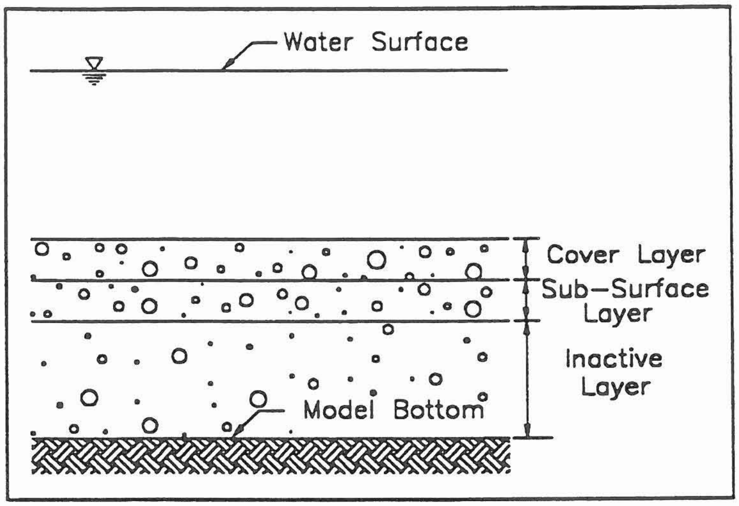

Figure 2-15
Bed Layers at Intermediate Exchange Increment.

- Cover layer composition coarsens with erosion, gets finer with deposition.
- Sub-surface composition coarsens with erosion because it has supplied finer materials to cover layer and to flow. It is unchanged with deposition or if armored.
- Inactive layer is unchanged.

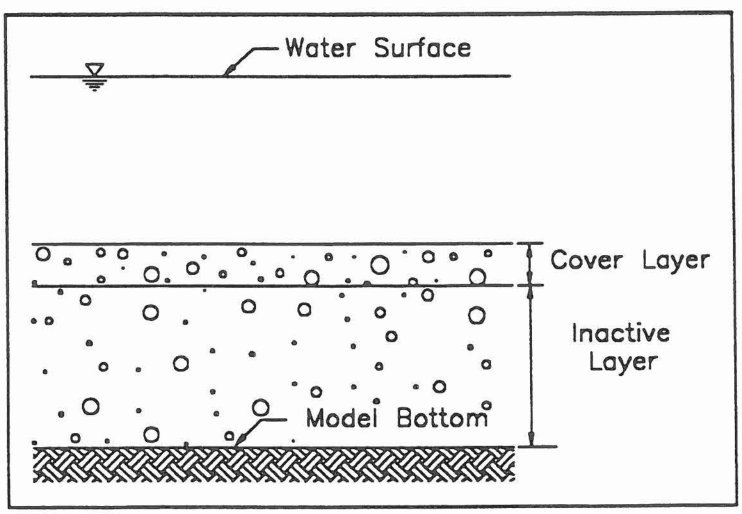

Figure 2-16
Bed Layers at End of Time Step.

- Cover layer saved and carried over to next time step.
- Sub-surface and inactive layers combined and completely mixed.

At the beginning of each exchange increment (subdivision of a time step in which the active layer gradation is re-computed, see Section 2.3.1.4) the volume of the cover layer is checked to make sure that there is sufficient material available to cover the bed surface to at least one grain diameter. If not, the cover layer and sub-surface layer are combined to form a new cover layer. This represents a condition where the cover layer is effectively destroyed by the flow energy. A new sub-surface layer is then created from the inactive layer with a thickness and composition identical to the subsurface layer established during the first exchange increment (Figure 2-17).

Bed material size fractions used to calculate sediment transport capacity are based on the composition of the active layer; i.e., the combined volume of both the cover and sub-surface layers.

The sediment continuity equation is then solved for the exchange increment, adding or removing material of the various size classes into or out of the active layer. Deposited material is placed in the cover layer. Eroded material is removed from the cover layer first. The cover layer is intended to act as a moving pavement or armor layer, reducing the sediment transport capacity of finer materials. If there is insufficient volume of a size class present in the cover layer to meet the sediment deficit, then material may be withdrawn from the sub-surface layer. However, material from a size class cannot be withdrawn from the subsurface layer if there is a sufficient volume of coarser size classes in the cover layer to cover the bed to a thickness of one grain diameter. When there is not a sufficient volume of coarser material in the cover layer to cover 40% of the bed to a thickness of one grain diameter, then supply from the sub-layer is not constrained by the cover layer. A linear supply constraint function is applied to cases when the bed cover is between 40% and 100%.

- New cover layer is mixture of old cover and sub-surface layers.
- New sub-surface layer taken from inactive layer has same thickness and composition as at beginning of time step.

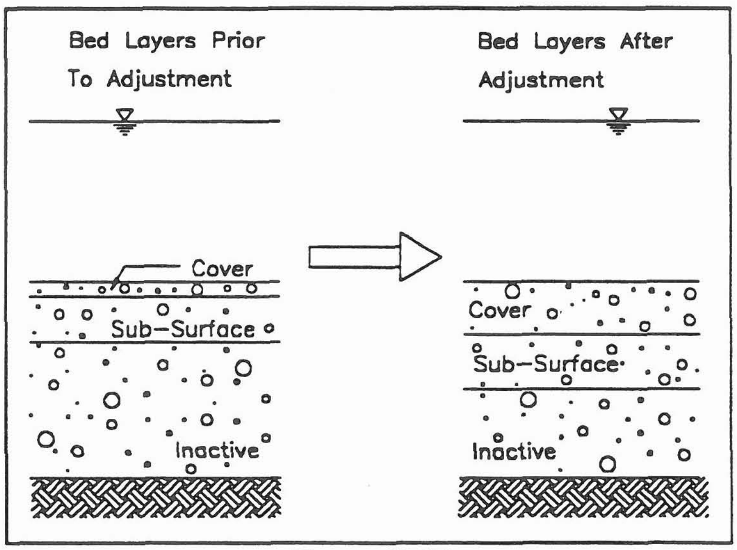

Figure 2-17
Bed Layers Change When Cover Layer is Depleted.

2.3.4.1 Sub-Surface Layer

The sub-surface layer is composed of well mixed sediments brought up from the inactive layer plus residual sediment left when the cover layer is destroyed. During erosion it may supply bed sediment as required to meet sediment transport capacity. However, supply of a specific size class from the sub-layer is constrained by coarser material in the cover layer. Availability of material is a constraint. Thickness of the active layer is considered to be very important and is calculated as described earlier.

2.3.4.2 Characteristic Rate of Entrainment

The characteristic rate of entrainment is associated with flow turbulence. Turbulence simulation, however, is beyond the scope of HEC-6. Since sediment entrainment is not instantaneous, a characteristic "flow-distance" was created to approximate a finite rate of entrainment. Using the distance one would need to sample equilibrium concentrations in a flume as a guide, the characteristic distance for entrainment was set at 30 times the flow depth. The entrainment ratio, **ENTRLR**, associated with the rate at which a flow approaches its equilibrium load, is calculated by dividing the reach length by the characteristic distance for entrainment as follows:

$$ENTRLR = \frac{REACH\ LENGTH}{30 \cdot DEPTH} \qquad (2\text{-}53)$$

The entrainment coefficient, **ETCON**, is then defined by:

$$ETCON = 1.368 - e^{-ENTRLR} \qquad (2\text{-}54)$$

ETCON is used to determine what percentage of the equilibrium concentration (for each grain size) is achieved in the reach, and has a maximum of 1.0. Research is needed to substantiate this entrainment hypothesis as well as the appropriate equation and coefficients.

2.3.4.3 Characteristic Rate for Deposition

Deposition occurs when the inflowing sediment discharge is greater than the transport capacity. Not all size classes in a mixture will deposit; therefore, this process is calculated by size class. The rate at which sediment deposits from the flow field is controlled by particle settling velocity as follows:

$$DECAY(i) = \frac{V_s(i) \cdot \Delta t}{D_s(i)} \qquad (2\text{-}55)$$

where: $D_s(i)$ = effective depth occupied by sediment size i
Δt = duration of time step
$V_s(i)$ = settling velocity for particle size i

2.3.4.4 Some Limitations of Method 2

In low flow deposition zones, the cover layer becomes the depository for fine materials. In a natural river it is not mixed with sub-surface material; therefore, it retains its fine composition and can be easily removed at high flows. In HEC-6, however, transport capacity is calculated based on the composition of the entire active layer. This probably results in under-prediction of transport capacities for the finest size classes. This may depress the transport of fines, resulting in increased deposition and/or decreased scour. Modifications to the technique of computing PI_i for Method 2 may be considered in the future if this becomes a problem. The arbitrary maximum cover layer thickness of 2 ft may hinder deposition during low energy conditions. Mixing of fine material will probably result in underestimation of scour during high flows. Erosion of fine material may be too severely constrained by the Harrison (1950) observation (see Section 2.3.3) which also limits withdrawal from the sub-surface layer.

2.3.5 Bed Elevation Change

When scour or deposition occurs during a time step, HEC-6 adjusts cross section elevations within the movable bed portion of the cross section. For deposition, the streambed portion is moved vertically only if it is within the movable bed specified by the H or HD record and is below the water surface (i.e., wetted). Deposition is allowed outside of the conveyance limits defined by the XL record. Scour occurs only if it is within the movable bed, within the conveyance limits, within the effective flow limits defined by the X3 record, and below the water surface. Once the scour or deposition limits are determined, the volume of scour or deposition is divided by the effective width and length of the control volume to obtain the bed elevation change. The vertical components of the cross section coordinates within these scour/deposition limits are then adjusted as shown in Figures 2-18 and 2-19. An option for adjusting the geometry in a different manner for deposition is described in Section 3.7.2.

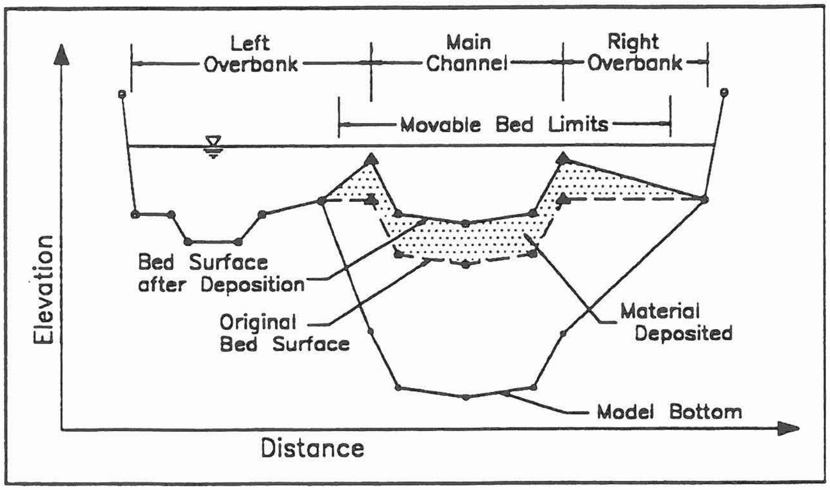

Figure 2-18
Cross Section Shape Due to Deposition

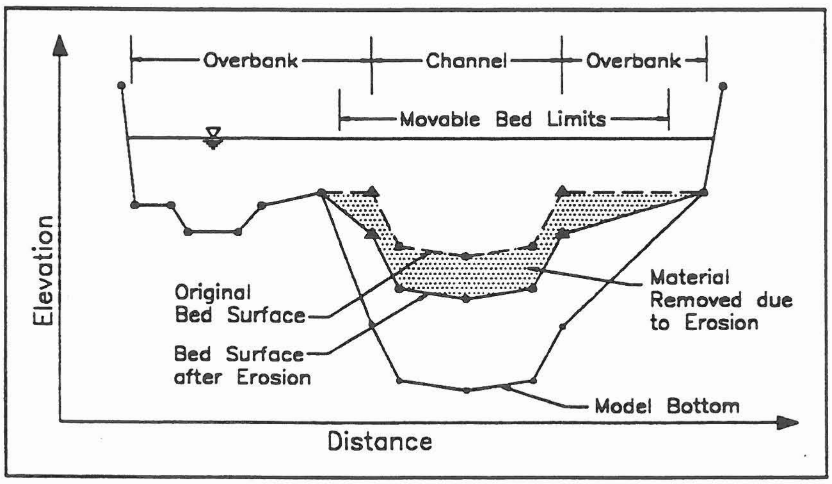

Figure 2-19
Cross Section Shape Due to Erosion

2.3.5.1 Hard Bottom Channel

The special condition of a hard channel bottom (as with a concrete channel) can be approximated by specifying zero sediment depth in the bed sediment reservoir. This is accomplished by specifying the model bottom, EMB, equal to the initial thalweg elevation, less a small amount. No sediment is contributed to the flow of sediment at that cross section. EMB is entered in field 2 of the H record.

2.3.6 Unit Weight of Deposits

2.3.6.1 Initial Unit Weight

Unit weight is the weight per unit volume of a deposit expressed as dry weight.

$$\gamma_s = (1 - P_d) \cdot SG \cdot \gamma \qquad (2\text{-}56)$$

where: P_d = porosity of deposits
SG = specific gravity of sediment particles
γ = unit weight of water
γ_s = unit weight of sediment

Standard field tests are recommended when major decisions depend on the unit weight. Otherwise, use tables on pages 39-41 of "Sedimentation Engineering" (Vanoni 1975) when field data is lacking at your project site.

2.3.6.2 Composite Unit Weight

When dealing with mixtures of particle sizes, the composite unit weight, γ_{SC}, of the mixture is computed using Colby's equation (Vanoni 1975):

$$\gamma_{SC} = \frac{1}{\left[\frac{F_{SA}}{\gamma_{SA}} + \frac{F_{SL}}{\gamma_{SL}} + \frac{F_{CL}}{\gamma_{CL}}\right]} \qquad (2\text{-}57)$$

where: $\gamma_{SA}, \gamma_{SL}, \gamma_{CL}$ =
unit weight of sand, silt, and clay, respectively
F_{SA}, F_{SL}, F_{CL} = fraction of sand, silt, and clay, respectively, in the deposit

2.3.6.3 Consolidated Unit Weight

Compaction of deposited sediments is caused by the grains reorienting and squeezing out the water trapped in the pores. The equation for consolidation (Vanoni 1975) is:

$$\gamma = \gamma_1 + B \cdot \log_{10} T \qquad (2\text{-}58)$$

where: B = coefficient of consolidation for silts or clay
T = accumulated time in years
γ_1 = initial unit weight of the sediment deposit, usually after one year of consolidation

Suggested values of γ_1 and B are given on page 43 of Vanoni (1975).

The average consolidated unit weight over a time period T requires integration over time. This is computed using the following relationship developed by Miller (1953).

$$\gamma_{ave} = \gamma_1 + B \cdot \left[\frac{T}{T-1}\right] \cdot \log_{10} T - 0.434\,B \qquad (2\text{-}59)$$

These unit weights are used to convert sediment weight to volume for computation of the bed elevation change.

2.3.7 Sediment Particle Properties

Four basic sediment properties are important in sediment transport prediction: size, shape factor, specific gravity, and fall velocity. Grain size classes are fixed in HEC-6 and described in Section 3.3. The particle shape factor, SF, is defined by:

$$SF = \frac{c}{(a \cdot b)^{1/2}} \tag{2-60}$$

where: a, b, c = the lengths of the longest, intermediate, and shortest, respectively, mutually perpendicular axes of a sediment particle

The particle shape factor is 1.0 for a perfect sphere and can be as low as 0.1 for very irregularly shaped particles. HEC-6 uses a shape factor default of 0.667 but it can be user specified. If a "sedimentation diameter" is used, which is determined by the particle's fall velocity characteristics, the particle shape factor of 1.0 should be used. If the actual sieve diameter is used, the actual shape factor should be used.

Specific gravity of a particle is governed by its mineral makeup. In natural river systems the bed material is dominated by quartz which has a specific gravity of 2.65. HEC-6 uses 2.65 as a default; however, values of specific gravities for sand, silt, and clay may be input.

Two techniques for calculating particle fall velocity are available in HEC-6. The first is based upon the fall velocities determined by Toffaleti (1966) and is similar to Rubey's method (Vanoni 1975). This method assumes 0.9 as the shape factor. The second, which takes into consideration the particle shape factor, utilizes the procedure described in ICWR (1957), and is described in detail by Williams (1980). The second method is the default.

2.3.8 Silt and Clay Transport

2.3.8.1 Cohesive Sediment Deposition

The equation for silt and clay deposition (Krone 1962) in a recirculating flume at slow aggregation rates and suspended sediment load concentrations less than 300 mg/ℓ is:

$$\ln \frac{C}{C_o} = -k't \tag{2-61}$$

or

$$\frac{C}{C_o} = e^{(-k't)} \tag{2-62}$$

where:
- C = concentration at end of time period
- C_o = concentration at beginning of time period
- D = water depth
- $k' = \dfrac{V_s P_r}{2.3D}$
- P_r = probability that a floc will stick to bed $(1 - \tau_b/\tau_d)$
- t = time = reach length/flow velocity
- V_s = settling velocity of sediment particles
- τ_b = bed shear stress
- τ_d = critical bed shear stress for deposition.

This ratio is multiplied by the inflowing clay or silt concentration to obtain the transport potential. The concentration is converted to volume and deposited on the bed.

2.3.8.2 Cohesive Sediment Scour

Erosion is based upon work by Parthenaides (1965) and adapted by Ariathurai and Krone (1976). Particle erosion is determined by:

$$C = \frac{M_1 \cdot S_a}{Q \cdot \gamma} \cdot \left[\frac{\tau_b}{\tau_s} - 1\right] + C_o \qquad (2\text{-}63)$$

where:
- C = concentration at end of time period
- C_o = concentration at beginning of time period
- M_1 = erosion rate for particle scour
- Q = water discharge
- S_a = surface area exposed to scour
- τ_b = bed shear stress
- τ_s = critical bed shear for particle scour
- γ = unit weight of water

As the bed shear stress increases, particle erosion gives way to mass erosion and the erosion rate increases. Because the mass erosion rate can theoretically be infinite, Ariathurai and Krone (1976) recommended that a "characteristic time", T_e, be used. With a computation interval of Δt, the mass erosion equation becomes:

$$C = \frac{M_2 \cdot S_a}{Q \cdot \gamma} \cdot \frac{T_e}{\Delta t} + C_o \qquad (2\text{-}64)$$

where:
- Δt = duration of time step
- M_2 = erosion rate for mass erosion
- T_e = characteristic time of erosion

Ariathurai and Krone (1976) give guidance on how to obtain or estimate T_e, M_1, and M_2. Because erosion thresholds and rates for cohesive sediments are dependent on specific sediment particle and ambient water conditions such as mineralogy, sodium adsorption ratio, cation exchange capacity, pH, salinity, and depositional history, in situ and/or laboratory testing are the recommended methods to determine the erosion characteristics of cohesive sediments. A good discussion of cohesive material transport is found in USACE (1991).

2.3.8.3 Influence of Clay on the Active Layer

The presence of clay in the streambed can cause the bed's strength to be greater than the shear stress required to move individual particles. This results in limiting the entrainment rate under erosion conditions. HEC-6 attempts to emulate this process by first checking the percentage of clay in the bed. If more than 10% of the bed is composed of clay, the entrainment rate of silts, sands and gravels is limited to the entrainment rate of the clay. This also prevents the erosion of silts, sands and gravels before the erosion of clay even if the bed shear is sufficient to erode those particles but not enough to erode the cohesive clay.

2.3.8.4 Mudflow Constraint on Transport Potential

Because Einstein's concept of the "equilibrium concentration" is utilized for the non-cohesive load, no additional constraints are required to limit the concentrations of sands and gravels. However, when cohesive sediments are included there is no equilibrium concentration. HEC-6 assumes that erosion and entrainment of fines is limited by a "maximum mudflow concentration". The maximum mudflow concentration used by HEC-6, based on two measurements at Mt. St. Helens, is 800,000 ppm. If the concentration of fines (i.e., silt and clay) at any cross section exceeds 50,000 ppm, a counter is incremented and a message will be printed stating the total number of times high concentrations were detected. When the concentration exceeds 800,000 ppm, each grain size concentration is proportionally reduced so that the total concentration is 800,000 ppm.

Chapter 3

General Input Requirements

3.1 General Description of Data Input

Input data are grouped into the categories of geometry, sediment, hydrology, and special commands. A description of input records is contained in Appendix A. The alphanumerics in parentheses after each section heading in this chapter refer to the input records that control the discussed data.

3.2 Geometric Data

Geometric data includes cross sections, reach lengths and *n* values. In addition, the movable bed portion of each cross section and the depth of sediment material in the bed are defined. The NC to H records are used to define the model geometry. The format used for geometric data is similar to that of HEC-2.

3.2.1 Cross Sections (X1, X3, GR)

Cross sections are specified for the initial conditions. Calculations are made directly from coordinate points (stations, elevations), not from tables or curves of hydraulic elements. GR records are used to input elevation-station coordinates to provide a description of the shape of a cross section. Elevations may be positive, zero or negative. Cross section identification numbers, entered in field 1 of the X1 record for each cross section, must be positive and should increase in the upstream direction. Corrections for skew (X1.8)[2] and changes in elevation (X1.9) can be made without re-entering coordinate points. If the water surface elevation exceeds the end elevations of a section, calculations continue by extending the end points vertically, neglecting the additional wetted perimeter.

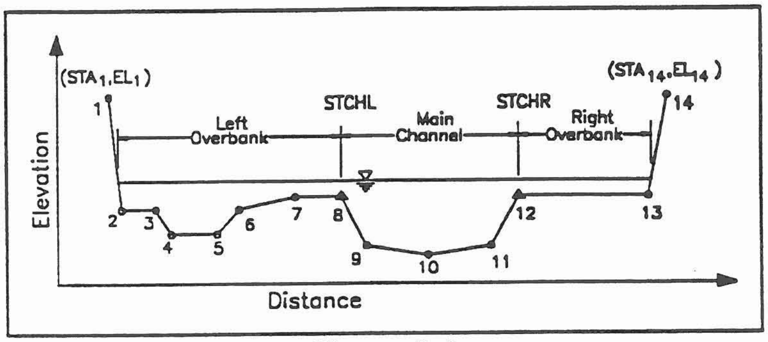

Figure 3-1
Cross Section Subsections

Each cross section may be subdivided into three parts called subsections - the left overbank, main channel and right overbank as shown in Figure 3-1. Each subsection must have a reach length. It extends from the previous (downstream) section to the present cross section. This enables the simulation of channel curves where the outer part of the bend, which is represented by an overbank area, has a reach length larger than the channel or the inside overbank area. For meandering rivers, the channel length is generally greater than the overbank reach lengths.

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2 The reference (X1.8) means that the variable being discussed, in this case, skew, can be entered in field 8 of the X1 record).

3.2.2 Manning's *n* Values (NC, NV, $KL, $KI)

A Manning's *n* value is required for each subsection of a cross section. It is not possible to automatically change *n* values with respect to time. Static or fixed *n* values are entered using the **NC** record. The *n* values may vary with either discharge or elevation in the main channel and overbank areas by using **NV** records. When *n* varies with discharge, the first *n* on the **NV** record should be a negative value. An **NC** record must precede the first cross section even if an **NV** record immediately follows and overrides it.

Limerinos' (1970) relationship is available for the determination of Manning's *n* based upon bed gradation. This relationship is:

$$n = \frac{0.0926R^{1/6}}{1.16 + 2.0\log_{10}\left(\frac{R}{d_{84}}\right)} \tag{3-1}$$

where: d_{84} = particle size in the stream bed of which 84 percent of the bed is finer, in feet

R = hydraulic radius, in feet

To compute *n* values utilizing Limerinos' relationship, the **$KL** record is placed in the hydrologic data. To return to the input *n* values, a **$KI** record must be input.

The calculation of friction loss through the reach between cross sections is made by averaging the end areas of a subsection, averaging the end hydraulic radii and applying the subsection *n* value and reach length to get a length-weighted subsection conveyance. Subsection conveyances are summed to get a total value for the cross section reach which is used to calculate friction loss.

3.2.3 Movable Bed (H, HD)

Each cross section is divided into movable and fixed-bed portions. The **H** (or **HD**) record is used to define the movable bed limits, **XSM** and **XFM**, which can extend beyond the channel bank station. Scour and deposition will cause the movable bed to fall or rise by changing the cross section elevations within the movable bed at the end of each time step.

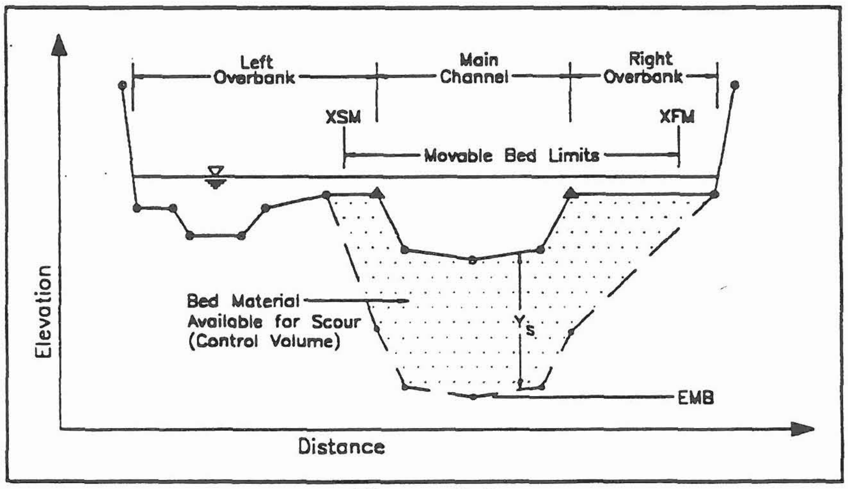

Figure 3-2
Sediment Material in the Stream Bed

The elevation of the model bottom is specified in field 2 of the **H** record. After determining the minimum channel elevation of each cross section, HEC-6 uses the model bottom elevation to compute the depth of sediment material available for scour. Optionally, the depth of sediment material, Y_s, can be specified directly by using an **HD** record instead of an **H** record for each cross section.

3.2.4 Dredging (H, HD, $DREDGE, $NODREDGE)

The H (or HD) record is also used to specify the bottom elevation and lateral limits of the dredged channel, as well as the depth of advanced maintenance dredging. The dredged channel limits must be within the movable bed. Dredging is initiated by the **$DREDGE** record in the hydrologic data and is assumed to be active for all discharges until a **$NODREDGE** record is encountered. These "on" and "off" records can be placed anywhere in the hydrologic data. Dredging can be activated any number of times during a simulation by placing pairs of **$DREDGE, $NODREDGE** records in the hydrologic data.

The elevation of the channel bottom is calculated at the end of each computation interval. When the dredging option is used, if the minimum channel elevation is higher than the specified dredging elevation, the dredged channel is lowered to the specified dredging or overdredge depth, whichever is lower. Outside of the dredged channel, the points are not changed. Sediment material is assumed to be removed from the channel and from the system. An option is available to initiate dredging if the channel bottom elevation is higher than a specified minimum draft depth (**$DREDGE** record). When this occurs, the channel is dredged to an elevation such that the minimum draft is achieved.

3.2.5 Bridges

HEC-6 has no provision for calculating flow at bridges other than by normal backwater calculations. Piers can be simulated by adjustment of GR points to reflect net flow area change if general scour information is of interest at a bridge. Be sure that the top elevations of the GR points used for piers are above the highest anticipated water surface elevation. This is to assure that deposition does not occur on the piers. In most situations the user should ignore bridges and match water surface profiles by adjusting *n* values to avoid the short time intervals required for analyzing general scour at bridges with closely spaced cross sections. All bridge routine records in an HEC-2 data file must be removed before use of the file in HEC-6.

3.2.6 Ineffective Flow Area (X3)

When high ground or some other obstruction such as a levee prevents water from flowing into a subsection, the area up to that point is ineffective for conveying flow and is not used for hydraulic computations until the water surface exceeds the top elevation of the obstruction. The barrier can be a natural levee, constructed levee or some other structure. End area, wetted perimeter, *n* value and conveyance computations are not made in the ineffective area portions of a cross section. This is similar to the ineffective flow option in HEC-2. Sediment computations will not be made for ineffective areas.

Three methods for describing ineffective flow area are available. Method 1 confines the water within the channel limits unless the water surface elevation is higher than the elevation of either channel limit. If either (or both) channel limit elevation(s) is exceeded, that overbank area is used for hydraulic conveyance calculations (see Figure 3-3).

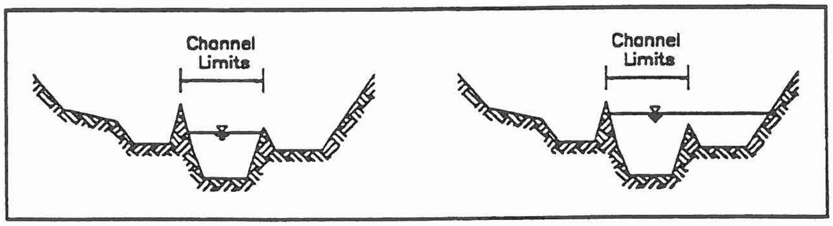

Figure 3-3
Examples of Ineffective Area, Method 1

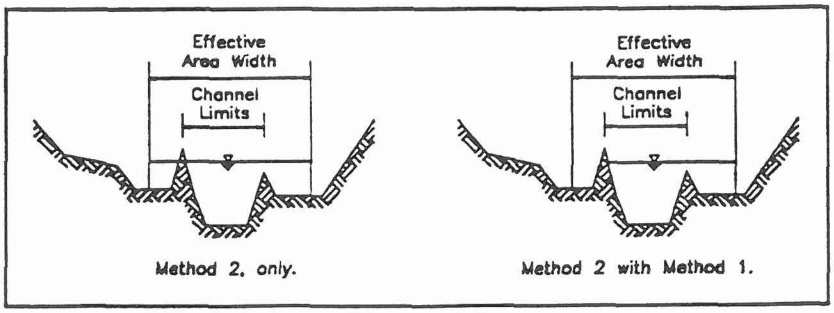

Figure 3-4
Examples of Ineffective Area, Method 2

Method 2 is used to specify an effective area width of which the left and right limits are equidistant from the centerline of the channel. This is similar to Method 2 of the encroachment option in HEC-2. Method 2 may be used in conjunction with Method 1 as shown in Figure 3-4.

Method 3 uses the exact locations (STENCL and STENCR for left and right overbanks) and elevations (ELENCL and ELENCR for left and right overbanks) of ineffective areas for each overbank area. This method is similar to Method 1 of the encroachment option in HEC-2 as demonstrated by Figure 3-5. Method 3 cannot be used together with Method 1 or 2.

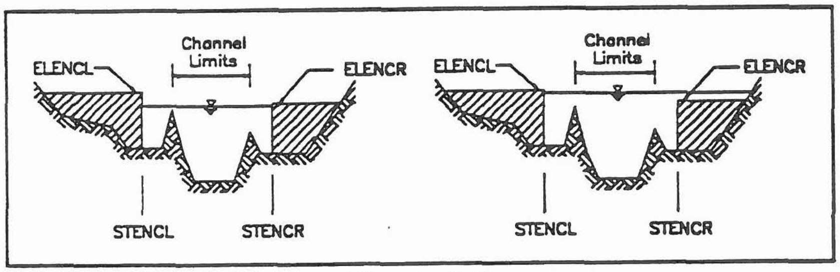

Figure 3-5
Examples of Ineffective Area, Method 3

HEC-6 automatically tests the first and last points in the movable bed to ascertain if natural levees are forming during the computations. If this occurs, HEC-6 overrides the ineffective area methods specified by input data. In fact, natural levees formed by the movable bed are always considered to establish ineffective area even if that option was not selected by input data, as illustrated in Figure 3-6.

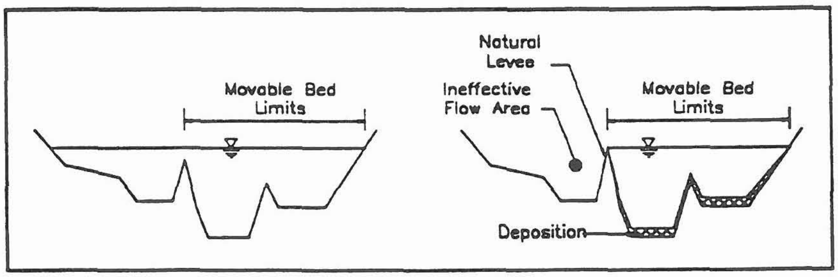

Figure 3-6
Ineffective Areas Due to Natural Levee Formation

3.2.7 Conveyance Limits (XL)

Sometimes water inundates areas that do not contribute to the water conveyance. Conveyance limits are specified by either entering a conveyance width to be centered between the channel limits or by input of two station locations that define the conveyance limits. Deposition is allowed to occur outside the conveyance limits (but within the movable bed); however, scour can occur only within the conveyance limits even if the movable bed limits are beyond the conveyance limits.

3.3 Sediment Data

Sediment data is specified on records I through PF. This data includes fluid and sediment properties, the inflowing sediment load data, and the gradation of material in the stream bed. The transport capacity relationship(s) and unit weights of deposited material are also input in this section.

The grain sizes of sediment particles commonly transported by rivers may range over several orders of magnitude. Small sizes behave much differently from large sizes. Therefore, it is necessary to classify sediment material into groups for application of different transport theories. The three basic classes considered by HEC-6 are clay, silt, and sands-boulders. The groups are identified and subdivided based on the American Geophysical Union (AGU) classification scale (Table 2-1, Vanoni 1975) as shown in Table 3-1. HEC-6 accounts for 20 different sizes of material including one size for clay, four silt sizes, five sand sizes, five gravel, two cobble sizes, and three boulder sizes. The representative size of each class is the geometric mean size, which is the square root of the class ranges multiplied together. For example, the geometric mean size for medium silt is $(0.016 \cdot 0.032)^{1/2}$ or 0.023 mm.

Table 3-1
Grain Size Classification of Sediment Material

Class Size Number Used in HEC-6	Sediment Material	Grain Diameter (mm)
	Clay	
1	Clay	0.002 - 0.004
	Silt	
1	Very Fine Silt	0.004 - 0.008
2	Fine Silt	0.008 - 0.016
3	Medium Silt	0.016 - 0.032
4	Coarse Silt	0.032 - 0.0625
	Sands - Boulders	
1	Very Fine Sand (VFS)	0.0625 - 0.125
2	Fine Sand (FS)	0.125 - 0.250
3	Medium Sand (MS)	0.25 - 0.50
4	Coarse Sand (CS)	0.5 - 1.0
5	Very Coarse Sand (VCS)	1 - 2
6	Very Fine Gravel (VFG)	2 - 4
7	Fine Gravel (FG)	4 - 8
8	Medium Gravel (MG)	8 - 16
9	Coarse Gravel (CG)	16 - 32
10	Very Coarse Gravel (VCG)	32 - 64
11	Small Cobbles (SC)	64 - 128
12	Large Cobbles (LC)	128 - 256
13	Small Boulders (SB)	256 - 512
14	Medium Boulders (MB)	512 - 1024
15	Large Boulders (LB)	1024 - 2048

3.3.1 Inflowing Sediment Load (LQ, LT, LF)

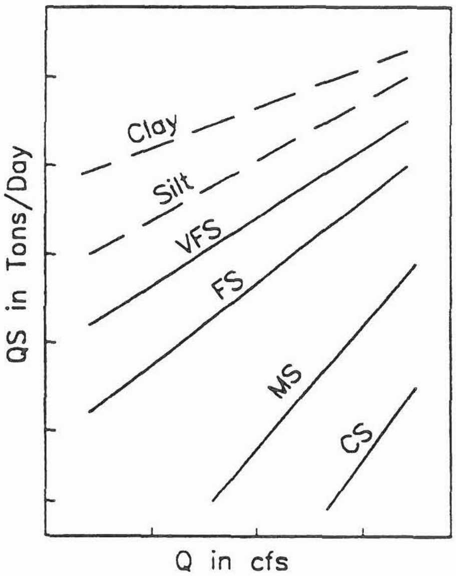

Figure 3-7
Water-Sediment Inflow Relationship

The aggradation or degradation of a stream bed profile depends upon the amount and size of sediment inflow relative to the transport capacity of the stream (see Section 2.3.1). The inflowing sediment supplies entering the upstream boundaries of the geometric model and at local inflow points are called inflowing sediment loads and are expressed in tons/day. The sediment load should include both bed and suspended load (total load) and is expressed as a log-log function of water discharge in cfs vs. sediment load in tons/day as depicted in Figure 3-7.

Data is entered on the **LT** and **LF** records as a table of sediment load by grain size class for a range of water discharges. The discharges entered on the **LQ** record should encompass the full range found in the computational hydrograph. A complete sediment load table is required for every inflow into the network. This includes the inflow to each stream segment as well as all local inflows.

In most projects, the sediment load table, once set, does not need to be modified. However, the option exists to modify or replace a sediment load table at any time during the simulation. This option is provide by the **$SED** option. See Appendix A for a description of this option.

If the inflowing sediment load is essentially of one grain size, that size should be located in Table 3-1, identified by its classification, and assigned the number of its grain size class. For instance, if the representative size is 0.035 mm, its classification is medium sand and its sand size number is 3. This number is then input for variables IGS and LGS on the **I4** record. But if the inflowing load is composed of a range of grain sizes, it is desirable to further subdivide sand and perhaps silts and clays into the classifications shown in Table 3-1. Use as many of these classifications as needed to describe the situation. It is not necessary to start with the smallest size nor is it necessary to go to the coarsest size, but once a range of sizes is selected, all grain sizes within that range must be included. The AGU classifications in Table 3-1 are stored internally in HEC-6 and cannot be modified.

3.3.2 Sediment Material in the Stream Bed (PF)

Transport theory for sand relates the total moving sand and coarser load to the gradation of sediment particles on the bed surface. Armor calculations require the gradation of material beneath the bed surface and knowledge about the depth to bedrock or some other material that might prevent degradation.

The gradation of sediment material in the stream bed (the subsurface gradation) is specified as a function of percent finer vs. grain size on the **PF** records. Cross section numbers are used in field 1 of the **PF** records to identify the subsurface gradation location within the geometric data set. Subsurface gradations are linearly interpolated for those cross sections for which **PF** records have not been specified.

The gradation of sediment particles on the stream bed (the bed surface gradation) and the distribution of sizes in the inflowing load are intimately related. One must complement the other in sediment transport theory. The significant depth for sediment transport calculations is two grain diameters and is difficult to sample. Therefore, in using HEC-6, it is customary to specify inflowing sediment load and the subsurface gradation and let HEC-6 calculate the bed surface gradation.

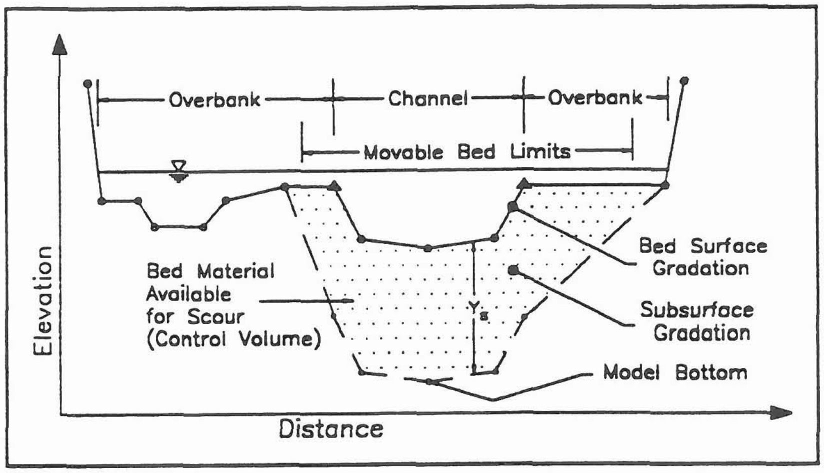

Figure 3-8
Bed Sediment Control Volume

3.3.3 Sediment Properties (I1, I2, I3, I4)

Five basic properties are considered: grain size, specific gravity, grain shape factor, unit weight of deposits and fall velocity. The grain size classifications shown in Table 3-1 are predefined in HEC-6. The specific gravity of bed material has a default value of 2.65 and the grain shape factor has a default value of 0.667. These values can be altered by providing the new values on the **I2-I4** records. The fall velocity method is input on the **I1** record.

3.3.4 Sediment Transport

3.3.4.1 Clay and Silt Transport (I2, I3)

Two methods for clay and silt transport are available in HEC-6. They are only applicable for flows with suspended sediment concentrations less than 300 mg/ℓ (Krone 1962). The first method (MTCL and MTSL = 1 in **I2** and **I3** records, respectively) allows the deposition of clays and silts but does not allow scour. The second method (MTCL and MTSL = 2) allows for both deposition and scour as described in Section 2.3.8. When this method is used, two additional **I2** records are required to provide information regarding critical shear stress thresholds for deposition and shear stress thresholds and erosion rates for both particle and mass erosion. Further details concerning these additional **I2** records are given in the **Special I2** record description in Appendix A.

3.3.4.2 Sand and Gravel Transport (I1, J, K)

There are several sand and gravel transport relationships available in HEC-6. The **I4** record is used to specify which of the following to use.

a. Toffaleti's (1966) transport function
b. Madden's (1963) modification of Laursen's (1958) relationship
c. Yang's (1973) stream power for sands
d. DuBoys' transport function (Vanoni 1975)

e. Ackers-White (1973) transport function
f. Colby (1964) transport function
g. Toffaleti (1966) and Schoklitsch (1930) combination
h. Meyer-Peter and Müller (1948)
i. Toffaleti and Meyer-Peter and Müller combination
j. Madden's (1985, unpublished) modification of Laursen's (1958) relationship
k. Copeland's (1990) modification of Laursen's relationship (Copeland and Thomas 1989)
l. User specification of transport coefficients based upon observed data

For the options involving two sediment transport relationships, the transport potential for each sediment size is computed using both methods and the largest transport potential is utilized.

If there is enough field data to develop a functional relationship between hydraulic parameters and sediment transport by grain size, the user-developed relationship using the J and K records should be considered. The functional relationship for each size class, i, is:

$$GP_i = \left[\frac{EFD \cdot SLO - C_i}{A_i}\right]^{B_i} \cdot EFW \cdot STO \qquad (3\text{-}2)$$

where:
- EFD = effective depth
- EFW = effective width
- SLO = energy slope
- STO = roughness correction factor, see Equation 3-3
- A, B, C = sediment transport coefficients developed using data
- GP = sediment transport potential

Often the transport potential is affected by variations in flow resistance. To account for this, the K record is used to define a factor, STO, which is multiplied by GP to determine the sediment transport potential. STO is defined by:

$$STO = 10^{-6} \cdot D \cdot n^{E} \qquad (3\text{-}3)$$

where:
- D,E = sediment transport coefficients developed using data
- n = Manning's roughness coefficient
- STO = multiplying factor of GP

3.4 Hydrologic Data

Hydrologic data is specified on records Q through W. The hydrologic data includes water discharges, temperatures, downstream water surface elevations and flow duration.

Having specified the initial geometry (size, shape, and slope of the channel) and the sediment relationships for the stream, the final step in sediment calculations is to simulate the response of these data to hydrologic inputs and, perhaps, reservoir operation rules. A continuous simulation is needed for a water discharge hydrograph since both sediment transport and hydraulics of flow are nonlinear functions of water discharge. The lack of coincidence between main stem and tributary flood hydrographs makes it essential to enter flow from tributaries at their correct locations along the main stem.

3.4.1 Flow Duration (W)

HEC-6 treats a continuous hydrograph as a sequence of discrete steady flows, each having a specified duration, ΔT, as illustrated in Figure 3-9. This is done to reduce the number of time steps used to simulate a given time period, and thus reduce execution time. A discharge hydrograph blocked out in this manner is referred to as a "computational hydrograph". One ΔT value is entered on each **W** record (each set of Q through **W** records in the hydrologic data represents a time step or increment of the computational hydrograph.)

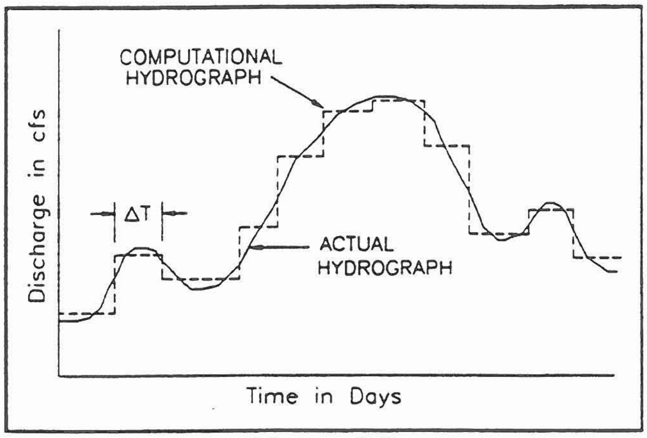

Figure 3-9
A Computational Hydrograph

3.4.2 Boundary Conditions

In a river system there are three types of boundaries: upstream, downstream, and internal. The upstream and downstream boundaries are at the cross sections that are most upstream and most downstream, respectively, on a stream segment. There are three types of internal boundaries: a local inflow point, a tributary junction point, and an hydraulic control point.

There are also three boundary conditions that can be prescribed by HEC-6: water discharge, sediment discharge, and water surface elevation (stage). The water and sediment discharges must be defined at each upstream boundary and at each local inflow point. Stage must be prescribed at the downstream boundary of the primary stream segment; and it can be prescribed at hydraulic control points.

3.4.2.1 Upstream Boundary Conditions

Water Discharge (Q, T)

The water discharge entering the river network at the upstream end of each stream segment is entered on the Q record. Each value on the Q record represents a discrete steady flow from the computational hydrograph for the each stream segment or local inflow.

The temperature of the inflowing water is set by inserting a T record in the *, Q, and **W** data. A water temperature (T) record is **required** for the first time step. The temperature is assumed to be the same for subsequent discharges until another T record is encountered. The water temperature of a stream segment downstream of a junction point is determined by discharge weighting of the tributary/local inflow and main stem temperatures. The water temperature is essential for the calculation of particle fall velocities. New fall velocities are calculated each time a new T record is read.

Sediment Discharge

The sediment discharge data is entered as a sediment load table vs. discharge on **LQ, LT** and LF records. This is outlined in Section 3.3.1.

3.4.2.2 Downstream Boundary Conditions ($RATING, RC, R, S)

A water surface elevation must be specified at the downstream boundary of the model for every time step. HEC-6 provides three options for prescribing this downstream boundary condition: (1) a rating curve, (2) **R** records, or (3) a combination of a rating curve and **R** records.

The first option involves the use of a rating curve which can be specified using a **$RATING** record followed by a set of **RC** records containing the water surface elevation data as a function of discharge (See Table 3-2). The rating curve need only be specified once at the start of the hydrologic data and a water surface elevation will be determined by interpolation using the discharge given on the **Q** record for each time step. The rating curve may be temporarily modified using the **S** record or replaced by entering a new set of **$RATING** and **RC** records before any * record in the hydrologic data.

In the second option, **R** records can be used **instead** of a rating curve to define the water surface elevation. This option is often used with reservoirs where the water surface elevations are a function of time and not flow. To use this method, an **R** record is required for the first time step. The elevation entered in Field 1 of this record will be used for each succeeding time step until another **R** record is found with a non-zero value in Field 1 to change it. In this way, you only insert **R** records to change the water surface to a new value.

Option 3 is a combination of the first two options. This option makes it possible to use the rating curve most of the time to determine the downstream water surface elevation while still allowing the user to specify the elevation exactly at given time steps. In this option, the **R** record's non-zero Field 1 value for the downstream water surface elevation will override the rating curve for that time step. On the next time step, HEC-6 will go back to using the rating curve unless another **R** record is found with a non-zero value in Field 1.

3.4.2.3 Internal Boundary Conditions (QT, X5, R)

The **QT** record defines the location of a local inflow or tributary junction. The methods for prescribing the inflowing water and sediment discharge data are discussed in Section 3.4.2.1 (these are upstream boundary conditions). The water surface elevation of the downstream boundary of a tributary cannot be prescribed by the user; HEC-6 assigns the water surface of the cross section downstream of the junction to the downstream boundary of the tributary (this is a downstream boundary).

An **X5** record in the geometry data creates an internal boundary (or hydraulic control point) at which the water surface may be specified. The specified water surface at this internal boundary is called an internal boundary condition. Two options are available to specify the water surface at this internal boundary. A rule-curve type of option can be specified to establish a constant operating elevation of a navigation pool within the geometric data. This is accomplished by specifying a water surface elevation and a head loss on the **X5** record. When the tailwater elevation plus the head loss term is higher than the specified water surface elevation, the pool rises. This option was originally developed for hinged pool operations which usually had constant head losses for all discharges. The second option allows users to specify a rating curve at an internal boundary by using a combination of **X5** and **R** records. This is helpful in modeling weirs and drop structures.

3.4.2.4 Transmissive Boundary Condition ($B)

If a **$B** record is encountered in the hydrologic data, a transmissive boundary condition is defined at every downstream boundary in the system. This transmissive boundary condition will allow sediment reaching that boundary to pass without changing that cross section. This is useful for situations where the conditions at the downstream boundary are anomalous (such as at a bridge, weir, drop structure, etc.) and may cause upstream computations to be in error if incorporated into the sediment transport/bed change computations.

3.4.3 Example Hydrology Input

An example set of hydrologic data for several time steps is shown in Table 3-2. The **$HYD** record indicates that the hydrologic data follows. The **$RATING** and **RC** records are used to input a discharge-elevation relationship. Every time step must have *****, **Q** and **W** (or **X**) records. The ***** records contain user comments and also control the output level for each time step. The A in Column 5 and the B in Column 6 of the ***** record for event number 1 will produce A-level output of the water surface profile computations and B-level output of the sediment transport computations.

The **Q** record contains the water discharge and its duration, in days, is on the **W** record. Because long time steps may cause computational oscillations, it may be desirable to divide long time steps into smaller increments. In time step 3, an **X** record is used to divide a long 10 day time step into 20 half day increments.

Table 3-2
Example of Hydrologic Input for HEC-6

```
$HYD
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3     100      0      0      520     525     528
*   AB  Time Step 1, A/B Level Output
Q    100
T     60
W      1
*       Time Step 2 - No Output
Q    200
W      2
*   A   Time Step 3 - 10 days at 20 increments
Q    200
R    527
T     70
X              .5      10
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3     100      0      0      520     525     528
*   BB  TIME STEP NO. 4
Q    200
W      1
$$END
```

A water temperature (**T**) record is always required for the first time step. In this example, no **T** record is given in time step 2; therefore, the second time step will use the same temperature as time step 1 (60°F). The **T** record in time step number 3 changes the temperature (70°F).

The water surface elevation in Field 1 on the **R** record in time step number 3 sets the stage for the downstream boundary to 527 ft. This value overrides the Stage-Discharge Rating curve entered before time step 1. The rating curve (**$RATING** and **RC** records) just before event number 4 is used to determine the starting water surface for time step number 4 and overrides elevation 527 from the **R** record in time step 3.

A **$$END** record marks the end the hydrologic data as well as the entire HEC-6 input file.

3.5 Special Command Records (EJ, $TRIB, $LOCAL, $HYD, $$END)

A command record structure was developed to enhance the flexibility of HEC-6. The **EJ**, **$HYD**, and **$$END** records are used to delineate the geometric, sediment and hydrologic data. These commands are **required** for all data sets. The **EJ** record identifies the end of geometric input. The **$HYD** record identifies the beginning of the hydrologic data. The **$$END** record identifies the end of the input. If tributaries or local inflow/outflow points are being modeled, **$TRIB** and **$LOCAL** records, respectively, are required. The **$TRIB** and **$LOCAL** records are used to distinguish tributary and local data from data for the primary stream segment in the geometric and sediment data sets.

3.6 Network Model

A network system in which sediment transport in tributaries is calculated can be simulated with HEC-6. This section describes the required data sequence.

The network option is designed so that individual segments of the stream network can be analyzed independently to calibrate and confirm the model. With only minor changes, the user will be able to link the data sets together and perform the final analysis on the entire stream network.

Correct methodology for labeling model segments is essential. HEC-6 saves information from the first title record in each geometric model as a label and prints it out as an identifier of the segment. Therefore, the stream's name and data model/test/run number code should be included on the T1 record. The date of the data set is also useful information.

The following are presented to define the terms used in this section.

Control Point: The downstream boundary of the main stem and the junction point of each tributary.

Local Inflow/Outflow Point: Points along any river segment at which water and sediment enters or exits that segment.

River Segment: A part of a river system which has an upstream water and sediment inflow point and has a downstream termination at a control point. Sediment transport is calculated along a segment.

Tributary: A river segment other than the main stem in which sediment transport is calculated.

Main Stem: The primary river segment with its outflow at the downstream end of the model.

3.6.1 Numbering Stream Segments

Stream segments and control points should not be numbered arbitrarily. To illustrate the numbering procedure, Figure 3-10 is used as an example and depicts a stream network. Each river segment's upstream-most inflow point is designated by I_k where k is the segment number. Local inflow/outflow points are marked with large arrows and labelled by $L_{i,j}$ where j is the sequence number (going upstream) of local inflow/outflow points along segment i. Control points are designated by a circled number. The numbering of segments, inflow/outflow points, and control points should follow these steps:

Step 1 - Sketch out the stream network system.

Step 2 - Number the control points 1, 2, and 3 along the main stem at the junctions with tributaries. With the main stem as segment 1, number segments 2 and 3. Number the main stem's upstream inflow point with I_1 and for segment 2, I_2 and for segment 3, I_3. Label the main stem's local inflow/outflow points, $L_{1,1}$ and $L_{1,2}$.

Step 3 - Starting from the downstream-most tributary (at control point 2) of the main stem, continue numbering control points 4 and 5. Number segments 4 and 5 coming off the control points and place inflow points I_4 and I_5. Label $L_{4,1}$ for the local inflow entering segment 4.

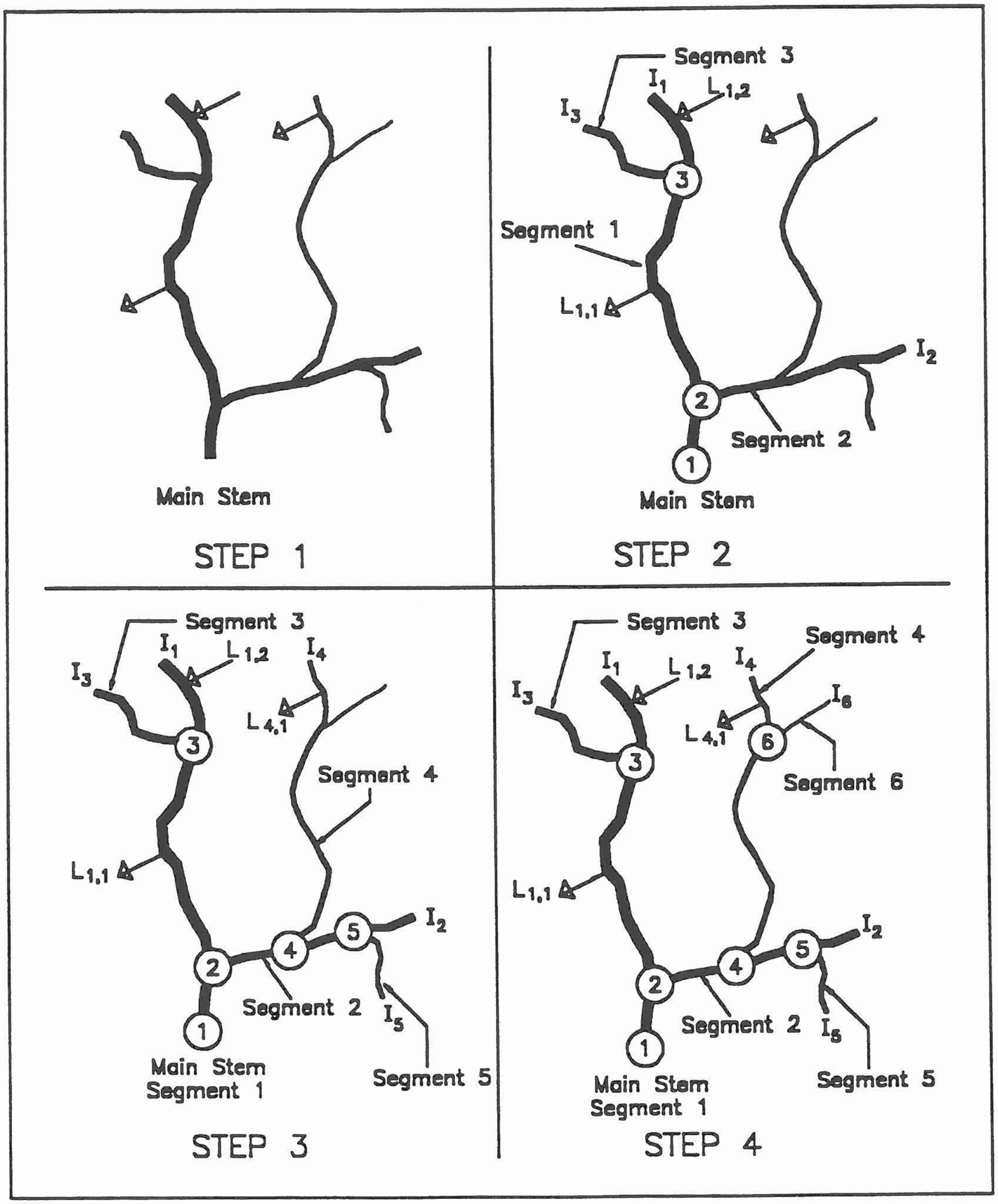

Figure 3-10
Example of Stream Network Numbering System

Step 4 - Starting from the downstream-most tributary of segment 2 (at control point 4), continue along segment 4, numbering control point 6, segment 6 and inflow point I_6. Since there are no tributaries on segment 6, check for tributaries on segment 5 (next upstream tributary of segment 4). Since there are no tributaries on segment 5 and all tributaries from control point 2 are accounted for, go to step 5.

Step 5 - Check the next upstream segment off the main stem, segment 3, for tributaries. If there were tributaries, the procedure would have continued as in steps 3 and 4 with the next control point being 7. Since there are no more tributaries, the numbering is complete.

3.6.2 Cross Section Data Sets of Main Stem and Tributaries

HEC-6 identifies segments by the order in which cross section sets are assembled in forming the geometric model. When HEC-6 reads the main stem geometry and, eventually, reaches the first EJ record in the geometric data set, it will read one more record. If that record is a $TRIB record, HEC-6 will begin reading data for a segment in a stream network. This process is repeated until all geometric data sets representing river segments are read. The CP record following the $TRIB record identifies the control point number associated with the geometry information for each tributary segment data set. Table 3-3 illustrates these requirements for the network shown in Figure 3-10.

Table 3-3
Sequence of Geometry Data for a River Network

Record		Comments
T1		MAIN STEM GEOMETRY COMES FIRST, THEN TRIBUTARIES.
T2		EXAMPLE ILLUSTRATES GEOMETRIC SEQUENCE OF FIGURE 3-10
T3		THIS RECORD TO EJ RECORD CONTAINS GEOMETRIC INFO.
———		Main stem geometry, incl. QT records for $L_{1,1}$, $L_{1,2}$ and segments 2 & 3.
EJ		End of main stem (Segment 1)
$TRIB		Warns HEC-6 that geometry for a tributary segment follows.
CP	2	This stream segment enters the network at control point 2.
T1		SEGMENT 2 - THE FIRST TRIBUTARY UPSTREAM OF CONTROL POINT 1.
T2		AMERICAN RIVER
T3		SEDIMENTATION STUDY OF SACRAMENTO RIVER DELTA
———		Geometry of Segment 2, contains QT records for segment 4 and 5.
EJ		End of Segment 2.
$TRIB		Indicates that data for additional tributary segments follow.
CP	3	This stream segment enters the network at control point 3.
T1		SEGMENT 3 - SECOND TRIBUTARY - UPSTREAM ON SACRAMENTO RIVER
T2		DRY CREAK
T3		SEDIMENTATION STUDY OF SACRAMENTO RIVER DELTA
———		Geometry of Segment 3.
EJ		End of Segment 3.
$TRIB		Indicates that data for additional tributary segments follow.
CP	4	This stream segment enters the network at control point 4.
T1		SEGMENT 4 - FIRST TRIBUTARY ON SEGMENT 2
T2		ARDEN CREEK
T3		SEDIMENTATION STUDY OF SACRAMENTO RIVER DELTA AND ENDS AT I4.
———		Geometry of Segment 4, contains QT records for Segment 6 and $L_{4,1}$.
EJ		End of Segment 4.
T4		Sediment data follows.

Figure 3-11 shows how to position cross sections at a control point. The location of the junction (control) point is specified by inserting a QT record just prior to the X1 record for the next cross section upstream from the control point location (e.g., 0.78 in Figure 3-11). The control point number must be coded on that QT record. It is not necessary to treat the control point reach any differently than other reaches. HEC-6 will mix flow, temperature and sediment concentrations as though this were a normal river reach. There is no accounting of momentum losses due to impinging flows.

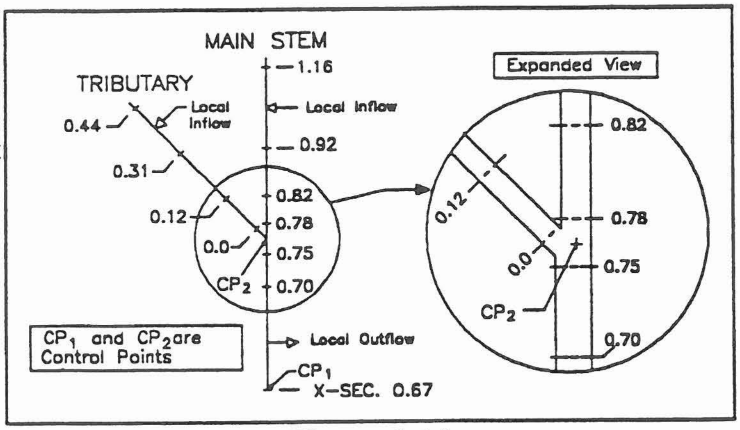

Figure 3-11
Locating Cross Sections for Stream Networks

3.6.3 Sediment Data

The main stem sediment data follows the geometric data in the data file. The main stem data specifies the fluid and sediment properties, number of grain size classes and unit weight of deposits for the entire network. If sediment properties in I1 through I5 records are present in the tributary data sets, they will be skipped by HEC-6. Information for local inflows and/or diversions on a segment are input as a part of that segment's sediment data. These are identified with a $LOCAL record followed by inflow/outflow sediment discharge tables.

After the main stem sediment data set is entered, it is followed by a $TRIB record and then the first tributary sediment data set. It is not necessary to enter a control point number since the sediment data must be in the same sequence as the geometric sets described earlier. This is illustrated in Table 3-4 which is for the network shown in Figure 3-10.

Table 3-4
Sequence of Sediment Data for a River Network

Record	Comments
———	Previous geometric records.
T4-T8	T4-T8 records are used for comments on main stem.
———	Rest of sediment data of main stem are entered.
$LOCAL	Indicates information on local inflow points follows.
LQL	Provide sediment load data for local inflow on LQL, LTL and LFL records.
LTL	Since there are two local inflow/diversion points in
LFL	segment 1 ($L_{1,1}$ and $L_{1,2}$), two complete sets of these records are
LQL	required; enter the data for $L_{1,1}$ first followed by that for $L_{1,2}$.
LTL	
LFL	
$TRIB	Sediment data for segment 2 begins here.
T4-T8	T4-T8 records are used for comments on segment 2.
———	Enter the LQ-LF and PF records for segment 2 here.
$TRIB	Sediment data for segment 3 begins here.
T4-T8	T4-T8 records are used for comments on segment 3.
———	Enter the LQ-LF and PF records for segment 3 here.
$TRIB	Sediment data for segment 4 begins here.
T4-T8	T4-T8 records are used for comments on segment 4.
———	Enter the LQ-LF and PF records for segment 4 here.
$LOCAL	Indicates information on local inflow/diversion points follows.
LQL	
LTL	These records are for the local inflow/diversion point $L_{4,1}$.
LFL	
$TRIB	Sediment data for segment 5 begins here.
———	Enter sediment data for the remaining segments in similar fashion.
$HYD	Start of hydrology.

3.6.4 Hydrologic Data

The Hydrologic data set depicted in Table 3-5 is for the stream network shown in Figure 3-10. In general the water discharge and temperatures (Q and T records) are entered in the order of the control point numbers. If the control point's segment contains local inflow/outflow points, their discharges and temperatures are entered in the fields after the control point information. The information for the next control point is then entered. An example of this procedure follows.

The information in field 1 of the Q (Q_1) and T (T_1) records refers to segment 1 (see Figure 3-10). Information on these records is for the water exiting segment 1 at control point 1. An example is given in Table 3-5. Information in fields 2 ($Q_1L_{1,1}$ and $T_1L_{1,1}$) and 3 ($Q_1L_{1,2}$ and $T_1 L_{1,2}$) are for the local inflow points $L_{1,1}$ and $L_{1,2}$, respectively, which are on segment 1. Field 4 (Q_2 and T_2) contains the information on the water entering control point 2 from segment 2. Segment 3 information is entered in field 5 (Q_3 and T_3) and is for water entering control point 3 from segment 3. This procedure is continued for each control point and segment. The flow duration (W record) data remains constant for the entire stream network computation for that time step. Since HEC-6 does not "route" the water, it is necessary to process the hydrologic data for each segment and produce a single duration which best simulates the hydraulic and sediment processes of the whole system.

Table 3-5
Hydrologic Data Input for Stream Networks

$HYD									
*	THIS ILLUSTRATES THE HYDROLOGIC DATA SEQUENCE.								
Q	Q_1	$Q_1L_{1,1}$	$Q_1L_{1,2}$	Q_2	Q_3	Q_4	$Q_4L_{4,1}$	Q_5	Q_6
T	T_1	$T_1L_{1,1}$	$T_1L_{1,2}$	T_2	T_3	T_4	$T_4L_{4,1}$	T_5	T_6
W	W_1								
*	Next Time Step								
——	Continue with sets of * to W records for all discharges								
$$END	End of model data input								

3.6.5 Summary of Data Input Sequence

The first data set in the data input is the geometric data. The main stem geometry is followed by a **$TRIB** command record, a **CP** record and then the geometric model for the first tributary, i.e., the stream segment joining the main stem at control point number 2. If more than one junction (control) point is present, each tributary data set must follow sequentially with a **$TRIB** command record followed by a **CP** record.

After all geometric data have been read, HEC-6 reads sediment data. Sediment data, one set for each stream segment, must be arranged in the sequence of the control point numbers. A **$TRIB** command record precedes the sediment data for each tributary.

Hydrologic data follows the sediment data, but a different concept is utilized for entering hydrologic data than was used in the geometric and sediment data sets. No **$TRIB** command records are required. Instead, the main stem flow, local inflows and tributary junction flows are all entered on the same Q record. The starting water surface elevation is read or calculated for the downstream boundary (control point 1), water temperatures are read for each water discharge, and the flow duration is read.

3.6.6 Calculation Sequence of Network Systems

3.6.6.1 Hydraulic Computations for Network Systems

Water surface profiles are calculated for the main stem first and the elevation at each control point is saved. Each time the water discharge changes, the water discharges are mixed and new water temperatures are calculated for the main stem and tributaries. Upon reaching the upstream end of stream segment number 1, computations return to control point number 2, its starting water surface elevation is retrieved from storage, and the hydraulic computations are made for stream segment number 2. Like the main stem, a tributary can have local inflows/diversions and tributary junctions. These are handled like the main stem, as presented above. Hydraulic computations are continued for segment 3 in a similar fashion until all stream segments have been analyzed; then sediment movement computations begin.

3.6.6.2 Sediment Computations

Although data input and hydraulic computations proceed through network segments in the same order in which the data was read, sediment computations are made in the reverse order. It is necessary for HEC-6 to process the most remote tributary first (highest segment number) to determine its sediment contribution to the next stream segment. After all sediment computations for the tributary are completed and results are printed, computations proceed to the next lower numbered segment. After the main stem calculations, HEC-6 cycles back to read the next discharge. The process is repeated until all water discharges have been analyzed.

3.7 Input Requirements for Other Options

3.7.1 Fixed-Bed Calculations

HEC-6 is capable of being executed as a "fixed bed" model similar to HEC-2. The minimum records required are: **T1-T3, NC, X1, GR, H, EJ, $HYD, *, Q, R, T, W** and **$$END**. The **H** record can be left blank. Optional records are **NV, X3, X5, $RATING** and **RC**. Note that **T4** through **PF** records are not required; if these records are present, a fixed-bed run is achieved by moving the **$HYD** through **$$END** records to just after the **EJ** record of the geometry data set. Fixed-bed runs are used to identify and correct any errors in the geometric data and analyze the hydraulic behavior of the model for a full range of flows. Calibration and confirmation of the hydraulics are performed similar to procedures used for HEC-2 (HEC 1990).

3.7.2 Multiple Fixed-Bed Calculations

Table 3-6
Example of Hydrologic Data Set for Multiple Fixed-Bed Calculations

```
$HYD
*  A   5 DISCHARGES FROM LOW TO HIGH
Q   100.    500.   1000.   5000. 10000.
R   510.    512.    513.    516.    518.
T    70.     70.     70.     70.     70.
W     1.      1.      1.      1.      1.
$$END
```

If there are no tributaries or local inflow/outflow points, up to ten profiles may be computed in one run. Table 3-6 contains an example of a time step using five discharges from 100 to 10,000 cfs with starting water surface elevations ranging from 510 to 518 ft. Multiple profile runs are preferred over single runs because the printout is more compact for the same number of discharges making it easier to make comparisons. If a **$RATING** record set has been entered, the **R** record is not needed.

3.7.3 Cross Section Shape Due to Deposition ($GR)

By default, HEC-6 adjusts the elevation of each cross section coordinate within the wet portion of the movable bed a constant amount for deposition or erosion as illustrated in Figure 3-12. A nonuniform deposition option is provided by the use of a **$GR** record in the hydrologic data. This nonuniform deposition is a function of water depth which, over time, will ultimately result in a horizontal deposition surface. Bed elevation adjustments for erosion remain uniform.

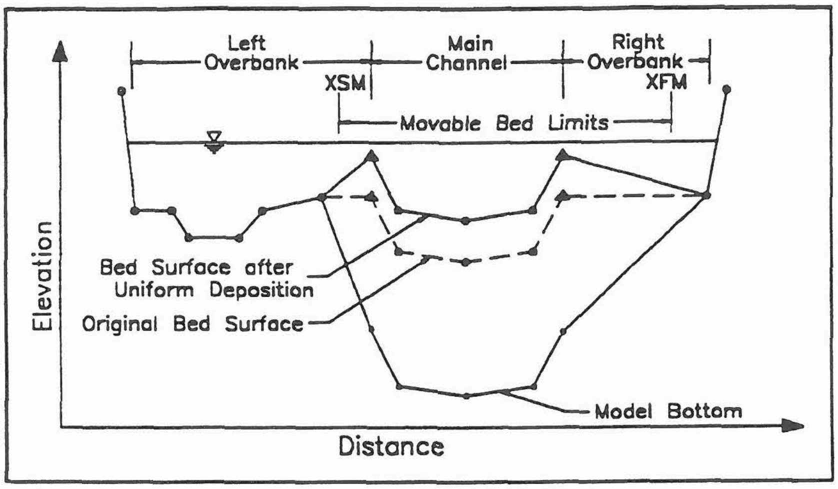

Figure 3-12
Uniform Deposition

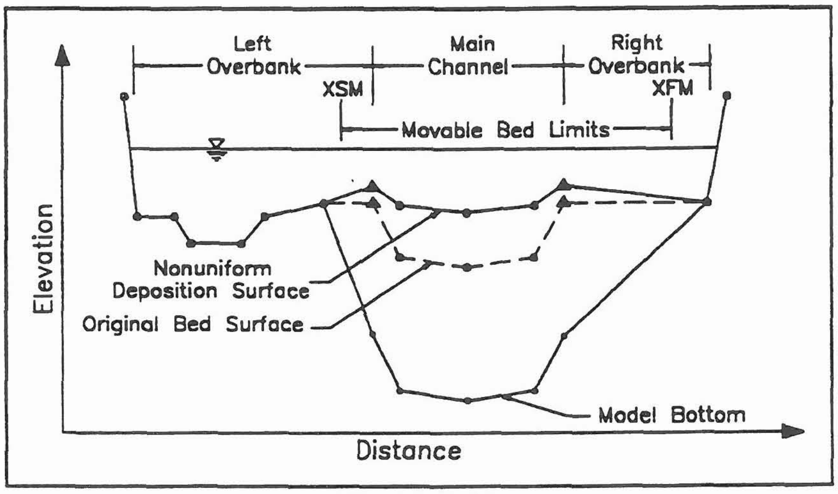

Figure 3-13
Nonuniform Deposition

3.7.4 Cumulative Volume Computations ($VOL)

An option is available in HEC-6 to compute the cumulative volume of sediment material passing each cross section. This option is initiated with the **$VOL** record. HEC-6 will also calculate the storage volume for a table of elevations for each cross section. The **VR** and **VR** records are use to define the table of elevations.

Chapter 4

Output Control

4.1 Output Levels

The user must determine what information is needed and request a level of output that provides it. By default, HEC-6 produces a minimum level of information so that the user will know that the data file has been processed and computations have completed; however, this output will not be sufficient for analyzing model performance.

Each major data group (geometry, sediment and hydrology) has a "normal" output level with one or more additional levels available to provide more detailed information. These output levels are summarized in Tables 4-1 and 4-2, described in the following paragraphs, and illustrated in the example problems in Chapter 6.

Table 4-1
Summary of Initial Conditions Output Options

Record	Level	Description
T1	-	Title records are echoed. Each cross section is identified by it's ID number. Each special option used is noted.
	B	Initial geometry, all geometry records are echoed.
	C	Trace output. Warning messages may be generated by inconsistent data.
T4	-	Initial condition of inflowing sediment loads and cross-sectional bed gradations. Also, secondary parameters computed from input information defining the initial conditions.
	B	Echo of input records. Trace Output.

4.2 Geometric Data, Initial Conditions (T1)

B-level geometric data output, available on the T1 record, is helpful in debugging the input records. After the geometry data is deemed correct, this option is usually turned off. For production simulations, it is suggested that this option be used to document geometric input.

4.3 Sediment Data, Initial Conditions (T4)

The default output produced during processing of the sediment data is usually sufficient for most needs. However, the B-level output option on the T4 record will provide echo of the input records as well as some trace information through the input routines. This output may allow the user to find some less common errors in the input data than is normally apparent. This option should be removed after the data have been checked for accuracy.

Table 4-2
Summary of Continuous Simulation Output Levels

Record	Level	Description
* Column 5	-	No output from hydraulics computations.
	A	Discharge, starting water surface elevation, water temperature, flow duration. General hydraulic parameters for each cross section.
	B	Initial geometry, distribution of hydraulic parameters across subsections.
	D	Trace information.
	E	Detailed trace information. Hydraulic data for each incremental area, each trial elevation in backwater computations at each cross section.
* Column 6	-	No output from sediment computations.
	A	Volume of sediment entering and exiting model, trap efficiency.
	B	Bed elevation changes, water surface elevations, thalweg elevation, sediment load exiting model.
	C	Detailed output; including transport potential, load, and bed gradation per grain size.
	D	Detailed trace information
$DREDGE Column 8	A - E	Levels A - E provide output from the dredging routines. The magnitude of this output ranges from simple data echo (level A) to detailed trace information (level E).
$PRT Column 8	N	Turn off output at all cross sections.
	A	Provide output for all cross sections at * record output level.
CP	-	The stream segment number where needed cross sections are located. Used with **$PRT** option.
PS	-	Cross sections where output is requested. Used with **$PRT** option.
END	-	End of **$PRT** records.
$VOL Column 7	-	Cumulative bed and volume change.
	X	Table of volume versus elevation.
$VOL Column 8	A	Cumulative weight of sediment passing each cross section for each sediment size class.
VJ, VR	-	Input parameters for elevation-volume table; used with **$VOL** record.

4.4 Hydraulic Calculations (*)

The water surface profile is calculated before the sediment calculations begin, therefore, an A-level hydraulic output for the first discharge calculations is useful for diagnosing immediate data problems. B-, D- and E-levels are increasingly detailed and may be useful for unusual situations. Subsequently, the user should request output using the A-level only when interested in velocity and flow distribution information. Output from the hydraulic calculations is not particularly useful once geometric problems are resolved and the *n* values are calibrated.

4.5 Sediment Transport Calculations (*, $PRT, CP, PN, END)

Interpretation of HEC-6 performance requires careful selection and analysis of computed information. The availability of this information in the output file is governed by the user. The most useful sediment output options are on the * record. Since this record is in the hydrology section, output can be turned on or off at any time in the simulation. The B-level sediment output is the most commonly used and provides all the essential sediment information for calibration, confirmation and production runs. C-level output is recommended only for the first discharge and then only if unusual results are encountered. D- and E-levels should be used only for analysis of suspected software errors. By default, output for every cross section is produced by the * record output options.

Often it is desirable to receive output only at selected points in time and only for those cross sections of interest. This is accomplished by providing **$PRT**, **CP**, **PS** and **END** records in the hydrologic data. The **$PRT** record tells HEC-6 that instructions for selective printout follow. The **CP** record indicates the stream segment where the cross sections listed on the following **PS** records are to be found and the **END** record completes the input for this option.

Caution must be exercised when interpreting the calculated "bed change". This change is related to the movement of the thalweg after scour and deposition and may not reflect the average bed elevation or sediment volume change of the cross section. To obtain this type of information, the **$VOL** option described in Section 4.6 should be utilized.

4.6 Accumulated Sediment Volumes ($VOL, VJ, VR)

The **$VOL** record in the hydrologic data causes HEC-6 to compute the cumulative bed elevation and volume change of each cross section and the sediment load that has passed each cross section. The sediment load information is provided for each grain size class. The **$VOL** record initiates the computation of an elevation-cumulative sediment volume table which is helpful for reservoir analysis. The elevation table displays the accumulated sediment volume between each parallel elevation plane specified by an elevation table which is defined by the **VJ** and **VR** records. In reservoir studies, these planes are usually horizontal but HEC-6 has the capability to determine the table based upon a user specified slope of the elevation planes.

4.7 Summary of Output Controls

Table 4-1 summarized the output controls for initial conditions. These controls affect the output level associated with input data, such as geometry, inflowing sediment loads, bed gradations, and sediment characteristics. Table 4-2 summarized the output controls for the simulation. These include volume of sediment entering and exiting the reach, sediment trap efficiency, bed elevation changes, subsectional water velocities, water surface elevations, and other hydraulic and sediment information.

Chapter 5

Modeling Guidelines

5.1 General

Training Document No. 13, entitled "Guidelines for the Calibration and Application of Computer Program HEC-6," (HEC 1992) describes methods and procedures for calibrating and applying computer program HEC-6. Other useful documents for sediment transport modeling are Thomas (1977), Gee (1984), Vanoni (1975), USACE (1989), and USACE (1993). Data requirements for river geometry, sediment characteristics and hydrology are discussed in these documents. Sensitivity of computed water surface profiles to data uncertainties is presented by HEC (1986).

5.2 Establishing Geometry

With the study reach located on a topographic map, mark the upstream boundary, the downstream boundary, the lateral limits and the location of each cross section. Assign an identification number to each cross section; river miles are recommended. Subdivide the floodplain into channel and overbank portions. These can be considered as subsections having similar hydraulic properties in the direction of flow. Within a subsection, flow conditions (depth, velocity, roughness) should be similar and, therefore, representative *n* values and reach lengths can be selected.

Plot each cross section as it appears at the starting time of the simulation (time zero) and divide each into two parts; the movable bed part in the main channel and the fixed part. Mark the elevations of geologic controls such as bedrock and clay layers on each cross section. If none are present, the program will arbitrarily assign ten feet below channel bottom to provide some finite depth of sediment material in the model. If more than ten feet of scour is expected, assign a lower bottom elevation.

It is necessary to locate the downstream end of the reach where there is a stable rating curve or known water surface elevation. For analysis of potential degradation this may be many miles downstream from the dam at a rock outcrop or concrete weir. For studies of reservoirs, the operating policy will define the reservoir level for the water surface profile computations and the program will adjust the bed according to calculated results.

5.3 Sediment Data

5.3.1 Sediment Particle Characteristics

Only inorganic sediments are addressed by the HEC-6 transport functions. Therefore, the amount of organic sediments in samples should be measured, expressed as a percentage, and removed before testing for the inorganic properties presented below. If a significant quantity of organic particles is present, such as on the Big Sandy River where coal amounted to 40% of the sample by weight, a suitable procedure for correcting the calculations must be developed. In the Big Sandy River case, the coal was represented by an equivalent sand size and treated as inorganic sediment having a specific gravity of 2.65.

5.3.2 Inflowing Sediment Load Synthesis

If the inflowing sediment load is not available, HEC-6 can calculate it from gradation curves for the bed material. This procedure is less desirable than obtaining measured inflowing sediment load data because of the difficulty of obtaining representative sediment samples for the entire bed. However, simulating conditions along a segment of the river permits the use of indicators such as aggradation, degradation and fluctuation in sediment discharge from one cross section to another. Use of these indicators helps to make a better estimate of the noncohesive sediment load than can be made by applying transport theory at only one point on the river.

5.4 Hydrologic Data

It is important that the water discharges in the computational hydrograph reproduce the long term flow-duration curve (for long term simulations). If a period of record flow sequence is not available, an annual pattern hydrograph can be determined from knowledge of the duration curve and the annual pattern of flows. It is important to include a wet and dry year in addition to an average year.

It is desirable to repeat discharges at selected time intervals throughout the hydrologic data set to provide a common basis for comparing rates of change. For example, the ending of each year with the same discharge (of short duration) will permit the comparison of water surface and bed profiles at fixed time intervals as time progresses.

Representation of the discharge hydrograph as a series of steady flows requires the preservation of total annual water and sediment volume while maintaining the shape and peak discharges of flood events. The duration of each discharge in the computational hydrograph should be at least long enough to permit the flow to pass through the longest reach. For instance, if the average water velocity is 10 ft/sec and the longest reach is 10,000 ft, the minimum flow duration for that flow is 10,000 ÷ 10 or 1,000 seconds (0.278 days). Longer durations may be used; however, since this is an explicit formulation of the basic equations, care must be taken to insure that time steps are not so long that oscillations are introduced into the sediment bed and water surface profiles. Limiting bed oscillations may require time steps on the order of the flow-through time for the shortest reach. See HEC (1992) for further information.

For moderate to large rivers, it is usually acceptable to approximate an annual hydrograph with 15 to 25 discharge segments. In general, the larger the discharge, the shorter its duration must be, because the larger discharges carry greater amounts of sediment and result in larger bed movements, increasing the possibility of numerical oscillations. A large discharge can be entered as several successive constant discharges to satisfy the requirement for shorter durations.

Chapter 6

Example Problems

This section presents several example problems that illustrate the contents of input data and computed results files for several typical applications of HEC-6. Detailed descriptions of the input data records can be found in the Input Description (Appendix A), and are not duplicated here. These example problems are **not** meant to provide engineering application guidance for use of HEC-6; such guidance can be found in Gee (1984), USACE (1989) and HEC (1992). These examples are provided **only** to illustrate the type and sequence of data needed to model various situations. They encompass a range of situations from fixed-bed backwater computation to simulation of the movement of sediment in a dendritic network of streams.

Although derived from an actual engineering application, the example problems have been altered for illustration purposes. Therefore, the values of the parameters used in these problems are not based on field data and **should not necessarily be used** in an actual project.

Figure 6-1 shows a schematic of the river system that was the basis for these example problems. Each example builds upon the previous examples, therefore, only the additional or changed data is described for each successive problem.

Several options are available that allow some data to be defined in more than one way. For example, the depth of the bed sediment control volume can be defined explicitly on the **HD** record or expressed in terms of the elevation of the model bottom on the **H** record; since only one **H** or **HD** record is required for each cross section, either record can be used at a given cross section. Each analyst should select the appropriate options for their particular application. The selection should be based on the physical circumstances, study objectives, data availability and ease of use of the selected option.

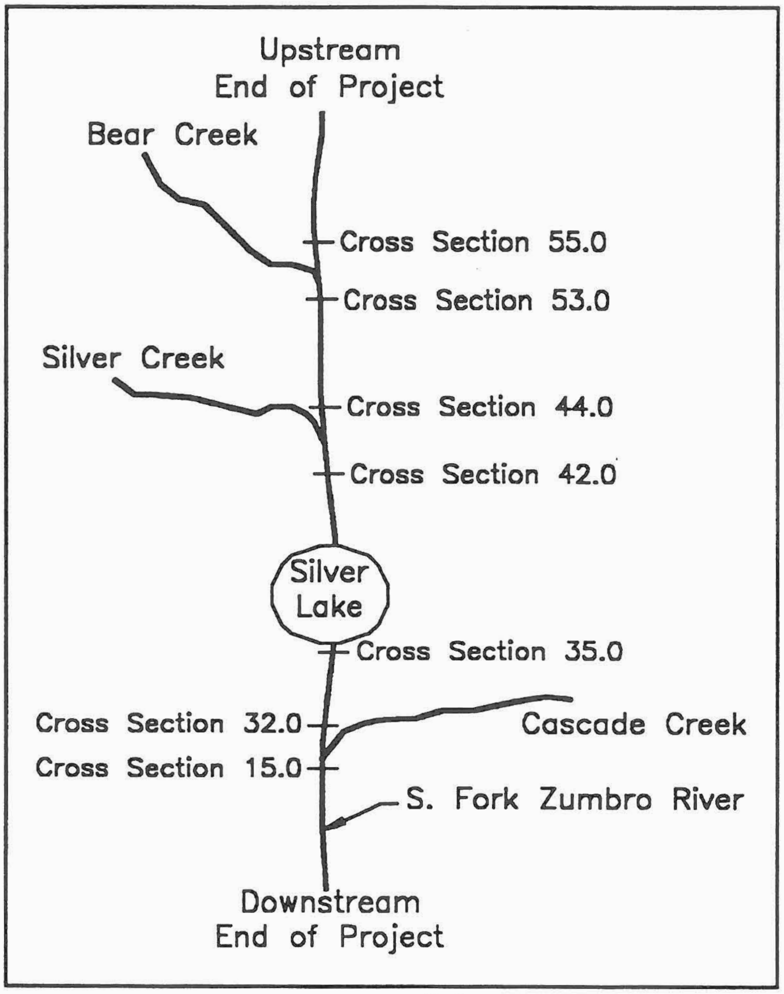

Figure 6-1
Schematic of Example River System

6.1 Example Problem 1 - Fixed-Bed Application

When initially preparing geometric data and calibrating energy loss coefficients, it is often worthwhile to use HEC-6 as a fixed-bed (backwater) model.

6.1.1 Input Data

The data for Example Problem 1, shown in Table 6-1a, is designed to operate HEC-6 as a fixed-bed model. Note that this data is quite similar to HEC-2 data, although some data records (such as **QT** and **X5**) have different parameters for HEC-6. These differences are noted in the Input Description (Appendix A). HEC-6 data begins with three title records, **T1**, **T2**, and **T3**. These are followed by bed roughness data (**NC**) and the geometry for each cross section, beginning with the **X1** record. **GR** records define the cross section's geometry as a series of elevation and station points. The **HD** records delineate the movable portion of the bed of each cross section; though irrelevant for fixed bed operation of HEC-6, an **HD** record must follow the **GR** data for every cross section in the data file.

In general, HEC-6 data records are position dependent. The cross sections are entered from **downstream** to **upstream**. The **QT** records locate inflow/outflow points and tributary junctions. **NC** records note changes in bed roughness. Comment records, however, are not position dependent; they can be placed anywhere in the data. Comment records are indicated by a blank ID in field 0 (i.e., the first two characters or columns of the record are blank). Comment records can be used throughout a data file to document unusual attributes or conditions in the model.

Duplicate or repeat cross sections are often used to provide extra computational nodes for improving the accuracy of integration of the energy loss equation (HEC, 1986). As indicated by the comment records, Section No. 33.3 is a *duplicate* of Section No. 33.0. This was accomplished by *copying* the data records for Section No. 33.0 and changing the section ID number and reach lengths. In this case, Section No. 33.3 also differs from Section No. 33.0 by width and elevation adjustments. Width and elevation modifications can be made to any cross section in a manner similar to the HEC-2 procedure. A *repeat* section is defined by an **X1**record with the number of station points (Field 2) equal to zero (see Section 53.1 in Example Problem 5); this is an indicator to HEC-6 that the geometry of the previous section should be re-used for this section. The repeat section option was instituted early in HEC-6's development due to the limitations of file editors and keypunch machines, however, with today's more sophisticated file editors (like COED), it is recommended that duplicated sections be used instead. Care must be taken to assure that duplicate or repeat cross sections have sediment transport characteristics that embody the theory of "reach representative" cross sections (Thomas, 1982).

The distinguishing characteristic of an HEC-6 fixed boundary simulation data file is that **there are no sediment data**. The geometric data is followed by the flow data which begins with a **$HYD** record. The flow data for this example contains a rating curve (**$RATING** and **RC** records), and flow information (*****, **Q**, **T**, and **W** records). The temperature (**T**) and duration (**W**) data, while necessary in the data file, play no role in fixed-bed computations. Example Problem 1 thus is a "multiple profile" run with two flow profiles being computed through a single project reach.

