BRIDGE-SCOUR DATA MANAGEMENT SYSTEM USER'S MANUAL

U.S. GEOLOGICAL SURVEY
Open-File Report 95-754

Prepared in cooperation with the

FEDERAL HIGHWAY ADMINISTRATION

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By Mark N. Landers, David S. Mueller, and Gary R. Martin

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CONTENTS

ILLUSTRATIONS

(in text)

(in Appendix A)

(in Appendix B)

(in Appendix C)

TABLES

(in Appendix A)

(in Appendix B)

(in Appendix C)

SYMBOLS

Symbols used in this report are defined below.

a is a coefficient based on the ratio of the shear velocity (u_*) to the fall velocity (ω) in the uncontracted channel.

A_e is a cross-sectional area of the flow obstructed by the embankment.

b is width of the bridge pier.

b' is width of the bridge pier projected normal to the approach flow.

B_c is bottom width of the contracted section.

B_u is bottom width of the uncontracted or approach section.

c is an exponent related to bed load.

c_1 is an exponent.

c_2 is an exponent.

d_m is mean grain size of the bed material.

d_{50} is median grain size of the bed material.

$\boldsymbol{F}_a$ is Froude number of the flow obstructed by the abutment.

$\boldsymbol{F}_o$ is Froude number of the flow just upstream from the pier or abutment.

$\boldsymbol{F}_p$ is pier Froude number.

f_b is bed factor.

g is acceleration of gravity.

K is a coefficient that is a function of boundary geometry, abutment shape, width of the piers, shape of the piers, and the angle of the approach flow.

K_s is a coefficient for pier shape.

K_{sa} is a coefficient based on the geometry of the abutment.

K_{S1} is a coefficient based on the shape of the pier nose.

K_{S2} is a coefficient based on the shape of the pier nose.

K_1 is a coefficient based on the shape of the pier nose.

K_2 is a coefficient based on the ratio of the pier length to pier width and the angle of the approach flow referenced to the bridge pier.

K_3 is a coefficient based on the bed conditions.

K_θ is a coefficient based on the inclination of an approach roadway embankment to the direction of the flow.

$K_{\alpha L}$ is a coefficient based on the angle of the approach flow referenced to the bridge pier (fig. A-16).

K_ξ is a coefficient for pier shape and flow attack angle.

L is length of the bridge pier.

l is length of an abutment, defined as, A_e/y_{oa} .

l_{ae} is effective length of an abutment.

l_{at} is abutment and embankment length measured at the top of the water surface and normal to the side of the channel.

n_c is Manning’s roughness coefficient for the part of the contracted channel represented by the specified bottom width.

n_u is Manning’s roughness coefficient for the part of the uncontracted or approach channel represented by the specified bottom width.

q is discharge per unit width just upstream from the pier.

SYMBOLS—Continued

q_{mc} is discharge per unit width in the main channel.
Q is discharge.
Q_c is discharge in the