Table 6-1a
Example Problem 1 - Input
Fixed Bed

```
T1       EXAMPLE PROBLEM NO 1.  FIXED-BED APPLICATION.  BASIC GEOMETRY.
T2       3 LOCAL INFLOWS WITH A RATING CURVE AT THE DOWNSTREAM BOUNDARY.
T3       SOUTH FORK, ZUMBRO RIVER    ** Example Problem 1 **
NC     .1       .1      .04       .1       .3
X1    1.0       31   10077.   10275.       0.        0.         0.
GR 1004.     9915.    978.4   10002.    956.0    10060.     959.2    10077.     959.3   10081.
GR 950.0    10092.   948.48   10108.    946.6    10138.     944.7    10158.     955.2   10225.
GR 956.2    10243.    958.9   10250.    959.8    10275.     959.8    10300.     959.9   10325.
GR 958.8    10350.    957.4   10400.    970.0    10700.     966.0    10960.     970.0   11060.
GR 968.0    11085.    968.0   11240.    970.0    11365.     970.0    11500.     970.0   11615.
GR 962.0    11665.    962.0   12400.    976.0    12550.     980.0    12670.     982.0   12730.
GR 984.0    12735.
HD    1.0
X1   15.0       27   10665.   10850.    3560.     3030.      3280.
GR 992.0     9570.    982.0   10110.    976.0    10300.     976.0    10490.     966.0   10610.
GR 964.7    10665.    956.0   10673.    953.0    10693.     954.0    10703.     955.6   10723.
GR 958.6    10750.    959.3   10800.    957.0    10822.     957.3    10825.     961.5   10850.
GR 962.0    10852.    964.0   10970.    966.0    11015.     961.0    11090.     962.0   11150.
GR 970.0    11190.    972.0   11310.    980.0    11410.     984.0    11570.     990.0   11770.
GR 990.0    11865.   1000.0   12150.
HD   15.0
   Model Cascade Creek as a local inflow.
QT
X1   32.0       29   10057.   10271.    3630.     3060.      4240.
GR 998.0     9080.    982.0    9250.    982.0     9510.     980.0     9600.    980.01    9925.
GR979.48    10000.    978.5   10057.    968.6    10075.    959.82    10087.     956.5   10097.
GR 956.8    10117.    957.8   10137.    959.4    10157.     959.6    10177.    959.82   10196.
GR 966.5    10225.    971.2   10250.    978.5    10271.     978.5    10300.     978.6   10350.
GR978.91    10370.   978.96   10387.    980.0    10610.     982.0    10745.     982.0   11145.
GR 984.0    11150.    992.0   11240.   1000.0    11330.     1008.    11425.
HD   32.0
X1   33.0       21    1850.    2150.    3130.     3250.      3320.
GR1000.0      980.    990.0    1060.    980.0     1150.     982.0     1180.     982.0    1215.
GR 980.0     1260.    982.0    1300.    982.0     1350.     980.0     1420.     980.0    1540.
GR 982.0     1730.    982.0    1830.   984.41     1850.    979.19     1851.     961.0  1900.8
GR 961.0   2099.2     976.0    2149.    984.5     2150.     982.0     2800.     990.0    3100.
GR 1000.     3170.
HD   33.0
   NOTE:        Section 33.3 is a duplicate of Section  33.0.
   Section 33.0 is a good representative cross section for a long reach.  A
   duplicate is used here to break up the long reach into two smaller reaches.
X1   33.3       21    1850.    2150.    1550.     1750.      1750.      .95      1.49
GR 1000.      980.    990.0    1060.    980.0     1150.     982.0     1180.     982.0    1215.
GR 980.0     1260.    982.0    1300.    982.0     1350.     980.0     1420.     980.0    1540.
GR 982.0     1730.    982.0    1830.    984.4     1850.     979.1     1851.     961.0  1900.8
GR 961.0   2099.2     976.0    2149.    984.5     2150.     982.0     2800.     990.0    3100.
GR 1000.     3170.
HD   33.3
X1   35.0       22     9894.  10245.    1050.     1050.      1050.
GR 984.0     9035.    980.0    9070.    978.0     9135.     980.0     9185.     982.0    9270.
GR 980.0     9465.    981.7    9595.    983.7     9745.     984.7     9894.     963.4  9894.1
GR 963.3     9954.    967.1    9974.    967.4    10004.     968.2    10044.     967.6   10054.
GR 973.4    10115.    977.4   10120.    983.7    10155.     984.0    10245.     982.0   10695.
GR 982.0    10895.   1004.0   11085.
HD   35.0
   Silver Lake occupies this reach
NC    .06      .06     .045
X1   42.0       32     9880.  10130.    5370.     5000.      5210.
GR 996.0     7130.    998.0    7310.    998.0     7930.     992.0     8205.     990.0    8495.
GR 988.0     8780.    986.0    8990.    985.7     9570.    986.45     9707.    989.44    9857.
GR 990.0     9880.    969.8    9881.    969.8     9941.     985.8     9941.     985.8    9943.
GR 969.8     9943.    969.8   10001.    986.7    10001.     986.7    10003.     969.8   10003.
GR 969.8    10067.    985.8   10067.    985.8    10069.     969.8    10069.     969.8   10129.
GR 989.9    10130.    989.5   10180.    988.6    10230.     987.6    10280.     985.2   10430.
GR 986.8    11720.    989.9   12310.
HD   42.0
   Model Silver Creek as a local inflow.
QT
X1   44.0       28     9845.  10127.    3200.     3800.      3500.
GR 1002.     8035.    992.0    8150.    990.0     8305.     990.0     8735.     988.0    8835.
GR 996.0     9285.   1017.6    9425.    990.0     9505.     986.0     9650.     984.1    9788.
GR 980.6     9845.    970.9    9868.    972.2     9898.     970.5     9968.     967.5    9998.
GR 968.9    10028.    967.4   10058.    967.1    10078.     971.9    10118.     976.8   10127.
GR 977.8    10150.    976.9   10193.    982.0    10206.     981.2    10300.     979.2   10325.
GR 983.1    10400.    999.8   10450.   1002.4    10464.
HD   44.0
```

```
X1  53.0       22  10000.  10136.   3366.   2832.   2942.
GR 1004.    7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0    8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8   10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2   10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.   10470.  1004.0  10700.
HD  53.0
   model Bear Creek as a local inflow
QT
X1  55.0       18   9931.  10062.   2275.   3430.   2770.
GR 1004.    7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3    9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8    9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8   10187.   986.0  10307.   990.0  10497.
HD  55.0
X1  58.0       22   9912.  10015.   1098.   1012.   1462.
GR 1006.    8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2    9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8   10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0   10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0   11137.   988.0  11192.
HD  58.0
EJ
$HYD
$RATING
RC             40    2000       0       0   950.0   955.1   958.0   960.0   962.0
RC          963.6   965.1   966.2   967.0   967.7   968.3   968.9   969.4   969.8
RC          970.2   970.6   971.0   971.4   971.8   972.1   972.4   972.7   972.9
RC          973.1   973.3   973.5   973.7   973.8   973.9   974.0   974.1   974.2
RC          974.3   974.4   974.5   974.6   974.7   974.8   974.9   975.0
*   A   PROFILE 1 = AVERAGE ANNUAL DISCHARGE
Q  1250.    150.     78.    340.
T
W     1.
*   A   PROFILE 2 = BANK FULL FLOW
Q  2500.    300.    150.    650.
W     1.
$$END
```

6.1.2 Output

The output from Example Problem 1 is shown in Table 6-1b. Various levels of output detail are available to the user. These are controlled by several input data items (see Chapter 4); the output produced by these options will be described as encountered in the problems. The terminology for output is; default, A-level, B-level, etc., each succeeding level providing increasing detail. The default HEC-6 output provides the minimum level of information.

HEC-6 first gives information regarding program version and date, and the date and time of the run. The input and output file names are placed in the output file for the user's future reference. Information regarding the geometric data follows.

In Example Problem 1, the default (minimum) geometric output is presented. Additional information can be obtained via switches on the **T1** record (see Appendix A). Each cross section is labelled by its identification number from the **X1** record. We suggest that river mile be used to identify cross sections. The "DEPTH of the Bed..." is based on information from the HD record. Information regarding cross section adjustment is echoed as well as the locations of local inflow points and changes to the energy loss coefficients.

Following the geometric data output, profiles (or time steps) 1 and 2 produced A-level output for the hydraulic, or backwater, computations. This output is triggered by an A in column 5 of the * record which causes the discharge, water surface elevation, energy grade line elevation, velocity head, alpha, top width, average bed elevation, and average velocity in each subsection for each cross section to be written to the output file. The discharge value represents the subtraction of local inflows as the backwater computation proceeds upstream. Local flow data should be checked to assure that the main river discharge never becomes negative. The average bed elevation (AVG BED) is the water surface elevation minus the effective depth (see Section 2.2.3.6). Subsection 1 is the left overbank, 2 the channel, and 3 the right overbank. This hydraulic information is very useful when first assembling geometric data; once the data are verified and the loss coefficients are calibrated, the A-level hydraulic output may be suppressed.

Table 6-1b
Example Problem 1 - Output
Fixed Bed

```
*****************************************************      **************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS   *      *  U.S. ARMY CORPS OF ENGINEERS     *
*       Version: 4.1.00 -  AUGUST 1993             *      *  HYDROLOGIC ENGINEERING CENTER    *
*  INPUT FILE:   EXAMPLE1.DAT                      *      *  609 SECOND STREET                *
*  OUTPUT FILE: EXAMPLE1.OUT                       *      *  DAVIS, CALIFORNIA 95616-4687     *
*  RUN DATE: 30 AUG 93      RUN TIME: 10:27:58     *      *  (916) 756-1104                   *
*****************************************************      **************************************

                X      X  XXXXXXX   XXXXX              XXXXX
                X      X  X        X     X            X     X
                X      X  X        X                  X
                XXXXXXX   XXXX     X          XXXXX   XXXXXX
                X      X  X        X                  X     X
                X      X  X        X     X            X     X
                X      X  XXXXXXX   XXXXX              XXXXX

         **********************************************************************
         *  MAXIMUM LIMITS FOR THIS VERSION ARE:                              *
         *        10  Stream Segments (Main Stem + Tributaries)               *
         *       150  Cross Sections                                          *
         *       100  Elevation/Station Points per Cross Section              *
         *        20  Grain Sizes                                             *
         *        10  Control Points                                          *
         **********************************************************************

T1       EXAMPLE PROBLEM NO 1.  FIXED-BED APPLICATION.  BASIC GEOMETRY.
T2       3 LOCAL INFLOWS WITH A RATING CURVE AT THE DOWNSTREAM BOUNDARY.
T3       SOUTH FORK, ZUMBRO RIVER    ** Example Problem 1 **

N values...   Left    Channel    Right     Contraction     Expansion
            0.1000    0.0400    0.1000         1.1000        0.7000

SECTION NO.      1.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     15.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  1 occurs upstream from Section No.       15.000

SECTION NO.     32.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     33.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     33.300
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.490 ft.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     35.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N values...   Left    Channel    Right     Contraction     Expansion
            0.0600    0.0450    0.0600         1.1000        0.7000

SECTION NO.     42.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  2 occurs upstream from Section No.       42.000

SECTION NO.     44.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     53.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  3 occurs upstream from Section No.       53.000

SECTION NO.     55.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.     58.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.
```

```
NO. OF CROSS SECTIONS IN STREAM SEGMENT= 11
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  11
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA
```

$HYD
FIXED-BED MODEL

$RATING

Downstream Boundary Condition - Rating Curve

Elevation	Stage	Discharge	Elevation	Stage	Discharge
950.000	950.000	0.000	972.400	972.400	40000.000
955.100	955.100	2000.000	972.700	972.700	42000.000
958.000	958.000	4000.000	972.900	972.900	44000.000
960.000	960.000	6000.000	973.100	973.100	46000.000
962.000	962.000	8000.000	973.300	973.300	48000.000
963.600	963.600	10000.000	973.500	973.500	50000.000
965.100	965.100	12000.000	973.700	973.700	52000.000
966.200	966.200	14000.000	973.800	973.800	54000.000
967.000	967.000	16000.000	973.900	973.900	56000.000
967.700	967.700	18000.000	974.000	974.000	58000.000
968.300	968.300	20000.000	974.100	974.100	60000.000
968.900	968.900	22000.000	974.200	974.200	62000.000
969.400	969.400	24000.000	974.300	974.300	64000.000
969.800	969.800	26000.000	974.400	974.400	66000.000
970.200	970.200	28000.000	974.500	974.500	68000.000
970.600	970.600	30000.000	974.600	974.600	70000.000
971.000	971.000	32000.000	974.700	974.700	72000.000
971.400	971.400	34000.000	974.800	974.800	74000.000
971.800	971.800	36000.000	974.900	974.900	76000.000
972.100	972.100	38000.000	975.000	975.000	78000.000

```
TIME STEP #        1
*    A    PROFILE 1 = AVERAGE ANNUAL DISCHARGE

EXAMPLE PROBLEM NO 1.  FIXED-BED APPLICATION.  BASIC GEOMETRY.
ACCUMULATED TIME (yrs)..........      0.000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                  DISCHARGE   TEMPERATURE  WATER SURFACE
                                    (cfs)       (deg F)        (ft)
                                  1250.000       0.00        953.188

**** DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP        AVG        AVG VEL (by subsection)
      (CFS)      SURFACE     LINE     HEAD              WIDTH       BED          1         2         3

SECTION NO.       1.000
****   1250.000   953.188   953.251   0.063     1.000    123.928   948.191    0.000     2.019     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      15.000
****   1250.000   957.150   958.285   1.135     1.000     67.126   954.971    0.000     8.546     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.       15.000 ---
                                  DISCHARGE   TEMPERATURE
                                    (cfs)       (deg F)
              Local Inflow:        150.000       0.00
                    Total:        1100.000       0.00

SECTION NO.      32.000
****   1100.000   963.529   963.580   0.051     1.000    130.197   958.863    0.000     1.811     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      33.000
****   1100.000   964.565   964.599   0.034     1.000    219.876   961.193    0.000     1.484     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      33.300
****   1100.000   965.348   965.405   0.057     1.000    205.246   962.559    0.000     1.922     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      35.000
****   1100.000   966.613   966.986   0.373     1.000     77.367   963.711    0.000     4.898     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      42.000
****   1100.000   972.961   972.994   0.032     1.000    242.312   969.815    0.000     1.443     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000

--- LOCAL INFLOW POINT #  2 is upstream of Section No.       42.000 ---
                                  DISCHARGE   TEMPERATURE
                                    (cfs)       (deg F)
              Local Inflow:         78.000       0.00
                    Total:        1022.000       0.00

SECTION NO.      44.000
****   1022.000   973.803   973.819   0.015     1.000    260.206   969.857    0.000     0.995     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
SECTION NO.      53.000
****   1022.000   975.218   975.804   0.586     1.000     78.162   973.089    0.000     6.141     0.000
                                                  FLOW DISTRIBUTION (%) =    0.000   100.000     0.000
```

```
--- LOCAL INFLOW POINT #  3 is upstream of Section No.       53.000 ---
                              DISCHARGE   TEMPERATURE
                                (cfs)       (deg F)
             Local Inflow:     340.000        0.00
                    Total:     682.000        0.00

SECTION NO.     55.000
****    682.000   978.823    978.863   0.040     1.000   101.072   974.641    0.000   1.614    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     58.000
****    682.000   979.887    980.091   0.204     1.000    56.154   976.536    0.000   3.625    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

==========================================================================================
TIME STEP #        2
*   A    PROFILE 2 = BANK FULL FLOW

EXAMPLE PROBLEM NO 1.  FIXED-BED APPLICATION.  BASIC GEOMETRY.
ACCUMULATED TIME (yrs)..........          0.003

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                              DISCHARGE   TEMPERATURE   WATER SURFACE
                                (cfs)       (deg F)         (ft)
                              2500.000        0.00        955.825

**** DISCHARGE      WATER      ENERGY  VELOCITY    ALPHA       TOP       AVG         AVG VEL (by subsection)
       (CFS)       SURFACE      LINE     HEAD                 WIDTH      BED           1        2          3

SECTION NO.      1.000
****   2500.000   955.825    955.927   0.102     1.000   151.140   949.377    0.000   2.565    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     15.000
****   2500.000   959.673    960.191   0.518     1.000   169.528   957.119    0.000   5.774    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.       15.000 ---
                              DISCHARGE   TEMPERATURE
                                (cfs)       (deg F)
             Local Inflow:     300.000        0.00
                    Total:    2200.000        0.00

SECTION NO.     32.000
****   2200.000   965.362    965.465   0.103     1.000   140.643   959.281    0.000   2.572    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     33.000
****   2200.000   966.551    966.604   0.053     1.000   232.014   961.404    0.000   1.842    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     33.300
****   2200.000   967.192    967.273   0.082     1.000   215.861   962.746    0.000   2.292    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     35.000
****   2200.000   968.416    968.811   0.395     1.000   168.513   965.827    0.000   5.043    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     42.000
****   2200.000   974.977    975.025   0.048     1.000   242.514   969.809    0.000   1.755    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

--- LOCAL INFLOW POINT #  2 is upstream of Section No.       42.000 ---
                              DISCHARGE   TEMPERATURE
                                (cfs)       (deg F)
             Local Inflow:     150.000        0.00
                    Total:    2050.000        0.00

SECTION NO.     44.000
****   2050.000   975.775    975.802   0.027     1.000   268.762   969.954    0.000   1.310    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     53.000
****   2050.000   977.052    977.665   0.613     1.000    97.657   973.710    0.000   6.281    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

--- LOCAL INFLOW POINT #  3 is upstream of Section No.       53.000 ---
                              DISCHARGE   TEMPERATURE
                                (cfs)       (deg F)
             Local Inflow:     650.000        0.00
                    Total:    1400.000        0.00

SECTION NO.     55.000
****   1400.000   980.715    980.794   0.080     1.000   108.982   975.039    0.000   2.264    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.     58.000
****   1400.000   981.937    982.255   0.318     1.000    63.384   977.053    0.000   4.522    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

------------------------------------------------------------------------------------------
$$END

      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =        2
TOTAL NO. OF WS PROFILES =            2
ITERATIONS IN EXNER EQ =              0

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  0.00 SECONDS
```

6.2 Example Problem 2 - Hydraulic and Geometric Options

This problem builds on Example Problem 1; it is also a fixed-bed run and illustrates some of the more frequently used options for describing certain geometric and hydraulic conditions. The input file for Example Problem 2 is shown in Table 6-2a. Input items that differ from Example Problem 1 are discussed in Sections 6.2.1 through 6.2.5. Output is described in Sections 6.2.6 through 6.2.7.

6.2.1 Manning's *n* Vs. Elevation

Some situations are better modeled by varying *n* values vertically rather than horizontally; this is done in Example Problem 2 at Section No. 15.0 by using **NV** records (see Appendix A for details). The *n* vs. elevation functions derived for Section No. 15.0 are shown graphically in Figure 6-2. These functions will be used at all subsequent (upstream) cross sections until another **NV** or **NC** record is found. Elevations on **NV** records are constant for all subsequent cross sections, therefore, as the computation proceeds upstream they may become too low. In this example, the **NC** record at Section No. 32.0 returns the computations to an *n* vs. subsection function. The **NV** record can also be used to vary *n* with discharge.

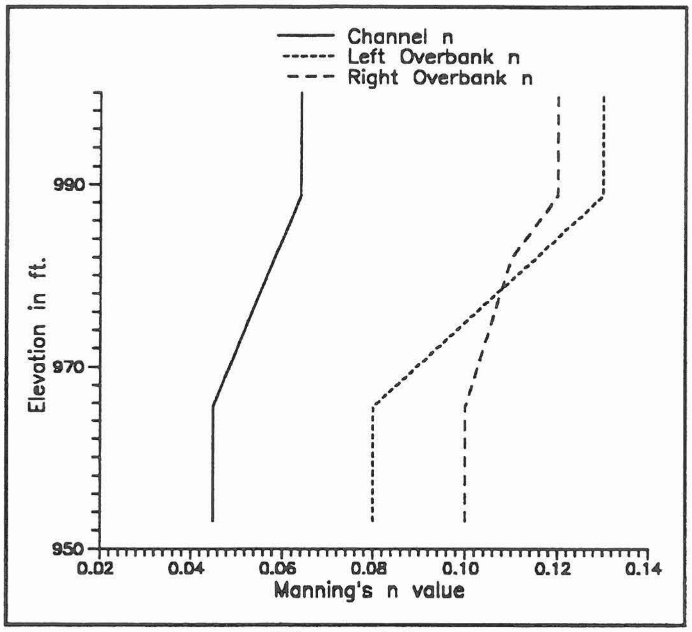

Figure 6-2
Manning's *n* vs. Elevation, Section No. 15

6.2.2 Internal Boundary Conditions

Study reaches will occasionally contain hydraulic controls, such as weirs and gated structures, where the step backwater solution is not appropriate. The effects of such structures can be simulated using **X5** and **R** data to define an Internal Boundary Condition (IBC). In Example Problem 2, Section No. 33.0 is immediately upstream of a gated spillway that can arbitrarily control the upstream water surface elevation. Also, Section No. 35.0 is at the upstream face of an erosion control weir which maintains a fixed water surface elevation of 974 ft at that section during low flow conditions.

An internal boundary condition breaks the project reach into two smaller subreaches, creating a new upstream boundary and a new downstream boundary at that break point. The new upstream boundary is the cross section downstream of the internal boundary condition; the new downstream boundary is the cross section containing the **X5** record defining the internal boundary condition.

Some modifications to the reach geometry are needed when an internal boundary condition is added to the model. Because Section No. 32.0 is representative of the reach downstream of the spillway at Section No. 33.0, Section No. 32.1, a duplicate of Section No. 32.0, was added at the downstream face of the spillway. This new cross section was assigned downstream reach lengths equal to those originally defined for Section No. 33.0 and the reach lengths of Section No. 33.0 were set to 0.0. The "2" in Field 4 of the **X5** record for Section

No. 33.0 causes the water surface elevation for that cross section to be read from Field 2 of the R record in the flow data. Thus, for this example, the specified water surface elevation at Section No. 33.0 will be 966 ft for the first discharge and 978 ft for the second. The larger of this water surface elevation or that computed by the step backwater is used.

Similarly, Section No. 33.9, a duplicate of Section No. 33.3, was added downstream of Section No. 35.0; its reach lengths are those originally set for Section No. 35.0 and the reach lengths for Section No. 35.0 were also set to 0.0. The **X5** record entered with this cross section indicates that the minimum water surface elevation and head loss at this point are 974 ft and 0.5 ft, respectively.

6.2.3 Ineffective Flow Area

A portion of Section No. 15.0 is deemed to be ineffective; that is, it carries no flow. This is described with the **X3** record, which allows easy modification of existing cross section data to reflect encroachments. In this case, the left encroachment starts at the intersection of the left bank at elevation 961 ft and extends at that elevation to station 10,700 ft. The right encroachment starts at station 11,000 ft and extends at elevation 970 ft to the right bank. This is implemented in HEC-6 by raising the **GR** points within an encroachment to the encroachment elevation.

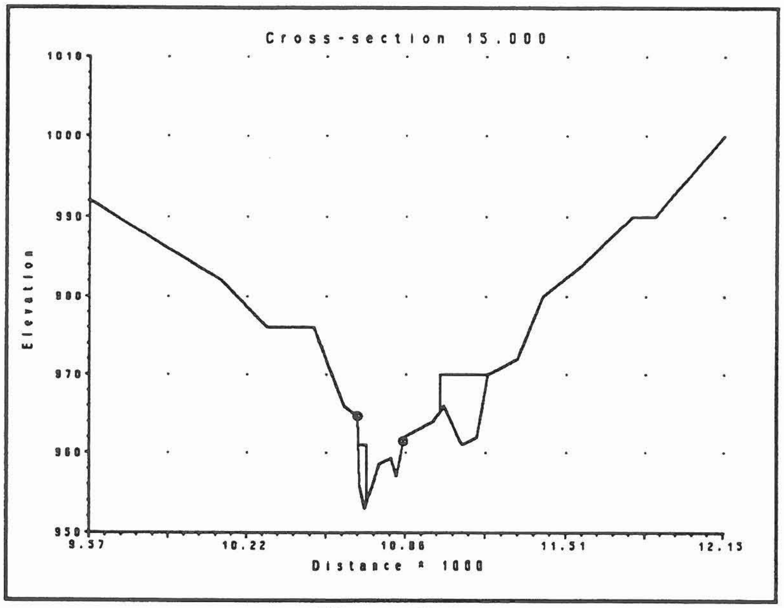

Figure 6-3
Cross Section 15.0 with encroachments

Another commonly used Ineffective Flow option is available to restrain flow within the channel until the water surface is above the bank elevation. This option is used in Section No. 33.9 and 35.0 to model the natural levees in that reach.

Table 6-2a
Example Problem 2 - Input
Hydraulic Options

```
T1        EXAMPLE PROBLEM NO 2.  HYDRAULIC AND GEOMETRIC OPTIONS.
T2        3 LOCAL INFLOWS, USE OF R RECORDS.
T3        SOUTH FORK, ZUMBRO RIVER      ** Example Problem 2 **
NC     .1        .1     .04       .1       .3
X1    1.0        31  10077.   10275.       0.        0.        0.
GR 1004.    9915.   978.4   10002.    956.0   10060.    959.2   10077.    959.3   10081.
GR 950.0   10092.  948.48   10108.    946.6   10138.    944.7   10158.    955.2   10225.
GR 956.2   10243.   958.9   10250.    959.8   10275.    959.8   10300.    959.9   10325.
GR 958.8   10350.   957.4   10400.    970.0   10700.    966.0   10960.    970.0   11060.
GR 968.0   11085.   968.0   11240.    970.0   11365.    970.0   11500.    970.0   11615.
GR 962.0   11665.   962.0   12400.    976.0   12550.    980.0   12670.    982.0   12730.
GR 984.0   12735.
HD    1.0
NV     22      .045   965.6     .064    988.8
NV     12       .08   965.6      .13    988.8
```

```
NV    33      .1   965.6     .11   982.0     .12   988.8
X1  15.0      27  10665.  10850.   3560.   3030.   3280.
X3                        10700.   961.0  11000.   970.0
GR 992.0   9570.   982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7  10665.   956.0  10673.   953.0  10693.   954.0  10703.   955.6  10723.
GR 958.6  10750.   959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0  10852.   964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0  11190.   972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0  11865.  1000.0  12150.
HD  15.0
   Model Cascade Creek as a local inflow.
QT
NC    .1      .1     .05
X1  32.0      29  10057.  10271.   3630.   3060.   4240.
GR 998.0   9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5  10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.   992.0  11240.  1000.0  11330.   1008.  11425.
HD  32.0
  Section 32.1 is a duplicate of Sec 32.0 which is representative of the reach
  downstream of the spillway at Sec 33.0.  Sec 32.1 is a new upstream boundary.
X1  32.1      29  10057.  10271.   3130.   3250.   3320.
X3    10
GR 998.0   9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5  10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.   992.0  11240.  1000.0  11330.   1008.  11425.
HD  32.1
  A spillway is located here.
X1  33.0      21   1850.   2150.       0       0       0
X5                             2
XL                  250.
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.0
  NOTE:       Section 33.3 is a duplicate of Section  33.0.
   Section 33.0 is a good representative cross section for a long reach.  A
   duplicate is used here to break up the long reach into two smaller reaches.
X1  33.3      21   1850.   2150.   1550.   1750.   1750.     .95    1.49
XL                  250.
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.3
  Section 33.9 is a duplicate of Section 33.3.  It is placed at the downstream
  face of the weir being defined at Section 35.0 and is a new upstream boundary.
X1  33.9      21   1850.   2150.   1050.   1050.   1050.     .95    1.65
X3    10
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.9
  A weir is located here.
X1  35.0      22   9894.  10245.       0       0       0
X3    10
X5          974.     0.5
GR 984.0   9035.   980.0   9070.   978.0   9135.   980.0   9185.   982.0   9270.
GR 980.0   9465.   981.7   9595.   983.7   9745.   984.7   9894.   963.4  9894.1
GR 963.3   9954.   967.1   9974.   967.4  10004.   968.2  10044.   967.6  10054.
GR 973.4  10115.   977.4  10120.   983.7  10155.   984.0  10245.   982.0  10695.
GR 982.0  10895.  1004.0  11085.
HD  35.0
NC   .06     .06    .045
X1  42.0      32   9880.  10130.   5370.   5000.   5210.
GR 996.0   7130.   998.0   7310.   998.0   7930.   992.0   8205.   990.0   8495.
GR 988.0   8780.   986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0   9880.   969.8   9881.   969.8   9941.   985.8   9941.   985.8   9943.
GR 969.8   9943.   969.8  10001.   986.7  10001.   986.7  10003.   969.8  10003.
GR 969.8  10067.   985.8  10067.   985.8  10069.   969.8  10069.   969.8  10129.
GR 989.9  10130.   989.5  10180.   988.6  10230.   987.6  10280.   985.2  10430.
GR 986.8  11720.   989.9  12310.
HD  42.0
   Model Silver Creek as a local inflow.
```

```
QT
X1  44.0       28   9845.  10127.   3200.   3800.   3500.
XL                          9850.  10200.
GR 1002.    8035.   992.0   8150.   990.0   8305.   990.0   8735.   988.0   8835.
GR 996.0    9285.  1017.6   9425.   990.0   9505.   986.0   9650.   984.1   9788.
GR 980.6    9845.   970.9   9868.   972.2   9898.   970.5   9968.   967.5   9998.
GR 968.9   10028.   967.4  10058.   967.1  10078.   971.9  10118.   976.8  10127.
GR 977.8   10150.   976.9  10193.   982.0  10206.   981.2  10300.   979.2  10325.
GR 983.1   10400.   999.8  10450.  1002.4  10464.
HD  44.0
X1  53.0       22  10000.  10136.   3366.   2832.   2942.
GR 1004.    7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0    8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8   10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2   10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.   10470.  1004.0  10700.
HD  53.0
   model Bear Creek as a local inflow.
QT
X1  55.0       18   9931.  10062.   2275.   3430.   2770.
GR 1004.    7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3    9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8    9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8   10187.   986.0  10307.   990.0  10497.
HD  55.0
X1  58.0       22  9912.0 10015.0   1098.   1012.   1462.
GR 1006.    8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2    9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8   10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0   10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0   11137.   988.0  11192.
HD  58.0
EJ
$HYD
*   A   PROFILE 1 = AVERAGE ANNUAL DISCHARGE
Q  1250.    150.     78.     340.
R   960.    966.
T    60.     60.      60.     60.
W     5.
*   B   PROFILE 2 = FLOOD EVENT  (0.5% CHANCE FLOOD)
Q 10000.   1200.    600.   2600.
R   973.    978.
W     1.
$$END
```

6.2.4 Conveyance Limits

Ineffective flow areas can also be specified with **XL** data. In Example Problem 2, Section No. 33.0 has non-conveying areas centered about the channel on both sides, leaving a conveyance width of 250 ft. Since Section No. 33.3 is a duplicate of Section No. 33.0, the conveyance limit is duplicated at this section. At Section No. 44.0, conveyance limits have been specified at stations 9,850 and 10,200, leaving a conveyance width of 350 ft (not centered about the channel). The difference between the ineffective flow area option and the conveyance limits option is that deposition may occur in wetted areas outside the conveyance limits, but not in ineffective flow areas. Although both methods may yield the same hydraulic conditions, sediment deposition may differ. Refer to Sections 3.2.7 for more details.

6.2.5 Downstream Boundary Water Surface Elevation

In Example Problem 1, the downstream boundary water surface elevation was computed for each flow by interpolation within a rating curve provided by the user. Alternately, when the downstream water surface elevation is independent of discharge, as with a reservoir pool elevation, the boundary condition can be specified as a time series of water surface elevations (i.e. a stage hydrograph). This is illustrated by the **R** records in the input data for Example Problem 2. For this problem the starting water surface elevation at the downstream boundary is 960 ft for the first discharge and 973 ft for the second.

6.2.6 A-Level Hydraulic Output

A-level hydraulic output was produced for the first flow profile (time step) of Example Problem 2. This output, shown in Table 6-2b, is quite similar to that of Example Problem 1. Note that the water surface elevation at Section No. 33.0 of 966 ft reflects the elevation specified on the **R** record.

A-level hydraulic output is a subset of B-level hydraulic output. It can, therefore, be seen that at time step 2, the 974 ft minimum pool elevation for Section No. 35.0 (as specified on the **X5** record) was submerged by tailwater and, therefore, a head loss of 0.5 ft was added to the tailwater elevation of 978.675 ft resulting in a computed water surface elevation of 979.175 ft.

The large discharge for time step 2 produced a sufficiently high water surface profile that the flow at Sections 33.0 and 44.0 is bounded by the conveyance limits. This can be seen in the column labeled "TOP WIDTH" where the values are 250 ft and 350 ft respectively for these cross sections.

6.2.7 B-Level Hydraulic Output

B-level hydraulic output was produced for the second flow profile of Example Problem 2. This output is more detailed than the A-level output produced by the first profile. It may be used to check the effective geometry of each cross section as well as the computed value of most of the hydraulic parameters used in the backwater calculations. For example, to check the operation of the *n* vs. elevation function at Section No. 15.0, refer to the table "REACH PROPERTIES BY STRIP". The *n* values used for the left overbank, channel, and right overbank are 0.0963, 0.0512, and 0.1046, respectively. These are interpolated from the input **NV** table for a computed water surface elevation of 973.158 ft. Also, note that the **GR** data shown for Section No. 15.0 reflect the **X3** encroachment. Elevations on the left side are kept above 961 ft to station 10,700. The same is seen on the right side as elevations are kept at 970 ft after station 11,000 until the original ground line is encountered.

Table 6-2b
Example Problem 2
Hydraulic Output

```
*****************************************************      **************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS     *      * U.S. ARMY CORPS OF ENGINEERS       *
*      Version: 4.1.00 -  AUGUST 1993               *      * HYDROLOGIC ENGINEERING CENTER      *
* INPUT FILE:   EXAMPLE2.DAT                        *      * 609 SECOND STREET                  *
* OUTPUT FILE: EXAMPLE2.OUT                         *      * DAVIS, CALIFORNIA 95616-4687       *
* RUN DATE: 30 AUG 93     RUN TIME: 10:28:02        *      * (916) 756-1104                     *
*****************************************************      **************************************

                         X     X  XXXXXXX   XXXXX          XXXXX
                         X     X  X        X     X        X     X
                         X     X  X        X              X
                         XXXXXXX  XXXX     X       XXXXX  XXXXXX
                         X     X  X        X              X     X
                         X     X  X        X     X        X     X
                         X     X  XXXXXXX   XXXXX          XXXXX

         ******************************************************************
         *  MAXIMUM LIMITS FOR THIS VERSION ARE:                          *
         *       10  Stream Segments (Main Stem + Tributaries)            *
         *      150  Cross Sections                                       *
         *      100  Elevation/Station Points per Cross Section           *
         *       20  Grain Sizes                                          *
         *       10  Control Points                                       *
         ******************************************************************

T1       EXAMPLE PROBLEM NO 2.  HYDRAULIC AND GEOMETRIC OPTIONS.
T2       3 LOCAL INFLOWS, USE OF R RECORDS.
T3       SOUTH FORK, ZUMBRO RIVER      ** Example Problem 2 **
```

```
N values...  Left   Channel   Right    Contraction    Expansion
           0.1000   0.0400   0.1000       1.1000       0.7000

SECTION NO.     1.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N-Values vs. Elevation Table
          Channel              Left Overbank            Right Overbank
  0.0450       966.        0.0800       966.        0.1000       966.
  0.0640       989.        0.1300       989.        0.1100       982.
  0.0000         0.        0.0000         0.        0.1200       989.

SECTION NO.    15.000
...Left Encroachment defined at station 10700.000 at elevation   961.000
...Right Encroachment defined at station 11000.000 at elevation   970.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  1 occurs upstream from Section No.       15.000

N values...  Left   Channel   Right    Contraction    Expansion
           0.1000   0.0500   0.1000       1.1000       0.7000

SECTION NO.    32.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    32.100
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
            Natural Levees at Station        10057.000      10271.000
                Ineffective Elevation          978.500        978.500
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.000
...Internal Boundary Condition
   Water Surface Elevation will be read from R-RECORD, Field  2
   Head Loss =      0.000
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.300
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.490 ft.
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.900
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.650 ft.
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
            Natural Levees at Station         1757.500       2042.500
                Ineffective Elevation          986.060        986.150
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    35.000
...Internal Boundary Condition
   Water Surface Elevation =   974.000
   Head Loss =      0.500
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
            Natural Levees at Station         9894.000      10245.000
                Ineffective Elevation          984.700        984.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N values...  Left   Channel   Right    Contraction    Expansion
           0.0600   0.0450   0.0600       1.1000       0.7000

SECTION NO.    42.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  2 occurs upstream from Section No.       42.000

SECTION NO.    44.000
...Limit CONVEYANCE between stations    9850.000 and   10200.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    53.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  3 occurs upstream from Section No.       53.000

SECTION NO.    55.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    58.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 13
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  13
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA

==========================================================================
```

```
$HYD
FIXED-BED MODEL

==========================================================================================
TIME STEP #       1
*   A    PROFILE 1 = AVERAGE ANNUAL DISCHARGE

EXAMPLE PROBLEM NO 2.  HYDRAULIC AND GEOMETRIC OPTIONS.
ACCUMULATED TIME (yrs)..........       0.000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                  DISCHARGE   TEMPERATURE  WATER SURFACE
                                    (cfs)       (deg F)        (ft)
                                  1250.000       60.00       960.000

****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP      AVG        AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD              WIDTH     BED          1        2        3

SECTION NO.      1.000
****  1250.000   960.000   960.008   0.008    1.266   412.262   951.520    0.120    0.731    0.075
                                                FLOW DISTRIBUTION (%) =    0.589   98.210    1.201
SECTION NO.     15.000
****  1250.000   960.343   960.518   0.174    1.000   143.121   957.736    0.000    3.350    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.       15.000 ---
                                  DISCHARGE   TEMPERATURE
                                    (cfs)       (deg F)
               Local Inflow:      150.000       60.00
                      Total:     1100.000       60.00

SECTION NO.     32.000
****  1100.000   964.111   964.151   0.041    1.000   133.277   959.020    0.000    1.621    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     32.100
****  1100.000   965.009   965.038   0.029    1.000   138.576   959.202    0.000    1.367    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     33.000
...Internal Boundary Condition - Water Surface =     966.000
                                     Head Loss =       0.000
****  1100.000   966.000   966.016   0.016    1.000   228.689   961.331    0.000    1.030    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     33.300
****  1100.000   966.410   966.441   0.031    1.000   210.966   962.711    0.000    1.410    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     33.900
****  1100.000   966.792   966.820   0.027    1.000   212.251   962.893    0.000    1.329    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     35.000
...Internal Boundary Condition - Water Surface =     974.000
                                     Head Loss =       0.500
****  1100.000   974.000   974.008   0.008    1.000   221.700   967.056    0.000    0.715    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     42.000
****  1100.000   974.356   974.371   0.016    1.000   242.451   969.819    0.000    1.000    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

--- LOCAL INFLOW POINT #  2 is upstream of Section No.       42.000 ---
                                  DISCHARGE   TEMPERATURE
                                    (cfs)       (deg F)
               Local Inflow:       78.000       60.00
                      Total:     1022.000       60.00

SECTION NO.     44.000
****  1022.000   974.697   974.707   0.010    1.000   264.095   969.892    0.000    0.805    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     53.000
****  1022.000   975.359   975.884   0.525    1.000    79.436   973.146    0.000    5.813    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

--- LOCAL INFLOW POINT #  3 is upstream of Section No.       53.000 ---
                                  DISCHARGE   TEMPERATURE
                                    (cfs)       (deg F)
               Local Inflow:      340.000       60.00
                      Total:      682.000       60.00

SECTION NO.     55.000
****   682.000   978.831   978.872   0.042    1.000   100.844   974.694    0.000    1.635    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     58.000
****   682.000   979.918   980.119   0.201    1.000    56.248   976.547    0.000    3.596    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

==========================================================================================
TIME STEP #       2
*   BB   PROFILE 2 = FLOOD EVENT   (0.5% CHANCE FLOOD)

EXAMPLE PROBLEM NO 2.  HYDRAULIC AND GEOMETRIC OPTIONS.
ACCUMULATED TIME (yrs)..........       0.014

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                  DISCHARGE   TEMPERATURE  WATER SURFACE
                                    (cfs)       (deg F)        (ft)
                                 10000.000       60.00       973.000
```

```
****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA      TOP       AVG        AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD               WIDTH      BED          1         2        3

SECTION NO.      1.000

 Cross Section Geometry  (STA,ELEV)
   9915.000  1004.000   10002.000   978.400   10060.000   956.000   10077.000   959.200   10081.000   959.300
  10092.000   950.000   10108.000   948.480   10138.000   946.600   10158.000   944.700   10225.000   955.200
  10243.000   956.200   10250.000   958.900   10275.000   959.800   10300.000   959.800   10325.000   959.900
  10350.000   958.800   10400.000   957.400   10700.000   970.000   10960.000   966.000   11060.000   970.000
  11085.000   968.000   11240.000   968.000   11365.000   970.000   11500.000   970.000   11615.000   970.000
  11665.000   962.000   12400.000   962.000   12550.000   976.000   12670.000   980.000   12730.000   982.000
  12735.000   984.000

****   10000.000   973.000   973.013   0.013     4.272  2501.875   951.520    0.301    1.243    0.258
                                                 FLOW DISTRIBUTION (%) =    1.914   52.875   45.211

        REACH PROPERTIES BY STRIP            1            2            3
                        INEFF FLOW  EL  -99999.000  -99999.000  -99999.000
  U/S SECTION...        CONVEYANCE       43459.641 1200769.591 1026719.286
                              AREA          635.95      4252.96    17543.21
                        HYD RADIUS          9.8620      20.9515      7.8160
  REACH...             Manning's N          0.1000       0.0400      0.1000
                           SQRT(L)          0.0000       0.0000      0.0000
  D/S SECTION...              AREA            0.00         0.00        0.00
                        HYD RADIUS           0.000        0.000       0.000

SECTION NO.     15.000

 Cross Section Geometry  (STA,ELEV)
   9570.000   992.000   10110.000   982.000   10300.000   976.000   10490.000   976.000   10610.000   966.000
  10665.000   964.700   10673.000   961.000   10693.000   961.000   10699.999   961.000   10700.000   953.700
  10703.000   954.000   10723.000   955.600   10750.000   958.600   10800.000   959.300   10822.000   957.000
  10825.000   957.300   10850.000   961.500   10852.000   962.000   10970.000   964.000   11000.000   965.333
  11000.001   970.000   11015.000   970.000   11090.000   970.000   11150.000   970.000   11190.000   970.000
  11310.000   972.000   11410.000   980.000   11570.000   984.000   11770.000   990.000   11865.000   990.000
  12150.000  1000.000

****   10000.000   973.158   973.259   0.102     2.191   800.329   958.554    0.795    2.878    0.700
                                                 FLOW DISTRIBUTION (%) =    5.853   77.741   16.406

        REACH PROPERTIES BY STRIP            1            2            3
                        INEFF FLOW  EL  -99999.000  -99999.000  -99999.000
  U/S SECTION...        CONVEYANCE       34197.889  454198.571   95851.669
                              AREA          736.62      2701.62     2342.75
                        HYD RADIUS          5.2173      13.9368      4.8880
  REACH...             Manning's N          0.0963       0.0512      0.1046
                           SQRT(L)         59.6657      57.2713     55.0454
  D/S SECTION...              AREA          635.95      4252.96    17543.21
                        HYD RADIUS           9.862       20.951       7.816

--- LOCAL INFLOW POINT #  1 is upstream of Section No.      15.000 ---
                                DISCHARGE    TEMPERATURE
                                  (cfs)        (deg F)
                 Local Inflow:   1200.000        60.00
                        Total:   8800.000        60.00

SECTION NO.     32.000

 Cross Section Geometry  (STA,ELEV)
   9080.000   998.000    9250.000   982.000    9510.000   982.000    9600.000   980.000    9925.000   980.010
  10000.000   979.480   10057.000   978.500   10075.000   968.600   10087.000   959.820   10097.000   956.500
  10117.000   956.800   10137.000   957.800   10157.000   959.400   10177.000   959.600   10196.000   959.820
  10225.000   966.500   10250.000   971.200   10271.000   978.500   10300.000   978.500   10350.000   978.600
  10370.000   978.910   10387.000   978.960   10610.000   980.000   10745.000   982.000   11145.000   982.000
  11150.000   984.000   11240.000   992.000   11330.000  1000.000   11425.000  1008.000

****    8800.000   974.581   974.786   0.205     1.000   195.704   962.193    0.000    3.630    0.000
                                                 FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

        REACH PROPERTIES BY STRIP            1            2            3
                        INEFF FLOW  EL  -99999.000  -99999.000  -99999.000
  U/S SECTION...        CONVEYANCE           0.000  377076.318       0.000
                              AREA            0.00      2424.45        0.00
                        HYD RADIUS          0.0000      11.9716      0.0000
  REACH...             Manning's N          0.1000       0.0500      0.1000
                           SQRT(L)         60.2495      65.1153     55.3173
  D/S SECTION...              AREA          736.62      2701.62     2342.75
                        HYD RADIUS           5.217       13.937       4.888

SECTION NO.     32.100

 Cross Section Geometry  (STA,ELEV)
   9080.000   998.000    9250.000   982.000    9510.000   982.000    9600.000   980.000    9925.000   980.010
  10000.000   979.480   10057.000   978.500   10075.000   968.600   10087.000   959.820   10097.000   956.500
  10117.000   956.800   10137.000   957.800   10157.000   959.400   10177.000   959.600   10196.000   959.820
  10225.000   966.500   10250.000   971.200   10271.000   978.500   10300.000   978.500   10350.000   978.600
  10370.000   978.910   10387.000   978.960   10610.000   980.000   10745.000   982.000   11145.000   982.000
  11150.000   984.000   11240.000   992.000   11330.000  1000.000   11425.000  1008.000

****    8800.000   976.143   976.304   0.161     1.000   202.931   962.684    0.000    3.222    0.000
                                                 FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
```

```
        REACH PROPERTIES BY STRIP          1            2            3
                     INEFF FLOW  EL    978.500   -99999.000     978.500
     U/S SECTION...     CONVEYANCE       0.000   448358.998       0.000
                              AREA        0.00      2731.27        0.00
                        HYD RADIUS      0.0000      12.9813      0.0000
     REACH...          Manning's N      0.1000       0.0500      0.1000
                           SQRT(L)     55.9464      57.6194     57.0088
     D/S SECTION...           AREA        0.00      2424.45        0.00
                        HYD RADIUS       0.000       11.972       0.000

SECTION NO.     33.000
...Internal Boundary Condition - Water Surface =     978.000
                                     Head Loss =       0.000

 Cross Section Geometry (STA,ELEV)
   980.000  1000.000     1060.000   990.000    1150.000   980.000    1180.000   982.000    1215.000   982.000
  1260.000   980.000     1300.000   982.000    1350.000   982.000    1420.000   980.000    1540.000   980.000
  1730.000   982.000     1830.000   982.000    1850.000   984.410    1851.000   979.190    1875.000   970.424
  1900.800   961.000     2099.200   961.000    2125.000   968.771    2149.000   976.000    2150.000   984.500
  2800.000   982.000     3100.000   990.000    3170.000  1000.000

****    8800.000    978.000    978.074    0.074     1.000   250.000   961.887    0.000    2.185    0.000
                                                     FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

        REACH PROPERTIES BY STRIP          1            2            3
                     INEFF FLOW  EL  -99999.000   -99999.000  -99999.000
     U/S SECTION...     CONVEYANCE       0.000   758052.954       0.000
                              AREA        0.00      4028.19        0.00
                        HYD RADIUS      0.0000      15.9335      0.0000
     REACH...          Manning's N      0.1000       0.0500      0.1000
                           SQRT(L)      0.0000       0.0000      0.0000
     D/S SECTION...           AREA        0.00      2731.27        0.00
                        HYD RADIUS       0.000       12.981       0.000

SECTION NO.     33.300

 Cross Section Geometry (STA,ELEV)
   931.000  1001.490     1007.000   991.490    1092.500   981.490    1121.000   983.490    1154.250   983.490
  1197.000   981.490     1235.000   983.490    1282.500   983.490    1349.000   981.490    1463.000   981.490
  1643.500   983.490     1738.500   983.490    1757.500   985.900    1758.450   980.680    1781.250   971.914
  1805.760   962.490     1994.240   962.490    2018.750   970.261    2041.550   977.490    2042.500   985.990
  2660.000   983.490     2945.000   991.490    3011.500  1001.490

****    8800.000    978.266    978.363    0.096     1.000   237.500   963.377    0.000    2.488    0.000
                                                     FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

        REACH PROPERTIES BY STRIP          1            2            3
                     INEFF FLOW  EL  -99999.000   -99999.000  -99999.000
     U/S SECTION...     CONVEYANCE       0.000   630880.219       0.000
                              AREA        0.00      3536.31        0.00
                        HYD RADIUS      0.0000      14.7069      0.0000
     REACH...          Manning's N      0.1000       0.0500      0.1000
                           SQRT(L)     39.3700      41.8330     41.8330
     D/S SECTION...           AREA        0.00      4028.19        0.00
                        HYD RADIUS       0.000       15.934       0.000

SECTION NO.     33.900

 Cross Section Geometry (STA,ELEV)
   931.000  1001.650     1007.000   991.650    1092.500   981.650    1121.000   983.650    1154.250   983.650
  1197.000   981.650     1235.000   983.650    1282.500   983.650    1349.000   981.650    1463.000   981.650
  1643.500   983.650     1738.500   983.650    1757.500   986.060    1758.450   980.840    1805.760   962.650
  1994.240   962.650     2041.550   977.650    2042.500   986.150    2660.000   983.650    2945.000   991.650
  3011.500  1001.650

****    8800.000    978.486    978.574    0.088     1.000   277.066   965.114    0.000    2.375    0.000
                                                     FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

        REACH PROPERTIES BY STRIP          1            2            3
                     INEFF FLOW  EL    986.060   -99999.000     986.150
     U/S SECTION...     CONVEYANCE       0.000   611504.940       0.000
                              AREA        0.00      3704.84        0.00
                        HYD RADIUS      0.0000      13.0880      0.0000
     REACH...          Manning's N      0.1000       0.0500      0.1000
                           SQRT(L)     32.4037      32.4037     32.4037
     D/S SECTION...           AREA        0.00      3536.31        0.00
                        HYD RADIUS       0.000       14.707       0.000

SECTION NO.     35.000
...Internal Boundary Condition - Water Surface =     974.000
                                     Head Loss =       0.500

 Cross Section Geometry (STA,ELEV)
  9035.000   984.000     9070.000   980.000    9135.000   978.000    9185.000   980.000    9270.000   982.000
  9465.000   980.000     9595.000   981.700    9745.000   983.700    9894.000   984.700    9894.100   963.400
  9954.000   963.300     9974.000   967.100   10004.000   967.400   10044.000   968.200   10054.000   967.600
 10115.000   973.400    10120.000   977.400   10155.000   983.700   10245.000   984.000   10695.000   982.000
 10895.000   982.000    11085.000  1004.000

****    8800.000    978.986    979.155    0.169     1.000   234.784   967.632    0.000    3.301    0.000
                                                     FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

        REACH PROPERTIES BY STRIP          1            2            3
                     INEFF FLOW  EL    984.700   -99999.000     984.000
     U/S SECTION...     CONVEYANCE       0.000   381293.994       0.000
```

```
                        AREA        0.00     '2665.83         0.00
                  HYD RADIUS      0.0000     10.5576        0.0000
REACH...         Manning's N      0.1000      0.0500        0.1000
                     SQRT(L)      0.0000      0.0000        0.0000
D/S SECTION...          AREA        0.00     3704.84          0.00
                  HYD RADIUS       0.000      13.088         0.000

SECTION NO.    42.000

 Cross Section Geometry (STA,ELEV)
   7130.000   996.000   7310.000   998.000   7930.000   998.000   8205.000   992.000   8495.000   990.000
   8780.000   988.000   8990.000   986.000   9570.000   985.700   9707.000   986.450   9857.000   989.440
   9880.000   990.000   9881.000   969.800   9941.000   969.800   9941.000   985.800   9943.000   985.800
   9943.000   969.800  10001.000   969.800  10001.000   986.700  10003.000   986.700  10003.000   969.800
  10067.000   969.800  10067.000   985.800  10069.000   985.800  10069.000   969.800  10129.000   969.800
  10130.000   989.900  10180.000   989.500  10230.000   988.600  10280.000   987.600  10430.000   985.200
  11720.000   986.800  12310.000   989.900

****    8800.000   981.452   981.603    0.151     1.000   243.155   969.845    0.000   3.118    0.000
                                                  FLOW DISTRIBUTION (%) =     0.000 100.000    0.000

    REACH PROPERTIES BY STRIP          1             2             3
                 INEFF FLOW EL   -99999.000   -99999.000   -99999.000
U/S SECTION...      CONVEYANCE        0.000   385783.789        0.000
                          AREA         0.00      2822.24         0.00
                    HYD RADIUS       0.0000       8.4220       0.0000
REACH...           Manning's N       0.0600       0.0450       0.0600
                       SQRT(L)      73.2803      72.1803      70.7107
D/S SECTION...            AREA         0.00      2665.83         0.00
                    HYD RADIUS        0.000       10.558        0.000


--- LOCAL INFLOW POINT #  2 is upstream of Section No.      42.000 ---
                            DISCHARGE    TEMPERATURE
                              (cfs)        (deg F)
              Local Inflow:  600.000        60.00
                    Total:  8200.000        60.00

SECTION NO.    44.000

 Cross Section Geometry (STA,ELEV)
   8035.000  1002.000   8150.000   992.000   8305.000   990.000   8735.000   990.000   8835.000   988.000
   9285.000   996.000   9425.000  1017.600   9505.000   990.000   9650.000   986.000   9788.000   984.100
   9845.000   980.600   9850.000   978.491   9868.000   970.900   9898.000   972.200   9968.000   970.500
   9998.000   967.500  10028.000   968.900  10058.000   967.400  10078.000   967.100  10118.000   971.900
  10127.000   976.800  10150.000   977.800  10193.000   976.900  10200.000   979.646  10206.000   982.000
  10300.000   981.200  10325.000   979.200  10400.000   983.100  10450.000   999.800  10464.000  1002.400

****    8200.000   982.491   982.571    0.079     1.085   350.000   970.182    0.000   2.301    0.958
                                                  FLOW DISTRIBUTION (%) =     0.000  95.679    4.321

    REACH PROPERTIES BY STRIP          1             2             3
                 INEFF FLOW EL   -99999.000   -99999.000   -99999.000
U/S SECTION...      CONVEYANCE        0.000   595477.263    26895.576
                          AREA         0.00      3409.65       369.93
                    HYD RADIUS       0.0000      12.1625       5.0296
REACH...           Manning's N       0.0600       0.0450       0.0600
                       SQRT(L)      56.5685      59.1608      61.6441
D/S SECTION...            AREA         0.00      2822.24         0.00
                    HYD RADIUS        0.000        8.422        0.000

SECTION NO.    53.000

 Cross Section Geometry (STA,ELEV)
   7550.000  1004.000   7760.000  1000.000   8440.000   998.000   8640.000   996.000   8780.000   996.000
   8940.000   994.000   9245.000   986.000   9555.000   986.300   9825.000   986.300   9900.000   983.800
  10000.000   982.800  10011.000   978.200  10041.000   974.000  10071.000   972.200  10101.000   972.600
  10121.000   978.200  10136.000   988.700  10154.000   989.300  10200.000   999.200  10320.000  1000.100
  10470.000  1002.000  10700.000  1004.000

****    8200.000   983.479   984.372    0.893     1.037   196.098   975.086    0.681   7.586    0.000
                                                  FLOW DISTRIBUTION (%) =     0.190  99.810    0.000

    REACH PROPERTIES BY STRIP          1             2             3
                 INEFF FLOW EL   -99999.000   -99999.000   -99999.000
U/S SECTION...      CONVEYANCE      274.155   144394.365        0.000
                          AREA        22.82      1078.93         0.00
                    HYD RADIUS       0.3378       8.1588       0.0000
REACH...           Manning's N       0.0600       0.0450       0.0600
                       SQRT(L)      58.0172      54.2402      53.2165
D/S SECTION...            AREA         0.00      3409.65       369.93
                    HYD RADIUS        0.000       12.163        5.030


--- LOCAL INFLOW POINT #  3 is upstream of Section No.      53.000 ---
                            DISCHARGE    TEMPERATURE
                              (cfs)        (deg F)
              Local Inflow: 2600.000        60.00
                    Total:  5600.000        60.00

SECTION NO.    55.000

 Cross Section Geometry (STA,ELEV)
   7592.000  1004.000   7947.000  1000.000   8627.000   996.000   9052.000   990.000   9337.000   986.000
   9737.000   984.300   9837.000   984.700   9910.000   985.500   9931.000   987.200   9955.000   978.100
```

```
   9975.000    974.800   10005.000    974.200   10035.000    972.900   10045.000    973.200   10062.000    983.800
  10187.000    985.800   10307.000    986.000   10497.000    990.000

****    5600.000    986.704    986.858    0.155    2.280  1047.266   976.369    0.750    3.454    0.649
                                               FLOW DISTRIBUTION (%) =   13.274   82.684    4.042

     REACH PROPERTIES BY STRIP          1           2           3
                INEFF FLOW  EL   -99999.000  -99999.000  -99999.000
  U/S SECTION...     CONVEYANCE   32889.590  204875.028   10016.492
                           AREA      990.96     1340.52      348.55
                     HYD RADIUS      1.5513      9.9567      1.2499
  REACH...           Manning's N     0.0600      0.0450      0.0600
                        SQRT(L)     47.6970     52.6308     58.5662
  D/S SECTION...           AREA       22.82     1078.93        0.00
                     HYD RADIUS       0.338       8.159       0.000

SECTION NO.      58.000

 Cross Section Geometry (STA,ELEV)
   8542.000   1006.000    8952.000   1004.000    9702.000   1000.000    9812.000    997.200    9912.000    996.300
   9944.000    976.200    9974.000    975.400    9991.000    978.200   10015.000    990.400   10062.000    988.300
  10065.000    988.800   10065.000    988.300   10169.000    989.300   10172.000    990.000   10242.000    992.000
  10492.000    992.000   10642.000    988.000   10852.000    986.700   11022.000    988.000   11097.000    986.000
  11137.000    986.000   11192.000    988.000

****    5600.000    987.850    988.551    0.701    1.806   576.704   978.997    0.000    6.959    1.060
                                               FLOW DISTRIBUTION (%) =    0.000   92.947    7.053

     REACH PROPERTIES BY STRIP          1           2           3
                INEFF FLOW  EL   -99999.000  -99999.000  -99999.000
  U/S SECTION...     CONVEYANCE       0.000  101054.470    7668.432
                           AREA        0.00      747.99      372.73
                     HYD RADIUS      0.0000      8.2752      0.7571
  REACH...           Manning's N     0.0600      0.0450      0.0600
                        SQRT(L)     33.1361     38.2361     31.8119
  D/S SECTION...           AREA      990.96     1340.52      348.55
                     HYD RADIUS       1.551       9.957       1.250

----------------------------------------------------------------------------------------------
$$END

      0    DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =         2
TOTAL NO. OF WS PROFILES =             2
ITERATIONS IN EXNER EQ =               0

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  1.00 SECONDS
```

6.3 Example Problem 3 - Movable Bed

The following example demonstrates how to add sediment data to the previously developed file. Existence of sediment data within the input file causes HEC-6 to compute sediment transport rates and modify the cross section geometry as described in Section 2.3. Sediment related data consists of the delineation of the movable bed, characteristics and gradation of sediment within the bed, and inflowing/outflowing sediment loads and gradations. The sediment data is inserted between the **EJ** record of the geometry data and the **$HYD** record of the flow data. Table 6-3a shows the input data developed for Example Problem 3.

6.3.1 Movable Bed Limits

Information delineating the movable bed have been added to the **HD** record of each cross section. For example, at Section No. 1.0, the movable bed limits have been defined at stations 10,081 and 10,250. The "fixed" **GR** points are those outside of the movable bed stations; that is, should a limit of the movable bed coincide with a **GR** point, that point is movable and the next point outward is fixed.

The vertical limit (initial depth) of the movable portion of the cross section must also be defined. Data describing the location of this bedrock is entered in Field 2 of the **HD** record for each cross section. In Example Problem 3, it was determined that the reach represented by Section No. 58.0 had bedrock 3.4 ft below the thalweg. Section No. 33.0 through Section No. 42.1 have either concrete or bedrock at the thalweg.

6.3.2 Sediment Title Records

Five title records (**T4-T8**) are required at the beginning of the sediment data; these records are available for user documentation of the sediment data.

6.3.3 Sediment Transport Control Parameters

Parameters governing the computation of sediment transport rates and selection of grain sizes are entered on the **I** records. For Example Problem 3, the number of times that the bed material gradation is to be re-calculated within a time step is set to 5 on the **I1** record (see Section 2.3.1.4). Default values for the other parameters on this record will be used. Only sands and gravels are analyzed in Example Problem 3. Since there are no clays or silts in either the bed or the inflowing load, there are no **I2** or **I3** records. Ten sand and gravel sizes are being analyzed as seen by the 1 in Field 3 and 10 in Field 4 of the **I4** record. The transport computation method chosen is that of Yang (4 in Field 2 of the **I4** record). Default values for the other parameters were selected, by not providing data. It is important to remember that the range of grain sizes selected on the **I** records **must** encompass the entire range of sizes found in both the bed material and inflowing load, even though some of those sizes may be missing in either the bed or inflowing materials.

The "most stable" weighting scheme for the hydraulic parameters has been selected via the **I5** record (see Section 2.2.4).

6.3.4 Inflowing Sediment Loads

The inflowing sediment load at the upstream end of the main river is described with a table of sediment load vs. water discharge by grain size. This table is entered using **LQ**, **LT**, and **LF** records. The **LQ** record contains the water discharges and the **LT** record contains the corresponding total inflowing sediment loads. The entire range of discharges in the hydrograph being simulated must be spanned by these data. For Example Problem 3, the range of water discharges in the load table is from 1 to 90,000 cfs and the related inflowing sediment loads vary from 0.011 to 400,000 tons/day. The distribution of grain sizes is described by the **LF** records which contain the **fraction** of the total load comprised of any particular grain size. These data are entered from fine to coarse and must correspond to the size ranges selected with the **I2** to **I4** data.

There are three local inflows of water and sediment in this problem; their locations are defined by the **QT** records in the geometric data. The tables of sediment load vs. local inflow are on **LQL**, **LTL**, and **LFL** records, analogous to the main river inflowing load data. The local flow load tables are entered in the same sequence as the geometric data; that is, downstream to upstream.

Table 6-3a
Example Problem 3 - Input
Movable Bed

```
T1      EXAMPLE PROBLEM NO 3.  MOVABLE BED
T2      3 LOCAL INFLOWS
T3      SOUTH FORK, ZUMBRO RIVER      ** Example Problem 3 **
NC    .1        .1      .04       .1       .3
X1   1.0        31   10077.   10275.       0.        0.       0.
GR 1004.    9915.    978.4   10002.    956.0   10060.   959.20   10077.    959.3   10081.
GR 950.0   10092.   948.48   10108.    946.6   10138.   944.70   10158.    955.2   10225.
GR 956.2   10243.    958.9   10250.    959.8   10275.   959.80   10300.    959.9   10325.
GR 958.8   10350.    957.4   10400.    970.0   10700.   966.00   10960.    970.0   11060.
GR 968.0   11085.    968.0   11240.    970.0   11365.   970.00   11500.    970.0   11615.
GR 962.0   11665.    962.0   12400.    976.0   12550.   980.00   12670.    982.0   12730.
GR 984.0   12735.
HD   1.0       10.  10081.0   10250.
NV    22      .045   965.6     .064    988.8
NV    12       .08   965.6      .13    988.8
NV    33        .1   965.6      .11    982.0      .12    988.8
X1  15.0        27 10665.0   10850.    3560.     3030.    3280.
X3                           10700.    961.0    11000.    970.0
GR 992.0    9570.    982.0   10110.    976.0   10300.   976.00   10490.    966.0   10610.
GR 964.7   10665.    956.0   10673.    953.0   10693.   954.00   10703.    955.6   10723.
GR 958.6   10750.    959.3   10800.    957.0   10822.   957.30   10825.    961.5   10850.
GR 962.0   10852.    964.0   10970.    966.0   11015.   961.00   11090.    962.0   11150.
GR 970.0   11190.    972.0   11310.    980.0   11410.   984.00   11570.    990.0   11770.
GR 990.0   11865.   1000.0   12150.
HD  15.0       10.  10673.0   10852.
   Cascade Creek - local inflow
QT
NC    .1        .1      .05
X1  32.0        29 10057.0   10271.    3630.     3060.    4240.
GR 998.0    9080.    982.0    9250.    982.0     9510.   980.00    9600.   980.01    9925.
GR979.48   10000.    978.5   10057.    968.6    10075.   959.82   10087.    956.5   10097.
GR 956.8   10117.    957.8   10137.    959.4    10157.   959.60   10177.   959.82   10196.
GR 966.5   10225.    971.2   10250.    978.5    10271.   978.50   10300.    978.6   10350.
GR978.91   10370.   978.96   10387.    980.0    10610.   982.00   10745.    982.0   11145.
GR 984.0   11150.    992.0   11240.   1000.0    11330.   1008.0   11425.
HD  32.0       10.   10075.   10275.
  Section 32.1 is a duplicate of Sec 32.0, needed to model IBC at Sec 33.0
X1  32.1        29 10057.0   10271.    3130.     3250.    3320.
X3    10
GR 998.0    9080.    982.0    9250.    982.0     9510.   980.00    9600.   980.01    9925.
GR979.48   10000.    978.5   10057.    968.6    10075.   959.82   10087.    956.5   10097.
GR 956.8   10117.    957.8   10137.    959.4    10157.   959.60   10177.   959.82   10196.
GR 966.5   10225.    971.2   10250.    978.5    10271.   978.50   10300.    978.6   10350.
GR978.91   10370.   978.96   10387.    980.0    10610.   982.00   10745.    982.0   11145.
GR 984.0   11150.    992.0   11240.   1000.0    11330.   1008.0   11425.
HD  32.1       10.   10075.   10275.
```

```
   A spillway is located here.
X1  33.0       21   1850.   2150.       0       0       0
X5                              2
XL                   250.
GR 1000.     980.   990.0   1060.   980.0   1150.  982.00   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0   1350.  980.00   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0   2099.2   976.0   2149.   984.5   2150.  982.00   2800.   990.0   3100.
GR 1000.    3170.
HD  33.0       0.   1851.   2149.
    NOTE:        Section 33.3 is a duplicate of Section  33.0.
    Section 33.0 is a good representative cross section for a long reach.  A
    duplicate is used here to break up the long reach into two smaller reaches.
X1  33.3       21   1850.   2150.   1550.   1750.    1750     .95    1.49
XL                   250.
GR 1000.     980.   990.0   1060.   980.0   1150.  982.00   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0   1350.  980.00   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0   2099.2   976.0   2149.   984.5   2150.  982.00   2800.   990.0   3100.
GR 1000.    3170.
HD  33.3       0.   1851.   2149.
   Section 33.9 is a duplicate of Sec 33.3, needed to model IBC at Sec 35.0
X1  33.9       21   1850.   2150.   1050.   1050.   1050.     .95    1.65
X3    10
GR 1000.     980.   990.0   1060.   980.0   1150.  982.00   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0   1350.  980.00   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0   2099.2   976.0   2149.   984.5   2150.  982.00   2800.   990.0   3100.
GR 1000.    3170.
HD  33.9       0.   1851.   2149.
   A weir is located here.
X1  35.0       22   9894.  10245.       0       0       0
X3    10
X5           974.     0.5
GR 984.0    9035.   980.0   9070.   978.0   9135.  980.00   9185.   982.0   9270.
GR 980.0    9465.   981.7   9595.   983.7   9745.  984.70   9894.   963.4  9894.1
GR 963.3    9954.   967.1   9974.   967.4  10004.  968.20  10044.   967.6  10054.
GR 973.4   10115.   977.4  10120.   983.7  10155.  984.00  10245.   982.0  10695.
GR 982.0   10895.  1004.0  11085.
HD  35.0       0.   9954.  10155.
    - - -  Silver Lake  - - -
NC   .06      .06    .045
X1  42.0       32   9880.  10130.   5370.   5000.   5210.
GR 996.0    7130.   998.0   7310.   998.0   7930.  992.00   8205.   990.0   8495.
GR 988.0    8780.   986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0    9880.   969.8   9881.   969.8   9941.  985.80   9941.   985.8   9943.
GR 969.8    9943.   969.8  10001.   986.7  10001.  986.70  10003.   969.8  10003.
GR 969.8   10067.   985.8  10067.   985.8  10069.  969.80  10069.   969.8  10129.
GR 989.9   10130.   989.5  10180.   988.6  10230.  987.60  10280.   985.2  10430.
GR 986.8   11720.   989.9  12310.
HD  42.0       0.   9881.  10021.
    Silver Creek - local inflow
QT
X1  44.0       28   9845.  10127.   3200.   3800.   3500.
XL                           9850.  10200.
GR 1002.    8035.   992.0   8150.   990.0   8305.  990.00   8735.   988.0   8835.
GR 996.0    9285.  1017.6   9425.   990.0   9505.  986.00   9650.   984.1   9788.
GR 980.6    9845.   970.9   9868.   972.2   9898.  970.50   9968.   967.5   9998.
GR 968.9   10028.   967.4  10058.   967.1  10078.  971.90  10118.   976.8  10127.
GR 977.8   10150.   976.9  10193.   982.0  10206.  981.20  10300.   979.2  10325.
GR 983.1   10400.   999.8  10450.  1002.4  10464.
HD  44.0       1.   9868.  10193.
X1  53.0       22  10000.  10136.   3366.   2832.   2942.
GR 1004.    7550.  1000.0   7760.   998.0   8440.  996.00   8640.   996.0   8780.
GR 994.0    8940.   986.0   9245.   986.3   9555.  986.30   9825.   983.8   9900.
GR 982.8   10000.   978.2  10011.   974.0  10041.  972.20  10071.   972.6  10101.
GR 978.2   10121.   988.7  10136.   989.3  10154.  999.20  10200.  1000.1  10320.
GR 1002.   10470.  1004.0  10700.
HD  53.0      10.  10000.  10136.
    Bear Creek - local inflow
QT
X1  55.0       18   9931.  10062.   2275.   3430.   2770.
GR 1004.    7592.  1000.0   7947.   996.0   8627.  990.00   9052.   986.0   9337.
GR 984.3    9737.   984.7   9837.   985.5   9910.  987.20   9931.   978.1   9955.
GR 974.8    9975.   974.2  10005.   972.9  10035.  973.20  10045.   983.8  10062.
GR 985.8   10187.   986.0  10307.   990.0  10497.
HD  55.0      10.   9931.  10062.
X1  58.0       22   9912.  10015.   1098.   1012.   1462.
GR 1006.    8542.  1004.0   8952.  1000.0   9702.  997.20   9812.   996.3   9912.
GR 976.2    9944.   975.4   9974.   978.2   9991.  990.40  10015.   988.3  10062.
GR 988.8   10065.   988.3  10065.   989.3  10169.  990.00  10172.   992.0  10242.
GR 992.0   10492.   988.0  10642.   986.7  10852.  988.00  11022.   986.0  11097.
GR 986.0   11137.   988.0  11192.
HD  58.0      3.4   9912.  10015.
```

```
EJ
T4      South Fork, Zumbro River - Stream Segment 1      ** Example Problem 3 **
T5      LOAD CURVE FROM GAGE DATA.
T6      BED GRADATIONS FROM FIELD SAMPLES.
T7      Use Full Range of Sands and Gravels
T8      SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]
I1             5
I4  SAND       4       1      10
I5            .5      .5     .25      .5     .25       0     1.0
LQ             1      50    1000    5800   90000
LT TOTAL   .0110     1.5     320   4500.  400000
LF   VFS    .119    .119    .498    .511    .582
LF    FS    .328    .328    .331    .306    .280
LF    MS    .553    .553    .156    .154    .110
LF    CS    .000    .000    .011    .016    .020
LF   VCS    .000    .000    .004    .008    .005
LF   VFG    .000    .000    .000    .004    .002
LF    FG    .000    .000    .000    .001    .001
LF    MG    .000    .000    .000    .000    .000
LF    CG    .000    .000    .000    .000    .000
LF   VCG      .0      .0    .000    .000    .000
PF EXAMP     1.0     1.0    32.0    16.0    96.5     8.0    95.0     4.0    91.0
PFC  2.0    85.0     1.0    73.0      .5    37.0     .25     8.0    .125     1.0
PFC.0625     0.0
PF EXAMP    32.0     1.0    64.0    32.0    99.5    16.0    99.0     8.0    98.5
PFC  4.0    96.0     2.0    93.5     1.0    83.0     .50    45.5    .250     8.0
PFC .125     1.0   .0625     0.0
PF EXAMP    58.0     1.0    64.0    32.0    97.0    16.0    94.0     8.0    94.0
PFC  4.0    90.0     2.0    79.0     1.0    56.0     .50     4.0    .125     0.0
$LOCAL
  LOAD TABLE - CASCADE CREEK - A LOCAL INFLOW
LQL            1     100    1000   10000
LTLTOTAL   .0040      10     500   30000
LFL  VFS    .664    .664    .015    .198
LFL   FS    .207    .207    .245    .181
LFL   MS    .086    .086    .605    .107
LFL   CS    .031    .031    .052    .098
LFL  VCS    .008    .008    .039    .127
LFL  VFG   .0030   .0030   .0200   .1160
LFL   FG   .0010   .0010   .0110   .0910
LFL   MG   .0000   .0000   .0110   .0530
LFL   CG   .0000   .0000   .0000   .0220
LFL  VCG   .0000   .0000   .0000   .0060
  LOAD TABLE - SILVER CREEK - A LOCAL INFLOW
LQL            1     100    1000   10000
LTLTOTAL   .0040      10     500   30000
LFL  VFS    .664    .664    .015    .198
LFL   FS    .207    .207    .245    .181
LFL   MS    .086    .086    .605    .107
LFL   CS    .031    .031    .052    .098
LFL  VCS    .008    .008    .039    .127
LFL  VFG   .0030   .0030   .0200   .1160
LFL   FG   .0010   .0010   .0110   .0910
LFL   MG   .0000   .0000   .0110   .0530
LFL   CG   .0000   .0000   .0000   .0220
LFL  VCG   .0000   .0000   .0000   .0060
  LOAD TABLE - BEAR CREEK - A LOCAL INFLOW
LQL           1.    100.    500.   1000.  30000.
LTLTOTAL   .0020    30.0    500.    1200   22500
LFL  VFS    .201    .201    .078    .078    .137
LFL   FS    .342    .342    .172    .175    .218
LFL   MS    .451    .451    .454    .601    .476
LFL   CS    .001    .001    .197    .142    .158
LFL  VCS    .000    .000    .000    .003    .008
LFL  VFG   .0000   .0000   .0000   .0000   .0020
LFL   FG   .0000    .000   .0000   .0000   .0010
LFL   MG   .0000    .000   .0000   .0000   .0000
LFL   CG   .0000    .000   .0000   .0000   .0000
LFL  VCG   .0000    .000   .0000   .0000   .0000
$HYD
*    A      FLOW 1 = BASE FLOW OF 750 CFS
Q  750.      61.     29.    128.
R  956.     962.
T   65.      72.     70.     67.
W    2.
*    B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.     300.    150.    650.
R  965.     970.
W   50.
$PRT
CP             1
PS          15.0    32.0    32.1
END
```

```
*   AC      FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.    150.     78.    340.
R   960.    966.
W     1.
$PRT   A
*    B      FLOW 4 = BASE FLOW OF 750 CFS
Q   750.     61.     29.    128.
R   957.    963.
W     1.
$$END
```

6.3.5 Bed Material Gradation

The **initial** gradation of material in the bed sediment control volume is described with **PF** (percent finer) and **PFC** (percent finer continuation) records. In Example Problem 3, this data has only been provided at Sections 1.0, 32.0, and 58.0 as noted in Field 2 of the **PF** records. The selection of which, and how many, cross sections at which to provide this data depends on study objectives, field data, etc. For intermediate cross sections HEC-6 will linearly interpolate the bed material gradation. Note that the points in the gradation tables need not coincide with the size classes selected for computation. See Appendix A for specific details of these data records.

6.3.6 Flow Data

The flow data input structure is similar to that shown in the previous examples. One of the differences, however, is the selection of A-, B- and C-level output for sediment computations on the * records. Also, the hydrologic data are extremely important to the results of a movable bed simulation. Particular care must be taken when selecting the period of record or hypothetical event to be simulated and time step sizes to be used. Water temperature may also be important in some instances. See Gee (1984) and HEC (1992) for information regarding preparation of flow data.

6.3.7 Output of Sediment Model

Table 6-3b shows the output file for Example Problem 3. The geometric data output, similar to that produced by Example Problem 2, is followed by sediment data. At this point, no hydraulic or sediment transport computations have been performed. Rather, the input data have been read and manipulated in preparation for the computations which begin when the flow data are read. The sediment title records are echoed followed by the information on the **I** records. Next is the inflowing sediment load table from stream segment 1; the sediment loads are in scientific notation because of the wide range of possible values. Note that a very small value is used instead of zero because log-log interpolation is used within these data tables.

The table headed "REACH GEOMETRY FOR STREAM SEGMENT 1" depicts the status of the bed sediment control volume at the beginning of the simulation, as described by the input data. Note that the movable bed widths are not necessarily the same as given in the **HD** data. For example, at Section No. 1.0, the movable bed limits are specified at stations 10,081 and 10,250 which coincide with existing points in the **GR** data, therefore, these points are part of the movable bed. The movable bed width used for computations extends halfway to the next, fixed, **GR** points (at stations 10,077 and 10,275).

$$\text{Movable Bed Width} = \frac{10275+10250}{2} - \frac{10081+10077}{2}$$
$$= 183.5 \text{ ft}$$

The table headed "BED MATERIAL GRADATION" contains the information from the **PF** and **PFC** records. That data has been converted from percent finer values to bed fractions per grain size and computed for each cross section. This table allows for checking of the interpolation at each grain size boundary as well as at each cross section.

The next section contains the load tables for the local inflows, these are similar to the table for the main river.

The last table produced by the sediment data is titled "Bed Sediment Control Volumes." The "control volume" is the volume of bed sediment used at each cross section for the sediment transport computations. Generally, this control volume is defined as the depth of the bed times the width times the length. The length used equals one-half the sum of the channel reach lengths upstream and downstream of the cross section. However, if a cross section is an upstream or downstream boundary, then the upstream or downstream reach length, respectively, is zero. As previously noted, an **X5** record creates an internal boundary condition within the model, effectively creating a downstream boundary at the **X5**'s cross section and an upstream boundary at the preceding cross section. In locating the new boundaries at these two cross sections, the reach length between them should be zero. For this reason, care should be taken when locating cross sections at internal boundary conditions.

6.3.8 Output of Hydraulic and Sediment Transport Computations

All output that follows the sediment data is produced by the hydraulic and sediment transport computations. By default, HEC-6 will produce no output from these computations unless an output flag is set for either (or both) the hydraulic or sedimentation computations. A-level sediment output was generated for the first time step of this example. This output is limited to "TABLE SA-1", which shows cumulative (since the beginning of the simulation) trap efficiency information. The "ENTRY POINT" is any cross section in the model at which something special occurs; "something special" includes upstream and downstream boundaries, local inflow and tributary junction points (**QT**), and internal boundary conditions (**X5**). Note that trap efficiency is computed at each downstream boundary. "TABLE SA-1" for the last time step shows that after 54 days, 13.29 acre-ft of sands and gravels had entered the model at Section No. 58.0; with 16.15 and 0.36 acre-ft entering at local inflows, the total inflowing sediment load to Section No. 35.0 is 29.81 acre-ft. The total load leaving Section No. 35.0 is 5.52 acre-ft, yielding a trap efficiency of 81% for that part of the model reach.

B-level sediment output was requested for the second and fourth time steps. This output begins with information regarding flow changes as the sediment computations proceed from **upstream to downstream**. Next is the A-level trap efficiency table. This information is followed by "TABLE SB-1", which shows the **instantaneous** ("snap shot") sediment inflows and outflows by grain size for the entire model. The "SEDIMENT INFLOW" enters the model at the upstream boundary (Section No. 58.0) and the "SEDIMENT OUTFLOW" leaves the model at the downstream boundary (Section No. 1.0). The last table produced by B-level output is "TABLE SB-2: STATUS OF THE BED..." which contains both cumulative and instantaneous information. The BED CHANGE is cumulative from time zero, while the rest of the data are for this time step, only. For example, the "REACH GEOMETRY" table produced after processing the sediment input data shows that the thalweg (minimum elevation **GR** point within the channel) at Section No. 1.0 was initially 944.70 ft. After a simulation time of 54 days, TABLE SB-2 for time step 4 shows that there was a computed bed change of 1.22 ft at Section No. 1.0, resulting in a thalweg elevation of 945.92 ft.

6.3.9 Detailed Sediment Output

Additional information regarding the sedimentation computations can be obtained with C-level output. Although this output was originally designed for use by HEC-6 developers, some of the information may be of use for project applications.

The Selective Printout option ($PRT) was used to limit output to Sections 15.0, 32.0 and 32.1 for time step 3. A-level hydraulics output for these cross sections begins the output for this time step. This is followed by C-level sediment output; first, the relevant flow information is listed for the Upstream boundary, then the fall velocity of each grain size is calculated based on the inflowing water temperature. Next is the detailed output for each of the selected cross sections. Because a local inflow enters the stream segment upstream of Section No. 15.0, local flow data and a new trap efficiency table precedes the detailed output for Section No. 15.0. The new fall velocity table is included because the particle fall velocities change due to the change in water temperature caused by the local inflow.

The detailed output for each cross section begins with the "HYDRAULIC PARAMETERS" table. This table contains the flow velocity (VEL), energy slope (SLO), effective depth (EFD), effective width (EFW), Manning's *n* (N-VALUE), average shear stress, τ (TAU), the grain shear velocity, U_* (USTARM), and the Froude number. See Vanoni (1975) for definitions of these hydraulic variables.

At this point, it should be noted that the velocity listed in the A-level hydraulics output table may not be equal to the velocity listed in the "HYDRAULIC PARAMETERS" table in the detailed sediment output. For example, at Section No. 15.0, the velocity calculated by the hydraulics computations is 1.637 ft/sec, but due to the weighting factors entered on the **I5** record, the weighted velocity at the current cross section that is used in the sedimentation computations is calculated as follows:

$$\begin{aligned} \textit{Weighted}\ \text{VEL} &= \text{XID} \cdot \text{VEL}\ \textit{at Downstream Section} \\ &\quad + \text{XIN} \cdot \text{VEL}\ \textit{at Current Section} \\ &\quad + \text{XIU} \cdot \text{VEL}\ \textit{at Upstream Section} \\ &= 0.25\ (1.371) + 0.5\ (1.637) + 0.25\ (3.048) \\ &= 1.923 \end{aligned}$$

Listed in the "BED SEDIMENT CONTROL VOLUME COMPUTATIONS" table is a new surface area of the bed sediment control volume. The K-PORTION is that area of the control volume bounded by the conveyance limits. The S-PORTION is the area of the control volume outside the conveyance limits; this will be greater than zero only when the movable bed limits extend beyond the conveyance limits.

The "GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS" table shows the gradation of the bed material at this cross section at this time. The first column is the contents of the bed by grain size, as fractions of the total bed. For example, at Section No. 15.0, 1% of the bed is very fine sand, 7% is fine sand, etc. These size classes were specified on the I records. The column is the same data as percent finer for each grain size; e.g., 99.1% of the bed material is smaller than coarse gravel.

At the start of the simulation, the bed sediment was 10 ft deep at Section No. 15.0 (**HD** data). The detailed output for this cross section shows that by the end of time step 3, 9.64 ft of sands and gravels remain in the inactive layer and 0.17 ft are in the active layer. This indicates a loss of 0.19 ft from the bed which corresponds to the 0.19 ft of erosion shown in TABLE SB-2 for this cross section.

Table 6-3b
Example Problem 3 - Output
Movable Bed

```
*****************************************************     **************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS   *     *  U.S. ARMY CORPS OF ENGINEERS      *
*       Version: 4.1.00 -  AUGUST 1993             *     *  HYDROLOGIC ENGINEERING CENTER     *
*  INPUT FILE:   EXAMPLE3.DAT                      *     *  609 SECOND STREET                 *
*  OUTPUT FILE:  EXAMPLE3.OUT                      *     *  DAVIS, CALIFORNIA 95616-4687      *
*  RUN DATE: 01 SEP 93     RUN TIME: 10:29:27      *     *  (916) 756-1104                    *
*****************************************************     **************************************

                         X     X  XXXXXXX   XXXXX             XXXXX
                         X     X  X        X     X           X     X
                         X     X  X        X                 X
                         XXXXXXX  XXXX     X         XXXXX   XXXXXX
                         X     X  X        X                 X     X
                         X     X  X        X     X           X     X
                         X     X  XXXXXXX   XXXXX             XXXXX

          ************************************************************************
          *  MAXIMUM LIMITS FOR THIS VERSION ARE:                                *
          *       10  Stream Segments (Main Stem + Tributaries)                  *
          *      150  Cross Sections                                             *
          *      100  Elevation/Station Points per Cross Section                 *
          *       20  Grain Sizes                                                *
          *       10  Control Points                                             *
          ************************************************************************

T1      EXAMPLE PROBLEM NO 3.  MOVABLE BED
T2      3 LOCAL INFLOWS
T3      SOUTH FORK, ZUMBRO RIVER      ** Example Problem 3 **

N values...  Left    Channel   Right     Contraction    Expansion
           0.1000   0.0400   0.1000        1.1000       0.7000

SECTION NO.     1.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

N-Values vs. Elevation Table
       Channel                Left Overbank          Right Overbank
  0.0450      966.          0.0800      966.        0.1000      966.
  0.0640      989.          0.1300      989.        0.1100      982.
  0.0000        0.          0.0000        0.        0.1200      989.

SECTION NO.    15.000
...Left Encroachment defined at station 10700.000 at elevation    961.000
...Right Encroachment defined at station 11000.000 at elevation    970.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

LOCAL INFLOW POINT  1 occurs upstream from Section No.       15.000

N values...  Left    Channel   Right     Contraction    Expansion
           0.1000   0.0500   0.1000        1.1000       0.7000

SECTION NO.    32.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    32.100
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station        10057.000      10271.000
              Ineffective Elevation          978.500        978.500
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    33.000
...Internal Boundary Condition
   Water Surface Elevation will be read from R-RECORD, Field  2
   Head Loss =     0.000
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.300
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.490 ft.
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.900
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.650 ft.
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station         1757.500       2042.500
              Ineffective Elevation          986.060        986.150
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    35.000
...Internal Boundary Condition
   Water Surface Elevation =  974.000
   Head Loss =     0.500
```

```
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station        9894.000       10245.000
              Ineffective Elevation         984.700         984.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N values...  Left    Channel   Right    Contraction    Expansion
           0.0600    0.0450   0.0600       1.1000       0.7000

SECTION NO.     42.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

LOCAL INFLOW POINT  2 occurs upstream from Section No.       42.000

SECTION NO.     44.000
...Limit CONVEYANCE between stations     9850.000 and    10200.000
...DEPTH of the Bed Sediment Control Volume =     1.00 ft.

SECTION NO.     53.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

LOCAL INFLOW POINT  3 occurs upstream from Section No.       53.000

SECTION NO.     55.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.     58.000
...DEPTH of the Bed Sediment Control Volume =     3.40 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 13
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  13
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA

====================================================================================================

T4       South Fork, Zumbro River - Stream Segment 1     ** Example Problem 3 **
T5       LOAD CURVE FROM GAGE DATA.
T6       BED GRADATIONS FROM FIELD SAMPLES.
T7       Use Full Range of Sands and Gravels
T8       SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]

         EXAMPLE PROBLEM NO 3.  MOVABLE BED
         3 LOCAL INFLOWS
         SOUTH FORK, ZUMBRO RIVER     ** Example Problem 3 **

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
SEDIMENT PROPERTIES AND PARAMETERS

        SPI     IBG     MNQ      SPGF       ACGR       NFALL     IBSHER
I1       5.       0       1     1.000     32.174           2          1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 SANDS - BOULDERS ARE PRESENT

        MTC     IASA    LASA     SPGS        GSF       BSAE        PSI      UWDLB
I4       4        1      10     2.650      0.667      0.500     30.000     93.000

USING TRANSPORT CAPACITY RELATIONSHIP #  4, YANG

GRAIN SIZES UTILIZED (mean diameter - mm)
-----------------------------------------------------------------------
     VERY FINE SAND....     0.088  |  VERY FINE GRAVEL..     2.828
     FINE SAND.........     0.177  |  FINE GRAVEL.......     5.657
     MEDIUM SAND.......     0.354  |  MEDIUM GRAVEL.....    11.314
     COARSE SAND.......     0.707  |  COARSE GRAVEL.....    22.627
     VERY COARSE SAND..     1.414  |  VERY COARSE GRAVEL    45.255

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED
         DBI        DBN       XID       XIN       XIU       UBI       UBN       JSL
I5     0.500      0.500     0.250     0.500     0.250     0.000     1.000        1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
           LOAD BY GRAIN SIZE CLASS (tons/day)
----------------------------------------------------------------------------
LQ         | 1.00000     | 50.0000     | 1000.00     | 5800.00     | 90000.0     |
             ------------  ------------  ------------  ------------  ------------
LF    VFS  |0.130900E-02 |0.178500     | 159.360     | 2299.50     | 232800.     |
LF     FS  |0.360800E-02 |0.492000     | 105.920     | 1377.00     | 112000.     |
LF     MS  |0.608300E-02 |0.829500     | 49.9200     | 693.000     | 44000.0     |
LF     CS  |0.100000E-19 |0.100000E-19 | 3.52000     | 72.0000     | 8000.00     |
LF    VCS  |0.100000E-19 |0.100000E-19 | 1.28000     | 36.0000     | 2000.00     |
LF    VFG  |0.100000E-19 |0.100000E-19 |0.100000E-19 | 18.0000     | 800.000     |
LF     FG  |0.100000E-19 |0.100000E-19 |0.100000E-19 | 4.50000     | 400.000     |
LF     MG  |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |
LF     CG  |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |
LF    VCG  |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |0.100000E-19 |
             ------------  ------------  ------------  ------------  ------------
   TOTAL   |0.110000E-01 | 1.50000     | 320.000     | 4500.00     | 400000.     |
----------------------------------------------------------------------------
```

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		*183.500*	959.300	*944.700*	958.900	0.000	0.000
	3280.000						
15.000		242.000	961.000	953.700	962.000	3280.000	0.621
	4240.000						
32.000		219.500	968.600	956.500	978.500	7520.000	1.424
	3320.000						
32.100		219.500	968.600	956.500	978.500	10840.000	2.053
	0.000						
33.000		299.000	979.190	961.000	976.000	10840.000	2.053
	1750.000						
33.300		284.050	980.680	962.490	977.490	12590.000	2.384
	1050.000						
33.900		284.050	980.840	962.650	977.650	13640.000	2.583
	0.000						
35.000		275.950	963.300	963.300	983.700	13640.000	2.583
	5210.000						
42.000		154.500	969.800	969.800	969.800	18850.000	3.570
	3500.000						
44.000		337.500	970.900	967.100	976.900	22350.000	4.233
	2942.000						
53.000		195.000	982.800	972.200	988.700	25292.000	4.790
	2770.000						
55.000		204.000	987.200	972.900	983.800	28062.000	5.315
	1462.000						
58.000		176.500	996.300	975.400	990.400	29524.000	5.592

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size					
1.000	1.000	0.105	0.105	1.000	1.000	VF SAND	0.010	VC SAND	0.120	M GRVL	0.015
						F SAND	0.070	VF GRVL	0.060	C GRVL	0.035
						M SAND	0.290	F GRVL	0.040	VC GRVL	0.000
						C SAND	0.360				
15.000	1.000	0.151	0.151	1.000	1.000	VF SAND	0.010	VC SAND	0.113	M GRVL	0.011
						F SAND	0.070	VF GRVL	0.045	C GRVL	0.022
						M SAND	0.327	F GRVL	0.033	VC GRVL	0.002
						C SAND	0.367				
32.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.010	VC SAND	0.105	M GRVL	0.005
						F SAND	0.070	VF GRVL	0.025	C GRVL	0.005
						M SAND	0.375	F GRVL	0.025	VC GRVL	0.005
						C SAND	0.375				
32.100	1.000	0.210	0.210	1.000	1.000	VF SAND	0.008	VC SAND	0.124	M GRVL	0.004
						F SAND	0.062	VF GRVL	0.038	C GRVL	0.009
						M SAND	0.321	F GRVL	0.027	VC GRVL	0.009
						C SAND	0.397				
33.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.008	VC SAND	0.124	M GRVL	0.004
						F SAND	0.062	VF GRVL	0.038	C GRVL	0.009
						M SAND	0.321	F GRVL	0.027	VC GRVL	0.009
						C SAND	0.397				
33.300	1.000	0.210	0.210	1.000	1.000	VF SAND	0.008	VC SAND	0.134	M GRVL	0.004
						F SAND	0.058	VF GRVL	0.045	C GRVL	0.011
						M SAND	0.293	F GRVL	0.028	VC GRVL	0.011
						C SAND	0.408				
33.900	1.000	0.210	0.210	1.000	1.000	VF SAND	0.007	VC SAND	0.140	M GRVL	0.004
						F SAND	0.056	VF GRVL	0.049	C GRVL	0.012
						M SAND	0.276	F GRVL	0.029	VC GRVL	0.012
						C SAND	0.415				
35.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.007	VC SAND	0.140	M GRVL	0.004
						F SAND	0.056	VF GRVL	0.049	C GRVL	0.012
						M SAND	0.276	F GRVL	0.029	VC GRVL	0.012
						C SAND	0.415				
42.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.005	VC SAND	0.169	M GRVL	0.002
						F SAND	0.044	VF GRVL	0.069	C GRVL	0.018
						M SAND	0.192	F GRVL	0.033	VC GRVL	0.018
						C SAND	0.450				
44.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.003	VC SAND	0.189	M GRVL	0.002
						F SAND	0.036	VF GRVL	0.082	C GRVL	0.022
						M SAND	0.136	F GRVL	0.035	VC GRVL	0.022
						C SAND	0.473				
53.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.002	VC SAND	0.206	M GRVL	0.001
						F SAND	0.030	VF GRVL	0.094	C GRVL	0.025
						M SAND	0.088	F GRVL	0.037	VC GRVL	0.025
						C SAND	0.492				

55.000	1.000	0.210	0.210	1.000	1.000	VF SAND 0.001	VC SAND 0.222	M GRVL 0.000
						F SAND 0.023	VF GRVL 0.104	C GRVL 0.028
						M SAND 0.044	F GRVL 0.039	VC GRVL 0.028
						C SAND 0.510		
58.000	1.000	0.210	0.210	1.000	1.000	VF SAND 0.000	VC SAND 0.230	M GRVL 0.000
						F SAND 0.020	VF GRVL 0.110	C GRVL 0.030
						M SAND 0.020	F GRVL 0.040	VC GRVL 0.030
						C SAND 0.520		

..LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL	1.00000	100.000	1000.00	10000.0
LFL VFS	0.265600E-02	6.64000	7.50000	5940.00
LFL FS	0.828000E-03	2.07000	122.500	5430.00
LFL MS	0.344000E-03	0.860000	302.500	3210.00
LFL CS	0.124000E-03	0.310000	26.0000	2940.00
LFL VCS	0.320000E-04	0.800000E-01	19.5000	3810.00
LFL VFG	0.120000E-04	0.300000E-01	10.0000	3480.00
LFL FG	0.400000E-05	0.100000E-01	5.50000	2730.00
LFL MG	0.100000E-19	0.100000E-19	5.50000	1590.00
LFL CG	0.100000E-19	0.100000E-19	0.100000E-19	660.000
LFL VCG	0.100000E-19	0.100000E-19	0.100000E-19	180.000
TOTAL	0.400000E-02	10.0000	499.000	29970.0

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 2
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL	1.00000	100.000	1000.00	10000.0
LFL VFS	0.265600E-02	6.64000	7.50000	5940.00
LFL FS	0.828000E-03	2.07000	122.500	5430.00
LFL MS	0.344000E-03	0.860000	302.500	3210.00
LFL CS	0.124000E-03	0.310000	26.0000	2940.00
LFL VCS	0.320000E-04	0.800000E-01	19.5000	3810.00
LFL VFG	0.120000E-04	0.300000E-01	10.0000	3480.00
LFL FG	0.400000E-05	0.100000E-01	5.50000	2730.00
LFL MG	0.100000E-19	0.100000E-19	5.50000	1590.00
LFL CG	0.100000E-19	0.100000E-19	0.100000E-19	660.000
LFL VCG	0.100000E-19	0.100000E-19	0.100000E-19	180.000
TOTAL	0.400000E-02	10.0000	499.000	29970.0

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 3
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL	1.00000	100.000	500.000	1000.00	30000.0
LFL VFS	0.402000E-03	6.03000	39.0000	93.6000	3082.50
LFL FS	0.684000E-03	10.2600	86.0000	210.000	4905.00
LFL MS	0.902000E-03	13.5300	227.000	721.200	10710.0
LFL CS	0.200000E-05	0.300000E-01	98.5000	170.400	3555.00
LFL VCS	0.100000E-19	0.100000E-19	0.100000E-19	3.60000	180.000
LFL VFG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	45.0000
LFL FG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	22.5000
LFL MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
TOTAL	0.199000E-02	29.8500	450.500	1198.80	22500.0

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 3. MOVABLE BED

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	V O L U M E (cu.ft)	(cu.yd)
1.000	1640.000	203.000	10.000	0.332920E+07	123304.
15.000	3760.000	229.266	10.000	0.862040E+07	319274.
32.000	3780.000	223.706	10.000	0.845610E+07	313189.
32.100	1660.000	219.500	10.000	0.364370E+07	134952.
33.000	875.000	294.017	0.000	0.000000	0.000000
33.300	1400.000	287.165	0.000	0.000000	0.000000
33.900	525.000	284.050	0.000	0.000000	0.000000
35.000	2605.000	235.467	0.000	0.000000	0.000000
42.000	4355.000	203.228	0.000	0.000000	0.000000
44.000	3221.000	282.665	1.000	910465.	33720.9
53.000	2856.000	220.920	10.000	0.630947E+07	233684.
55.000	2116.000	198.870	10.000	0.420808E+07	155855.
58.000	731.000	185.667	3.400	461456.	17091.0

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

```
$HYD
BEGIN COMPUTATIONS.

================================================================================
TIME STEP #        1
*    A      FLOW 1 = BASE FLOW OF 750 CFS

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 3.  MOVABLE BED
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
   2.00     58.000 *    0.09                         *
            53.000 *    0.04                         *
            42.000 *    0.00                         *
  TOTAL=    35.000 *    0.14      0.00      1.00     *
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
   2.00     35.000 *    0.00                         *
  TOTAL=    33.000 *    0.00      0.00      0.49     *
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
   2.00     33.000 *    0.00                         *
            15.000 *    0.00                         *
  TOTAL=     1.000 *    0.00      0.02     -3.36     *
*********************************************************

================================================================================
TIME STEP #        2
*    B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
EXAMPLE PROBLEM NO 3.  MOVABLE BED
      ACCUMULATED TIME (yrs)....     0.142
      FLOW DURATION (days)......    50.000

UPSTREAM BOUNDARY CONDITIONS
--------------------------------------------------------------------------
Stream Segment # 1    |   DISCHARGE    | SEDIMENT LOAD  | TEMPERATURE
Section No.    58.000 |     (cfs)      |  (tons/day)    |   (deg F)
--------------------------------------------------------------------------
               INFLOW |      1400.00   |       529.98   |      62.04

Upstream of SECTION NO.     53.000 is...
LOCAL INFLOW POINT # 3 |  DISCHARGE    | SEDIMENT LOAD  | TEMPERATURE
                       |    (cfs)      |  (tons/day)    |   (deg F)
--------------------------------------------------------------------------
     MAIN STEM INFLOW  |     1400.00   |       529.98   |      62.04
     LOCAL     INFLOW  |      650.00   |       647.71   |      67.00
--------------------------------------------------------------------------
                TOTAL  |     2050.00   |      1177.69   |      63.61

Upstream of SECTION NO.     42.000 is...
LOCAL INFLOW POINT # 2 |  DISCHARGE    | SEDIMENT LOAD  | TEMPERATURE
                       |    (cfs)      |  (tons/day)    |   (deg F)
--------------------------------------------------------------------------
     MAIN STEM INFLOW  |     2050.00   |      1177.69   |      63.61
     LOCAL     INFLOW  |      150.00   |        14.45   |      70.00
--------------------------------------------------------------------------
                TOTAL  |     2200.00   |      1192.13   |      64.05

Upstream of SECTION NO.     15.000 is...
LOCAL INFLOW POINT # 1 |  DISCHARGE    | SEDIMENT LOAD  | TEMPERATURE
                       |    (cfs)      |  (tons/day)    |   (deg F)
--------------------------------------------------------------------------
     MAIN STEM INFLOW  |     2200.00   |      1192.13   |      64.05
     LOCAL     INFLOW  |      300.00   |        40.00   |      72.00
--------------------------------------------------------------------------
                TOTAL  |     2500.00   |      1232.13   |      65.00

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 3.  MOVABLE BED
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
  52.00     58.000 *   13.17                         *
            53.000 *   16.03                         *
            42.000 *    0.36                         *
  TOTAL=    35.000 *   29.56      5.51      0.81     *
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
  52.00     35.000 *    5.51                         *
  TOTAL=    33.000 *    5.51      1.47      0.73     *
*********************************************************
   TIME      ENTRY *            SAND                 *
   DAYS      POINT *   INFLOW   OUTFLOW   TRAP EFF   *
  52.00     33.000 *    1.47                         *
            15.000 *    0.99                         *
  TOTAL=     1.000 *    2.46      0.07      0.97     *
*********************************************************
```

```
TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  1
--------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ----------------------------------------------------------------------------
    VERY FINE SAND....         265.63  |  VERY FINE GRAVEL..          0.00
    FINE SAND.........         173.06  |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......          82.59  |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......           6.27  |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..           2.42  |  VERY COARSE GRAVEL          0.00
                          -------------                       -------------
                                             TOTAL =          529.98
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ----------------------------------------------------------------------------
    VERY FINE SAND....           0.24  |  VERY FINE GRAVEL..          0.00
    FINE SAND.........           0.27  |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......           0.72  |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......           0.59  |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..           0.13  |  VERY COARSE GRAVEL          0.00
                          -------------                       -------------
                                             TOTAL =            1.94

TABLE SB-2:  STATUS OF THE BED PROFILE AT TIME =     52.000 DAYS
--------------------------------------------------------------------------------
  SECTION   BED CHANGE   WS ELEV   THALWEG        Q       TRANSPORT RATE (tons/day)
  NUMBER       (ft)       (ft)      (ft)        (cfs)          SAND
     58.000    -0.60     981.86    974.80      1400.          557.
     55.000     0.10     980.67    973.00      1400.          525.
     53.000     0.40     977.12    972.60      2050.         1044.
     44.000     0.08     975.90    967.18      2050.         1014.
     42.000     0.92     975.15    970.72      2200.          300.
     35.000     0.17     974.00    963.47      2200.          223.
     33.900     0.57     970.36    963.22      2200.          160.
     33.300     0.12     970.19    962.61      2200.          124.
     33.000     0.33     970.00    961.33      2200.           59.
     32.100    -0.19     967.63    956.31      2200.          105.
     32.000    -0.13     966.55    956.37      2200.          157.
     15.000    -0.19     965.13    953.51      2500.          232.
      1.000     1.03     965.00    945.73      2500.            2.

------------------------------------------------------------------------------------------
$PRT
...Selective Printout Option
   - Print at the following cross sections
CP             1
PS          15.0     32.0     32.1
END

==========================================================================================
TIME STEP #        3
*   AC      FLOW 3 = NEAR BANK FULL DISCHARGE

EXAMPLE PROBLEM NO 3.  MOVABLE BED
ACCUMULATED TIME (yrs)..........      0.142

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                 DISCHARGE   TEMPERATURE  WATER SURFACE
                                   (cfs)       (deg F)        (ft)
                                 1250.000       65.00       960.000

**** DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP      AVG        AVG VEL (by subsection)
       (CFS)     SURFACE     LINE     HEAD              WIDTH     BED          1        2        3

SECTION NO.     15.000
****  1250.000   960.477   960.622   0.144    1.000   144.463   957.639    0.000    3.048    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.      15.000 ---
                                 DISCHARGE   TEMPERATURE
                                   (cfs)       (deg F)
               Local Inflow:      150.000       72.00
                     Total:      1100.000       64.05

SECTION NO.     32.000
****  1100.000   963.899   963.941   0.042    1.000   132.795   958.838    0.000    1.637    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000
SECTION NO.     32.100
****  1100.000   964.813   964.842   0.029    1.000   138.333   959.013    0.000    1.371    0.000
                                                FLOW DISTRIBUTION (%) =    0.000  100.000    0.000

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
EXAMPLE PROBLEM NO 3.  MOVABLE BED
       ACCUMULATED TIME (yrs)....       0.145
       FLOW DURATION (days)......       1.000

UPSTREAM BOUNDARY CONDITIONS
---------------------------------------------------------------------
Stream Segment # 1       |   DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
Section No.      58.000  |     (cfs)      |  (tons/day)   |   (deg F)
---------------------------------------------------------------------
                 INFLOW  |        682.00  |       149.81  |       61.89
```

```
  SEDIMENT INFLOW at SECTION NO.      58.000
      GRAIN SIZE        LOAD (tons/day) |     GRAIN SIZE      LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....           66.90  |  VERY FINE GRAVEL..          0.00
    FINE SAND.........           53.32  |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......           29.58  |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......            0.01  |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..            0.00  |  VERY COARSE GRAVEL          0.00
                           -------------                       -------------
                                                   TOTAL =          149.81

    FALL VELOCITIES - Method 2
               DIAMETER   VELOCITY        REY. NO.           CD
    --------------------------------------------------------------
    VF SAND   0.000290  0.1860300E-01  0.4558130          59.31192
    F  SAND   0.000580  0.5765145E-01   2.825166          12.35143
    M  SAND   0.001160  0.1327884       13.01437          4.656360
    C  SAND   0.002320  0.2803304       54.94943          2.089569
    VC SAND   0.004640  0.4807405       188.4667          1.421041
    VF GRVL   0.009280  0.7191215       563.8404          1.270145
    F  GRVL   0.018559   1.039704       1630.395          1.215254
    M  GRVL   0.037118   1.472894       4619.401          1.211086
    C  GRVL   0.074237   2.082985       13065.61          1.211086
    VC GRVL   0.148474   2.945788       36955.21          1.211086

******************************************************************************************
                 TRACE OUTPUT FOR SECTION NO.     32.100
           ------------------------------------------------------

HYDRAULIC PARAMETERS:
     VEL      SLO          EFD        EFW      N-VALUE     TAU      USTARM     FROUDE NO.
   1.371  0.000271       6.763    118.634    0.0500    0.11467   0.24306      0.093

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL          K-PORTION        S-PORTION
                             214970.00       214970.00           0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:    BED FRACTION  PERCENT FINER             BED FRACTION  PERCENT FINER
                       VF SAND    0.012074      1.207441      VF GRVL     0.038537     94.998190
                       F  SAND    0.062093      7.416711      F  GRVL     0.027800     97.778156
                       M  SAND    0.319568     39.373478      M  GRVL     0.004329     98.211069
                       C  SAND    0.394570     78.830455      C  GRVL     0.008945     99.105534
                       VC SAND    0.123140     91.144443      VC GRVL     0.008945     99.999998

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      0.81992
MIN.GRAIN DIAM        =    0.001943
BED SURFACE EXPOSED   =     0.28365

         INACTIVE LAYER       ACTIVE LAYER
            %       DEPTH       %       DEPTH
 CLAY   0.0000      0.00     0.0000     0.00
 SILT   0.0000      0.00     0.0000     0.00
 SAND   1.0000      9.76     1.0000     0.05
TOTAL   1.0000      9.76     1.0000     0.05

       AVG. UNIT             AVG. UNIT
        WEIGHT                 WEIGHT
       0.046500               0.046500

    COMPOSITE UNIT WT OF ACTIVE LAYER    (t/cf)=        0.046500
    COMPOSITE UNIT WT OF INACTIVE LAYER  (t/cf)=        0.046500
    DEPTH OF SURFACE LAYER (ft)              DSL=            0.1
    WEIGHT IN SURFACE LAYER (tons)          WTSL=          833.0
    DEPTH OF NEW ACTIVE LAYER (ft)           DSE=         0.0008
    WEIGHT IN NEW ACTIVE LAYER(tons)      WTMXAL=            7.6
    WEIGHT IN OLD ACTIVE LAYER(tons)         WAL=          497.7
    USEABLE WEIGHT, OLD INACTIVE LAYER       WIL=        97534.4
    SURFACE AREA OF DEPOSIT (sq ft)         SABK= 0.21497000E+06

** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION  PERCENT FINER             BED FRACTION  PERCENT FINER
                       VF SAND    0.008485      0.848488      VF GRVL     0.038120     95.056453
                       F  SAND    0.062410      7.089446      F  GRVL     0.027476     97.804037
                       M  SAND    0.321199     39.209296      M  GRVL     0.004279     98.231907
                       C  SAND    0.396583     78.867631      C  GRVL     0.008840     99.115953
                       VC SAND    0.123768     91.244461      VC GRVL     0.008840     99.999998
** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION  PERCENT FINER             BED FRACTION  PERCENT FINER
                       VF SAND    0.715456     71.545615      VF GRVL     0.120357     83.581306
                       F  SAND    0.000000     71.545615      F  GRVL     0.091254     92.706690
                       M  SAND    0.000000     71.545615      M  GRVL     0.014211     94.127749
                       C  SAND    0.000000     71.545615      C  GRVL     0.029361     97.063875
                       VC SAND    0.000000     71.545615      VC GRVL     0.029361    100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.237600E+07
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.560062E+03  VF GRVL 0.100000E-06
                                 F  SAND 0.199470E+03  F  GRVL 0.100000E-06
                                 M  SAND 0.125719E+03  M  GRVL 0.100000E-06
                                 C  SAND 0.947155E+02  C  GRVL 0.100000E-06
                                 VC SAND 0.765651E+02  VC GRVL 0.100000E-06
```

```
  SEDIMENT OUTFLOW FROM SECTION NO.      32.100
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE      LOAD (tons/day)
  ----------------------------------------------------------------------------
    VERY FINE SAND....        148.98   |  VERY FINE GRAVEL..         0.00
    FINE SAND.........          9.07   |  FINE GRAVEL.......         0.00
    MEDIUM SAND.......         23.59   |  MEDIUM GRAVEL.....         0.00
    COARSE SAND.......         21.05   |  COARSE GRAVEL.....         0.00
    VERY COARSE SAND..          5.30   |  VERY COARSE GRAVEL         0.00

************************************************************************************
                  TRACE OUTPUT FOR SECTION NO.      32.000
                  ------------------------------------------------------
HYDRAULIC PARAMETERS:
     VEL        SLO         EFD        EFW      N-VALUE     TAU      USTARM     FROUDE NO.
     1.923   0.000527      5.733    110.118     0.0500   0.18875   0.31184     0.142

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL          K-PORTION        S-PORTION
                             495163.69        495163.69          0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                        VF SAND    0.011063       1.106303      VF GRVL      0.025317      95.945944
                        F  SAND    0.070203       8.126581      F  GRVL      0.025337      98.479681
                        M  SAND    0.374483      45.574892      M  GRVL      0.005068      98.986453
                        C  SAND    0.373745      82.949358      C  GRVL      0.005068      99.493225
                        VC SAND    0.104649      93.414209      VC GRVL      0.005068      99.999998

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      0.76487
MIN.GRAIN DIAM       =     0.003170
BED SURFACE EXPOSED  =      1.00000

        INACTIVE LAYER       ACTIVE LAYER
           %      DEPTH         %      DEPTH
 CLAY   0.0000    0.00       0.0000    0.00
 SILT   0.0000    0.00       0.0000    0.00
 SAND   1.0000    9.84       1.0000    0.03
TOTAL   1.0000    9.84       1.0000    0.03

      AVG. UNIT              AVG. UNIT
       WEIGHT                 WEIGHT
      0.046500               0.046500

    COMPOSITE UNIT WT OF ACTIVE LAYER   (t/cf)=        0.046500
    COMPOSITE UNIT WT OF INACTIVE LAYER (t/cf)=        0.046500
    DEPTH OF SURFACE LAYER (ft)              DSL=           0.1
    WEIGHT IN SURFACE LAYER (tons)          WTSL=        1918.8
    DEPTH OF NEW ACTIVE LAYER (ft)           DSE=        0.0042
    WEIGHT IN NEW ACTIVE LAYER(tons)      WTMXAL=          97.6
    WEIGHT IN OLD ACTIVE LAYER(tons)         WAL=         635.8
    USEABLE WEIGHT, OLD INACTIVE LAYER       WIL=      226538.3
    SURFACE AREA OF DEPOSIT (sq ft)         SABK= 0.49516369E+06

** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                        VF SAND    0.009994       0.999449      VF GRVL      0.025198      95.968320
                        F  SAND    0.069961       7.995595      F  GRVL      0.025198      98.488119
                        M  SAND    0.374794      45.474949      M  GRVL      0.005040      98.992078
                        C  SAND    0.374794      82.954303      C  GRVL      0.005040      99.496038
                        VC SAND    0.104942      93.448522      VC GRVL      0.005040      99.999998
** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                        VF SAND    0.391813      39.181331      VF GRVL      0.067850      87.972420
                        F  SAND    0.156193      54.800582      F  GRVL      0.075005      95.472886
                        M  SAND    0.263868      81.187410      M  GRVL      0.015090      96.981924
                        C  SAND    0.000000      81.187410      C  GRVL      0.015090      98.490962
                        VC SAND    0.000000      81.187410      VC GRVL      0.015090     100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.237600E+07
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.279192E+04  VF GRVL 0.108066E+01
                                 F  SAND 0.906230E+03  F  GRVL 0.100000E-06
                                 M  SAND 0.533420E+03  M  GRVL 0.100000E-06
                                 C  SAND 0.403607E+03  C  GRVL 0.100000E-06
                                 VC SAND 0.382254E+03  VC GRVL 0.100000E-06

  SEDIMENT OUTFLOW FROM SECTION NO.      32.000
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE      LOAD (tons/day)
  ----------------------------------------------------------------------------
    VERY FINE SAND....        256.66   |  VERY FINE GRAVEL..         0.04
    FINE SAND.........         78.38   |  FINE GRAVEL.......         0.00
    MEDIUM SAND.......        185.55   |  MEDIUM GRAVEL.....         0.00
    COARSE SAND.......        116.49   |  COARSE GRAVEL.....         0.00
    VERY COARSE SAND..         30.96   |  VERY COARSE GRAVEL         0.00

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Upstream of SECTION NO.       15.000 is...
LOCAL INFLOW POINT # 1 |   DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
                       |     (cfs)     |  (tons/day)   |   (deg F)
----------------------------------------------------------------------
     MAIN STEM INFLOW  |     1100.00   |      362.61   |     64.05
     LOCAL    INFLOW   |      150.00   |       14.45   |     72.00
----------------------------------------------------------------------
               TOTAL   |     1250.00   |      377.06   |     65.00
```

```
 SEDIMENT LOAD FROM LOCAL INFLOW:
    GRAIN SIZE      LOAD (tons/day) |    GRAIN SIZE      LOAD (tons/day)
 ------------------------------------------------------------------------
   VERY FINE SAND....        6.78   | VERY FINE GRAVEL..        0.08
   FINE SAND.........        4.25   | FINE GRAVEL.......        0.03
   MEDIUM SAND.......        2.41   | MEDIUM GRAVEL.....        0.00
   COARSE SAND.......        0.68   | COARSE GRAVEL.....        0.00
   VERY COARSE SAND..        0.21   | VERY COARSE GRAVEL        0.00
                     ------------              ------------
                                          TOTAL =          14.45

   FALL VELOCITIES - Method 2
            DIAMETER   VELOCITY        REY. NO.         CD
   -------------------------------------------------------------
   VF SAND   0.000290  0.1931441E-01  0.4941259       55.02308
   F  SAND   0.000580  0.5916114E-01  3.027072        11.72910
   M  SAND   0.001160  0.1355164      13.86779        4.470784
   C  SAND   0.002320  0.2833008      57.98200        2.045980
   VC SAND   0.004640  0.4824925      197.4999        1.410740
   VF GRVL   0.009280  0.7200893      589.5120        1.266733
   F  GRVL   0.018559   1.040325      1703.352        1.213806
   M  GRVL   0.037118   1.472894      4823.231        1.211086
   C  GRVL   0.074237   2.082985      13642.13        1.211086
   VC GRVL   0.148474   2.945788      38585.85        1.211086

*************************************************************************************************
                  TRACE OUTPUT FOR SECTION NO.     15.000
          ------------------------------------------------------
HYDRAULIC PARAMETERS:
    VEL       SLO          EFD        EFW      N-VALUE     TAU      USTARM     FROUDE NO.
   2.137   0.000485      6.241     112.022     0.0450    0.18889   0.31196     0.151

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL          K-PORTION       S-PORTION
                             543327.92        543327.92           0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER             BED FRACTION   PERCENT FINER
                    VF SAND      0.010618       1.061792       VF GRVL     0.045645      93.051050
                    F  SAND      0.070017       8.063516       F  GRVL     0.034096      96.460669
                    M  SAND      0.325449      40.608371       M  GRVL     0.010834      97.544118
                    C  SAND      0.365690      77.177345       C  GRVL     0.022336      99.777722
                    VC SAND      0.113092      88.486534       VC GRVL     0.002223      99.999998

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      0.78731
MIN.GRAIN DIAM      =      0.002878
BED SURFACE EXPOSED  =      0.00000

        INACTIVE LAYER        ACTIVE LAYER
          %       DEPTH         %       DEPTH
 CLAY   0.0000     0.00      0.0000     0.00
 SILT   0.0000     0.00      0.0000     0.00
 SAND   1.0000     9.64      1.0000     0.17
TOTAL   1.0000     9.64      1.0000     0.17

       AVG. UNIT             AVG. UNIT
         WEIGHT                WEIGHT
       0.046500              0.046500

    COMPOSITE UNIT WT OF ACTIVE LAYER    (t/cf)=        0.046500
    COMPOSITE UNIT WT OF INACTIVE LAYER  (t/cf)=        0.046500
    DEPTH OF SURFACE LAYER (ft)               DSL=           0.1
    WEIGHT IN SURFACE LAYER (tons)           WTSL=        2105.4
    DEPTH OF NEW ACTIVE LAYER (ft)            DSE=        0.0000
    WEIGHT IN NEW ACTIVE LAYER(tons)       WTMXAL=           0.0
    WEIGHT IN OLD ACTIVE LAYER(tons)          WAL=        4252.7
    USEABLE WEIGHT, OLD INACTIVE LAYER        WIL=      243631.1
    SURFACE AREA OF DEPOSIT (sq ft)          SABK= 0.54332792E+06

** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER             BED FRACTION   PERCENT FINER
                    VF SAND      0.010000       1.000000       VF GRVL     0.044734      93.180849
                    F  SAND      0.070000       8.000000       F  GRVL     0.033457      96.526594
                    M  SAND      0.327074      40.707446       M  GRVL     0.010638      97.590423
                    C  SAND      0.366543      77.361700       C  GRVL     0.021915      99.781913
                    VC SAND      0.113457      88.707445       VC GRVL     0.002181      99.999998
** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION   PERCENT FINER             BED FRACTION   PERCENT FINER
                    VF SAND      0.046017       4.601728       VF GRVL     0.097841      85.615105
                    F  SAND      0.071005      11.702227       F  GRVL     0.070689      92.683996
                    M  SAND      0.232303      34.932536       M  GRVL     0.022074      94.891357
                    C  SAND      0.316834      66.615964       C  GRVL     0.046463      99.537628
                    VC SAND      0.092150      75.831001       VC GRVL     0.004624     100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.270000E+07
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.326022E+04  VF GRVL 0.230126E+01
                                 F  SAND 0.107158E+04  F  GRVL 0.328571E-03
                                 M  SAND 0.638850E+03  M  GRVL 0.100000E-06
                                 C  SAND 0.495316E+03  C  GRVL 0.100000E-06
                                 VC SAND 0.491224E+03  VC GRVL 0.100000E-06
```

SEDIMENT OUTFLOW FROM SECTION NO. 15.000

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	138.47	VERY FINE GRAVEL..	0.18
FINE SAND.........	75.72	FINE GRAVEL.......	0.00
MEDIUM SAND.......	168.18	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	162.61	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	47.90	VERY COARSE GRAVEL	0.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 3. MOVABLE BED
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
53.00	58.000	13.25		
	53.000	16.13		
	42.000	0.36		
TOTAL=	35.000	29.74	5.52	0.81

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
53.00	35.000	5.52		
TOTAL=	33.000	5.52	1.54	0.72

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
53.00	33.000	1.54		
	15.000	1.00		
TOTAL=	1.000	2.54	0.07	0.97

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	66.90	VERY FINE GRAVEL..	0.00
FINE SAND.........	53.32	FINE GRAVEL.......	0.00
MEDIUM SAND.......	29.58	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.01	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	149.81

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	2.05	VERY FINE GRAVEL..	0.00
FINE SAND.........	1.13	FINE GRAVEL.......	0.00
MEDIUM SAND.......	2.94	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	2.79	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	1.08	VERY COARSE GRAVEL	0.00
		TOTAL =	9.99

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 53.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-0.83	979.94	974.57	682.	818.
55.000	0.04	979.11	972.94	682.	1476.
53.000	0.25	975.42	972.45	1022.	4056.
44.000	0.19	974.82	967.29	1022.	560.
42.000	0.94	974.43	970.74	1100.	15.
35.000	0.17	974.00	963.47	1100.	6.
33.900	0.48	966.96	963.13	1100.	528.
33.300	0.13	966.48	962.62	1100.	442.
33.000	0.36	966.00	961.36	1100.	156.
32.100	-0.20	964.81	956.30	1100.	208.
32.000	-0.15	963.90	956.35	1100.	668.
15.000	-0.19	960.48	953.51	1250.	593.
1.000	1.07	960.00	945.77	1250.	10.

Accumulated Water Discharge from day zero (sfd)
MAIN
127750.00

$PRT A
...Selective Printout Option
A - Print at all cross sections

TIME STEP # 4
* B FLOW 4 = BASE FLOW OF 750 CFS

EXAMPLE PROBLEM NO 3. MOVABLE BED
ACCUMULATED TIME (yrs).... 0.148
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	532.00	93.30	63.44

Upstream of SECTION NO. 53.000 is...

LOCAL INFLOW POINT # 3	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	532.00	93.30	63.44
LOCAL INFLOW	128.00	43.20	67.00
TOTAL	660.00	136.50	64.13

Upstream of SECTION NO. 42.000 is...

LOCAL INFLOW POINT # 2	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	660.00	136.50	64.13
LOCAL INFLOW	29.00	1.22	70.00
TOTAL	689.00	137.72	64.38

Upstream of SECTION NO. 15.000 is...

LOCAL INFLOW POINT # 1	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	689.00	137.72	64.38
LOCAL INFLOW	61.00	4.32	72.00
TOTAL	750.00	142.04	65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 3. MOVABLE BED
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
54.00	58.000	13.29		
	53.000	16.15		
	42.000	0.36		
TOTAL=	*35.000*	*29.81*	*5.52*	*0.81*

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
54.00	35.000	5.52		
TOTAL=	33.000	5.52	2.04	0.63

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
54.00	33.000	2.04		
	15.000	1.00		
TOTAL=	1.000	3.04	0.08	0.97

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	38.08	VERY FINE GRAVEL..	0.00
FINE SAND.........	34.16	FINE GRAVEL.......	0.00
MEDIUM SAND.......	21.06	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	93.30

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	6.28	VERY FINE GRAVEL..	0.15
FINE SAND.........	2.82	FINE GRAVEL.......	0.19
MEDIUM SAND.......	6.67	MEDIUM GRAVEL.....	0.07
COARSE SAND.......	6.38	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	2.69	VERY COARSE GRAVEL	0.00
		TOTAL =	25.24

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 54.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-0.94	979.24	974.46	532.	415.
55.000	0.00	978.47	972.90	532.	833.
53.000	0.23	974.73	972.43	660.	1274.
44.000	0.22	974.40	967.32	660.	138.
42.000	0.94	974.18	970.74	689.	1.
35.000	0.17	974.00	963.47	689.	0.
33.900	0.40	965.77	963.05	689.	433.
33.300	0.11	965.05	962.60	689.	713.
33.000	0.33	963.74	961.33	689.	1000.

```
     32.100       -0.10    963.74    956.40         689.         49.
     32.000       -0.18    963.13    956.32         689.        694.
     15.000       -0.24    957.66    953.46         750.       1530.
      1.000        1.22    957.00    945.92         750.         25.

--------------------------------------------------------------------------------------------
$$END

      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =        4
TOTAL NO. OF WS PROFILES =            4
ITERATIONS IN EXNER EQ =            260

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  2.00 SECONDS
```

6.4 Example Problem 4 - Some Sediment Options

Several options are available in HEC-6 to control sedimentation. Among these are dredging, transmissive boundary conditions, an alternate bed roughness computation method, and the opportunity to enter a new sediment load table or rating curve at any point in the hydrograph. In any study, selection and use of any of these options must be based on sound engineering analysis. Example Problem 4 illustrates how to use these options.

The data for this example problem (shown in Table 6-4a) also shows the use of output control to select output at specified cross sections (**$PRT** and **PN**) and request cumulative volumes of sediment passing each cross section (**$VOL**). Table 6-4b shows the simulation output for this example; since the output produced by the geometry and sediment input data does not differ from that of Example Problem 3, it has been omitted from Table 6-4b.

6.4.1 Dredging

Frequent dredging occurs in the reach bounded by Sections 35.0 and 44.0. The geometric data for the cross sections in this reach were modified via the **HD** record to identify the dredged channel template. The dredging option is activated by a **$DREDGE** record in the flow data and will be performed at the start of each time step until deactivated by a **$NODREDGE** record.

The default output produced by the dredging option is limited to the quantity of material removed from the bed and is only given for those cross sections at which material was removed. The output for Example Problem 4 (Table 6-4b), shows that the dredging algorithm was initiated before time step 2 and terminated after time step 3. The table labelled "TONS OF SEDIMENT DREDGED FROM THIS REACH" indicates that prior to time step 3, 13568.3 tons of material was dredged from Sections 42.0 and 44.0.

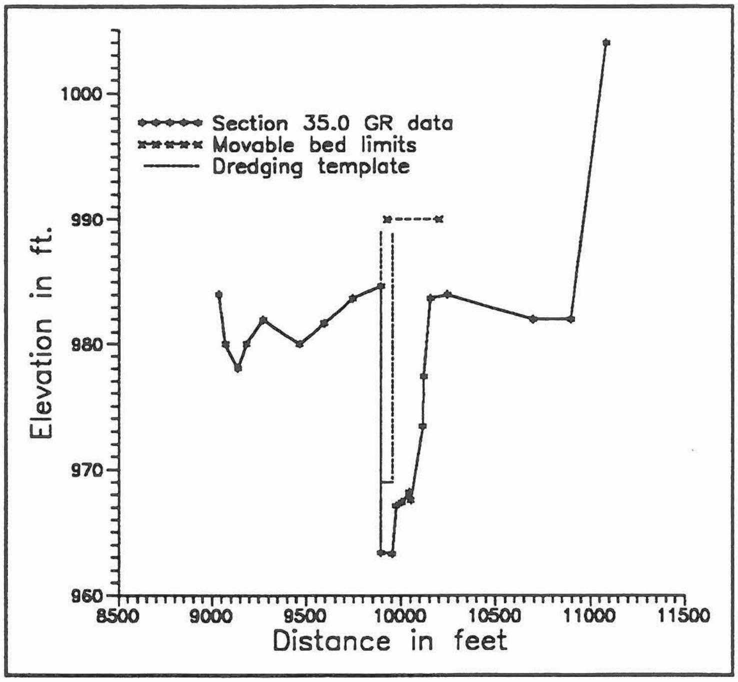

Figure 6-4
Cross Section 35.0, Example Problem 4

Table 6-4a
Example Problem 4 - Input
Sediment Options

```
T1       EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.
T2       3 LOCAL INFLOWS
T3       SOUTH FORK, ZUMBRO RIVER      ** Example Problem 4 **
NC    .1       .1      .04      .1       .3
X1   1.0       31   10077.   10275.      0.       0.       0.
GR 1004.    9915.    978.4   10002.    956.0   10060.    959.2   10077.    959.3   10081.
GR 950.0   10092.   948.48   10108.    946.6   10138.    944.7   10158.    955.2   10225.
GR 956.2   10243.    958.9   10250.    959.8   10275.    959.8   10300.    959.9   10325.
```

```
GR 958.8  10350.    957.4  10400.   970.0  10700.   966.0  10960.   970.0  11060.
GR 968.0  11085.    968.0  11240.   970.0  11365.   970.0  11500.   970.0  11615.
GR 962.0  11665.    962.0  12400.   976.0  12550.   980.0  12670.   982.0  12730.
GR 984.0  12735.
HD   1.0     10.   10081.  10250.
NV    22    .045    965.6    .064   988.8
NV    12     .08    965.6     .13   988.8
NV    33      .1    965.6     .11   982.0     .12   988.8
X1  15.0      27   10665.  10850.   3560.   3030.   3280.
X3                         10700.   961.0  11000.   970.0
GR 992.0   9570.    982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7  10665.    956.0  10673.   953.0  10693.   954.0  10703.   955.6  10723.
GR 958.6  10750.    959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0  10852.    964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0  11190.    972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0  11865.   1000.0  12150.
HD  15.0     10.   10673.  10852.
  CASCADE CREEK - Local Inflow
QT
NC    .1      .1      .05
X1  32.0      29 10057.0 10271.0   3630.   3060.   4240.
GR 998.0   9080.    982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.    978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.    957.8  10137.   959.4  10157.   959.6  10177.   959.8  10196.
GR 966.5  10225.    971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.   978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.    992.0  11240.  1000.0  11330.   1008.   11425.
HD  32.0     10.   10075.  10275.
  Section 32.1 is a duplicate of Sec 32.0 - Needed to model IBC at Sec 33.0
X1  32.1      29 10057.0 10271.0   3130.   3250.   3320.
X3    10
GR 998.0   9080.    982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.    978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.    957.8  10137.   959.4  10157.   959.6  10177.   959.8  10196.
GR 966.5  10225.    971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.   978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.    992.0  11240.  1000.0  11330.   1008.   11425.
HD  32.1     10.   10075.  10275.
  A spillway is located here.
X1  33.0      21    1850.   2150.      0       0       0
X5                              2
XL                  250.
GR 1000.    980.    990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.    982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.    982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.0      0.    1851.   2149.
  Section 33.3 is a duplicate of Section 33.0.
X1  33.3      21    1850.   2150.   1550.   1750.   1750.     .95    1.49
XL                  250.
GR 1000.    980.    990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.    982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.    982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.3      0.    1851.   2149.
  Section 33.9 is a duplicate of Sec 33.3 - Needed to model IBC at Sec 35.0
X1  33.9      21    1850.   2150.   1050.   1050.   1050.     .95    1.65
X3    10
GR 1000.    980.    990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.    982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.    982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.9      0.    1851.   2149.
  A weir is located here.
X1  35.0      22    9894.  10245.      0       0       0
X3    10
X5          974.      0.5
GR 984.0   9035.    980.0   9070.   978.0   9135.   980.0   9185.   982.0   9270.
GR 980.0   9465.    981.7   9595.   983.7   9745.   984.7   9894.   963.4  9894.1
GR 963.3   9954.    967.1   9974.   967.4  10004.   968.2  10044.   967.6  10054.
GR 973.4  10115.    977.4  10120.   983.7  10155.   984.0  10245.   982.0  10695.
GR 982.0  10895.   1004.0  11085.
HD  35.0      0.    9954.  10155.           969.0   9894.   9954.             1.0
    - - -  SILVER LAKE  - - -
NC   .06     .06     .045
X1  42.0      32    9880.  10130.   5370.   5000.   5210.
GR 996.0   7130.    998.0   7310.   998.0   7930.   992.0   8205.   990.0   8495.
GR 988.0   8780.    986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0   9880.    969.8   9881.   969.8   9941.   985.8   9941.   985.8   9943.
GR 969.8   9943.    969.8  10001.   986.7  10001.   986.7  10003.   969.8  10003.
GR 969.8  10067.    985.8  10067.   985.8  10069.   969.8  10069.   969.8  10129.
GR 989.9  10130.    989.5  10180.   988.6  10230.   987.6  10280.   985.2  10430.
```

```
GR 986.8  11720.   989.9  12310.
HD  42.0      0.   9881.  10021.            971.0   9881.   9941.             1.0
  SILVER CREEK - Local Inflow
QT
X1  44.0      28   9845.  10127.   3200.   3800.   3500.
XL                         9850.  10200.
GR 1002.   8035.   992.0   8150.   990.0   8305.   990.0   8735.   988.0   8835.
GR 996.0   9285.  1017.6   9425.   990.0   9505.   986.0   9650.   984.1   9788.
GR 980.6   9845.   970.9   9868.   972.2   9898.   970.5   9968.   967.5   9998.
GR 968.9  10028.   967.4  10058.   967.1  10078.   971.9  10118.   976.8  10127.
GR 977.8  10150.   976.9  10193.   982.0  10206.   981.2  10300.   979.2  10325.
GR 983.1  10400.   999.8  10450.  1002.4  10464.
HD  44.0      1.   9868.  10193.            971.0   9968.  10028.             1.0
X1  53.0      22  10000.  10136.   3366.   2832.   2942.
GR 1004.   7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0   8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8  10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2  10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.  10470.  1004.0  10700.
HD  53.0     10.  10000.  10136.
  BEAR CREEK - Local Inflow
QT
X1  55.0      18   9931.  10062.   2275.   3430.   2770.
GR 1004.   7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3   9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8   9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8  10187.   986.0  10307.   990.0  10497.
HD  55.0     10.   9931.  10062.
X1  58.0      22   9912.  10015.   1098.   1012.   1462.
GR 1006.   8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2   9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8  10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0  10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0  11137.   988.0  11192.
HD  58.0     3.4   9912.  10015.
EJ
T4       South Fork, Zumbro River - Stream Segment 1      ** Example Problem 4 **
T5       LOAD CURVE FROM GAGE DATA.
T6       BED GRADATIONS FROM FIELD SAMPLES.
T7       FULL RANGE OF SANDS AND GRAVELS
T8       SEDIMENT TRANSPORT BY YANG'S STREAM POWER [REF-ASCE JOURNAL (YANG 1971)]
I1             5
I4  SAND       4       1      10
I5            .5      .5     .25      .5     .25       0     1.0
LQ             1      50    1000    5800   90000
LT TOTAL   .0110     1.5     320   4500.  400000
LF   VFS    .119    .119    .498    .511    .582
LF    FS    .328    .328    .331    .306    .280
LF    MS    .553    .553    .156    .154    .110
LF    CS    .000    .000    .011    .016    .020
LF   VCS    .000    .000    .004    .008    .005
LF   VFG    .000    .000    .000    .004    .002
LF    FG    .000    .000    .000    .001    .001
LF    MG    .000    .000    .000    .000    .000
LF    CG    .000    .000    .000    .000    .000
LF   VCG      .0      .0    .000    .000    .000
PF EXAMP     1.0     1.0    32.0    16.0    96.5     8.0    95.0     4.0    91.0
PFC  2.0    85.0     1.0    73.0      .5    37.0     .25     8.0    .125     1.0
PFC.0625     0.0
PF EXAMP    32.0     1.0    64.0    32.0    99.5    16.0    99.0     8.0    98.5
PFC  4.0    96.0     2.0    93.5     1.0    83.0     .50    45.5    .250     8.0
PFC .125     1.0   .0625     0.0
PF EXAMP    58.0     1.0    64.0    32.0    97.0    16.0    94.0     8.0    94.0
PFC  4.0    90.0     2.0    79.0     1.0    56.0     .50     4.0    .125     0.0
$LOCAL
  LOAD TABLE - CASCADE CREEK - A LOCAL INFLOW
LQL            1     100    1000   10000
LTLTOTAL   .0040      10     500   30000
LFL  VFS    .664    .664    .015    .198
LFL   FS    .207    .207    .245    .181
LFL   MS    .086    .086    .605    .107
LFL   CS    .031    .031    .052    .098
LFL  VCS    .008    .008    .039    .127
LFL  VFG   .0030   .0030   .0200   .1160
LFL   FG   .0010   .0010   .0110   .0910
LFL   MG   .0000   .0000   .0110   .0530
LFL   CG   .0000   .0000   .0000   .0220
LFL  VCG   .0000   .0000   .0000   .0060
  LOAD TABLE - SILVER CREEK - A LOCAL INFLOW
LQL            1     100    1000   10000
LTLTOTAL   .0040      10     500   30000
LFL  VFS    .664    .664    .015    .198
LFL   FS    .207    .207    .245    .181
LFL   MS    .086    .086    .605    .107
LFL   CS    .031    .031    .052    .098
```

```
LFL  VCS    .008     .008     .039     .127
LFL  VFG   .0030    .0030    .0200    .1160
LFL   FG   .0010    .0010    .0110    .0910
LFL   MG   .0000    .0000    .0110    .0530
LFL   CG   .0000    .0000    .0000    .0220
LFL  VCG   .0000    .0000    .0000    .0060
  LOAD TABLE - BEAR CREEK - A LOCAL INFLOW
LQL           1.     100.     500.    1000.   30000.
LTLTOTAL   .0020     30.0     500.     1200    22500
LFL  VFS    .201     .201     .078     .078     .137
LFL   FS    .342     .342     .172     .175     .218
LFL   MS    .451     .451     .454     .601     .476
LFL   CS    .001     .001     .197     .142     .158
LFL  VCS    .000     .000     .000     .003     .008
LFL  VFG   .0000    .0000    .0000    .0000    .0020
LFL   FG   .0000     .000    .0000    .0000    .0010
LFL   MG   .0000     .000    .0000    .0000    .0000
LFL   CG   .0000     .000    .0000    .0000    .0000
LFL  VCG   .0000     .000    .0000    .0000    .0000
$HYD
$B             2
$KL
*     A    FLOW 1 = BASE FLOW OF 750 CFS
Q   750.     61.      29.     128.
R   956.    962.
T    65.     72.      70.      67.
W     2.
$DREDGE
*     B    FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q  2500.    300.     150.     650.
R   965.    970.
X            2.5      50.
*          FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.    150.      78.     340.
R   960.    966.
W     1.
$SED
  NEW LOAD TABLE FOR MAIN STEM...
LPOINT         1        0
LQ             1       50     1000     5800    90000
LT TOTAL   .0110      1.5      320    4500.   400000
LF   VFS    .119     .119     .498     .511     .582
LF    FS    .328     .328     .331     .306     .280
LF    MS    .553     .553     .156     .154     .110
LF    CS    .345     .345     .011     .016     .020
LF   VCS    .025     .025     .004     .008     .005
LF   VFG    .005     .005     .000     .004     .002
LF    FG    .000     .000     .000     .001     .001
LF    MG    .000     .000     .000     .000     .000
LF    CG    .000     .000     .000     .000     .000
LF   VCG      .0       .0     .000     .000     .000
  NEW LOAD TABLE FOR SILVER CREEK - A LOCAL INFLOW
LPOINT         1        2
LQL            1      100     1000    10000
LTLTOTAL   .0040       10      500    30000
LFL  VFS    .664     .664     .015     .198
LFL   FS    .207     .207     .245     .181
LFL   MS    .086     .086     .605     .107
LFL   CS    .031     .031     .052     .098
LFL  VCS    .008     .008     .039     .127
LFL  VFG   .0030    .0030    .0200    .1160
LFL   FG   .0010    .0010    .0110    .0910
LFL   MG   .0000    .0000    .0110    .0530
LFL   CG   .0000    .0000    .0000    .0220
LFL  VCG   .0000    .0000    .0000    .0060
END
$RATING
RC            40     2000        0        0    950.0    955.1    958.0    960.0    962.0
RC         963.6    965.1    966.2    967.0    967.7    968.3    968.9    969.4    969.8
RC         970.2    970.6    971.0    971.4    971.8    972.1    972.4    972.7    972.9
RC         973.1    973.3    973.5    973.7    973.8    973.9    974.0    974.1    974.2
RC         974.3    974.4    974.5    974.6    974.7    974.8    974.9    975.0
$PRT
CP             1
PS           1.0     15.0
END
$NODREDGE
*     C    FLOW 4 = BASE FLOW OF 750 CFS
Q   750.     61.      29.     128.
R   957.    963.
W     1.
$VOL   A
$$END
```

6.4.2 Transmissive Boundary Condition

With the addition of the **$B** record at the beginning of the hydrologic data, HEC-6 implements a transmissive boundary condition at each downstream boundary. This option causes all inflowing sediment to pass through the affected cross section without interacting with the bed. A caution: this option applies to all downstream boundaries in the model.

As in Example Problems 2 and 3, this example has two internal boundary conditions which effectively divide the model into 3 subreaches, each with its own downstream boundary. The effect of the transmissive boundary condition on the 3 downstream boundaries can be seen by carefully reviewing the output of Example Problem 4. For instance, looking at TABLE SB-2 for the last time step, Sections 35.0, 33.0, and 1.0 all show that no bed change has occurred after a simulation of 52 days.

6.4.3 Limerinos' Bed Form Roughness Function

The Limerinos function (16) for bed form roughness is used in this example (**$KL** record). The value of Manning's *n* resulting from this computation can be found in the "HYDRAULIC PARAMETERS" table of the C-level sediment output. For example, the *n* value calculated by the Limerinos equation for the last time step for Section No. 42.1 is 0.0153. Note, this computation overrides the roughness data (**NC** and **NV** records) in the geometric data.

6.4.4 Flow Duration Option

The use of **X** rather than **W** data to select the time step is also illustrated in this problem. This option allows a long period of constant flow to be subdivided into multiple computational time steps without repeating *****, **Q**, **W** data.

In this example, time step 2 represents 20 separate (incremental or computational) time steps each having a duration of 2.5 days. At the end of the last incremental time step, output is produced depicting the state of the river system for the last 2.5 day time step (i.e., instantaneous data such as the sediment load data in TABLE SB-2 are only for the last 2.5 day time step, while cumulative data, such as trap efficiency and bed change, represent changes since the start of the simulation.) Caution, because of this dichotomy, output produced by a time step such as this can be misleading. See Example Problem 7, Section 6.7.2.

6.4.5 Modifying the Sediment Load Tables

Sometimes the inflowing water vs. sediment relationship will change in time due to land use changes or even seasonal variations in vegetation. Such changes, should they be known or predicted, can be described in the flow data by using the **$SED** option. Example Problem 4 demonstrates the use of this option by changing the inflowing load curve for the main river and one local inflowing load curve prior to the last flow in the hydrograph. Tables echoing this data are shown in the output after time step 3.

6.4.6 Downstream Rating Curve

Prior to the last time step, a rating curve (**$RATING**) was added to replace the stage hydrograph (R records). Although a rating curve is usually defined prior to the first time step, it can be placed (or replaced) before any time step of the simulation.

6.4.7 Accumulated Sediment Transported

Summary information regarding weight and volume of sediment can be requested via the A-level output option on the **$VOL** record. A-level output begins with the table labelled "SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT". This table lists cumulative values of sediment transported through and deposited at each cross section since time zero. The difference between the sediment volume entering and leaving a cross section represents the material scoured from or deposited into the control volume associated with that cross section. This value is given under the heading "SEDIMENT DEPOSITED IN REACH IN CUBIC YARDS"; negative values represent scour. Under the heading "TOTAL SEDIMENT per grain size THROUGH EACH CROSS SECTION" are tables listing the total sediment transported through each cross section's control volume since the start of the simulation by grain size. Because the $PRT option was invoked to limit output to Sections 1.0 and 15.0, only tables for these cross sections have been produced.

Table 6-4b
Example Problem 4 - Output
Sediment Options

```
*****************************************************     ************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS   *     *  U.S. ARMY CORPS OF ENGINEERS    *
*       Version: 4.1.00 -  AUGUST 1993              *     *  HYDROLOGIC ENGINEERING CENTER   *
*  INPUT FILE:  example4.DAT                        *     *  609 SECOND STREET               *
*  OUTPUT FILE: example4.OUT                        *     *  DAVIS, CALIFORNIA 95616-4687    *
*  RUN DATE: 31 AUG 93     RUN TIME: 16:06:03       *     *  (916) 756-1104                  *
*****************************************************     ************************************

                    X     X  XXXXXXX   XXXXX          XXXXX
                    X     X  X        X     X        X     X
                    X     X  X        X              X
                    XXXXXXX  XXXX     X        XXXXX XXXXXX
                    X     X  X        X              X     X
                    X     X  X        X     X        X     X
                    X     X  XXXXXXX   XXXXX          XXXXX

          *******************************************************************
          *  MAXIMUM LIMITS FOR THIS VERSION ARE:                           *
          *        10  Stream Segments (Main Stem + Tributaries)            *
          *       150  Cross Sections                                       *
          *       100  Elevation/Station Points per Cross Section           *
          *        20  Grain Sizes                                          *
          *        10  Control Points                                       *
          *******************************************************************
```

The output produced during processing of the geometry and sediment data does not differ from that produced for Example Problem 3. It has therefore been omitted from this table. Refer to Table 6-3b.

```
==========================================================================================

$HYD
BEGIN COMPUTATIONS.
------------------------------------------------------------------------------------------
$B           2
...Transmissive Boundary Condition - ON
------------------------------------------------------------------------------------------
$KL
...USING LIMERINOS METHOD TO CALCULATE BED ROUGHNESS.
==========================================================================================
```

```
TIME STEP #       1
*   A      FLOW 1 = BASE FLOW OF 750 CFS

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
    TIME        ENTRY *            SAND                *
    DAYS        POINT *   INFLOW   OUTFLOW   TRAP EFF  *
    2.00       58.000 *    0.09                        *
               53.000 *    0.04                        *
               42.000 *    0.00                        *
   TOTAL=      35.000 *    0.14      0.00       1.00   *
*****************************************************************
    TIME        ENTRY *            SAND                *
    DAYS        POINT *   INFLOW   OUTFLOW   TRAP EFF  *
    2.00       35.000 *    0.00                        *
   TOTAL=      33.000 *    0.00      0.00       0.36   *
*****************************************************************
    TIME        ENTRY *            SAND                *
    DAYS        POINT *   INFLOW   OUTFLOW   TRAP EFF  *
    2.00       33.000 *    0.00                        *
               15.000 *    0.00                        *
   TOTAL=       1.000 *    0.00      2.96    -692.13   *
*****************************************************************

--------------------------------------------------------------------------------------------
$DREDGE
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

STREAM SEGMENT #  1: EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.

SEC NO.      42.000
ELEVATION OF DREDGED CHANNEL INCLUDING    1.00 FEET OF OVER DREDGING=      970.00

============================================================================================
TIME STEP #       2
*   B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
COMPUTING FROM TIME=      2.0000 DAYS TO TIME=      52.0000 DAYS IN    20 COMPUTATION STEPS

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.
       ACCUMULATED TIME (yrs)....      0.142
       FLOW DURATION (days)......      2.500

UPSTREAM BOUNDARY CONDITIONS
--------------------------------------------------------------------------
Stream Segment # 1      |   DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
Section No.     58.000  |     (cfs)     |  (tons/day)   |   (deg F)
--------------------------------------------------------------------------
                 INFLOW |      1400.00  |       529.98  |       62.04

Upstream of SECTION NO.      53.000 is...
LOCAL INFLOW POINT # 3  |   DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
                        |     (cfs)     |  (tons/day)   |   (deg F)
--------------------------------------------------------------------------
       MAIN STEM INFLOW |      1400.00  |       529.98  |       62.04
       LOCAL     INFLOW |       650.00  |       647.71  |       67.00
--------------------------------------------------------------------------
                  TOTAL |      2050.00  |      1177.69  |       63.61

Upstream of SECTION NO.      42.000 is...
LOCAL INFLOW POINT # 2  |   DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
                        |     (cfs)     |  (tons/day)   |   (deg F)
--------------------------------------------------------------------------
       MAIN STEM INFLOW |      2050.00  |      1177.69  |       63.61
       LOCAL     INFLOW |       150.00  |        14.45  |       70.00
--------------------------------------------------------------------------
                  TOTAL |      2200.00  |      1192.13  |       64.05

Upstream of SECTION NO.      15.000 is...
LOCAL INFLOW POINT # 1  |   DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
                        |     (cfs)     |  (tons/day)   |   (deg F)
--------------------------------------------------------------------------
       MAIN STEM INFLOW |      2200.00  |      1192.13  |       64.05
       LOCAL     INFLOW |       300.00  |        40.00  |       72.00
--------------------------------------------------------------------------
                  TOTAL |      2500.00  |      1232.13  |       65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
    TIME        ENTRY *            SAND                *
    DAYS        POINT *   INFLOW   OUTFLOW   TRAP EFF  *
   52.00       58.000 *   13.17                        *
               53.000 *   16.03                        *
               42.000 *    0.36                        *
   TOTAL=      35.000 *   29.56      2.05       0.93   *
*****************************************************************
    TIME        ENTRY *            SAND                *
    DAYS        POINT *   INFLOW   OUTFLOW   TRAP EFF  *
   52.00       35.000 *    2.05                        *
   TOTAL=      33.000 *    2.05      0.08       0.96   *
*****************************************************************
```

TIME DAYS	ENTRY POINT	*	INFLOW	SAND OUTFLOW	TRAP EFF	*
52.00	33.000	*	0.08			*
	15.000	*	0.99			*
TOTAL=	1.000	*	1.07	3.42	-2.21	*

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	265.63	VERY FINE GRAVEL..	0.00
FINE SAND.........	173.06	FINE GRAVEL.......	0.00
MEDIUM SAND.......	82.59	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	6.27	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	2.42	VERY COARSE GRAVEL	0.00
		TOTAL =	529.98

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	1.42	VERY FINE GRAVEL..	0.03
FINE SAND.........	1.61	FINE GRAVEL.......	0.00
MEDIUM SAND.......	7.44	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	9.01	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	3.68	VERY COARSE GRAVEL	0.00
		TOTAL =	23.18

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 52.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-2.79	978.33	972.61	1400.	577.
55.000	-1.24	978.30	971.66	1400.	837.
53.000	-1.55	976.02	970.65	2050.	1885.
44.000	0.92	974.67	968.02	2050.	1258.
42.000	1.75	974.19	971.55	2200.	138.
35.000	*0.00*	974.00	963.30	2200.	138.
33.900	0.69	970.03	963.34	2200.	9.
33.300	0.01	970.01	962.50	2200.	4.
33.000	*0.00*	970.00	961.00	2200.	4.
32.100	-0.52	965.75	955.98	2200.	107.
32.000	-0.05	965.23	956.45	2200.	138.
15.000	-0.18	964.99	953.52	2500.	23.
1.000	*0.00*	965.00	944.70	2500.	23.

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. SOME SEDIMENT OPTIONS.

SEC NO. 42.000
ELEVATION OF DREDGED CHANNEL INCLUDING 1.00 FEET OF OVER DREDGING= 970.00

SEC NO. 44.000
ELEVATION OF DREDGED CHANNEL INCLUDING 1.00 FEET OF OVER DREDGING= 970.00
TONS OF SEDIMENT DREDGED FROM THIS REACH= 13568.3 ACCUMULATED FROM DOWNSTREAM END= 13568.
CUBIC YARDS= 10807.1 10807.

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. SOME SEDIMENT OPTIONS.

$SED
LPOINT 1 0
SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ		1.00000	50.0000	1000.00	5800.00	90000.0
LF	VFS	0.130900E-02	0.178500	159.360	2299.50	232800.
LF	FS	0.360800E-02	0.492000	105.920	1377.00	112000.
LF	MS	0.608300E-02	0.829500	49.9200	693.000	44000.0
LF	CS	0.379500E-02	0.517500	3.52000	72.0000	8000.00
LF	VCS	0.275000E-03	0.375000E-01	1.28000	36.0000	2000.00
LF	VFG	0.550000E-04	0.750000E-02	0.100000E-19	18.0000	800.000
LF	FG	0.100000E-19	0.100000E-19	0.100000E-19	4.50000	400.000
LF	MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF	CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF	VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
	TOTAL	0.151250E-01	2.06250	320.000	4500.00	400000.

LPOINT 1 2
SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 2
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL		1.00000	100.000	1000.00	10000.0
LFL	VFS	0.265600E-02	6.64000	7.50000	5940.00
LFL	FS	0.828000E-03	2.07000	122.500	5430.00
LFL	MS	0.344000E-03	0.860000	302.500	3210.00
LFL	CS	0.124000E-03	0.310000	26.0000	2940.00
LFL	VCS	0.320000E-04	0.800000E-01	19.5000	3810.00

LFL	VFG	0.120000E-04	0.300000E-01	10.0000	3480.00
LFL	FG	0.400000E-05	0.100000E-01	5.50000	2730.00
LFL	MG	0.100000E-19	0.100000E-19	5.50000	1590.00
LFL	CG	0.100000E-19	0.100000E-19	0.100000E-19	660.000
LFL	VCG	0.100000E-19	0.100000E-19	0.100000E-19	180.000
	TOTAL	0.400000E-02	10.0000	499.000	29970.0

$RATING

Downstream Boundary Condition - Rating Curve

Elevation	Stage	Discharge	Elevation	Stage	Discharge
950.000	950.000	0.000	972.400	972.400	40000.000
955.100	955.100	2000.000	972.700	972.700	42000.000
958.000	958.000	4000.000	972.900	972.900	44000.000
960.000	960.000	6000.000	973.100	973.100	46000.000
962.000	962.000	8000.000	973.300	973.300	48000.000
963.600	963.600	10000.000	973.500	973.500	50000.000
965.100	965.100	12000.000	973.700	973.700	52000.000
966.200	966.200	14000.000	973.800	973.800	54000.000
967.000	967.000	16000.000	973.900	973.900	56000.000
967.700	967.700	18000.000	974.000	974.000	58000.000
968.300	968.300	20000.000	974.100	974.100	60000.000
968.900	968.900	22000.000	974.200	974.200	62000.000
969.400	969.400	24000.000	974.300	974.300	64000.000
969.800	969.800	26000.000	974.400	974.400	66000.000
970.200	970.200	28000.000	974.500	974.500	68000.000
970.600	970.600	30000.000	974.600	974.600	70000.000
971.000	971.000	32000.000	974.700	974.700	72000.000
971.400	971.400	34000.000	974.800	974.800	74000.000
971.800	971.800	36000.000	974.900	974.900	76000.000
972.100	972.100	38000.000	975.000	975.000	78000.000

$PRT
...*Selective Printout Option*
- Print at the following cross sections

CP 1
PS 1.0 15.0
END

$NODREDGE

TIME STEP # 4
* C FLOW 4 = BASE FLOW OF 750 CFS

EXAMPLE PROBLEM NO 4. SOME SEDIMENT OPTIONS.
ACCUMULATED TIME (yrs).... 0.148
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	532.00	96.26	63.44

SEDIMENT INFLOW at SECTION NO. 58.000

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	38.08	VERY FINE GRAVEL..	0.00
FINE SAND.........	34.16	FINE GRAVEL.......	0.00
MEDIUM SAND.......	21.06	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	2.35	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.61	VERY COARSE GRAVEL	0.00
		TOTAL =	96.26

FALL VELOCITIES - Method 2

	DIAMETER	VELOCITY	REY. NO.	CD
VF SAND	0.000290	0.1895778E-01	0.4746927	57.11272
F SAND	0.000580	0.5840962E-01	2.925091	12.03287
M SAND	0.001160	0.1341560	13.43676	4.561910
C SAND	0.002320	0.2818261	56.45410	2.067449
VC SAND	0.004640	0.4816294	192.9560	1.415800
VF GRVL	0.009280	0.7196122	576.5988	1.268414
F GRVL	0.018559	1.040018	1666.653	1.214521
M GRVL	0.037118	1.472894	4720.706	1.211086
C GRVL	0.074237	2.082985	13352.15	1.211086
VC GRVL	0.148474	2.945788	37765.65	1.211086

```
Upstream of SECTION NO.      15.000 is...
LOCAL INFLOW POINT # 1 |   DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
                       |     (cfs)      |  (tons/day)   |   (deg F)
------------------------------------------------------------------------
     MAIN STEM INFLOW  |      689.00    |      140.68   |     64.38
     LOCAL     INFLOW  |       61.00    |        4.32   |     72.00
------------------------------------------------------------------------
                TOTAL  |      750.00    |      145.00   |     65.00

  SEDIMENT LOAD FROM LOCAL INFLOW:
     GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....          2.87  |  VERY FINE GRAVEL..          0.01
    FINE SAND.........          0.89  |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......          0.37  |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......          0.13  |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..          0.03  |  VERY COARSE GRAVEL          0.00
                           -------------                     -------------
                                               TOTAL =               4.32

    FALL VELOCITIES - Method 2
              DIAMETER    VELOCITY          REY. NO.          CD
    ----------------------------------------------------------------
    VF SAND   0.000290  0.1931441E-01  0.4941259        55.02308
    F  SAND   0.000580  0.5916114E-01   3.027072        11.72910
    M  SAND   0.001160  0.1355164       13.86779        4.470784
    C  SAND   0.002320  0.2833008       57.98200        2.045980
    VC SAND   0.004640  0.4824925       197.4999        1.410740
    VF GRVL   0.009280  0.7200893       589.5120        1.266733
    F  GRVL   0.018559   1.040325       1703.352        1.213806
    M  GRVL   0.037118   1.472894       4823.231        1.211086
    C  GRVL   0.074237   2.082985       13642.13        1.211086
    VC GRVL   0.148474   2.945788       38585.85        1.211086

***************************************************************************************
                  TRACE OUTPUT FOR SECTION NO.      15.000
              ---------------------------------------------------

HYDRAULIC PARAMETERS:
      VEL       SLO          EFD        EFW     N-VALUE      TAU      USTARM     FROUDE NO.
     4.382  0.000558       4.555     72.960     0.0167   0.15863   0.28588       0.362

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL          K-PORTION        S-PORTION
                             336901.25        336901.25           0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:    BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                       VF SAND    0.010519       1.051939       VF GRVL     0.045573       93.063185
                       F  SAND    0.068551       7.907044       F  GRVL     0.034049       96.468071
                       M  SAND    0.324948      40.401812       M  GRVL     0.010808       97.548838
                       C  SAND    0.367062      77.107991       C  GRVL     0.022292       99.777989
                       VC SAND    0.113979      88.505902       VC GRVL     0.002220       99.999998

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=     0.80177
MIN.GRAIN DIAM       =    0.030569
BED SURFACE EXPOSED  =     0.00000

        INACTIVE LAYER       ACTIVE LAYER
          %       DEPTH       %       DEPTH
 CLAY  0.0000     0.00     0.0000     0.00
 SILT  0.0000     0.00     0.0000     0.00
 SAND  1.0000     9.25     1.0000     0.57
TOTAL  1.0000     9.25     1.0000     0.57

       AVG. UNIT              AVG. UNIT
         WEIGHT                 WEIGHT
       0.046500               0.046500

    COMPOSITE UNIT WT OF ACTIVE LAYER    (t/cf)=       0.046500
    COMPOSITE UNIT WT OF INACTIVE LAYER  (t/cf)=       0.046500
    DEPTH OF SURFACE LAYER (ft)             DSL=            0.1
    WEIGHT IN SURFACE LAYER (tons)         WTSL=         1305.5
    DEPTH OF NEW ACTIVE LAYER (ft)          DSE=         0.0373
    WEIGHT IN NEW ACTIVE LAYER(tons)     WTMXAL=          584.9
    WEIGHT IN OLD ACTIVE LAYER(tons)        WAL=         8927.8
    USEABLE WEIGHT, OLD INACTIVE LAYER      WIL=       144962.8
    SURFACE AREA OF DEPOSIT (sq ft)        SABK= 0.33690125E+06

** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                       VF SAND    0.010000       1.000000       VF GRVL     0.044734       93.180849
                       F  SAND    0.070000       8.000000       F  GRVL     0.033457       96.526593
                       M  SAND    0.327074      40.707446       M  GRVL     0.010638       97.590423
                       C  SAND    0.366543      77.361700       C  GRVL     0.021915       99.781912
                       VC SAND    0.113457      88.707445       VC GRVL     0.002181       99.999998

** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION   PERCENT FINER               BED FRACTION   PERCENT FINER
                       VF SAND    0.018953       1.895284       VF GRVL     0.059193       91.152666
                       F  SAND    0.045024       6.397700       F  GRVL     0.043652       95.517835
```

```
                                M  SAND     0.290415      35.439182       M  GRVL      0.013558       96.873609
                                C  SAND     0.375493      72.988468       C  GRVL      0.028407       99.714290
                                VC SAND     0.122449      85.233411       VC GRVL      0.002857      100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.162000E+07
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.767631E+04  VF GRVL 0.540007E+02
                                 F  SAND 0.222208E+04  F  GRVL 0.856678E+02
                                 M  SAND 0.120096E+04  M  GRVL 0.924255E+02
                                 C  SAND 0.879011E+03  C  GRVL 0.343755E+01
                                 VC SAND 0.885363E+03  VC GRVL 0.100000E-06

BED MATERIAL PER GRAIN SIZE:    BED FRACTION  PERCENT FINER                BED FRACTION  PERCENT FINER
                                VF SAND     0.011944       1.194380       VF GRVL      0.064549       90.362954
                                F  SAND     0.037695       4.963900       F  GRVL      0.047476       95.110553
                                M  SAND     0.276179      32.581777       M  GRVL      0.014690       96.579579
                                C  SAND     0.387609      71.342665       C  GRVL      0.031077       99.687310
                                VC SAND     0.125654      83.908024       VC GRVL      0.003127      100.000000

  SEDIMENT OUTFLOW FROM SECTION NO.     15.000
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE      LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....        115.42   |  VERY FINE GRAVEL..         3.19
    FINE SAND.........        101.72   |  FINE GRAVEL.......         3.74
    MEDIUM SAND.......        348.91   |  MEDIUM GRAVEL.....         1.25
    COARSE SAND.......        332.83   |  COARSE GRAVEL.....         0.10
    VERY COARSE SAND..        108.39   |  VERY COARSE GRAVEL         0.00

**************************************************************************************************
                  TRACE OUTPUT FOR SECTION NO.      1.000
           ---------------------------------------------------

HYDRAULIC PARAMETERS:
      VEL       SLO          EFD        EFW      N-VALUE     TAU      USTARM     FROUDE NO.
    4.011  0.000004        5.838     83.730      0.0176   0.00159   0.02864      0.293

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):     TOTAL          K-PORTION        S-PORTION
                            209373.61       209373.61           0.00


TRANSMISSIVE BOUNDARY CONDITION = TYPE     2
BED MATERIAL PER GRAIN SIZE:    BED FRACTION  PERCENT FINER                BED FRACTION  PERCENT FINER
                                VF SAND     0.010000       1.000000       VF GRVL      0.060000       90.999998
                                F  SAND     0.070000       8.000000       F  GRVL      0.040000       94.999998
                                M  SAND     0.290000      36.999999       M  GRVL      0.015000       96.499998
                                C  SAND     0.360000      72.999998       C  GRVL      0.035000       99.999998
                                VC SAND     0.120000      84.999998       VC GRVL      0.000000       99.999998

  SEDIMENT OUTFLOW FROM SECTION NO.      1.000
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE      LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....        115.42   |  VERY FINE GRAVEL..         3.19
    FINE SAND.........        101.72   |  FINE GRAVEL.......         3.74
    MEDIUM SAND.......        348.91   |  MEDIUM GRAVEL.....         1.25
    COARSE SAND.......        332.83   |  COARSE GRAVEL.....         0.10
    VERY COARSE SAND..        108.39   |  VERY COARSE GRAVEL         0.00


TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 4.  SOME SEDIMENT OPTIONS.
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
***************************************************************
    TIME       ENTRY *               SAND               *
    DAYS       POINT *     INFLOW   OUTFLOW   TRAP EFF  *
   54.00      58.000 *      13.30                       *
              53.000 *      16.15                       *
              42.000 *       0.36                       *
  TOTAL=      35.000 *      29.81      2.05      0.93   *
***************************************************************
    TIME       ENTRY *               SAND               *
    DAYS       POINT *     INFLOW   OUTFLOW   TRAP EFF  *
   54.00      35.000 *       2.05                       *
  TOTAL=      33.000 *       2.05      1.22      0.40   *
***************************************************************
    TIME       ENTRY *               SAND               *
    DAYS       POINT *     INFLOW   OUTFLOW   TRAP EFF  *
   54.00      33.000 *       1.22                       *
              15.000 *       1.00                       *
  TOTAL=       1.000 *       2.22      4.07     -0.83   *
***************************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  1
-------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE      LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....         38.08   |  VERY FINE GRAVEL..         0.00
    FINE SAND.........         34.16   |  FINE GRAVEL.......         0.00
    MEDIUM SAND.......         21.06   |  MEDIUM GRAVEL.....         0.00
    COARSE SAND.......          2.35   |  COARSE GRAVEL.....         0.00
    VERY COARSE SAND..          0.61   |  VERY COARSE GRAVEL         0.00
                        ------------                          ------------
                                              TOTAL =               96.26
```

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	115.42	VERY FINE GRAVEL..	3.19
FINE SAND.........	101.72	FINE GRAVEL.......	3.74
MEDIUM SAND.......	348.91	MEDIUM GRAVEL.....	1.25
COARSE SAND.......	332.83	COARSE GRAVEL.....	0.10
VERY COARSE SAND..	108.39	VERY COARSE GRAVEL	0.00
		TOTAL =	1015.54

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 54.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-2.93	976.06	972.47	532.	195.
55.000	-1.23	975.95	971.67	532.	193.
53.000	-1.54	974.32	970.66	660.	156.
44.000	0.01	974.07	968.04	660.	7.
42.000	0.00	974.02	970.00	689.	0.
35.000	*0.00*	974.00	963.30	689.	0.
33.900	0.22	964.63	962.87	689.	2576.
33.300	0.03	963.41	962.52	689.	2295.
33.000	*0.00*	963.00	961.00	689.	2295.
32.100	-0.31	961.87	956.19	689.	85.
32.000	-0.07	961.21	956.43	689.	241.
15.000	-0.23	957.71	953.47	750.	1016.
1.000	*0.00*	957.00	944.70	750.	1016.

Accumulated Water Discharge from day zero (sfd)
MAIN
3500.00

$VOL A

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. SOME SEDIMENT OPTIONS.

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT THROUGH SECTION (tons) TOTAL	SAND	SILT	CLAY	SEDIMENT DEPOSITED IN REACH in cu. yds TOTAL	CUMULATIVE	SAND	SILT	CLAY
INFLOW	26932.	26932.	0.	0.	21451.				
58.000	34630.	34630.	0.	0.	-6132.	-6132.	-6132.	0.	0.
55.000	47052.	47052.	0.	0.	-9894.	-16025.	-9894.	0.	0.
LOCAL	32721.	32721.	0.	0.	26062.				
53.000	104248.	104248.	0.	0.	-19495.	-35520.	-19495.	0.	0.
44.000	73173.	73173.	0.	0.	24751.	-10769.	24751.	0.	0.
LOCAL	733.	733.	0.	0.	583.				
42.000	4159.	4159.	0.	0.	55553.	44784.	55553.	0.	0.
35.000	4159.	4159.	0.	0.	0.	44784.	0.	0.	0.
33.900	2940.	2940.	0.	0.	971.	45755.	971.	0.	0.
33.300	2475.	2475.	0.	0.	370.	46125.	370.	0.	0.
33.000	2475.	2475.	0.	0.	0.	46125.	0.	0.	0.
32.100	5577.	5577.	0.	0.	-2471.	43655.	-2471.	0.	0.
32.000	7299.	7299.	0.	0.	-1371.	42283.	-1371.	0.	0.
LOCAL	2027.	2027.	0.	0.	1615.				
15.000	8242.	8242.	0.	0.	863.	43147.	863.	0.	0.
1.000	8242.	8242.	0.	0.	0.	43147.	0.	0.	0.

TOTAL SEDIMENT - per grain size - THROUGH EACH CROSS SECTION (tons)

UPSTREAM INFLOW

VF SAND	13463.	VC SAND	122.	C GRVL	0.
F SAND	8809.	VF GRVL	0.	VC GRVL	0.
M SAND	4222.	F GRVL	0.		0.
C SAND	316.				

LOCAL INFLOW

VF SAND	2765.	VC SAND	0.	C GRVL	0.
F SAND	6123.	VF GRVL	0.	VC GRVL	0.
M SAND	17758.	F GRVL	0.		0.
C SAND	6075.				

LOCAL INFLOW

VF SAND	346.	VC SAND	11.	C GRVL	0.
F SAND	214.	VF GRVL	4.	VC GRVL	0.
M SAND	122.	F GRVL	2.		0.
C SAND	34.				

LOCAL INFLOW

VF SAND	367.	VC SAND	55.	C GRVL	0.
F SAND	732.	VF GRVL	24.	VC GRVL	0.

```
      M  SAND      709.   F  GRVL       10.                   0.
      C  SAND      129.

 SECTION NO.     15.000
      VF SAND      320.   VC SAND      851.   C  GRVL         3.
      F  SAND     1079.   VF GRVL       13.   VC GRVL         0.
      M  SAND     3214.   F  GRVL       14.                   0.
      C  SAND     2742.
 SECTION NO.      1.000
      VF SAND      320.   VC SAND      851.   C  GRVL         3.
      F  SAND     1079.   VF GRVL       13.   VC GRVL         0.
      M  SAND     3214.   F  GRVL       14.                   0.
      C  SAND     2742.

-----------------------------------------------------------------------------------
$$END

      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =         4
TOTAL NO. OF WS PROFILES =            23
ITERATIONS IN EXNER EQ =            1150

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES & 9.00 SECONDS
```

6.5 Example Problem 5 - Reservoirs

HEC-6 simulates reservoirs by allowing the water surface elevation at the reservoir location to be a function of time, as defined by input data. The hydraulic computations are still steady state; therefore, there is no routing of the water (i.e outflow equals inflow at all times).

6.5.1 Reservoir Data

Example Problem 5 input is shown in Table 6-5a and illustrates the data for a problem with two reservoirs; one at the downstream boundary (Section No. 1.0) and one at Silver Lake - which begins at Section No. 35.0 and extends upstream to Section No. 53.0 (much farther upstream than is illustrated in Figure 6-1). Section No. 33.3 is at the approximate upstream extent of the pool for the downstream reservoir and Section No. 53.0 is at the upstream end of Silver Lake. The operation of the downstream reservoir is simulated by the time history of pool elevations entered in field 1 of the **R** records in the flow data. Similarly, the **X5** record at Section No. 35.0 that defines the downstream boundary of the Silver Lake reservoir indicates that the time history of pool elevations will be in Field 2 of the **R** record. The **X5** record at Section No. 53.1 marks the upstream limit of Silver Lake. The two **X5** records divide the model into 3 subreaches; the first, which represents the downstream reservoir, is bounded by Sections 1.0 and 33.9, the second subreach, Silver Lake, is bounded by Sections 35.0 and 53.0, and the third, the contributing upstream reach, is bounded by Sections 53.1 and 58.0. Thus the information produced for each subreach can be used to analyze the behavior of the two reservoirs and the contributing upstream reach.

Table 6-5a
Example Problem 5 - Input
Reservoir Model

```
T1        EXAMPLE PROBLEM NO 5.  RESERVOIRS.
T2        2 RESERVOIRS, 3 LOCAL INFLOWS.
T3        SOUTH FORK, ZUMBRO RIVER     ** Example Problem 5 **
NC    .1      .1     .04      .1      .3
X1   1.0      31  10077.  10275.      0.      0.      0.
GR 1004.   9915.   978.4  10002.   956.0  10060.   959.2  10077.   959.3  10081.
GR 950.0  10092.  948.48  10108.   946.6  10138.   944.7  10158.   955.2  10225.
GR 956.2  10243.   958.9  10250.   959.8  10275.   959.8  10300.   959.9  10325.
GR 958.8  10350.   957.4  10400.   970.0  10700.   966.0  10960.   970.0  11060.
GR 968.0  11085.   968.0  11240.   970.0  11365.   970.0  11500.   970.0  11615.
GR 962.0  11665.   962.0  12400.   976.0  12550.   980.0  12670.   982.0  12730.
GR 984.0  12735.
HD   1.0     10.  10081.  10250.
NV    22    .045   965.6    .064   988.8
NV    12     .08   965.6     .13   988.8
NV    33      .1   965.6     .11   982.0     .12   988.8
X1  15.0      27  10665.  10850.   3560.   3030.   3280.
X3                        10700.   961.0  11000.   970.0
GR 992.0   9570.   982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7  10665.   956.0  10673.   953.0   10693   954.0  10703.   955.6  10723.
GR 958.6  10750.   959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0  10852.   964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0  11190.   972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0  11865.  1000.0  12150.
HD  15.0     10.  10673.  10852.
  CASCADE CREEK - LOCAL INFLOW
QT
NC    .1      .1     .05
X1  32.0      29  10057.  10271.   3630.   3060.   4240.
GR 998.0   9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5  10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.   992.0  11240.  1000.0  11330.   1008.  11425.
```

```
HD  32.0     10.  10075.  10275.
X1  33.0      21   1850.   2150.    3130.    3250.    3320.
XL                  250.
GR 1000.     980.   990.0   1060.   980.0    1150.   982.0   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0    1350.   980.0   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41    1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5    2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.0      0.   1851.   2149.
   NOTE:       Section 33.3 is a duplicate of Section  33.0.
X1  33.3      21  1850.0  2150.0   1550.    1750.    1750.     .95    1.49
XL                  250.
GR 1000.     980.   990.0   1060.   980.0    1150.   982.0   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0    1350.   980.0   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41    1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5    2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.3      0.   1851.   2149.                              .95    1.65
  Section 33.9 is a duplicate of Sec 33.3, needed to model IBC at Sec 35.0
X1  33.9      21  1850.0  2150.0   1050.    1050.    1050.
X3    10
GR 1000.     980.   990.0   1060.   980.0    1150.   982.0   1180.   982.0   1215.
GR 980.0    1260.   982.0   1300.   982.0    1350.   980.0   1420.   980.0   1540.
GR 982.0    1730.   982.0   1830.  984.41    1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2    976.0   2149.   984.5    2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.
HD  33.9      0.   1851.   2149.
X1  35.0      22   9894.  10245.       0        0        0
X3    10
X5                             2
GR 984.0   9035.    980.0   9070.   978.0    9135.   980.0   9185.   982.0   9270.
GR 980.0   9465.    981.7   9595.   983.7    9745.   984.7   9894.   963.4  9894.1
GR 963.3   9954.    967.1   9974.   967.4   10004.   968.2  10044.   967.6  10054.
GR 973.4  10115.    977.4  10120.   983.7   10155.   984.0  10245.   982.0  10695.
GR 982.0  10895.   1004.0  11085.
HD  35.0      0.   9954.  10155.
  - - -  SILVER LAKE  - - -
NC   .06     .06    .045
X1  42.0      32   9880.  10130.   5370.    5000.    5210.
GR 996.0   7130.    998.0   7310.   998.0    7930.   992.0   8205.   990.0   8495.
GR 988.0   8780.    986.0   8990.   985.7    9570.   986.4   9707.   989.4   9857.
GR 990.0   9880.    969.8   9881.   969.8    9941.   985.8   9941.   985.8   9943.
GR 969.8   9943.    969.8  10001.   986.7   10001.   986.7  10003.   969.8  10003.
GR 969.8  10067.    985.8  10067.   985.8   10069.   969.8  10069.   969.8  10129.
GR 989.9  10130.    989.5  10180.   988.6   10230.   987.6  10280.   985.2  10430.
GR 986.8  11720.    989.9  12310.
HD  42.0      0.   9881.  10021.
  SILVER CREEK - LOCAL INFLOW
QT
X1  44.0      28   9845.  10127.   3200.    3800.    3500.
XL                         9850.0 10200.0
GR 1002.   8035.    992.0   8150.   990.0    8305.   990.0   8735.   988.0   8835.
GR 996.0   9285.   1017.6   9425.   990.0    9505.   986.0   9650.   984.1   9788.
GR 980.6   9845.    970.9   9868.   972.2    9898.   970.5   9968.   967.5   9998.
GR 968.9  10028.    967.4  10058.   967.1   10078.   971.9  10118.   976.8  10127.
GR 977.8  10150.    976.9  10193.   982.0   10206.   981.2  10300.   979.2  10325.
GR 983.1  10400.    999.8  10450.  1002.4   10464.
HD  44.0     10.   9868.  10193.
X1  53.0      22  10000.  10136.   3366.    2832.    2942.
GR 1004.   7550.   1000.0   7760.   998.0    8440.   996.0   8640.   996.0   8780.
GR 994.0   8940.    986.0   9245.   986.3    9555.   986.3   9825.   983.8   9900.
GR 982.8  10000.    978.2  10011.   974.0   10041.   972.2  10071.   972.6  10101.
GR 978.2  10121.    988.7  10136.   989.3   10154.   999.2  10200.   1000.  10320.
GR 1002.  10470.   1004.0  10700.
HD  53.0     10.  10000.  10136.
  Section 53.1 is a REPEAT of Sec 53.0, needed to model an IBC at THIS location.
  NOTE: no water surface is defined at this IBC, i.e. No Hydraulic Cntrl Strctr
X1  53.1       0  10000.  10136.       0        0        0
X5
HD  53.1     10.  10000.  10136.
  BEAR CREEK - LOCAL INFLOW
QT
X1  55.0      18   9931.  10062.   2275.    3430.    2770.
GR 1004.   7592.   1000.0   7947.   996.0    8627.   990.0   9052.   986.0   9337.
GR 984.3   9737.    984.7   9837.   985.5    9910.   987.2   9931.   978.1   9955.
GR 974.8   9975.    974.2  10005.   972.9   10035.   973.2  10045.   983.8  10062.
GR 985.8  10187.    986.0  10307.   990.0   10497.
HD  55.0     10.   9931.  10062.
X1  58.0      22   9912.  10015.   1098.    1012.    1462.
GR 1006.   8542.   1004.0   8952.  1000.0    9702.   997.2   9812.   996.3   9912.
GR 976.2   9944.    975.4   9974.   978.2    9991.   990.4  10015.   988.3  10062.
GR 988.8  10065.    988.3  10065.   989.3   10169.   990.0  10172.   992.0  10242.
GR 992.0  10492.    988.0  10642.   986.7   10852.   988.0  11022.   986.0  11097.
GR 986.0  11137.    988.0  11192.
```

```
HD   58.0      3.4    9912.   10015.
EJ
T4        South Fork, Zumbro River - Stream Segment 1      ** Example Problem 5 **
T5        LOAD CURVE FROM GAGE DATA.
T6        BED GRADATIONS FROM FIELD SAMPLES.
T7        Use full range of Sands and Gravels
T8        SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]
I1               5
I4   SAND        4        1       10
I5              .5       .5      .25       .5      .25        0      1.0
LQ               1       50     1000     5800    90000
LT TOTAL     .0110      1.5      320    4500.   400000
LF    VFS     .119     .119     .498     .511     .582
LF     FS     .328     .328     .331     .306     .280
LF     MS     .553     .553     .156     .154     .110
LF     CS     .000     .000     .011     .016     .020
LF    VCS     .000     .000     .004     .008     .005
LF    VFG     .000     .000     .000     .004     .002
LF     FG     .000     .000     .000     .001     .001
LF     MG     .000     .000     .000     .000     .000
LF     CG     .000     .000     .000     .000     .000
LF    VCG       .0       .0     .000     .000     .000
PF EXAMP       1.0      1.0     32.0     16.0     96.5      8.0     95.0      4.0     91.0
PFC  2.0      85.0      1.0     73.0       .5     37.0      .25      8.0     .125      1.0
PFC.0625       0.0
PF EXAMP      32.0      1.0     64.0     32.0     99.5     16.0     99.0      8.0     98.5
PFC  4.0      96.0      2.0     93.5      1.0     83.0      .50     45.5     .250      8.0
PFC .125       1.0    .0625      0.0
PF EXAMP      58.0      1.0     64.0     32.0     97.0     16.0     94.0      8.0     94.0
PFC  4.0      90.0      2.0     79.0      1.0     56.0      .50      4.0     .125      0.0
$LOCAL
  LOAD TABLE - CASCADE CREEK - A LOCAL INFLOW
LQL              1      100     1000    10000
LTLTOTAL     .0040       10      500    30000
LFL   VFS     .664     .664     .015     .198
LFL    FS     .207     .207     .245     .181
LFL    MS     .086     .086     .605     .107
LFL    CS     .031     .031     .052     .098
LFL   VCS     .008     .008     .039     .127
LFL   VFG    .0030    .0030    .0200    .1160
LFL    FG    .0010    .0010    .0110    .0910
LFL    MG    .0000    .0000    .0110    .0530
LFL    CG    .0000    .0000    .0000    .0220
LFL   VCG    .0000    .0000    .0000    .0060
  LOAD TABLE - SILVER CREEK - A LOCAL INFLOW
LQL              1      100     1000    10000
LTLTOTAL     .0040       10      500    30000
LFL   VFS     .664     .664     .015     .198
LFL    FS     .207     .207     .245     .181
LFL    MS     .086     .086     .605     .107
LFL    CS     .031     .031     .052     .098
LFL   VCS     .008     .008     .039     .127
LFL   VFG    .0030    .0030    .0200    .1160
LFL    FG    .0010    .0010    .0110    .0910
LFL    MG    .0000    .0000    .0110    .0530
LFL    CG    .0000    .0000    .0000    .0220
LFL   VCG    .0000    .0000    .0000    .0060
  LOAD TABLE - BEAR CREEK - A LOCAL INFLOW
LQL             1.     100.     500.    1000.   30000.
LTLTOTAL     .0020     30.0     500.     1200    22500
LFL   VFS     .201     .201     .078     .078     .137
LFL    FS     .342     .342     .172     .175     .218
LFL    MS     .451     .451     .454     .601     .476
LFL    CS     .001     .001     .197     .142     .158
LFL   VCS     .000     .000     .000     .003     .008
LFL   VFG    .0000    .0000    .0000    .0000    .0020
LFL    FG    .0000     .000    .0000    .0000    .0010
LFL    MG    .0000     .000    .0000    .0000    .0000
LFL    CG    .0000     .000    .0000    .0000    .0000
LFL   VCG    .0000     .000    .0000    .0000    .0000
$HYD
$PRT
CP               1
PS             1.0     35.0     53.1
END
$VOL  X          0
VJ   16
VR  944        946      948      950      952      954      956      958      960      962
VR  964        966      968      970      972      974
$PRT  A
*    A      FLOW 1 = BASE FLOW OF 750 CFS
Q   750         61       29      128
R  960.      973.5
```

```
T     65      72       70       67
W    10.
*     A       FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0     300.     150.     650.
R    965.     975
X             2.5      50.
*     A       FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.     150.      78.     340.
R   963.     974.5
W     1.
*     B       FLOW 4 = BASE FLOW OF 750 CFS
Q   750.      61       29       128
R   960.     973
W     1.
$PRT
CP             1
PS            1.0      35.0     53.1
END
$VOL  X
VJ    16       0
VR   944      946      948      950      952      954      956      958      960      962
VR   964      966      968      970      972      974
$$END
```

6.5.2 Elevation-Surface Area and Elevation-Storage Tables

Tables of elevation *vs.* surface area and storage can be obtained by use of the **$VOL**, **VJ**, and **VR** records in the flow data. In this example, these records were used to request that these tables be produced for a series of horizontal planes extending from elevation 944 ft (the approximate thalweg of Section No. 1.0) to elevation 974 ft (the approximate thalweg of section No. 53.0) in 2 ft increments. Care should be taken to ensure that the endpoints of each cross section are higher than these elevations; otherwise, HEC-6 will extend the ends of the sections vertically and the surface areas and volumes will be too small.

The output for Example Problem 5 is shown in Table 6-5b. Prior to time step 1 and after time step 4, tables containing the surface areas and storage volumes for Sections 1.0, 35.0, and 53.1 at each elevation specified on the **VR** records. (The **$PRT** option was used to limit the **$VOL** output to these cross sections.) For example, at Section No. 35.0, the initial storage volume at elevation 968 ft is 859.78 acre-ft; and after the last time step, the storage volume is 855.45 acre-ft. This indicates that approximately 4.3 acre-ft of sediment was deposited between Sections 35.0 and 58.0 below elevation 968 ft, reducing the storage capability of Silver Lake. One only needs to use information in the table for elevations above the thalweg of the cross section at the dam of interest. These tables can be used to construct elevation-deposition and deposition-distance relations.

6.5.3 Trap Efficiency

The computation of trap efficiency and the interpretation of "TABLE SA-1" were presented in Section 6.3.8 for Example Problem 3. In this example, the **X5** records were used to delineate the upstream and downstream extent of the reservoirs causing trap efficiency to be computed for each. For example, looking at TABLE SA-1 of time step 4 for the middle reach which represents Silver Lake, 42.71 acre-ft has entered the reservoir from the upstream reach, 0.37 acre-ft from Silver Creek and 3.55 acre-ft have passed through Silver Lake, giving it a trap efficiency of 91% for this simulation. The downstream reservoir has a trap efficiency of 99%. Negative trap efficiencies indicate scour.

Table 6-5b
Example Problem 5 - Output
Reservoir Model

```
*****************************************************       **************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS    *       *  U.S. ARMY CORPS OF ENGINEERS      *
*       Version: 4.1.00 -  AUGUST 1993              *       *  HYDROLOGIC ENGINEERING CENTER     *
*  INPUT FILE:   EXAMPLE5.DAT                       *       *  609 SECOND STREET                 *
*  OUTPUT FILE: EXAMPLE5.OUT                        *       *  DAVIS, CALIFORNIA 95616-4687      *
*  RUN DATE: 31 AUG 93     RUN TIME: 15:53:06       *       *  (916) 756-1104                    *
*****************************************************       **************************************

                         X     X XXXXXXX  XXXXX       XXXXX
                         X     X X       X     X     X     X
                         X     X X       X           X
                         XXXXXXX XXXX    X     XXXXX XXXXXX
                         X     X X       X           X     X
                         X     X X       X     X     X     X
                         X     X XXXXXXX  XXXXX       XXXXX

          ***************************************************************
          *  MAXIMUM LIMITS FOR THIS VERSION ARE:                       *
          *       10  Stream Segments (Main Stem + Tributaries)         *
          *      150  Cross Sections                                    *
          *      100  Elevation/Station Points per Cross Section        *
          *       20  Grain Sizes                                       *
          *       10  Control Points                                    *
          ***************************************************************

T1       EXAMPLE PROBLEM NO 5.  RESERVOIRS.
T2       2 RESERVOIRS, 3 LOCAL INFLOWS.
T3       SOUTH FORK, ZUMBRO RIVER       ** Example Problem 5 **

N values...  Left    Channel   Right    Contraction    Expansion
           0.1000    0.0400   0.1000       1.1000       0.7000

SECTION NO.     1.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

N-Values vs. Elevation Table
     Channel               Left Overbank          Right Overbank
  0.0450      966.        0.0800     966.        0.1000     966.
  0.0640      989.        0.1300     989.        0.1100     982.
  0.0000        0.        0.0000       0.        0.1200     989.

SECTION NO.    15.000
...Left Encroachment defined at station 10700.000 at elevation    961.000
...Right Encroachment defined at station 11000.000 at elevation    970.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

LOCAL INFLOW POINT  1 occurs upstream from Section No.       15.000

N values...  Left    Channel   Right    Contraction    Expansion
           0.1000    0.0500   0.1000       1.1000       0.7000

SECTION NO.    32.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    33.000
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.300
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.490 ft.
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.900
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station         1850.000        2150.000
              Ineffective Elevation          984.410         984.500
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    35.000
...Internal Boundary Condition
   Water Surface Elevation will be read from R-RECORD, Field  2
   Head Loss =     0.000
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station         9894.000       10245.000
              Ineffective Elevation          984.700         984.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N values...  Left    Channel   Right    Contraction    Expansion
           0.0600    0.0450   0.0600       1.1000       0.7000

SECTION NO.    42.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.
```

```
LOCAL INFLOW POINT  2 occurs upstream from Section No.      42.000

SECTION NO.    44.000
...Limit CONVEYANCE between stations    9850.000 and   10200.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    53.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    53.100
...Internal Boundary Condition
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

LOCAL INFLOW POINT  3 occurs upstream from Section No.      53.100

SECTION NO.    55.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    58.000
...DEPTH of the Bed Sediment Control Volume =     3.40 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 13
NO. OF INPUT DATA MESSAGES =   0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  13
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA
```

The output produced during processing of the sediment data does not differ from that produced for Example Problem 3. It has therefore, been omitted from this table. Refer to Table 6-3b.

```
$HYD
BEGIN COMPUTATIONS.
-----------------------------------------------------------------------------------------
$PRT
...Selective Printout Option
     - Print at the following cross sections
CP            1
PS           1.0     35.0     53.1
END
-----------------------------------------------------------------------------------------
$VOL  X

STREAM SEGMENT #  1: EXAMPLE PROBLEM NO 5.  RESERVOIRS.
```

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT THROUGH SECTION (tons) TOTAL	SAND	SILT	CLAY	SEDIMENT DEPOSITED IN REACH in cu. yds TOTAL	CUMULATIVE	SAND	SILT	CLAY
INFLOW	0.	0.	0.	0.	0.				
58.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
55.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
53.100	0.	0.	0.	0.	0.	0.	0.	0.	0.
53.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
44.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
42.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
35.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
33.900	0.	0.	0.	0.	0.	0.	0.	0.	0.
33.300	0.	0.	0.	0.	0.	0.	0.	0.	0.
33.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
32.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.000	0.	0.	0.	0.	0.	0.	0.	0.	0.

	ELEV	*SURFACE AREA*	*VOLUME AC-FT*	*VOLUME CY*
SECTION NO.	1.000			
	974.00	0.00	0.00	0.00
SECTION NO.	35.000			
	944.00	0.00	0.00	0.00
	946.00	0.83	0.54	867.78
	948.00	2.39	3.67	5915.09
	950.00	3.76	9.89	15949.33
	952.00	4.33	17.97	28994.35
	954.00	5.16	27.24	43939.75
	956.00	8.11	40.39	65164.13

```
               958.00        17.48        64.33   103778.95
               960.00        36.80       116.56   188053.68
               962.00        83.01       210.59   339749.19
               964.00       102.86       399.48   644489.52
               966.00       114.88       616.41   994482.30
               968.00       133.90       859.78  1387110.86
               970.00       174.82      1146.51  1849704.72
               972.00       188.44      1509.87  2435927.43
               974.00       195.16      1893.47  3054796.73

SECTION NO.     53.100
               944.00         0.00         0.00        0.00
               946.00         0.83         0.54      867.78
               948.00         2.39         3.67     5915.09
               950.00         3.76         9.89    15949.33
               952.00         4.33        17.97    28994.35
               954.00         5.16        27.24    43939.75
               956.00         8.11        40.39    65164.13
               958.00        17.48        64.33   103778.95
               960.00        36.80       116.56   188053.68
               962.00        83.01       210.59   339749.19
               964.00       106.66       401.88   648370.52
               966.00       119.32       627.06  1011649.74
               968.00       147.00       883.72  1425731.27
               970.00       219.64      1211.25  1954147.00
               972.00       242.73      1671.97  2697446.67
               974.00       254.16      2170.41  3501589.08
```

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

$PRT   A
...Selective Printout Option
   A - Print at all cross sections

================================================================================
TIME STEP #        1
*     A      FLOW 1 = BASE FLOW OF 750 CFS

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 5.   RESERVOIRS.
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   10.00       58.000 *     0.46                            *
               53.100 *     0.21                            *
   TOTAL=      53.100 *     0.67       5.24       -6.78 *
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   10.00       53.100 *     5.24                            *
               42.000 *     0.01                            *
   TOTAL=      35.000 *     5.25       0.00        1.00 *
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   10.00       35.000 *     0.00                            *
               15.000 *     0.02                            *
   TOTAL=       1.000 *     0.02       0.00        0.98 *
**************************************************************

================================================================================
TIME STEP #        2
*    A      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
COMPUTING FROM TIME=     10.0000 DAYS TO TIME=      60.0000 DAYS IN     20 COMPUTATION STEPS

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 5.   RESERVOIRS.
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   60.00       58.000 *    13.54                            *
               53.100 *    16.20                            *
   TOTAL=      53.100 *    29.74      40.95       -0.38 *
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   60.00       53.100 *    40.95                            *
               42.000 *     0.36                            *
   TOTAL=      35.000 *    41.31       3.55        0.91 *
**************************************************************
    TIME        ENTRY *              SAND                   *
    DAYS        POINT *    INFLOW    OUTFLOW   TRAP EFF *
   60.00       35.000 *     3.55                            *
               15.000 *     1.01                            *
   TOTAL=       1.000 *     4.56       0.06        0.99 *
**************************************************************
```

TIME STEP # 3
* A FLOW 3 = NEAR BANK FULL DISCHARGE

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 5. RESERVOIRS.
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
61.00	58.000	13.62		
	53.100	16.30		
TOTAL=	53.100	29.92	41.19	-0.38

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
61.00	53.100	41.19		
	42.000	0.37		
TOTAL=	35.000	41.56	3.55	0.91

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
61.00	35.000	3.55		
	15.000	1.02		
TOTAL=	1.000	4.57	0.06	0.99

TIME STEP # 4
* B FLOW 4 = BASE FLOW OF 750 CFS

EXAMPLE PROBLEM NO 5. RESERVOIRS.
ACCUMULATED TIME (yrs).... 0.170
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	532.00	93.30	63.44

Upstream of SECTION NO. 53.100 is...

LOCAL INFLOW POINT # 3	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	532.00	93.30	63.44
LOCAL INFLOW	128.00	43.20	67.00
TOTAL	660.00	136.50	64.13

Upstream of SECTION NO. 42.000 is...

LOCAL INFLOW POINT # 2	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	660.00	136.50	64.13
LOCAL INFLOW	29.00	1.22	70.00
TOTAL	689.00	137.72	64.38

Upstream of SECTION NO. 15.000 is...

LOCAL INFLOW POINT # 1	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	689.00	137.72	64.38
LOCAL INFLOW	61.00	4.32	72.00
TOTAL	750.00	142.04	65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 5. RESERVOIRS.
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
62.00	58.000	13.66		
	53.100	16.32		
TOTAL=	53.100	29.99	41.34	-0.38

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
62.00	53.100	41.34		
	42.000	0.37		
TOTAL=	35.000	41.71	3.55	0.91

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
62.00	35.000	3.55		
	15.000	1.02		
TOTAL=	1.000	4.57	0.06	0.99

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	38.08	VERY FINE GRAVEL..	0.00
FINE SAND.........	34.16	FINE GRAVEL.......	0.00
MEDIUM SAND.......	21.06	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	93.30

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	0.06	VERY FINE GRAVEL..	0.00
FINE SAND.........	0.05	FINE GRAVEL.......	0.00
MEDIUM SAND.......	0.11	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.08	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.02	VERY COARSE GRAVEL	0.00
		TOTAL =	0.32

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 62.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-2.12	978.00	973.28	532.	196.
55.000	-0.97	977.02	971.93	532.	237.
53.100	-1.18	975.27	971.02	660.	303.
53.000	-2.09	975.27	970.11	660.	243.
44.000	1.98	974.14	969.08	660.	85.
42.000	0.68	973.32	970.48	689.	17.
35.000	0.23	973.00	963.53	689.	1.
33.900	0.00	965.13	961.00	689.	1.
33.300	0.00	964.81	962.49	689.	7.
33.000	0.00	963.72	961.00	689.	11.
32.000	-0.55	962.68	955.95	689.	159.
15.000	0.25	960.18	953.95	750.	175.
1.000	0.93	960.00	945.63	750.	0.

```
$PRT
...Selective Printout Option
    - Print at the following cross sections
CP          1
PS          1.0     35.0     53.1
END
```

$VOL X

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 5. RESERVOIRS.

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT THROUGH SECTION (tons) TOTAL	SAND	SILT	CLAY	SEDIMENT DEPOSITED IN REACH in cu. yds TOTAL	CUMULATIVE	SAND	SILT	CLAY
INFLOW	27675.	27675.	0.	0.	22043.				
58.000	33913.	33913.	0.	0.	-4968.	-4968.	-4968.	0.	0.
55.000	43560.	43560.	0.	0.	-7684.	-12652.	-7684.	0.	0.
LOCAL	33067.	33067.	0.	0.	26338.				
53.100	83742.	83742.	0.	0.	-5667.	-18319.	-5667.	0.	0.
53.000	104383.	104383.	0.	0.	-16441.	-34760.	-16441.	0.	0.
44.000	38587.	38587.	0.	0.	52407.	17646.	52407.	0.	0.
LOCAL	742.	742.	0.	0.	591.				
42.000	12452.	12452.	0.	0.	21408.	39054.	21408.	0.	0.
35.000	7197.	7197.	0.	0.	4185.	43240.	4185.	0.	0.
33.900	7193.	7193.	0.	0.	3.	43243.	3.	0.	0.
33.300	7192.	7192.	0.	0.	0.	43243.	0.	0.	0.
33.000	7186.	7186.	0.	0.	5.	43248.	5.	0.	0.
32.000	25290.	25290.	0.	0.	-14420.	28828.	-14420.	0.	0.
LOCAL	2062.	2062.	0.	0.	1642.				
15.000	16144.	16144.	0.	0.	8927.	37755.	8927.	0.	0.
1.000	119.	119.	0.	0.	12764.	50519.	12764.	0.	0.

	ELEV	*SURFACE AREA*	*VOLUME AC-FT*	*VOLUME CY*
SECTION NO.	1.000			
	974.00	0.00	0.00	0.00
SECTION NO.	35.000			
	944.00	0.00	0.00	0.00
	946.00	0.23	0.04	68.42
	948.00	1.60	1.80	2907.75

```
                 950.00        3.16         6.65     10729.40
                 952.00        4.06        14.05     22667.32
                 954.00        4.67        22.74     36692.89
                 956.00        7.60        34.72     56007.76
                 958.00       17.55        59.75     96392.34
                 960.00       36.89       112.36    181277.81
                 962.00       83.15       206.06    332439.56
                 964.00      103.07       394.36    636234.41
                 966.00      115.08       611.72    986900.29
                 968.00      134.04       855.45   1380128.58
                 970.00      174.87      1142.37   1843028.68
                 972.00      188.44      1505.77   2429301.12
                 974.00      195.16      1889.36   3048170.38

SECTION NO.        53.100
                 944.00        0.00         0.00         0.00
                 946.00        0.23         0.04        68.42
                 948.00        1.60         1.80      2907.75
                 950.00        3.16         6.65     10729.40
                 952.00        4.06        14.05     22667.32
                 954.00        4.67        22.74     36692.89
                 956.00        7.60        34.72     56007.76
                 958.00       17.55        59.75     96392.34
                 960.00       36.89       112.36    181277.81
                 962.00       83.15       206.06    332439.56
                 964.00      106.80       396.31    639386.72
                 966.00      119.44       621.76   1003106.83
                 968.00      142.01       875.94   1413188.12
                 970.00      197.85      1186.47   1914179.58
                 972.00      236.59      1632.71   2634112.44
                 974.00      253.24      2120.94   3421777.07

------------------------------------------------------------------------------------------
$$END

       0    DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =          4
TOTAL NO. OF WS PROFILES =             23
ITERATIONS IN EXNER EQ =             1495

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  6.00 SECONDS
```

6.6 Example Problem 6 - River Network System

This example problem adds tributaries to the existing problem. Tributaries are described with cross section and sediment data; therefore, sediment transport and bed movement is calculated for the tributaries as well as for the main stem. See Chapter 3, Section 3.6 for a detailed description of data preparation for network systems. It is suggested that the data for each segment of the system be tested and corrected separately so that any subsequent errors are due to the construction of the network system data and not due to errors in any individual segments. A schematic of the system is shown in Figure 6-5. Silver Creek is treated as a local inflow, all other segments are tributaries.

6.6.1 Network Layout and Numbering

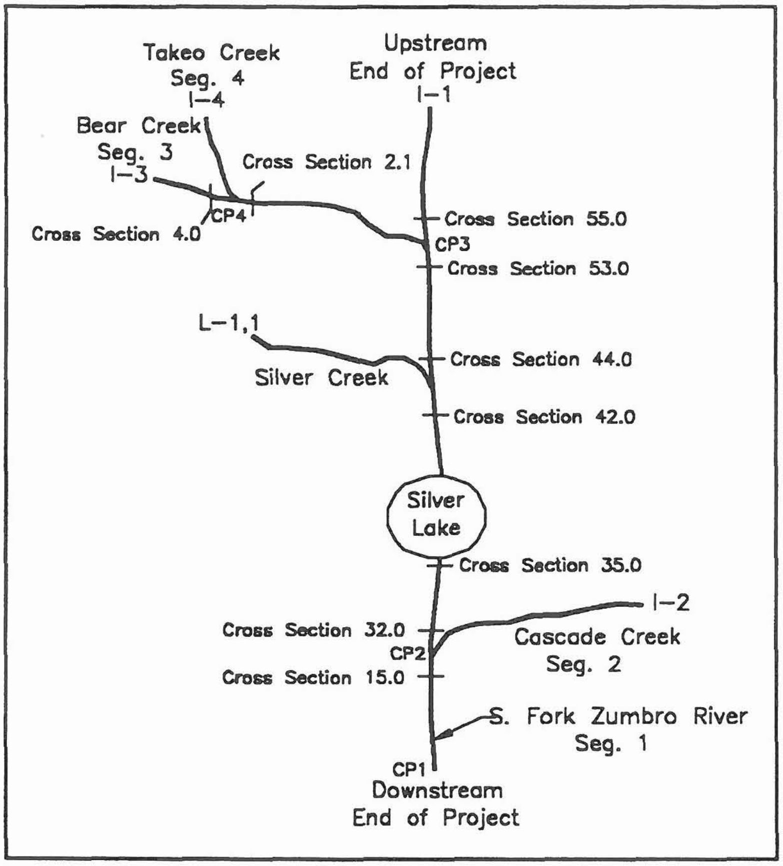

Figure 6-5
Schematic of a Network System

The numbering of stream segments and control points must follow the scheme presented in Section 3.6. This is shown for Example Problem 6 in Figure 6-5. The stream segments, control points (**CP**), and inflows are numbered from downstream to upstream. The control points are numbered first, then each tributary is given a segment number that corresponds to the control point at its confluence with another segment or the main stem. The inflow points of each segment are then numbered corresponding to the segment number, e.g. the inflow to Bear Creek is designated I-3. Silver Creek is the only local inflow, so it is designated L-1,1, with the first number being the segment into which it flows and the second being which local it is on that segment.

6.6.2 Geometric Data Structure

The input data file for Example Problem 6 is shown in Table 6-6a. The data for the main river segment is first, with **QT** records indicating locations of the tributaries (see Section 3.6.2); an **EJ** record marks the end of the geometry data for each stream segment. The number in Field 1 of the **QT** record is the control point associated with the entering tributary; thus, the first **QT** record encountered is for Cascade Creek which enters the main stem at control point 2 (upstream of Section No. 15.0). A second **QT** record is located after Section No. 42.0; since this is a local inflow, there is no control point number on the **QT** record. A third **QT** record, entered after Section No. 53.0, marks the entrance of Bear Creek at control point 3. The geometry data for each tributary is then entered in sequence by segment number. Therefore, the second set of cross section data is for Cascade Creek, the third is Bear Creek, and the fourth is Takeo Creek. Note the use of the **QT** record within the Bear Creek geometry data to locate the confluence of Takeo Creek at control point 4.

6.6.3 Sediment Data Structure

The sediment data are entered in a sequence similar to the geometric data. Note, however, that the sediment load tables for local inflows on a given segment follow the sediment data for that segment. In other words, first the sediment data for the main river segment is entered, then the load tables for any local inflows on that segment; thereafter the sediment data for each tributary follows in sequence of segment number. The sediment data for each tributary begins with a **$TRIB** record.

6.6.4 Flow Data Structure

The flows and temperatures for local and tributary flows must be entered in the proper sequence on the Q and T records. The flows entering this system for the last (fourth) time step are shown on Figure 6-6. The first flow on the Q record is that leaving the downstream boundary of the main stem (500 cfs), the next is the local inflow (Silver Creek) to the main stem (29 cfs). Since there are no more local inflows on the main stem, Field 3 contains the flow (61 cfs) for segment 2, Cascade Creek. Bear Creek flow (128 cfs) is in Field 4 and Takeo Creek flow (90 cfs) in Field 5. Note, this sequence is the same as the order in which the sediment load tables were defined.

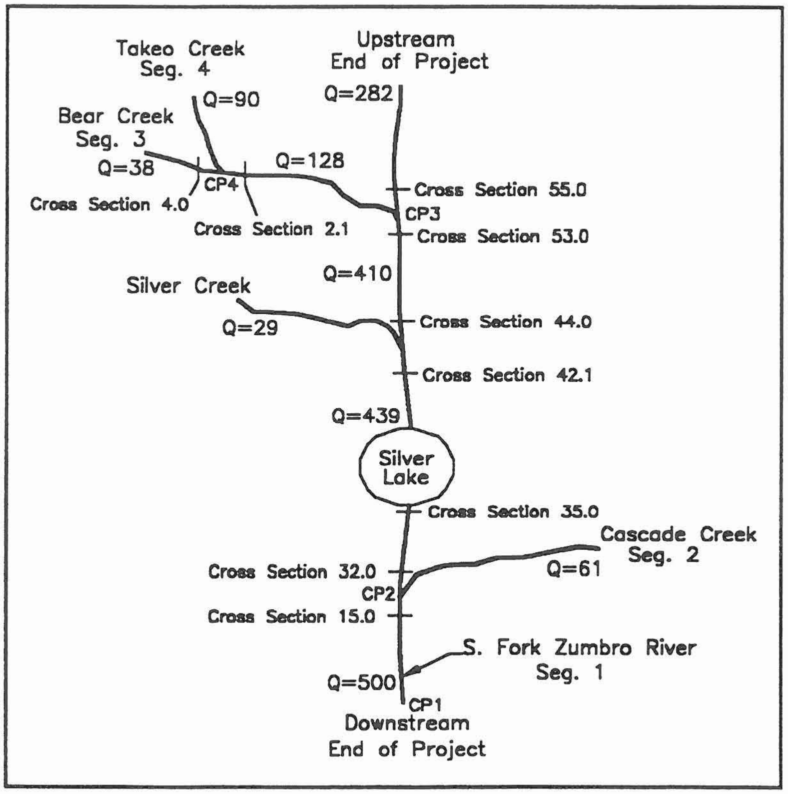

Figure 6-6
Flows of a Network System

Table 6-6a
Example Problem 6 - Input
Network System

```
T1      EXAMPLE PROBLEM NO 6.  South Fork, ZUMBRO RIVER - Stream Segment 1
T2      CASCADE & BEAR: TRIBS OF ZUMBRO;  TAKEO: TRIB OF BEAR;  SILVER: LOCAL
T3      ZUMBRO RIVER PROJECT - Dendritic System    ** Example Problem 6 **
NC  .100     .100     .040       .1       .3
X1   1.0       31   10077.   10275.       0.        0.        0.
GR 1004.    9915.    978.4   10002.    956.0    10060.    959.2   10077.    959.3   10081.
GR 950.0   10092.   948.48   10108.    946.6    10138.    944.7   10158.    955.2   10225.
GR 956.2   10243.    958.9   10250.    959.8    10275.    959.8   10300.    959.9   10325.
GR 958.8   10350.    957.4   10400.    970.0    10700.    966.0   10960.    970.0   11060.
GR 968.0   11085.    968.0   11240.    970.0    11365.    970.0   11500.    970.0   11615.
```

```
GR 962.0  11665.   962.0  12400.   976.0  12550.   980.0  12670.   982.0  12730.
GR 984.0  12735.
HD   1.0     10.  10081.  10250.
NV    12     .08   965.6     .13   988.8
NV    22    .045   965.6    .064   988.8
NV    33      .1   965.6     .11   982.0     .12   988.8
X1  15.0      27  10665.  10850.   3560.   3030.   3280.
X3                        10700.   961.0  11000.   970.0
GR 992.0   9570.   982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7  10665.   956.0  10673.   953.0  10693.   954.0  10703.   955.6  10723.
GR 958.6  10750.   959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0  10852.   964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0  11190.   972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0  11865.  1000.0  12150.
HD  15.0     10.  10673.  10852.
  CASCADE CREEK - TRIBUTARY
QT     2
NC   .10     .10     .05
X1  32.0      29  10057.  10271.   3630.   3060.   4240.
GR 998.0   9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5  10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.   992.0  11240.  1000.0  11330.   1008.  11425.
HD  32.0     10.  10075.  10275.
X1  33.0      21   1850.   2150.   3130.   3250.   3320.
XL                   250
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.     0.0      0.     0.0      0.     0.0      0.     0.0      0.
HD  33.0     0.0   1851.   2149.
  Section 33.3 is a duplicate of Section  33.0.
X1  33.3      21   1850.   2150.   1550.   1750.   1750.     .95    1.49
XL                   250
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.     0.0      0.     0.0      0.     0.0      0.     0.0      0.
HD  33.3     0.0   1851.   2149.
  Section 33.9 is a duplicate of Sec 33.3, needed to model IBC at Sec 35.0
X1  33.9      21   1850.   2150.   1050.   1050.   1050.     .95    1.65
X3    10
GR 1000.    980.   990.0   1060.   980.0   1150.   982.0   1180.   982.0   1215.
GR 980.0   1260.   982.0   1300.   982.0   1350.   980.0   1420.   980.0   1540.
GR 982.0   1730.   982.0   1830.  984.41   1850.  979.19   1851.   961.0  1900.8
GR 961.0  2099.2   976.0   2149.   984.5   2150.   982.0   2800.   990.0   3100.
GR 1000.   3170.     0.0      0.     0.0      0.     0.0      0.     0.0      0.
HD  33.9     0.0   1851.   2149.
X1  35.0      22   9894.  10245.       0       0       0
X3    10
X5                             2
GR 984.0   9035.   980.0   9070.   978.0   9135.   980.0   9185.   982.0   9270.
GR 980.0   9465.   981.7   9595.   983.7   9745.   984.7   9894.   963.4  9894.1
GR 963.3   9954.   967.1   9974.   967.4  10004.   968.2  10044.   967.6  10054.
GR 973.4  10115.   977.4  10120.   983.7  10155.   984.0  10245.   982.0  10695.
GR 982.0  10895.  1004.0  11085.
HD  35.0       0   9954.  10155.
  - - -  SILVER LAKE  - - -
NC   .06     .06    .045
X1  42.0      32   9880.  10130.   5370.   5000.   5210.
GR 996.0   7130.   998.0   7310.   998.0   7930.   992.0   8205.   990.0   8495.
GR 988.0   8780.   986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0   9880.   969.8   9881.   969.8   9941.   985.8   9941.   985.8   9943.
GR 969.8   9943.   969.8  10001.   986.7  10001.   986.7  10003.   969.8  10003.
GR 969.8  10067.   985.8  10067.   985.8  10069.   969.8  10069.   969.8  10129.
GR 989.9  10130.   989.5  10180.   988.6  10230.   987.6  10280.   985.2  10430.
GR 986.8   11720   989.9  12310.
HD  42.0       0   9881.  10021.
  SILVER CREEK - LOCAL INFLOW
QT
X1  44.0      28   9845.  10127.   3200.   3800.   3500.
XL                          9850   10200
GR 1002.   8035.   992.0   8150.   990.0   8305.   990.0   8735.   988.0   8835.
GR 996.0   9285.   1017.   9425.   990.0   9505.   986.0   9650.   984.1   9788.
GR 980.6   9845.   970.9   9868.   972.2   9898.   970.5   9968.   967.5   9998.
GR 968.9  10028.   967.4  10058.   967.1  10078.   971.9  10118.   976.8  10127.
GR 977.8  10150.   976.9  10193.   982.0  10206.   981.2  10300.   979.2  10325.
GR 983.1  10400.   999.8  10450.  1002.4  10464.
HD  44.0     10.   9868.  10193.
X1  53.0      22  10000.  10136.   3366.   2832.   2942.
```

```
GR 1004.    7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0    8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8   10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2   10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.   10470.  1004.0  10700.
HD  53.0      10.  10000.  10136.
  BEAR CREEK - TRIBUTARY
QT      3
X1  55.0       18   9931.  10062.   2275.   3430.   2770.
GR 1004.    7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3    9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8    9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8   10187.   986.0  10307.   990.0  10497.
HD  55.0      10.   9931.  10062.
X1  58.0       22   9912.  10015.   1098.   1012.   1462.
GR 1006.    8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2    9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8   10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0   10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0   11137.   988.0  11192.
HD  58.0      3.4   9912.  10015.
EJ
$TRIB                CASCADE GEOMETRY, SEGMENT 2, CONTROL POINT 2
CP      2
T1        EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
T2        CASCADE IS A TRIBUTARY OF THE ZUMBRO RIVER DOWNSTREAM OF SILVER LAKE
T3        CASCADE CREEK GEOMETRY - STREAM SEGMENT 2      ** Example Problem 6 **
NC  .120     .120    .045      .1      .3
X1   1.0       25   5000.   5100.      0.      0.      0.
GR 995.0    4570.   980.0   4600.   970.0   4690.   968.0   4740.   968.0   4850.
GR965.24    4900.   964.6   4950.   964.0   4975.   963.7   5000.   961.5   5003.
GR 959.8    5014.   960.2   5025.   959.9   5038.   960.1   5068.   960.4   5073.
GR 962.5    5075.   963.1   5083.   968.9   5094.   969.6   5100.   970.3   5150.
GR 970.0    5260.   972.0   5280.   972.0   5400.   980.0   5460.    982.   5780.
H    1.0            4925.   5121.
X1   3.0       24   4942.   5050.    460.    280.    537.
GR 1000.    4715.   983.9   4897.   982.9   4942.   973.2   4959.   973.0   4967.
GR 970.2    5000.  964.78   5007.   964.3   5017.   965.1   5027.  965.17   5027.
GR 968.7    5042.   969.9   5050.   969.4   5067.   971.1   5092.   970.3   5103.
GR 972.7    5180.     970   5207.   972.8   5217.   971.1   5242.   970.7   5267.
GR 975.2    5277.  976.56   5300.   980.0   5360.   982.0   5690.
H    3.0    964.3   4942.   5103.
X1   4.0       18   4950.   5045.    300.    280.    240.
GR 1000.    4775.   991.3   4875.   988.1   4931.   981.6   4941.   981.7   4950.
GR 975.4    4961.   972.9   4975.   970.6   5004.   968.3   5015.   969.2   5025.
GR 969.4    5040.   981.2   5045.   981.2   5075.   985.7   5082.   985.9   5100.
GR 980.0    5270.   982.0   5330.   982.0   5700.
H    4.0    968.3   4950.   5047.
X1   6.2       17   5000.   5130.    405.    350.    474.
X3    10
GR 994.0    4700.   990.0   4720.   986.0   4750.   986.0   4940.   987.4   5000.
GR 983.1    5000.   979.0   5016.   972.0   5032.   972.0   5092.   974.0   5100.
GR 976.0    5109.   982.7   5126.   987.5   5130.   986.0   5210.   980.0   5420.
GR 980.0    5830.   982.0   5900.
H    6.2    972.0   5000.   5130.
EJ
$TRIB              BEAR CREEK GEOMETRY,   SEGMENT 3 CONTROL POINT 3
CP      3
T1        EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
T2        BEAR IS A TRIBUTARY OF THE ZUMBRO RIVER UPSTREAM OF SILVER CREEK
T3        BEAR CREEK GEOMETRY - STREAM SEGMENT 3      ** Example Problem 6 **
NC  .090     .090    .046      .3      .5
X1   1.0       19  10115.  10250.      0.      0.      0.
GR 996.0    9020.   990.0   9420.   988.0   9550.   994.0   9780.   985.3  10055.
GR 985.0   10115.  978.18  10137.   977.2  10147.   977.0  10157.   977.1  10200.
GR 978.2   10209.   981.6  10216.   982.8  10225.   984.7  10250.   985.9  10275.
GR 987.1   10300.   988.0  10380.   990.0  10560.  1000.0  10890.
H    1.0           10115.  10275.
X1   2.1       21   1511.   1629.    210.    310.    260.
GR 995.2     600.   992.0    790.   990.0    970.   990.0    971.   990.0    972.
GR 989.0    1000.   988.0   1080.   988.0   1290.   990.0   1450.   990.8   1490.
GR 989.8    1493.   986.7   1511.   977.3   1516.   977.3   1629.   986.7   1629.
GR 990.7    1650.   988.0   1840.   992.0   2000.   994.0   2100.   998.0   2450.
GR 1002.    2580.
H    2.1            1511.   1629.
  TAKEO CREEK - TRIBUTARY
QT      4
X1   4.0       30  10537.  10660.   1053.    533.    708.
GR 998.0    8370.   997.0   8860.   998.3   9100.   994.5   9350.   996.0   9480.
GR 999.0    9560.   996.0   9640.   994.0   9900.   992.0   9980.   993.9  10400.
GR 994.0   10425.   995.2  10506.   993.1  10523.   986.3  10537.   986.0  10550.
GR 985.8   10561.   980.9  10570.   978.7  10585.   978.3  10595.   978.4  10600.
GR 980.5   10625.   980.8  10636.  991.77  10657.   992.3  10660.   991.3  10675.
GR 991.4   10700.   998.0  10970.   998.0  11120.  1000.0  11290.  1006.0  11400.
```

```
H    4.0   978.3  10537.  10660.
X1   6.0      29  10100.  10222.     330.     570.     665.
X3    10
GR 998.0   8500.   997.1   8650.  1000.0    8900.  1002.0    9110.  1001.0    9400.
GR 999.8   9525.  1002.0   9610.  1002.0    9730.  1000.0    9840.  995.16  10000.
GR 995.6  10100.   994.2  10109.   990.8   10125.   987.3   10140.   985.8   10150.
GR 986.2  10161.  985.24  10162.   983.3   10172.   983.3   10182.   982.8   10202.
GR985.24  10210.   992.0  10222.   992.2   10250.   993.5   10300.   994.2   10325.
GR 1000.  10470.   997.8  10640.   998.0   10770.  1004.6   10910.
H    6.0   982.7 10100.0 10325.0
EJ
$TRIB              TAKEO CREEK GEOMETRY, SEGMENT 4, CONTROL POINT 4
CP       4
T1       EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
T2       TAKEO CREEK IS A TRIBUTARY OF BEAR CREEK UPSTREAM OF SECTION 2.1
T3       TAKEO CREEK GEOMETRY - STREAM SEGMENT 4      ** Example Problem 6 **
NC  .090    .090    .046      .3      .5
X1   1.0      19  10115.  10250.      0.       0.      0.               2.
GR 996.0   9020.   990.0   9420.   988.0    9550.   994.0    9780.   985.3   10055.
GR 985.0  10115.  978.18  10137.   977.2   10147.   977.0   10157.   977.1   10200.
GR 978.2  10209.   981.6  10216.   982.8   10225.   984.7   10250.   985.9   10275.
GR 987.1  10300.   988.0  10380.   990.0   10560.  1000.0   10890.
H    1.0          10115.  10275.
X1   2.1      21   1511.   1629.    210.     310.    260.               2.
GR 995.2    600.   992.0    790.   990.0     970.   990.0     971.   990.0     972.
GR 989.0   1000.   988.0   1080.   988.0    1290.   990.0    1450.   990.8    1490.
GR 989.8   1493.   986.7   1511.   977.3    1516.   977.3    1629.   986.7    1629.
GR 990.7   1650.   988.0   1840.   992.0    2000.   994.0    2100.   998.0    2450.
GR1002.0   2580.
H    2.1          1511.0  1629.0
X1   4.0      30  10537.  10660.   1053.     533.    708.               2.
GR 998.0   8370.   997.0   8860.   998.3    9100.   994.5    9350.   996.0    9480.
GR 999.0   9560.   996.0   9640.   994.0    9900.   992.0    9980.   993.9   10400.
GR 994.0  10425.   995.2  10506.   993.1   10523.   986.3   10537.   986.0   10550.
GR 985.8  10561.    980.  10570.   978.7   10585.   978.3   10595.   978.4   10600.
GR 980.5  10625.   980.8  10636.  991.77   10657.   992.3   10660.   991.3   10675.
GR 991.4  10700.   998.0  10970.   998.0   11120.  1000.0   11290.  1006.0 11400.0
H    4.0   978.3  10537.  10660.
X1   6.0      29  10100.  10222.    330.     570.    665.               2.
X3    10
GR 998.0   8500.   997.1   8650.  1000.0    8900.  1002.0    9110.  1001.0    9400.
GR 999.8   9525.  1002.0   9610.  1002.0    9730.  1000.0    9840.  995.16  10000.
GR 995.6  10100.   994.2  10109.   990.8   10125.   987.3   10140.   985.8   10150.
GR 986.2  10161.  985.24  10162.   983.3   10172.   983.3   10182.   982.8   10202.
GR985.24  10210.   992.0  10222.   992.2   10250.   993.5   10300.   994.2   10325.
GR 1000.  10470.   997.8  10640.   998.0   10770.  1004.6   10910.
H    6.0   982.7  10100.  10325.
EJ
T4       South Fork, Zumbro River - Stream Segment 1       ** Example Problem 6 **
T5       LOAD CURVE FROM GAGE DATA.
T6       BED GRADATIONS FROM FIELD SAMPLES.
T7       Use full range of sands and gravels
T8       SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]
I1     0       5
I4  SAND       4       1      10
I5            .5      .5     .25      .5     .25        0     1.0
LQ             1      50    1000    5800   90000
LT TOTAL   .0110     1.5     320   4500.  400000
LF   VFS    .119    .119    .498    .511    .582
LF    FS    .328    .328    .331    .306    .280
LF    MS    .553    .553    .156    .154    .110
LF    CS    .000    .000    .011    .016    .020
LF   VCS    .000    .000    .004    .008    .005
LF   VFG    .000    .000    .000    .004    .002
LF    FG    .000    .000    .000    .001    .001
LF    MG    .000    .000    .000    .000    .000
LF    CG    .000    .000    .000    .000    .000
LF   VCG      .0      .0    .000    .000    .000
PF EXAMP     1.0     1.0    32.0    16.0    96.5      8.0    95.0     4.0    91.0
PFC  2.0    85.0     1.0    73.0      .5    37.0      .25     8.0    .125     1.0
PFC.0625     0.0
PF EXAMP    32.0     1.0    64.0    32.0    99.5     16.0    99.0     8.0    98.5
PFC  4.0    96.0     2.0    93.5     1.0    83.0      .50    45.5    .250     8.0
PFC .125     1.0   .0625     0.0
PF EXAMP    58.0     1.0    64.0    32.0    97.0     16.0    94.0     8.0    94.0
PFC  4.0    90.0     2.0    79.0     1.0    56.0      .50     4.0    .125     0.0
$LOCAL
LQ             1     100    1000   10000
LT TOTAL   .0040      10     500   30000
LF   VFS    .664    .664    .015    .198
LF    FS    .207    .207    .245    .181
LF    MS    .086    .086    .605    .107
LF    CS    .031    .031    .052    .098
```

```
LF   VCS    .008     .008     .039     .127
LF   VFG   .0030    .0030    .0200    .1160
LF    FG   .0010    .0010    .0110    .0910
LF    MG   .0000    .0000    .0110    .0530
LF    CG   .0000    .0000    .0000    .0220
LF   VCG   .0000    .0000    .0000    .0060
$TRIB
T4        CASCADE CREEK - STREAM SEGMENT 2        ** Example Problem 6 **
T5        FIRST TRIB ON Zumbro River.
T6        LOAD CURVE FROM GAGE DATA.  BED GRADATIONS FROM FIELD SAMPLES.
T7        Use full range of sands and gravels - Yang's Stream Power.
T8        Zumbro River Project
LQL            1      100     1000    10000
LTLTOTAL   .0040       10      500    30000
LFL  VFS    .664     .664     .015     .198
LFL   FS    .207     .207     .245     .181
LFL   MS    .086     .086     .605     .107
LFL   CS    .031     .031     .052     .098
LFL  VCS    .008     .008     .039     .127
LFL  VFG   .0030    .0030    .0200    .1160
LFL   FG   .0010    .0010    .0110    .0910
LFL   MG   .0000    .0000    .0110    .0530
LFL   CG   .0000    .0000    .0000    .0220
LFL  VCG   .0000    .0000    .0000    .0060
PF  CASC     1.0      1.0      64.      32.      94.      16.      85.       8.      70.
PFC   4.     50.       2.      32.       1.      18.       .5       9.      .25      5.
PFC .125     2.5    .0625       0.
$TRIB
T4        BEAR CREEK - Stream Segment 3       ** Example Problem 6 **
T5        SECOND UPSTREAM TRIB ON Zumbro River.
T6        LOAD CURVE FROM GAGE DATA.  BED GRADATIONS FROM FIELD SAMPLES
T7        Use full range of sands and gravels.  Yang's Stream Power.
T8        Zumbro River Project
LQL            1      100      500     1000    30000
LTLTOTAL   .0020     30.0     500.     1200    22500
LFL  VFS    .201     .201     .078     .078     .137
LFL   FS    .342     .342     .172     .175     .218
LFL   MS    .451     .451     .454     .601     .476
LFL   CS    .001     .001     .197     .142     .158
LFL  VCS    .000     .000     .000     .003     .008
LFL  VFG   .0000    .0000    .0000    .0000    .0020
LFL   FG   .0000     .000    .0000    .0000    .0010
LFL   MG   .0000     .000    .0000    .0000    .0000
LFL   CG   .0000     .000    .0000    .0000    .0000
LFL  VCG   .0000     .000    .0000    .0000    .0000
PF  BEAR      1.       1.       4.       2.     99.5       1.      99.       .5      93.
PFC  .25      27     .125       3.    .0625       0.
PF  BEAR      6.       1.       4.       2.     99.5       1.      99.       .5    89.5
PFC  .25    22.5     .125      2.5    .0625       0.
$TRIB
T4        TAKEO CREEK - Stream Segment 4        ** Example Problem 6 **
T5        FIRST TRIBUTARY ON Bear Creek.
T6        LOAD CURVE IS FROM GAGE DATA. BED GRADATIONS FROM FIELD SAMPLES.
T7        Use full range of sands and gravels.  Yang's Stream Power.
T8        Zumbro River Project
LQL            1      100      500     1000    30000
LTLTOTAL   .0020     30.0     500.     1200    22500
LFL  VFS    .201     .201     .078     .078     .137
LFL   FS    .342     .342     .172     .175     .218
LFL   MS    .451     .451     .454     .601     .476
LFL   CS    .001     .001     .197     .142     .158
LFL  VCS    .000     .000     .000     .003     .008
LFL  VFG   .0000    .0000    .0000    .0000    .0020
LFL   FG   .0000     .000    .0000    .0000    .0010
LFL   MG   .0000     .000    .0000    .0000    .0000
LFL   CG   .0000     .000    .0000    .0000    .0000
LFL  VCG   .0000     .000    .0000    .0000    .0000
PF TAKEO      1.       1.       4.       2.     99.5       1.      99.       .5      93.
PFC  .25     27.     .125       3.    .0625       0.
PF TAKEO      6.       1.       4.       2.     99.5       1.      99.       .5    89.5
PFC  .25    22.5     .125      2.5    .0625       0.
$HYD
*   AB      FLOW 1 = BASE FLOW OF 750 CFS
Q    750      29       61      128       90
R   956.    970.
T     65      70       72       67       73
W      2
$PRT
  Zumbro River, Sections 35.1 and 55.0
CP             1
PS  35.1    55.0
```

```
  Takeo Creek, Section 6.0
CP                4
PS   6.0
END
*    AC       FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0        150     300     650     450
R    965.     978.
X                 5      50
*    A        FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.         78     150    340.     250
R    960.     975.
W      1.
*    B        FLOW 4 = BASE FLOW OF 500 CFS
Q    500         29      61     128      90
R    955.     973.
W       2
$$END
```

6.6.5 Network Output

The output produced for a network system is very similar to that of a single stream problem. The output for Example Problem 6 is shown in Table 6-6b. The geometric data is output (as entered) in increasing segment order. Sediment data are then given for the main stem, the local inflow (Silver Creek), and the tributaries. The user is advised to take advantage of the title (and comment) records to annotate the output file. The information from the **T1** records is used throughout the output so they should contain the name of each stream segment.

The A-level hydrologic data are output in the sequence in which the backwater computation is performed. Segment 1 is calculated first, from downstream to upstream and the water surface elevation at each control point is printed. When segment 1 is complete, the backwater computations start at the downstream boundary of segment 2 using the water surface computed at control point 2 as the starting water surface. This process continues though the remainder of the tributaries in order.

The temperature in each stream segment changes as differing water temperatures enter from the tributaries and local inflows. For example, in time step 1, the inflow from Cascade Creek is 61 cfs at 72°F and the flow in the main stem below that confluence is 750 cfs at 65°F. Therefore, the flow in the main stem above the confluence is 689 cfs at 64.38°F ($689 \cdot 64.38 + 61 \cdot 72 = 750 \cdot 65$).

In previous examples it was noted that the sedimentation computations proceed from upstream to downstream, in reverse order from the hydraulic computations. In this example network system, this means that the sedimentation computations begin at the upstream boundary of segment 4, work downstream to the confluence with segment 3, then proceed to the upstream boundary of segment 3 and so on. Sediment output contains the same information previously discussed; identified primarily by cross section and segment.

Output can be limited to specified cross sections on any stream segment. As seen in the previous example problems, this is done via the **$PRT**, **CP**, and **PN** records. The output level is governed by the output options on the * record. For example, prior to time step 2, the **$PRT** option was used to limit output to Sections 35.1 and 55.0 on the main river segment and Section No. 6.0 on segment 4, Takeo Creek; A-level hydraulic and C-level sediment output was requested for time step 2 on the * record.

Table 6-6b
Example Problem 6 - Output
Network System

```
*****************************************************     **************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS   *     *  U.S. ARMY CORPS OF ENGINEERS      *
*       Version: 4.1.00 -   AUGUST 1993            *     *  HYDROLOGIC ENGINEERING CENTER     *
*  INPUT FILE:  example6.DAT                       *     *  609 SECOND STREET                 *
*  OUTPUT FILE: example6.OUT                       *     *  DAVIS, CALIFORNIA 95616-4687      *
*  RUN DATE: 31 AUG 93     RUN TIME: 18:54:00      *     *  (916) 756-1104                    *
*****************************************************     **************************************

                    X     X  XXXXXXX   XXXXX          XXXXX
                    X     X  X        X     X        X     X
                    X     X  X        X              X
                    XXXXXXX  XXXX     X       XXXXX  XXXXXX
                    X     X  X        X              X     X
                    X     X  X        X     X        X     X
                    X     X  XXXXXXX   XXXXX          XXXXX

          *******************************************************************
          *  MAXIMUM LIMITS FOR THIS VERSION ARE:                           *
          *       10  Stream Segments (Main Stem + Tributaries)             *
          *      150  Cross Sections                                        *
          *      100  Elevation/Station Points per Cross Section            *
          *       20  Grain Sizes                                           *
          *       10  Control Points                                        *
          *******************************************************************

T1      EXAMPLE PROBLEM NO 6.  South Fork, ZUMBRO RIVER - Stream Segment 1
T2      CASCADE & BEAR: TRIBS OF ZUMBRO;  TAKEO: TRIB OF BEAR;  SILVER: LOCAL
T3      ZUMBRO RIVER PROJECT - Dendritic System      ** Example Problem 6 **

N values...  Left    Channel   Right    Contraction    Expansion
           0.1000    0.0400   0.1000       1.1000        0.7000

SECTION NO.      1.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

N-Values vs. Elevation Table
   Left Overbank            Channel               Right Overbank
  0.0800      966.      0.0450      966.       0.1000      966.
  0.1300      989.      0.0640      989.       0.1100      982.
  0.0000        0.      0.0000        0.       0.1200      989.

SECTION NO.    15.000
...Left Encroachment defined at station 10700.000 at elevation    961.000
...Right Encroachment defined at station 11000.000 at elevation    970.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

TRIBUTARY ENTRY POINT  1 occurs upstream from Section No.     15.000  at Control Point #  2

N values...  Left    Channel   Right    Contraction    Expansion
           0.1000    0.0500   0.1000       1.1000        0.7000

SECTION NO.    32.000
...DEPTH of the Bed Sediment Control Volume =    10.00 ft.

SECTION NO.    33.000
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.300
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.490 ft.
...Limit CONVEYANCE to  250.000 ft. centered about midpoint of channel.
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    33.900
...Adjust Section WIDTH to  95.00% of original.
...Adjust Section ELEVATIONS by     1.650 ft.
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
            Natural Levees at Station        1757.500        2042.500
                 Ineffective Elevation        986.060         986.150
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

SECTION NO.    35.000
...Internal Boundary Condition
   Water Surface Elevation will be read from R-RECORD, Field  2
   Head Loss =     0.000
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
            Natural Levees at Station        9894.000       10245.000
                 Ineffective Elevation        984.700         984.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.

N values...  Left    Channel   Right    Contraction    Expansion
           0.0600    0.0450   0.0600       1.1000        0.7000

SECTION NO.    42.000
...DEPTH of the Bed Sediment Control Volume =     0.00 ft.
```

```
LOCAL INFLOW POINT  1 occurs upstream from Section No.      42.000

SECTION NO.    44.000
...Limit CONVEYANCE between stations     9850.000 and    10200.000
...DEPTH of the Bed Sediment Control Volume =     10.00 ft.

SECTION NO.    53.000
...DEPTH of the Bed Sediment Control Volume =     10.00 ft.

TRIBUTARY ENTRY POINT  2 occurs upstream from Section No.      53.000   at Control Point #  3

SECTION NO.    55.000
...DEPTH of the Bed Sediment Control Volume =     10.00 ft.

SECTION NO.    58.000
...DEPTH of the Bed Sediment Control Volume =      3.40 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 12
NO. OF INPUT DATA MESSAGES =    0
--------------------------------------------------------------------------------------------

T1      EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
T2      CASCADE IS A TRIBUTARY OF THE ZUMBRO RIVER DOWNSTREAM OF SILVER LAKE
T3      CASCADE CREEK GEOMETRY - STREAM SEGMENT 2       ** Example Problem 6 **

N values...  Left    Channel   Right    Contraction    Expansion
           0.1200    0.0450   0.1200       1.1000       0.7000

SECTION NO.     1.000
...ELEVATION of Model Bottom =     949.800 ft.

SECTION NO.     3.000
...ELEVATION of Model Bottom =     964.300 ft.

SECTION NO.     4.000
...ELEVATION of Model Bottom =     968.300 ft.

SECTION NO.     6.200
...Ineffective Flow Area - Method 1 - Left Overbank   Right Overbank
          Natural Levees at Station        5000.000         5130.000
              Ineffective Elevation         987.400          987.500
...ELEVATION of Model Bottom =     972.000 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=   4
NO. OF INPUT DATA MESSAGES =    0
--------------------------------------------------------------------------------------------

T1      EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
T2      BEAR IS A TRIBUTARY OF THE ZUMBRO RIVER UPSTREAM OF SILVER CREEK
T3      BEAR CREEK GEOMETRY - STREAM SEGMENT 3       ** Example Problem 6 **

N values...  Left    Channel   Right    Contraction    Expansion
           0.0900    0.0460   0.0900       1.3000       0.5000

SECTION NO.     1.000
...ELEVATION of Model Bottom =     967.000 ft.

SECTION NO.     2.100
...ELEVATION of Model Bottom =     967.300 ft.

TRIBUTARY ENTRY POINT  1 occurs upstream from Section No.       2.100   at Control Point #  4

SECTION NO.     4.000
...ELEVATION of Model Bottom =     978.300 ft.

SECTION NO.     6.000
...Ineffective Flow Area - Method 1 - Left Overbank   Right Overbank
          Natural Levees at Station      10100.000        10222.000
              Ineffective Elevation        995.600          992.000
...ELEVATION of Model Bottom =     982.700 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=   4
NO. OF INPUT DATA MESSAGES =    0
--------------------------------------------------------------------------------------------

T1      EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
T2      TAKEO CREEK IS A TRIBUTARY OF BEAR CREEK UPSTREAM OF SECTION 2.1
T3      TAKEO CREEK GEOMETRY - STREAM SEGMENT 4       ** Example Problem 6 **

N values...  Left    Channel   Right    Contraction    Expansion
           0.0900    0.0460   0.0900       1.3000       0.5000

SECTION NO.     1.000
...Adjust Section ELEVATIONS by      2.000 ft.
...ELEVATION of Model Bottom =     969.000 ft.

SECTION NO.     2.100
...Adjust Section ELEVATIONS by      2.000 ft.
...ELEVATION of Model Bottom =     969.300 ft.

SECTION NO.     4.000
```

```
...Adjust Section ELEVATIONS by    2.000 ft.
...ELEVATION of Model Bottom =   980.300 ft.

SECTION NO.     6.000
...Adjust Section ELEVATIONS by    2.000 ft.
...Ineffective Flow Area - Method 1 - Left Overbank  Right Overbank
          Natural Levees at Station      10100.000      10222.000
              Ineffective Elevation        997.600        994.000
...ELEVATION of Model Bottom =   984.700 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  4
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  24
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   4
END OF GEOMETRIC DATA
```

```
T4      South Fork, Zumbro River - Stream Segment 1      ** Example Problem 6 **
T5      LOAD CURVE FROM GAGE DATA.
T6      BED GRADATIONS FROM FIELD SAMPLES.
T7      Use full range of sands and gravels
T8      SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]

        EXAMPLE PROBLEM NO 6.  South Fork, ZUMBRO RIVER - Stream Segment 1
        CASCADE & BEAR: TRIBS OF ZUMBRO;  TAKEO: TRIB OF BEAR;  SILVER: LOCAL
        ZUMBRO RIVER PROJECT - Dendritic System     ** Example Problem 6 **
```

SEDIMENT PROPERTIES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACCR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	CSF	BSAE	PSI	UWDLB
I4	4	1	10	2.650	0.667	0.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

VERY FINE SAND....	0.088	VERY FINE GRAVEL..	2.828
FINE SAND.........	0.177	FINE GRAVEL.......	5.657
MEDIUM SAND.......	0.354	MEDIUM GRAVEL.....	11.314
COARSE SAND.......	0.707	COARSE GRAVEL.....	22.627
VERY COARSE SAND..	1.414	VERY COARSE GRAVEL	45.255

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	0.500	0.500	0.250	0.500	0.250	0.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ		1.00000	50.0000	1000.00	5800.00	90000.0
LF	VFS	0.130900E-02	0.178500	159.360	2299.50	232800.
LF	FS	0.360800E-02	0.492000	105.920	1377.00	112000.
LF	MS	0.608300E-02	0.829500	49.9200	693.000	44000.0
LF	CS	0.100000E-19	0.100000E-19	3.52000	72.0000	8000.00
LF	VCS	0.100000E-19	0.100000E-19	1.28000	36.0000	2000.00
LF	VFG	0.100000E-19	0.100000E-19	0.100000E-19	18.0000	800.000
LF	FG	0.100000E-19	0.100000E-19	0.100000E-19	4.50000	400.000
LF	MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF	CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF	VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
TOTAL		0.110000E-01	1.50000	320.000	4500.00	400000.

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		183.500	959.300	944.700	958.900	0.000	0.000
	3280.000						
15.000		242.000	961.000	953.700	962.000	3280.000	0.621
	4240.000						
32.000		219.500	968.600	956.500	978.500	7520.000	1.424
	3320.000						
33.000		299.000	979.190	961.000	976.000	10840.000	2.053
	1750.000						
33.300		284.050	980.680	962.490	977.490	12590.000	2.384
	1050.000						
33.900		284.050	980.840	962.650	977.650	13640.000	2.583
	0.000						
35.000		275.950	963.300	963.300	983.700	13640.000	2.583
	5210.000						
42.000		154.500	969.800	969.800	969.800	18850.000	3.570

44.000	3500.000	337.500	970.900	967.100	976.900	22350.000	4.233
53.000	2942.000	195.000	982.800	972.200	988.700	25292.000	4.790
55.000	2770.000	204.000	987.200	972.900	983.800	28062.000	5.315
58.000	1462.000	176.500	996.300	975.400	990.400	29524.000	5.592

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	VF SAND	F SAND	M SAND	C SAND	VC SAND	VF GRVL	F GRVL	M GRVL	C GRVL	VC GRVL
						BED MATERIAL FRACTIONS per grain size									
1.000	1.000	0.105	0.105	1.000	1.000	0.010	0.070	0.290	0.360	0.120	0.060	0.040	0.015	0.035	0.000
15.000	1.000	0.151	0.151	1.000	1.000	0.010	0.070	0.327	0.367	0.113	0.045	0.033	0.011	0.022	0.002
32.000	1.000	0.210	0.210	1.000	1.000	0.010	0.070	0.375	0.375	0.105	0.025	0.025	0.005	0.005	0.005
33.000	1.000	0.210	0.210	1.000	1.000	0.008	0.062	0.321	0.397	0.124	0.038	0.027	0.004	0.009	0.009
33.300	1.000	0.210	0.210	1.000	1.000	0.008	0.058	0.293	0.408	0.134	0.045	0.028	0.004	0.011	0.011
33.900	1.000	0.210	0.210	1.000	1.000	0.007	0.056	0.276	0.415	0.140	0.049	0.029	0.004	0.012	0.012
35.000	1.000	0.210	0.210	1.000	1.000	0.007	0.056	0.276	0.415	0.140	0.049	0.029	0.004	0.012	0.012
42.000	1.000	0.210	0.210	1.000	1.000	0.005	0.044	0.192	0.450	0.169	0.069	0.033	0.002	0.018	0.018
44.000	1.000	0.210	0.210	1.000	1.000	0.003	0.036	0.136	0.473	0.189	0.082	0.035	0.002	0.022	0.022
53.000	1.000	0.210	0.210	1.000	1.000	0.002	0.030	0.088	0.492	0.206	0.094	0.037	0.001	0.025	0.025
55.000	1.000	0.210	0.210	1.000	1.000	0.001	0.023	0.044	0.510	0.222	0.104	0.039	0.000	0.028	0.028
58.000	1.000	0.210	0.210	1.000	1.000	0.000	0.020	0.020	0.520	0.230	0.110	0.040	0.000	0.030	0.030

..LOCAL INFLOW DATA...
SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ		1.00000	100.000	1000.00	10000.0
LF	VFS	0.265600E-02	6.64000	7.50000	5940.00
LF	FS	0.828000E-03	2.07000	122.500	5430.00
LF	MS	0.344000E-03	0.860000	302.500	3210.00
LF	CS	0.124000E-03	0.310000	26.0000	2940.00
LF	VCS	0.320000E-04	0.800000E-01	19.5000	3810.00
LF	VFG	0.120000E-04	0.300000E-01	10.0000	3480.00
LF	FG	0.400000E-05	0.100000E-01	5.50000	2730.00
LF	MG	0.100000E-19	0.100000E-19	5.50000	1590.00
LF	CG	0.100000E-19	0.100000E-19	0.100000E-19	660.000
LF	VCG	0.100000E-19	0.100000E-19	0.100000E-19	180.000
	TOTAL	0.400000E-02	10.0000	499.000	29970.0

T4 *CASCADE CREEK - STREAM SEGMENT 2 ** Example Problem 6 ***
T5 FIRST TRIB ON Zumbro River.
T6 LOAD CURVE FROM GAGE DATA. BED GRADATIONS FROM FIELD SAMPLES.
T7 Use full range of sands and gravels - Yang's Stream Power.
T8 Zumbro River Project

EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
CASCADE IS A TRIBUTARY OF THE ZUMBRO RIVER DOWNSTREAM OF SILVER LAKE
CASCADE CREEK GEOMETRY - STREAM SEGMENT 2 ** Example Problem 6 **

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 2
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL		1.00000	100.000	1000.00	10000.0
LFL	VFS	0.265600E-02	6.64000	7.50000	5940.00
LFL	FS	0.828000E-03	2.07000	122.500	5430.00
LFL	MS	0.344000E-03	0.860000	302.500	3210.00
LFL	CS	0.124000E-03	0.310000	26.0000	2940.00
LFL	VCS	0.320000E-04	0.800000E-01	19.5000	3810.00
LFL	VFG	0.120000E-04	0.300000E-01	10.0000	3480.00
LFL	FG	0.400000E-05	0.100000E-01	5.50000	2730.00
LFL	MG	0.100000E-19	0.100000E-19	5.50000	1590.00
LFL	CG	0.100000E-19	0.100000E-19	0.100000E-19	660.000
LFL	VCG	0.100000E-19	0.100000E-19	0.100000E-19	180.000
	TOTAL	0.400000E-02	10.0000	499.000	29970.0

REACH GEOMETRY FOR STREAM SEGMENT 2

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		200.000	964.600	959.800	969.600	0.000	0.000
	537.000						
3.000		222.000	982.900	964.300	970.300	537.000	0.102
	240.000						
4.000		114.500	981.700	968.300	981.200	777.000	0.147
	474.000						
6.200		200.000	987.400	972.000	987.500	1251.000	0.237

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size					
1.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.025	VC SAND	0.140	M GRVL	0.150
						F SAND	0.025	VF GRVL	0.180	C GRVL	0.090
						M SAND	0.040	F GRVL	0.200	VC GRVL	0.060
						C SAND	0.090				
3.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.025	VC SAND	0.140	M GRVL	0.150
						F SAND	0.025	VF GRVL	0.180	C GRVL	0.090
						M SAND	0.040	F GRVL	0.200	VC GRVL	0.060
						C SAND	0.090				
4.000	1.000	0.210	0.210	1.000	1.000	VF SAND	0.025	VC SAND	0.140	M GRVL	0.150
						F SAND	0.025	VF GRVL	0.180	C GRVL	0.090
						M SAND	0.040	F GRVL	0.200	VC GRVL	0.060
						C SAND	0.090				
6.200	1.000	0.210	0.210	1.000	1.000	VF SAND	0.025	VC SAND	0.140	M GRVL	0.150
						F SAND	0.025	VF GRVL	0.180	C GRVL	0.090
						M SAND	0.040	F GRVL	0.200	VC GRVL	0.060
						C SAND	0.090				

T4 *BEAR CREEK - Stream Segment 3 ** Example Problem 6 ***
T5 SECOND UPSTREAM TRIB ON Zumbro River.
T6 LOAD CURVE FROM GAGE DATA. BED GRADATIONS FROM FIELD SAMPLES
T7 Use full range of sands and gravels. Yang's Stream Power.
T8 Zumbro River Project

EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
BEAR IS A TRIBUTARY OF THE ZUMBRO RIVER UPSTREAM OF SILVER CREEK
BEAR CREEK GEOMETRY - STREAM SEGMENT 3 ** Example Problem 6 **

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 3
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL		1.00000	100.000	500.000	1000.00	30000.0
LFL	VFS	0.402000E-03	6.03000	39.0000	93.6000	3082.50
LFL	FS	0.684000E-03	10.2600	86.0000	210.000	4905.00
LFL	MS	0.902000E-03	13.5300	227.000	721.200	10710.0
LFL	CS	0.200000E-05	0.300000E-01	98.5000	170.400	3555.00
LFL	VCS	0.100000E-19	0.100000E-19	0.100000E-19	3.60000	180.000

LFL VFG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	45.0000
LFL FG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	22.5000
LFL MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
TOTAL	0.199000E-02	29.8500	450.500	1198.80	22500.0

REACH GEOMETRY FOR STREAM SEGMENT 3

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		202.500	985.000	977.000	985.900	0.000	0.000
	260.000						
2.100		137.500	986.700	977.300	986.700	260.000	0.049
	708.000						
4.000		137.500	986.300	978.300	992.300	968.000	0.183
	665.000						
6.000		347.500	995.600	982.800	994.200	1633.000	0.309

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size		
1.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.030	VC SAND 0.005	M GRVL 0.000
						F SAND 0.240	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.660	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.060		
2.100	1.000	0.013	0.013	1.000	1.000	VF SAND 0.029	VC SAND 0.005	M GRVL 0.000
						F SAND 0.234	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.662	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.066		
4.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.027	VC SAND 0.005	M GRVL 0.000
						F SAND 0.216	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.666	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.081		
6.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.025	VC SAND 0.005	M GRVL 0.000
						F SAND 0.200	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.670	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.095		

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*T4 TAKEO CREEK - Stream Segment 4 ** Example Problem 6 ***
T5 FIRST TRIBUTARY ON Bear Creek.
T6 LOAD CURVE IS FROM GAGE DATA. BED GRADATIONS FROM FIELD SAMPLES.
T7 Use full range of sands and gravels. Yang's Stream Power.
T8 Zumbro River Project

EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
TAKEO CREEK IS A TRIBUTARY OF BEAR CREEK UPSTREAM OF SECTION 2.1
TAKEO CREEK GEOMETRY - STREAM SEGMENT 4 ** Example Problem 6 **

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 4
LOAD BY GRAIN SIZE CLASS (tons/day)

LQL	1.00000	100.000	500.000	1000.00	30000.0
LFL VFS	0.402000E-03	6.03000	39.0000	93.6000	3082.50
LFL FS	0.684000E-03	10.2600	86.0000	210.000	4905.00
LFL MS	0.902000E-03	13.5300	227.000	721.200	10710.0
LFL CS	0.200000E-05	0.300000E-01	98.5000	170.400	3555.00
LFL VCS	0.100000E-19	0.100000E-19	0.100000E-19	3.60000	180.000
LFL VFG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	45.0000
LFL FG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	22.5000
LFL MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LFL VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
TOTAL	0.199000E-02	29.8500	450.500	1198.80	22500.0

REACH GEOMETRY FOR STREAM SEGMENT 4

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		202.500	987.000	979.000	987.900	0.000	0.000
	260.000						
2.100		137.500	988.700	979.300	988.700	260.000	0.049
	708.000						
4.000		137.500	988.300	980.300	994.300	968.000	0.183
	665.000						
6.000		347.500	997.600	984.800	996.200	1633.000	0.309

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size		
1.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.030	VC SAND 0.005	M GRVL 0.000
						F SAND 0.240	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.660	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.060		
2.100	1.000	0.013	0.013	1.000	1.000	VF SAND 0.029	VC SAND 0.005	M GRVL 0.000
						F SAND 0.234	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.662	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.066		
4.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.027	VC SAND 0.005	M GRVL 0.000
						F SAND 0.216	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.666	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.081		
6.000	1.000	0.013	0.013	1.000	1.000	VF SAND 0.025	VC SAND 0.005	M GRVL 0.000
						F SAND 0.200	VF GRVL 0.005	C GRVL 0.000
						M SAND 0.670	F GRVL 0.000	VC GRVL 0.000
						C SAND 0.095		

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	1640.000	203.000	10.000	0.332920E+07	123304.
15.000	3760.000	229.266	10.000	0.862040E+07	319274.
32.000	3780.000	235.344	10.000	0.889600E+07	329481.
33.000	2535.000	279.927	0.000	0.000000	0.000000
33.300	1400.000	287.165	0.000	0.000000	0.000000
33.900	525.000	284.050	0.000	0.000000	0.000000
35.000	2605.000	235.467	0.000	0.000000	0.000000
42.000	4355.000	203.228	0.000	0.000000	0.000000
44.000	3221.000	282.665	10.000	0.910465E+07	337209.
53.000	2856.000	220.920	10.000	0.630947E+07	233684.
55.000	2116.000	198.870	10.000	0.420808E+07	155855.
58.000	731.000	185.667	3.400	461456.	17091.0

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 2: EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	268.500	207.333	10.000	556690.	20618.1
3.000	388.500	205.864	0.000	0.000000	0.000000
4.000	357.000	145.465	0.000	0.000000	0.000000
6.200	237.000	171.500	0.000	0.000000	0.000000

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 3: EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	130.000	180.833	10.000	235083.	8706.79
2.100	484.000	143.320	10.000	693667.	25691.4
4.000	686.500	171.404	0.000	0.000000	0.000000
6.000	332.500	277.500	0.100	9226.87	341.736

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 4: EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	130.000	180.833	10.000	235083.	8706.79
2.100	484.000	143.320	10.000	693667.	25691.4
4.000	686.500	171.404	0.000	0.000000	0.000000
6.000	332.500	277.500	0.100	9226.87	341.736

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

$HYD
BEGIN COMPUTATIONS.

TIME STEP # 1
* AB FLOW 1 = BASE FLOW OF 750 CFS

EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED TIME (yrs).......... 0.000

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--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                    DISCHARGE    TEMPERATURE   WATER SURFACE
                                      (cfs)        (deg F)         (ft)
                                     750.000        65.00        956.000

****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP       AVG        AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD               WIDTH      BED          1        2        3

SECTION NO.      1.000
****   750.000   956.000   956.009   0.009     1.000   154.497   949.519    0.000    0.749    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     15.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.     15.000 TIME =      2.000 DAYS.
TRIAL     TRIAL          COMPUTED        CRITICAL
 NO.        WS              WS              WS
  0.     957.779         956.256
  1.     957.873         956.309         957.823
****   750.000   957.873   958.688   0.815     1.000    58.210   956.094    0.000    7.243    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  2 is upstream of Section No.       15.000 ---
                                    DISCHARGE    TEMPERATURE
                                      (cfs)        (deg F)
          Tributary Inflow:          61.000         72.00
                     Total:         689.000         64.38

SECTION NO.     32.000
****   689.000   963.275   963.297   0.022     1.000   128.771   958.809    0.000    1.198    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.000
****   689.000   964.126   964.144   0.018     1.000   217.196   961.158    0.000    1.069    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.300
****   689.000   964.929   964.962   0.032     1.000   202.548   962.570    0.000    1.442    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.900
****   689.000   965.528   965.551   0.023     1.000   205.131   962.752    0.000    1.210    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     35.000
...Internal Boundary Condition - Water Surface =      970.000
                                     Head Loss =        0.000
****   689.000   970.000   970.014   0.014     1.000   185.172   966.132    0.000    0.962    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     42.000
****   689.000   971.707   971.743   0.036     1.000   242.186   969.833    0.000    1.517    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.       42.000 ---
                                    DISCHARGE    TEMPERATURE
                                      (cfs)        (deg F)
              Local Inflow:          29.000         70.00
                     Total:         660.000         64.13

SECTION NO.     44.000
****   660.000   972.831   972.842   0.011     1.000   256.448   969.726    0.000    0.829    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     53.000
****   660.000   974.325   975.010   0.685     1.000    68.355   972.871    0.000    6.641    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  3 is upstream of Section No.       53.000 ---
                                    DISCHARGE    TEMPERATURE
                                      (cfs)        (deg F)
          Tributary Inflow:         128.000         67.00
                     Total:         532.000         63.44

SECTION NO.     55.000
****   532.000   978.436   978.466   0.030     1.000    99.479   974.567    0.000    1.382    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     58.000
****   532.000   979.363   979.535   0.172     1.000    54.345   976.417    0.000    3.323    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  2 at Control Point #  2 ---
                                    DISCHARGE    TEMPERATURE   WATER SURFACE
                                      (cfs)        (deg F)         (ft)
                                     61.000         72.00        957.873

****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP       AVG        AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD               WIDTH      BED          1        2        3

SECTION NO.      1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.      1.000 AT TIME =       2.000 DAYS.**              **ELOEQ**
****    61.000   960.360   960.545   0.186     1.000    60.932   960.070    0.000    3.457    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.      3.000
****    61.000   965.937   966.008   0.071     1.000    24.774   964.785    0.000    2.137    0.000
                                                  FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.      4.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.      4.000 TIME =      2.000 DAYS.
```

```
TRIAL    TRIAL        COMPUTED       CRITICAL
 NO.       WS            WS             WS
  0.     969.500       968.272
  1.     969.594       967.882       969.544
****      61.000   969.594   969.797   0.203     1.000    31.272   969.055   0.000   3.616    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       6.200
****      61.000   972.744   972.771   0.026     1.000    64.729   972.019   0.000   1.300    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  3 at Control Point #  3 ---
                                       DISCHARGE   TEMPERATURE  WATER SURFACE
                                         (cfs)       (deg F)        (ft)
                                        128.000       67.00       974.325

**** DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL (by subsection)
      (CFS)      SURFACE    LINE     HEAD               WIDTH     BED        1        2        3

SECTION NO.       1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.       1.000 AT TIME =       2.000 DAYS.**               **ELOEQ**
****     128.000   977.612   977.924   0.312     1.000    60.598   977.140   0.000   4.478    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       2.100
****     128.000   978.595   978.607   0.011     1.000   113.709   977.267   0.000   0.847    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  4 is upstream of Section No.       2.100 ---
                                       DISCHARGE   TEMPERATURE
                                         (cfs)       (deg F)
         Tributary Inflow:               90.000       73.00
                    Total:               38.000       52.79

SECTION NO.       4.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.       4.000 TIME =       2.000 DAYS.
TRIAL    TRIAL        COMPUTED       CRITICAL
 NO.       WS            WS             WS
  2.     978.920       978.649
  3.     979.014       978.687       978.964
****      38.000   979.014   979.198   0.184     1.000    24.453   978.563   0.000   3.441    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       6.000
****      38.000   983.945   983.973   0.028     1.000    37.207   983.189   0.000   1.351    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  4 at Control Point #  4 ---
                                       DISCHARGE   TEMPERATURE  WATER SURFACE
                                         (cfs)       (deg F)        (ft)
                                         90.000       73.00       978.595

**** DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL (by subsection)
      (CFS)      SURFACE    LINE     HEAD               WIDTH     BED        1        2        3

SECTION NO.       1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.       1.000 AT TIME =       2.000 DAYS.**               **ELOEQ**
****      90.000   979.501   979.688   0.188     1.000    59.777   979.067   0.000   3.475    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       2.100
****      90.000   980.319   980.328   0.009     1.000   113.557   979.275   0.000   0.759    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       4.000
****      90.000   981.486   981.662   0.176     1.000    37.369   980.771   0.000   3.369    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000
SECTION NO.       6.000
****      90.000   986.358   986.422   0.064     1.000    40.719   985.269   0.000   2.029    0.000
                                                   FLOW DISTRIBUTION (%) =   0.000 100.000    0.000

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EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
       ACCUMULATED TIME (yrs)....      0.005
       FLOW DURATION (days)......      2.000

UPSTREAM BOUNDARY CONDITIONS
----------------------------------------------------------------------------
Stream Segment # 4      |   DISCHARGE   |  SEDIMENT LOAD  |  TEMPERATURE
Section No.      6.000  |     (cfs)     |   (tons/day)    |     (deg F)
----------------------------------------------------------------------------
                 INFLOW |         90.00 |           23.96 |         73.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  4
            EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *            SAND                 *
    DAYS        POINT *    INFLOW  OUTFLOW   TRAP EFF   *
    2.00        6.000 *     0.02                        *
   TOTAL=       1.000 *     0.02      0.93     -38.26   *
*********************************************************
```

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--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                                   DISCHARGE   TEMPERATURE  WATER SURFACE
                                     (cfs)       (deg F)        (ft)
                                    750.000       65.00        956.000

****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD              WIDTH     BED        1        2        3

SECTION NO.      1.000
****    750.000   956.000   956.009   0.009    1.000   154.497   949.519   0.000    0.749    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     15.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.     15.000 TIME =      2.000 DAYS.
TRIAL    TRIAL        COMPUTED      CRITICAL
 NO.       WS            WS            WS
  0.     957.779      956.256
  1.     957.873      956.309       957.823
****    750.000   957.873   958.688   0.815    1.000    58.210   956.094   0.000    7.243    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  2 is upstream of Section No.       15.000 ---
                                   DISCHARGE   TEMPERATURE
                                     (cfs)       (deg F)
            Tributary Inflow:        61.000       72.00
                       Total:       689.000       64.38

SECTION NO.     32.000
****    689.000   963.275   963.297   0.022    1.000   128.771   958.809   0.000    1.198    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.000
****    689.000   964.126   964.144   0.018    1.000   217.196   961.158   0.000    1.069    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.300
****    689.000   964.929   964.962   0.032    1.000   202.548   962.570   0.000    1.442    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     33.900
****    689.000   965.528   965.551   0.023    1.000   205.131   962.752   0.000    1.210    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     35.000
...Internal Boundary Condition - Water Surface =      970.000
                                   Head Loss =          0.000
****    689.000   970.000   970.014   0.014    1.000   185.172   966.132   0.000    0.962    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     42.000
****    689.000   971.707   971.743   0.036    1.000   242.186   969.833   0.000    1.517    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- LOCAL INFLOW POINT #  1 is upstream of Section No.       42.000 ---
                                   DISCHARGE   TEMPERATURE
                                     (cfs)       (deg F)
                Local Inflow:        29.000       70.00
                       Total:       660.000       64.13

SECTION NO.     44.000
****    660.000   972.831   972.842   0.011    1.000   256.448   969.726   0.000    0.829    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     53.000
****    660.000   974.325   975.010   0.685    1.000    68.355   972.871   0.000    6.641    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  3 is upstream of Section No.       53.000 ---
                                   DISCHARGE   TEMPERATURE
                                     (cfs)       (deg F)
            Tributary Inflow:       128.000       67.00
                       Total:       532.000       63.44

SECTION NO.     55.000
****    532.000   978.436   978.466   0.030    1.000    99.479   974.567   0.000    1.382    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     58.000
****    532.000   979.363   979.535   0.172    1.000    54.345   976.417   0.000    3.323    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  2 at Control Point #  2 ---
                                   DISCHARGE   TEMPERATURE  WATER SURFACE
                                     (cfs)       (deg F)        (ft)
                                     61.000       72.00        957.873

****  DISCHARGE    WATER     ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL  (by subsection)
        (CFS)     SURFACE     LINE     HEAD              WIDTH     BED        1        2        3

SECTION NO.      1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.        1.000 AT TIME =      2.000 DAYS.**          **ELOEQ**
****     61.000   960.360   960.545   0.186    1.000    60.932   960.070   0.000    3.457    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.      3.000
****     61.000   965.937   966.008   0.071    1.000    24.774   964.785   0.000    2.137    0.000
                                                FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.      4.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.      4.000 TIME =      2.000 DAYS.
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TRIAL   TRIAL       COMPUTED     CRITICAL
 NO.     WS            WS           WS
  0.    969.500     968.272
  1.    969.594     967.882      969.544
****     61.000   969.594   969.797   0.203    1.000     31.272   969.055   0.000    3.616    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     6.200
****     61.000   972.744   972.771   0.026    1.000     64.729   972.019   0.000    1.300    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  3 at Control Point #  3 ---
                                DISCHARGE   TEMPERATURE  WATER SURFACE
                                  (cfs)       (deg F)        (ft)
                                 128.000       67.00        974.325

****  DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA      TOP      AVG       AVG VEL (by subsection)
        (CFS)     SURFACE    LINE     HEAD               WIDTH     BED         1         2        3

SECTION NO.     1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.       1.000 AT TIME =       2.000 DAYS.**                 **ELOEQ**
****    128.000   977.612   977.924   0.312    1.000     60.598   977.140   0.000    4.478    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     2.100
****    128.000   978.595   978.607   0.011    1.000    113.709   977.267   0.000    0.847    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

--- TRIBUTARY JUNCTION - CONTROL POINT #  4 is upstream of Section No.        2.100 ---
                                DISCHARGE   TEMPERATURE
                                  (cfs)       (deg F)
       Tributary Inflow:         90.000        73.00
                  Total:         38.000        52.79

SECTION NO.     4.000
** SUPERCRITICAL **  Using Critical Water Surface +
SECTION NO.     4.000 TIME =      2.000 DAYS.
TRIAL   TRIAL       COMPUTED     CRITICAL
 NO.     WS            WS           WS
  2.    978.920     978.649
  3.    979.014     978.687      978.964
****     38.000   979.014   979.198   0.184    1.000     24.453   978.563   0.000    3.441    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     6.000
****     38.000   983.945   983.973   0.028    1.000     37.207   983.189   0.000    1.351    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  4 at Control Point #  4 ---
                                DISCHARGE   TEMPERATURE  WATER SURFACE
                                  (cfs)       (deg F)        (ft)
                                  90.000       73.00        978.595

****  DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA      TOP      AVG       AVG VEL (by subsection)
        (CFS)     SURFACE    LINE     HEAD               WIDTH     BED         1         2        3

SECTION NO.     1.000
** CRITICAL WATER SURFACE USED AT SECTION NO.       1.000 AT TIME =       2.000 DAYS.**                 **ELOEQ**
****     90.000   979.501   979.688   0.188    1.000     59.777   979.067   0.000    3.475    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     2.100
****     90.000   980.319   980.328   0.009    1.000    113.557   979.275   0.000    0.759    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     4.000
****     90.000   981.486   981.662   0.176    1.000     37.369   980.771   0.000    3.369    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000
SECTION NO.     6.000
****     90.000   986.358   986.422   0.064    1.000     40.719   985.269   0.000    2.029    0.000
                                                 FLOW DISTRIBUTION (%) =   0.000  100.000    0.000

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EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
       ACCUMULATED TIME (yrs)....      0.005
       FLOW DURATION (days)......      2.000

UPSTREAM BOUNDARY CONDITIONS
-------------------------------------------------------------------
Stream Segment # 4       |   DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
Section No.      6.000   |     (cfs)      |  (tons/day)   |   (deg F)
-------------------------------------------------------------------
                INFLOW   |        90.00   |        23.96  |       73.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  4
            EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************
    TIME       ENTRY *             SAND               *
    DAYS       POINT *   INFLOW   OUTFLOW   TRAP EFF  *
    2.00       6.000 *    0.02                        *
   TOTAL=      1.000 *    0.02      0.93     -38.26   *
*****************************************************
```

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 4

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	4.84	VERY FINE GRAVEL..	0.00
FINE SAND.........	8.23	FINE GRAVEL.......	0.00
MEDIUM SAND.......	10.86	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.02	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	23.96

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	31.85	VERY FINE GRAVEL..	1.42
FINE SAND.........	231.57	FINE GRAVEL.......	0.00
MEDIUM SAND.......	615.85	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	55.40	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	4.42	VERY COARSE GRAVEL	0.00
		TOTAL =	940.52

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 2.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.000	-0.10	986.36	984.70	90.	53.
4.000	0.01	981.49	980.31	90.	42.
2.100	-0.20	980.32	979.10	90.	250.
1.000	-2.85	979.50	976.15	90.	941.

- -

EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3

ACCUMULATED TIME (yrs).... 0.005
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 3 Section No. 6.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	38.00	3.96	52.79

Upstream of SECTION NO. 2.100 is...

TRIBUTARY JUNCTION # 4	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	38.00	3.96	52.79
TRIBUTARY INFLOW	90.00	940.52	73.00
TOTAL	128.00	944.48	67.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 3
EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	6.000	0.00		
	2.100	0.93		
TOTAL=	1.000	0.93	1.31	-0.41

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 3

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	0.80	VERY FINE GRAVEL..	0.00
FINE SAND.........	1.36	FINE GRAVEL.......	0.00
MEDIUM SAND.......	1.79	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	3.96

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	51.95	VERY FINE GRAVEL..	1.95
FINE SAND.........	363.17	FINE GRAVEL.......	0.00
MEDIUM SAND.......	838.78	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	69.59	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	5.54	VERY COARSE GRAVEL	0.00
		TOTAL =	1330.97

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 2.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.000	-0.10	983.95	982.70	38.	32.
4.000	0.01	979.01	978.31	38.	26.
2.100	0.51	978.60	977.81	128.	447.
1.000	-3.65	977.61	973.35	128.	1331.

EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
ACCUMULATED TIME (yrs).... 0.005
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 2 Section No. 6.200	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	61.00	4.32	72.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 2
EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	6.200	0.00		
TOTAL=	1.000	0.00	0.02	-3.99

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 2

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	2.87	VERY FINE GRAVEL..	0.01
FINE SAND.........	0.89	FINE GRAVEL.......	0.00
MEDIUM SAND.......	0.37	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.13	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.03	VERY COARSE GRAVEL	0.00
		TOTAL =	4.32

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	2.57	VERY FINE GRAVEL..	3.14
FINE SAND.........	1.56	FINE GRAVEL.......	2.08
MEDIUM SAND.......	1.96	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	4.05	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	6.21	VERY COARSE GRAVEL	0.00
		TOTAL =	21.57

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 2.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.200	0.00	972.74	972.00	61.	3.
4.000	0.00	969.59	968.30	61.	3.
3.000	0.00	965.94	964.30	61.	2.
1.000	-0.06	960.36	959.74	61.	22.

EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED TIME (yrs).... 0.005
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	532.00	93.30	63.44

Upstream of SECTION NO. 53.000 is...

TRIBUTARY JUNCTION # 3	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	532.00	93.30	63.44
TRIBUTARY INFLOW	128.00	1330.97	67.00
TOTAL	660.00	1424.27	64.13

Upstream of SECTION NO. 42.000 is...

LOCAL INFLOW POINT # 1	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	660.00	1424.27	64.13
LOCAL INFLOW	29.00	1.22	70.00
TOTAL	689.00	1425.49	64.38

Upstream of SECTION NO. 15.000 is...

TRIBUTARY JUNCTION # 2	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
MAIN STEM INFLOW	689.00	1425.49	64.38
TRIBUTARY INFLOW	61.00	21.57	72.00
TOTAL	750.00	1447.06	65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #` 1
EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	58.000	0.09		
	53.000	1.31		
	42.000	0.00		
TOTAL=	35.000	1.41	0.03	0.98

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	35.000	0.03		
	15.000	0.02		
TOTAL=	1.000	0.05	0.02	0.62

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	38.08	VERY FINE GRAVEL..	0.00
FINE SAND.........	34.16	FINE GRAVEL.......	0.00
MEDIUM SAND.......	21.06	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	93.30

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	0.99	VERY FINE GRAVEL..	0.60
FINE SAND.........	2.37	FINE GRAVEL.......	0.72
MEDIUM SAND.......	5.74	MEDIUM GRAVEL.....	0.25
COARSE SAND.......	5.70	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	2.49	VERY COARSE GRAVEL	0.00
		TOTAL =	18.86

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 2.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-0.13	979.36	975.27	532.	284.
55.000	-0.07	978.44	972.83	532.	616.
53.000	0.07	974.32	972.27	660.	1413.
44.000	0.07	972.83	967.17	660.	326.
42.000	0.01	971.71	969.81	689.	56.
35.000	0.00	970.00	963.30	689.	28.
33.900	0.00	965.53	962.65	689.	22.
33.300	0.00	964.93	962.49	689.	18.
33.000	0.00	964.13	961.00	689.	13.
32.000	-0.05	963.28	956.45	689.	602.
15.000	-0.14	957.87	953.56	750.	1724.
1.000	0.37	956.00	945.07	750.	19.

$PRT
...Selective Printout Option
- Print at the following cross sections
CP 1
PS 35.1 55.0
CP 4
PS 6.0
END

TIME STEP # 2
* AC FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
COMPUTING FROM TIME= 2.0000 DAYS TO TIME= 52.0000 DAYS IN 10 COMPUTATION STEPS

EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED TIME (yrs).......... 0.005

--- *Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1* ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
2500.000	65.00	965.000

--- TRIBUTARY JUNCTION - CONTROL POINT # 3 is upstream of Section No. 53.000 ---

	DISCHARGE (cfs)	TEMPERATURE (deg F)
Tributary Inflow:	650.000	67.00
Total:	1400.000	62.04

SECTION NO. 55.000

****	DISCHARGE (CFS)	WATER SURFACE	ENERGY LINE	VELOCITY HEAD	ALPHA	TOP WIDTH	AVG BED	AVG VEL (by subsection) 1	2	3
****	1400.000	980.829	980.903	0.074	1.000	109.662	974.980	0.000	2.182	0.000
					FLOW DISTRIBUTION (%) =			0.000	100.000	0.000

```
EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  4 at Control Point #  4 ---
                                     DISCHARGE   TEMPERATURE  WATER SURFACE
                                       (cfs)       (deg F)        (ft)
                                      450.000       73.00        979.221

****  DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA     TOP      AVG        AVG VEL (by subsection)
        (CFS)     SURFACE    LINE     HEAD              WIDTH     BED          1       2        3

SECTION NO.      6.000
****   450.000   988.475   988.626   0.151    1.000    67.244   986.328    0.000    3.117    0.000
                                               FLOW DISTRIBUTION (%) =     0.000  100.000   0.000

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EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
      ACCUMULATED TIME (yrs)....      0.142
      FLOW DURATION (days)......      5.000

UPSTREAM BOUNDARY CONDITIONS
----------------------------------------------------------------------
Stream Segment # 4      |  DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
Section No.       6.000 |    (cfs)      |  (tons/day)   |   (deg F)
----------------------------------------------------------------------
                 INFLOW |       450.00 |         356.05 |         73.00

  SEDIMENT INFLOW at SECTION NO.        6.000
      GRAIN SIZE        LOAD (tons/day)  |    GRAIN SIZE       LOAD (tons/day)
  ------------------------------------------------------------------------------
    VERY FINE SAND....           34.51  |  VERY FINE GRAVEL..          0.00
    FINE SAND.........           74.83  |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......          188.73  |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......           57.98  |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..            0.00  |  VERY COARSE GRAVEL          0.00
                          -------------                        -------------
                                                 TOTAL =             356.05

    FALL VELOCITIES - Method 2
              DIAMETER    VELOCITY        REY. NO.          CD
    -------------------------------------------------------------------
    VF SAND   0.000290   0.2115882E-01   0.6021239        45.84847
    F  SAND   0.000580   0.6288557E-01    3.579113        10.38092
    M  SAND   0.001160   0.1423402        16.20246         4.052398
    C  SAND   0.002320   0.2905100        66.13704         1.945695
    VC SAND   0.004640   0.4865262        221.5240         1.387444
    VF GRVL   0.009280   0.7223283        657.7777         1.258893
    F  GRVL   0.018559    1.041785        1897.368         1.210406
    M  GRVL   0.037118    1.472894        5365.081         1.211086
    C  GRVL   0.074237    2.082985        15174.71         1.211086
    VC GRVL   0.148474    2.945788        42920.64         1.211086
*******************************************************************************************
                    TRACE OUTPUT FOR SECTION NO.        6.000
            -----------------------------------------------------

HYDRAULIC PARAMETERS:
     VEL        SLO          EFD       EFW      N-VALUE      TAU      USTARM      FROUDE NO.
    3.117    0.008268       2.838    50.874     0.0460    1.46520    0.86883      0.326

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:
NEW SURFACE AREA (SQ FT):       TOTAL          K-PORTION          S-PORTION
                              22942.50          22942.50            0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:     BED FRACTION    PERCENT FINER              BED FRACTION   PERCENT FINER
                       VF SAND     0.080074        8.007434      VF GRVL     0.000000       99.999999
                       F  SAND     0.214080       29.415438      F  GRVL     0.000000       99.999999
                       M  SAND     0.539976       83.413004      M  GRVL     0.000000       99.999999
                       C  SAND     0.165870       99.999999      C  GRVL     0.000000       99.999999
                       VC SAND     0.000000       99.999999      VC GRVL     0.000000       99.999999

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      0.04195
MIN.GRAIN DIAM       =     0.013194
BED SURFACE EXPOSED  =      0.00000

          INACTIVE LAYER         ACTIVE LAYER
            %       DEPTH         %       DEPTH
  CLAY   0.0000     0.00       0.0000     0.00
  SILT   0.0000     0.00       0.0000     0.00
  SAND   1.0000     0.00       1.0000     0.36
 TOTAL   1.0000     0.00       1.0000     0.36

        AVG. UNIT                AVG. UNIT
         WEIGHT                   WEIGHT
        0.046500                 0.046500
-- CAUTION --
SECTION NO.       6.000 AT TIME =      52.00 DAYS.
ACTIVE LAYER THICKNESS EXCEEDS DEPTH OF SEDIMENT RESERVOIR.
...LOWER THE MODEL BOTTOM BY MORE THAN      1.35 FT.
```

```
    COMPOSITE UNIT WT OF ACTIVE LAYER    (t/cf)=        0.046500
    COMPOSITE UNIT WT OF INACTIVE LAYER  (t/cf)=        0.046500
    DEPTH OF SURFACE LAYER (ft)            DSL=              0.1
    WEIGHT IN SURFACE LAYER (tons)         WTSL=             88.9
    DEPTH OF NEW ACTIVE LAYER (ft)         DSE=           0.3588
    WEIGHT IN NEW ACTIVE LAYER(tons)     WTMXAL=           382.8
    WEIGHT IN OLD ACTIVE LAYER(tons)       WAL=            382.8
    USEABLE WEIGHT, OLD INACTIVE LAYER     WIL=              0.0
    SURFACE AREA OF DEPOSIT (sq ft)        SABK= 0.22942500E+05

** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION  PERCENT FINER           BED FRACTION  PERCENT FINER
                      VF SAND    0.000000      0.000000     VF GRVL    0.000000      0.000000
                      F  SAND    0.000000      0.000000     F  GRVL    0.000000      0.000000
                      M  SAND    0.000000      0.000000     M  GRVL    0.000000      0.000000
                      C  SAND    0.000000      0.000000     C  GRVL    0.000000      0.000000
                      VC SAND    0.000000      0.000000     VC GRVL    0.000000      0.000000
** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:   BED FRACTION  PERCENT FINER           BED FRACTION  PERCENT FINER
                      VF SAND    0.080074      8.007434     VF GRVL    0.000000    100.000000
                      F  SAND    0.214080     29.415438     F  GRVL    0.000000    100.000000
                      M  SAND    0.539976     83.413004     M  GRVL    0.000000    100.000000
                      C  SAND    0.165870    100.000000     C  GRVL    0.000000    100.000000
                      VC SAND    0.000000    100.000000     VC GRVL    0.000000    100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.972000E+06
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.897832E+05  VF GRVL 0.204164E+02
                                 F  SAND 0.221666E+05  F  GRVL 0.182502E+02
                                 M  SAND 0.964949E+04  M  GRVL 0.846757E+00
                                 C  SAND 0.557199E+04  C  GRVL 0.100000E-06
                                 VC SAND 0.432242E+04  VC GRVL 0.100000E-06

  SEDIMENT OUTFLOW FROM SECTION NO.       6.000
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -----------------------------------------------------------------------------
    VERY FINE SAND....         40.64   | VERY FINE GRAVEL..        0.00
    FINE SAND.........         91.22   | FINE GRAVEL.......        0.00
    MEDIUM SAND.......        230.08   | MEDIUM GRAVEL.....        0.00
    COARSE SAND.......         70.67   | COARSE GRAVEL.....        0.00
    VERY COARSE SAND..          0.00   | VERY COARSE GRAVEL        0.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 4
            EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*******************************************************
    TIME        ENTRY *          SAND              *
    DAYS        POINT *   INFLOW   OUTFLOW  TRAP EFF *
   52.00        6.000 *     8.81                   *
   TOTAL=       1.000 *     8.81     15.35     -0.74 *
*******************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT # 4
---------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -----------------------------------------------------------------------------
    VERY FINE SAND....         34.51   | VERY FINE GRAVEL..        0.00
    FINE SAND.........         74.83   | FINE GRAVEL.......        0.00
    MEDIUM SAND.......        188.73   | MEDIUM GRAVEL.....        0.00
    COARSE SAND.......         57.98   | COARSE GRAVEL.....        0.00
    VERY COARSE SAND..          0.00   | VERY COARSE GRAVEL        0.00
                        -------------                     -------------
                                           TOTAL =          356.05
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -----------------------------------------------------------------------------
    VERY FINE SAND....         34.75   | VERY FINE GRAVEL..        0.01
    FINE SAND.........         90.86   | FINE GRAVEL.......        0.00
    MEDIUM SAND.......        261.12   | MEDIUM GRAVEL.....        0.00
    COARSE SAND.......         68.94   | COARSE GRAVEL.....        0.00
    VERY COARSE SAND..          0.35   | VERY COARSE GRAVEL        0.00
                        -------------                     -------------
                                           TOTAL =          456.03

TABLE SB-2:  STATUS OF THE BED PROFILE AT TIME =    52.000 DAYS
---------------------------------------------------------------------------------
  SECTION  BED CHANGE  WS ELEV   THALWEG          Q       TRANSPORT RATE (tons/day)
  NUMBER      (ft)       (ft)      (ft)         (cfs)       SAND
    6.000     -0.10    988.47    984.70         450.         433.
    4.000      0.08    982.54    980.38         450.         428.
    2.100     -5.56    979.39    973.74         450.         461.
    1.000     -2.93    979.22    976.07         450.         456.

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EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
       ACCUMULATED TIME (yrs)....       0.142
       FLOW DURATION (days)......       5.000

UPSTREAM BOUNDARY CONDITIONS
-----------------------------------------------------------------------
Stream Segment # 3      |   DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
Section No.      6.000  |     (cfs)      |  (tons/day)   |   (deg F)
-----------------------------------------------------------------------
               INFLOW   |        200.00  |        85.67  |      53.50
```

```
TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  3
            EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
   TIME        ENTRY *           SAND                *
   DAYS        POINT *   INFLOW  OUTFLOW  TRAP EFF *
  52.00        6.000 *    2.12                       *
               2.100 *   15.35                       *
  TOTAL=       1.000 *   17.46    18.72     -0.07 *
*****************************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  3
--------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ------------------------------------------------------------------------------
    VERY FINE SAND....          13.47  |  VERY FINE GRAVEL..           0.00
    FINE SAND.........          25.63  |  FINE GRAVEL.......           0.00
    MEDIUM SAND.......          45.58  |  MEDIUM GRAVEL.....           0.00
    COARSE SAND.......           0.98  |  COARSE GRAVEL.....           0.00
    VERY COARSE SAND..           0.00  |  VERY COARSE GRAVEL           0.00
                         -------------                         ------------
                                              TOTAL =                 85.67
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ------------------------------------------------------------------------------
    VERY FINE SAND....          37.77  |  VERY FINE GRAVEL..           0.00
    FINE SAND.........          62.53  |  FINE GRAVEL.......           0.00
    MEDIUM SAND.......          97.21  |  MEDIUM GRAVEL.....           0.00
    COARSE SAND.......          19.34  |  COARSE GRAVEL.....           0.00
    VERY COARSE SAND..           0.13  |  VERY COARSE GRAVEL           0.00
                         -------------                         ------------
                                              TOTAL =                216.98

TABLE SB-2:  STATUS OF THE BED PROFILE AT TIME =      52.000 DAYS
--------------------------------------------------------------------------------
  SECTION   BED CHANGE   WS ELEV   THALWEG        Q      TRANSPORT RATE (tons/day)
  NUMBER       (ft)        (ft)      (ft)       (cfs)          SAND
    6.000        0.05     985.16    982.85       200.             69.
    4.000        0.02     979.89    978.32       200.             73.
    2.100       -2.39     979.22    974.91       650.            589.
    1.000        4.42     979.11    972.82       650.            217.

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EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
      ACCUMULATED TIME (yrs)....       0.142
      FLOW DURATION (days)......       5.000

UPSTREAM BOUNDARY CONDITIONS
--------------------------------------------------------------------
Stream Segment # 2     |  DISCHARGE    | SEDIMENT LOAD | TEMPERATURE
Section No.      6.200 |    (cfs)      |  (tons/day)   |   (deg F)
--------------------------------------------------------------------
                INFLOW |       300.00  |        40.00  |      72.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  2
            EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
   TIME        ENTRY *           SAND                *
   DAYS        POINT *   INFLOW  OUTFLOW  TRAP EFF *
  52.00        6.200 *    0.99                       *
  TOTAL=       1.000 *    0.99     0.76      0.23 *
*****************************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  2
--------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ------------------------------------------------------------------------------
    VERY FINE SAND....           7.04  |  VERY FINE GRAVEL..           0.48
    FINE SAND.........          14.50  |  FINE GRAVEL.......           0.20
    MEDIUM SAND.......          14.10  |  MEDIUM GRAVEL.....           0.00
    COARSE SAND.......           2.57  |  COARSE GRAVEL.....           0.00
    VERY COARSE SAND..           1.10  |  VERY COARSE GRAVEL           0.00
                         -------------                         ------------
                                              TOTAL =                 40.00
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE       LOAD (tons/day) |     GRAIN SIZE       LOAD (tons/day)
  ------------------------------------------------------------------------------
    VERY FINE SAND....           5.88  |  VERY FINE GRAVEL..           0.65
    FINE SAND.........          13.30  |  FINE GRAVEL.......           1.02
    MEDIUM SAND.......          11.37  |  MEDIUM GRAVEL.....           0.57
    COARSE SAND.......           2.01  |  COARSE GRAVEL.....           0.00
    VERY COARSE SAND..           0.99  |  VERY COARSE GRAVEL           0.00
                         -------------                         ------------
                                              TOTAL =                 35.77
```

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 52.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.200	0.06	973.80	972.06	300.	32.
4.000	0.03	970.92	968.33	300.	26.
3.000	0.02	966.52	964.32	300.	22.
1.000	0.21	965.15	960.01	300.	36.

- -

EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED TIME (yrs).... 0.142
FLOW DURATION (days)...... 5.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	1400.00	529.98	62.04

SEDIMENT INFLOW at SECTION NO. 58.000

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	265.63	VERY FINE GRAVEL..	0.00
FINE SAND.........	173.06	FINE GRAVEL.......	0.00
MEDIUM SAND.......	82.59	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	6.27	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	2.42	VERY COARSE GRAVEL	0.00
		TOTAL =	529.98

FALL VELOCITIES - Method 2

	DIAMETER	VELOCITY	REY. NO.	CD
VF SAND	0.000290	0.1863592E-01	0.4575463	59.10251
F SAND	0.000580	0.5772227E-01	2.834376	12.32115
M SAND	0.001160	0.1329160	13.05331	4.647428
C SAND	0.002320	0.2804704	55.08844	2.087483
VC SAND	0.004640	0.4808243	188.8821	1.420545
VF GRVL	0.009280	0.7191678	565.0209	1.269982
F GRVL	0.018559	1.039734	1633.750	1.215185
M GRVL	0.037118	1.472894	4628.774	1.211086
C GRVL	0.074237	2.082985	13092.12	1.211086
VC GRVL	0.148474	2.945788	37030.19	1.211086

****

TRACE OUTPUT FOR SECTION NO. 55.000

HYDRAULIC PARAMETERS:

VEL	SLO	EFD	EFW	N-VALUE	TAU	USTARM	FROUDE NO.
2.978	0.000661	6.346	86.708	0.0450	0.26180	0.36726	0.208

BED SEDIMENT CONTROL VOLUME COMPUTATIONS:

NEW SURFACE AREA (SQ FT):	TOTAL	K-PORTION	S-PORTION
	230938.67	230938.67	0.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL PER GRAIN SIZE:

	BED FRACTION	PERCENT FINER		BED FRACTION	PERCENT FINER
VF SAND	0.003404	0.340403	VF GRVL	0.106364	90.239202
F SAND	0.023017	2.642100	F GRVL	0.039881	94.227344
M SAND	0.043820	7.024101	M GRVL	0.000336	94.260950
C SAND	0.506025	57.626611	C GRVL	0.028706	97.131515
VC SAND	0.219762	79.602775	VC GRVL	0.028685	99.999998

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT= 0.84259
MIN.GRAIN DIAM = 0.003556
BED SURFACE EXPOSED = 1.00000

	INACTIVE LAYER %	INACTIVE LAYER DEPTH	ACTIVE LAYER %	ACTIVE LAYER DEPTH
CLAY	0.0000	0.00	0.0000	0.00
SILT	0.0000	0.00	0.0000	0.00
SAND	1.0000	9.82	1.0000	0.06
TOTAL	1.0000	9.82	1.0000	0.06

AVG. UNIT WEIGHT 0.046500 AVG. UNIT WEIGHT 0.046500

COMPOSITE UNIT WT OF ACTIVE LAYER	(t/cf)=	0.046500
COMPOSITE UNIT WT OF INACTIVE LAYER	(t/cf)=	0.046500
DEPTH OF SURFACE LAYER (ft)	DSL=	0.1
WEIGHT IN SURFACE LAYER (tons)	WTSL=	894.9
DEPTH OF NEW ACTIVE LAYER (ft)	DSE=	0.0159
WEIGHT IN NEW ACTIVE LAYER(tons)	WTMXAL=	170.4
WEIGHT IN OLD ACTIVE LAYER(tons)	WAL=	625.6
USEABLE WEIGHT, OLD INACTIVE LAYER	WIL=	105466.0
SURFACE AREA OF DEPOSIT (sq ft)	SABK=	0.23093867E+06

```
** INACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION   PERCENT FINER              BED FRACTION   PERCENT FINER
                       VF SAND      0.000671        0.067089     VF GRVL      0.105367       90.305284
                       F  SAND      0.023154        2.382439     F  GRVL      0.039383       94.243549
                       M  SAND      0.043769        6.759378     M  GRVL      0.000335       94.277093
                       C  SAND      0.509027       57.662047     C  GRVL      0.028615       97.138545
                       VC SAND      0.221065       79.768566     VC GRVL      0.028615       99.999998

** ACTIVE LAYER **
BED MATERIAL PER GRAIN SIZE:    BED FRACTION   PERCENT FINER              BED FRACTION   PERCENT FINER
                       VF SAND      0.464173       46.417286     VF GRVL      0.274462       79.098798
                       F  SAND      0.000000       46.417286     F  GRVL      0.123966       91.495417
                       M  SAND      0.052353       51.652597     M  GRVL      0.000440       91.539461
                       C  SAND      0.000000       51.652597     C  GRVL      0.044068       95.946230
                       VC SAND      0.000000       51.652597     VC GRVL      0.040538      100.000000

C FINES, COEF(CFFML), MX POTENTIAL= 0.000000E+00 0.100000E+01 0.302400E+07
POTENTIAL TRANSPORT (tons/day):  VF SAND 0.101876E+05  VF GRVL 0.133530E+02
                                 F  SAND 0.305709E+04  F  GRVL 0.122091E+02
                                 M  SAND 0.170276E+04  M  GRVL 0.100000E-06
                                 C  SAND 0.126234E+04  C  GRVL 0.100000E-06
                                 VC SAND 0.124827E+04  VC GRVL 0.100000E-06

  SEDIMENT OUTFLOW FROM SECTION NO.     55.000
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -------------------------------------------------------------------------
    VERY FINE SAND....        294.06   |  VERY FINE GRAVEL..          2.48
    FINE SAND.........        175.65   |  FINE GRAVEL.......          0.96
    MEDIUM SAND.......         69.90   |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......         30.28   |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..         13.04   |  VERY COARSE GRAVEL          0.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 6.  South Fork, ZUMBRO RIVER - Stream Segment 1
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*******************************************************
    TIME      ENTRY *            SAND              *
    DAYS      POINT *    INFLOW  OUTFLOW  TRAP EFF *
   52.00     58.000 *     13.17                    *
             53.000 *     18.72                    *
             42.000 *      0.36                    *
   TOTAL=    35.000 *     32.25     0.34      0.99 *
*******************************************************
    TIME      ENTRY *            SAND              *
    DAYS      POINT *    INFLOW  OUTFLOW  TRAP EFF *
   52.00     35.000 *      0.34                    *
             15.000 *      0.76                    *
   TOTAL=     1.000 *      1.10     0.07      0.93 *
*******************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  1
-----------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -------------------------------------------------------------------------
    VERY FINE SAND....        265.63   |  VERY FINE GRAVEL..          0.00
    FINE SAND.........        173.06   |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......         82.59   |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......          6.27   |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..          2.42   |  VERY COARSE GRAVEL          0.00
                        ------------                       ------------
                                              TOTAL =          529.98
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE       LOAD (tons/day) |    GRAIN SIZE       LOAD (tons/day)
  -------------------------------------------------------------------------
    VERY FINE SAND....          0.24   |  VERY FINE GRAVEL..          0.00
    FINE SAND.........          0.32   |  FINE GRAVEL.......          0.00
    MEDIUM SAND.......          0.96   |  MEDIUM GRAVEL.....          0.00
    COARSE SAND.......          0.80   |  COARSE GRAVEL.....          0.00
    VERY COARSE SAND..          0.19   |  VERY COARSE GRAVEL          0.00
                        ------------                       ------------
                                              TOTAL =            2.50

TABLE SB-2:  STATUS OF THE BED PROFILE AT TIME =     52.000 DAYS
-----------------------------------------------------------------------------------
  SECTION   BED CHANGE   WS ELEV   THALWEG        Q      TRANSPORT RATE (tons/day)
  NUMBER       (ft)        (ft)      (ft)       (cfs)       SAND
     58.000     -1.11    981.78    974.29      1400.        559.
     55.000     -0.13    980.83    972.77      1400.        586.
     53.000     -0.04    979.11    972.16      2050.       1005.
     44.000      1.50    978.55    968.60      2050.        274.
     42.000      0.26    978.28    970.06      2200.         31.
     35.000      0.02    978.00    963.32      2200.         16.
     33.900      0.00    968.54    962.65      2200.         13.
     33.300      0.00    968.08    962.49      2200.         10.
     33.000      0.00    967.49    961.00      2200.          8.
     32.000     -0.51    966.51    955.99      2200.        285.
     15.000      0.00    965.15    953.70      2500.        232.
      1.000      1.01    965.00    945.71      2500.          3.

Accumulated Water Discharge from day zero (sfd)
    MAIN
   1500.00
=================================================================================
```

```
TIME STEP #        3
*    A       FLOW 3 = NEAR BANK FULL DISCHARGE

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  4
             EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   53.00        6.000 *     8.87                      *
   TOTAL=       1.000 *     8.87     15.87     -0.79  *
*********************************************************

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  3
             EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   53.00        6.000 *     2.13                      *
                2.100 *    15.87                      *
   TOTAL=       1.000 *    18.00     20.27     -0.13  *
*********************************************************

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  2
             EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   53.00        6.200 *     1.00                      *
   TOTAL=       1.000 *     1.00      0.97      0.03  *
*********************************************************

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 6.  South Fork, ZUMBRO RIVER - Stream Segment 1
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   53.00       58.000 *    13.25                      *
               53.000 *    20.27                      *
               42.000 *     0.36                      *
   TOTAL=      35.000 *    33.88      0.34      0.99  *
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   53.00       35.000 *     0.34                      *
               15.000 *     0.97                      *
   TOTAL=       1.000 *     1.31      0.08      0.94  *
*********************************************************

==============================================================================
TIME STEP #        4
*    B       FLOW 4 = BASE FLOW OF 500 CFS

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
      ACCUMULATED TIME (yrs)....       0.151
      FLOW DURATION (days)......       2.000

UPSTREAM BOUNDARY CONDITIONS
-------------------------------------------------------------------------
Stream Segment # 4      |  DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
Section No.      6.000  |    (cfs)     |  (tons/day)   |   (deg F)
-------------------------------------------------------------------------
                INFLOW  |        90.00 |         23.96 |      73.00

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  4
             EXAMPLE 6 Cont. ZUMBRO RIVER Project - TAKEO CREEK - Stream Segment 4
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*********************************************************
    TIME        ENTRY *             SAND              *
    DAYS        POINT *    INFLOW   OUTFLOW  TRAP EFF *
   55.00        6.000 *     8.90                      *
   TOTAL=       1.000 *     8.90     16.24     -0.83  *
*********************************************************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  4
-------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
      GRAIN SIZE        LOAD (tons/day) |    GRAIN SIZE          LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....             4.84  |  VERY FINE GRAVEL..           0.00
    FINE SAND.........             8.23  |  FINE GRAVEL.......           0.00
    MEDIUM SAND.......            10.86  |  MEDIUM GRAVEL.....           0.00
    COARSE SAND.......             0.02  |  COARSE GRAVEL.....           0.00
    VERY COARSE SAND..             0.00  |  VERY COARSE GRAVEL           0.00
                          -------------                          -------------
                                                      TOTAL =          23.96
  SEDIMENT OUTFLOW from the Downstream Boundary
      GRAIN SIZE        LOAD (tons/day) |    GRAIN SIZE          LOAD (tons/day)
  ---------------------------------------------------------------------------
    VERY FINE SAND....            15.35  |  VERY FINE GRAVEL..           0.09
    FINE SAND.........            91.96  |  FINE GRAVEL.......           0.00
```

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
MEDIUM SAND.......	244.08	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	22.05	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	1.39	VERY COARSE GRAVEL	0.00
		TOTAL =	374.91

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 55.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.000	-0.10	986.44	984.70	90.	34.
4.000	0.00	981.30	980.30	90.	35.
2.100	-6.28	976.88	973.02	90.	375.
1.000	-2.99	976.52	976.01	90.	375.

- -

EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
ACCUMULATED TIME (yrs).... 0.151
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 3 Section No. 6.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	38.00	3.96	52.79

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 3
EXAMPLE 6 Cont. ZUMBRO RIVER Project - BEAR CREEK - Stream Segment 3
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	SAND INFLOW	SAND OUTFLOW	TRAP EFF
55.00	6.000	2.13		
	2.100	16.24		
TOTAL=	1.000	18.37	20.32	-0.11

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 3

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	0.80	VERY FINE GRAVEL..	0.00
FINE SAND.........	1.36	FINE GRAVEL.......	0.00
MEDIUM SAND.......	1.79	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	3.96

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	9.72	VERY FINE GRAVEL..	0.01
FINE SAND.........	15.97	FINE GRAVEL.......	0.00
MEDIUM SAND.......	26.14	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	2.18	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.09	VERY COARSE GRAVEL	0.00
		TOTAL =	54.11

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 55.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.000	-0.10	983.91	982.70	38.	3.
4.000	0.00	978.95	978.30	38.	9.
2.100	-2.90	975.20	974.40	128.	718.
1.000	4.08	974.82	972.48	128.	54.

- -

EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
ACCUMULATED TIME (yrs).... 0.151
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 2 Section No. 6.200	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	61.00	4.32	72.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 2
EXAMPLE 6 Cont. ZUMBRO RIVER Project - CASCADE CREEK - Stream Segment 2
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	SAND INFLOW	SAND OUTFLOW	TRAP EFF
55.00	6.200	1.00		
TOTAL=	1.000	1.00	0.98	0.02

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 2

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	2.87	VERY FINE GRAVEL..	0.01
FINE SAND.........	0.89	FINE GRAVEL.......	0.00
MEDIUM SAND.......	0.37	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.13	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.03	VERY COARSE GRAVEL	0.00
		TOTAL =	4.32

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	1.47	VERY FINE GRAVEL..	3.51
FINE SAND.........	0.46	FINE GRAVEL.......	1.94
MEDIUM SAND.......	0.19	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.07	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.02	VERY COARSE GRAVEL	0.00
		TOTAL =	7.65

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 55.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
6.200	0.00	972.81	972.00	61.	3.
4.000	0.00	969.50	968.30	61.	3.
3.000	0.00	965.80	964.30	61.	2.
1.000	-0.30	960.06	959.50	61.	8.

EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED TIME (yrs).... 0.151
FLOW DURATION (days)...... 2.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	282.00	28.81	62.06

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 6. South Fork, ZUMBRO RIVER - Stream Segment 1
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	SAND INFLOW	SAND OUTFLOW	TRAP EFF
55.00	58.000	13.28		
	53.000	20.32		
	42.000	0.36		
TOTAL=	35.000	33.96	0.34	0.99

TIME DAYS	ENTRY POINT	SAND INFLOW	SAND OUTFLOW	TRAP EFF
55.00	35.000	0.34		
	15.000	0.98		
TOTAL=	1.000	1.32	0.09	0.93

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	9.03	VERY FINE GRAVEL..	0.00
FINE SAND.........	10.94	FINE GRAVEL.......	0.00
MEDIUM SAND.......	8.84	MEDIUM GRAVEL.....	0.00
COARSE SAND.......	0.00	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	0.00	VERY COARSE GRAVEL	0.00
		TOTAL =	28.81

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
VERY FINE SAND....	1.82	VERY FINE GRAVEL..	0.12
FINE SAND.........	1.76	FINE GRAVEL.......	0.15
MEDIUM SAND.......	4.38	MEDIUM GRAVEL.....	0.05
COARSE SAND.......	3.89	COARSE GRAVEL.....	0.00
VERY COARSE SAND..	1.61	VERY COARSE GRAVEL	0.00
		TOTAL =	13.77

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 55.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) SAND
58.000	-1.28	977.69	974.12	282.	81.
55.000	-0.13	976.93	972.77	282.	111.
53.000	0.12	974.82	972.32	410.	279.
44.000	1.53	973.46	968.63	410.	78.
42.000	0.26	973.12	970.06	439.	1.
35.000	0.02	973.00	963.32	439.	0.

```
    33.900      0.00    964.90    962.65       439.         0.
    33.300      0.00    964.25    962.49       439.         0.
    33.000      0.00    962.87    961.00       439.         0.
    32.000     -0.54    961.80    955.96       439.       211.
    15.000     -0.12    957.22    953.58       500.      1054.
     1.000      1.37    955.00    946.07       500.        14.

------------------------------------------------------------------------------------------
$$END

      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ =        4
TOTAL NO. OF WS PROFILES =           13
ITERATIONS IN EXNER EQ =           1560

COMPUTATIONS COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  9.00 SECONDS
```

6.7 Example Problem 7 - Cohesive Sediment

Example Problem 7 illustrates the deposition of clays and silts in an impoundment at the downstream end of a single stream segment. Subsequent lowering of the pool level in that impoundment causes erosion of the cohesive deposits. Table 6-7a shows the input data for this example and Table 6-7b shows the output.

6.7.1 Cohesive Sediment Data

This example uses Method 2 (see Sections 2.3.8, 3.3.4.1 and the **I2** record in Appendix A) to compute the deposition and erosion rates for clay and silts. This method requires the addition of two **Special I2** records to provide the data; one for the active layer and one for the inactive layer. The data for the active layer is described below and is illustrated (along with the data for the inactive layer) in Figure 6-7.

The shear stress threshold above which clays and silts will not deposit is 0.02 lb/ft^2. The shear stress at which deposited cohesive material will scour is 0.05 lb/ft^2. The shear stress above which mass erosion occurs is 0.10 lb/ft^2. The erosion rate at that shear stress is 1.5 $lb/ft^2/hr$. The slope of the mass erosion rate curve is 60/hr. These values are depicted in Figure 30 for both the active and inactive layers. Note that the shear strength of the inactive layer is larger than that of the active layer and it erodes more slowly. This represents, perhaps, the effect of consolidation.

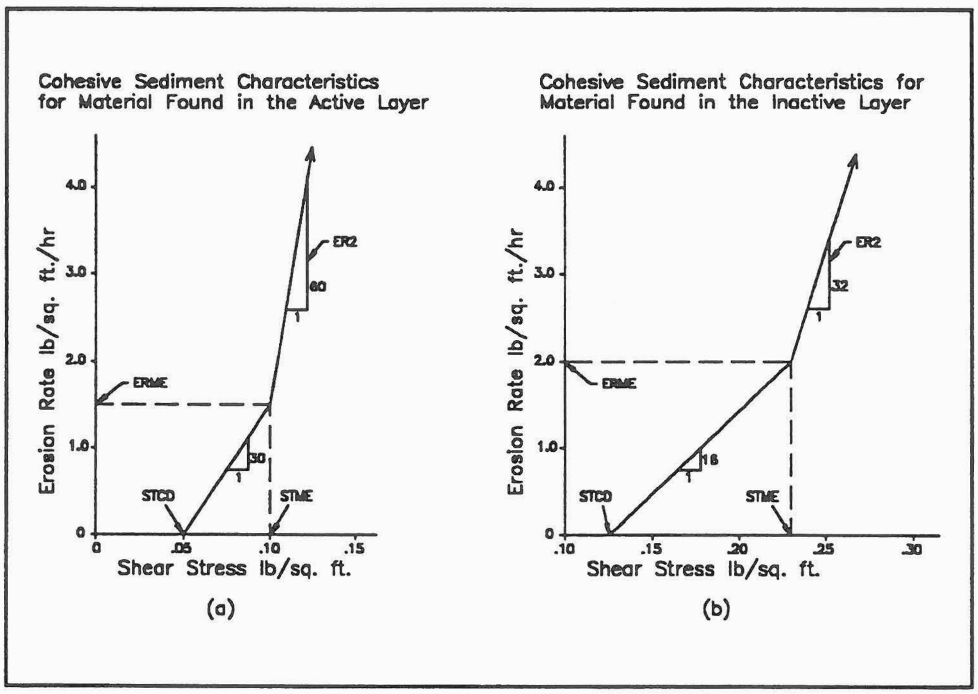

Figure 6-7
Erosion Rate Characteristics

Caution, the cohesive sediment values given in Example Problem 7 are not factual and **should not be used** under any circumstances without field verification. To determine these values, laboratory tests must be performed on the sediments to be simulated. These tests must be done under the same physical and chemical conditions as in the prototype (see Section 2.3.8).

Table 6-7a
Example Problem 7 - Input
Cohesive Sediment

```
T1      EXAMPLE PROBLEM NO 7.  COHESIVE SEDIMENT.
T2      A LAKE IS CREATED.
T3      SOUTH FORK, ZUMBRO RIVER      ** Example Problem 7 **
NC     .1      .1     .04      .1      .3
X1    1.0      31  10077.  10275.      0.      0.       0.
GR 1004.    9915.   978.4  10002.   956.0  10060.   959.2  10077.   959.3  10081.
GR 950.0   10092.  948.48  10108.   946.6  10138.   944.7  10158.   955.2  10225.
GR 956.2   10243.   958.9  10250.   959.8  10275.   959.8  10300.   959.9  10325.
GR 958.8   10350.   957.4  10400.   970.0  10700.   966.0  10960.   970.0  11060.
GR 968.0   11085.   968.0  11240.   970.0  11365.   970.0  11500.   970.0  11615.
GR 962.0   11665.   962.0  12400.   976.0  12550.   980.0  12670.   982.0  12730.
GR 984.0   12735.
HD    1.0     10.  10081.  10250.
NV     22    .045   965.6    .064   988.8
NV     12     .08   965.6     .13   988.8
NV     33      .1   965.6     .11   982.0     .12   988.8
X1   15.0      27  10665.  10850.   3560.   3030.   3280.
X3                         10700.   961.0  11000.   970.0
GR 992.0    9570.   982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7   10665.   956.0  10673.   953.0  10693.   954.0  10703.   955.6  10723.
GR 958.6   10750.   959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0   10852.   964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0   11190.   972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0   11865.  1000.0  12150.
HD   15.0     10.  10673.  10852.
NC     .1      .1     .05
   CASCADE CREEK
X1   32.0      29  10057.  10271.   3630.   3060.   4240.
GR 998.0    9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48   10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8   10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5   10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91   10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0   11150.   992.0  11240.  1000.0  11330.   1008.  11425.
HD   32.0     10.  10075.  10275.
NC    .06     .06    .045
X1   42.0      32   9880.  10130.   8500.   8250.   8530.
GR 996.0    7130.   998.0   7310.   998.0   7930.   992.0   8205.   990.0   8495.
GR 988.0    8780.   986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0    9880.   969.8   9881.   969.8   9941.   985.8   9941.   985.8   9943.
GR 969.8    9943.   969.8  10001.   986.7  10001.   986.7  10003.   969.8  10003.
GR 969.8   10067.   985.8  10067.   985.8  10069.   969.8  10069.   969.8  10129.
GR 989.9   10130.   989.5  10180.   988.6  10230.   987.6  10280.   985.2  10430.
GR 986.8   11720.   989.9  12310.
HD   42.0       0   9881.  10021.
  SILVER CREEK
X1   44.0      28   9845.  10127.   3200.   3800.   3500.
XL                          9850.  10200.
GR 1002.    8035.   992.0   8150.   990.0   8305.   990.0   8735.   988.0   8835.
GR 996.0    9285.  1017.6   9425.   990.0   9505.   986.0   9650.   984.1   9788.
GR 980.6    9845.   970.9   9868.   972.2   9898.   970.5   9968.   967.5   9998.
GR 968.9   10028.   967.4  10058.   967.1  10078.   971.9  10118.   976.8  10127.
GR 977.8   10150.   976.9  10193.   982.0  10206.   981.2  10300.   979.2  10325.
GR 983.1   10400.   999.8  10450.  1002.4  10464.
HD   44.0     10.   9868.  10193.
X1   53.0      22  10000.  10136.   3366.   2832.   2942.
GR 1004.    7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0    8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8   10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2   10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.   10470.  1004.0  10700.
HD   53.0     10.  10000.  10136.
  BEAR CREEK
X1   55.0      18   9931.  10062.   2275.   3430.   2770.
GR 1004.    7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3    9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8    9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8   10187.   986.0  10307.   990.0  10497.
HD   55.0     10.   9931.  10062.
X1   58.0      22   9912.  10015.   1098.   1012.   1462.
GR 1006.    8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2    9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8   10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0   10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0   11137.   988.0  11192.
HD   58.0     3.4   9912.  10015.
EJ
```

6.7 Example Problem 7 - Cohesive Sediment

Example Problem 7 illustrates the deposition of clays and silts in an impoundment at the downstream end of a single stream segment. Subsequent lowering of the pool level in that impoundment causes erosion of the cohesive deposits. Table 6-7a shows the input data for this example and Table 6-7b shows the output.

6.7.1 Cohesive Sediment Data

This example uses Method 2 (see Sections 2.3.8, 3.3.4.1 and the **I2** record in Appendix A) to compute the deposition and erosion rates for clay and silts. This method requires the addition of two **Special I2** records to provide the data; one for the active layer and one for the inactive layer. The data for the active layer is described below and is illustrated (along with the data for the inactive layer) in Figure 6-7.

The shear stress threshold above which clays and silts will not deposit is 0.02 lb/ft^2. The shear stress at which deposited cohesive material will scour is 0.05 lb/ft^2. The shear stress above which mass erosion occurs is 0.10 lb/ft^2. The erosion rate at that shear stress is 1.5 lb/ft^2/hr. The slope of the mass erosion rate curve is 60/hr. These values are depicted in Figure 30 for both the active and inactive layers. Note that the shear strength of the inactive layer is larger than that of the active layer and it erodes more slowly. This represents, perhaps, the effect of consolidation.

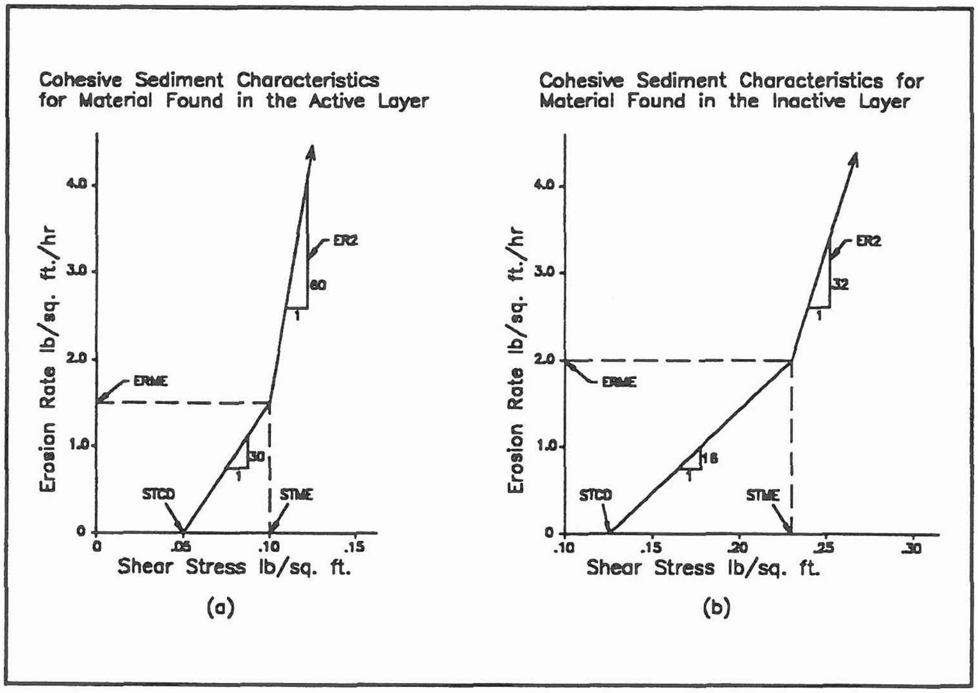

Figure 6-7
Erosion Rate Characteristics

Caution, the cohesive sediment values given in Example Problem 7 are not factual and **should not be used** under any circumstances without field verification. To determine these values, laboratory tests must be performed on the sediments to be simulated. These tests must be done under the same physical and chemical conditions as in the prototype (see Section 2.3.8).

Table 6-7a
Example Problem 7 - Input
Cohesive Sediment

```
T1      EXAMPLE PROBLEM NO 7.  COHESIVE SEDIMENT.
T2      A LAKE IS CREATED.
T3      SOUTH FORK, ZUMBRO RIVER       ** Example Problem 7 **
NC    .1      .1     .04      .1      .3
X1   1.0      31  10077.  10275.      0.      0.      0.
GR 1004.   9915.   978.4  10002.   956.0  10060.   959.2  10077.   959.3  10081.
GR 950.0  10092.  948.48  10108.   946.6  10138.   944.7  10158.   955.2  10225.
GR 956.2  10243.   958.9  10250.   959.8  10275.   959.8  10300.   959.9  10325.
GR 958.8  10350.   957.4  10400.   970.0  10700.   966.0  10960.   970.0  11060.
GR 968.0  11085.   968.0  11240.   970.0  11365.   970.0  11500.   970.0  11615.
GR 962.0  11665.   962.0  12400.   976.0  12550.   980.0  12670.   982.0  12730.
GR 984.0  12735.
HD   1.0     10.  10081.  10250.
NV    22    .045   965.6    .064   988.8
NV    12     .08   965.6     .13   988.8
NV    33      .1   965.6     .11   982.0     .12   988.8
X1  15.0      27  10665.  10850.   3560.   3030.   3280.
X3                        10700.   961.0  11000.   970.0
GR 992.0   9570.   982.0  10110.   976.0  10300.   976.0  10490.   966.0  10610.
GR 964.7  10665.   956.0  10673.   953.0  10693.   954.0  10703.   955.6  10723.
GR 958.6  10750.   959.3  10800.   957.0  10822.   957.3  10825.   961.5  10850.
GR 962.0  10852.   964.0  10970.   966.0  11015.   961.0  11090.   962.0  11150.
GR 970.0  11190.   972.0  11310.   980.0  11410.   984.0  11570.   990.0  11770.
GR 990.0  11865.  1000.0  12150.
HD  15.0     10.  10673.  10852.
NC    .1      .1     .05
    CASCADE CREEK
X1  32.0      29  10057.  10271.   3630.   3060.   4240.
GR 998.0   9080.   982.0   9250.   982.0   9510.   980.0   9600.  980.01   9925.
GR979.48  10000.   978.5  10057.   968.6  10075.  959.82  10087.   956.5  10097.
GR 956.8  10117.   957.8  10137.   959.4  10157.   959.6  10177.  959.82  10196.
GR 966.5  10225.   971.2  10250.   978.5  10271.   978.5  10300.   978.6  10350.
GR978.91  10370.  978.96  10387.   980.0  10610.   982.0  10745.   982.0  11145.
GR 984.0  11150.   992.0  11240.  1000.0  11330.   1008.  11425.
HD  32.0     10.  10075.  10275.
NC   .06     .06    .045
X1  42.0      32   9880.  10130.   8500.   8250.   8530.
GR 996.0   7130.   998.0   7310.   998.0   7930.   992.0   8205.   990.0   8495.
GR 988.0   8780.   986.0   8990.   985.7   9570.  986.45   9707.  989.44   9857.
GR 990.0   9880.   969.8   9881.   969.8   9941.   985.8   9941.   985.8   9943.
GR 969.8   9943.   969.8  10001.   986.7  10001.   986.7  10003.   969.8  10003.
GR 969.8  10067.   985.8  10067.   985.8  10069.   969.8  10069.   969.8  10129.
GR 989.9  10130.   989.5  10180.   988.6  10230.   987.6  10280.   985.2  10430.
GR 986.8  11720.   989.9  12310.
HD  42.0       0   9881.  10021.
  SILVER CREEK
X1  44.0      28   9845.  10127.   3200.   3800.   3500.
XL                         9850.  10200.
GR 1002.   8035.   992.0   8150.   990.0   8305.   990.0   8735.   988.0   8835.
GR 996.0   9285.  1017.6   9425.   990.0   9505.   986.0   9650.   984.1   9788.
GR 980.6   9845.   970.9   9868.   972.2   9898.   970.5   9968.   967.5   9998.
GR 968.9  10028.   967.4  10058.   967.1  10078.   971.9  10118.   976.8  10127.
GR 977.8  10150.   976.9  10193.   982.0  10206.   981.2  10300.   979.2  10325.
GR 983.1  10400.   999.8  10450.  1002.4  10464.
HD  44.0     10.   9868.  10193.
X1  53.0      22  10000.  10136.   3366.   2832.   2942.
GR 1004.   7550.  1000.0   7760.   998.0   8440.   996.0   8640.   996.0   8780.
GR 994.0   8940.   986.0   9245.   986.3   9555.   986.3   9825.   983.8   9900.
GR 982.8  10000.   978.2  10011.   974.0  10041.   972.2  10071.   972.6  10101.
GR 978.2  10121.   988.7  10136.   989.3  10154.   999.2  10200.  1000.1  10320.
GR 1002.  10470.  1004.0  10700.
HD  53.0     10.  10000.  10136.
  BEAR CREEK
X1  55.0      18   9931.  10062.   2275.   3430.   2770.
GR 1004.   7592.  1000.0   7947.   996.0   8627.   990.0   9052.   986.0   9337.
GR 984.3   9737.   984.7   9837.   985.5   9910.   987.2   9931.   978.1   9955.
GR 974.8   9975.   974.2  10005.   972.9  10035.   973.2  10045.   983.8  10062.
GR 985.8  10187.   986.0  10307.   990.0  10497.
HD  55.0     10.   9931.  10062.
X1  58.0      22   9912.  10015.   1098.   1012.   1462.
GR 1006.   8542.  1004.0   8952.  1000.0   9702.   997.2   9812.   996.3   9912.
GR 976.2   9944.   975.4   9974.   978.2   9991.   990.4  10015.   988.3  10062.
GR 988.8  10065.   988.3  10065.   989.3  10169.   990.0  10172.   992.0  10242.
GR 992.0  10492.   988.0  10642.   986.7  10852.   988.0  11022.   986.0  11097.
GR 986.0  11137.   988.0  11192.
HD  58.0     3.4   9912.  10015.
EJ
```

```
T4       South Fork, Zumbro River      ** Example Problem 7 **
T5       LOAD CURVE FROM GAGE DATA.
T6       BED GRADATIONS FROM FIELD SAMPLES.
T7       CLAY and SILT added to full range of Sands and Gravels.
T8       SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]
I1     0       5
I2  CLAY       2
I2  CLAY       1      .02      .05       .1      1.5      60.
I2  CLAY       2      .02     .125      .23      2.0      32.
I3  SILT       2        1        4
I4  SAND       4        1       10
I5            .5       .5      .25       .5      .25        0      1.0
LQ             1       50     1000     5800    90000
LT TOTAL   .0220      3.0      640    9000.   800000
LF  CLAY     .22      .22      .15      .13      .10
LF SILT1     .25      .25      .15     .104      .07
LF SILT2     .18      .18      .13      .12      .05
LF SILT3     .13      .13      .17     .145      .08
LF SILT4     .10      .10     .185     .170     .150
LF   VFS     .06      .06     .105     .156     .230
LF    FS     .04      .04     .066     .090     .160
LF    MS     .02      .02     .027     .060     .115
LF    CS       0        0     .014     .016     .030
LF   VCS       0        0     .003     .005     .010
LF   VFG       0        0        0     .002     .004
LF    FG       0        0        0     .001     .001
LF    MG       0        0        0        0        0
LF    CG       0        0        0        0        0
LF   VCG       0        0        0        0        0
PF EXAMP     1.0      1.0     32.0     16.0     96.5      8.0     95.0      4.0     91.0
PFC  2.0    85.0      1.0     73.0       .5     37.0      .25      8.0     .125      1.0
PFC.0625     0.0
PF EXAMP    32.0      1.0     64.0     32.0     99.5     16.0     99.0      8.0     98.5
PFC  4.0    96.0      2.0     93.5      1.0     83.0      .50     45.5     .250      8.0
PFC .125     1.0    .0625      0.0
PF EXAMP    58.0      1.0     64.0     32.0     97.0     16.0     94.0      8.0     94.0
PFC  4.0    90.0      2.0     79.0      1.0     56.0      .50      4.0     .125      0.0
$HYD
*   B        FLOW 1 = WARM-UP BASE FLOW OF 750 CFS, LAKE IMPOUNDED.
Q   750
R   985
T    65
W     1
$PRT
CP             1
PS          32.0
END
*   AB       FLOW 2 = 100 DAYS AT BANK FULL Q, LAKE IMPOUNDED.
Q  1250.
R   985
X             10      100
$RATING
RC            40     2000        0        0    950.0    955.1    958.0    960.0    962.0
RC         963.6    965.1    966.2    967.0    967.7    968.3    968.9    969.4    969.8
RC         970.2    970.6    971.0    971.4    971.8    972.1    972.4    972.7    972.9
RC         973.1    973.3    973.5    973.7    973.8    973.9    974.0    974.1    974.2
RC         974.3    974.4    974.5    974.6    974.7    974.8    974.9    975.0
*   AC       FLOW 3 = NEAR BANK FULL Q, LAKE LOWERED.
Q  1250.
W    .2
$PRT  A
*   B        FLOW 4 = NEAR BANK FULL Q, LAKE LOWERED.
Q  1250.
X              1      20.
*   B        FLOW 5 = LAST FLOW, BASE FLOW OF 750 CFS, LAKE IS LOWERED.
Q   750.
X              2      20.
$$END
```

6.7.2 Output

The geometric and sediment output provide the same information as in previous examples. When the sediment data is read, HEC-6 produces tables of cohesive sediment properties under the headings "CLAY IS PRESENT" and "SILT IS PRESENT". The remainder of the input sediment data is output as before.

The first time step has a flow of 750 cfs, a duration of 1 day and a downstream water surface (or pool elevation) of 985 ft. The "TRAP EFFICIENCY..." table, TABLE SA-1, shows that only 7% of the inflowing clay load was deposited in the reservoir since the beginning of the simulation, while 73% of the inflowing silts and 100% of the inflowing sands and gravels were deposited. TABLE SB-2, the "STATUS OF THE BED PROFILE...", shows the outflowing load at each cross section for this time step and the cumulative bed change since the start of the simulation. Only Section No. 58.0 shows a significant bed change, but because there are no local inflows, diversions, or tributaries affecting the load at any cross section, the progressive decrease in the outflowing load at each cross section indicates deposition.

In this example, time step 2 represents 10 separate (incremental) time steps each having a duration of 10 days with a starting water surface of 985 ft and a flow of 1250 cfs. At the end of the last incremental time step, output is produced depicting the state of the reservoir for the last 10 day time step (i.e., instantaneous values such as the sediment load data in TABLE SB-2 are only for the last 10 days, while cumulative data, such as trap efficiency and bed change, represent changes since the start of the simulation - 101 days.) Because of this, output produced by this time step can be misleading. For example, the trap efficiency of clay has decreased since time step 1 indicating that erosion has occurred during the 100 days of this time step. However, the outflowing clay load compared to the inflowing clay load (as shown in TABLE SB-1) indicates that deposition is occurring which reflects the difference between instantaneous and cumulative values.

A rating curve representing channel control at the downstream-most section precedes the data for time step 3. Although the flow for time step 3 and 4 remains at 1250 cfs, the starting water surface obtained from the rating curve is much lower, significantly altering the hydraulic parameters. C-level output was requested for time step 3 and limited to Sections 32.0 and 42.0. The increased velocity at Section No. 32.0 results in a bed shear stress of 0.2980 lb/sq ft, which, from Figure 6-7, results in mass erosion of both layers. The computed potential erosion rates for both clay and silt are 141,700 and 44,214 tons/day for the active and inactive layers respectively. The actual erosion rates will be limited by the availability of these materials.

Table 6-7b
Example Problem 7 - Output
Cohesive Sediment

```
*****************************************************      ************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS  *        *  U.S. ARMY CORPS OF ENGINEERS    *
*       Version: 4.1.00 -  AUGUST 1993            *        *  HYDROLOGIC ENGINEERING CENTER   *
*  INPUT FILE:   EXAMPLE7.DAT                     *        *  609 SECOND STREET               *
*  OUTPUT FILE:  EXAMPLE7.OUT                     *        *  DAVIS, CALIFORNIA 95616-4687    *
*  RUN DATE: 31 AUG 93      RUN TIME: 08:21:08    *        *  (916) 756-1104                  *
*****************************************************      ************************************

                         X     X  XXXXXXX   XXXXX          XXXXX
                         X     X  X        X     X        X     X
                         X     X  X        X              X
                         XXXXXXX  XXXX     X       XXXXX  XXXXXX
                         X     X  X        X              X     X
                         X     X  X        X     X        X     X
                         X     X  XXXXXXX   XXXXX          XXXXX

          *********************************************************************
          *  MAXIMUM LIMITS FOR THIS VERSION ARE:                             *
          *       10  Stream Segments (Main Stem + Tributaries)               *
          *      150  Cross Sections                                          *
          *      100  Elevation/Station Points per Cross Section              *
          *       20  Grain Sizes                                             *
          *       10  Control Points                                          *
          *********************************************************************

T1     EXAMPLE PROBLEM NO 7.  COHESIVE SEDIMENT.
T2     A LAKE IS CREATED.
T3     SOUTH FORK, ZUMBRO RIVER        ** Example Problem 7 **

N values...   Left    Channel    Right    Contraction    Expansion
            0.1000    0.0400    0.1000       1.1000        0.7000
```

```
SECTION NO.     1.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

N-Values vs. Elevation Table
       Channel               Left Overbank          Right Overbank
  0.0450     966.         0.0800     966.         0.1000     966.
  0.0640     989.         0.1300     989.         0.1100     982.
  0.0000       0.         0.0000       0.         0.1200     989.

SECTION NO.    15.000
...Left Encroachment defined at station 10700.000 at elevation   961.000
...Right Encroachment defined at station 11000.000 at elevation   970.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

N values...  Left    Channel   Right    Contraction    Expansion
           0.1000   0.0500   0.1000       1.1000        0.7000

SECTION NO.    32.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

N values...  Left    Channel   Right    Contraction    Expansion
           0.0600   0.0450   0.0600       1.1000        0.7000

SECTION NO.    42.000
...DEPTH of the Bed Sediment Control Volume =    0.00 ft.

SECTION NO.    44.000
...Limit CONVEYANCE between stations    9850.000 and   10200.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    53.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    55.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    58.000
...DEPTH of the Bed Sediment Control Volume =    3.40 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  8
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =   8
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA
==========================================================================================

T4       South Fork, Zumbro River      ** Example Problem 7 **
T5       LOAD CURVE FROM GAGE DATA.
T6       BED GRADATIONS FROM FIELD SAMPLES.
T7       CLAY and SILT added to full range of Sands and Gravels.
T8       SEDIMENT TRANSPORT BY Yang's STREAM POWER [ref ASCE JOURNAL (YANG 1971)]

         EXAMPLE PROBLEM NO 7.  COHESIVE SEDIMENT.
         A LAKE IS CREATED.
         SOUTH FORK, ZUMBRO RIVER      ** Example Problem 7 **

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
SEDIMENT PROPERTIES AND PARAMETERS

       SPI      IBG     MNQ       SPGF       ACGR      NFALL      IBSHER
I1     5.        0        1      1.000     32.174          2           1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
CLAY IS PRESENT.

       MTCL     SPGC      PUCD       UWCL       CCCD
I2     2       2.650    78.000     30.000     16.000


  DEPOSITION COEFFICIENTS BY LAYER
                          DEPOSITION
                          THRESHOLD
                            SHEAR
                 LAYER      STRESS
                  NO.      lb/sq.ft

  ACTIVE LAYER   1         0.0200
INACTIVE LAYER   2         0.0200

  EROSION COEFFICIENTS BY LAYER
                      PARTICLE    MASS         MASS         SLOPE OF     SLOPE OF
                      EROSION     EROSION      EROSION      PARTICLE     MASS
                      SHEAR       SHEAR        RATE         EROSION      EROSION
                 LAYER STRESS     STRESS                    LINE=ER1     LINE=ER2
                  NO   lb/sq.ft   lb/sq.ft.    lb/sf/hr     1/hr         1/hr

  ACTIVE LAYER   1     0.0500     0.1000       1.5000       30.0000      60.0000
INACTIVE LAYER   2     0.1250     0.2300       2.0000       19.0476      32.0000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
SILT IS PRESENT

       MTCL     IASL     LASL      SGSL      PUSDLB     UWSDLB      CCSDLB
I3     2        1        4        2.650     82.000     65.000       5.700
```

DEPOSITION COEFFICIENTS BY LAYER

	LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER	1	0.0200
INACTIVE LAYER	2	0.0200

EROSION COEFFICIENTS BY LAYER

	LAYER NO	*PARTICLE EROSION* SHEAR STRESS lb/sq.ft	*MASS EROSION* SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER	1	*0.0500*	*0.1000*	1.5000	30.0000	60.0000
INACTIVE LAYER	2	*0.1250*	*0.2300*	2.0000	19.0476	32.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	10	2.650	0.667	0.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY.............	0.003	COARSE SAND.......	0.707
VERY FINE SILT....	0.006	VERY COARSE SAND..	1.414
FINE SILT.........	0.011	VERY FINE GRAVEL..	2.828
MEDIUM SILT.......	0.022	FINE GRAVEL.......	5.657
COARSE SILT.......	0.044	MEDIUM GRAVEL.....	11.314
VERY FINE SAND....	0.088	COARSE GRAVEL.....	22.627
FINE SAND.........	0.177	VERY COARSE GRAVEL	45.255
MEDIUM SAND.......	0.354		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	0.500	0.500	0.250	0.500	0.250	0.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	1.00000	50.0000	1000.00	5800.00	90000.0
LF CLAY	0.484000E-02	0.660000	96.0000	1170.00	80000.0
LF SILT1	0.550000E-02	0.750000	96.0000	936.000	56000.0
LF SILT2	0.396000E-02	0.540000	83.2000	1080.00	40000.0
LF SILT3	0.286000E-02	0.390000	108.800	1305.00	64000.0
LF SILT4	0.220000E-02	0.300000	118.400	1530.00	120000.
LF VFS	0.132000E-02	0.180000	67.2000	1404.00	184000.
LF FS	0.880000E-03	0.120000	42.2400	810.000	128000.
LF MS	0.440000E-03	0.600000E-01	17.2800	540.000	92000.0
LF CS	0.100000E-19	0.100000E-19	8.96000	144.000	24000.0
LF VCS	0.100000E-19	0.100000E-19	1.92000	45.0000	8000.00
LF VFG	0.100000E-19	0.100000E-19	0.100000E-19	18.0000	3200.00
LF FG	0.100000E-19	0.100000E-19	0.100000E-19	9.00000	800.000
LF MG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF CG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
LF VCG	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19	0.100000E-19
TOTAL	0.220000E-01	3.00000	640.000	8991.00	800000.

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
	0.000						
1.000		183.500	959.300	944.700	958.900	0.000	0.000
	3280.000						
15.000		242.000	961.000	953.700	962.000	3280.000	0.621
	4240.000						
32.000		219.500	968.600	956.500	978.500	7520.000	1.424
	8530.000						
42.000		154.500	969.800	969.800	969.800	16050.000	3.040
	3500.000						
44.000		337.500	970.900	967.100	976.900	19550.000	3.703
	2942.000						
53.000		195.000	982.800	972.200	988.700	22492.000	4.260
	2770.000						
55.000		204.000	987.200	972.900	983.800	25262.000	4.784
	1462.000						
58.000		176.500	996.300	975.400	990.400	26724.000	5.061

BED MATERIAL GRADATION

SECNO	SAE	DMAX (ft)	DXPI (ft)	XPI	TOTAL BED	CLAY	VF SILT	F SILT	M SILT	C SILT	VF SAND	F SAND	M SAND	C SAND	VC SAND	VF GRVL	F GRVL	M GRVL	C GRVL	VC GRVL
1.000	1.000	0.105	0.105	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.010	0.070	0.290	0.360	0.120	0.060	0.040	0.015	0.035	0.000
15.000	1.000	0.151	0.151	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.010	0.070	0.327	0.367	0.113	0.045	0.033	0.011	0.022	0.002
32.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.010	0.070	0.375	0.375	0.105	0.025	0.025	0.005	0.005	0.005
42.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.006	0.048	0.217	0.439	0.161	0.063	0.032	0.003	0.016	0.016
44.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.004	0.039	0.153	0.466	0.183	0.078	0.034	0.002	0.021	0.021
53.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.002	0.031	0.098	0.488	0.202	0.091	0.037	0.001	0.024	0.024
55.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.001	0.024	0.047	0.509	0.220	0.104	0.039	0.000	0.028	0.028
58.000	1.000	0.210	0.210	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.020	0.520	0.230	0.110	0.040	0.000	0.030	0.030

(BED MATERIAL FRACTIONS per grain size)

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	1640.000	203.000	10.000	0.332920E+07	123304.
15.000	3760.000	229.266	10.000	0.862040E+07	319274.
32.000	6385.000	207.517	10.000	0.132500E+08	490740.
42.000	6015.000	187.610	0.000	0.000000	0.000000
44.000	3221.000	282.665	10.000	0.910465E+07	337209.
53.000	2856.000	220.920	10.000	0.630947E+07	233684.
55.000	2116.000	198.870	10.000	0.420808E+07	155855.
58.000	731.000	185.667	3.400	461456.	17091.0

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

$HYD
BEGIN COMPUTATIONS.

TIME STEP # 1
* B FLOW 1 = WARM-UP BASE FLOW OF 750 CFS, LAKE IMPOUNDED.

EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED TIME (yrs).... 0.003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	750.00	373.33	65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	*CLAY* INFLOW	*CLAY* OUTFLOW	*CLAY* TRAP EFF	*SILT* INFLOW	*SILT* OUTFLOW	*SILT* TRAP EFF	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF
1.00	58.000	0.09			0.17			0.04		
TOTAL=	1.000	0.09	0.09	*0.07*	0.17	0.05	*0.73*	0.04	0.00	*1.00*

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	59.51	COARSE SAND.......	0.09
VERY FINE SILT....	60.24	VERY COARSE SAND..	0.02
FINE SILT.........	51.29	VERY FINE GRAVEL..	0.00
MEDIUM SILT.......	63.35	FINE GRAVEL.......	0.00
COARSE SILT.......	66.69	MEDIUM GRAVEL.....	0.00
VERY FINE SAND....	38.05	COARSE GRAVEL.....	0.00
FINE SAND.........	24.05	VERY COARSE GRAVEL	0.00
MEDIUM SAND.......	10.03		
		TOTAL =	373.33

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	55.63	COARSE SAND.......	0.00
VERY FINE SILT....	45.88	VERY COARSE SAND..	0.00
FINE SILT.........	17.36	VERY FINE GRAVEL..	0.00
MEDIUM SILT.......	0.88	FINE GRAVEL.......	0.00
COARSE SILT.......	0.00	MEDIUM GRAVEL.....	0.00
VERY FINE SAND....	0.00	COARSE GRAVEL.....	0.00
FINE SAND.........	0.00	VERY COARSE GRAVEL	0.00
MEDIUM SAND.......	0.00		
		TOTAL =	119.76

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) *CLAY*	*SILT*	SAND
58.000	0.02	985.12	975.42	750.	60.	242.	5.
55.000	0.00	985.06	972.90	750.	60.	242.	0.
53.000	0.00	985.01	972.20	750.	59.	196.	0.
44.000	0.00	985.01	967.10	750.	59.	144.	0.
42.000	0.00	985.01	969.80	750.	58.	100.	0.
32.000	0.00	985.00	956.50	750.	57.	79.	0.
15.000	0.00	985.00	953.70	750.	56.	69.	0.
1.000	0.00	985.00	944.70	750.	56.	64.	0.

```
$PRT
...Selective Printout Option
    - Print at the following cross sections
CP          1
PS         32.0
END
```

TIME STEP # 2

* AB FLOW 2 = 100 DAYS AT BANK FULL Q, LAKE IMPOUNDED.

COMPUTING FROM TIME= 1.0000 DAYS TO TIME= 101.0000 DAYS IN 10 COMPUTATION STEPS

EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED TIME (yrs).......... 0.003

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
1250.000	65.00	985.000

****	DISCHARGE (CFS)	WATER SURFACE	ENERGY LINE	VELOCITY HEAD	ALPHA	TOP WIDTH	AVG BED	AVG VEL (by subsection) 1	2	3
SECTION NO. 32.000										
****	1250.000	985.002	985.002	0.001	3.255	1943.167	963.558	0.037	0.214	0.037
					FLOW DISTRIBUTION (%) =			10.548	78.455	10.997

EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED TIME (yrs).... 0.277
FLOW DURATION (days)...... 10.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 58.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	1250.00	890.88	65.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF
101.00	58.000	20.27			39.47			10.04		
TOTAL=	1.000	20.27	19.54	0.04	39.47	13.42	0.66	10.04	0.00	1.00

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	131.86	COARSE SAND.......	12.75
VERY FINE SILT....	128.18	VERY COARSE SAND..	2.87
FINE SILT.........	115.20	VERY FINE GRAVEL..	0.00
MEDIUM SILT.......	149.14	FINE GRAVEL.......	0.00
COARSE SILT.......	163.84	MEDIUM GRAVEL.....	0.00
VERY FINE SAND....	98.84	COARSE GRAVEL.....	0.00
FINE SAND.........	61.46	VERY COARSE GRAVEL	0.00
MEDIUM SAND.......	26.75		
		TOTAL =	890.88

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	127.12	COARSE SAND.......	0.00
VERY FINE SILT....	110.63	VERY COARSE SAND..	0.00
FINE SILT.........	64.14	VERY FINE GRAVEL..	0.00
MEDIUM SILT.......	14.76	FINE GRAVEL.......	0.00
COARSE SILT.......	0.02	MEDIUM GRAVEL.....	0.00
VERY FINE SAND....	0.00	COARSE GRAVEL.....	0.00
FINE SAND.........	0.00	VERY COARSE GRAVEL	0.00
MEDIUM SAND.......	0.00		
		TOTAL =	316.67

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 101.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
58.000	-0.25	985.38	975.15	1250.	132.	556.	216.
55.000	1.18	985.20	974.08	1250.	132.	556.	79.
53.000	0.24	985.04	972.44	1250.	132.	556.	3.
44.000	0.43	985.03	967.53	1250.	131.	430.	0.
42.000	0.35	985.01	970.15	1250.	130.	292.	0.
32.000	0.14	985.00	956.64	1250.	129.	232.	0.
15.000	0.10	985.00	953.80	1250.	128.	202.	0.
1.000	0.12	985.00	944.82	1250.	127.	190.	0.

$RATING

Downstream Boundary Condition - Rating Curve

Elevation	Stage	Discharge	Elevation	Stage	Discharge
950.000	950.000	0.000	972.400	972.400	40000.000
955.100	955.100	2000.000	972.700	972.700	42000.000
958.000	958.000	4000.000	972.900	972.900	44000.000
960.000	960.000	6000.000	973.100	973.100	46000.000
962.000	962.000	8000.000	973.300	973.300	48000.000
963.600	963.600	10000.000	973.500	973.500	50000.000
965.100	965.100	12000.000	973.700	973.700	52000.000
966.200	966.200	14000.000	973.800	973.800	54000.000
967.000	967.000	16000.000	973.900	973.900	56000.000
967.700	967.700	18000.000	974.000	974.000	58000.000
968.300	968.300	20000.000	974.100	974.100	60000.000
968.900	968.900	22000.000	974.200	974.200	62000.000
969.400	969.400	24000.000	974.300	974.300	64000.000
969.800	969.800	26000.000	974.400	974.400	66000.000
970.200	970.200	28000.000	974.500	974.500	68000.000
970.600	970.600	30000.000	974.600	974.600	70000.000
971.000	971.000	32000.000	974.700	974.700	72000.000
971.400	971.400	34000.000	974.800	974.800	74000.000
971.800	971.800	36000.000	974.900	974.900	76000.000
972.100	972.100	38000.000	975.000	975.000	78000.000

TIME STEP # 3

* AC FLOW 3 = NEAR BANK FULL Q, LAKE LOWERED.

EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED TIME (yrs).......... 0.277

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
1250.000	65.00	953.188

****	DISCHARGE (CFS)	WATER SURFACE	ENERGY LINE	VELOCITY HEAD	ALPHA	TOP WIDTH	AVG BED	AVG VEL (by subsection) 1	2	3
SECTION NO. 32.000										
****	1250.000	965.170	965.207	0.037	1.000	138.791	959.334	0.000	1.543	0.000
					FLOW DISTRIBUTION (%) =			0.000	100.000	0.000

EXAMPLE PROBLEM NO 7. COHESIVE SEDIMENT.
ACCUMULATED TIME (yrs).... 0.277
FLOW DURATION (days)...... 0.200

Vanoni 1975
Vanoni, V. (ed.), *Sedimentation Engineering*, ASCE Manual 54, ASCE, New York, 1975.

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Williams, David T., *H0910 - Computation of Particle Fall Velocity by Shape Factor*, Program No. 722-F3-RO-091, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, September 1980.

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Yang, C. T., "Incipient motion and sediment transport," *Journal of the Hydraulics Division*, ASCE, Vol. 99, No. HY10, Proc. Paper 10067, pp. 1679-1704, October 1973.

Appendix A

Input Description

Introduction

HEC-6 processes data from a single input data file. This introduction provides some basic information about an HEC-6 input data file and its records.

The HEC-6 Input Data Record

This appendix contains a detailed description of the data input requirement for each variable on each input record. In general, the descriptions of records are ordered as the records would appear in a data file. Many of the records described can be omitted if the options to which they apply are not needed.

HEC-6 input records follow the basic HEC-2 input record format. Each record is divided into ten fields of eight columns each, except Field 1. A variable in Field 1 may only occupy columns 3 through 8 since columns 1 and 2 (called Field 0) are reserved for record identification.

The location of the variables for each input record is shown by field number. The values a variable may assume and the conditions for each are described. Where the value of a variable is to be zero, unless otherwise noted, the field may be left blank since a blank field is read as zero. Any number without a decimal point must be right justified in its field. Any number without a sign is considered positive.

The location of variables on records is often referred to by an abbreviated designation;

> Comment records may be used to annotate the input file. HEC-6 identifies any record with Field 0 blank as a comment record. These records are ignored by HEC-6 and will not be repeated in the output.

for example, **X1**.5 refers to the fifth field of the **X1** record.

HEC-6 recognizes only the records described in this appendix. Any unrecognized or misplaced records will, in most cases, cause HEC-6 to terminate execution.

The HEC-6 Input File

A typical HEC-6 input file consists of 3 basic parts. The first part is the river system geometry; the second part is the sediment properties; and the third is the hydrology.

The records described in Section A1 are used to define the geometry of the river system being modeled. Title records (**T1-T3**) are required at the beginning of each stream segment. Each set of **X1** through **H** (or **HD**) records are used to describe the geometry and special features of a cross section along a stream segment. The **QT**, **$TRIB**, and **CP** records are used to combine single stream segments into a river network.

The initial sediment properties and quantities for the model are defined using the records in Section A2. Each stream segment in the river network must be described with a separate set of **T4-PF** records. The information entered on the **I1** through **I5** records pertain to the whole network system. Therefore, they need only be entered with the mainstem sediment data records. If these records are entered with the sediment data for any other stream segment, they will be ignored. Local inflow data (**$LOCAL** and **LQL-LFL** records) are entered after the complete set of sediment records has been entered for the stream segment in which they are located and before the records for the next stream segment.

The records that make up the hydrology data are described in Section A3. The **$HYD** record is used only once to indicate the beginning of the hydrologic data section in the input file. The *, **Q**, and **W** records are entered as a set for each time step (discharge) to be modeled in the hydrologic data. The **T** record is required with the first time step (discharge) and is optional thereafter. All other records are optional and are to be added to the appropriate time step(s). The **$$END** record should be entered as the last record of the input file and can also occur only once.

Section A4 describes records that can be entered to trigger one or more special options. These commands are inserted into the HYDROLOGIC data after the **$HYD** record and immediately before any * record. They are entered one after another, inserted singularly, or used as many times as desired. Some require additional data as explained in the detailed instructions that follow.

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Section A1

Geometry and Channel Properties

A1.1 Title Records (T1 - T3)

Three title records are required at the beginning of the geometric data for each stream segment. Additional output of geometric data can be requested by specifying a B or C in Column 3 on the **T1** record.

Field	Variable	Value	Description
0	ID	T1	Record identification in Columns 1 and 2. Enter **T1**, **T2** and **T3** for the first, second and third title records, respectively.
Column 3 of **T1**, record only	OPTION	Blank (zero not allowed)	**Normal output**-lists data from title records and the **NC** record. Only the cross section identification number is listed for records **X1** through **EJ**.
		B	This option outputs the initial geometry of the model and causes the input records to be echoed in the output enabling the user to verify the initial geometry of the model. B-level output is normally not recommended, but it may provide useful additional information when initially developing a data set.
		C	This option activates trace level output. Use of this print option is not recommended. C-level trace output is intended only for error checking purposes.
2-10		Comments	Fields 2 through 10 (Columns 9-80) may be used for identification purposes such as labeling the data set, noting the date of the run, or other relevant information.

A1.2 NC Record - Manning's *n* values (required for first cross section)

The **NC** record specifies Manning's *n* values and the expansion and contraction coefficients for transition losses. An **NC** is required prior to the first cross section definition (the first **X1** record). When changing previously specified values additional **NC** records are required at those cross sections where *n* values change. The **NC** record values are constant with depth and will be used until changed by the next **NC** record. **NC** records may be inserted before any **X1** record. The *n* values apply over the reach, and will be used starting in the reach in which the record appears in the data set. Expansion and/or contraction coefficients apply to the next upstream reach.

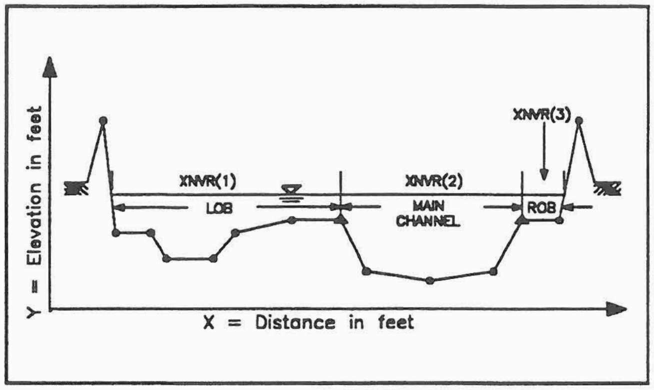

Figure A1-1
Channel and Overbank *n* values

Note: HEC-6 applies *n* values to the upstream reach whereas HEC-2 applies them halfway to the cross section on either side of the one for which they appear in the data set. However, results using either method are usually in close agreement without changing the *n* values.

Field	Variable	Value	Description
0	ID	NC	Record identification.
1	XNVR(1)	+	**Manning's *n* value** for the **left overbank.**
		0	No change from previous *n* value for the left overbank.
2	XNVR(3)	+	**Manning's *n* value** for the **right overbank.**
		0	No change from previous *n* value for the right overbank.
3	XNVR(2)	+	**Manning's *n* value** for the **channel.**
		0	No change from previous *n* value for the **channel.**
4	CC	+	**Contraction coefficient** used in computing transition losses.
		0	No change in contraction coefficient.
5	CE	+	**Expansion coefficient** used in computing transition losses.
		0	No change in expansion coefficient.
6-10			Leave blank.

@ 1.4 D the true overbank N is representative.

A1.3 NV Record[1] - Vary *n* Values by Elevation or Discharge (optional)

A table of Manning's *n* values vs. either elevations or discharges can be entered on the **NV** record. The left overbank, the channel, and the right overbank are the three subsections. A separate **NV** record must be entered for each subsection. Code values in order of **increasing elevation** or **discharge.** The values on this record will be used for all succeeding cross sections until changed by the next **NC** or **NV** record.

HEC-6 linearly interpolates when elevations or discharges are between values specified in the table. When elevations or discharges are outside the range of values specified in the table the extreme values are used; i.e., no extrapolation occurs.

Field	Variable	Value	Description
0	ID	NV	Record identification.
1	NPAR, NCH	++	Enter subsection number in Column 7 and number of *n* values in Column 8. Subsection numbers are: 1 = left overbank 2 = channel 3 = right overbank A maximum of five *n* values are permitted per subsection. (For example, 13 denotes that three *n* values are coded for subsection number 1, the left overbank.)
2	VALN(1)	+	**Manning's *n* value** for lowest elevation in the table. A positive (+) *n* value denotes that a "*n* vs. elevation" table is being defined.
		-	Manning's *n* value for smallest discharge in the table. A negative (-) *n* value denotes that a "*n* vs. discharge" table is being defined. **Note:** Do not mix discharge tables and elevation tables at the same cross section.
3	ELQ(1)	-, 0, +	**The elevation** for positive VALN(1) **or the discharge** for negative VALN(1).
4	VALN(2)	+	Enter the next *n* value in the table. This can be blank if there is only one *n* value for this subsection.
5	ELQ(2)	-, 0, +	Enter the elevation or discharge for VALN(2).
6-10			Continue entering table values across the record. Code the fifth elevation or discharge value in Field 1 of a second **NV** record if five points are desired. **Note:** A maximum of five points may be entered per subsection.

1 This record is different from HEC-2's NV record.

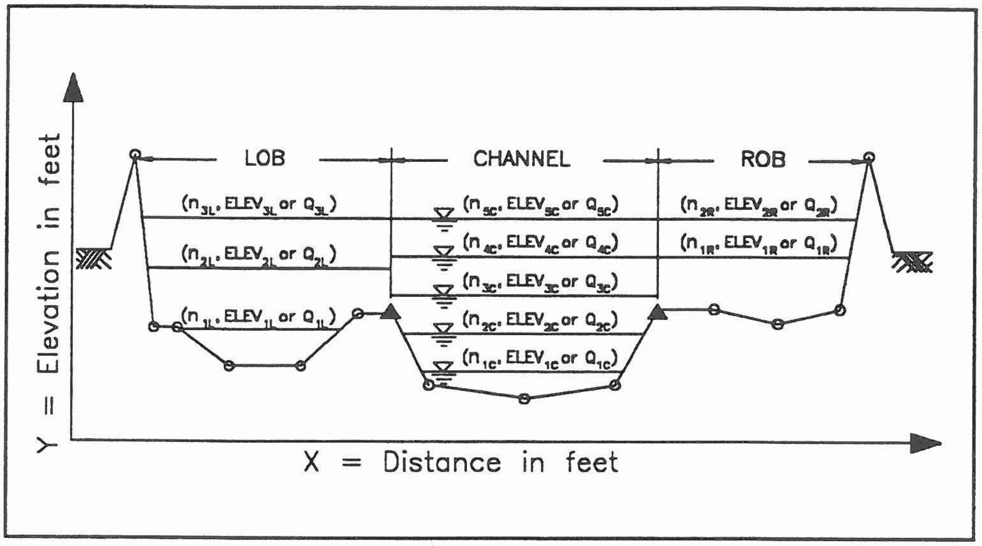

Figure A1-2
An Illustration of VALN and ELQ

Table A1-1
Relationship of *n* values to Elevations or Flows

***n* vs. Elevation**			***n* vs. Discharge**	
VALN(i)	ELQ(i)		VALN(i)	ELQ(i)
$+n_1$	$ELEV_1$		$-n_1$	Q_1
n_2	$ELEV_2$	OR	n_2	Q_2
n_3	$ELEV_3$		n_3	Q_3
n_4	$ELEV_4$		n_4	Q_4
n_5	$ELEV_5$		n_5	Q_5

A1.4 QT Record - Tributary or Local Inflow/Outflow Location (optional)

This record identifies the location of a tributary or a diversion point. It should be placed immediately before the **X1** record for the first cross section upstream from the tributary or local inflow/outflow location. See Section 3.6.2.

Field	Variable	Value	Description
0	ID	QT	Record identification.
1	KQCH		**Control point number.**
			A local inflow/diversion point. When defining a local inflow/outflow point, leave Field 1 blank.
		2-10	**A tributary junction (control) point.** When defining a tributary junction point, a value **must** be entered in Field 1. This value should be within the range 2 through 10.
2-10			Leave blank.

A1.5 X1 Record - Cross Section Location (required for each cross section)

This record is used to identify the cross section and define its location relative to its downstream neighbor. Figure A1-3 illustrates the basic cross section information entered on this record.

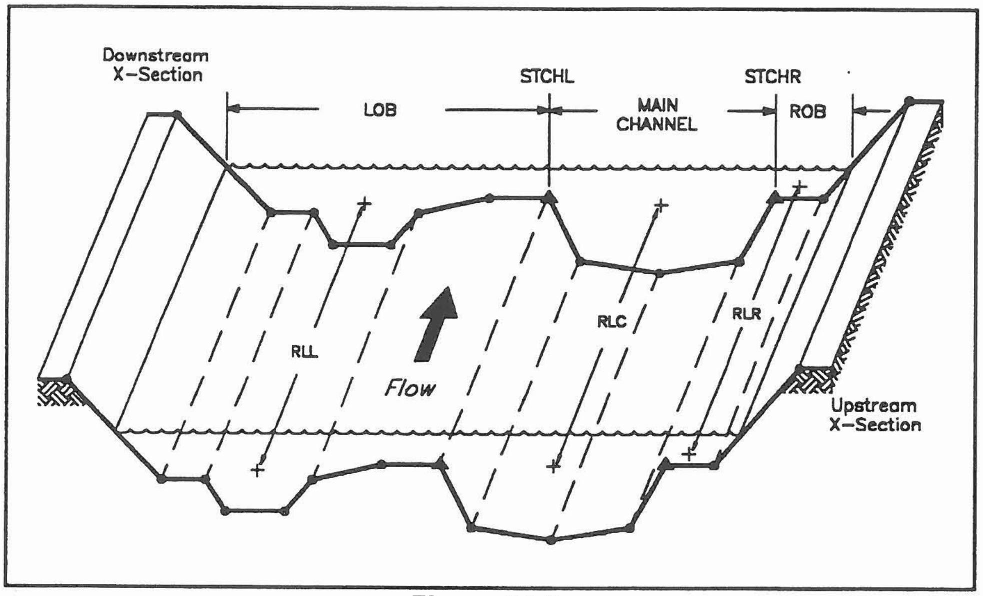

Figure A1-3
Example Illustrating the Main Channel and Right and Left Overbank Reach Lengths Between Consecutive Cross Sections

Field	Variable	Value	Description
0	ID	X1	Record identification.
1	SECID	-, 0, +	**Cross section identification number.**
2	NXY	+	Total **number of coordinate points** used to describe the cross section's geometry on the **GR** records which follow (5 ≤ NXY ≤ 100).
		0	**Repeat Cross Section Option.** The geometry of the previous (downstream) cross section (**GR** records) will be repeated for the present cross section. Therefore, no **GR** records will be entered for this section. Do not enter zero for the first cross section.
3	STCHL	-, +	**Station** of the **left** bank of the channel. Use top-bank when the bank roughness is included in channel *n* values. Toe of bank is recommended when channel bank roughness is included in overbank *n* values. STCHL need not equal one of the station values entered on the **GR** records for this cross section.
		0	For a repeat cross section, enter zero (or blank); i.e., when NXY is zero. The bank stations from the previous section will be used.

Field	Variable	Value	Description
4	STCHR	-, 0, +	**Station** of the **right** bank of the channel. Same rules as for STCHL above.
5	RLL	+	**Reach length** of the **left** overbank between current cross section and the (previous) downstream cross section.
		0	Enter zero (or blank) for the first cross section or when there is no left overbank subsection.
6	RLR	0, +	**Reach length** of the **right** overbank. Same rules apply as for RLL above.
7	RLC	0, +	**Channel Reach Length**. The same rules apply as for overbank reach lengths (RLL and RLR) above.
8	RX		**Cross Section Width Adjustment Factor**. Each station value defined in the **GR** data for this cross section will be **multiplied** by RX. For a repeat cross section, station values from the previous cross section will be changed before they are reused. For example, an RX value of 1.1 would increase each station by 10% and thereby, effectively widen the entire cross section by 10%. **Note:** The left and right channel stations, conveyance limits, ineffective area limits, movable bed limits, and limits of the dredged channel will all be adjusted by RX.
		+	Use a value for RX between 0.0 and 1.0 to narrow the cross section. Use a value greater than 1.0 to widen the cross section.
		0	No change to cross section stations.
9	DH		**Cross Section Elevation Adjustment Factor.** The constant DH will be **added** to each elevation value defined in the **GR** data for the cross section. For a repeat cross section, elevation values from the previous cross section will be changed before they are reused. For example, to describe a 4,000 ft long flume having a 1 ft/thousand slope, just enter the **GR** data for the first cross section and insert four repeat cross sections spaced 1,000 ft apart with DH=1. **Note:** If **NV** records are present, **elevations** will be changed, but the dredging template elevation, **EDC**, (**H**.6 or **HD**.6), is not changed.
		+	Constant that will be added to all elevations.
		-	Constant that will be subtracted from all elevations.
		0	No change to cross section elevations.

A1.6 X3 Record[2] - Encroachments (optional)

The **X3** record provides three methods for defining encroachments to a cross section. These methods are: (1) ineffective flow area, defined using Field 1; (2) effective width, defined using Field 3; and (3) encroachment stations, defined using Fields 4-7. See Section 3.2.6 for a complete description of these three methods.

Field	Variable	Value	Description
0	ID	X3	Record identification.
1	MEID		**Method 1.** Ineffective flow area option.
		10	All water is confined to the channel, as defined by variables STCHL and STCHR on the **X1** record, until the calculated water surface elevation exceeds the channel bank elevation (the elevations corresponding to STCHL and STCHR on the **X1** record). The rest of this record may be left blank. See Figure A1-4.
		0	No ineffective flow area. Total area of the cross section described on **GR** records below the water surface elevation is used in the computations.
2			Leave blank.
3	ENCFP		**Method 2.** Effective width for all flow.
		+	HEC-6 confines all flow to the width specified by ENCFP. It will be centered between the left and right bank stations of the channel (STCHL and STCHR on **X1** record). Side boundaries will be vertical and frictionless. Method 2 may be used in conjunction with Method 1.
		0	The width option is not being used or is not changed from previous value.

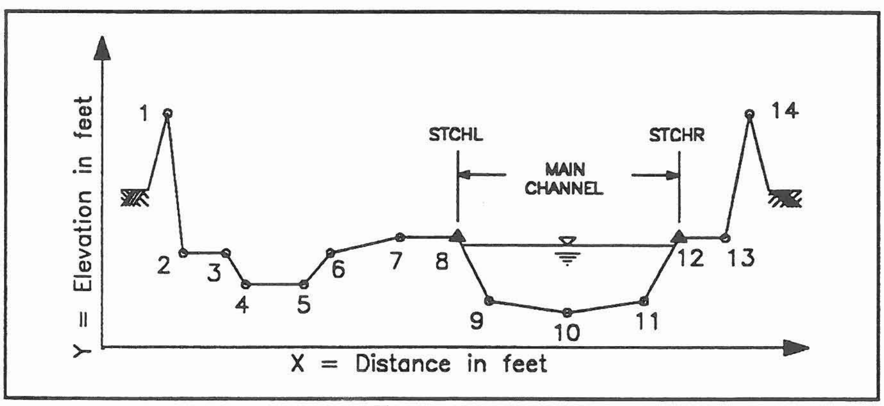

Figure A1-4
Example of Method 1 Encroachment to Keep Flow in the Main Channel up to the Designated Bank Elevations

[2] The HEC-6 **X3** record is different from the HEC-2 **X-3** record.

Field	Variable	Value	Description
4	STENCL		**Method 3.** Encroachment station left. **Method 3 may not be used in conjunction with Methods 1 and/or 2.**
		-, +	STENCL sets a limit for flow on the **left** side of the channel. The side will be vertical and frictionless unless ELENCL is also used (see Field 5 below). See also Figure A1-5. **Note:** Do not enter a station value of zero since it will be treated as if no value was entered. Enter a small positive number like 0.01 instead.
5	ELENCL		**Method 3.** Encroachment elevation left.
		-, +	Enter the elevation at the top of the **left** encroachment. All cross section elevations for stations to the left of STENCL are raised to this elevation. **Note:** Do not enter a value of zero since it will be treated as if no value was entered as cautioned above.
6	STENCR		**Method 3.** Encroachment station right.
		-, +	Same rules and purpose as STENCL but for use on the **right** side of the channel.
7	ELENCR		**Method 3.** Encroachment elevation right.
		-, +	Same rules and purpose as ELENCL but for use on the **right** side of the channel.

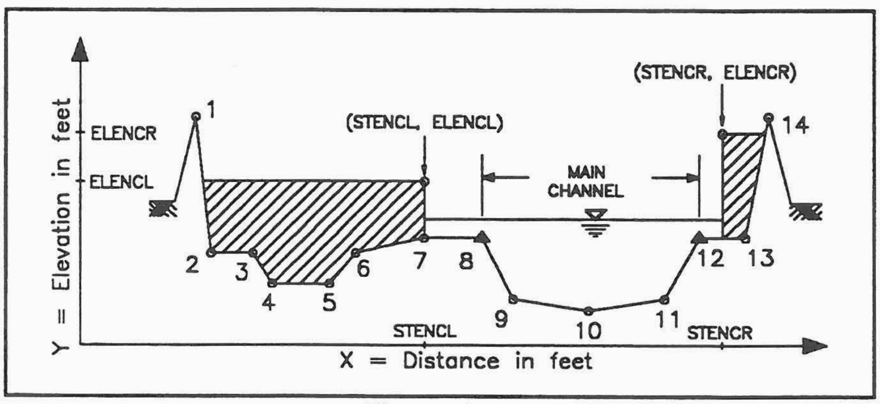

Figure A1-5
Example of Method 3 Encroachment Using Prescribed Stations and Elevations (STENCL, ELENCL)

A1.7 X5[3] Record - Internal Boundary Condition (optional)

The **X5** record creates an internal boundary (or hydraulic control point) within a project reach. If a minimum water surface elevation is specified at this internal boundary, it is called an internal boundary condition.

An internal boundary effectively divides the reach into two subreaches; the cross section where the **X5** is placed becomes the downstream boundary for the reach upstream and the cross section immediately downstream becomes an upstream boundary for the downstream reach. Therefore, **X5** records cannot be placed at successive cross sections, nor can they be placed at the cross section immediately upstream of an existing downstream boundary. It is important to note that the reach immediately downstream from the cross section at which an **X5** record is placed is "transmissive"; i.e., no sediment interaction with the bed is computed in this reach. Therefore, the length of the reach downstream from the **X5** location should be quite short or zero. Because this reach is transmissive, its length can be short (or zero) without impacting upon the time step selection. Use of repeat cross sections facilitates use of the **X5** option.

An internal boundary can be used for two functions: (1) it provides two methods for setting an internal boundary condition as discussed below, and (2) it separates the reach into smaller subreaches for the purposes of sediment volume accounting and trap efficiency calculations. Example Problems 2 through 5 show how to use both methods of feature (1) and Example Problem 7 has an example using feature (2).

Method 1 is used to establish a minimum water surface elevation at dams, weirs, bridges, etc. This method allows the user to define a minimum water surface elevation as the internal boundary condition at an internal cross section. If the computed water surface at the next downstream cross section plus a specified head loss (field 3) is less than the minimum water surface elevation, then the specified elevation is assigned to the internal cross section and the step backwater computations proceed upstream.

Method 2 enables the user to prescribe the minimum water surface elevation at an internal cross section at each time step during the hydraulic computations. This is accomplished by specifying (in field 4 of the **X5** record) the field on the **R** record where the minimum water surface elevation for this cross section can be found. Fields 2 through 10 are available on the **R** record for this purpose, therefore the user may not specify a value less than two nor greater than ten in Field 4 of the **X5** record. The effect of this **R** record field specification occurs each time an **R** record is encountered in the hydrologic data set with a new value in the specified field. When this occurs, the new minimum water surface elevation is compared to the computed water surface of the downstream cross section plus the specified head loss (field 3). As in Method 1, the greater water value is assigned to the internal cross section as the computed water surface elevation.

By separating the project reach into smaller subreaches, the **X5** record provides a mechanism for obtaining trap efficiency and sediment volume accounting for each subreach. This feature is invoked simply by the existence of the **X5** record in the cross section definition. If it is not desired to specify the water surface elevation (internal boundary condition), but trap efficiency values are of interest, simply enter an **X5** record with Fields 1-10 blank.

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[3] The HEC-6 **X5** record is different from the HEC-2 **X5** record.

Field	Variable	Value	Description
0	ID	X5	Record Identification
1			Leave blank.
2	UPE	-, +	**Method 1 - Minimum Water Surface Elevation.** The water surface elevation at this cross section will be UPE unless the water surface at the downstream section plus HLOS exceeds UPE. (HLOS is coded in Field 3.)
		0	Zero indicates that Method 1 is not used. If the desired minimum water surface elevation is zero, enter a small positive value (e.g., 0.001).
3	HLOS	0, +	**Head loss** between this section and the cross section immediately downstream. The specified water surface elevation is overridden when the tailwater elevation plus HLOS is higher.
4	ICSH	2-10	**Method 2 - R Record Field.** This method allows the user to specify the minimum water surface elevation for this cross section on each **R** record in the hydrologic data set. The value entered here is the number of the field of each **R** record where HEC-6 will look for the minimum water surface elevation for this cross section (see R record description in Section A3.4). **Note:** Do not use ICSH=1. Field 1 is reserved for specifying the water surface elevation at the downstream boundary control point.
		0	Zero indicates that Method 2 is not used. When using Method 2, allowable values are in the range from 2 to 10.

Allows deposition beyond limits but not scour.

A1.8 XL Record - Conveyance Limits (optional)

Shows deposition beyond w/o conveyance

Two methods are available for specifying conveyance limits. In Method 1, only a width is specified which is centered between the left and right bank stations specified on the **X1** record. Use Field 3 to specify this width and leave Fields 4 and 5 blank. In Method 2 both a left and right station must be specified to define the conveyance portion of the channel. Enter the left and right stations for the conveyance limits in Fields 4 and 5 and enter a zero in Field 3 or simply leave it blank.

Field	Variable	Value	Description
0	ID	XL	Record identification.
1-2			Leave blank.
3	CLC	+	**Method 1.** Enter the width of the conveyance channel. It will be centered between left and right bank stations (STCHL and STCHR on **X1** record).
		0	Use Method 2.
4	CLL	-, +	**Method 2.** Enter the cross section station for the **left** side of the conveyance channel. It does not have to coincide with a **GR** station point. It can be any place in the cross section, but it must be less than CLR. **Note:** Do not enter a value of zero since it will be interpreted as though no value was entered. Enter a small positive value (e.g., 0.001) when a value of zero is desired.
5	CLR	-, +	**Method 2.** Enter the cross section station on the right side of the conveyance channel. It does not have to coincide with a coordinate point. It can be any place in the cross section, but it must be greater than CLL. **Note:** Do not enter a value of zero since it will be interpreted as though no value was entered. Enter a small positive value (e.g., 0.001) when a value of zero is desired.
6-10			Leave blank.

Scour Area – place movable bed in the channel

Deposit Area – place movable bed beyond the channel

A1.9 GR Record - Cross Section Coordinates (required)

Cross section geometry is defined as a series of elevation and station coordinates. The **GR** records specify the elevation and station of each coordinate used to describe the geometry of a cross section as illustrated in Figure A1-6. A set of **GR** records is required for each cross section unless NXY (**X1**.2) is zero indicating a repeat cross section. Stations must be entered in increasing order. Enter up to five coordinates per **GR** record. A maximum of 100 points (or twenty **GR** records) per cross section is permitted.

Field	Variable	Value	Description
0	ID	GR	Record identification.
1	EL(1)	-, 0, +	**Elevation** of first ground point.
2	STA(1)	-, 0, +	**Station** of first ground point.
3	EL(2)	-, 0, +	**Elevation** of second ground point.
4	STA(2)	-, 0, +	**Station** of second ground point.
5-10			Etc., continue elevation and station values for up to 100 ground point pairs. Each continuation record is identified with **GR** in Field 0, and the format is identical for all records.

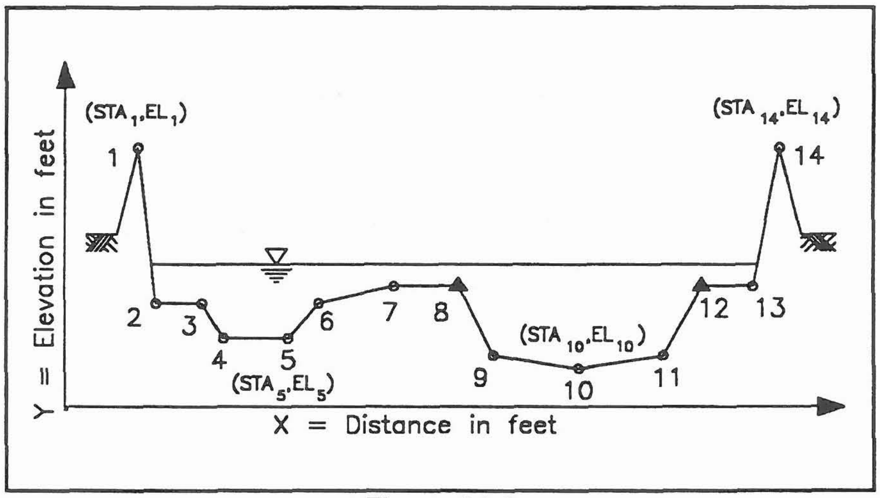

Figure A1-6
Example of GR Station and Elevation Pairs Defining a Channel Cross Section

A1.10 H Record - Movable Bed Limits (required if not using HD Record)

This record prescribes the width and depth of the bed sediment control volume and the dredging template at a cross section. HEC-6 computes the depth of sediment in the bed from the elevation of the model bottom, **EMB**, defined in Field 2 of this record. The **HD** record allows the user to directly prescribe the depth of the bed sediment control volume in Field 2. Other data on this record is the same as the **HD** record and either record is acceptable. Note that if a movable bed limit coincides with a GR point, that point is movable.

Field	Variable	Value	Description
0	ID	H or HD	Record identification.
1	SECID	-, +	**Cross Section Identification Number.** Use the same value as previously entered in **X1.1** for this cross section.
For H Record			
2	EMB	-, +	**Elevation of Model Bottom** (EMB). Enter the desired elevation. HEC-6 will not scour the bed below this elevation. **Beware**, a large depth of sediment can cause calculated volumes to be too large for computer word lengths, resulting in program failure.
		0	HEC-6 sets EMB to 10 ft below the minimum channel elevation of this cross section.
For HD Record			Scour should not be grtr than DSM
2	DSM	0, +	**Depth of the Bed Sediment Control Volume** at this cross section. Negative values are not permitted. There is no default. (See warning for EMB above.) Lv blank for concrete lined channel for no scour
3	XSM	-, +	**Movable Bed Boundary, Left.** Cross section station at change from fixed bed to movable bed; counterpart to XFM (H.4). Cross section coordinates between and including XSM and XFM will be adjusted vertically for scour and deposition. This station need not coincide with an existing **GR** point.
		0	HEC-6 will automatically set the movable bed limits according to the location of the water surface.
4	XFM	-, +	**Movable Bed Boundary, Right.** Cross section station at change from movable bed to fixed, counterpart to XSM (H.3). See XSM.
		0	HEC-6 will automatically set the movable bed limits according to the location of the water surface.
5			Leave blank.

A1.9 GR Record - Cross Section Coordinates (required)

Cross section geometry is defined as a series of elevation and station coordinates. The **GR** records specify the elevation and station of each coordinate used to describe the geometry of a cross section as illustrated in Figure A1-6. A set of **GR** records is required for each cross section unless NXY (**X1**.2) is zero indicating a repeat cross section. Stations must be entered in increasing order. Enter up to five coordinates per **GR** record. A maximum of 100 points (or twenty **GR** records) per cross section is permitted.

Field	Variable	Value	Description
0	ID	GR	Record identification.
1	EL(1)	-, 0, +	**Elevation** of first ground point.
2	STA(1)	-, 0, +	**Station** of first ground point.
3	EL(2)	-, 0, +	**Elevation** of second ground point.
4	STA(2)	-, 0, +	**Station** of second ground point.
5-10			Etc., continue elevation and station values for up to 100 ground point pairs. Each continuation record is identified with **GR** in Field 0, and the format is identical for all records.

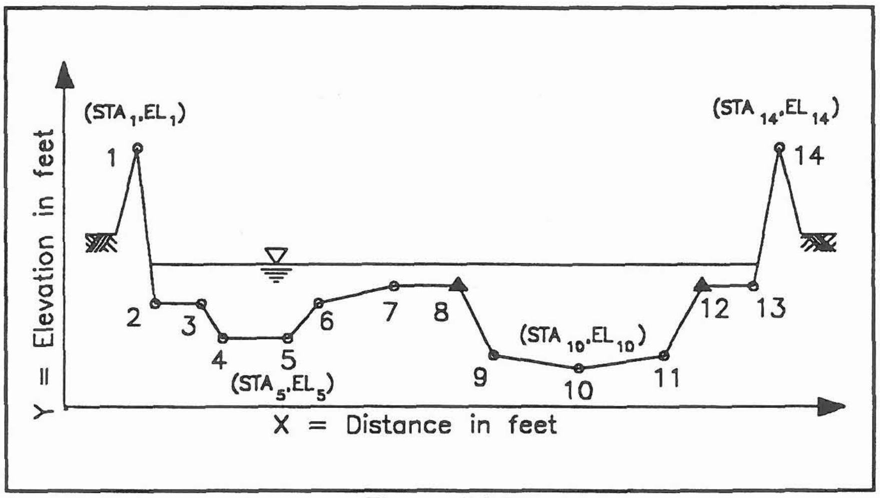

Figure A1-6
Example of GR Station and Elevation Pairs Defining a Channel Cross Section

A1.10 H Record - Movable Bed Limits (required if not using HD Record)

This record prescribes the width and depth of the bed sediment control volume and the dredging template at a cross section. HEC-6 computes the depth of sediment in the bed from the elevation of the model bottom, **EMB**, defined in Field 2 of this record. The **HD** record allows the user to directly prescribe the depth of the bed sediment control volume in Field 2. Other data on this record is the same as the **HD** record and either record is acceptable. Note that if a movable bed limit coincides with a GR point, that point is movable.

Field	Variable	Value	Description
0	ID	H or HD	Record identification.
1	SECID	-, +	**Cross Section Identification Number.** Use the same value as previously entered in **X1.1** for this cross section.
For H Record			
2	EMB	-, +	**Elevation of Model Bottom** (EMB). Enter the desired elevation. HEC-6 will not scour the bed below this elevation. **Beware**, a large depth of sediment can cause calculated volumes to be too large for computer word lengths, resulting in program failure.
		0	HEC-6 sets EMB to 10 ft below the minimum channel elevation of this cross section.
For HD Record			Scour should not be grtr than DSM
2	DSM	0, +	**Depth of the Bed Sediment Control Volume** at this cross section. Negative values are not permitted. There is no default. (See warning for EMB above.) Lv blank for concrete lined channel for no scour
3	XSM	-, +	**Movable Bed Boundary, Left.** Cross section station at change from fixed bed to movable bed; counterpart to XFM (H.4). Cross section coordinates between and including XSM and XFM will be adjusted vertically for scour and deposition. This station need not coincide with an existing **GR** point.
		0	HEC-6 will automatically set the movable bed limits according to the location of the water surface.
4	XFM	-, +	**Movable Bed Boundary, Right.** Cross section station at change from movable bed to fixed, counterpart to XSM (H.3). See XSM.
		0	HEC-6 will automatically set the movable bed limits according to the location of the water surface.
5			Leave blank.

Field	Variable	Value	Description
6	EDC	-, +	**Elevation of Bottom of Dredged Channel.** Do not include overdredging here (see H.10). This value should always be above the model bottom. (EMB in field H.2.)
		0	Dredging is not desired at this cross section. If the desired elevation of the dredged bottom channel is zero, enter a small positive value.
7	XSD	-, +	**Dredged Channel Boundary, Left.** Enter the station of the cross section coordinate point on the left side of the dredged channel, so that the elevation of coordinate points within the dredged channel (from XSD to XFD (H.8)) can be corrected for dredging. XSD **should always be greater than or equal to** XSM.
		0	XSD is set equal to XSM (H.3).
8	XFD	+	**Dredged Channel Boundary, Right**. Enter the station of the cross section point at the right of the dredged channel, beyond which no dredging is performed, counterpart to XSD. XFD **should always be less than or equal** to XFM.
		0	XFD is set equal to XFM (H.4).
9	XDM	+	Cross section **station of highest elevation** inside the dredge template. HEC-6 tests the elevation of that point against the elevation of dredged channel to determine whether or not dredging is required. Enter the station value of the cross section having the highest elevation within the portion of channel to be dredged.
		0	HEC-6 uses the first (left-most) station within the dredged channel portion of the cross section.
10	DOD	+	Depth of Overdredging. Used to establish some extra depth below the required bottom elevation. Enter the amount of overdredging desired at this cross section. Do not allow overdepth dredging below the bottom of the bed sediment control volume.
		0, b	Leave blank if overdredging is not required.

A1.11 EJ Record (required) - End of Geometric Data

End of geometric model data is established by an **EJ** record. This record must be the last geometry record entered for each stream segment described in the geometry section.

Field	Variable	Value	Description
0	ID	EJ	Record identification.
1-10			Leave blank.

A1.12 $TRIB Record - Tributary Inflow Point (optional)

This is the HEC-6 record which identifies the beginning of the geometry or sediment data set for each tributary in the stream network. The difference between a tributary and a local inflow is that the tributary is a branch in the network geometry data set whereas a local inflow point has no geometry. Refer to Section 3.6 for instructions on assembling data for tributary systems.

Place a **$TRIB** command in front of each tributary geometric data set and in front of each tributary sediment data set.

Important Note: A **$TRIB** record for this version of HEC-6 has a different meaning than a **$TRIB** record for versions released prior to June 1991. A **$TRIB** record from an old (pre 1991) data file should be changed to a **$LOCAL** record in order to run the data using Version 4.0 or later of HEC-6.

Field	Variable	Value	Description
0	ID	$TRIB	Record identification (Columns 1 - 5).
2-10			Leave blank.

A1.13 CP Record - Control Point Identification (optional)

The **CP** record is used to associate each tributary data set with the cross section where it enters the network. The value entered in Field 1 should equal that given on the **QT** record associated with the tributary.

A **CP** record must follow each **$TRIB** record used in the geometry data set. The appropriate records (described previously in this section) needed to detail the geometry of the tributary should follow the **CP** record.

Field	Variable	Value	Description
0	ID	CP	Record identification.
1	JPNUM	+	Junction (control) point number.
2-10			Leave blank.

Section A2

Sediment Properties

and

Transport Functions

A2.1 Title Records - Comments (five required - T4 - T8)

Five Title Records are required to precede the sediment data **for each segment** in a network. They each have a T in Column 1 and the sequence number in Column 2. The number four is suggested for the first sequence number. A Data Echo print option is available; see below for details.

Field	Variable	Value	Description
0	ID	T4	Record identification in Columns 1 and 2. **T4**, **T5**, **T6**, **T7**, and **T8** for the fourth through eighth title records, respectively.
Column 4 of **T4** record only	OPTION	B	**Data Echo.** Each input record is echoed to the output file as it is read. This is available to help the user verify the initial conditions and is not recommended for normal use. To exercise this option, enter B in Column 4 of the first title record (**T4**) of this group. Otherwise leave blank.
1-10[4]			Fields 1 through 10 (Columns 5-80) may be used for identifying the stream segment, project date, or any other relevant information.

[4] Column 4 of the first title record (T4) is reserved for requesting an output option that echoes the input and should be left blank if a data echo is not required.

A2.2 I1 Record - Sediment Properties (required)

The **I1** record contains sediment properties.

Field	Variable	Value	Description
0	ID	I1	Record identification.
1			Leave Blank.
2	SPI		**Iterations** of the Exner computations.
		+	Specify the number of exchange increments used during each time step to recalculate the composition of material in the bed. **Note:** More than any other input variable, SPI affects computation time. If too small of a value is used, calculations may display oscillations in the amount of sediment being transported and in the bed profile. The value can be increased to 20 or more, until the computed results are essentially the same as those calculated with SPI left blank or zero.
		0	HEC-6 calculates a value for SPI. **Note:** The value of SPI computed by HEC-6 (if the user does not specify a value) can be very large for some problems. We suggest that users avoid using values greater than SPI = 50. A message will appear in your output if the computed SPI value is greater than 50. If the user chooses to use the larger values, the desired SPI must be entered in Field 2 (**I1**.2) and HEC-6 re-executed. Refer to Section 2.3.4.1 and Training Document No. 13, "Guidelines for the Calibration and Application of Computer Program HEC-6" (HEC 1992), for further discussion.
3	IBG		**Gradation Calculation Method**. Instructs HEC-6 to calculate gradation in surface layer based upon transport capacity required to just transport the inflowing load with no scour or deposition if possible. Use this option only if bed material gradations are not available.
		0	HEC-6 uses gradation on **PF** records to calculate transport capacity.
		+IBG	HEC-6 calculates gradation of surface layer based on inflowing load and sediment transport theory. Iterative process performed in IBG iterations.
4			Leave Blank.

Field	Variable	Value	Description
5	SPGF	+	**Specific Gravity of Fluid.** It is used with density and acceleration of gravity to calculate unit weight.
		0	HEC-6 uses SPGF=1.0000 (fresh water at 39.2 degrees F).
6	ACGR	+	**Acceleration Due to Gravity.**
		0	HEC-6 uses G=32.174 ft/sec^2 (standard at 45 degrees latitude, sea level).
7	NFALL		**Fall Velocity Computation Method.** Refer to Section 2.3.7, for a discussion of the available methods.
		0	HEC-6 defaults to Method 2.
		1	Original Toffaleti (1966) method for computing fall velocities.
		2	Federal Interagency Sedimentation Project (ICWR 1957 & Williams 1980) method for computing fall velocities.
8	IBSHER		**Bed Shear Stress Computation Method.**
		0, 1	HEC-6 calculates bed shear stress as γDS for clay/silt erosion and deposition.
		2	HEC-6 uses U_* from smooth wall law to calculate bed shear stress for clay/silt erosion and deposition.

A2.3 I2 Record - Parameters Required for Clay Transport (optional)

The presence of an **I2** record instructs HEC-6 to calculate transport of clay. The data included on this record provides parameters and guidelines with which to structure the computations for clay transport.

Note: The clay transport relationships were derived from experiments where the suspended sediment concentrations were less than 300 mg/ℓ (Krone 1962). Applications to field situations where suspended sediment concentrations are greater than 300 mg/ℓ may exceed the intended range of applicability of the relationships. Also note, that the relationships for clay deposition were derived from one-dimensional channels where the velocity and sediment concentration profiles are reasonably uniform. Users may experience difficulty simulating clay deposition rates in deep reservoirs.

If the **I2** record is used by itself, HEC-6 will only compute **deposition** of clay. However, if two **Special I2** records are used in addition to the first **I2**, both deposition **and** erosion of cohesive sediment (clay and silt) will be computed.

Field	Variable	Value	Description
0	ID	I2	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	MTCL		**Clay Transport Method.**
		0, 1	**Deposition** of clay using settling velocity is computed **only. No clay erosion** is computed.
		2	**Deposition and erosion of cohesive sediments** are computed. Deposition is computed by the Krone (1962) equation and erosion by the Ariathurai (1976) method. Note that this method requires the addition of two **Special I2** records.
3	ICS	b, 1	Initial size class interval for clay - there is only one clay size available, so enter 1 or leave blank.
4	LCS	b, 1	Last size class interval for clay - there is only one clay size available, so enter 1 or leave blank.
5	SPGC	+	**Specific gravity** of clay particles.
		0	The default is 2.65.
6	DTCL	+	**The shear threshold for clay deposition.** This is the average bed shear stress in lbs/sq ft above which clay will not be deposited. This value is ignored when the **Special I2** records are used.
		0	The default is 0.02 lb/sq ft.
7			Leave blank.

Field	Variable	Value	Description
8	PUCD	+	The unit of weight for fully compacted clay deposits, lb/cu ft.
		0	The default is 78 lb/cu ft.
9	UWCL	+	The initial (before compaction) unit weight for clay deposits, lb/cu ft.
		0	The default is 30 lb/cu ft.
10	CCCD	+	Compaction coefficient for clay deposits for the equation: $\gamma_{clay} = UWCL + [CCCD \cdot \log_{10}(Time)]$ where time is in years. See Section 2.3.6.3.
		0	The default is 16 lb/cu ft.

A2.4 Special I2 Records - Cohesive Sediment Transport Method 2 - Supplemental Parameters (optional)

The **Special I2** records are used to prescribe the depositional and erosional shear stress thresholds for fine grained cohesive sediment (clay and silt) to be used by clay and silt transport Method 2 (MTCL - **I2**.2, MTSL - **I3**.2). Refer to Section 2.3.9. If used, two **Special I2** records must be employed (in addition to the first **I2** record described on the preceding pages): one to describe the active layer and one to describe the inactive layer.

Note: The clay transport algorithms were derived from experiments where the suspended sediment concentrations were less than 300 mg/ℓ (see Krone, 1962). Applications to field situations where suspended sediment concentrations may be greater than 300 mg/ℓ may exceed the intended range of applicability of the relationships. Also note, that the relationships for clay deposition were derived from one-dimensional channels where the velocity and sediment concentration profiles are reasonably uniform. Users may experience difficulty simulating clay deposition rates in deep reservoirs.

The erosion parameters defined on the **Special I2** records apply to silt as well as clay sediments. If erosion of silt sizes is desired, then an **I3** record must follow the **Special I2** record.

Field	Variable	Value	Description
0	ID	I2	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	J	1	Data on this record applies to the active layer (the first **Special I2** record).
		2	Data on this record applies to the inactive layer (the second **Special I2** record).
3	DTCL	+	**The shear threshold for clay and silt deposition.** This is the average bed shear stress in lbs/sq ft above which clay and silt will not be deposited.
		0	The default is 0.02 lb/sq ft.
4	STCD	+	**Shear stress threshold for erosion of clay and silt particles,** lb/sq ft. This is the shear stress above which clay and silt material will be scoured from the bed[5].
5	STME	+	**Shear stress threshold for mass erosion,** lb/sq ft.[5]
6	ERME	+	**Erosion rate of clay and silt** at STME, lb/sq ft/hr.[5]
7	ER2	+	**Slope of the erosion rate curve** for mass erosion, 1/hr.[5]

[5] There is no default, user must enter a value.

A2.5 I3 Record - Parameters Required for Silt Transport (optional)

The presence of an **I3** record instructs HEC-6 that the mixture of sediment to be analyzed contains silt size particles. The data included on this record provides parameters and guidelines within which to structure the computations for silt transport. Do not attempt to include silt particles without also including clay. If no clay is present in the system, enter zero for clay on the **LF** and **PF** records.

When modeling erosion of silts, you must provide an **I2** and two **Special I2** records to define erosion parameters of silt grains.

Field	Variable	Value	Description
0	ID	I3	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	MTSL		**Silt Transport Method**
		1	Settling velocity method for calculating deposition of silt.
		2	Method for computing scour and deposition of silt. **Note:** This method requires the use of an **I2** record and two **Special I2** records, as described on the preceding pages.
3	IASL	+	ID number of the **smallest grain size classification** of silt to be transported (see Table A2-1). IASL must always be less than LASL.
		0	Default IASL=1.
4	LASL	+	ID number of the **largest grain size classification** of silt to be transported (see Table A2-1).
		0	Default LASL=4.

Table A2-1
Grain Size Classes; Silts

ID Number	Classification	Grain Size (mm)	Geometric Mean (mm)
1	Very fine silt	.004 - .0080	.005
2	Fine	.008 - .0160	.011
3	Medium	.016 - .0310	.022
4	Coarse	.031 - .0625	.044

The data in Table A-2 is predefined in HEC-6; IASL and LASL must be selected from this table. HEC-6 automatically includes all sizes between IASL and LASL if the **I3** record is present in the input. If transport of clay is to be computed as well as silts, IASL should equal one to provide a continuous representation of grain size classes from clay to silts. If transport of sands is to be computed as well as silts, LASL should equal four for the same reason. Grain sizes which are not found in the bed may be so noted (with zero values) in the bed material gradation specified on the **PF** records.

Field	Variable	Value	Description
5	SGSL	+	**Specific gravity** of silt particles.
		0	Default = 2.65
6	DTSL		**Deposition threshold** for silt.
		+	The average bed shear stress in lb/sq ft above which silt material will not be deposited. This value is ignored if **Special I2** records are used.
		0	Default = 0.02 lb/sq ft (for lack of better data).
7			Leave blank.
8	PUSD	+	**Unit weight** of fully consolidated silt deposits in lb/cu ft.
		0	Default = 82 lb/cu ft.
9	UWSL	+	**Unit weight** of silt material at the moment it is deposited on the stream bed.
		0	Default = 65 lb/cu ft.
10	CCSD	+	**Compaction coefficient** for silt deposits for the equation $\gamma_{silt} = UWSL + [CCSD \cdot (\log_{10}(Time)]$ where time is the accumulated simulation time expressed in years.
		0	Default = 5.7 lb/cu ft/yr.

A2.6 I4 Record - Parameters Required for Sand Transport (optional)

The presence of an **I4** record indicates that sand sizes are present in the mixture of sediment to be analyzed. The data on this record provides parameters and guidelines within which to perform the computations for sand transport.

Field	Variable	Value	Description
0	ID	I4	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	MTC		**Transport capacity relationship**[6] to be used by HEC-6 to compute sediment load for a given water discharge.
		0, 1	Toffaleti's (1966) transport function.
		2	**User Specified Transport Function.** User specification of transport coefficients based upon observed data. User must supply his own transport relationship in the form of DS vs. transport coefficients (on records **J** and **K**), where DS is depth times slope. See instructions for the **J** and **K** records for a more complete description.
		3	Madden's (1963) modification of Laursen's (1958) relationship
		4	Yang's (1973) stream power for sands
		5	DuBoys' transport function (Vanoni 1975)
		6	Not used
		7	Ackers-White (1973) transport function
		8	Colby (1964) transport function
		9	Toffaleti (1966) and Schoklitsch (1930) combination
		10	Meyer-Peter and Müller (1948)
		11	Not used
		12	Toffaleti and Meyer-Peter and Müller combination
		13	Madden's (1985, unpublished) modification of Laursen's (1958) relationship
		14	Copeland's (1990) modification of Laursen's relationship (Copeland and Thomas 1989)

[6] Users should refer to Chapter 2 of Vanoni's Sedimentation Engineering (1975), for information regarding the best transport function to use for specific types of rivers and bed material types.

Field	Variable	Value	Description
3	IASA	+	ID number of the **smallest grain size classification** of sand to be transported in the calculations (see Table A-3). IASA must always be less than LASA.
		0	Default IASA = 1.
4	LASA	+	ID number of the **largest grain size classification** of sand to be transported in the calculations (see Table A-3).
		0	Default LASA = 10.

The following table of grain sizes is predefined in HEC-6. IASA and LASA must be selected from this table. All sizes between, and including, IASA and LASA will be transported. If transport of silts is to be computed as well as sands, IASA should equal one to provide a continuous representation of grain size classes from silts to sands even if the very fine sand sizes are not found in the bed. Grain sizes which are not found in the bed may be so noted in the bed material gradation specified on the **PF** record.

Table A2-2
Grain Size Classes; Sands

ID Number	Classification	Grain Size (mm)	Geometric Mean (mm)
1	Very Fine Sand	.062 - .125	.088
2	Fine Sand	.125 - .250	.177
3	Medium Sand	.25 - .50	.354
4	Coarse Sand	.50 - 1.0	.707
5	Very Coarse Sand	1 - 2	1.414
6	Very Fine Gravel	2 - 4	2.828
7	Fine Gravel	4 - 8	5.657
8	Medium Gravel	8 - 16	11.31
9	Coarse Gravel	16 - 32	22.63
10	Very Coarse Gravel	32 - 64	45.26
11	Small Cobbles (SC)	64 - 128	90.51
12	Large Cobbles (LC)	128 - 256	181.0
13	Small Boulders (SB)	256 - 512	362.0
14	Medium Boulders (MB)	512 - 1024	724.1
15	Large Boulders (LB)	1024 - 2048	1446.2

Field	Variable	Value	Description
5	SPGS	+	**Specific gravity of sand particles.** (Not the unit weight of deposited material.)
		0	Default = 2.65.
6	GSF	+	**Grain shape factor.**
		0	Default = 0.667.
7	BSAE	+	**Coefficient in surface area exposed function.** Equation is as follows: $FSAE = ASAE(SAE^{BSAE}) + CSAE$
		0	Default = 0.5.
8	PSI	+	**The parameter ψ from Einstein's (1950) method** is used to approximate ψ^* for calculating equilibrium bed elevation. See Section 2.3.2.1.
		0	Default = 30.
9	UWD	+	**Unit weight of deposited sediment.** Specify in lb/cu ft.
		0	Default UWD = 93 lb/cu ft, a reasonable value for sand. HEC-6 does not change this value with time.

A2.7 I5 Record - Weighting Factors for Numerical Integration Method (optional)

Use this record to enter hydraulic parameter weighting factors. Section 2.2.4 presents two sets or schemes of weighting factors for the numerical integration method used by HEC-6. If the **I5** record is omitted, HEC-6 defaults to the Scheme 2 weighting factors. All values must be supplied.

Field	Variable	Value	Description
0	ID	I5	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	DBI	+	Weight assigned to hydraulic properties at second cross section when calculating at downstream boundary.
3	DBN	+	Weight assigned to hydraulic properties at downstream boundary for downstream boundary calculations.
			Note: DBI + DBN must equal 1.0.
4	XID	+	Weight assigned to hydraulic properties at the downstream cross section - interior point calculations.
5	XIN	+	Weight assigned to hydraulic properties at cross section of interest - interior point calculations.
6	XIU	+	Weight assigned to hydraulic properties at the upstream cross section - interior point calculations.
			Note: XID + XIN + XIU must equal 1.0.
7	UBI	+	Weight assigned to hydraulic properties at next to last cross section for calculation at upstream boundary.
8	UBN	+	Weight assigned to hydraulic properties at upstream boundary.
			Note: UBI + UBN must equal 1.0.

A2.8 J Record[7] - User Specified Transport Function (optional)

Use the J record to define the coefficients of the User Specified Transport Function. This function is expressed by the equation:

$$GP_i = ((((EFD \cdot SLO) - C_i)/A_i)^{B_i}) \cdot EFW \cdot STO$$

where: A_i, B_i, C_i = coefficients entered on the J records in units of tons/day/foot of width for each grain size
STO = correction factor computed from the coefficients on the K record
EFD = effective depth
EFW = effective width
SLO = energy slope
GP = potential transport per grain size

A separate J record is required for each grain size fraction being evaluated. Enter data from fine to coarse. The data contained on the J and K records is relevant to HEC-6 only if the selected transport capacity relationship, MTC (I4.2), equals two. If MTC does not equal two, HEC-6 will simply ignore the data contained on these records. Section 3.3.4.1 contains a complete description of the user specified transport function option.

Field	Variable	Value	Description
0	ID	J	Record identification (Column 1).
1		Comment	Comment information such as the name of the grain size classification to which the data on this record relates.
2	A_i	+	Coefficient corresponding to A in above equation for grain size i.
3	B_i	+	Coefficient corresponding to B in above equation for grain size i.
4	C_i	+	Coefficient corresponding to C in above equation for grain size i.

7 If the user decides to use the special transport function option, then both a set of J records and K record must be provided in order to specify the required information and coefficients to use this option.

A2.9 K Record - User Specified Transport Function (optional)

Use the K record to define the coefficients of the function which is used to correct the User Specified Transport Function for variation in *n* value. This correcting function is expressed by the equation:

$$STO = 10^{-6} \cdot D \cdot n^{E}$$

The data contained on the J and K records is relevant to HEC-6 only if the selected transport capacity relationship, MTC (**I4.2**), equals two. If MTC does not equal two, HEC-6 will simply ignore the data contained on these records. Section 3.3.4.1 provides a complete description of this transport function option.

Field	Variable	Value	Description
0	ID	K	Record identification (Column 1).
1		Comment	Comment information.
2	D		Coefficient corresponding to D in the above equation.
3	E		Coefficient corresponding to E in the above equation.

A2.10 LQ Record - Water Discharge for the Water Discharge-Sediment Load Relationship (required)

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the **LQ** record, total sediment load in tons per day on the **LT** record and the fraction of the sediment load in each grain size class on **LF** records. Each **LF** record will describe one grain size fraction and they should be entered from fine to coarse. Enter the water discharge in cfs on the **LQ** record as follows.

Field	Variable	Value	Description
0	ID	LQ	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	QWATER	+	**Water discharge** in cfs. Enter the first discharge value[8] for the water discharge vs. sediment load table. If the range of water discharges in the inflow hydrograph is beyond that specified in this table, the extreme values of sediment load from the table will be used (i.e., HEC-6 will not extrapolate beyond the ends of the table).
3	QWATER	+	The second water discharge for the water discharge vs. sediment load table. Each consecutive water discharge must be greater than the previous one.
4-10	QWATER	+	Continue to enter increasing water discharge values in Fields 4 through 10. A maximum of nine water discharge values is permitted.

[8] QWATER cannot be zero or negative.

A2.11 LT Record - Total Sediment Load for the Water Discharge-Sediment Load Relationship (required)

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the **LQ** record, total sediment load in tons per day on the **LT** record and the fraction of the sediment load in each grain size class on **LF** records. Each **LF** record describes one grain size fraction; they should be entered from fine to coarse. Enter the total sediment load in tons per day on the **LT** record as follows.

Field	Variable	Value	Description
0	ID	LT	Record identification.
1		Comment	Any alphanumeric characters or comments.
2	QSED	+, 0	**Total sediment load** in tons per day. This value corresponds to the water discharge entered in Field 2 of the **LQ** record.
3	QSED	+, 0	Total sediment load in tons per day. This value corresponds to the water discharge entered in Field 3 of the **LQ** record.
4-10	QSED	+, 0	Continue to enter the total sediment load values for each subsequent water discharge entered on the **LQ** record. A maximum of nine values is permitted.

A2.12 LF Record - Fraction of Load for the Water Discharge-Sediment Load Relationship (required)

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the **LQ** record, total sediment load in tons per day on the **LT** record and the fraction of the sediment load in each grain size class on **LF** records.

Each **LF** record describes the sediment load of one grain size fraction. There must be one **LF** record for each grain size classification selected on records **I2** through **I4** even if the fraction of the load for any grain size is zero. **LF** records should be entered from fine to coarse.

Field	Variable	Value	Description
0	ID	LF	Record identification.
1		Comment	Any alphanumeric characters or comments. (It is recommended that the name of the grain size class to which the data on this record relates be used in this field; i.e., CLAY, SILT1, SILT2, VFS, FS, ... VCG.)
2	QSF	+, 0	The fraction for this grain size of the total sediment load corresponding to the water discharge in Field 2 of the **LQ** record.
3	QSF	+, 0	The fraction for this grain size of the total sediment load corresponding to the water discharge in Field 3 of the **LQ** record.
4-10	QSF	+, 0	Continue to enter the fraction of the total sediment load corresponding to each subsequent water discharge entered on the **LQ** record. A maximum of nine values is permitted.

A2.13 PF Record - Bed Material Gradation - Percent Finer

The **PF** record defines the gradation of the bed sediment reservoir (in percent finer) at each cross section as a grain size distribution curve. The sediment computations require gradation information for each cross section; however, it is not necessary to enter **PF** records for every cross section. Specific rules are:

a. There must be at least one **PF** record for each stream segment in the network. If only one **PF** record is present, that gradation is used for all cross sections on that stream segment.

b. The cross section ID number (i.e., river mile) is coded in Field 2 to tell HEC-6 where the **PF** data applies. The cross section ID number on each **PF** record must correspond to one used previously on an **X1** record. If more than one **PF** record is present, but not one for each cross section on the stream segment, a linear interpolation is made to fill in the missing data.

c. If the cross section ID number is omitted from a **PF** record, it will be assigned to the last cross section (i.e., the one most upstream), and values to the previous **PF** record will be interpolated.

d. The gradation for any cross sections after the final **PF** record will be assigned the values on that record.

e. Do not skip grain sizes when entering the **I2** through **I4** data (i.e., set LASL = 4 (**I3**.4) and IGS = 1 (**I4**.3) if silts as well as sands are being transported). It is not necessary to calculate all 20 grain sizes.

Field	Variable	Value	Description
0	ID	PF	Record identification.
		PFC	Record identification, continuation records.
1		Comment	Comment on **PF** record; data on **PFC** records.
2	SECID	-, 0, +	Cross section ID number (i.e., river mile). There is no default. Do not leave this field blank.
3	SAE	b, 0	**The fraction of the bed surface** that is exposed to erosion. That is, a portion of the bed may be armored or partially covered with bedrock. Usually SAE is left blank in which case, HEC-6 will use a default value of 1.0.
		.001-1.0	The normal range.
4	DMAX	+	**The diameter of the maximum particle size.** Code all diameters in millimeters. Always code a value. HEC-6 assigns a percent finer (PFXIS(1)=100) to correspond with DMAX. Although not required for execution, it is best if DMAX corresponds to a class interval boundary. DMAX is also known as DAXIS(1).

Field	Variable	Value	Description
5	DAXIS(2)	+	**The grain size diameter** in millimeters at the first coordinate point down the percent finer curve from DMAX. If DAXIS (1) or (2) particle size is larger than 2048 mm, choose a point that will approximate the PF-Curve with two straight line segments from DMAX to 2048 mm. **Note:** It is not necessary that this or any PF-coordinate correspond to a grain size class interval boundary - although they can. Semi-log interpolation is used to calculate the percent finer at each class interval boundary and these are subtracted to calculate the fraction of sediment in each size class.
	PFAXIS(2)	0, +	**The percent finer** corresponding to DAXIS(2). Code as a percent (e.g., enter 10 for 10%, 20 for 20%, etc.).
7-10	DAXIS-PFAXIS	0, +	Continue to code points from the percent finer curve in (grain size diameter, percent finer) pairs. Use up to 3 continuation **PFC** records to code a maximum of 16 points. Begin coding data in Field 1 of continuation records.

A2.14 $LOCAL Record - Local Inflow (optional)

This record indicates that a water-sediment discharge table for a local inflow or diversion follows. It is used to separate inflow/diversion data from other data in the data stream.

Place the **$LOCAL** record after the **PF** records in the sediment data to separate the sediment data for the current stream segment from the water-sediment discharge table information needed for the local inflow(s) on the same stream segment. Use only one **$LOCAL** record per branch of the network even though several sediment inflow/diversion data sets may be present on that stream segment.

A separate set of **LQL**, **LTL** and **LFL** records is required to specify **each** local inflow and/or diversion. Enter each set of **LQL**, **LTL** and **LFL** records in the same order as the local inflow points appear in the stream segment's geometry (downstream to upstream). The range of water discharges are specified on the **LQL** records, with corresponding sediment loads (for each water discharge) on the **LTL** records. Each **LFL** record specifies the sediment load fraction associated with each grain size defined by the **I2 - I4** records.

Note: The **$LOCAL** record replaces the **$TRIB** record in old data sets.

Field	Variable	Value	Description
0	ID	$LOCAL	Record identification (Columns 1 through 6).

A2.15 LQL Record - Water Discharge for Local Inflows/Diversions Specification (optional)

A set of **LQL**, **LTL**, and **LFL** records are used to specify the water discharge and sediment load associated with a local inflow or diversion. The **LQL** record specifies the water discharge portion of the load curve associated with local inflows and diversions. If only local inflow occurs, the data values on the **LQL** record are all positive and have the same format as specified on the **LQ** record. If a diversion is to be modeled, two negative values must be entered that **bracket** the maximum and minimum diversion values in the hydrograph. These values are entered as negative numbers in Fields 2 and 3. Fields 4 through 10 are left blank. If the local flows are mixed with diversions and inflows at various times, then specify the range of the diversion flows with negative QWATER values in Fields 2 and 3 and enter positive QWATER values in Fields 4 through 10 to specify the flow curve for the positive inflows.

Note: No continuation record is permitted. If a flow value in the hydrograph is above the extreme discharges on the **LQL** record, HEC-6 will use the sediment load value associated with the extreme discharge. If diversions are entered, they must fall between **LQL**.2 and **LQL**.3.

Field	Variable	Value	Description
0	ID	LQL	Record identification (Columns 1 through 3).
1		Comment	Any alphanumeric character comment.
Inflows			
2	QWATER	+	**Water Discharge** - Enter a positive discharge whose value is less than the smallest inflow value in the local hydrograph.
3-10	QWATER	+	**Water Discharge** - Enter increasing water discharges for the local inflow curve.
Diversions			
2	QWATER	-	**Water Discharge** - Enter a number slightly larger in absolute value than the maximum diversion value here. For example, if the maximum diversion value was 10.0, then one might enter -10.1. **Note:** The values entered in Fields 2 and 3 **must be negative** to denote diversions.
3	QWATER	-	Enter a number slightly smaller in absolute value than the minimum diversion value. For example, if the minimum diversion value was 1.0, a user might enter -0.9.
4-10			Leave blank.

A2.16 LTL Record - Total Sediment Load for Local Inflows/Diversions Specification (optional)

A set of **LQL**, **LTL**, and **LFL** records are used to specify the water discharge and sediment load associated with a local inflow or diversion. The total sediment load corresponding to the discharges entered on the **LQL** record is entered on the **LTL** record in units of tons/day.

Field	Variable	Value	Description
0	ID	LTL	Record identification (Columns 1 through 3).
1		Comment	Any alphanumeric characters or comments.
Inflows			
2-10	QSED	+	**Total sediment load** (tons/day) corresponding to each water discharge given on the **LQL** record, for the local flow-sediment load table. A maximum of nine values is permitted.
Diversions			
2, 3	QSED	1.0	If only diversions make up the local hydrograph, enter 1.0 in Fields 2 and 3 and leave Fields 4 through 10 blank.
4-10			Leave blank.
Combined Diversions and Inflows			
2, 3	QSED	1.0	If diversions are included in the local hydrograph, enter 1.0 in Fields 2 and 3.
4-10	QSED	+	**Total sediment load** (tons/day) corresponding to each water discharge given on the **LQL** record, for the local flow-sediment load table. A maximum of seven values is permitted.

A2.17 LFL Record - Sediment Grain Size Distribution for Local Inflows/Diversions (optional)

A set of **LQL**, **LTL**, and **LFL** records are used to specify the water discharge and sediment load associated with a local inflow or diversion. The **LFL** records specify the fraction of the total local sediment load per size class.

The **LFL** records should be entered from fine to coarse with one **LFL** record for **each** of the sediment size classes specified on the **I2 - I4** records. If only inflows occur as this local point, then the **LFL** records have the same format and rules as the **LF** records. Diversion points and combination inflow-diversion points require a slight variation from the upstream inflowing sediment load table. All diversions are prescribed by a ratio of the concentration of sediment in diverted water to that in the main channel just upstream from the diversion point.

Field	Variable	Value	Description
0	ID	LFL	Record identification (Columns 1 through 3).
1		Comment	Any alphanumeric character comment. (It is recommended that the grain size class be entered in the comment field, i.e. CLAY, SILT1, SILT2, VFS, FS, ... VCG).
Inflows			
2-10	QSF	+, 0	Enter the **fraction of the total sediment load** for this sediment size class corresponding to each water discharge specified on the **LQL** record.
Diversions			
2, 3	QSF		Enter the **diversion coefficient** (ratio of diverted sediment concentration to the ambient channel concentration) for the corresponding diversion (negative) discharge specified on the **LQL** record.
		+	When field data is available, calculate the ratio of $C_{Diverted}/C_{Ambient}$ and use that value. Otherwise, a value of 1.0 may be appropriate for suspended load and possibly, >1.0 for bed load.
4-10			Leave blank.

Field	Variable	Value	Description
Combined Diversions and Inflows			
2, 3	QSF		Enter the **diversion coefficient** (ratio of diverted sediment concentration to the ambient channel concentration) for the corresponding diversion (negative) discharge specified on the **LQL** record.
		+	When field data is available, calculate the ratio of $D_{diverted}/C_{Ambient}$ and use that value. Otherwise, a value of 1.0 may be appropriate for suspended load and possibly, >1.0 for bed load.
4-10	QSF	+, 0	Enter the **fraction of the total sediment load** or this sediment size class corresponding to each water discharge specified on the **LQL** record.

Section A3

Hydrologic Data

A3.1 $HYD Record - Hydrologic Data (required)

The **$HYD** record marks the beginning of the hydrologic data. This record is required and precedes discharge data described on the following pages.

Field	Variable	Value	Description
0	ID	$HYD	Record identification.

A3.2 * Record - Comment and Output Control (required)

One comment record is required for each **Q** record in the hydrologic data. This record provides title information for each time step. It also allows the user to select various output options.

Field	Variable	Value	Description
0	ID	*	Record identification (Column 1).

Output Control for Hydraulic Information

Column 5	OPTION		Optional output from **the hydraulic computations** (water surface profiles) is obtained by specifying one of the following codes in Column 5 on the * record.
		blank	Discharge, starting water surface elevation, water temperature and flow duration in days is output. For this option, leave Column 5 blank, not zero. This is the standard hydraulic output option.
		A	Water surface and energy line elevations, velocity head, alpha, top width, average bed elevation, and velocity in each subsection are output for each discharge at each cross section.
		B	Cross section coordinates at the current time and distribution of hydrologic data across the section for the final calculated water surface are output.
		D	Trace information. (Not recommended for most users.)
		E	Detailed Trace Information. All of the above information plus coordinates, area and wetted perimeter for each trapezoidal area in each cross section and for each trial elevation at each cross section. (Not recommended for most users.)

Note: Output levels D and E produce very large quantities of output from the hydraulic computations. This output was designed for software error checking. Execution time will increase and output files will become very large if either of these options are used.

Field	Variable	Value	Description

Output Control for Sediment Transport Information

Field	Variable	Value	Description
Column 6	OPTION		Optional output from **sediment transport computations.**
		blank	No output except summary at end of job. For this option leave Column 6 blank, not zero.
		A	A table showing the volume of sediment entering and leaving each segment and the computed trap efficiency for each segment.
		B	In addition to A, the cumulative bed change, the water surface and thalweg elevations, and the sediment load passing in tons/day for clay, silt and sand for each cross section. This and all higher output levels cause a supplemental output file to be written at this time step for post-processing purposes.
		C	In addition to the above, values of the detailed distribution by grain size fraction for the bed surface material at each cross section before the values are corrected by percentage present in the bed. (Not recommended for most users.)
		D, E	Detailed Trace Information. (Not recommended for most users.)

Note: Output levels C, D and E produce very large quantities of output from the sedimentation computations. This trace output was designed primarily for software error checking. Execution time will increase and output files will become very large if any of these options are used.

Time Step Title Information

Field	Variable	Value	Description
2-10	Comment		Comment data for discharge-elevation-duration data that follows. Use the remainder of this record to provide title/comment information for this time step. This data will appear in the output file.

A3.3 Q Record - Water Discharges in cfs (required)

A **Q** record is required for each time step defined in the hydrologic data. The **Q** record provides HEC-6 with the outflow at the downstream boundary as well as flow conditions at each of the control points in a stream network. See Sections 3.4.2.1, 3.6.4, and Section 6.6.4 for descriptions of how to enter data on the **Q** record.

Field	Variable	Value	Description
0	ID	Q	Record identification (Column 1).
1	Q(1)	+	Outflow from downstream boundary of geometric model for this time step.

If Tributaries, Local Inflows or Diversions <u>are</u> Present in the Geometric Data

Field	Variable	Value	Description
2	Q(2)	0, +	Tributary discharge of first local inflow (diversion) point on main stem. If no local flows, enter discharge from stream segment at control point 2.
		-	Diversion flows are identified by a negative discharge. Otherwise, diversions and tributaries are subject to the same coding rules. They may be mixed but they both may not occur at the same time at the same cross section.
3-10	Q(3)-Q(10)	0, +, -	The discharge, inflow or outflow, of the next control/junction point defined in the network (see Section 3.6 and Sections 6.1 through 6.4 for details).

If Tributaries, Local Inflows, and Divisions are <u>not</u> Present in the Geometric Data

Field	Variable	Value	Description
2-10	Q(2)-Q(10)	+	Up to MNQ (I1.4) parallel discharges may be entered across the **Q** record.

A3.4 R Record - Downstream Water Surface Elevation Boundary Condition (required[9])

A water surface elevation must be specified at the downstream boundary of the model for every time step to begin the backwater computations. HEC-6 provides three methods for prescribing this downstream boundary condition: (1) a rating curve, (2) stage vs. time (**R** records), or (3) a combination of a rating curve and **R** records.

Method 1 involves the use of a rating curve which is specified using a **$RATING** record followed by a set of **RC** records containing the water surface elevation data as a function of discharge. The rating curve need only be specified once at the start of the hydrologic data (immediately following the **$HYD** record) and a water surface elevation will be determined by interpolation using the discharge given on the **Q** record for each time step. The rating curve may be temporarily modified using the **S** record or replaced by entering a new set of **$RATING** and **RC** records before any ***** record in the hydrologic data.

In Method 2, **R** records are used **instead** of a rating curve to define the water surface elevation. To use this method, an **R** record is required for the first time step. The elevation entered in Field 1 of this record will be used for each succeeding time step until another **R** record is found with a non-zero value in Field 1. In this way, you need only insert **R** records to change the downstream water surface elevation to a new value.

Method 3 is a combination of the first two methods. This method makes it possible to use the rating curve most of the time to determine the downstream water surface elevation while still allowing the user to specify the elevation exactly at given time steps. In this method, the **R** record's non-zero Field 1 value for the downstream water surface elevation will override the rating curve for that time step. On the next time step, HEC-6 will obtain the downstream water surface from to the rating curve unless another **R** record is found with a non-zero value in Field 1.

Water Surface Elevation at Internal Boundaries

R records have a secondary purpose. They may also be used to define the water surface elevation at certain internal boundaries in the geometry. The location of an internal boundary is defined by an **X5** record. **R** records are then necessary to define the water surface at those internal boundaries where an **R** record field has been specified in field 4 of the **X5** record. The water surface elevation (UPE) for that time step will be read from the **R** record at the field prescribed on the **X5** record (**X5**.4). See the **X5** record description (Section A1.7) for further details.

---

9 An R record is required only if a rating table is not used, and then it is only required for the first time step.

If Internal Boundaries are not Present in the Geometry

Field	Variable	Value	Description
0	ID	R	Record identification (Column 1).
1	WS(1)	+	The **water surface elevation** for the downstream boundary. This water surface elevation corresponds to the discharge in Field 1 of the **Q** record.
		0	When no internal boundaries are present, then a zero in Field 1 **should not be used.** To define a water surface elevation at zero, use a small positive value (e.g., 0.001)
2-10			The downstream water surface corresponding to each parallel[10] discharge on the **Q** record.

If Internal Boundaries are Present in the Geometry

Field	Variable	Value	Description
0	ID	R	Record identification (Column 1).
1	WS(1)	+	The **water surface elevation** for the downstream boundary. This water surface elevation corresponds to the discharge in Field 1 of the **Q** record.
		0	When internal boundaries are present (defined on **X5** records) and a rating curve exists, the water surface will be determined from the rating curve (**$RATING** and **RC** records). If a rating curve does not exist, the water surface from the previous time step will be reused.
2-10	WS(n)	+	Enter the water surface elevation for the internal boundary for which ICSH (**X5**.4)=n, where n equals the current field.
		0	Use the water surface value from the previous time step. To define a water surface elevation of zero, use a small positive value (e.g., 0.001).

[10] The parallel flow option may not be used if tributaries or local inflows, or diversions are present in the system.

A3.5 S Record - Rating Shift (optional)

This record allows the user to alter the starting water surface elevation at the downstream boundary by a constant value. This alteration will remain in effect for succeeding time steps until another **S** record is read with a new shift value. The shift value is not cumulative.

Field	Variable	Value	Description
0	ID	S	Record identification (Column 1).
1	SHIFT	+, -	Enter the shift for starting water surface elevations in Field 1. All starting elevations will be shifted by this amount for this and subsequent Q's until a new shift value is read from an **S** record. To return to zero shift, enter an **S** record with Field 1 blank or zero.
		b, 0	Use original water surface elevation. No alteration.
2-10			Leave blank.

A3.6 T Record - Water Temperature (optional)

The **T** record provides water temperature data (refer to Section 3.4.2.1). This record is required only in the first time step. Include subsequent **T** records only if the water temperature changes. The water temperature(s) entered on this record will remain in effect until another **T** record is entered to change it. Water temperature is important for computing sediment settling velocity (especially for fine materials).

Field	Variable	Value	Description
0	ID	T	Record identification (Column 1).
1-10	WT(1)..WT(10)	+	**Water temperature,** in degrees Fahrenheit, corresponding to each discharge on the **Q** record. **T.1** corresponds to **Q.1**, etc. Enter new values only if the water temperature changes from the values entered on the previous **T** record.

A3.7 W Record - Duration (required)

The **W** record defines the duration of the flow for the present time step. A **W** record is required for each time step in the hydrologic data set (refer to Section 3.4 and Figure 3.7).

Field	Variable	Value	Description
0	ID	W	Record identification (Column 1).
1	DD	+	**The flow duration** of this time step in days or fractions of days.
2			Leave Blank.

A3.9 $$END Record - Required

. Last record in the data file.

Field	Variable	Value	Description
0	ID	$$END	Record identification (Columns 1 through 5).

Section A4

Special Commands

and

Output Control

A4.1 $B Record - Transmissive Boundary Condition (optional)

The **$B** record is used to suspend the sedimentation computations at each downstream boundary. The sediment discharge for each downstream boundary is set to the rate of sediment leaving the next upstream cross section. Use this option when sediment deposits at the downstream boundary and there is no physical explanation for it (e.g., as in a supercritical flow reach when the sediment concentration is very high). See Section 3.4.2.4 for a brief discussion of this option.

Field	Variable	Value	Description
0	ID	$B	Record identification.
2	ISBT	1	Approaching sediment discharge is transmitted past the outflow boundary section without change. This turns the option on.
		2	Sediment discharge is calculated at the outflow boundary. This returns the computation to the default conditions; i.e., it turns this option off.

Table A4-1
$B - Transmissive Boundary

```
$HYD
$B           2
$RATING
RC      3    100       0       0      520     525     528
  field1|field 2|field 3|field 4|field 5|field 6|field 7|..
*   AB  Time Step 1, A level hydraulics, B level sediment
Q    100
T     60
W      1
*       Time Step 2 - No Output
Q    200
W      2
       .
       .
$$END
```

A4.2 $DREDGE Record - Dredging Option (optional)

The **$DREDGE** record initiates dredging calculations to be performed at all cross sections where dredging parameters have been specified (H.6 - H.10). When the depth of water required for navigation (draft depth) specified in Field 2 is not available, HEC-6 will determine dredging elevations and compute the volume of dredged material removed during dredging. The dredging option is initiated at the beginning of the next time step following the **$DREDGE** record. It continues to operate until turned off by a **$NODREDGE** record later in the hydrologic data. The first **$DREDGE** record must not precede the records which define the first time step. See Section 3.2.4 and Section 6.4.1 for further discussion of this option.

Field	Variable	Value	Description
0	ID	$DREDGE	Record identification.
2	DFT	+	Depth of water required for navigation. **Note:** Detailed dredging output can be obtained by entering a print level flag in column 8 of the **$DREDGE** record. Print levels range from Level A, which provides a small level of output to Level E which produces a detailed trace output through the dredging routines. For example, the **$DREDGE** record in Table A4-2 the following record will turn on the dredging option, specify a draft depth of 10 ft and obtain a B level trace output.

Table A4-2
Example - $DREDGE Record

```
$HYD
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
*    AB  Time Step 1, A level hydraulics, B level sediment
Q     100
R     521
T      60
W       1
$DREDGEB        10
*     A  Time Step 2 - A level sediment output
Q     200
W       2
      .
      .
$$END
```

A4.3 $NODREDGE Record - Dredging Option (optional)

The presence of a **$NODREDGE** record stops the dredging option triggered previously by the **$DREDGE** record.

Field	Variable	Value	Description
0	ID	$NODREDGE	Record identification

A4.4 $EX Record - Exner Options (optional)

HEC-6 has two different methods for solving the Exner equation. Method 1 (also known as EXNER1) is the original method used by HEC-6 prior to Version 4.0. Method 1 is described in detail in Section 2.3.3. Method 2 (a.k.a. EXNER5) is currently the default method used in HEC-6. A detailed discussion of this method can be found in Section 2.3.4.

The purpose of the **$EX** record is to provide the user access to Method 1. To exercise this option, place a **$EX** record with a 1 in field 1 immediately after the **$HYD** record. Otherwise, HEC-6 will default to Method 2.

Field	Variable	Value	Description
0	ID	$EX	Record identification.
1	OPTION	1	Method 1 for hydraulic sorting will be used (see Section 2.3.3).
		2	Method 2 for hydraulic sorting will be used (see Section 2.3.4). Default.

Table A4-3
$EX - Alternate Exner Equation

```
$HYD
$EX    1
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
*   AB  Time Step 1, A/B Level Output
Q    100
T     60
W      1
R    521
*       Time Step 2 - No Output
Q    200
W      2
    .
    .
    .
$$END
```

A4.5 $GR Record - Cross Section Shape Option (optional)

By default, HEC-6 retains the original cross section shape by adjusting the elevation of each cross section point below the water surface and within the movable bed by a constant amount for deposition and erosion after each time step. The **$GR** option 2 causes HEC-6 to vary the depth of deposit in a cross section according to the depth of flow. Thus, deeper portions of a cross section will receive more deposited material than more shallow areas. The elevation of each point in the wet portion of the movable bed is still adjusted, but the amount of deposition at each point depends on the depth of flow at that point in the cross section. Erosion remains uniform. Figures 3-12 and 3-13 in Section 3.7.3 illustrate this operation.

Field	Variable	Value	Description
0	ID	$GR	Record identification.
1	OPTION	2	Vary the amount of deposition depending on depth. (A "2" in field 1 turns the **$GR** option on.)
		0	Move Y-coordinates by a constant amount after each computation. (A "0" in field 1 turns the **$GR** option off; i.e., this returns the method of deposition back to the default.)

Table A4-4
$GR - Nonuniform Deposition Option

```
$HYD
$GR    2
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3      100       0       0     520     525     528
*   AB  Time Step 1, A/B Level Output
Q    100
T     60
W      1
*       Time Step 2 - No Output
Q    200
W      2
       .
       .
       .
$$END
```

A4.6 $KL - $KI Records - Channel *n* Values by Relative Roughness (optional)

When a **$KL** record is encountered, HEC-6 ignores the Manning's *n* values for the channel given on the **NC** and/or **NV** records and calculates bed roughness as a function of the bed material gradation via Limerinos' (1970) relative roughness method. A detailed description of this option is given in Section 3.2.2.

Field	Variable	Value	Description
0	ID	$KL	Record identification. Use Limerinos' Roughness Method.
		$KI	Use Manning's *n* values. Default Method.

Table A4-5
$KL - Limerinos' Relative Roughness Option

```
$HYD
$KL
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3      100        0        0      520      525      528
*   AB  Time Step 1, A/B Level Output
Q    100
T     60
W      1
*       Time Step 2 - No Output
Q    200
W      2
       .
       .
       .
$$END
```

A4.7 $PRT Record - Selective Output Option (optional)

The **$PRT** record is used alone to turn output on or off for all cross sections. It is also used preceding **CP** and **PS** records to generate output at specified cross sections. An **END** record is required at the end of the **CP-PS** record set to mark the end of the selective output request. See Example Problem 6 in Chapter 6 for an example of this option.

Field	Variable	Value	Description
0	ID	$PRT	Record identification.
Column 8	OPTION	N	Turn output **off** at all sections.
		A	Turn output **on** at all sections.
		blank	Directs HEC-6 to look for **CP** and **PS** records to determine selected cross sections for output.

Table A4-6
$PTR - Selective Output Option

```
$HYD
  Turn output OFF for ALL cross section
$PRT   N
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3    100       0       0     520     525     528
*   AB  Time Step 1, A level hydraulics, B level sediment
Q    100
T     60
W      1
  Turn output ON for ALL cross section
$PRT   A
*       Time Step 2 - B level sediment output
Q    200
W      2
*       Time Step 3 - B level sediment
Q    200
W      2
  Turn output on at cross sections 15.0 and 33.2 ONLY
$PRT
CP     1
PN          15.0    33.2
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC     3    120       0       0     530     536     540
*       Time Step 4 - C level sediment
Q    200
W      2
       .
       .
       .
$$END
```

A4.8 CP Record - Selective Output (see $PRT record - optional)

The **CP** record defines the stream segment for which the cross sections given on the **PS** record(s) apply. Each **CP** record must be followed by one or more **PS** records.

Field	Variable	Value	Description
0	ID	CP	Record identification.
2	NGDS	+	Stream segment number.

A4.9 PS Record - Selective Output (see $PRT Record - optional)

Use the **PS** record to specify the cross sections where output is desired. Each set of **PS** records applies to the stream segment defined on the **CP** record immediately preceding it. Additional **PS** records may be used if more than ten cross sections per stream segment are requested. When specifying the desired cross section for printing, use its identification number, as entered on the **X1** record.

Field	Variable	Value	Description
0	ID	PS	Record identification.
1-10	SECID	+	Enter the identification number of the desired cross section as given in Field 1 of the **X1** record. HEC-6 generates output for each SECNO on the current stream segment defined by the preceding **CP** record.

A4.10 END Record - Selective Output (see $PRT Record; optional)

An **END** record is used to indicate the end of the **$PRT** data. This record should be placed after the last **PS** record. If output for cross sections on more than one stream segment is desired, sets of **CP** and **PS** records may be stacked one after another. The **END** record is inserted only after the last set.

Field	Variable	Value	Description
0	ID	END	Record identification.

A4.11 $RATING Record - Tailwater Rating (optional)

A starting water surface elevation must be specified at the downstream boundary for every time step. HEC-6 provides several methods for prescribing this downstream boundary condition. Specification of a tailwater rating curve is one of these methods.

The rating curve is specified using a **$RATING** record followed by a set of **RC** records. The **$RATING** record indicates that a set of **RC** records follows containing rating curve information. The rating curve can be input immediately after the **$HYD** record or before any ***** record in the hydrologic data. Once a rating curve has been input it can be changed by inputting a new rating curve (a new set of **$RATING** and **RC** records) before any ***** record later in the hydrologic data. Table A4-6 illustrates the use of the **$RATING** option.

Field	Variable	Value	Description
0	ID	$RATING	Record identification.

A4.12 RC Record - Tailwater Rating

The **RC** (rating curve) records prescribe the tailwater elevation as a rating curve.

Field	Variable	Value	Description
0	ID	RC	Record identification.
1			Leave blank.
2	MNI	+	The number of water surface values that will be read. (May not exceed forty).
3	TINT	+	The **discharge interval** between water surface values in cfs. Use as small an interval as desired, but it must be a constant for the full range of water surface elevations that follow.
4	QBASE	+	If the **first discharge** in the table is not zero enter its value here in cfs.
5	GZRO	+	If the rating table is a stage-discharge curve rather than elevation-discharge, enter **gage zero** here.
6	RAT(1)	+	Lowest **water surface elevation or stage** goes here.
7-10	RAT(2)... RAT(MNI)		Continue entering **water surface elevation or stage values** defining the rating curve using Fields 7-10 on this record and Fields 2-10 on continuation **RC** records. A maximum of forty points can be entered to define the curve.

A4.13 $SED Record - Water Discharge-Sediment Load Table (optional)

This HEC-6 command option allows the user to change a sediment load table during a simulation. A change to a sediment load table can be made by either entering a new sediment load table definition on **LPOINT, LQ, LT** and **LF** records or by altering the existing table with a ratio defined on an **LRATIO** record.

A **$SED** command precedes a **LPOINT, LQ, LT, LF** record combination that defines the discharge-sediment load rating curve. It should also precede an **LRATIO** record. The **LPOINT** record is used to specify the location where the new sediment load table applies. It is required with the **LQ, LT** and **LF** records. An **END** record completes the **$SED** data records.

If the sediment load table for the main stem or a tributary is to be replaced, see the input descriptions for the **LQ, LT** and **LF** records given in Sections A2.10 to A2.12. However, if the sediment load table for a local inflow or outflow is to be replaced, refer to the input description for the **LQL, LTL,** and **LFL** records given in Sections A2.15 to A2.17 instead (i.e. **LQ, LT, LF** records are used for the main channel and tributaries. The **LQL, LTL** and **LFL** records are used for local inflows and outflows).

Field	Variable	Value	Description
0	ID	$SED	Record identification.

Table A4-7
$SED - Replace Sediment Load Table

```
$HYD
  field1|field 2|field 3|field 4|field 5|field 6|field 7|...
$RATING
RC    3      100       0       0      520      525      528
*    AB  Time Step 1, A/B Level Output
Q    100
T     60
W      1
$SED
LPOINT          1       1
LQ
LT
LF CLAY
       .
       .
LF VCS
END
*          Time Step 2 - No Output
Q    200
W      2
$SED
LRATIO          3       0     1.1
       .
       .
*    AB  Time Step n, A/B Level Output
Q    100
W      1
$$END
```

A4.14 LPOINT Record - Inflow Point Identification for the Water Discharge-Sediment Load Table (optional)

The **LPOINT** record defines the stream segment and/or inflow point whose sediment load table will be modified by the succeeding set of **LQ**, **LT**, and **LF** records. The **LPOINT** record is only used with the **$SED** option and should not be used with the **L** records in the sediment data.

Field	Variable	Value	Description
0	ID	LPOINT	Record identification.
2	NGDS	+	Stream segment number
3	NLOC	+	Local inflow/outflow point number.

A4.15 LRATIO Record - Ratio for the Water Discharge-Sediment Load Table (optional)

When changing the sediment discharge with the **$SED** option, the existing sediment-discharge load table can be modified by entering an **LRATIO** record with a constant multiplier, rather than by entering a whole new table.

Field	Variable	Value	Description
0	ID	LRATIO	Record identification.
2	NGDS	+	Stream segment number.
3	NLOC	+	Local inflow/outflow point number.
4	RATIO	+	Existing sediment-discharge rating curve will be multiplied by RATIO.

A4.16 END Record - Termination Record for the $SED Option

An **END** record is used to indicate the end of the changes made to the sediment load table(s). This record should be inserted after the last **LRATIO** or **LF** record. If changes are to be made to more than one sediment load table, **LRATIO** records and/or sets of **LPOINT, LQ, LT, LF** records may be stacked one after another. Insert the **END** record only after the last set of change records.

Field	Variable	Value	Description
0	ID	END	Record identification

A4.17 $VOL Record - Compute Cumulative Volume and Deposits at all Sections (optional)

The **$VOL** command causes HEC-6 to calculate the cumulative bed change and load passing each cross section.

Field	Variable	Value	Description
0	ID	$VOL	Record identification
Column 7	OPTION	X	Causes HEC-6 to look for a **VJ** record immediately after the **$VOL** command and compute the storage volume for a table of elevations specified on succeeding **VR** records.
Column 8	TRACE	A	Additional output showing cumulative weight of sediment passing each cross section by size class.
		B	A-level output plus extra trace information from the PRTVOL and STOVOL routines. (Not recommend for normal applications.)

A4.18 VJ Record - Elevation Table for Cumulative Volume Computations (optional; see $VOL Record)

Field	Variable	Value	Description
0	ID	VJ	Record identification.
1	JM	1-30	The number of elevation values which are listed on the following **VR** records. Limited to thirty values.
2	AVGSLO	0	Compute volumes based on planes with no slope.
		+	Compute volumes based on planes having slope AVGSLO.

A4.19 VR Record - Elevation Table for Cumulative Volume Computations (optional; see $VOL Record)

Field	Variable	Value	Description
0	ID	VR	Record identification.
1	ELSTO(1)	-, 0, +	Enter up to thirty elevations in Fields 1 through 10 on this and succeeding **VR** records.

Appendix B

Glossary

ACCURACY Degree of conformity of a measure to a standard or true value.

ACTIVE BED The active bed is the layer of material between the bed surface and a hypothetical depth at which no transport will occur for the given gradation of bed material and flow conditions. See also, ACTIVE LAYER.

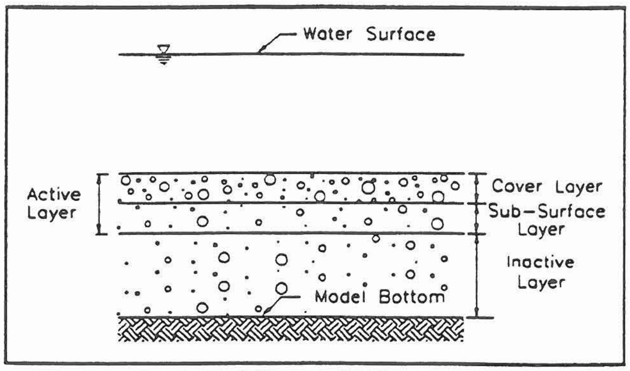

Figure B-1
Composition of the Active Layer

ACTIVE LAYER The depth of material from bed surface to equilibrium depth continually mixed by the flow, but it can have a surface of slow moving particles that shield the finer particles from being entrained by the flow. See Figure B-1.

AGGRADATION The geologic process by which stream beds, floodplains, and the bottoms of other water bodies are raised in elevation by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

ALGORITHM A procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation. A step by step procedure for solving a problem or accomplishing an end. A set of numerical steps or routines to obtain a numerical output from a numerical input.

ALLUVIAL Pertains to alluvium deposited by a stream or flowing water.

ALLUVIAL DEPOSIT Clay, silt, sand, gravel, or other sediment deposited by the action of running or receding water.

ALLUVIAL REACH A reach of river with a sediment bed composed of the same type of sediment material as that moving in the stream.

ALLUVIAL STREAM A stream whose channel boundary is composed of appreciable quantities of the sediments transported by the flow, and which generally changes its bed forms as the rate of flow changes.

ALLUVIUM A general term for all detrital deposits resulting directly or indirectly from the sediment transported by (modern) streams, thus including the sediments laid down in riverbeds, floodplains, lakes, fans, and estuaries.

ARMOR LAYER See ARMORING.

ARMORING The process of progressive coarsening of the bed layer by removal of fine particles until it becomes resistant to scour. The coarse layer that remains on the surface is termed the "armor layer". Armoring is a temporary condition; higher flows may destroy an armor layer and it may re-form as flows decrease. Or simply, the formation of a resistant layer of relatively large particles resulting from removal of finer particles by erosion.

AVERAGE END CONCEPT The averaging of the two end cross sections of a reach in order to smooth the numerical results.

BACKWATER PROFILE Longitudinal profile of the water surface in a stream where the water surface is raised above its normal level by a natural or artificial obstruction.

BANK SEDIMENT RESERVOIR The portion of the alluvium on the sides of a channel. See Figure B-2. (Note: HEC-6 only uses the BED SEDIMENT RESERVOIR as the source-sink of material.)

BED FORMS Irregularities found on the bottom (bed) of a stream that are related to flow characteristics. They are given names such as "dunes", "ripples", and "antidunes". They are related to the transport of sediment and interact with the flow because they change the roughness of the stream bed. An analog to stream bed forms are desert sand dunes (although the physical mechanisms for their creation and movement may be different).

BED LAYER An arbitrary term used in various procedures for computation of sediment transport. From observation of slow motion movies of laboratory flume experiments, H. Einstein defined the "bed layer" as: "A flow layer, 2 grain diameters thick, immediately above the bed. The thickness of the bed layer varies with the particle size."

BED LOAD Material moving on or near the stream bed by rolling, sliding, and sometimes making brief excursions into the flow a few diameters above the bed, i.e. jumping. The term "saltation" is sometimes used in place of "jumping". Bed load is bed material that moves in continuous contact with the bed; contrast with SUSPENDED LOAD.

BED LOAD DISCHARGE The quantity of bed load passing a cross section in a unit of time, i.e. the rate. Usually presented in units of tons per day. May be measured or computed. See BED LOAD.

BED MATERIAL The sediment mixture of which the moving bed is composed. In alluvial streams, bed material particles are likely to be moved at any moment or during some future flow condition. Bed material consists of both bed load and suspended load. Contrast with WASH LOAD.

BED MATERIAL DISCHARGE The total rate (tons/day) at which bed material (see BED MATERIAL) is transported by a given flow at a given location on a stream.

BED MATERIAL LOAD The total rate (tons/day) at which bed material is transported by a given location on a stream. It consists of bed material moving both as bed load and suspended load. Contrast with WASH LOAD.

BEDROCK A general term for the rock, usually solid, that underlies soil or other unconsolidated, bed material.

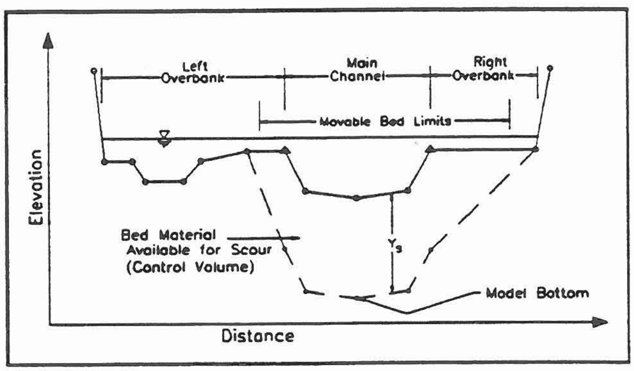

Figure B-2
Sediment Material in the Streambed

BED SEDIMENT CONTROL VOLUME The source-sink component of sediment sources in a river system (the other component is the suspended sedment in the inflowing discharge). Its user-defined dimensions are the movable bed width and depth, and the average reach length.

BOUNDARY CONDITIONS Definition or statement of conditions or phenomena at the boundaries. Water surface elevations, flows, sediment concentrations, etc., that are specified at the boundaries of the area being modeled. The downstream water surface elevation and the incoming upstream water and sediment discharges are the standard HEC-6 boundary conditions.

BOUNDARY ROUGHNESS The roughness of the bed and banks of a stream or river. The greater the roughness, the greater the frictional resistance to flows; and, hence, the greater the water surface elevation for any given discharge.

BRAIDED CHANNEL A stream that is characterized by random interconnected channels divided by islands or bars. Bars which divide the stream into separate channels at low flows are often submerged at high flow.

CHANNEL A natural or artificial waterway which periodically or continuously contains moving water.

CHANNEL INVERT The lowest point in the channel.

CHANNEL STABILIZATION A stable channel is neither progressively aggrading nor degrading, or changing its cross-sectional area through time. It could aggrade or degrade slightly, but over the period of a year, the channel would remain similar in shape and dimensions and position to previous times. Unstable channels are depositing or eroding in response to some exterior conditions. Stabilization techniques consist of bank protection and other measures that work to transform an unstable channel into a stable one.

CLAY See Table B-1.

COBBLES See Table B-1.

Table B-1[1]
Scale for Size Classification of Sediment Particles

Class Name	Millimeters	Feet	PHI Value
Boulders	> 256	–	< -8
Cobbles	256 - 64	–	-8 to -6
Very Coarse Gravel	64 - 32	.148596	-6 to -5
Coarse Gravel	32 - 16	.074216	-5 to -4
Medium Gravel	16 - 8	.037120	-4 to -3
Fine Gravel	8 - 4	.018560	-3 to -2
Very Fine Gravel	4 - 2	.009279	-2 to -1
Very Coarse Sand	2.0 - 1.0	.004639	-1 to 0
Coarse Sand	1.0 - 0.50	.002319	0 to +1
Medium Sand	0.50 - 0.25	.001160	+1 to +2
Fine Sand	0.25 - 0.125	.000580	+2 to +3
Very Fine Sand	0.125 - 0.0625	.000288	+3 to +4
Coarse Silt	0.0625 - 0.031	.000144	+4 to +5
Medium Silt	0.031 - 0.016	.000072	+5 to +6
Fine Silt	0.016 - 0.008	.000036	+6 to +7
Very Fine Silt	0.008 - 0.004	.000018	+7 to +8
Coarse Clay	0.004 - 0.0020	.000009	+8 to +9
Medium Clay	0.0020 - 0.0010	–	+9 to +10
Fine Clay	0.0010 - 0.0005	–	+10 to +11
Very Fine Clay	0.005 - 0.00024	–	+11 to +12
Colloids	<0.00024	–	> +12

[1] Portions of Table B-1 are taken from EM 1110-2-4000, March 1988.

COHESIVE SEDIMENTS Sediments whose resistance to initial movement or erosion is affected mostly by cohesive bonds between particles.

COMPUTATIONAL HYDROGRAPH A sequence of discrete steady flows, each having a specified duration in days, is used to represent the continuous discharge hydrograph. This is done to minimize the number of time steps needed to simulate a given time period, and, thus minimize computer time. See Figure B-3.

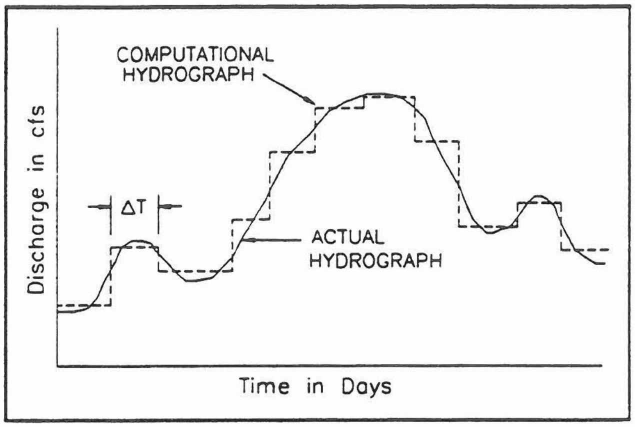

Figure B-3
Computational Hydrograph

CONCENTRATION OF SEDIMENT The dry weight of sediment per unit volume of water-sediment mixture, i.e. mg/ℓ. (Note: In earlier writings, concentration was calculated as the ratio of the dry weight of sediment in a water-sediment mixture to the total weight of the mixture multiplied by 1,000,000. It was expressed as parts per million, i.e. ppm. Either method gives the same result, within one percent, for concentrations up to 16,000 mg/ℓ. A correction is needed for concentrations in excess of that value.) The conversion to mg/ℓ (miligrams per liter) from ppm (parts per million) is as follows:

$$mg/\ell = K \cdot (ppm) = K \cdot \frac{\text{weight of sediment} \cdot 1{,}000{,}000}{\text{weight of water - sediment mixture}}$$

where: K = correction factor

CONCEPTUAL MODEL A simplification of prototype behavior used to demonstrate concepts.

CONSOLIDATION The compaction of deposited sediments caused by grain reorientation and by the squeezing out of water trapped in the pores.

CONTROL POINT The downstream boundary of the main river segment and the junction point of each tributary. In Figure B-4, each control point is designated by a circled number.

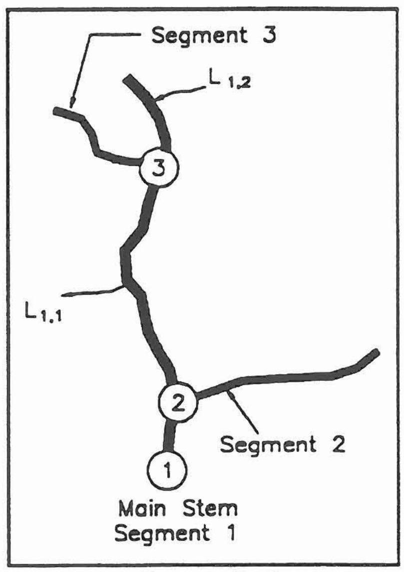

Figure B-4
Control Point Numbering

CONVERGENCE The state of tending to a unique solution. A given scheme is convergent if an increasingly finer computational grid leads to a more accurate solution.

CONVEYANCE A measure of the carrying capacity of the channel section. Flow is directly proportional to conveyance for steady flow. From Manning's equation, the proportionality factor is the square root of the energy slope.

COVER LAYER One of the two sublayers of the active layer. It lies above the sub-surface layer (the second sublayer in the active layer). See Figure B-1.

CRITICAL BED SHEAR STRESS See CRITICAL TRACTIVE FORCE.

CRITICAL DEPTH If discharge is held constant and the water depth allowed to decrease, as in the case of water approaching a free overfall, velocity head will increase, pressure head will decrease, and total energy will decrease toward a minimum value where the rate of decrease in the pressure head is just counter-balanced by the rate of increase in velocity head. This is the critical depth. More generally, the critical depth is the depth of flow that would produce the minimum total energy head.

CRITICAL FLOW The state of flow where the water depth is at the critical depth and when the inertial and gravitational forces are equal.

CRITICAL TRACTIVE FORCE The critical tractive force is the maximum unit tractive force that will not cause serious erosion of the material forming the channel bed on a level surface.

CROSS SECTION Depicts the shape of the channel in which a stream flows. Measured by surveying the stream bed elevation across the stream on a line perpendicular to the flow. Necessary data for the computation of hydraulic and sediment transport information.

CROSS-SECTIONAL AREA The area of a cross section between the stream bed and the water surface.

DEGRADATION The geologic process by which stream beds, floodplains, and the bottoms of other water bodies are lowered in elevation by the removal of material from the boundary. It is the opposite of aggradation.

DEPOSITION The mechanical or chemical processes through which sediments accumulate in a (temporary) resting place. The raising of the stream bed by settlement of moving sediment that may be due to local changes in the flow, or during a single flood event.

DEPTH OF FLOW The depth of flow is the vertical distance from the bed of a stream to the water surface.

DISCHARGE The discharge (Q) is the volume of a fluid or solid passing a cross section of a stream per unit time.

DISTRIBUTARIES Diverging streams which do not return to the main stream, but discharge into another stream or the ocean.

DOMINANT DISCHARGE A particular magnitude of flow which is sometimes referred to as the "channel forming" discharge. Empirical relations have been developed between "equilibrium" stream width, depth, and slope and dominant discharge. It has been variously defined as the bank full flow, mean annual discharge, etc.

DRAFT DEPTH The depth measured perpendicularly from the water surface to the bottom of a boat, ship, etc. (i.e., a "clearance" depth).

DROP A structure in an open conduit or canal installed for the purpose of dropping the water to a lower level and dissipating its energy. It may be vertical or inclined; in the latter case it is usually called a chute.

EFFECTIVE (GRAIN) SIZE The diameter of the particles in an assumed rock or soil that would transmit water at the same rate as the rock or soil under consideration, and that is composed of spherical particles of equal size and arranged in a specific manner. The effective grain size is that single particle diameter that best depicts the bed material properties. The D50 grain size is often used as the effective grain size.

EQUILIBRIUM DEPTH The minimum water depth for the condition of no sediment transport.

ENTRAINMENT The carrying away of bed material produced by erosive action of moving water.

EQUILIBRIUM LOAD The amount of sediment that a system can carry for a given discharge without an overall accumulation (deposit) or scour (degradation).

EROSION The wearing away of the land surface by detachment and movement of soil and rock fragments through the action of moving water and other geological agents.

FALL VELOCITY The falling or settling rate of a particle in a given medium.

FIXED BED MODEL Model in which the bed and side materials are nonerodible. Deposition does not occur as well.

FLOW DURATION CURVE A measure of the range and variability of a stream's flow. The flow duration curve represents the percent of time during which specified flow rates are exceeded at a given location. This is usually presented as a graph of flow rate (discharge) versus percent of time that flows are greater than, or equal to, that flow.

FREQUENCY The number of repetitions of a periodic process in a certain time period.

GEOLOGIC CONTROL A local rock formation or clay layer that limits (within the engineering time frame) the vertical and/or lateral movement of a stream at a particular point. Note that man-made controls such as drop structures also exist.

GRADATION The proportion of material of each particle size, or the frequency distribution of various sizes, constituting a particulate materialsuch as a soil, sediment, or sedimentary rock. The limits of each size are chosen arbitrarily. Four different gradations are significant: the gradation of the suspended load, the gradation of the bed load, the gradation of the material comprising the bed surface, and the gradation of material beneath the bed surface.

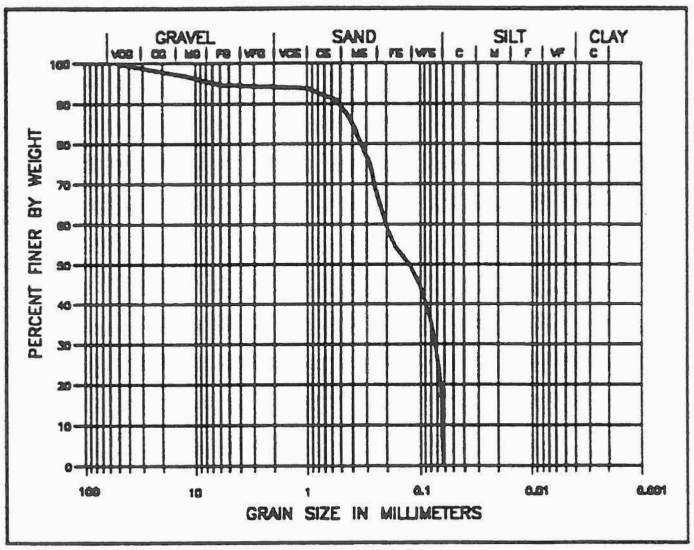

Figure B-5
Sample Gradation Curve

GRADATION CURVE Sediment samples usually contain a range of grain sizes, and it is customary to break this range into classes of percentages of the total sample weight contained in each class. After the individual percentages are accumulated, a graph, the "gradation curve", shows the grain size versus the accumulated percent of material that is finer than that grain size. These curves are used by movable boundary models to depict the bed sediment material properties (e.g., grain size distribution of the bed material). See Figure B-5.

GRAIN SHAPE FACTOR See PARTICLE SHAPE FACTOR.

GRAIN SIZE See PARTICLE SIZE.

GRAIN SIZE DISTRIBUTION (GRADATION) A measure of the variation in grain (particle) sizes within a mixture. Usually presented as a graph of grain diameter versus percent of the mixture that is finer than that diameter. See Figure B-5.

GRAVEL See Table B-1.

HISTORIC FLOWS The collection of recorded flow data for a stream during the period of time in which steam gages were in operation.

HYDRAULIC MODEL A physical scale model of a river used for engineering studies.

HYDRAULICS The study and computation of the characteristics, e.g. depth (water surface elevation), velocity and slope, of water flowing in a stream or river.

HYDROGRAPH A graph showing, for a given point on a stream or conduit, the discharge,water surface elevation, stage, velocity, available power, or other property of water with respect to time.

HYDROLOGY The study of the properties, distribution, and circulation of water on the surface of the land, in the soil, and in the atmosphere.

INACTIVE LAYER The depth of material beneath the active layer. See Figure B-1.

INCIPIENT MOTION The flow condition at which a given size bed particle just begins to move. Usually related to a "threshold" shear stress.

INEFFECTIVE FLOW When high ground or some other obstruction such as a levee prevents water from flowing into a subsection, the area up to that point is ineffective for conveying flow and is not used for hydraulic computations until the water surface exceeds the top elevation of the obstruction. The barrier can be a natural levee, man-made levee or some other structure.

INFLOWING LOAD CURVE See SEDIMENT RATING CURVE.

INITIAL CONDITIONS The value of water levels, velocities, concentrations, etc., that are specified everywhere in the mesh at the beginning of a model run. For an iterative solution, the initial conditions represent the first estimate of the variables the model is trying to solve.

IN SITU In (its original) place.

LEFT OVERBANK See OVERBANK.

LOCAL INFLOW/OUTFLOW POINT Points along any river segment at which water and sediment enter or exit that segment as a local flow. Each local inflow/outflow point is designated by an arrow and $L_{n,m}$ where *n* is the segment number and m is the sequence number (going upstream) of the local inflow/outflow points located along segment n, as shown in Figure B-6.

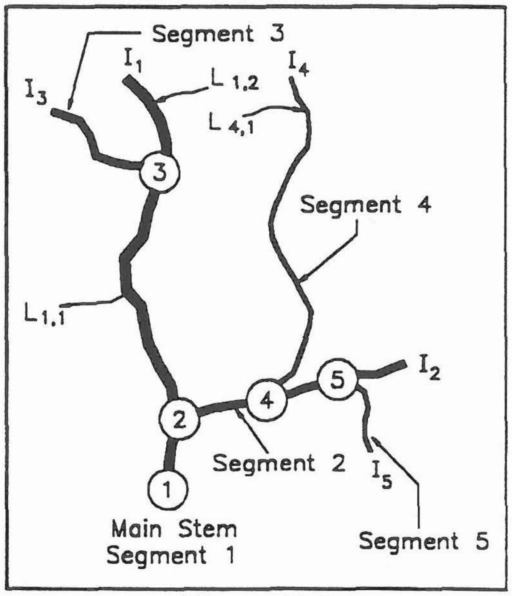

Figure B-6
Local Inflow/Outflow Points

LOCAL SCOUR Erosion caused by an abrupt change in flow direction or velocity. Examples include erosion around bridge piers, downstream of stilling basins, at the ends of dikes, and near snags.

M1 AND M2 CURVES M1 and M2 curves represent mild sloping water surface profiles.

MAIN STEM The primary river segment with its outflow at the downstream end of the model.

MANNING'S EQUATION The empirical Manning's equation commonly applied in water surface profile calculations defines the relationship between surface roughness, discharge, flow geometry, and rate of friction loss for a given stream location.

MANNING'S *n* VALUE *n* is the coefficient of roughness with the dimensions of $T \cdot L^{-1/3}$. *n* accounts for energy loss due to the friction between the bed and the water. In fluvial hydraulics (movable boundary hydraulics), the Manning's *n* value includes the effects of all losses, such as grain roughness of the movable bed, form roughness of the movable bed, bank irregularities, vegetation, bend losses, and junction losses. Contraction and expansion losses are not included in Manning's *n*, but are typically accounted for separately.

MATHEMATICAL MODEL A model that uses mathematical expressions (i.e., a set of equations, usually based upon fundamental physical principles) to represent a physical process.

MEANDERING STREAM An alluvial stream characterized in planform by a series of pronounced alternating bends. The shape and existence of the bends in a meandering stream are a result of alluvial processes and not determined by the nature of the terrain (geology) through which the stream flows.

MODEL A representation of a physical process or thing that can be used to predict the process's or thing's behavior or state.

Examples: A conceptual model: If I throw a rock harder, it will go faster.
A mathematical model: $F = m \cdot a$
A hydraulic model: Columbia River physical model.

MOVABLE BED That portion of a river channel cross section that is considered to be subject to erosion or deposition.

MOVABLE BED LIMITS The lateral limits of the movable bed that define where scour or deposition occur. See Figure B-2.

MOVABLE BED MODEL Model in which the bed and/or side material is erodible and transported in a manner similar to the prototype.

NETWORK MODEL A network model is a network of main stem, tributary, and local inflow/outflow points that can be simulated simultaneously and in which tributary sediment transport can be calculated.

NORMAL DEPTH The depth that would exist if the flow were uniform is called normal depth.

NUMERICAL EXPERIMENTS Varying the input data, or internal parameters, of a numerical model to ascertain the impact on the output.

NUMERICAL MODEL A numerical model is the representation of a mathematical model as a sequence of instructions (program) for a computer. Given approximate data, the execution of this sequence of instructions yields an approximate solution to the set of equations that comprise the mathematical model.

ONE-DIMENSIONAL ENERGY EQUATION This equation has the same form as the Bernoulli Equation and the same terms are present. In addition, an α term has been added to correct for velocity distribution.

OPERATING POLICY See OPERATING RULE.

OPERATING RULE The rule that specifies how water is managed throughout a water resource system. Often they are defined to include target system states, such as storage, above which one course of action is implemented and below which another course is taken.

OVERBANK In a river reach, the surface area between the bank on the main channel and the limits of the floodplain. See Figure B-7.

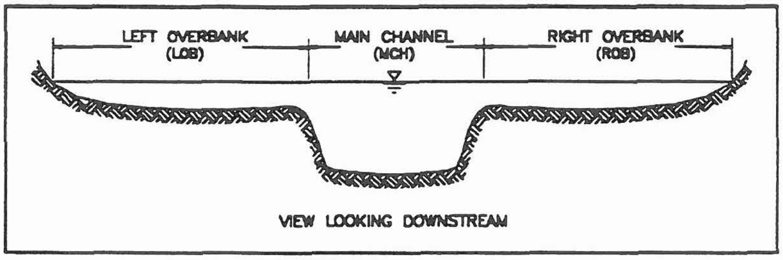

Figure B-7
Examples of Overbanks

OVERDREDGING The additional depth dredged beyond the minimum dredging depth used to provide sufficient navigational depth, to minimize redredging, and to help compensate for the sloughing off and resettling of sediment after dredging occurs

PARAMETER Any set of physical properties whose values determine the characteristics or behavior of something.

PARTICLE SHAPE FACTOR The particle shape factor of a perfect sphere is 1.0 and can be as low as 0.1 for very irregular shapes. It is defined by:

$$SF = \frac{c}{(a \cdot b)^{1/2}}$$

where: a,b,c = the lengths of the longest, intermediate, and shortest, respectively, mutually perpendicular axes on a sediment particle.

PARTICLE SIZE A linear dimension, usually designated as "diameter", used to characterize the size of a particle. The dimension may be determined by any of several different techniques, including sedimentation sieving, micrometric measurement, or direct measurement.

PERMEABILITY The property of a soil that permits the passage of water under a gradient of force.

PLANFORM The shape and size of channel and overbank features as viewed from directly above.

PRIMARY TRIBUTARY A tributary that is directly connected to or that joins with the main river segment.

PROTOTYPE The full-sized structure, system process, or phenomenon being modeled.

QUALITATIVE Relating to or involving quality or kind.

RATING CURVE See STAGE-DISCHARGE CURVE.

REACH (1) The length of a channel, uniform with respect to discharge, depth, area, and slope, e.g., "study reach", "typical channel reach" or "degrading reach", etc. (2) The length of a stream between two specified gaging stations.

RIGHT OVERBANK See OVERBANK.

RIPPLES Small triangular-shaped bed forms, similar to dunes but have much smaller heights and are 0.3m or less in length. They develop when the Froude number is less than 0.3.

RIVER SEGMENT See STREAM SEGMENT.

S1 AND S2 CURVES S1 and S2 curves represent steep sloping water surface profiles.

SAND See Table B-1.

SATURATION The degree to which voids in soil are filled with water.

SCOUR The enlargement of a flow section by the removal of bed material through the action of moving water.

SECONDARY CURRENTS (OR FLOW) The movement of water particles on a cross section normal to the longitudinal direction of the channel.

SEDIMENT (1) Particles derived from rocks or biological materials that have been transported by a fluid. (2) Solid material (sludges) suspended in or settled from water. A collective term meaning an accumulation of soil, rock and mineral particles transported or deposited by flowing water.

SEDIMENTATION A broad term that pertains to the five fundamental process responsible for the formation of sedimentary rocks: (1) weathering, (2) detachment, (3) transportation, (4) deposition (sedimentation), and (5) diagenesis; and to the gravitational settling of suspended particles that are heavier than water.

SEDIMENTATION DIAMETER The diameter of a sphere of the same specific weight and the same terminal settling velocity as the given particle in the same fluid.

SEDIMENT DISCHARGE The mass or volume of sediment (usually mass) passing a stream cross section in a unit of time. The term may be qualified, for example; as suspended-sediment discharge, bed load discharge, or total-sediment discharge. See SEDIMENT LOAD.

SEDIMENT-DISCHARGE RELATIONSHIP Tables which relate inflowing sediment loads to water discharge for the upstream ends of the main stem, tributaries, and local inflows.

SEDIMENT LOAD A general term that refers to material in suspension and/or in transport. It is not synonymous with either discharge or concentration. It may also refer to a particular type of load; e.g. total, suspended, wash, bed, or material.

SEDIMENT PARTICLE Fragments of mineral or organic material in either a singular or aggregate state.

SEDIMENT TRANSPORT (RATE) See SEDIMENT DISCHARGE.

SEDIMENT TRANSPORT FUNCTION A formula or algorithm for calculating the sediment transport rate given the hydraulics and bed material at a cross section. Most sediment transport functions compute the bed material load capacity. The actual transport may be less than the computed capacity due to armoring, geologic controls, etc.

SEDIMENT TRANSPORT ROUTING The computation of sediment movement for a selected length of stream (reach) for a period of time with varying flows. Application of sediment continuity relations allow the computation of aggradation and deposition as functions of time.

SEDIMENT TRAP EFFICIENCY See TRAP EFFICIENCY.

SETTLING VELOCITY See FALL VELOCITY.

SHAPE FACTOR See PARTICLE SHAPE FACTOR.

SHEAR INTENSITY A dimensionless number that is taken from Einstein's bed load function. It is the inverse of Shield's parameter.

SHEAR STRESS Frictional force per unit of bed area exerted on the bed by the flowing water. An important factor in the movement of bed material.

SHIELD'S DETERMINISTIC CURVE A curve of the dimensionless tractive force plotted against the grain Reynolds number (i.e., $U_* \cdot D_s/v$ where, U_* = turbulent shear velocity, D_s = characteristic or effective size of the grains or roughness elements, v = kinematic viscosity) and which is used to help determine the CRITICAL TRACTIVE FORCE.

SHIELD'S PARAMETER A dimensionless number referred to as a dimensionless shear stress. The beginning of motion of bed material is a function of this dimensionless number.

$$\frac{\tau_c}{(\gamma_s - \gamma)\, D_s}$$

where: τ_c = critical tractive force
γ_s = specific weight of the particle
γ = specific weight of water
D_s = characteristic or effective size of the grains or roughness elements

SIEVE DIAMETER The smallest standard sieve opening size through which a given particle of sediment will pass.

SILT See Table B-1.

SILTATION An unacceptable term. Use sediment deposition, sediment discharge, or sediment yield as appropriate.

SIMULATE To express a physical system in mathematical terms.

SINUOSITY A measure of meander "intensity". Computed as the ratio of the length of a stream measured along its thalweg (or centerline) to the length of the valley through which the stream flows.

SORTING The dynamic process by which sedimentary particles having some particular characteristic (such as similarity of size, shape, or specific gravity) are naturally selected and separated from associated but dissimilar particles by the agents of transportation. Also, see GRADATION.

SPLIT FLOW Flow that leaves the main river flow and takes a completely different path from the main river [Case (a)]. Split flow can also occur in the case of flow bifurcation around an island [Case (b)]. See Figure B-8.

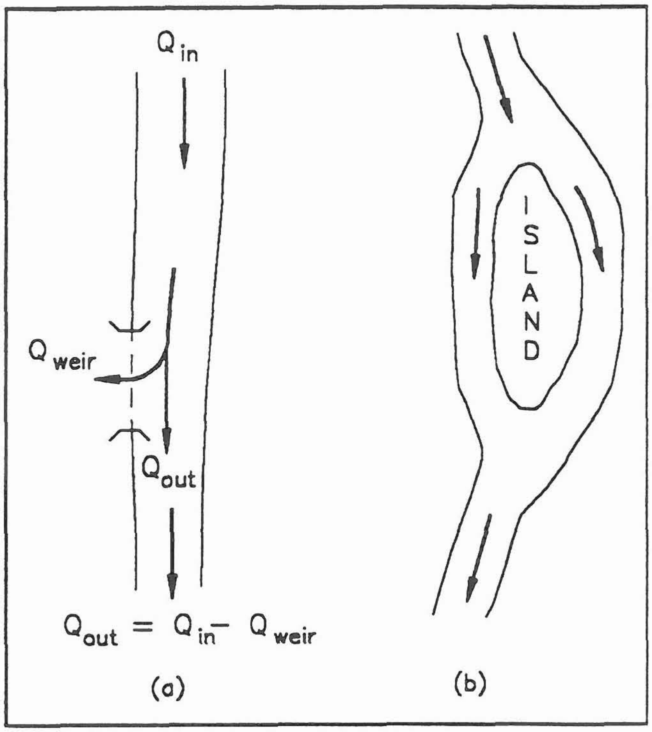

Figure B-8
Split Flow

STABLE CHANNEL A stream channel that does not change in planform or bed profile during a particular period of time. For purposes of this glossary the time period is years to tens of years.

STAGE-DISCHARGE (RATING) CURVE Defines a relationship between discharge and water surface elevation at a given location.

STANDARD STEP METHOD Method where the total distance is divided into reaches by cross sections at fixed locations along the channel and, starting from one control, profile calculations proceed in steps from cross section to cross section to the next control.

STEADY STATE MODEL Model in which the variables being investigated do not change with time.

STREAM GAGE A device that measures and records flow characteristics such as water discharge and water surface elevation at a specific location on a stream. Sediment transport measurements are usually made at stream gage sites.

STREAM POWER The product of bed shear stress and mean cross-sectional velocity at a cross section for a given flow.

STREAM PROFILE A plot of the elevation of a stream bed versus distance along the stream.

STREAM SEGMENT A stream segment is a specified portion of a river with an upstream inflow point and with a downstream termination at a control point. Primary Inflow points are designated by I_n, where *n* is the segment number. Primary inflow points are always at the upstream most end of a tributary or main stem segment. See Figure 3-7.

SUBCRITICAL FLOW The state of flow where the water depth is above the critical depth. Here, the influence of gravity forces dominate the influences of inertial forces, and flow, having a low velocity, is often described as tranquil.

SUB-SURFACE LAYER The sub-surface layer is composed of well mixed sediments brought up from the inactive layer plus sediment which has deposited from the water column. It will replenish the cover layer and thereby supply bed sediment as required to meet sediment transport capacity. When the weight in the sub-surface layer becomes less than the weight required to cover 100% of the bed surface to a depth of two times the size of the largest particle in transport, a new sub-surface layer is brought up from the inactive layer. See Figure B-1.

SUPERCRITICAL FLOW The state of flow where the water depth is below the critical depth, inertial forces dominate the gravitational forces, and the flow is described as rapid or shooting.

SUSPENDED BED MATERIAL LOAD That portion of the suspended load that is composed of particle sizes found in the bed material.

SUSPENDED LOAD Includes both suspended bed material load and wash load. Sediment that moves in suspension is continuously supported in the water column by fluid turbulence. Contrast with BED LOAD.

SUSPENDED-SEDIMENT DISCHARGE The quantity of suspended sediment passing a cross section in a unit of time usually given in tons/day. See SUSPENDED LOAD.

TAIL WATER The water surface elevation downstream from a structure, such as below a dam, weir or drop structure.

THALWEG The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part or middle of the bed or channel of a river.

TOTAL SEDIMENT DISCHARGE The total rate at which sediment passes a given point on the stream (tons/day). See TOTAL SEDIMENT LOAD.

TOTAL-SEDIMENT LOAD (TOTAL LOAD) Includes bed load, suspended bed material load, and wash load. In general, total sediment load cannot be calculated or directly measured.

TRACTIVE FORCE When water flows in a channel, a force is developed that acts in the direction of flow on the channel bed. This force, which is simply the pull of water on the wetted area, is known as the tractive force. In a uniform flow, the equation for the unit tractive force (i.e., the average value to the tractive force per unit wetted area) is:

$$\tau_0 = \gamma RS$$

where: τ_o = unit tractive force
γ = unit weight of water
R = the hydraulic radius
S = the slope of the channel

TRANSMISSIVE BOUNDARY A boundary (cross section) that will allow sediment that reaches it to pass without changing that cross section.

TRANSPORTATION (SEDIMENT) The complex processes of moving sediment particles from place to place. The principal transporting agents are flowing water and wind.

TRANSPORT CAPACITY The ability of the stream to transport a given volume or weight of sediment material of a specific size per time for a given flow condition. The units of transport capacity are usually given in Tons per day of sediment transported passed a given cross section for a given flow. Transport capacity for each sediment grain size is the transport potential for that size material multiplied by the actual fraction of each size class present in the bed and bank material.

TRANSPORT POTENTIAL Transport potential is the rate at which a stream could transport sediment of a given grain size for given hydraulic conditions if the bed and banks were composed entirely of material of that size.

TRAP EFFICIENCY Proportion of sediment inflow to a stream reach (or reservoir) that is retained within that reach (or reservoir). Computed as inflowing sediment volume minus outflowing sediment volume divided by inflowing sediment volume. Positive values indicate aggradation; negative values, degradation.

TRIBUTARY A river segment other than the main stem in which sediment transport is calculated. More generally, a stream or other body of water, surface or underground, that contributes its water to another and larger stream or body of water.

TURBULENCE In general terms, the irregular motion of a flowing fluid.

WASH LOAD That part of the suspended load that is finer than the bed material. Wash load is limited by supply rather than hydraulics. What grain sizes constitute wash load varies with flow and location in a stream. Sampling procedures that measure suspended load will include both wash load and suspended bed material load. Normally, that is of sediment particles smaller than 0.062 mm.

WATER COLUMN An imaginary vertical column of water used as a control volume for computational purposes. Usually the size of a unit area and as deep as the depth of water at that location in the river.

WATER DISCHARGE See STREAM DISCHARGE.

WATERSHED A topographically defined area drained by a river/stream or system of connecting rivers/streams such that all outflow is discharged through a single outlet. Also called a drainage area.

WEIR A small dam in a stream, designed to raise the water level or to divert its flow through a desired channel. A diversion dam.

WETTED PERIMETER The wetted perimeter is the length of the wetted contact between a stream of flowing water and its containing channel, measured in a direction normal to the flow.

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US Army Corps
of Engineers
Hydrologic Engineering Center

Guidelines for the Calibration and Application of Computer Program HEC-6

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TD-13

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Conversion Factors, Non-SI to SI (metric) Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	5/9*	degrees Celsius or Kelvin
feet	0.3048	meters
inches	2.54	centimeters
miles (US statute)	1.609347	kilometers
tons (2,000 pounds, mass)	907.1847	kilograms

*To obtain Celsius (C) temperature values from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

Preface

This document provides guidance on the engineering aspects of applying HEC-6; it is, therefore, a supplement to the HEC-6 User's Manual. Originally published in 1981, this edition contains substantial new material based on program enhancements and applications experience gained since then.

This document was prepared by D. Michael Gee, Training Division, HEC. William A. (Tony) Thomas, Hydraulics Laboratory, WES, provided most of the concepts and material included herein. Vern Bonner was Chief, Training Division and Darryl W. Davis, Director, HEC, during preparation of this report.

Chapter 1

Introduction

1.1 General

HEC-6 (HEC, 1991) is a one-dimensional movable boundary open channel flow and sediment model designed to simulate changes in river profiles due to scour and deposition over fairly long time periods (typically years, although applications to single flood events are possible). The continuous flow record is broken into a sequence of steady flows of variable discharge and duration. For each flow a water surface profile is calculated thereby providing energy slope, velocity, depth, etc. at each cross section. Potential sediment transport rates are then computed at each section. These rates, combined with the duration of the flow allow for a volumetric accounting of sediment for each reach. The amount of scour or deposition at each section is then computed and the cross section shape adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. The sediment calculations are performed by grain size fraction thereby allowing for the simulation of hydraulic sorting and armoring. Features of the model include: capability to analyze networks of streams, automatic channel dredging, various levee and encroachment options, and several options for computation of sediment transport rates.

Experience has shown that successful application of movable boundary models may require substantial effort to reproduce field observations, i.e. calibration. This document complements the HEC-6 User's Manual (HEC, 1991) and provides guidelines for calibration and application. The general topic of application and calibration of numerical river models is thoroughly covered in Cunge, et al. (1980).

1.2 Additional Guidance

Additional information on related topics can be found in EM 1110-2-4000, "Sedimentation Investigations of Rivers and Reservoirs" (USACE, 1989), "Stability of Flood Control Channels" (USACE, 1990), and EM 1110-2-1415 "River Hydraulics" (USACE, 1992). These documents describe general approaches to analyzing river systems, data acquisition, analytical techniques, numerical model usage, and the Corps of Engineers study process.

Chapter 2

Historical Behavior of the Stream System

2.1 Introduction

It is essential for the engineer to comprehend the past behavior of the stream system early in the study. Development of appropriate representative data and assessment of HEC-6's performance require such an understanding. Contemporary engineering analyses address time frames ranging from a single flood event to the project life. It is also necessary to try to understand the behavior of the river system at the geologic time scale in order to understand how the steam developed its present planform and profile, what its likely future characteristics will be, and the likely responses to various activities.

2.2 Documenting Past Behavior

To ascertain the historical behavior of the stream system, assemble all pertinent information from previous studies and office files: for example; maps, surveyed cross sections, observed water surface profiles, aerial photographs, ground photographs, flow and stage records, stage-discharge rating curves, water temperature records, suspended sediment loads, total sediment loads, gradation of the suspended and total loads, and gradation of the bed material. It is also important to determine and document locations, dates, and sizes of impoundments, extent of construction activities adjacent to, and within, the stream channels, amounts and material gradations of dredging activities in the study area, existing and future land use, and soil types. The availability of each type of data may be shown on a time line. This is particularly useful for flow data to determine a base period for calibration.

2.3 Analyzing Past Behavior

Once the data have been inventoried and assembled, the analyst should attempt to do the following:

- Examine extreme flow events in the study area and determine how the system responded in terms of channel changes and amount of sediment transported.

- Estimate the response time of the stream system; e.g. the rate of movement of flood hydrographs, the rate of channel response to changes in sediment load, etc.

- Evaluate the impacts that impoundments have had on the water discharge hydrograph and the sediment load.

- Establish a general understanding of the past behavior of the stream system. It is often useful to try to partition, conceptually, the stream behavior into what would have occurred naturally and what may be attributable to human activities in the watershed; both land use and stream use activities.

- Locate irregularities in geometric, hydrologic, hydraulic and sediment characteristics within the study area.

- Locate and date each bridge crossing, cut-off (natural or not), encroachment, levee, diversion and/or bifurcation.

- Note overbank areas which flood first and locate their natural levees.

- Refine the study objectives, if necessary, and identify possible alternative plans and appropriate analytical approaches.

- Identify missing or deficient data which can only be obtained by field measurements and/or field reconnaissance.

- Identify all locations where scour or deposition occurred during a flood and the stream did not return to its original cross section or alignment.

- Locate rock outcroppings or other geologic formations which will resist scour and therefore control the vertical movement of the stream bed.

The grain size of sediment on point bars should be observed and locations of abrupt changes noted. Note any sand deposits on overbank areas. Of particular interest are locations on point bars where the gradual change from coarse to fine particles, in the downstream direction, is interrupted by a sudden change in bed material gradation which persists in the downstream direction.

Determine as much information as possible about bed roughness, and particularly about changes in bed roughness that occur along the stream or that may occur as discharge changes. Roughness may also vary seasonally due to temperature and/or vegetative changes. More information on this subject is presented in USACE (1992).

Chapter 3

Data Requirements

3.1 Selection of the Study Area

Selection of the study area requires several considerations. The area should extend sufficiently far upstream from the project area that alternatives being evaluated do not produce changes to the bed profile or the sediment load at the upstream boundary of the area being modeled. The study area should also include all major sediment producing tributaries (see Figure 1). Hydraulic structures may also be used as a study boundaries. Identify and locate all major streams and reservoirs, gaging stations, controls such as drop structures, etc. on a basin map.

The project area and study area boundaries should be marked on a map to delineate areas needing data. The lateral limits of the study area and the tributaries should be shown. One should use U.S. Geological Survey topographic maps, Corps of Engineers topographic maps, or other agency maps that provide detailed topography of the area, and are current. In the case of reservoir studies, highlight the existing channel, outline the reservoir surface area at the bottom of conservation pool contour, and locate the dam axis on the map. Identify and indicate on the map all pertinent features such as urban areas, recreation sites, harbors, levees, pumping plants, etc., that border the existing channel. Mark all locations where rock outcrops cross, or border, the channel. Use of a geographic information system (GIS) and digital terrain model may aid in organizing and displaying the many data types of interest (HEC, 1992).

Plot the bed (thalweg) profile from field survey and/or topographic data. It is useful to mark the locations of pertinent elevations. This profile will serve as a reference for displaying simulated changes in water surface and bed profiles.

3.2 Types of Data

3.2.1 Data for Model Application

It is important to distinguish between two general categories of data; one chronicles the behavior of the prototype, the other is required to operate a numerical model. The first are commonly called "calibration" data; the second, "input" or "run" data. The first type is summarized here for completeness. The second, beginning with geometry, is presented in more detail.

Bed profiles from historical surveys in the study area are valuable for determining historical trends. Aerial photographs and mosaics of the study area are useful for identifying historical trends of channel width, meander wave length, rate of bank line movement, land use, etc. Gage records can be used to determine the annual water delivery to the study area and the water yield from it. They are also useful for establishing hydraulic parameters such as depth, velocity, *n*-values, and trends in stage-discharge curves in, or close to, the study reach. It is important to differentiate between "measured" and "extrapolated" data. For example, the extrapolated portion of a rating curve should not be given the same weight as

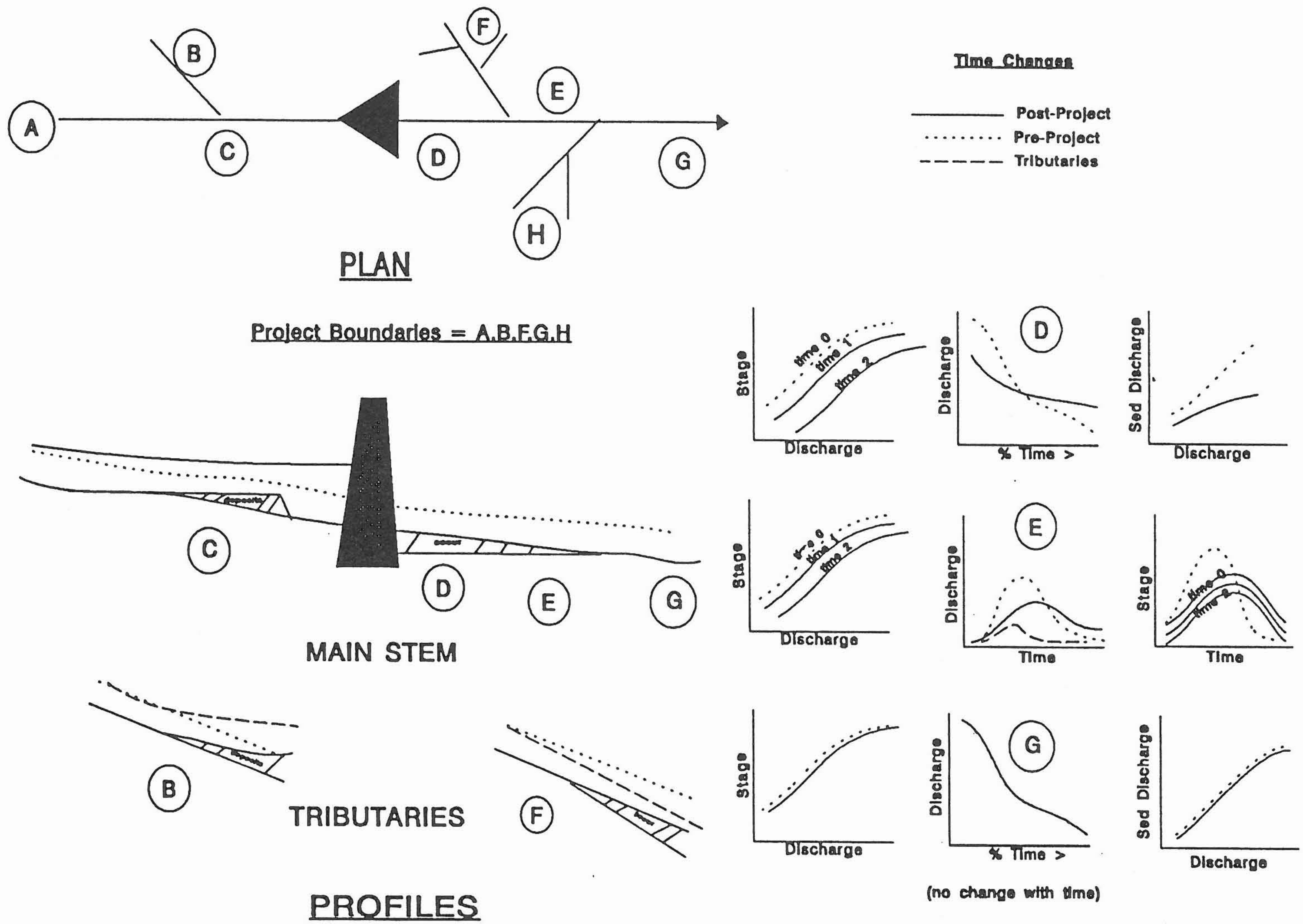

Figure 1.
Example Project Boundaries and Possible Impacts.

measured data. An example is shown in Figure 2 where, in this situation, the measured flows were all less than 1,850 cfs whereas the project formulation flows ranged up to 16,000 cfs. Be aware also, that all measured data are subject to various errors and uncertainties as discussed in (USACE, 1992). Reconnaissance of the project reach is a valuable aid for determining channel morphology, geometric anomalies, the existence of structures and construction activity, and sediment characteristics of the channel. Geotechnical, geomorphological, and environmental specialists should be present at the field reconnaissance. Document observations of the prototype in project reports. View as much of the prototype as is feasible, and not just at bridge crossings. Hydraulic data such as surveyed high water marks, velocities, and flood limits in the study reach are extremely valuable. Local agencies, newspapers, and residents along the stream are valuable sources of qualitative information that can supplement field measurements.

The quantity of data necessary to operate HEC-6 for long-term simulations can be quite large. Therefore, it is beneficial to have a systematic procedure for storing, manipulating, analyzing, and displaying those data (Gee, 1983; HEC, 1990b).

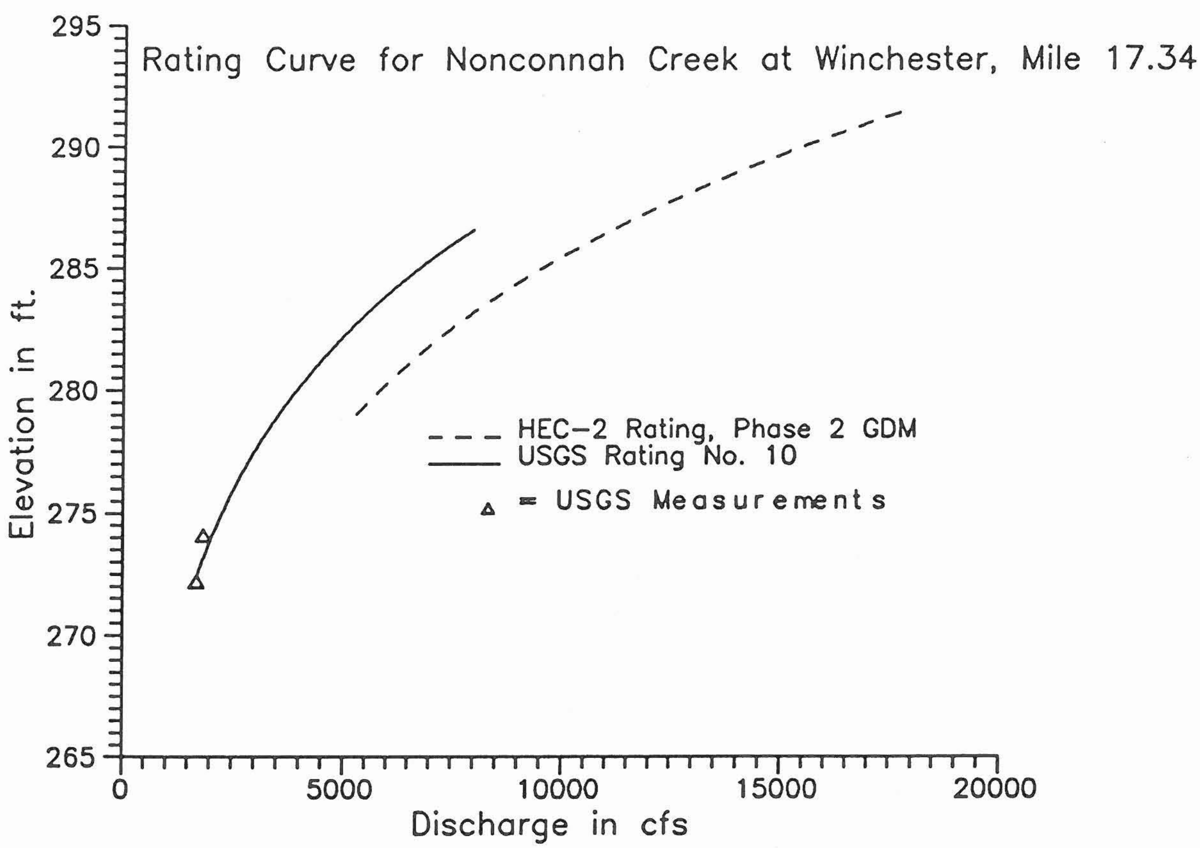

Figure 2.
Rating Curve at a Gage.

3.2.2 Development of Representative Data

Developing a one-dimensional representation of a three-dimensional open channel flow situation is an art. It requires one to visualize the three-dimensional flow lines in the prototype system and translate that image into a one-dimensional description.

Representative data are not necessarily averages of many samples. For example, representative geometry preserves channel width, depth, and roughness and yields numerical model results that reproduce observed water surface elevations, velocities, energy losses, and flow distributions. The representative inflowing sediment load preserves both the volume of sediment and the rate of sediment inflow at the upstream boundary of the study area. The representative bed material gradation and gradation of inflowing sediment loads produce model results that have transport rates and changes in bed elevation that are consistent with prototype observations. Representative water discharges include flow rate, and to a lesser extent, flow volume and amount of attenuation of flood hydrographs as they move down the system. Having flows match the appropriate flow-duration relationship is important (i.e., representative flows for the calibration period are those which occurred during that period, whereas representative flows for the study period are those producing the long-term flow-duration curve). Development of representative data often requires several iterations to arrive at an acceptable representation. A useful approach is to move towards the solution by first performing a fixed bed simulation and then adding sediment.

Beginning with geometric data, procedures for developing representative data are suggested below. These are not all inclusive guidelines, but they stress the most important characteristics of the prototype system which should be preserved in the data.

3.3 Geometric Data

HEC-6 computes the water surface and bed surface elevations as they change over time. It is therefore necessary to prescribe the initial geometry with input data. As the computations proceed through time, the cross sections aggrade or degrade in response to movable bed theory. The cross sections never change locations.

3.3.1 Cross Sections

There is no established maximum spacing for cross sections; it depends on both study needs and accuracy criteria related to the particular numerical model being used. Some studies have required distances between sections as short as a fraction of the river width. Others have successfully used sections spaced several miles apart. The objective is to develop input data that yield model results that reconstitute the historical behavior of the bed profile and also capture key features of the flow and the boundary movement. The usual approach is to begin the study with geometric data that were developed for fixed bed calculations, if available. Note, however, because most fixed bed data sets are prepared to analyze flood flows, they may be biased towards constrictions such as bridges and deficient of reach-typical sections that are important for long-term river behavior. There may also be cases where cross sections were selected to reflect local conditions, such as at deep bends or junctions where the shape is molded by turbulence and not one-dimensional sediment transport. These exceptions may not become obvious until the calibration phase and may require the addition of "reach-typical" sections. Locate all cross sections on a map for future reference and reporting.

Cross sections should be located at major changes in bed profile, at points where the channel or valley width changes, at tributaries, at changes in roughness, at structures, and at all points where calculated results are required (e.g., stream gaging stations). Assign an identification number to each cross section; river miles are preferable. Avoid arbitrary section identifiers because they fail to convey descriptive information. As in fixed bed calculations, it is important to locate the cross sections so that they reflect the channel contractions and expansions. It is particularly important in movable boundary modeling to also recognize and set conveyance limits. That is, when active flow does not occupy the entire lateral extent of a cross section in the prototype, conveyance limits should be set in the input data.

A portion of the section must be specified as "movable" (see Figure 3) for HEC-6. Typically it will be just inside the left and right channel stations. Only the coordinates between, and including, these limits will be moved vertically due to scour and deposition; overbank areas beyond the left and right boundaries of the movable portion are treated as fixed bed areas[1]. Selection of the movable bed limits requires good engineering judgment; they will usually require adjustment during calibration.

Avoid locating cross sections too close together. The shorter the distance between sections, the shorter the computation interval has to be in HEC-6. Short computation intervals require more computer time and, therefore, should be avoided in long period studies. Methods for establishing proper computational time step lengths are discussed in section 3.6, "Hydrologic Data."

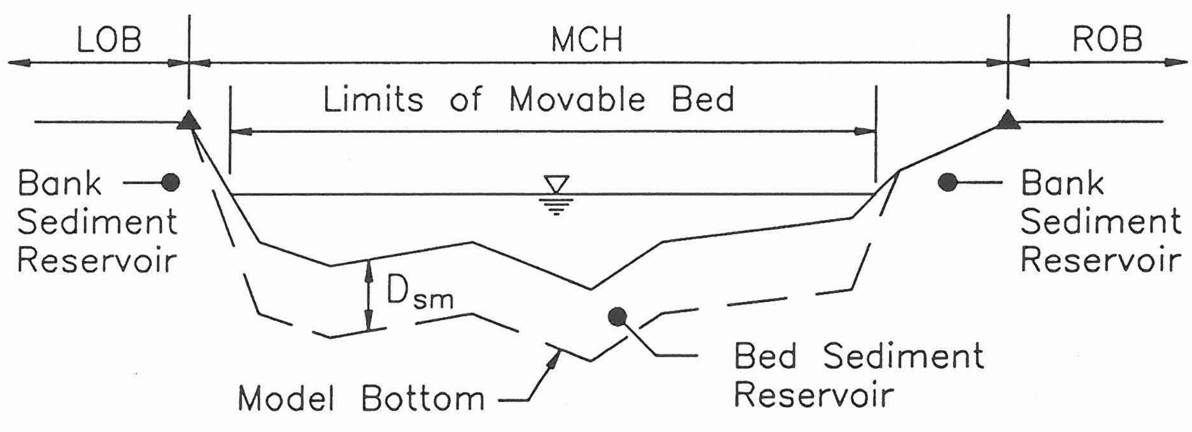

Figure 3.
HEC-6 Movable Bed Definition.

[1] Note, the exact operation of HEC-6 with regard to movement of cross section coordinate points continues to evolve; check with HEC for the current status.

Include, in the data, the top of rock elevation for geologic formations at any cross section where it occurs at the bed surface or within the anticipated maximum scour depth. Erroneous answers for sediment transport and bed movement may result if an existing hard-bottom geologic control, such as a rock outcropping, is not reflected in the input data.

When modeling a reservoir, the study reach must extend sufficiently far upstream from the reservoir area so that the upstream end is beyond any backwater effects of the dam. In a reservoir study, it is also useful to note the various anticipated pool elevations on plots of the cross sections.

3.3.2 Error Checking Geometric Data

Movable bed profile calculations are more sensitive to inaccuracies in boundary geometry than are fixed bed water surface profile calculations; consequently, more care is required to assemble and check geometry than is typical for fixed bed water surface profile studies. A cross section which is too wide or too deep will show up as a point of deposition; one which is too narrow or shallow will exhibit a tendency to scour. Not only will the inaccurate section be affected, but also the calculated results at sections upstream and downstream. Geometric data errors, therefore, are difficult to locate when HEC-6 is executing in the movable bed mode. The first step in correcting and calibrating the geometric data is to run the model in fixed bed mode. This allows calibration of the geometric and hydraulic portions of the data separately from the sediment portions. This is a critical first step because the validity of subsequent sediment computations is dependent both upon having an accurate description of the system geometry for hydraulic computations and having representative sediment data.

3.4 Energy Loss Coefficients

3.4.1 Selection of *n* Values[2]

Note that there is a difference in Manning's *n* between fixed and movable bed situations. Fixed bed *n*'s are values which do not depend on the characteristics of the movable boundary, movable bed *n*'s are values which may depend on the rate of sediment transport and, hence, the discharge. Appropriate values for Manning's *n* should be initially determined by executing HEC-6 in fixed bed mode, i.e., as a step-backwater program. This is necessary to properly compare calculated water surface elevations with observed water surface profiles, with established rating curves, or with results from a different backwater program, such as HEC-2. During the analysis of geometric data and calibration of *n* values, many program executions will usually be required.

Careful consideration should be given to the rationale for selection of *n* values. Changing *n* values with distance should be justified based on changes in vegetation, channel form, structures, or sediment size. Avoid changes where the only reason is to reconstitute an observed stage. Oftentimes, it is more logical to approximately reconstitute the stages at several gage or high water mark locations over a long reach using a constant *n* value for a

[2] A useful summary and overview of this topic has been prepared by WES (1992). See also USACE (1992).

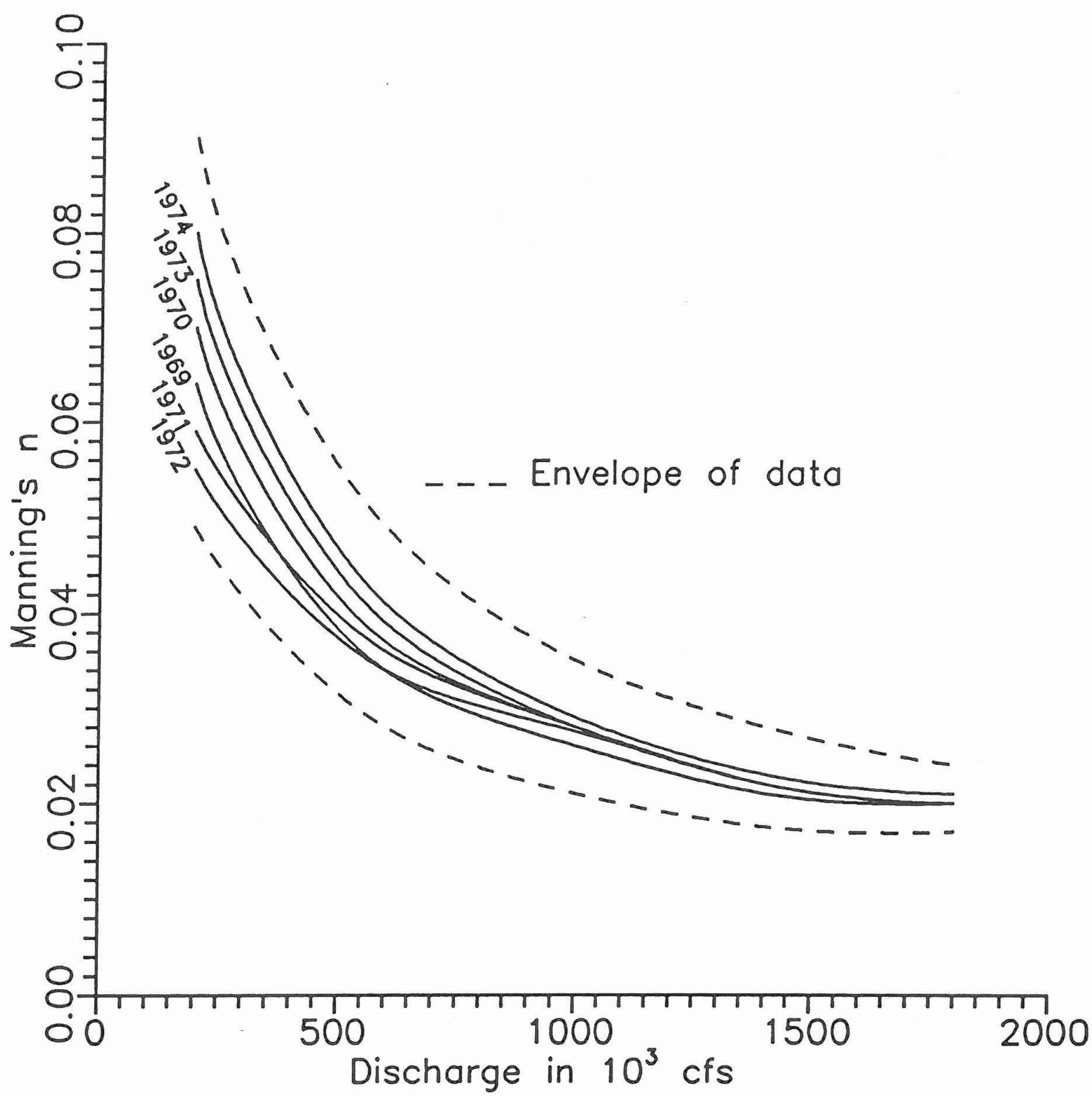

Figure 4.
Variation of Manning's *n* with Discharge for the Mississippi River at Arkansas City.

given discharge, than it is to change *n* values at each location in order to exactly match the observed stage. Also, *n* values may vary with discharge (Figure 4), that is, the bed form in alluvial rivers often changes during the passing of a flood event. As yet, it is not possible to accurately predict such changes (Barnes, 1967; Einstein and Barbarossa, 1952; Simons and Richardson, 1966; Vanoni, 1975).

Determining *n* values as described above implies that a fixed bed model is satisfactory throughout a range of flows, including floods. The technique assumes that the entire bed of the river is stationary and does not move or change roughness during a flood event. This assumption may be valid over long distances (several miles) whereas it may not be valid at a single section. Also, the technique assumes that the channel is well defined. Some other procedure may be required in areas where each flood forms its own channel such as on an alluvial fan.

When there are no reliable field measurements the recourse is to use movable boundary roughness predictors for the movable bed portion of the cross section (Brownlie, 1981; Limerinos, 1970) and calibrated photographs (Barnes, 1967; Chow, 1959) for the overbank and fixed bed portions. Document prototype conditions with photographs during the field reconnaissance. An alternative is to use a relationship between Manning's *n* and discharge based on field measurements of flow and stage.

3.4.2 Selection of Contraction and Expansion Coefficients

Information for contraction and expansion losses is more sparse than that for *n* values. King and Brater (1963) give values of 0.5 and 1.0 respectively for a sudden change in area accompanied by sharp corners, and values of 0.05 and 0.10 for the most efficient transitions. Design values of 0.1 and 0.2 are suggested. They cite Hinds (1928) as their reference. Values often cited by the Corps of Engineers (HEC, 1990a) are 0.1 and 0.3, contraction and expansion respectively, for gradual transitions.

3.5 Sediment Data

3.5.1 Introduction

Preparation of accurate sediment data and development of a representative inflowing sediment load curve are essential. The objective in preparing sediment data for reservoir deposition studies is to develop a relationship between the water discharge and the inflowing sediment load which depicts the long-term, average sediment yield. In river studies, however, the objective is to establish the sediment load and gradation that accompanies river flows entering the study area and to determine the proper size distribution and character of the bed material. For any given year, the representative load curve, when integrated with the water hydrograph for that year, should produce the proper annual volume of sediment. The total inflowing load, and the distribution of grain sizes within that load, must be adjusted until a representative curve has been established.

3.5.2 Sediment Inflows

(1) *Inflowing sediment concentrations*. Occasionally suspended sediment concentration measurements, expressed as milligrams per liter, are available. These are usually plotted against water discharge and often exhibit very little correlation with the discharge; however, use of such graphs is encouraged when developing or extrapolating the inflowing sediment data. As the analysis proceeds, it is desirable in most situations to convert the concentrations to sediment discharge in tons/day and to relate that to water discharge as shown in Figure 5. A scatter of about 1 log cycle is common in such graphs. The scatter is smaller than on the concentration plot because water discharge appears on both axes. The scatter may result from seasonal effects (e.g., vegetation and fires), random measurement errors, changes in the watershed or hydrology during the measurement period, or other sources. The analyst should carefully examine these data and attempt to understand the shape and variance of the relationship using knowledge of the river system and its past

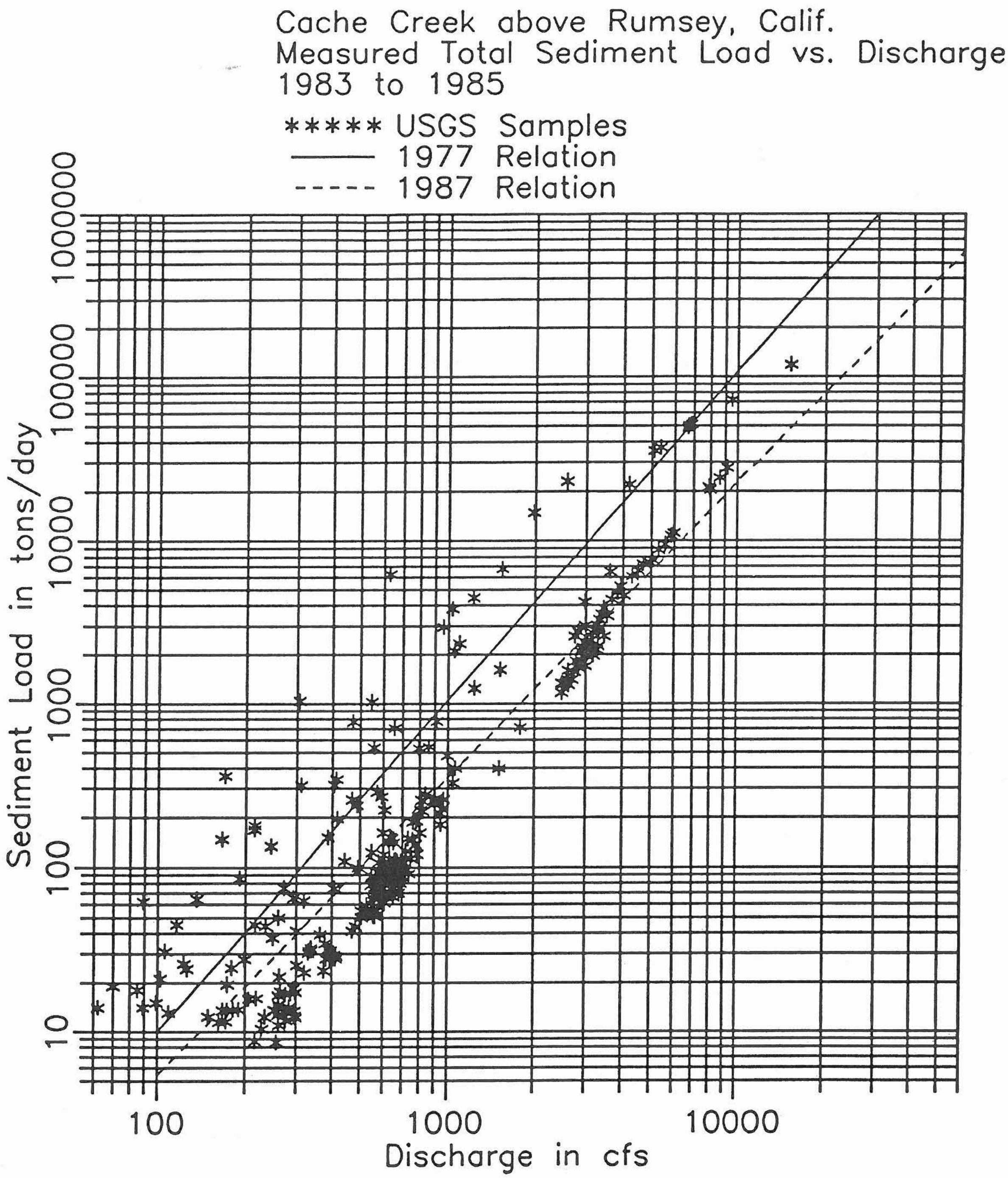

Figure 5.
Sediment-Discharge Rating Curve.

behavior. Note that, typically, 80 - 90% of the total load is "wash load" which is of little importance for river mechanics, but of great importance for reservoir deposition.

(2) *Grain size classes*. The total sediment discharge should be partitioned into size classes for movable bed computations. Table 1 shows a procedure that was used for the Clearwater River at Lewiston, Idaho. Figure 6 is the graph of that data. Note that, due to the availability of various size fractions in the bed and the suspended load gradation, for a given flow the transport rate does not necessarily decrease with increasing particle size. This phenomenon occurs primarily at low flows and may, therefore, be of little consequence to the overall stream behavior.

(3) *Calculating sediment inflow with transport theory*. When no measurements are available, the inflowing sediment boundary condition must be calculated. This is possible for the bed material load by using open channel hydraulics and sediment transport theory (there is no comparable theory for the wash load). When making such a calculation for the boundary condition, select the reach of channel very carefully. It should be one upstream of the study reach which has a slope, velocity, width, and depth typical of the reach which is transporting the sediment into the study area. It should also have a bed surface that is approximately in equilibrium with the bed material discharge being transported by the flow. Having located such a reach, sample the bed surface over a distance of several times the channel width. Focus on point bars or alternate bars rather than the thalweg of the cross section. Measure the geometry of the reach. Make the calculation by particle size for the full range of water discharges to be studied using the selected transport function (see Section 3.5.4). An inflowing load relationship calculated in this manner will usually require adjustment during calibration.

(4) *Sediment inflow from tributaries*. The sediment inflow from tributaries is more difficult to establish than it is for the main stem because there is usually less data for the tributaries. The recourse is to assess each tributary during the site reconnaissance. For example, look for a delta at the mouth of the tributary. Look for channel bed scour or deposition along the lower end of the tributary. Look for drop structures or other controls that aid in stabilizing a tributary and indicate past problems. Look for significant deposits if the tributaries have concrete lining. These observations will help guide the development of tributary sediment discharges.

3.5.3 Bed Material Sampling

The bed material gradation is necessary to calculate the sediment discharge. Computed transport rates are quite sensitive to the bed material gradation; the rate of transport typically increases exponentially as the grain size decreases, as shown on Figure 7. There is no simple rule for locating bed material samples. The general rule is to always seek representative samples. That is, very carefully select sampling locations and avoid anomalies which would bias either the calculated sediment discharge or the calculated bed stability against erosion. Samples taken near structures such as bridges will rarely be representative of reach transport characteristics. In reservoir deposition studies, where silt and clay dominate the volume and bed material movement is minimal, a detailed description of the bed gradation may not be necessary.

Table 1.

Distribution of Sediment Load by Grain Size Class

Water discharge: 35,000 cfs

Total Bed Load, tons/day. . . . . .130[a]
Total Susp. Load, tons/day. . . . . .1500[b]
Total Sediment Load. 1630

Grain Size Diameter mm	Classification	Percent Bed Load	Bed Load tons/day	Percent Suspended Load	Susp. Load tons/day	Total Load Col. (4) + (6) tons/day
(1)	(2)	(3)	(4)	(5)	(6)	(7)
< .0625	silt & clay	0.04	0.05	54	810	810
0.0625-.125	VFS	0.10	0.13	10	150	150
0.125-.250	FS	2.75	4.00	13	195	199
0.250-.500	MS	16.15	21.00	19	285	306
0.500-1	CS	13.28	17.00	4	60	77
1-2	VCS	1.19	2.00			2
2-4	VFG	1.00	1.00			1
4-8	FG	1.41	2.00			2
8-16	MG	2.34	3.00			3
16-32	CG	6.33	8.00			8
32-64	VCG	23.38	30.00			30
> 64	cobbles & larger	32.03	42.00			42
TOTAL		100.0	130.18	100.0	1500	1630

Notes:

a. The distribution of sizes in the bed load is usually computed using a bed load transport function and field samples of bed material gradation. The bed load rate is rarely measured and may have to be computed.

b. The suspended load and its gradation can be obtained from field measurements.

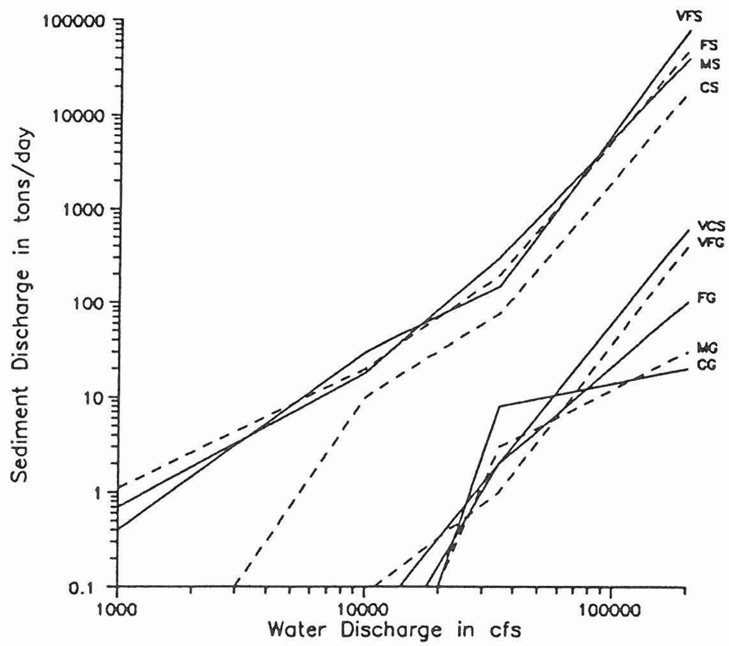

Figure 6.
Sediment Load Curves.

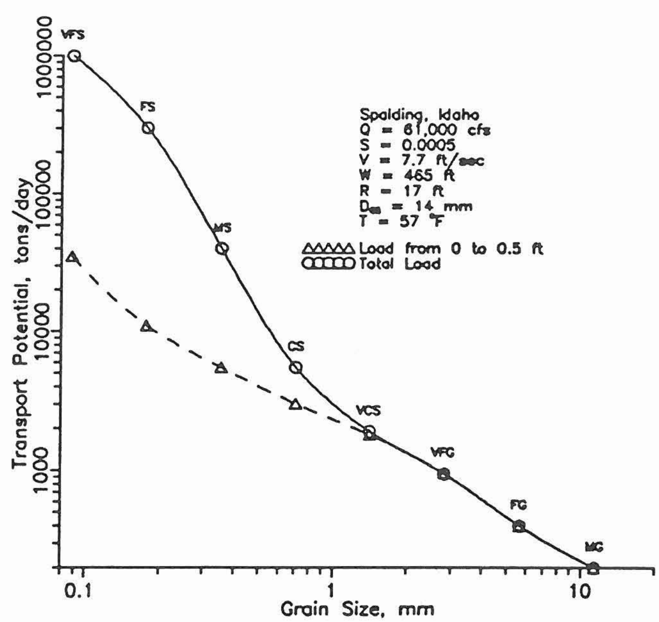

Figure 7.
Variation of Sediment Transport with Grain Size.

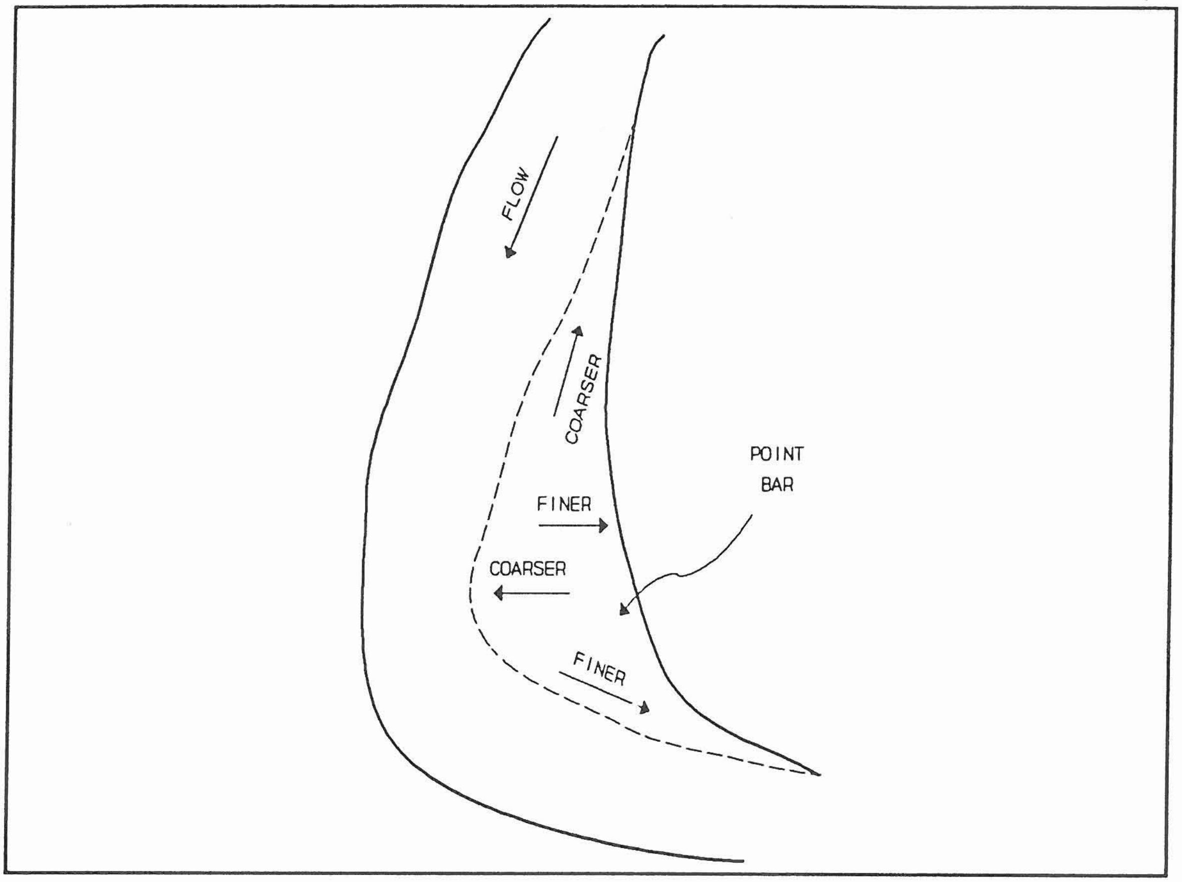

Figure 8.
Gradation Pattern on a Bar.

The gradation of material on point bars is often a good indicator of the appropriate mixture for computing bed movement. Figure 8 illustrates a typical sediment gradation pattern on a point bar. Such information should be used to select bed material sampling sites for sediment transport calculations. Note that, although the grain sizes found on the bar surface typically form a pattern as shown on Figure 8, there is no one location which always contains the specific distribution which will represent the entire range of processes in the prototype.

Bed material data should be analyzed before developing the input data file. Figure 9 shows an example plot of profiles of grain size gradation versus river mile. Plots such as these assist the analyst in understanding the stream's behavior by illustrating grain size changes along the study reach, which reflect the influences of geologic controls, tributaries, etc. These data will usually require some smoothing for reasonable HEC-6 computations as they represent samples taken at a single point in time and (usually relatively few) selected points in space.

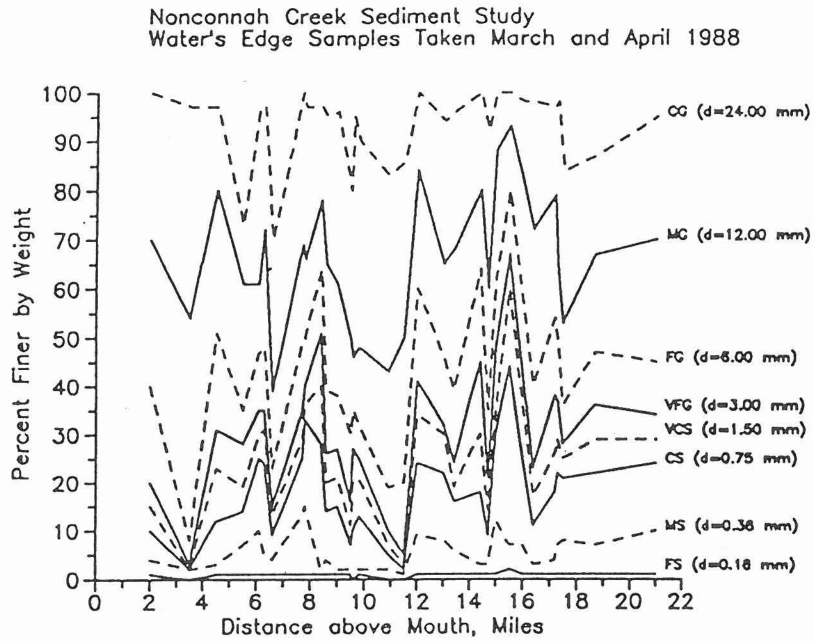

Figure 9.
Bed Surface Gradation Based on Water Edge Samples.

3.5.4 Selection of a Sediment Transport Function

Numerous transport functions have been developed with the aim of computing the rate and size distribution of the transport of bed material, given the hydraulics and bed material gradation (Vanoni, 1975). As it cannot be stated which one is the "best" to use given a particular situation, the engineer should become familiar with how the functions were derived, what types of data they have been compared to (laboratory flume versus river measurements), and past usage. A recent study (Yang and Wan, 1991) rated the accuracy of several transport functions compared with both laboratory and river data and concluded that, for river data, the accuracy in descending order was; Yang, Toffaleti, Einstein, Ackers and White, Colby, Laursen, Engelund and Hansen. It also states that the rating does not guarantee that any particular formula is superior to others under all flow and sediment conditions. Another study (Gomez and Church, 1989) favored the formulas of Einstein, Parker, and Ackers-White for gravel bed rivers. An "applicability index" based on river characteristics was developed by Williams and Julien (1989). The WES-SAM (WES, 1991) package offers a procedure to aid in the selection. It is based on screening of the various transport functions using information from past studies that compared computed and calculated transport rates and the hydraulic characteristics of the particular stream. Use of such an approach is documented by HEC (1990c). The HEC-6 user should be aware that different transport functions will probably yield different answers. The impact will most likely be greater on transport rates than on geometry changes. Extreme situations, such as mud and debris flows require different analytic techniques, see HEC (1990d) for an example.

3.6 Hydrologic Data

3.6.1 Introduction

Hydrologic data consist of the following items:

1. Water discharges for the main stem and for all tributary inflows and all local inflow and outflow points.

2. A stage hydrograph, rating curve, or operating rule giving water surface elevations at the downstream end of the study reach.

3. Temperatures for the inflowing water discharges, see Vanoni (1975) for an explanation of the role of temperature in sediment transport mechanics.

3.6.2 Water Inflows

Although an instantaneous water discharge (e.g., a flood peak) may be of interest, it is not sufficient for movable bed analysis because sediment volumes, which are rates integrated over time, create channel geometry changes. Consequently, a water discharge hydrograph must be developed. This may involve manipulations of measured flows, or it may require calculation of a runoff hydrograph. Period of record flows are needed to reconstitute behavior observed in the river; future flows must be developed to forecast the future stream bed profile. Most HEC-6 applications use the period of record flows to analyze future conditions.

The length of the study period is important. Trends such as a consistent change (scour or deposition) of a tenth of a foot per year in bed elevation become significant during a 50- or 100-year project life. A long period hydrograph can become a computational and data handling burden. In some cases, data compression techniques may be useful. As an example, Figure 10 shows how a year of mean daily flows might be represented by a computational hydrograph with fewer discharges of longer durations.

Tributaries are lateral inflow boundary conditions. They should be located, identified, and grouped as required to define inflowing water and sediment distributions. The locations should be shown on the map of the cross section locations. It is important that the water and sediment inflows from all gaged and ungaged areas within the study reach be included. A water balance should be performed for the study period. Keep in mind that a 10 percent increase in water discharge may result in a 20 percent increase in bed material transport capacity. Inflows from ungaged areas must be developed. Drainage area ratios may be used in some cases; in others, however, use or development of a hydrologic model of the basin may be necessary (HEC, 1982). Document how inflows were determined for ungaged areas.

3.6.3 Computation Intervals

The computation interval (or time step) used for HEC-6 is usually variable. Short time steps must be taken during flood events when large amounts of sediment are moving and the hydrograph is rapidly changing, longer time steps are used during low flow periods (Figure 10). Generally, the closer the cross sections, the smaller the required time step. The modeler is confronted with the dilemma of wanting to use small time steps for an accurate simulation

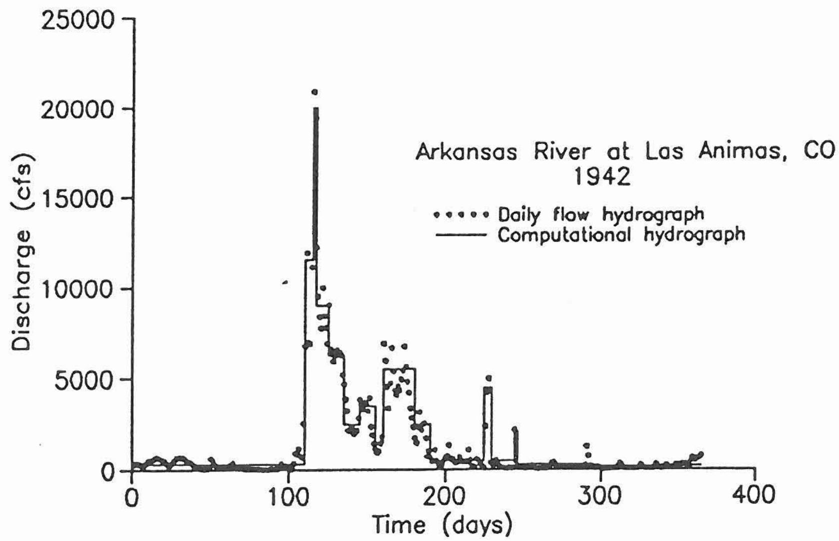

Figure 10.
Flow Data Compression.

and large time steps for an economic simulation. For a multi-year simulation the time step typically ranges from one day to one month. For many situations, if computational time is not a problem, it may be best to use mean daily flows directly from USGS data without expending the effort to process them into longer time steps. Certain situations, such as single event simulations, may require time steps of less than one day.

If a longer computation interval is needed than that of the basic data, the following process is suggested to identify that interval. (This step is always useful to identify the stability bounds for the computational time step.) At this point in the study, the inflowing sediment load and cross-sectional spacing are known. The transport function should be selected. Three test discharges should be examined: bank-full, low flow and a peak flood flow. Starting with the bank-full flow, prepare a sample test hydrograph that includes, for example: 5 time steps at 1-day each with that flow, 5 more with a 2-day interval, followed by 5 with a 3-day time step, followed by 5 more at 5-day intervals. Results from this series of computations will indicate the most desirable computation interval to use for flows that are nearly bank-full. Be sure to run HEC-6 in movable bed mode for this test.

Because the computation interval will usually exceed one day on major rivers, simulating five or more time steps at one day each lets initial instabilities dampen out before the critical test interval is reached. Use a constant downstream water surface elevation from a "natural conditions" discharge rating curve at the downstream boundary. Scan the output file for the first few time steps to locate the cross section having the largest change in bed elevation. Plot the bed elevation change at that section as a function of time as shown in Figure 11. Note that the bed changes that are in the HEC-6 output file are cumulative from the beginning of the simulation. The resulting graph should approach a smooth curve, as is illustrated between days 10 and 30 in Figure 11. This indicates the range of stable computation intervals for that flow (e.g., 2 or 3 days in Figure 11). Oscillations usually occur at the beginning of a simulation because of inconsistent initial conditions, but they should dampen out by using a "warm-up" period of constant flow. When the computation intervals for the test discharge become too long, oscillations will appear as illustrated between days 35

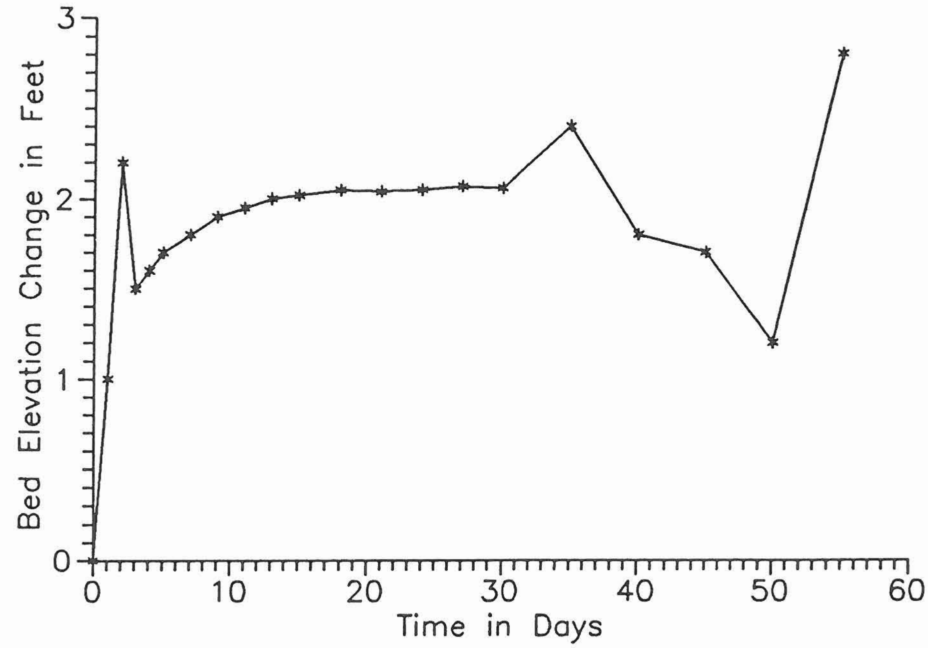

Figure 11.
Results of Testing HEC-6 Time Step at a Particular Cross Section.

and 55 (Δt = 5 days) in Figure 11. If the initial oscillations do not dampen out, perhaps the first computation interval is too long. Shorten the computation intervals and make a second run. If problems persist, examine the geometry again for errors. Repeat this procedure until a stable interval has been determined. Note: HEC-6 does not simulate the movement of dunes; therefore, a saw-tooth bed elevation as a function of time at a section indicates that numerical oscillations are occurring and the computation interval should be reduced.

At this point in data testing, the **GR** data resulting from the HEC-6 computations should be examined to check the time step as well as the locations of channel, ineffective flow, and movable bed stations.

3.6.4 Preparing Flow Data

The main points to consider in developing flow data are:

1. Preserve the total volume of water in the observed hydrograph.

2. Preserve the total volume of sediment which was transported during the hydrograph period.

3. Make the computation intervals as long as possible and still preserve computational stability.

4. Provide a "warm-up" period at the start of all simulations. This should consist of several time steps at a constant discharge (equal to the first discharge in the hydrograph) to allow the bed material gradations and bed elevations to become computationally compatible with the flow hydraulics.

There is usually a strong correlation between the annual volume of water that passes a gage and the annual sediment yield of that basin upstream of that gage. The rate of sediment movement, called sediment load, is not a function of water volume. It is a function, however, of water discharge (Figure 5), and the availability of sediment material. In many cases, three-quarters of the annual sediment yield will be transported in less that one-quarter of the year. Therefore, it is necessary that all flow records contain the flood peaks.

3.7 Initial Testing of the Data

Operation of the model for a test period (say an "average" year) should be performed as a check on data consistency and reasonableness prior to attempting calibration runs. The flow record for an average year can be constructed from the flow-duration relationship, if necessary. Key items to check at this time are:

1. Silt and clay should not deposit in the channel under natural river conditions. Any cross section which exhibits a reduction in silt or clay load passing through that section should be carefully checked. The cross section may be too large or a false channel control may exist downstream.

2. The sand load should approach a steady value with time, about equal to the inflowing load, from section to section rather than an erratic variation. Cross sections used in HEC-6 are representative of reaches, therefore, some smoothing of field data may be required. Sections which have very little transport capacity should be checked for errors in cross section geometry, reach length, *n* values, limits of movable bed or, perhaps, bed material gradation.

If the model's performance approximates the prototype behavior, the computation interval, parameters such as loss coefficients, and geometric and sediment data have been assembled in a consistent, realistic, fashion. Otherwise, one must ascertain what is causing the questionable performance. For example, excessive fill may mean that the limits of the movable bed are too narrow or that the natural levee is too low. If the prototype is depositing sediment above the overbank elevation, expand the movable bed limits to include the overbank. If water is spilling onto the overbank in the simulation, but that area is not effective for conveyance in the prototype, raise the natural levees in the input data. If excessive scour is indicated by the computed results, it may mean the prototype has either an armored bottom or a non-erosive or rocky bottom that is resistant to scour.

3.8 Data Sources

3.8.1 General

The data that will be needed for the study may come from office files, other federal agencies, state or local agencies, universities and consultants, from the team making the field reconnaissance of the project site and study reach, from surveys initiated specifically for the study, etc.

3.8.2 U. S. Geological Survey (USGS)

USGS topographic maps and mean daily discharges are used routinely in hydraulic and hydrology studies and are also common data sources for sediment studies. Mean daily flows, however, are often not adequate for sediment studies. Data for intervals less than one day or stage-hydrographs for specific events, if needed, can be obtained from strip-chart stage recordings that are available by special request. It may be preferable to use USGS discharge-duration tables rather than developing such in house; these are available from the state office of the USGS. Water quality data sometimes include suspended sediment concentrations and grain size distributions. Published daily maximum and minimum sediment discharges for each year and for the period of record are available as are periodic measurements of particle size gradations for bed sediments.

3.8.3 National Weather Service (NWS)

There are cases where mean daily runoff can be calculated directly from rainfall records and expressed as a flow-duration curve without detailed hydrologic routing. In those cases, use the rainfall data published monthly by the National Weather Service for each state. Hourly and daily rainfall data, depending on the station, are readily accessible. Shorter interval or period-of-record rainfall data can be obtained from the NWS National Climatic Center at Asheville, North Carolina.

3.8.4 Soil Conservation Service (SCS)

The local SCS office is a good point of contact for historic land use information, estimates of future land use, land surface erosion, and sediment yield. They have soil maps, ground cover maps, and aerial photographs which can be used as aids to estimate sediment yield. Input data for the Universal Soil Loss Equation is available for much of the United States. The SCS also updates reservoir sedimentation reports for hundreds of reservoirs throughout the country every 5 years, providing a valuable source of measured sediment data.

3.8.5 Agricultural Stabilization & Conservation Service (ASCS)

This agency of the Department of Agriculture accumulates aerial photography of crop lands for allotment purposes. Those photographs include the streams crossing those lands and are, therefore, extremely valuable for establishing historical channel behavior because overflights are made periodically.

3.8.6 Corps of Engineers

Because the Corps gathers discharge data for operation of existing projects and for those being studied for possible construction, considerable data for a particular study area may already exist. The Corps has acquired considerable survey data, aerial and ground photography, and channel cross sections in connection with floodplain information studies. Corps laboratories have expertise and methods to assist in development of digital models.

3.8.7 State Agencies

A number of states have climatologic, hydrologic, and sediment data collection programs. Topographic data, drainage areas, stream lengths, slopes, ground cover, travel times, etc. are often available.

3.8.8 Local Agencies, Universities, Consultants, Businesses, and Residents

Land use planning data can normally be obtained from local planning agencies. Cross section and topographic mapping data are also often available. Local agencies and local residents have, in their verbal and photographic descriptions of changes in the area over time, information that is most valuable to the engineer. This source may include descriptions of channel changes associated with large flood events, incidents of caving banks, significant land use changes and when these changes occurred, records of channel clearing/dredging operations, and other information. Newspapers and individuals who use rivers and streams for their livelihood are likewise valuable sources for data.

Chapter 4

Calibration of Geometric Parameters

4.1 General Process

Begin the analysis of geometric data and calibration of *n* values with natural river conditions and select three water discharges, as described below, to check model performance. Testing should begin with fixed bed computations and then use movable bed computations. As each study is unique, the contents of these sections should be regarded as suggestions that illustrate the analysis process and not complete checklists.

4.2 Single Discharge, Fixed Bed Tests

4.2.1 Bank-Full Flow

Start with a steady state discharge of about bank-full. In a regime channel this is expected to be about the 2-year flood peak discharge. Ascertain that the model is producing acceptable hydraulic results by not only reconstituting the water surface profile, but also by plotting and examining the water velocity, depth, and width profiles. This test will often reveal width increases between cross sections that are greater than the expansion rate of the fluid and, therefore, require conveyance limits. Computed velocities at extremely deep bend sections may not be representative of sediment transport around the bend; one recourse is to eliminate those sections from the model. The results from this test will also give some insight into how close the existing channel is to a "normal regime." That is, if there is overbank flow, justify that it does indeed occur in the prototype and is not the consequence of a data problem.

The left and right top-bank profiles are usually very irregular. In movable bed calculations it is very important to specify bank elevations that are "representative" of prototype conditions since successful simulation of the prototype requires that water begin to occupy the floodplains at the proper discharge. This requires assigning bank elevations which are representative of the reach rather than just accepting point values from a field survey. To check, plot both the bank elevations and the calculated water surface profile. Smooth out any irregularities in bank elevation which fail to be representative of the reach by modifying input data. Examination of aerial photographs can assist in the identification of bank lines.

4.2.2 Low Flow

Also examine an extremely low flow; the lowest in the hydrographic record during the anticipated study period is acceptable. Extreme changes in velocity, depth, or width from one section to another may reflect a data error and should be checked.

4.2.3 High Flow

The third test discharge should equal the maximum value anticipated in the hydrograph of flows to be used for the study or for project formulation. Usually the water surface profile for this discharge approximates the valley slope more closely than the channel slope. Therefore, plotting it with the other profiles, including bed and banks, gives the opportunity to compare changes in slope with valley width and thereby ensure that flow controls are actual and not the result of data errors. Other key parameters to observe are flow distributions between channel and overbanks, widths, and velocities.

4.3 Single Discharge, Movable Bed Tests

It is useful to evaluate the model performance for the bank-full flow with a movable bed. If the channel is near regime, this should approximate the dominant discharge and result in little aggradation or degradation. Before focusing on sediment transport, however, demonstrate that the Manning's *n* value for the channel is appropriate for a movable boundary. Make whatever adjustments are necessary to ensure that the *n* value for the movable portion of the cross section is in reasonable agreement with that obtained from bed roughness predictors. Also, the sediment transport rate will usually be higher at the beginning of the simulation than later because there is normally an abundance of fines in the bed samples which will be flushed out of the system as the bed layers are formed. A physical analogy is starting water to flow down a newly constructed ditch. It is important to balance the sizes in the inflowing bed material sediment load with transport potential and bed gradation. The scatter in measured data is usually sufficiently great to allow smoothing, but the adopted curves should remain within that scatter.

Chapter 5

Calibration of Sediment Parameters

5.1 Calibration Measures

Selection of appropriate calibration measures, or tests, for a movable boundary model such as HEC-6 is not straightforward. Ideally, one would have sets of surveyed cross sections and measured sediment transport rates periodically throughout the calibration period. Such data sets are extremely rare. Consequently, different calibration measures may be used for different studies depending on study objectives, data availability, etc. A useful calibration measure is the observed drift of the rating curve for a stream gage. This is a good measure because the rating curve drift integrates, to a certain extent, behavior of a stream reach rather than representing a single point or cross section. Care should be taken that the rating curve drift is being caused by general scour or deposition and not by roughness changes or local scour/deposition. The gage selected for use in calibration should not be within the influence of the downstream boundary. An example reproduction of a rating curve shift is shown on Figure 12.

Agreement between calculated and measured water surface elevations of ± 0.5 ft. is usually satisfactory for movable boundary studies of natural rivers. Profiles of the computed average bed elevation may not correlate well with the prototype, but cross-sectional area changes should match prototype behavior. Should cross section surveys be available over an appropriate time interval, care must be taken to appropriately compare model results and field data. Amounts of scour/deposition may not be exactly reproduced at specific cross section locations. Regions, that is several consecutive sections, of scour or deposition should correspond between model and prototype, however. In some cases it is appropriate to compare volumes of scour/deposition as a calibration measure (Dyhouse, 1982; Williams, 1977).

It is important to base the evaluation of model performance on those processes which will impact decision making. These may include the water surface profiles, flow distributions between channel and overbanks, water velocities, changes in cross-sectional area, sediment discharge passing each cross section, or accumulated sediment load by size class passing each cross section. Note, a one-dimensional model may not precisely reconstitute thalweg elevations because the thalweg behavior is a three-dimensional process. Therefore, use cross-sectional area changes or other volumetric measures rather than thalweg elevation when calibrating. Three types of graphs should be prepared to evaluate results. The first is "variable vs. elevation." An example, the comparison of calculated stages with the observed rating curve, is shown in Figure 13. The second graph is "variable vs. distance" at specific times as illustrated by the water surface and bed surface profiles in Figure 14. The third is "variable vs. time" at selected cross sections along the study reach as was shown in Figure 12.

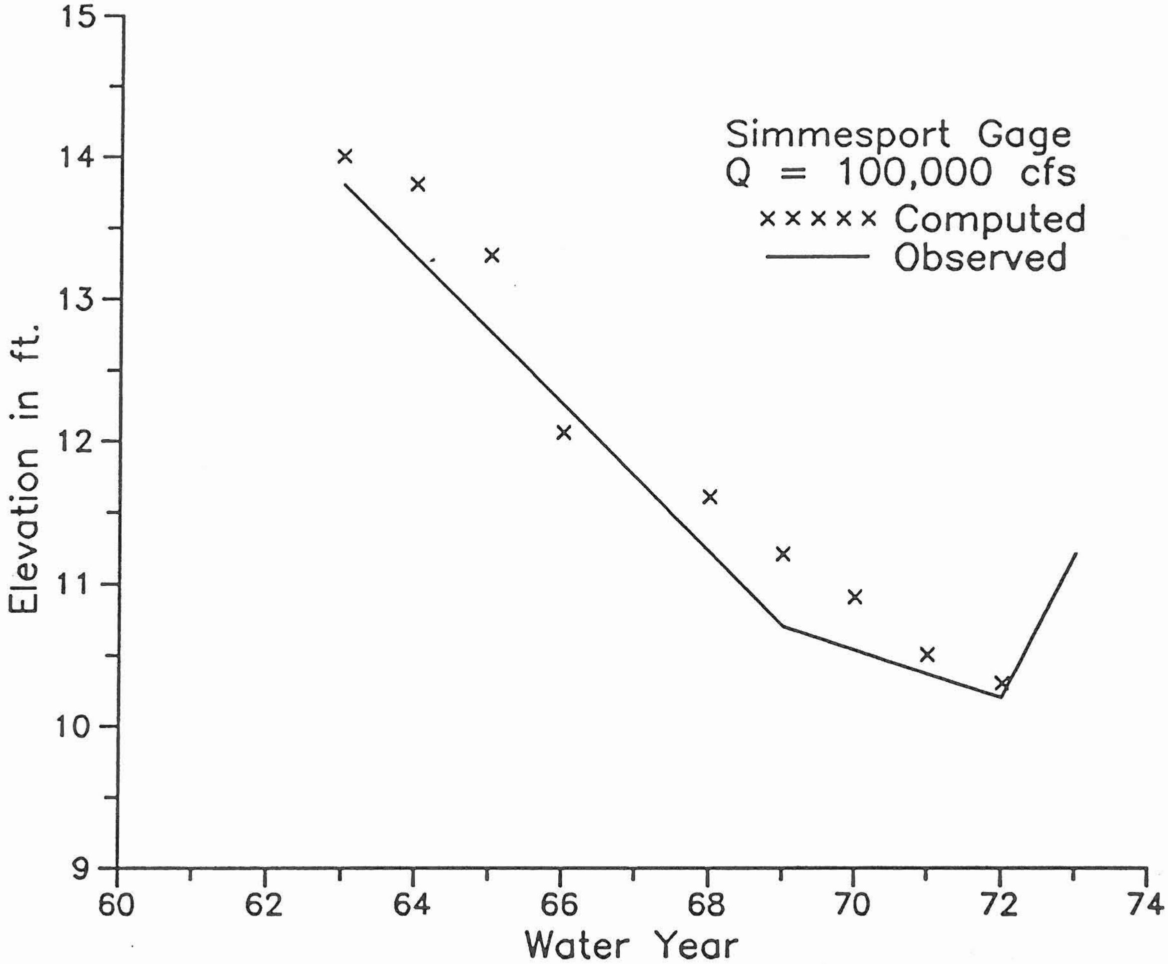

Figure 12.
Indication of a Rating Curve Shift (Specific Gage Plot).

5.2 Data Adjustment

5.2.1 General

Data adjustment is the process of data modification that produces simulation results that are in acceptable agreement with the observed prototype behavior. Adjustment consists of the selection of values for fixed and movable bed coefficients, and application of the art of transforming three-dimensional prototype measurements into "representative" one-dimensional data. Development of representative data for one-dimensional computations was presented in Section 3.2.2.

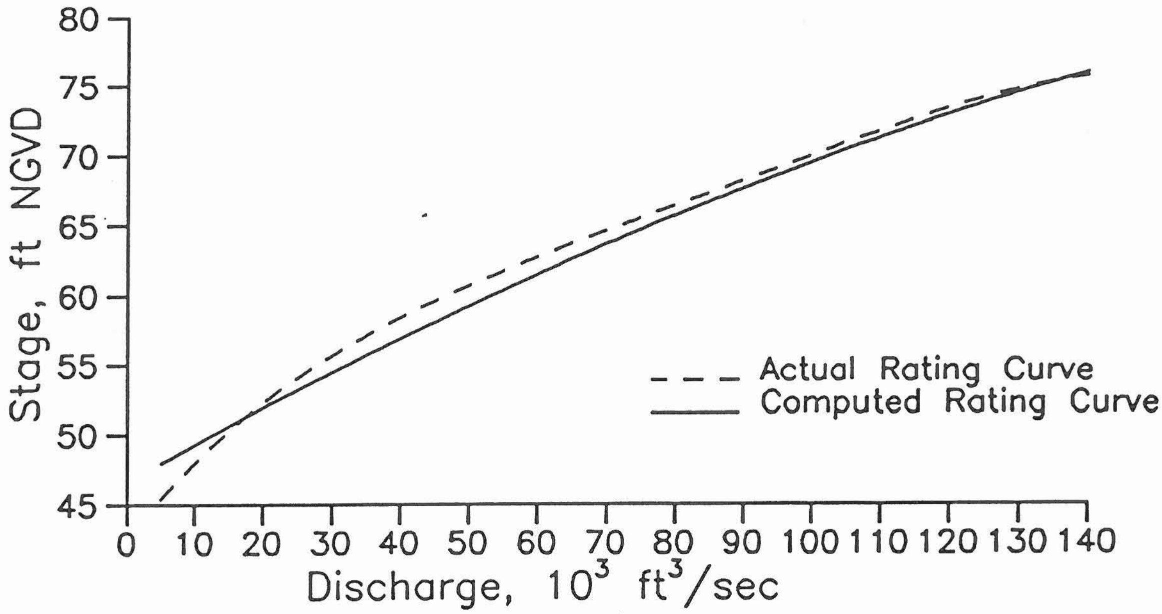

Figure 13.
Reconstituting the Stage-Discharge Rating Curve.

Computed results should be compared with measurements from the prototype to identify data deficiencies or physically unrealistic coefficients. Coefficients should then be adjusted as necessary, within the bounds associated with their uncertainty, to improve the agreement between observed and calculated values. Model adjustment does not imply the use of physically unrealistic coefficients to force a poorly conceived model to exactly match prototype measurements. If a discrepancy between model results and prototype data persists, then either there is something wrong with the model representation of the dominant physical processes (a model deficiency, usually the result of limiting assumptions), there is a deficiency in the representation of field data as model input (an application error), and/or there is something wrong with the measured data (a data deficiency). Therefore, if model calibration cannot be accomplished through the use of physically realistic values of the coefficients, the measured prototype data should be checked for possible errors and the numerical model (input data, basic equations and solution algorithms) examined.

5.2.2 Consequences of Inaccurate *n* Values

In fixed bed hydraulics, a range of *n* values is typically chosen. The low end of that range provides velocities for riprap design and the high end provides the water surface profile for flood protection needs. In movable bed studies such an approach is usually not satisfactory because of the feedback linkage between sediment transport and bed roughness.

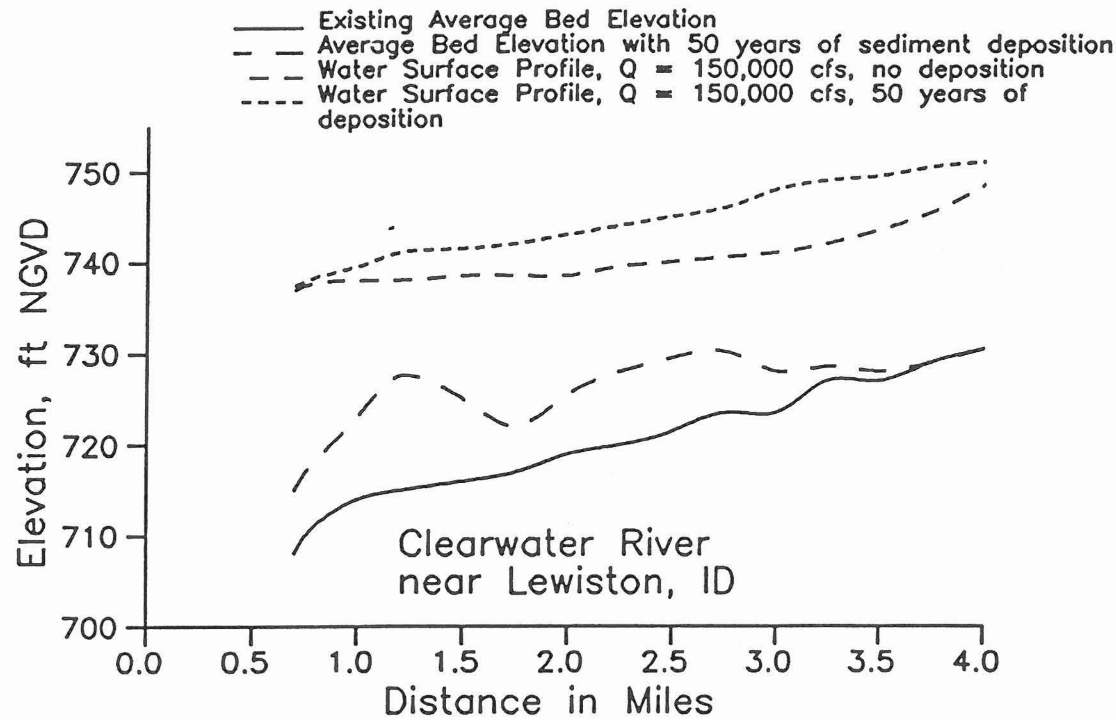

Figure 14.
Water Surface and Bed Surface Profiles.

Use of Manning's *n* values which do not conform with that linkage can result in either too much degradation or too much aggradation.

5.2.3 Correcting Model Performance

If the calculated results do not follow the observed trends, take the following steps. First, plot the active bed gradation from cross sections at, and downstream from, inflow points using results from near the end of the hydrograph along with a bed gradation curve from field measurements. If the model is reproducing the dominant processes in the prototype, the key parameters should match reasonably well. The following suggestions illustrate the thought process that should occur when there is an unacceptable deviation.

1. Be sure the model is numerically stable before adjusting any coefficients, data, or processes. Because sediment computations are very sensitive to hydraulic parameters, close attention should be paid to the hydraulics. Small changes in energy slope, velocity, etc. from section to section can result in large changes in transport capacity. It is recommended that the hydraulic variables be averaged among adjacent sections by use of the HEC-6 **I5** record.

2. Then position the upstream boundary of the model in a reach of the river which is stable, and be sure the model exhibits that stability. That means that cross sections near the

upstream end of the reach should neither significantly erode nor deposit. Attend to hydraulic problems starting at the downstream end and proceeding toward the upstream end of the model. Reverse that direction for sediment problems. Do not worry about computed scour or deposition at the downstream end of the reach until the model is demonstrating proper behavior upstream from that point.

3. Once the above two conditions are met, focus attention on overall model performance. Check the boundary conditions to ascertain that the particle size classes in the inflowing sediment load have been assigned "representative" concentrations. Use the depth and gradation of the bed sediment reservoir to confirm that the model bed matches the prototype. Make plots for several different times because the gradation of the model bed will vary with the inflowing water-sediment mixture. Correct any inconsistencies in these data and try another execution. If any problem persists, check the field data for possible rock outcroppings and check calculated profiles for possible errors in nearby sections.

4. If calculated transport rates are too high, check prototype data for a gravel deposit which could be forming an armor layer.

5. If calculated rates of deposition are too high or rates of erosion are too low, check bank elevations and ineffective flow limits to ensure that the model is not allowing so much flow on the overbanks that the channel is becoming a sink.

6. Finally, if none of the above actions produce acceptable performance, change the inflowing sediment load. First use a constant ratio to translate the curve without rotation. If that is not successful, rotate the curve within the scatter of data.

5.3 Confirmation of Model Performance

5.3.1 General

Prior to using a numerical model for the analysis of a project, the model's performance needs to be confirmed. Ideally this consists of a split record test: selection (or calibration) of coefficients and verification of coefficients. The selection phase is intended to allow values for the coefficients to be chosen and adjusted so that the computed results reproduce field measurements within an acceptable error range.

5.3.2 Verification Process

The second step, the verification process, is to change boundary conditions (for example, use a different time period) and rerun the simulation without changing the coefficients. This step establishes whether or not the coefficients which were selected in the first step will also describe the prototype behavior when applied to events not used in their selection. Change the inflowing sediment load as necessary to correspond with that during the time period selected for verification. Start with a constant discharge and progress to a hydrograph of flows.

The verification period used may be several years long. If so, select only a few key values per year to examine. Plot the calculated water surface elevations at all gages in the study area as well as the observed elevations that occurred at the same time. Model performance may be quantified by computing the mean of the absolute values of error. Of course, the lower the mean value of error, the better the performance. Unfortunately, performance quality is defined by study-specific characteristics and will probably differ from study to study. Good engineering judgment should be used to determine when the model's performance is satisfactory or requires additional adjustment.

Chapter 6

Development of Base Test and Analysis of Alternatives

6.1 Introduction

The most appropriate use of a movable bed simulation is to compare an alternative plan of action with a base condition.

6.2 The Base Test

In most cases the base condition will be the simulated behavior of the river under a "no action future." In a reservoir study, for example, the base test should simulate the behavior of the river and tributaries, both upstream and downstream of the proposed dam site, without the dam in place. In many cases, the base test simulation should show little or no net scour or deposition. These are river reaches which are near equilibrium (where scour approximately equals deposition) under existing conditions.

6.3 Plan Tests

The project alternatives are simulated by modifying the base test data file appropriately. In the case of a reservoir, a dam can be simulated by inserting "operating rule data" into the base test data. For a channel improvement project, cross-sectional geometry and roughness will be changed. If a major change is to be analyzed, make the evaluation in steps. Avoid changing more than one parameter at a time because that makes the results difficult to interpret. For example, it is best to analyze a channel modification project in two steps. First, change the hydraulic roughness values and simulate future flows in the existing geometry. It will be necessary to select and justify Manning's n for future conditions. Justify values by consideration of proposed design shapes, depths, channel lining materials, proposed vegetation on the overbanks, probable channel debris, anticipated riprap requirements, and maintenance agreements. Second, insert the modified cross sections into the data and complete the analysis by simulating the alternatives to be tested. Also select appropriate contraction and expansion coefficients. Use model results as an aid in predicting future conditions; rely heavily on engineering judgment and look for anomalies in the calculated results. These "surprises" can be used by the experienced river engineer to locate data inadequacies and to better understand the behavior of the prototype system. Any unexpected response of the model should be analyzed very carefully and justified before accepting the results.

6.4 Presentation of Results

Results should be presented as change from the base case wherever possible, rather than absolute values. This will provide an assessment of the impacts of proposed actions compared with a no action future.

Chapter 7

Sensitivity Testing

7.1 Introduction

It is usually desirable during the course of an HEC-6 application to perform a sensitivity test. Quite often certain input data (such as inflowing sediment load) are not available, or subject to substantial measurement error. The impacts of these uncertainties on model results can be studied by modifying the suspected input data by ± x % and re-running the simulation. If there is little change in the simulation results, the uncertainty in the data is of no consequence. If large changes occur, however, the input data needs to be refined. Refinement should then proceed using good judgment and by modifying only one parameter or quantity at a time so as to be able to see the exact effect that the changes have. Sensitivity studies performed in this manner will provide sound insight into the prototype's behavior and lead to a credible model description of the real system.

7.2 Sensitivity of Simulation Results to Data Uncertainties

The sensitivity of simulated bed profile changes to various input data uncertainties can be examined with respect to the reliability of field measurements of those data. An extensive study of the sensitivity of fixed bed water surface profile computations to errors in geometry and bed roughness has shown that geometric errors are controllable and estimation of bed roughness is the major source of uncertainty (HEC, 1986). In addition to field data, there are various model parameters that cannot be measured directly and must be estimated by the model user and adjusted, if necessary, during the calibration process. Guidance on selection of model parameters is given in (USACE, 1992). A qualitative assessment, based on experience gained from many past applications of HEC-6, of the model sensitivity to variations in the various input data is presented in Table 2. Note that, in any particular study where uncertainty exists in the value of any particular input item, the model can be run for a range of values of that input item to assess the resultant variation in simulation results. This information can then be used to identify what, if any, additional field measurements or observations are necessary to accomplish the study objectives.

Table 2
Sensitivity of Model Results to Field Data

Data Item	Field Measurement Reliability	Model Sensitivity	Remarks
1. Geometry			
Cross sections	H	H	
Movable bed limits	L	H	Field estimation and calibration
Roughness	M	M	Field estimation and calibration
2. Sediment			
Bed material gradation	M	H	
Inflowing load	L	H	H locally, M elsewhere
3. Hydrology			
Flow record	H	M	Developing long-term flow records can be difficult (Gee,1983)
Rating curve	H	L	Local effect
Temperature	H	L	

Notes: H = high, M = medium, L = low

Chapter 8

Computational Aspects

Applications of a movable boundary model such as HEC-6 can require major computational resources, particularly for studies of long time periods (50-100 years). Operation of the numerical model is only one component of the computational requirements. It is also important to have software available for storage and manipulation of the hydrologic data and graphical display of input data and results; the HEC-DSS (HEC, 1990b) can be useful for managing and displaying time series data. Single event analyses are less computationally intensive because the study reach is relatively short, the hydrographs are usually synthetic and of short duration, and the sediment loads may also be synthetically generated. Calibration data are rarely available for single event analyses.

Chapter 9

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US Army Corps
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GENERALIZED COMPUTER PROGRAM

COED

Corps of Engineers Editor

User's Manual

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Table of Contents

1.0 Introduction

COED is an editor containing full-screen editing capabilities, along with a powerful line-oriented command set that can be executed interactively or in a batch mode. COED is functional for most general text editing necessary for data preparation and program development. COED contains some additional features to aid in the preparation of data input files for several HEC programs. This includes right justifying data into predefined fields, and providing data variable names and definitions identified by the cursor location. For more information, see the Help Program (HP) command in section 3.6.

COED is available for a variety of computers and terminals. In the line-edit mode, it may be used on any terminal. In the full-screen mode, it is available for MS-DOS personal computers (or compatible), and can be implemented on any terminal conforming to the ANSI standards for terminals (a rate of 4800 baud or higher is recommended). (At the time of printing of this document, a full-screen version for some non-ANSI terminals was being planned.) COED is written in FORTRAN 77 and is transportable between machines. It has been implemented for Harris mini-computers, MS-DOS personal computers and compatibles.

1.0.1 New Features for this Version

A. The FILE, and SAVE commands can not be abbreviated; They each require all 4 characters to be specified.

B. LOCATE WILD (LW) and CHANGE WILD (CW) commands allow the use of 'wild' characters for locating and changing character strings.

C. Column commands allow a range of columns to be duplicated (CD), moved (CM), removed (CR), or set (CS) to a specific character.

D. CUT (CU) and SPLICE (SP) allow one line to be cut into two, or two to be spliced into one.

E. LOCATE EXCEPT (LE), and FIND EXCEPT (FE) commands will search for lines that do not contain a given character string.

F. X and Y commands have been expanded to include X1 through X5, and Y1 through Y5, adding 10 more X or Y commands than can be remembered.

G. On-line help (HE) has been added for the line edit and full screen edit modes.

H. The direction of movement through the file can be reversed by preceding certain commands by a minus '-' sign (e.g. -L /text/).

I. Type-ahead capability has been implemented for terminals on Harris Async ports.

J. A temporary backup copy of the file to be edited is automatically made.

1.1 Getting Started

The COED Editor is initiated by typing:

COED filename [cmdfile] [S=n]

where:

'filename' is the file that you wish to edit. If the file does not exist, COED will create the file.

'cmdfile' is an optional parameter providing the name of a file that contains a list of commands for COED to use. If this parameter is omitted commands are read from the keyboard, or standard input.

'S=n' is an optional parameter specifying the column length (n) of the lines to be edited. All lines are truncated to this length by COED. If this parameter is omitted, the first 100 lines of the file are examined to determine if a line length of 80 should be used. If characters are found beyond column 80, a column length of 133 will be used.

While COED is initializing, it makes a copy of your file for recovery purposes. If, for some reason, you save unwanted changes in your file, you can use this back copy to restore the file to its original condition. This must be done immediately after the edit session; if you log off, or edit another file, the backup copy will be destroyed. On Harris computers, this backup copy is kept in work file T1. On personal computers, the backup copy is named COED.BUP and is stored in the root directory (unless another directory is specified by using the "SETUP" command).

If COED is to be installed, refer to the appendix.

1.2 Recovery

In the event of a system crash during an edit session, the session can be recovered by using the recover option. This option uses two files to reconstruct the session up to the most recent command issued. One of the files is a copy of the original file before editing was begun. The other file is a record of all edit transactions performed by the editor.

To recover from a crash and resume editing, enter:

COED.R	(Harris systems only)
or COED -R	(All systems)

Note that no parameters, such as the filename or column length, may be used. When the recovery has been completed, the editor will be at the same position as at the time of termination. Zones and other attributes will all be the same as before the interruption.

WARNING: When continuing after a system halt on a Harris computer the user must log-on to the same port that was in use at the time of the halt (the same dialup port for dialup terminals). This is because the editor uses system work files that are identified by user and port number.

On MS-DOS systems, the recovery files are stored under the names COED.BUP and COED.REC in the root directory (unless another directory is specified by using the "SETUP" command). The COED.BUP file is a copy of the original file before the edit session was started. COED.REC is a record of all edit transactions made to the file during the edit session.

On Harris computers, the recovery files are stored in work files T1 and T2. Work file T1 is a copy of the original file before the edit session began. Work file T2 is a record of all edit transactions made to the file during the edit session.

1.3 Basic COED Commands

Command	Purpose	Examples
COED	Begin edit session	COED MYFILE COED OUTFILE S-132
FS	Go into Full Screen mode	FS
T	Go to Top of file (line zero)	T
B	Go to Bottom of file	B
P	Print line(s)	P (print 1) P 3 (print 3) P A (print all) P * (print to bottom)
N	Go to Next line	N (next line) N 3 (go down 3 lines)
U	Go Up	U 2 (go up 2)
L	Locate a string	L /ABC/
C	Change a string	C /ABC/XYZ/
I	Insert a line	I THIS IS A LINE
I	Input mode	I LINE ONE OF TWO LINE TWO OF TWO
$$$	Exit input mode	$$$
R	Replace a line	R NEW INFORMATION
DE	Delete a line	DE
CL	Show column banner	CL
FILE	Update file and exit	FILE NEWFILE
QU	Quit edit session (nothing saved)	QU

Note: A blank line (just a carriage return) causes the previous command to be repeated.

1.4 Command Syntax

This section describes the format and syntax of COED commands and how they are represented in this documentation.

COED prompts the user with 'E>' when it is ready for a command. The general form of a command is:

```
E>command  [parameters]
```

The 'command' is always a command name followed by a blank or a comma, and any parameters, then a carriage return. Commands may be abbreviated to a 1, 2 or 4 letter command identifier. See the list of commands for valid command identifiers.

The syntax convention used in this document is represented in the following table.

Syntax Conventions

Symbol	Meaning
[]	Brackets surround optional parts of the commands.
|	Separates mutually exclusive parameter choices.
...	Three dots mean that parameters may be repeated.
CAP	Capital letters indicate that a specific parameter string must be used as shown.
/	Slashes are used as string delimiters in this documentation. However, any character may be used as a string delimiter so long as the character does not appear within the string.
c	Column number should be substituted.
m, n, r	Specifies a numeric value should be substituted.
*	The asterisk represents "all occurrences" in a numeric field and can be used in most places where an infinitely large numeric value is appropriate.
string (or stg)	Specifies a string of characters.
char	Specifies one character should be provided.

An example of the CUT command can illustrate the command syntax.

```
CU c|/string/ [n]
```

The command identifier is CU. It is shown in capital letters indicating it must be used exactly as given. A blank separates the command identifier from the parameter. The parameter, which is required, consists of two choices separated from each other by a vertical bar (|) symbol. This indicates the choices are mutually exclusive, that is one or the other must be used, but not both. The lowercase c indicates a numeric column number may be entered. The other possibility for this parameter is a string. If the string is used it must be delimited by a character such as the slash (/). The next parameter is optional because it is shown in brackets []. The n represents the number of lines upon which this command should operate. If the parameter n is not given, the default of one line is used.

```
       CU 40 12
and    CU /THEN/
```

are both valid CUT commands.

1.5 Command Modifiers

Certain line-edit COED commands may be modified by use of special symbols:

Modifier	Purpose
.	Preceding a command by a period '.' suppresses the echo of the command results. This effectively turns off the verify option for that command only. See the verify command for more details.
=	Preceding certain commands by an equal sign '=' displays the last use of the command. Several COED commands have a "memory"; that is, they will remember the parameters from their most recent use. Commands that have a memory are: CHANGE, FIND, LOCATE, ZONE, X and Y. For example, if the same string is to be searched for several times with a LOCATE command, it can be specified the first time the LOCATE command is used; thereafter the L can be used to repeat the last LOCATE command. A equal sign used alone on a blank line will return current COED status information.
-	Preceding a command by a minus (-) reverses the direction of movement through the file for that command execution. The command "-L /ABC/" will locate the string "ABC" upwards, from the current line (until the top of the file is reached). Commands for which the minus sign can be used are CHANGE, LOCATE, FIND, and PRINT.
>	The greater than symbol (>) may be used in two ways: 1) If the <u>last</u> character of an INSERT, OVERLAY or REPLACE command is a '>' (followed by a carriage return) it indicates that the next line is to be placed at the end of the current line (a continuation line). The continuation character can be changed with the TERMDEF command. 2) If the '>' character is used within a line in an INSERT, OVERLAY, or REPLACE command the column location will move to the next tab stop (only the '>' is echoed).
<CR>	If a carriage return is entered (i.e., a blank line) the previous command issued will be repeated. This is very useful for repeating the Next, Locate, Print, DElete, and other commands.

1.6 Sample Commands

The following table provides examples of using the line-edit command syntax and modifiers.

Command	Description
HELP	Request help.
T	Move to top of file.
P 23	Print next 23 lines, starting at the current line.
C /ABC/XYZ/	Change ABC to XYZ on current line.
F C	Find next line beginning with "C".
.C /Z/AT/ * *	Change all occurrences of 'Z' to 'AT' from current position to end of file. Suppress the echo of changes.
-L /END/	Locate first occurrence of 'END' upward in the file.
FILE MYDATA	Store edit results in a file named 'MYDATA', and exit COED.
CU /THEN/	Cut the current line into two lines after the string 'THEN'.
SP 40 4	Splice (combine) the current line with the next line at column 40 (of the current line), and repeat this operation 4 times.
X ;L /ABC/;N;C /1/2/;	Set an X command to locate ABC, move to next line and change the first 1 to 2.
X 20	Execute the previously set X command 20 times.

2.0 Full Screen Edit Mode

2.1 Introduction

The COED full-screen edit mode enables text files to be edited by displaying a section of the text (about 20 lines worth) on the screen, and allowing the user to make changes by typing new or replacement text directly where desired. The four cursor keys and the page up, page down, home and end keys provide a means of movement around the file. This mode, combined with access to all of the line edit commands, provides a powerful text editing capability.

The full-screen mode operates in a "type-over" atmosphere: in the normal mode, whatever is typed replaces what is on the screen. The "Insert Character mode" allow characters to be inserted without erasing other characters. The "Insert Line mode" provides a means of inserting lines in the text file. In a new file, or at the bottom of an existing file, a carriage return provides an implicit new line. Thus to enter text into a new file in the full-screen mode, all one has to do is to type normally. Any of the line edit commands can be accessed from the full-screen mode by pressing the line-edit function key.

The full-screen feature is currently available for terminals that meet ANSI standards, and for MS-DOS compatible personal computers. Work is currently under way to provide full screen editing for some "smart" terminals that do not meet the ANSI standards.

2.2 Initiating the Full Screen Mode

When COED is executed, it enters the line-edit mode. To go into the full screen mode, the FULL SCREEN command must be entered. The syntax of the FULL SCREEN command is:

E>FS [L][C]

On Harris computers, with a terminal that meets ANSI standards, the "L" parameter will cause the current line number to be displayed on the status line. The "C" parameter will cause the current column number to be displayed on the status line. Due to transmission (baud) rates, these parameters can cause slower cursor movement on some terminals. Either (or both) parameters can be set permanently in the COED terminal definition file (SYST*COEDTD).

The Keypad keys (located on the right side of the keyboard) are used for moving around the file, and inserting and deleting characters. Function keys (located on the left side of the most personal computer keyboards, and along the top of many terminal keyboards) are used for editing functions such as deleting lines, inserting lines and issuing line-edit commands. On ANSI terminals, the function keys (if available) are located in different areas. Their functions are defined (and can be changed) in the COED terminal definition file (SYST*COEDTD).

2.3.3 Edit Control Keys (continued).

Key	Description
REFRESH SCREEN	The REFRESH SCREEN key repaints the screen. This key may be used when the screen is accidentally cleared or changed locally (at the terminal).
SETUP (PC only)	The SETUP key on the personal computer provides a means of setting parameters that will be saved across editing sessions. This includes screen colors, the directory of accessory files (e.g. the help file and recovery files), and an option causing COED to enter the full-screen mode automatically after initiated. Follow the directions printed on the screen, after pressing this key.

2.4 Key Locations

2.4.1 IBM P.C. and Compatibles

A key location template for the function keys and keypad key is located in the appendix.

A. Keypad. The keypad is located on the right side of the keyboard.

Key	Function
.	Delete Character
0	Insert Character Mode
1	End
2	Cursor Down
3	Page Down
4	Cursor Left
6	Cursor Right
7	Home
8	Cursor Up
9	Page Up
-	Scroll Up
+	Scroll Down
5 then 2	Bottom of Screen
5 then 4	Beginning of Line
5 then 6	End of Line
5 then 8	Top of Screen
Ctrl 4	Previous Word
Ctrl 6	Next Word

B. Function Keys. The function keys are the 10 keys marked F1 through F10 either on the left side of the keyboard, or along the top of the keyboard.

Key	Function
F1	Help
Alt F1	Help Variable
F2	Restore
Ctl F2	PC Setup
F3	Delete Line
F4	Insert Line Mode
F5 - F8	Reserved
F9	Single Command
F10	Line Edit Mode
Alt F10	File
Sft F10	Save
Ctl F10	Quit

2.4.2 Terminals (Meeting ANSI Standards)

A. Keypad. The keypad is located on the right side of the keyboard. A key location template for the keypad is provided in the appendix.

Key	Function
.	Delete Character
0	Insert Character Mode
1	End
2	Cursor Down
3	Page Down
4	Cursor Left
6	Cursor Right
7	Home
8	Cursor Up
9	Page Up
-	Scroll Up
, (tab)	Scroll Down
5 then 2	Bottom of Screen
5 then 4	Beginning of Line
5 then 6	End of Line
5 then 8	Top of Screen
"enter"	Next Word
5 enter	Previous Word

B. Function Keys. The number and location of function keys vary among terminals (these are defined in the SYST*COEDTD file). Function key identifications may be shown by pressing the HELP key from the full screen mode. Function key templates for some ANSI terminals are provided in the appendix. See your site manager for more information. The following table provides control characters that will provide the same functions.

Control Character	Function
^A	Single Command
^B	Line Edit Mode
^C	Restore Line
^D	Help
^F	Insert Line Mode
^G	Delete Line
^N	Num-Lock

3.0 Command Documentation

3.1 Basic Line Movement Commands

3.1.0 Summary

Name	Use
Top	T
Bottom	B
Next	N [n]
Up	U [n|/string/]
Print	P [n|ALL]
Locate	L [/string/] [AND|OR|NOT /string2/] [n]
Find	F [string]
Goto	G n

3.1.1 TOP

T

The TOP command moves the line pointer to the top of the file. This line is defined as line number zero and is not saved with the file (this line allows for insertion of new lines at the top of the file). Line zero cannot be changed, deleted, etc. The top of file identifier "TOF.." is displayed here.

3.1.2 BOTTOM

B

The BOTTOM command moves the line pointer to the bottom of the file. The end of file identifier "EOF.." is displayed here.

3.1.3 NEXT

N [n]

The NEXT command moves the line pointer down n lines. The default number of lines is 1.

3.1.4 UP

U [n|/string/]

The UP command moves the line pointer up n lines. If n is not specified, 1 is assumed. If a string is specified, the UP command searches upward for "string", starting with the line above the current line.

3.1.5 PRINT

P [n|ALL]

The PRINT command prints the next n lines, starting with the current line. If "*" is used for the line count n, the remainder of the file, beginning with the current line, is printed. In these cases, the line pointer is moved to the last line printed. If the "ALL" option is used, the entire file is printed, but the line pointer is not affected. "ALL" may be abbreviated to "A". To stop execution of the PRINT command, press control-X. Prefixing the PRINT command with a minus sign (-P) will print upward n lines.

3.1.6 LOCATE

L [/string/] [AND|OR|NOT /string2/] [n]

The LOCATE command searches for the next n occurrences of "string" beginning with the next line. If n is not specified, only the next occurrence of "string" is located. If an asterisk (*) is given for n, all occurrences of "string" will be located (beginning with the next line). The pointer is positioned to the line containing the string. If the string is not found, the pointer is positioned to the last line in the file. The LOCATE command without any parameter will repeat the most recent LOCATE command. Prefixing the LOCATE command with a minus sign "-L" will locate the specified string upward from the current line.

LOCATE can also be used with the operators "AND", "OR", and "NOT" along with a second string to find lines which meet one of these three conditions. The syntax is:

L /str1/OR/str2/	(Locate the next line containing the string "str1" or the string "str2".)
L /str1/AND/str2/	(Locate the next line containing both string "str1" and string "str2".)
L /str1/NOT/str2/	(Locate the next line containing the string "str1", but not containing the string "str2".)

As an example, if one wants to determine what FORTRAN subroutines the variable "XYZ" is located in, the following LOCATE command can be given:

```
L /SUBROUTINE/OR/XYZ/ *
```

3.1.7 FIND

F [string]

The FIND command searches each line, beginning with the next line, attempting to match each character of "string", with an identical string which starts in the first column of the line. When found, the line pointer is repositioned to that line. The first character of string is the next character following the single blank after the command name. Only non-blank characters in string are compared. The FIND command without any parameter will repeat the most recent FIND command. String delimiters are not used.

3.1.8 GOTO

G n

The GOTO command moves the line pointer to line number n, where n is a decimal number with respect to the top of the file.

3.2 Basic Line Edit Commands

3.2.0 Summary

Name	Use
Change	C [/stgl/stg2/ [n|n m]]
DElete	DE [n]
Insert	I [line]
Replace	R line
Overlay	O line

3.2.1 CHANGE

C [/stgl/stg2/ [n|n m]]

The CHANGE command replaces the m-th occurrence of "stgl" with "stg2" for the next n lines. The default value for m and n is 1. A "*" used for n denotes all lines from the current line to the bottom of file; a "*" used for m denotes all occurrences of "stgl". The line pointer will advance n-1 lines toward the bottom of the file. The CHANGE command without any parameter will repeat the most recent CHANGE command.

Prefixing the CHANGE command with a minus sign (-C) will reverse the pointer direction and will replace the mth occurrence of "stgl" with "stg2" up through the file for n lines.

3.2.2 DELETE

DE [n]

The DELETE command deletes n lines from the file starting with the current line. If n is omitted, just the current line will be deleted. An asterisk (*) used for n will delete all lines from the current line to the bottom of file.

3.2.3 INSERT

I [line]

The INSERT command inserts "line" after the line at which the pointer is currently positioned, and advances the pointer to the new line. If no string follows the INSERT command, the editor enters the "input" mode. In the input mode, the prompt is changed to "I>". All lines entered thereafter are inserted in the file directly below the current line. The input mode is terminated by typing three dollar signs ($$$) at the beginning of the line. Upon exit from the input mode, the line pointer is positioned to the last line inserted.

3.2.4 REPLACE

R line

The REPLACE command replaces the current line with "line".

3.2.5 OVERLAY

O line

The OVERLAY command places the non-blank characters of "line" in the corresponding positions of the current line. The first character of line is the next character following the single blank after the command name.

3.3 Terminate Edit Commands

3.3.0 Summary

Name	Use
FILE	FILE [filename]
SAVE	SAVE [filename]
QUIT	QU

3.3.1 FILE

FILE [filename]

The FILE command stores the edited file on the disk, replacing the existing copy of the file. Following the update of the file, COED exits. If an optional file name is specified, the edited file is stored in the specified disk file, leaving the original file unmodified.

3.3.2 SAVE

SAVE [filename]

The SAVE command stores the updated copy of the file on the disk, replacing the existing copy. If an optional file name is given, the edited file is stored in this file, leaving the original file unmodified. The current line pointer not affected, and the editor is not exited.

3.3.3 QUIT

QU

The QUIT command causes COED to exit without updating the file. The user should be sure to use QUIT only when the edit session results are to be discarded. The recovery option may be used when a QUIT is accidently requested.

3.4 Block Commands

3.4.0 Summary

Name	Use	
STart	ST	
ENd	EN	
DUplicate	DU	[n]
MOve	MO	
REmove	RE	
GEt	GE	[filename] [m|m n]
PUt	PU	[filename]

3.4.1 START

ST

The START command defines the current line as the beginning of a block.

3.4.2 END

EN

The END command defines the current line as the end of a block. A START command must have been entered to define the beginning of the block before an END is given.

3.4.3 DUPLICATE

DU [n]

The DUPLICATE command copies the previously defined block, inserting it directly below the current line. If the parameter n is given, the block is copied n times (n defaults to 1). The DUPLICATE command may be repeated without redefining the start and end of the block. The line pointer remains in the same position.

3.3 Terminate Edit Commands

3.3.0 Summary

Name	Use
FILE	FILE [filename]
SAVE	SAVE [filename]
QUIT	QU

3.3.1 FILE

FILE [filename]

The FILE command stores the edited file on the disk, replacing the existing copy of the file. Following the update of the file, COED exits. If an optional file name is specified, the edited file is stored in the specified disk file, leaving the original file unmodified.

3.3.2 SAVE

SAVE [filename]

The SAVE command stores the updated copy of the file on the disk, replacing the existing copy. If an optional file name is given, the edited file is stored in this file, leaving the original file unmodified. The current line pointer not affected, and the editor is not exited.

3.3.3 QUIT

QU

The QUIT command causes COED to exit without updating the file. The user should be sure to use QUIT only when the edit session results are to be discarded. The recovery option may be used when a QUIT is accidently requested.

3.4 Block Commands

3.4.0 Summary

Name	Use	
STart	ST	
ENd	EN	
DUplicate	DU	[n]
MOve	MO	
REmove	RE	
GEt	GE	[filename] [m|m n]
PUt	PU	[filename]

3.4.1 START

ST

The START command defines the current line as the beginning of a block.

3.4.2 END

EN

The END command defines the current line as the end of a block. A START command must have been entered to define the beginning of the block before an END is given.

3.4.3 DUPLICATE

DU [n]

The DUPLICATE command copies the previously defined block, inserting it directly below the current line. If the parameter n is given, the block is copied n times (n defaults to 1). The DUPLICATE command may be repeated without redefining the start and end of the block. The line pointer remains in the same position.

3.4.4 MOVE

MO

The MOVE command removes the previously defined block from its former location and inserts it directly below the current line. The line pointer remains in the same position.

3.4.5 REMOVE

RE

The REMOVE command eliminates the defined block from the file.

3.4.6 GET

GE [filename] [m|m n]

The GET command inserts line m or lines m through n of the specified file directly below the current line. If m and n are omitted, the entire file is inserted. If the file name is omitted the file previously specified will be used. The line pointer will be positioned at the inserted line or the last line of the inserted block.

3.4.7 PUT

PU [filename]

The PUT command copies the defined block to another file. If the file specified does not exist, it will be created. If the file already exists, the block is appended to the file. If the file name is omitted the file previously specified will be used.

3.5 Advanced Line Edit Commands

3.5.0 Summary

Name	Use	
ALter	AL	
CoLumn scale	CL	
Column Duplicate	CD	m-n c [r]
Column Move	CM	m-n c [r]
Column Remove	CR	m-n [r]
Column Set	CS	m[-n] "char" [r]
Locate Except	LE	/string/
Find Except	FE	string
Locate Wild	LW	/string/ [n]
Change Wild	CW	/string1/string2/ [n|n m]
Define Wild chars	DW	[c1 c2]
CUt line	CU	c|/string/ [n]
SPlice lines	SP	c|/string/ [n]
FRee	FR	[OFF|VERIFY]
TRuncate	TR	c [n]
X	X	[/command/[command/[...]]|n]
Y	Y	[/command/[command/[...]]|n]

3.5.1 ALTER

AL

The ALTER command allows one to change, delete, or insert characters correspondingly to their column position in a line. This is accomplished by printing the current line, then a new line with no prompt. The user then spaces out and types those characters to be changed, according to the following rules:

1) A space leaves the corresponding position unchanged.
2) A character replaces the character in the corresponding position.
3) A "#" replaces the corresponding character with a blank.
4) A "@" deletes the corresponding character and compresses the line.
5) A "%" inserts one blank before the corresponding character.
6) A "%/string/" inserts the string before the corresponding character.

After any changes, the line is printed again, and more changes can be made, or a carriage return with no changes will terminate the ALTER mode.

3.5.2 COLUMN SCALE

CL

The COLUMN SCALE command will print the current line and a column scale, beginning in column one, as an aid to identifying column position. If control characters appear in the line, it is displayed by a caret (^) with the control character under it.

3.5.3 COLUMN DUPLICATE

CD m-n c [r]

The COLUMN DUPLICATE command will duplicate the inclusive range of columns (m-n) to the position after column (c) for (r) lines. If (r) is omitted, the duplication will occur only on the current line. For example, "CD 40-70 0 4" will duplicate columns 40 through 70 to the position after column 0 for 4 lines.

3.5.4 COLUMN MOVE

CM m-n c [r]

The COLUMN MOVE command will move the inclusive range of columns (m-n) to the position after column (c) for (r) lines. If (r) is omitted, the move will occur only on the current line. For example, "CM 1-9 20 2" will move columns 1 through 9 to the position after column 20 for 2 lines.

3.5.5 COLUMN REMOVE

CR m-n [r]

The COLUMN REMOVE command will remove the inclusive range of columns m through n from (r) lines. If (r) is omitted, the remove will occur only on the current line. For example, "CR 20-29 3" will remove columns 20-29 (inclusively) for the current line and next two lines.

3.5.6 COLUMN SET

CS m[-n] "char" [r]

The COLUMN SET command will set the inclusive range of columns m through n (or just column m if -n is excluded), to the single specified character "char" for r lines. If (r) is omitted, the set will occur only on the current line. For example, "CS 73-80 ' ' *" will set columns 73-80 to blank on all lines, and "CS 73 H" will set column 73 to 'H' on the current line. Single quotes are required around a blank, a comma, a single quote, or other delimiter.

3.5.7 LOCATE EXCEPT

LE /string/ [n]

The LOCATE EXCEPT command operates similar to the LOCATE command, except that the lines where "string" does not appear are located. The LOCATE EXCEPT command searches for the next n times where "string" does not appear in the line, beginning with the next line. If n is not specified, only the next non-occurrence of "string" is located. If an asterisk (*) is given for n, all non-occurrences of "string" will be located (beginning with the next line). The pointer is positioned to the last line with a non-occurrence The memory will be retained until a LOCATE (or another LOCATE EXCEPT) command is given.

3.5.8 FIND EXCEPT

FE string

The FIND EXCEPT command operates similar to the FIND command, except that this command finds strings that do not match. The FIND EXCEPT command searches each line, beginning with the following line, attempting to find a non-match for each character in the string. When this non-match occurs, the line pointer is repositioned to that line. The first character of the string is the next character following the single blank after the command name. Only non-blank characters in the string are compared. String delimiters are not used. The find memory will be retained until a FIND (or another FIND EXCEPT) command is issued.

3.5.9 LOCATE WILD

LW /string/ [n]

The LOCATE WILD command allows one to locate string using wild characters that will match other characters. Two wild characters are available, a "?" and a "*". A "?" in the string will match any other single character. A "*" in the string will match any number of characters (including zero). For example:

```
LW / IF*THEN /          will locate the following strings:

    IF (X.GT.Y) THEN
    IF (LFIRST) THEN
    IFTHEN

LW /XARY(?)=/           will locate the following strings:

    XARY(1) = 2 * X * 3.1416
    XARY(4) = Y / XARY(3)
```

There may be up to 40 wild characters in any combination in a string. Wild characters may be redefined by using the DEFINE WILD CHARACTERS command. The LOCATE WILD command will locate the next "n" occurrences of the sting, and position the pointer to the last occurrence. If no "n" value is provided, the next occurrence will be located. If a "*" is substituted for n, all occurrences will be located, and the pointer will be positioned at the end of the file.

3.5.10 CHANGE WILD

CW [/stg1/stg2/ [n|n m]]

The CHANGE WILD command allows one to change a string using wild characters that will match other characters. Two wild characters are available, a "?" and a "*". A "?" in the string will match any other single character. A "*" in the string will match any number of characters (including zero). For example:

```
CW /SUBROUTINE * */*/ 100    will change

SUBROUTINE INPUT (IUNIT,CLINE,LTIME)
SUBROUTINE COMPUT (XARY,PIE,ILOCS,YARY)
SUBROUTINE ENDPRG

to

INPUT
COMPUT
ENDPRG
```

The first string may have up to 40 wild characters in any combination. The second string must have the same number, fewer, or no wild characters. If the same number or fewer wild characters are used in the second string, they must be in the same order as in the first string. For example,

```
CW /SUBROUTINE *(?ARY/SUBROUTINE *(XARY/      is legal
CW /SUBROUTINE *(?ARY/SUBROUTINE ?(*ARY/      is illegal
```

The optional m and n parameters correspond to the m-th occurrence of the string for the next n lines. The default values for m and n is 1. A "*" used for n or m denotes all lines from the current line to the bottom of file or all occurrences of "stg1", respectively. The line pointer will advance n-1 lines toward the bottom of the file.

3.5.11 DEFINE WILD CHARACTERS

DW [cs [cm]]

The DEFINE WILD CHARACTERS command allows one to change the wild characters used in the LOCATE WILD and CHANGE WILD commands. If no parameters follow the command, the current wild characters are displayed. The parameter "cs" must be a single character to use as the single wild character. The parameter "cm" must be a single character to use as the multiple character wild character. To specify "cm", "cs" must also be provided. The default single character wild character is "?" and the default multiple character wild character is "*".

3.5.12 CUT

CU c|/string/ [n]

The CUT command will divide one line into two lines after column c or after "string" for the next n lines. The cut may be either by column or by string location. After a cut, the current location is on the second half of the cut line. For example, "CU 80 *" will cut all lines into two lines after column 80 from the current line to the bottom of the file.

3.5.13 SPLICE

SP c|/string/ [n]

The SPLICE command causes the next line to be added on to the current line after either the column or string location given. This will be performed on n lines (default of 1 line) following the current line. For example, "SP 40" will add the next line on to the end of the current line after column 40.

3.5.14 TRUNCATE

TR c [n]

The TRUNCATE command truncates n lines to c columns, beginning at the current line. If n is omitted, only the current line is truncated. If a "*" is used for n, all lines from (and including) the current line will be truncated.

3.5.15 FREE

FR [OFF|VERIFY]

The FREE command causes input lines to be treated as free-field. The input lines that are affected include single line input, input mode (the prompt is "F>") and replace lines. If the VERIFY option is specified, the input lines are echoed to the terminal after formatting. A free-field input line consists of data elements, blanks, delimiters and strings. The fixed output fields are defined by the tab settings. Entering a FREE command changes the current tab settings to those most useful for generating input for several HEC programs, i.e.

2 8 16 24 32 40 48 56 64 72 80

1) A data field is a contiguous set of characters not containing a delimiter.

2) A delimiter is:

- a) One or more blanks
- b) , > <
- c) Single or double quotes for string delimiters ' "
- d) The tab character (default >)

3) A null data field is defined by two adjacent non-blank delimiters (ignoring blanks) and causes the corresponding output field to be blanked.

4) A string is a data field which begins with a string delimiter and contains all subsequent characters (including blanks and other delimiters) until the next occurrence of that delimiter. The beginning and ending string delimiters are not included in the string.

5) Input data fields are mapped into output fields. A data element may not be longer than its corresponding output field. A string may overflow its corresponding field and therefore span several fields.

6) Data fields are right justified into their corresponding output fields except when the ending delimiter (ignoring blanks) is < in which case the data field is left justified.

3.5.16 X and Y

X [/command/[command/[...]]|n]
Y [/command/[command/[...]]|n]

and
X1 through X5
Y1 through Y5

The X and Y commands allow the execution of several commands contained in one command. To define an X or Y "command string", enter X (or Y) followed by a space, then individual commands, each separated by a delimiter (e.g. a period "."). An unlimited number of commands may be placed in the X or Y command string. Once the command string has been defined, entering X (or Y) followed optionally by a count n will execute the defined command string n times. If n is not specified, it will default to 1.

X1 to X5, and Y1 to Y5 expand the number of X and Y commands that can be defined. The definition of the latest use of the X or Y commands will be retained until changed. The current definition will be displayed by preceding the command with an = sign, as =X or =Y2 .

3.6 Edit Control Commands

3.6.0 Summary

Name	Use	
HElp	HE	[command|number]
File Name	FN	[filename]
Full Screen	FS	[L][C]
Line Numbers	LN	[OFF]
Print Line number	PL	
Help Program	HP	[program-name|?|OFF|ON]
Help Variable	HV	[variable-name|line-id.field]
JUstify	JU	[DATA|OFF]
Job Control	JC	
Special Characters	SC	ON|OFF
TAb Settings	TA	[c][,c[...]]
Tab Character	TC	char
TErm definition	TE	[S=n] [L=m] [C=char]
Verify	V	[OFF]
Zone	Z	[m-n]

3.6.1 HELP

HE [command|number]

The HELP command provides on-line access to the COED documentation. When used without a parameter a help selection menu is displayed. When used with a 1 or 2 letter command identifier, information on that command will be displayed. When used with a number, various messages from the selection menu will be displayed.

3.6.2 FILE NAME

FN [filename]

The FILE NAME command allows the file name to be reset while editing a file. The new file name is used when a SAVE or FILE command is subsequently issued. If the file name is not specified, the current file name is displayed.

3.6.3 FULL SCREEN

FS [L] [C]

The FULL SCREEN command causes COED to operate in the full screen edit mode for certain terminals/computers. In this mode editing may be performed using the cursor keys to move around file. See the section on full screen editing for details.

On Harris computers, with a terminal that meets ANSI standards, the "L" parameter will cause the current line number to be displayed on the status line. The "C" parameter will cause the current column number to be displayed on the status line. These parameters can cause slower cursor movement on some terminals. Either (or both) parameters can be set in the COED terminal definition file (SYST*COEDTD).

3.6.4 LINE NUMBER

LN [OFF]

The LINE NUMBER command prints the line number along with each line. LN OFF turns off the line number printout.

3.6.5 PRINT LINE NUMBER

PL

The PRINT LINE NUMBER command prints the current line number.

3.6.6 HELP PROGRAM

HP [program-name|?|OFF|ON]

The HELP PROGRAM feature assists users in the preparation of data input files for HEC programs when using the full screen mode. This capability includes:

1) A prompt line at the bottom of the screen, indicating the names of variables for the current line (identified by the first two characters of the line).

2) Automatically setting tabs for the current line.

3) Automatically setting the justification for the current line.

4) Providing definitions of the current variable (where the cursor is) by pressing the HELP VARIABLE key (or the COMMAND key, then enter HV).

A general description of the HELP PROGRAM capabilities is included in the appendix.

The HP command followed by a question mark (?), or nothing, will display a list of those programs for which help is available. The HP, command followed by the name of one of the programs displayed, will activate help for that program. After help has been activated, it can be disabled by entering the command "HP OFF", and re-enabled with "HP ON".

3.6.7 HELP VARIABLE

HV [variable-name|line-id.field]

The HELP VARIABLE command provides definitions of HEC program variables as an aid in preparing data input files. HELP PROGRAM must be on in order to access this command.

In the full screen mode, HELP VARIABLE is requested by placing the cursor on the line and data field for which the variable help is desired, then pressing the HELP VARIABLE key. If no HELP VARIABLE key is available for the terminal you are on, press the COMMAND key, then type HV (return) to access help.

HELP VARIABLE may be used from the line edit mode by entering the command (HV), followed by either the variable name (e.g. HV METRIC), or the data line identifier and field number (e.g. HV J1.02).

3.6.8 JUSTIFY

JU [DATA|OFF]

The justify command controls how information is entered into fields in the full screen mode. When JUSTIFY is active (the default is off), and the cursor is on the right edge of a data field (by pressing the tab key), new characters entered cause those characters already in that field to be shifted to the left, so that entries are always aligned with the right side of the field. For more information see the Help Program Appendix.

When HELP PROGRAM is on, JUSTIFY is controlled by information in the HP program file, and cannot be turned off or on. JUSTIFY is normally used for entering data for programs that do not have a HP file.

3.6.9 JOB CONTROL

JC
DOS (on the PC)

The JOB CONTROL command temporarily moves you into Job Control, retaining your edit session. In Job Control, you can do limited things, such as list a file, get a directory (or map on the Harris). DO NOT edit any other files in this mode; If you do, your entire edit session may be lost.

On Harris computers, do not attempt a "FREE ALL". To return to your COED session, type "EXIT". You will be returned to the where you were when you issued the JC command.

On the PC, you are moved into an abbreviated version of DOS. In this version, there is no prompt (the cursor will remain at the end of the last line printed). To return to COED, press only a carriage return. The command "DOS" can be used instead of "JC" on the PC.

3.6.10 SPECIAL CHARACTERS

SC ON|OFF

The SPECIAL CHARACTERS command allows control characters to be entered, and will print control characters when encountered. Control characters are displayed as a caret (^) with the control character under it. For example, a control-G in a line would be printed as:

```
This is^ a test line.
       G
```

The COLUMN SCALE (CL) command will always print control characters, regardless if SPECIAL CHARACTERS is on or off. (Note: The delete key is not a control character, and its printing is dependent upon the terminal being used.)

3.6.11 TAB SETTINGS

TA [c1][,c[...]]

The TAB SETTINGS command sets tabs at columns c1, c2, etc. Up to twenty tab fields may be set. Tabs may be removed by typing "TA" with no parameters. Default settings are 7, 10, 13, 16, 19, 22 and 73. The tab settings are automatically changed to data style by entering a FREE command. The current tab settings may be displayed with the TERMINAL DEFINITION command.

On Harris computers, the default settings may be changed in the COEDTD file (see Site Installation).

3.6.12 TAB CHARACTER

TC char

The TAB CHARACTER command defines the character "char" to be used for tabbing. The default tab character is ">".

3.6.13 TERMINAL DEFINITION

TE [S=n] [L=m] [C=char]

The TERMINAL DEFINITION command describes the attributes of the individual terminal to the editor. This is separate from the terminal definition file used in full screen editing.

The "S=" option describes the line size to be used for printing. The default value is either 80 or 132 characters, depending on the file being edited.

The "L=" option specifies the number of lines per text line to print. The default value is 1 line.

The "C=" option defines the continuation character for input. This is useful when input lines are greater than the terminal column width. The default character is ">".

If TE is entered with no parameters, the current values of S, L, C and the current tab settings are displayed.

3.6.14 VERIFY

V [OFF]

The VERIFY command, when used in conjunction with the "OFF" parameter, suppresses output (unless explicitly requested using the PRINT command). The verification may be reinstated by entering V without "OFF".

3.6.15 ZONE

Z [m-n]

The ZONE command causes subsequent execution of the CHANGE and LOCATE commands to apply only to the zone (columns) specified. m is the starting column and n is the ending column. If no parameters are specified, the current zone settings are displayed.

4.0 Machine Specific Attributes

4.1 IBM PC (MS-DOS) Specifics

4.1.1 General Information

The P.C. version of COED requires MS-DOS Version 2.1 or later, and at least 512 KB of memory. The 8087 math co-processor is not needed. If COED will not run, the number of files specified in the "\CONFIG.SYS" file should be changed to 15, and the number of buffers set to 10, that is:

```
FILES=15
BUFFERS=10
```

The PC version has been tailored to take advantage of the speed of in-core editing. If the file being edited exceeds available memory, a spill file will be used (this occurs at about 2000 lines at 80 columns). When the spill file is needed, editing speed performance is degraded, so appropriately sized files is recommended.

4.1.2 Files Used

When a file is edited, two backup files are created for recovery purposes. By default, these files will be generated in the root directory, unless an accessory file directory has be defined as described in section 4.1.3. Their names are:

```
COED.BUP
COED.REC
```

The file COED.BUP will contain a copy of the last file edited, before any modifications were made. This file can be used, if unwanted changes are accidently saved.

The file COED.HLP must be available for HELP features to function. The file \COED.TRM will be created in the root directory of the default drive if any setup features are used (see below).

4.1.3 Setup Function for Full Screen

The control-F2 function key in the full-screen edit mode provides a means of setting screen colors (for color monitors), defining the directory for the COED accessory files, and making COED come up in the full screen mode. After pressing control-F2, a short menu will appear, requesting the user to enter a "P", or a "N" to set the Full Screen mode to Permanent (or unset it), a "D" to change the accessory file directory, or a "C" to change screen colors. If a "P" is entered, then COED will always go directly in to the Full Screen mode at the beginning of an edit session, without the user having to type "FS". To reset this feature, so that COED will begin with the line edit mode, type a "N". The user is returned to the full screen mode when either of these characters are pressed.

If the accessory file directory is changed, then COED will generate the recovery files in this directory, and look for the help file (COED.HLP) here. After setting the directory, and terminating the edit session, the user should copy all of these files from the old directory (the default is the root directory) into the new directory, with the exception of the file \COED.TRM. COED.TRM must always remain in the root directory.

To change the screen colors, enter a "C" from this menu. This will cause another short menu to appear, allowing one to change the foreground and background colors for the main screen, the status line, and the help program prompt line on a color screen. These colors are retained between edit sessions (in file \COED.TRM). By pressing the "F" key, the colors scroll through the foreground color (16 colors). "B" changes the background color (8 colors), "S" changes the status line foreground color, and "T" changes the status line background color. A "H" toggles through the help program prompt line foreground colors, while a "P" toggles through the prompt line background colors. When complete, a carriage return returns to the edit mode.

4.2 Harris Specific Information

If $ADD is set to "ON", COED will turn if off and print a message to that effect. To edit a file with $ADD ON, the "A" option must be used ($ADD does not have to be set on, COED will automatically set it to on). For example:

```
COED.A  MYFILE
```

COED uses the file "SYST*COEDTD", which must be located in the system qualifier, to identify parameters (such as the duplex), and and terminal definitions for full screen editing. Located in this file is the qualifier name of where additional accessory files may be found (such as COEDHE, for on-line documentation, and the help program files). See the Harris installation section for more information on the COEDTD file.

In order to achieve the most effective performance on Harris mini-computers in use by the Corps of Engineers, several COED capabilities have been tailored for that system. Most editing is done in-core with the operating system providing virtual memory paging through the in-core 'file' instead of using less efficient user disk I/O. This makes COED require a larger amount of memory than previously. Some system site managers are reluctant to provide users with permission to use more memory under the belief that it will have detrimental effects on their system performance. Our testing has shown that limiting the program size may cause less efficient use of computer resources. The additional overhead of the user disk I/O implementation is far more demanding on system resources than the currently implemented virtual memory approach.

APPENDICES

Appendix A
Alphabetical Command Summary

Command	Use	
Alter	AL	
Bottom	B	
Change	C	[/stg1/stg2/ [n|n m]]
Change Wild	CW	/stg1/stg2/ [n|n m]
Column Duplicate	CD	m-n c [r]
Column Move	CM	m-n c [r]
Column Remove	CR	m-n [r]
CoLumn scale	CL	
Column Set	CS	m[-n] 'char' [r]
CUt line	CU	c|/string/ [n]
DElete	DE	[n]
Define Wild	DW	[cs] [cm]
DUplicate	DU	
ENd	EN	
Find	F	[string]
Find Except	FE	string
FILE	FILE	[filename]
File Name	FN	[filename]
FRee	FR	[OFF|VERIFY]
Full Screen	FS	[L][C]
GEt	GE	[filename] [m|m n]
Goto	G	n
HElp	HE	[command|number]
Help Program	HP	[program-name|?|OFF|ON]
Help Variable	HV	[variable-name|line-id.field]
Insert	I	[line]
Job Control	JC	
JUstify	JU	[DATA|OFF]
Line Numbers	LN	[OFF]
Locate	L	[/string/ [n]]
Locate Except	LE	/string/ [n]
Locate Wild	LW	/string/ [n]
MOve	MO	
Next	N	[n]
Overlay	O	line
Print	P	[n|ALL]
Print Line number	PL	
PUt	PU	[filename]
QUit	QU	
Replace	R	line
REmove	RE	
STart	ST	

SAVE	SAVE	[filename]
Special Characters	SC	ON|OFF
SPlice lines	SP	c|/string/ [n]
TAb settings	TA	[c][,c[...]]
Tab Character	TC	char
TErm definition	TE	[S=n] [L=m] [C=char]
Top	T	
TRuncate	TR	c [n]
Up	U	[n|/string/]
Verify	V	[OFF]
X	X	[/command/[command/[...]]|n]
Y	Y	[/command/[command/[...]]|n]
Zone	Z	[m-n]

Appendix A
Alphabetical Command Summary

Command	Use	
Alter	AL	
Bottom	B	
Change	C	[/stg1/stg2/ [n|n m]]
Change Wild	CW	/stg1/stg2/ [n|n m]
Column Duplicate	CD	m-n c [r]
Column Move	CM	m-n c [r]
Column Remove	CR	m-n [r]
CoLumn scale	CL	
Column Set	CS	m[-n] 'char' [r]
CUt line	CU	c|/string/ [n]
DElete	DE	[n]
Define Wild	DW	[cs] [cm]
DUplicate	DU	
ENd	EN	
Find	F	[string]
Find Except	FE	string
FILE	FILE	[filename]
File Name	FN	[filename]
FRee	FR	[OFF|VERIFY]
Full Screen	FS	[L][C]
GEt	GE	[filename] [m|m n]
Goto	G	n
HElp	HE	[command|number]
Help Program	HP	[program-name|?|OFF|ON]
Help Variable	HV	[variable-name|line-id.field]
Insert	I	[line]
Job Control	JC	
JUstify	JU	[DATA|OFF]
Line Numbers	LN	[OFF]
Locate	L	[/string/ [n]]
Locate Except	LE	/string/ [n]
Locate Wild	LW	/string/ [n]
MOve	MO	
Next	N	[n]
Overlay	O	line
Print	P	[n|ALL]
Print Line number	PL	
PUt	PU	[filename]
QUit	QU	
Replace	R	line
REmove	RE	
STart	ST	

SAVE	SAVE	[filename]
Special Characters	SC	ON|OFF
SPlice lines	SP	c|/string/ [n]
TAb settings	TA	[c][,c[...]]
Tab Character	TC	char
TErm definition	TE	[S=n] [L=m] [C=char]
Top	T	
TRuncate	TR	c [n]
Up	U	[n|/string/]
Verify	V	[OFF]
X	X	[/command/[command/[...]]|n]
Y	Y	[/command/[command/[...]]|n]
Zone	Z	[m-n]

Appendix B
Table of COED Commands

AL	-ALter	FR	-FRee	PL	-Print Line number
B	-Bottom	FS	-Full Screen	PU	-PUt
C	-Change	G	-Goto	QU	-QUit
CD	-Column Duplicate	GE	-GEt	R	-Replace
CL	-CoLumn scale	HE	-HElp	RE	-REmove
CM	-Column Move	HP	-Help Program	SAVE	-SAVE
CR	-Column Remove	HV	-Help Variable	SC	-Special Characters
CS	-Column Set	I	-Insert	SP	-SPlice lines
CU	-CUt line	JC	-Job Control	ST	-STart
CW	-Change Wild	JU	-Justify	T	-Top
DE	-DElete	L	-Locate	TA	-TAb settings
DU	-DUplicate	LE	-Locate Except	TC	-Tab Character
DW	-Define Wild	LN	-Line Numbers	TE	-TErm definition
EN	-ENd	LW	-Locate Wild	TR	-TRuncate
F	-Find	MO	-MOve	U	-Up
FE	-Find Except	N	-Next	V	-Verify
FILE	-FILE	O	-Overlay	X	-X
FN	-File Name	P	-Print	Z	-Zone

Appendix C

Help Program Information

This section describes the COED Help Program capabilities that aid in generating and editing data input files for engineering programs. The following topics are covered in this section:

1) Prompting with data input line definitions.
2) Automatic tab stops for each data input line.
3) Automatic justification of data in each field.
4) Checking for non-numeric data at time of entry.
5) Use of the numeric key pad for data input.
6) Data input variable definitions.
7) Program Help files.

C.1 Data Input Line Prompts

The first two characters of the line that the cursor is on governs the contents of a program prompt line located at the bottom of the screen. These characters are compared against a list of line identifiers from a file containing that program's help information. If the identifier is recognized, the prompt line associated with that identifier is displayed. If the identifier is not recognized, a default prompt is displayed. The prompt is changed if the identifier on the current line is changed, or if the cursor is moved to a different line.

C.2 Automatic Tab Stops

The tab stops are dynamically reset for each line, according to the line identifier and information from the program's help file. If the line identifier is not recognized, then default tab stops are set.

C.3 Automatic Justification

With Help Program on, the justification setting is dynamically set for each line and field, according to the line identifier and information from the program's help file. When Help Program is off, the justification mode may be set by the JUSTIFY key or command. Without data justification on, data entry and tab stops operate normally. With data-justify on, characters entered are right justified within each field. If the cursor is on the right edge of a field, any characters typed are aligned to the right of the field. If the cursor in not on the right edge of the field, then any characters typed will be placed normally, until reaching the right edge. The tab key is used to move to the next field, whereby the cursor is placed on the right edge of the field. When data justification is on, the backspace and the delete key will remove the character at the cursor location.

C.4 Checking for Non-numeric Data

When entering data, the data may be checked to assure only numeric digits are entered. This can prevent the entry of the letter "O" when a zero was intended. When numeric data checking is performed, only the following fourteen characters may be entered: "0123456789 .-+". Numeric data checking is governed by information in the program's help file.

C.5 Use of the Numeric Keypad

Numeric data may be entered most rapidly from the numeric keypad. Unfortunately, on many keyboards this disables the use of the keypad for cursor movement. The keypad may be set in a numeric mode by pressing the COED "NUM-LOCK" key. To return the keypad to a cursor movement operation, press the COED "NUM-LOCK" key again. On personal computers with programs that emulate terminals, the local keyboard "NUM-LOCK" key may need to be set on, and the separate COED "NUM-LOCK" key is used to toggle between the cursor movement application and numeric application.

C.6 Variable Definitions

If the Help Program mode is on, and the program's help file contains variable definitions, the definitions may be displayed on the screen by use of the HELP VARIABLE command.

In the full screen mode, HELP VARIABLE is requested by placing the cursor on the line and data field for which the variable help is desired, then pressing the HELP VARIABLE key. If no HELP VARIABLE key is available for the terminal you are on, press the COMMAND key, then type HV (return) to access help.

HELP VARIABLE may be used from the line edit mode by entering the command (HV), followed by either the variable name (e.g. HV METRIC), or the data line identifier and field number (e.g. HV J1.02).

C.7 Help Program Files

The Help Program feature uses an external file, for each program, that contains information on the line variable names, tab settings, justification, non-numeric checking, and variable definitions. The file "COEDHP" contains a list of all programs for which help is available, and the names of each program's help file. (The format of the COEDHP file is self-explanatory.) The COEDHP file is located in the directory or qualifier defined in the 0000SYST*COEDTD or \COED.TRM file.

The program help files are indexed text files. If a progran help file is changed, the byte or line count that is used for indexing may become incorrect, and the help for that program will not operate properly. If you wish to modify or add a help file, contact the HEC for assistance.

Appendix D

Harris Installation Information

Several default settings may be specified in the file "SYST*COEDTD", along with terminal definitions for full-screen editing. These settings include: 1) the duplex (echoplex); 2) the column size; 3) tab settings; 4) the qualifier location for the help file; and 5) the terminal definition to be used for full-screen editing.

D.1 Setting General Editing Defaults.

In order to change the default settings, the first four characters of the first line in file "SYST*COEDTD" must be LOAD. On subsequent lines, instructions can be given to change the default settings. This typically consists of a four character keyword, followed by an equal sign, then the new setting. Comments may be inserted (as separate lines) by using an asterisk (*) as the first character in the line. The settings must end with an ENDLOAD statement.

D.1.1 Duplex (Echoplex)

By default, COED checks the Harris string register "SDX" to determine if the duplex is FULL or HALF (by checking a register, different terminals may have different duplexes). If that register is nonexistent, full duplex is assumed. The COEDTD file may specify a different register to check, or "hardwire" the duplex. If the duplex is half, and full-screen editing is desired, see the notes under Full-Screen Terminal Definition that follows.

To have COED check another register, use the keyword "DREG", followed by an equal sign (=), then the register name. For example, to check the register "DPX", use:

```
DREG=DPX
```

To "hardwire" a duplex setting, use the keyword "DUPL", followed by an equal sign (=), then the word "FULL" or "HALF". For example:

```
DUPL=HALF
```

D.1.2 Column Size (S=value)

The default column size (length) is set to the optimum 80 characters. With this setting, COED will check the first 100 lines, to see if any lines are longer than 80 characters. If so, the column size will be set to 132 characters. Any value specified on the execution line will override this. If a default column size other than 80 is desired, it may be specified by the keyword "S", followed by an equal sign, then the new value. For example:

```
S=132
```

[In this case, COED will not check the first 100 lines.] In any case, if the user specifies an S value on the execution line, it will override any setting in the COEDTD file.

D.1.3 Tab settings

The default tab settings (7, 10, 13, 16, 19, 22, and 73) may be re-specified by giving a tab command in this section. This is done by entering the letters "TAB" followed by the new tabs. For example:

```
TAB 7, 11, 18, 30, 73
```

D.1.4 Qualifier Containing Help File

A separate qualifier may be specified for the location of the COED help file (COEDHE), and the help program files (COEDHP). This is accomplished by giving the letters "QUAL", followed by an equal sign, then the qualifier. For example:

```
QUAL=1000COED
```

If no qualifier is given, the default of "SYST" is used.

D.1.5 Terminal name for Full Screen

When a user first goes into full-screen mode, COED will check the register "STM" to identify the type of terminal being used. If that register is not present, a list of the terminals defined will be given, and the user will asked for the name of the terminal in use.

A different register can be checked, or the terminal name may be hardwired (useful only where a site has one type of terminal). To have COED check a different register, use the keyword "TREG", followed by an equal sign (=), then the 3 character register name. The register should contain a four character name or abbreviation for the terminal. For example to have COED check the register "TRM":

```
TREG=TRM
```

To "hardwire" COED so that only one type of terminal can be used, use the keyword "TERM", followed by an equal sign (=), then the 4 character terminal name or abbreviation. For example, to set the terminal name to "TABG":

```
TERM=TABG
```

D.2 Example Top Portion of the "SYST*COEDTD" File

```
LOAD
* SET THE DUPLEX REGISTER TO "DUP"
DREG=DUP
* SET THE ACCESSORY FILE QUALIFIER TO HLIB
QUAL=HLIB
* RESET THE DEFAULT COLUMN SIZE (LENGTH) TO 132:
S=132
* RESET THE DEFAULT TABS:
TAB 7 11 20
* SET THE TERMINAL REGISTER TO "TRM":
TREG=TRM
ENDLOAD
```

D.3 Terminal Definitions for Full-Screen Editing

In order to use full-screen features on the Harris, the terminal type being used must be defined in the file "SYST*COEDTD". The definitions include the number of lines and columns the terminal screen has, any messages that need to be sent to the terminal to set it to the proper mode, or reset it when done, down-loading information to any programmable softkeys, redefining any keys, and providing any help messages to the user.

Currently, full-screen editing can only be done on terminals that meet ANSI terminal standards (this includes most newer terminals). Unfortunately, many Harris terminals, such as the Beehive, do not meet these standards. It is planned that a future release will have provisions for those terminals.

Full-screen editing can only work in a full duplex mode. If you use half duplex, a message can be sent to some terminals to change them into full duplex during full-screen editing, then back to half duplex during the regular line edit mode. For more information, see the "BM" and "EM" keywords (following).

A terminal definition begins with the keyword "TERM" (starting in the left-most column), followed by a blank then the terminal name (only the first four characters are used). If more than one model of terminal meets the same definition, one or more TERM statements can follow this. A terminal definition ends with the keyword "ENDTERM" (starting in the left most column). For example:

```
* Define Tektronix 4105, 4017, and 4109
TERM 4105
TERM 4107
TERM 4109
(definitions)
ENDTERM
```

Each terminal definition must contain at least the following keywords: "TERM", "ENDTERM", "NL", and "NC". Except for TERM and ENDTERM, each keyword consists of two upper case characters. All parameters are separated from the keyword by a blank.

D.3.1 Keyword Definitions.

a) TERM: Identifies the beginning of a terminal definition. The terminal name must follow, of which only the first four character are used.

b) ENDTERM: Defines the end of a terminal definition.

c) NL: Number of lines the terminal screen has. This number may be followed by the word "ON", which indicates the current file line number should be displayed on the status line. On most terminals at most baud rates it takes too long to change the line number while moving through the file. Example:

```
NL 24 ON
```

d) NC: Number of column the terminal screen has. If the terminal has two mode (e.g. 80 columns or 132 columns) or if the terminal can scroll horizontally, use the larger number (e.g. 132). This number may be followed by the word "ON", which indicates the column number should be displayed on the status line. On most terminals at most baud rates it takes too long to change the column number. Example:

```
NC 132
```

e) IM: Initiate Message. Upon entering full-screen mode (for the first time), the message that follows will be sent to the terminal. Most of the time this message is to set the terminal in a mode necessary to do full-screen editing. The message is defined by a beginning and ending delimiter (e.g. a quote ('), or dollar sign ($)), which may not appear anywhere else in the message. Control characters are sent by using a caret (^) preceding the character. For example, a ^A will send a control-A, a ^[will send an escape character. To send a caret, supply two carets (e.g. ^^). The message is sent exactly as is; No carriage return or line feed is appended. For example:

```
* Set terminal to ANSI mode
IM '^[<'
```

This will send an escape character followed by a less-than sign character (<). Also:

```
* Set horizontal scroll on
IM '^[[=4h'
```

This will send an escape character followed by a left bracket ([) followed by an equal sign (=), a 4, and a lower case h.

The initiate message is often used to send information to the terminal for programmable soft keys. There may be as many initiate messages as needed.

f) RM: Reset message. The message following the keyword is sent upon termination of COED. The message follows the same conventions used above. This is often used to return the terminal to its initial state.

g) BM: Begin Message (this keyword is used infrequently). The Begin Message is typically used for setting the duplex to full upon entry of full-screen on a half duplex system. The message following the keyword will be sent to the terminal every time COED goes from a line-edit mode to a full-screen mode. The same conventions used in "IM" are used here. Only 5 "BM's" may be used per terminal. [An "IM" is sent only the first time COED enters full-screen mode during an edit session. A "BM" is sent every time COED enters full-screen mode.]

h) EM: End Message. Used in accordance with Begin Message. The message following the keyword is sent to the terminal every time COED goes into the line edit mode from full-screen model.

i) HE: Help. The message following the HE keyword is sent to the terminal when the user requests help from full-screen mode. Typically a series of HE's are provided to fill up the screen to indicate to the user what keys or control characters do what functions. The messages follow the conventions given under "IM", except that a carriage return and a line feed are appended to each message.

j) HK: Help Key. This provides the name of the help key, which is displayed on the status line. Up to four characters may be used as the help key name. Example:

```
HK F22
```

D.4 Redefining Keys for Full-Screen Functions

Many terminals provide alternative keys to provide functions such as cursor movement, or the function keys may not be programmable. By redefining the COED full-screen function sequence these keys can be utilized. The keys to be used must either send out a single control character, or an a control code sequence of up to 5 characters (a control character followed by up to 4 more characters). All sequences for a particular control character must be the same length.

The keywords for redefining the function sequence are DEFINE and DEFINE2. DEFINE will add on that key's definition, and remove any other definitions for that function, while DEFINE2 will add on to that key's definition. There may be several definitions for each function (there is room for a total of 200 definitions).

Suppose that the terminal you are installing has 4 keys, separate from the key pad, with arrows on them; one right, one left, one up, one down. If you want the key with the left arrow to preform a cursor left, and that key produces an "escape [D" when pressed, the COED cursor left function can be defined by providing the following line in the definition file:

```
* Set the alternative cursor-left key
DEFINE2 CURL=^[[D
```

The other cursor left key will remain defined (by default) as the 4 on the key pad. If DEFINE only were used, the keypad 4 would preform no function.

If you wish the backspace to move the cursor left (a non-destructive backspace) without blanking the character, you can add another definition to the cursor left:

```
* Make the Backspace Non-Destructive
DEFINE2 CURL=^H
```

(The backspace key sends a control-H when pressed). For these examples, a total of 3 keys performed the cursor left function.

Several functions can be combined into one key in order to make more powerful keys. For example, to create a key to clear to the end of the line, you could program a softkey (terminal dependent) to send the delete function, a carriage return, then another delete key. However, COED limits its type-ahead capability only to standard characters (if someone were to keep the "Page Down" key pressed, it would continue paging down long after the key was released if type-ahead was used). Type-ahead may be turned completely on by sending an escape then ++, and back off by sending a escape then --. In order to make a multiple function key, type-ahead must be first turned on (and reset to off when done). For example to download a "clear to end of line" sequence to a terminal softkey, the following Initiate Message may be sent:

```
* Download Clear to end of line key (multiple function key)
* Sequence: Type-ahead on, delete char, carriage return,
* delete char, type-ahead off.
IM '^[++^[On^M^[On^[--'
```

D.5 Define Function Keywords.

The keywords (and the default character sequences that invoke that function) to used when redefining keys for functions (section D.4) are provided in the following table. In this table a caret (^) indicates that the next letter is a control character. For example a ^A represents control A and a ^[represents the escape character.

Keyword	Default Sequence	Function
COMN	^A	Command (single)
LINE	^B	Line-Edit
CURR	^[Ov	Cursor Right
CURL	^[Ot	Cursor Left
CURU	^[Ox	Cursor Up
CURD	^[Or	Cursor Down
PGUP	^[Oy	Page Up
PGDN	^[Os	Page Down
HOME	^[Ow	Home
END	^[Oq	End
BOL	see below	Beginning of Line
EOL	see below	End of Line
TABR	^I	Tab Right
TABL	none	Tab Left
INSC	^[Op	Insert Character Mode
DELC	^[On	Delete Character
INSL	^F	Insert Line Mode
DELL	^G	Delete Line
HELP	^D	Help
REST	^C	Restore
SCUP	^[Om	Scroll Up
SCDN	^[Ol	Scroll Down
NUML	^T	Numb-Lock
NXTW	^[OM	Next Word
PREW	see below	Previous Word
TOS	see below	Top of Screen
BOS	see below	Bottom of Screen
SAVE	none	Save File
FILE	none	File
QUIT	none	Quit
KEY5	^[Ou	Key 5 on the Keypad
JUST	none	Justify
HLPV	none	Help Variable
EFLD	none	Erase Field
REFR	none	Refresh Screen

Several functions (such as Beginning of Line) use 2 keys for their default definition: the keypad 5, then another keypad key. These may be refined to use only one key, if desired.

D.6 ASCII Control Character Code Representations

Decimal Value	Mnemonic	COED Representation
00	NUL	^@
01	SOH	^A
02	STX	^B
03	ETX	^C
04	EOT	^D
05	ENQ	^E
06	ACK	^F
07	BEL	^G
08	BS	^H
09	TAB	^I
10	LF	^J
11	VT	^K
12	FF	^L
13	CR	^M
14	SO	^N
15	SI	^O
16	DLE	^P
17	DC1 (X-ON)	^Q
18	DC2	^R
19	DC3 (X-OFF)	^S
20	DC4	^T
21	NAK	^U
22	SYN	^V
23	ETB	^W
24	CAN	^X
25	EM	^Y
26	SUB	^Z
27	ESC	^[
28	FS	^\
29	GS	^]
30	RS	^/
31	US	^_
127	Delete	^?

D.7 Example Terminal Definition.

The following provides an example terminal definition used for the TAB 132/15-G terminal.

```
TERM TABG
NL 24
NC 132
*  Define alternative cursor keys
DEFINE2 CURU=^[[A
DEFINE2 CURD=^[[B
DEFINE2 CURL=^[[D
DEFINE2 CURR=^[[C
DEFINE2 HLPV=^V
*
* Define backspace as non-destructive (i.e. cursor left)
* DEFINE2 CURL=^H
*
*  Set terminal to ANSI mode
IM '^[<'
*  Set "TABMODE" on
IM '^[_TABON^[\'
*  Set Horizonal scroll on
IM '^[[=4h'
*  Set Black Background
IM '^[[?5l'
*  Set normal attributes
IM '^[[0m'
*  Set replacement mode (instead of insert)
IM '^[[4l'
*  Set alternative Keypad on
IM '^[='
*
*  Set Soft key ledgends
IM '^[_L1Delete Ln^[\'
IM '^[_L2Insert Ln^[\'
IM '^[_L3 Num-Lock^[\'
*  Ledgened 4 is reserved for future use
IM '^[_L4        ^[\'
IM '^[_L5  Help   ^[\'
IM '^[_L6 Restore ^[\'
IM '^[_L7 Command ^[\'
IM '^[_L8Line-Edit^[\'
```

```
*  Set Soft Key Messages
IM '^[_M1^G^[\'
IM '^[_M2^F^[\'
IM '^[_M3^N^[\'
IM '^[_M4^[\'
IM '^[_M5^D^[\'
IM '^[_M6^C^[\'
IM '^[_M7^A^[\'
IM '^[_M8^B^[\'
*  Display these settings
IM '^[9'
*
*  TAB Reset Messages
RM '^[[=6h'
RM '^[>'
RM '^[_TABOFF^[\'
* TAB HELP MESSAGES
* TAB Help Key is S5
HK S5
HE '-----------------------------------------------------------------------'
HE '|   --------------- TAB  TERMINAL  COED FUNCTION  KEYS ------------------  |'
HE '|   | S1 - Delete current line              S5 - HELP                   |   |'
HE '|   | S2 - Insert line mode (toggle)        S6 - Restore line           |   |'
HE '|   | S3 - Number-Lock                      S7 - Command                |   |'
HE '|   | S4 - (reserved)                       S8 - Line edit mode         |   |'
HE '|   ---------------------------------------------------------------------   |'
HE '|                                          K E Y   P A D   K E Y S          |'
HE '|                                        ----------------------------------  |'
HE '|     Other Keypad Functions            | HOME |  ^^   | PAGE | SCROLL |   |'
HE '|                                       |      |  |    |  UP  |   UP   |   |'
HE '|   Key 5 then 4:  Beginning of line    |-----------------------------------|   |'
HE '|   Key 5 then 6:  End of line          | <--- |       | ---> | SCROLL |   |'
HE '|   Key 5 then 2:  Bottom of screen     |      |   5   |      |  DOWN  |   |'
HE '|   Key 5 then 8:  Top of screen        |-----------------------------------|   |'
HE '|   Key 5 then "print":  Previous       |  END |  |    | PAGE |        |   |'
HE '|                        Word           |      |  V    | DOWN |  NEXT  |   |'
HE '|                                       |--------------------------  WORD  |   |'
HE '|                                       |    INSERT    | DEL  |        |   |'
HE '| Press <space> for more help           |     CHAR     | CHAR |        |   |'
HE '| Press <S5> (HELP) to resume edit      -----------------------------------   |'
HE '-----------------------------------------------------------------------'
ENDTERM
```

Appendix E

MS-DOS P.C. Installation Information

The MS-DOS version of COED can either be used on a dual-floppy system, or on a hard disk system. On either system, at least 460 Kbytes of free memory (equivalent to 512 Kbytes of total memory running DOS 3.1) and DOS 2.1 (or later) are required. The math coprocessor is not needed. Make sure that the \CONFIG.SYS file has at least the following: FILES=15 and BUFFERS=10.

Three diskettes are supplied for COED. The first diskette contains the executable program, the on-line help file, some installation setup files, and some accessory files. The second diskette contains the HEC help program files, for use with the help program feature of COED. The third diskette contains a copy of the COED documentation, if a hard copy is not already available.

Included with the first diskette is a Crosstalk file (HARRIS.XTK) that emulates a Televideo terminal for communication with a Harris computer. Since the Televideo meets ANSI terminal standards, it can be used for full-screen editing. This file may be used by those, with Crosstalk, for full-screen editing by pressing the NUM LOCK key to enable use of the key pad (to communicate with the Crosstalk program, press the NUM LOCK key a second time). Communication parameters (e.g., baud rate, port) may need to be changed.

On a dual-floppy system, insert the first COED diskette into one of the drives, and edit file(s) on the other drive. The default drive may be either drive, as COED will check both drives for the COED.TRM file (the file that remembers the screen colors). (Make sure that no directory is set in the COED.TRM file).

The following are instructions for installing COED on a hard disk (assumed to be drive C: in these examples). The instructions in section one are for loading the COED program into the root directory, and the accessory files into directory C:\UTIL. Section two provides instructions on loading the COED accessory files into an alternative directory. If you have an old version of COED, backup that version, then erase all the old COED files on the hard disk before you begin.

1) A batch file (SETUP-C.BAT) has been included on diskette 1, which will load COED.EXE and COED.TRM into the hard disk root directory, then copy the accessory files into the directory \UTIL (which will be created, if not present). To install COED in this manner, insert diskette one into drive A, then type: A:SETUP-C and follow the instructions on the screen.

2) If you desire to load the COED accessory files (i.e. help files, recovery files, and help program files) in a alternative directory, complete the following instructions:

   a) Create the directory for the accessory files if it does not yet exists (e.g., type: MD \UTIL).

   b) Place the first COED diskette in the A drive and change the default drive to A: (type: A: in DOS).

   c) Use COED to edit an dummy file (e.g., type: COED XYZ).

   d) After the E> prompt has appeared, enter into full-screen mode (type: FS). Now press the setup key (control-F2).

   e) Set the drive and the alternative directory by pressing the "D" key. Enter the drive and directory selected (e.g., type: C:\UTIL\).

   f) Exit COED by pressing the quit key (control F10).

   g) Change the default drive back to the hard disk drive (type C:) then copy A:COED.TRM into <u>the root directory</u> of the hard disk (type: COPY A:COED.TRM C:\COED.TRM).

   h) Copy the COED.HLP file from diskette one into the directory selected (e.g., type: COPY A:COED.HLP C:\UTIL).

   i) Copy the COED program from diskette one into the root directory (or alternative directory according to the note below) (e.g., type: COPY A:\COED.EXE \COED.EXE).

   j) Copy all of the files on diskette two into the directory selected (e.g., type: COPY A:*.* C:\UTIL).

3) If you desire to store all the COED files in your root directory, copy all of the COED files from diskettes one and two into the root directory (e.g., type: COPY A:*.* C:\). The setup files may be erased after copying.

<u>Notes:</u>

The COED documentation file on diskette three does not need to be placed on the hard disk (only use it if you desire a hard copy of the documentation).

The COED executable may optionally be stored in an alternative directory by setting the path to that directory. This is done by modifying the autoexec.bat file to contain a PATH command that includes the directory where the executable is. For example, if COED is to be stored in "\UTIL", add (or modify) the following line to autoexec.bat:

```
PATH C:\;C:\UTIL
```

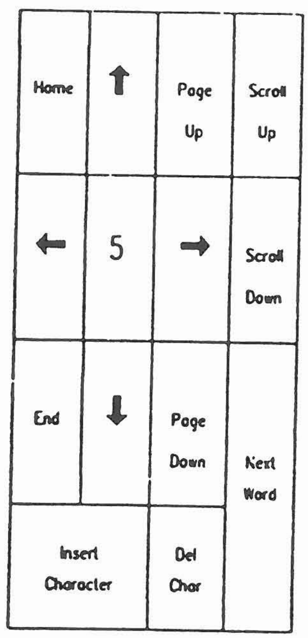
See your DOS Documentation for further information on the PATH command.

Copy the executable file (COED.EXE) from diskette one into this directory.

Appendix F
Full Screen Key Templates

MS-DOS Personal Computer

COED FULL SCREEN KEYS

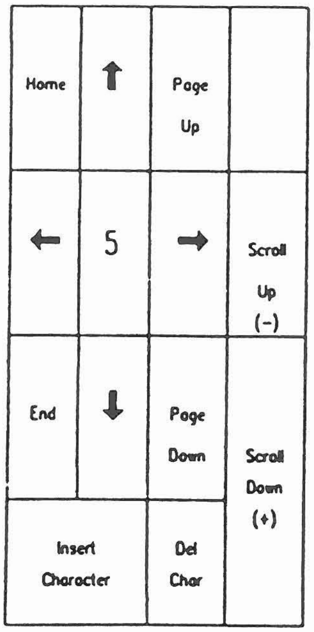


Beg of Line: 5 ←
End of Line: 5 →
Top of Screen: 5 ↑
Bot of Screen: 5 ↓
Prev Word: 5 Nxt Wd

COED FUNCTION KEYS

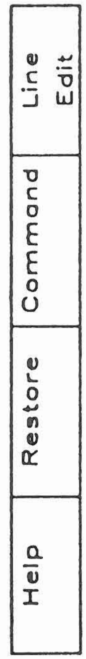
Key Control + Key Shift + Key Alt + Key	
Help – – Help Var.	Restore PC Setup – –
Delete Line – Erase Field –	Insert Line – – –
– – – –	– – – –
– – – –	– – – –
Command – – –	Line–Edit Quit Save File

COED FULL SCREEN KEYS

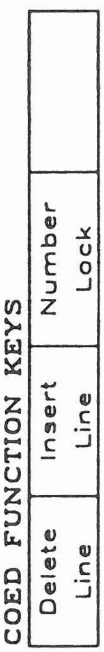


Beg of Line: 5 ←
End of Line: 5 →
Top of Screen: 5 ↑
Bot of Screen: 5 ↓

Next Word: Cntl →
Prev Word: Cntl ←



COED FUNCTION KEYS



COED FUNCTION KEYS F1–F5

		Delete Ln	Refresh	Save	Shift
Insert Ch	Delete Ch	Insert Ln	Del to EOL	File	

COED FUNCTION KEYS F17–F23

			Help Var				Shift
Delete Ln	Insert Ln	Num–Lock	Help	Restore	Command	Line Edit	

COED FULL SCREEN KEYS

Home	↑	Page Up	
←	5	→	Scroll Up (-)
End	↓	Page Down	Scroll Down (+)
Insert Character		Del Char	

Beg of Line: 5 ←
End of Line: 5 →
Top of Screen: 5 ↑
Bot of Screen: 5 ↓

Next Word: Cntl →
Prev Word: Cntl ←

INDEX

ANSI Standard Terminals

COED FULL SCREEN KEYS

Home	↑	Page Up	Scroll Up
←	5	→	Scroll Down
End	↓	Page Down	Next Word
Insert Character		Del Char	

Beg of Line: 5 ←
End of Line: 5 →
Top of Screen: 5 ↑
Bot of Screen: 5 ↓
Prev Word: 5 Nxt Wd

TAB Terminals

Delete Ln	Insert Ln	Num-Lock		Help	Restore	Command	Line-Edit

Tektronix 4100 Series Terminals

COED FUNCTION KEYS

Delete Line	Insert Line	Number Lock	

Help	Restore	Command	Line Edit

Human Design Systems (HDS) Terminals

COED FUNCTION KEYS F1-F5

		Delete Ln	Refresh	Save	Shift
Insert Ch	Delete Ch	Insert Ln	Del to EOL	File	

COED FUNCTION KEYS F17-F23

Delete Ln	Insert Ln	Num-Lock

Help Var				Shift
Help	Restore	Command	Line Edit	

COED FULL SCREEN KEYS

Home	↑	Page Up	Scroll Up
←	5	→	Scroll Down
End	↓	Page Down	Next Word
Insert Character		Del Char	

Beg of Line: 5 ←
End of Line: 5 →
Top of Screen: 5 ↑
Bot of Screen: 5 ↓
Prev Word: 5 Nxt Wd

COED FUNCTION KEYS

Key Control + Key Shift + Key Alt + Key	
Help – – Help Var.	Restore PC Setup – –
Delete Line – Erase Field –	Insert Line – – –
– – – –	– – – –
– – – –	– – – –
Command – – –	Line-Edit Quit Save File

Installation Instructions for the Microcomputer Versions of HEC-6 Version 4.1 - October 1993

I. SYSTEM REQUIREMENTS

The DOS (low memory) version of HEC-6 will run on an IBM or compatible microcomputer equipped with:

* 570 Kilobytes of *available* Random Access Memory
* 8087 (or higher) math co-processor - recommended but not required
* MS DOS 3.1 or greater
* At least 20 Megabytes (Mb) of hard disk space *available*

The Extended Memory version of HEC-6 will run on an IBM 386 (or higher) compatible microcomputer equipped with:

* 2 Megabytes (Mb) of *available* extended memory
* 80287 (or higher) math co-processor - required
* MS DOS 5.0 or greater
* At least 20 Megabytes of hard disk space *available*

If your computer does not meet or exceed either configuration, you will be unable to execute HEC-6.

II. PROGRAM INSTALLATION

A. Contents of the HEC-6 Package Diskettes

The HEC-6 Package contains programs, example input data, and example output. The HEC-6 program files are provided on one 5 1/4" double sided, high-density (1.2Mb) diskette and the COED program is provided on one 5 1/4" double-sided, double density (360K) diskette as follows:

INSTALL Diskette

PKUNZIP.EXE: Software used to uncompress archived files into their original form.
ASKME.COM, FLIP.COM, INSTALLA.BAT & INSTALLB.BAT, TMP6INS.BAT, PROMPT6.EXE: These files comprise the "INSTALL" procedure.
INSTALL6.DOC: This document.
HEC6.ZIP: This archive contains HEC6.EXE, the executable HEC-6 program (DOS (640K) Version)
HEC6X.ZIP: This archive contains HEC6.EXE, the executable HEC-6 program (Extended Memory Version)
MENU6.ZIP: This archive contains:
- HEC6MENU.EXE: The MENU6 program.
- MENU6.BAT: The batch file that is used to run the MENU6 program.
- LIST.COM: Utility program that provides convenient screen display of files.
- LIST.DOC: Documentation for LIST.
- PROUT.EXE: Utility program that sends files to the printer with carriage control invoked.

PLOT2.ZIP: This archive contains PLOT2.EXE, a program to plot cross sections from an HEC-2 or HEC-6 input data file (CGA, EGA or VGA graphics).
TABLE6.ZIP: This archive contains TABLE6.EXE, a program to generate tables from data contained in HEC-6 supplemental output files.

COEDHEC6.ZIP: This archive contains COEDHEC6.HPG, the COED help file for HEC-6.
HEC6DATA.ZIP: This archive contains the following files:
HEC601.DAT-HEC613.DAT & EXAMPLE1.DAT-EXAMPLE7.DAT:
HEC-6 test data files.
HEC601.ANS-HEC613.ANS & EXAMPLE1.ANS-EXAMPLE7.ANS:
Output files (produced by the DOS version) corresponding to the test data files.

COED Diskette

COEDEXE.ZIP: This archive contains the following file:
COED.EXE: Executable program of COED.
COEDHLP.ZIP: This archive contains the following files:
COED.HLP: Basic help file (for general help).
COED.HPG: An index of the current COED help files that are available.
COEDANY.HPG: A help file for use with HEC programs that do not have a "help" file. It will default to ten data fields of eight columns each with appropriate tab settings.
COEDDOC.ZIP: This archive contains the following file:
COED.DOC: COED Users Manual (February 1987).
COED.TRM: The file where COED default settings are saved.
COED.XTK: A command file for the communications program CROSSTALK (XVI) that may be used when you are connected to a mainframe computer with COED.

B. Standard Installation

Installation is accomplished through the execution of a procedure called INSTALL. To install the HEC-6 Package onto your hard disk, do the following:

1. Place the INSTALL DISKETTE into the A: (or B:) drive.

2. Type **A:INSTALLA** or **B:INSTALLB**

3. At this point, the INSTALL procedure will lead you through the installation of the HEC-6 System.

4. Modify your AUTOEXEC.BAT. To allow access of HEC-6 from any directory, it will be necessary to edit your AUTOEXEC.BAT file to include a path to the \HECEXE directory. The AUTOEXEC.BAT file must be in your root (C:\) directory. The following command line is an example command that can be added to the AUTOEXEC.BAT file after the existing PATH command to allow access to the \HECEXE directory:

   PATH = %PATH%;C:\HECEXE

   For more information on the PATH command and the AUTOEXEC.BAT file, consult your DOS manual.

5. Modify CONFIG.SYS. Many HEC programs require the capability to open more than eight (8) files at any one time. Because eight is the DOS default, you must edit your CONFIG.SYS file to include the following two lines:

   FILES=20
   BUFFERS=20

For more information concerning the CONFIG.SYS file, consult your DOS manual. Use COED or another text editor to make these changes. **AFTER THE CHANGES ARE MADE, YOU WILL NEED TO RE-BOOT YOUR COMPUTER.**

C. Alternate Installation

As stated previously, the preferred method of installation is to use the INSTALL procedure, which will install the software using the HEC recommended directory configuration. If, for any reason, you do not wish to use INSTALL, you will need to do the following to install the HEC-6 Package.

1. You will need to create three directories. One of the directories should be labeled \HECEXE. This directory will be used to store all of the HEC executable programs. A second directory should be labeled \HECEXE\SUP. This directory will be used to store all of the supplemental files required by the executable programs. A third directory should be created to store data files. This data directory can be given any name. You may want this data directory to represent a specific project, person, or program. In the examples below, the program name (i.e., HEC6) is used for the data directory name. To accomplish these tasks do the following:

   * Go to the root directory of the drive (e.g. C:) on which you would like to install the HEC-6 program files.
   * Type **MD \HECEXE** then ...
   * Type **MD \HECEXE\SUP** then ...
   * Type **MD \HEC6**

2. Place the INSTALL Diskette into the A: drive. You will need to copy the PKUNZIP.EXE file from this diskette to the root (C:\) directory.

   * Type **COPY A:PKUNZIP.EXE**

   The PKUNZIP.EXE program will be used to uncompress the HEC-6 Package of programs into the target directory.

3. Uncompress the utility programs. If you do not wish to use the utility programs, skip this step and proceed with Step 4.

   * Type **PKUNZIP A:PLOT2 \HECEXE** then ...
   * Type **PKUNZIP A:TABLE6 \HECEXE**

4. Uncompress the HEC-6 COED help file. If you use COED, you should uncompress this file; if not, proceed to Step 5.

   * Type **PKUNZIP A:COEDHEC6 \HECEXE\SUP**

5. Uncompress the HEC-6 Menu program.

   * Type **PKUNZIP A:MENU6 \HECEXE**

6. Uncompress the HEC-6 program.

   * Type **PKUNZIP A:HEC6 \HECEXE** (for the DOS version)
     or **PKUNZIP A:HEC6X \HECEXE** (for the Extended Memory version)

7. Uncompress the test input and output files. If you do not want these files on your hard disk, skip this step and proceed to Step 8.

   * Type **PKUNZIP A:HEC6DATA \HEC6**

8. Install the Full Screen Editor COED onto your hard disk. COED has several advanced editing features, as well as several capabilities that aid in generating input files specifically for HEC programs. If you have already installed COED with another HEC program or if you do not want to install COED, skip this step. To install COED, place the COED Diskette into the A: drive and perform the following commands:

   * Type **PKUNZIP A:COEDEXE \HECEXE** then ...
   * Type **PKUNZIP A:COEDHLP \HECEXE\SUP *-n*** then...
   * Type **PKUNZIP A:COEDDOC \HECEXE\SUP**

9. Modify your AUTOEXEC.BAT. To allow access of HEC-6 from any directory, it will be necessary to edit your AUTOEXEC.BAT file to include a path to the \HECEXE directory. The AUTOEXEC.BAT file must be in your root (C:\) directory. The following command line is an example command that can be added to the AUTOEXEC.BAT file after the existing PATH command to allow access to the \HECEXE directory:

   PATH = %PATH%;C:\HECEXE

   For more information on the PATH command and the AUTOEXEC.BAT file, consult your DOS manual.

10. Modify CONFIG.SYS. Many HEC programs require the capability to open more than eight (8) files at any one time. Because eight is the DOS default, you must edit your CONFIG.SYS file to include the following two lines:

    FILES=20
    BUFFERS=20

    For more information concerning the CONFIG.SYS file, consult your DOS manual. Use COED or another text editor to make these changes. **AFTER THE CHANGES ARE MADE, YOU WILL NEED TO RE-BOOT YOUR COMPUTER.**

III. PROGRAM EXECUTION

A. Executing HEC-6 Through The Menu System

You are now ready to test HEC-6. The preferred mode of execution is through MENU6, the HEC-6 menu system, although you *can* run the program without using MENU6 (see Section B). To execute MENU6, first change to your data or project directory containing the HEC-6 data files (e.g. CD \HEC6) then type MENU6. This will invoke the batch file (MENU6.BAT) that is used for running the menu system. You must execute the menu system through this batch file or the menu system will not function correctly. The HEC-6 System Main Menu (as illustrated in Figure 1) will now appear on your screen. The background and text colors can be changed by pressing the F9 and F10 keys, respectively. As you can see, five options are presented with the first option highlighted. The status or message line at the bottom of the screen is also highlighted; look to this line for instructions on how to proceed for the currently highlighted choice. In general, the user operates the menu by using the cursor arrow keys to move to the desired option and then pressing enter to execute that option. The five options are outlined below:

```
HEC6 System Menu

1. Define input/output files
2. Create/edit input file
3. Run HEC6
4. Display output to console
5. Exit to DOS

Input: (specify)  |  Output: CON  |  Supplemental Output: NO

Press number or <Enter> to select highlighted option ¦ ↑↓ moves cursor
October 1993
```

Figure 1. HEC-6 System - Main Menu

1. Define Input/Output files

This option is used to define the input and output filenames that will be used when executing one of the programs available in the HEC-6 System. When option 1 is chosen, a Popup Files Menu will appear as illustrated in Figure 2.

```
HEC6 System Menu

1. Define input/output files

    Input file ...(specify)
    Output file ..CON
    Supplemental Output?...NO
    Output GR's? ...NO

    Default extensions ..YES
    Data directory ......E:\

    Return to previous menu

Input: (specify)  |  Output: CON  |  Supplemental Output: NO

Type file name or press ? for file directory
October 1993
```

Figure 2. HEC-6 System - Popup Files Menu

When you enter your input filename, the menu is configured to use the default extensions .DAT and .OUT for the input and output filenames, respectively. The Default extensions option on this menu allows you to turn this default off by pressing the <space bar>. If you do not know the name of the input file you wish to use, type a "?" in place of the input filename and the File Selection Window (see Figure 3) will appear with all the .DAT files available in the current directory. Choose one of these files by using the arrow keys to highlight the file you want, then press <enter>. This window will disappear and the filename you chose will be in the input and output filename positions.

```
                         HEC6 System Menu

                    1. Define input/output files

   Input file ...*.DAT
   Output file ..CON
   Supplemental Output?...NO
   Output GR's? ...NO
 Directory of: E:\
 EXAMPLE1.DAT | HEC601  .DAT | HEC608  .DAT |
 EXAMPLE2.DAT | HEC602  .DAT | HEC609  .DAT |
 EXAMPLE3.DAT | HEC603  .DAT | HEC610  .DAT |
 EXAMPLE4.DAT | HEC604  .DAT | HEC611  .DAT |
 EXAMPLE5.DAT | HEC605  .DAT | HEC612  .DAT |
 EXAMPLE6.DAT | HEC606  .DAT | HEC613  .DAT |
 EXAMPLE7.DAT | HEC607  .DAT |              |

 Input: (specify)   |  Output: CON   |  Supplemental Output: NO
 Press <Enter> to select file name ; ↑↓←→ to move cursor through file names
                            October 1993
```

Figure 3. HEC-6 System - File Selection Window

The option, "Supplemental Output?" is a program option of HEC-6; if set to "YES", HEC-6 will produce supplemental output files that can be used by the TABLE6 program described in Section IV; these files will have the default extensions .SUP and .GEO. The <space bar> is used to toggle between "YES" and "NO".

The option, "Output GR's?" is also an HEC-6 program option; if set to "YES", HEC-6 will produce a file with a default extension of .GRS containing the X1-GR data representing the adjusted geometry for each cross section in the system at the end of each time step for which "B" level sediment output has been requested. The purpose of this option is described in Section V. Use the <space bar> to toggle between "YES" and "NO".

After you have made your choices, move the cursor to the line that reads "Return to previous menu" and press <enter>. The main menu will now appear. Note that at the bottom of this menu there is a line that displays the names of the current input and output files.

2. Create/Edit input file

This option is used to create or edit an input file for use with HEC-6. COED is executed when this option is chosen. By default, the input file will be edited, although the menu will allow you to change the name of the file to be edited before COED is executed. When COED is executed through the menu system, the HEC-6 on-line documentation file (COEDHEC6.HPG) is automatically loaded and COED goes directly into full screen mode. A help message line will appear at the bottom of the screen; this line is context sensitive to the line currently being edited. For extra help with HEC-6 input variable definitions, press the ALT-F1 key and help for the variable belonging in the current field will be displayed. When you are finished editing and exit from COED, you will be returned to MENU6.

3. Run HEC-6

This option executes the HEC-6 program as well as PLOT2 and TABLE6. Use the arrow keys to move to this option and highlight it, then press the <space bar> to "toggle" between the program choices. Whichever program name appears, that is the program that will be executed if the <enter> key is then pressed.

4. Display output to the console

This option is used to display output to your screen (console) or to send it to your printer. You can toggle between console and printer by pressing the <space bar>. If you choose to view the output on the console, the utility program LIST will be executed with the output filename being passed to it. See the LIST.DOC file to familiarize yourself will the various useful options available in LIST. To exit LIST and return control back to MENU6, simply type an X. If you choose to send the output to the printer, the utility program PROUT will be executed with the output filename passed to it.

5. Exit to Dos

You can exit the menu program by invoking this option, or you can continue working with the other four options. If this option is chosen, it is assumed that you are completely finished with the menu system and control is returned to DOS.

B. Executing HEC-6 Without The Menu System

Though the preferred mode to execute HEC-6 is through the MENU6 program, you can run the program without using the menu. To run HEC-6 without using the menu system, do the following:

HEC6 IN=*infile* OUT=*outfile*

where: *infile* is the test input data filename, and
outfile is the corresponding output filename

If you do not specify the files on the execution line, the program will request the filenames as follows:

ENTER THE FILENAME FOR INPUT [CON]

ENTER THE FILENAME FOR OUTPUT [CON]

By pressing the <ENTER> key in response to the questions, the default option will be selected.

IV. SUPPLEMENTAL OUTPUT

TABLE6 is a utility program designed to allow the user to produce a file of column formatted data for input to a data graphing program such as Lotus 123 or Grapher. TABLE6 reads two supplemental output files produced (optionally) by HEC-6. The HEC-6 directives necessary to produce these files are:

(1) the SUPFLAG option on the HEC-6 command line must equal "YES". MENU6 has an option for setting this flag in the "Define input/output files" popup menu. If you are not executing HEC-6 from MENU6, the HEC-6 command line syntax is: HEC6 IN=*infile* OUT=*outfile* SUPFLAG=YES. And,

(2) the sediment print level must be "B" level or higher for each time step for which supplemental output will be produced. See the * record in Appendix A of the HEC-6 User's Manual for a description of the output levels that can be set for each time step.

HEC-6 uses the *base-name* of the input file and appends the extensions .SUP and .GEO to produce the filenames for the two supplemental output files. These filenames are passed to TABLE6 by MENU6 as input files. MENU6 sets the TABLE6 output file to *base-name*.TAB. If you are not using MENU6, TABLE6 can be executed by typing:

TABLE6

TABLE6 will then prompt you for three filenames; input, geometry, and output. The input file is the .SUP file, the geometry file is the .GEO file and the output file is whatever filename you want (just don't use the same name as the HEC-6 output file or it will be overwritten). Or you can give the file names on the TABLE6 command line using the following syntax.

TABLE6 SUP=*supfile.SUP* GEO=*geofile.GEO* OUT=*outfile.TAB*

TABLE6 assumes that you are producing data for input to a graphics program; therefore, among the first questions it will ask is what type of plot you wish to produce. Then, depending on your plot type choice, TABLE6 will prompt you for further information that it will need to find the data and produce the plot you requested.

V. OUTPUT OF GR's

An option is available in HEC-6 to produce a file of X1-GR records which represent the geometry of each cross section in the model at the end of each "selected" time step. The purpose of these files is to give the user access to the geometry of each cross section at each point in the hydrograph that may be of interest. The HEC-6 directives necessary to produce these files are:

(1) the GRSFLAG option on the HEC-6 command line must equal "YES". MENU6 has an option for setting this flag in the "Define input/output files" popup menu. If you are not executing HEC-6 from MENU6, the HEC-6 command line syntax is: HEC6 IN=*infile* OUT=*outfile* GRSFLAG=YES. And,

(2) the sediment print level must be "B" level or higher for each time step for which output of X1-GR data will be produced. See the * record in Appendix A of the HEC-6 User's Manual for a description of the output levels that can be set for each time step.

HEC-6 names each file based on the time step number associated with the flow data and adds the extension .GRS (e.g. the file of X1-GR data for time step 11 would be GEO00011.GRS). Note, PLOT2 can be used to graphically view the cross section data contained in these files.

VI. VERIFICATION OF PROGRAM OPERATION

A set of test data has been provided. The files HEC601.DAT-HEC613.DAT represents the 13 standard test data files used by HEC to test several major functions of the HEC-6 software for quality control and consistency. The files EXAMPLE1.DAT-EXAMPLE7.DAT are the seven example input data files illustrated in Chapter 6 of the HEC-6 User's Manual.

These data files provide input/output examples of most program features. They are NOT meant to provide engineering application guidance for use of HEC-6. Such guidance can be found in:

U.S. Army Corps of Engineers, Hydrologic Engineering Center, *Guidelines for the Calibration and Application of Computer Program HEC-6*, Training Document No. 13, Davis, CA, October 1992.

GEE, D. Michael, *Role of Calibration in the Application of HEC-6*, Technical Paper No. 102, Hydrologic Engineering Center, Davis, CA, December 1984.

After installing the HEC-6 executable program, you may wish to run all 20 test data files and check them against the output files provided in HEC6DATA.ZIP. The output files corresponding to the above data files as executed using the DOS version and checked by HEC have the extension .ANS. A batch file named RUNEM.BAT has been included for your convenience to execute all 20 data files. The output files will have a .OUT extension. Comparison of the output files can be accomplished by viewing each file with the LIST utility, or by using the DOS file compare command (FC). Check your results to ensure that they are the same as those provided to you. This will ensure that the program is functioning correctly on your computer system.

VI. PROGRAM PROBLEMS

If any errors are encountered which indicate potential problems in this HEC-6 Package, please contact us at:

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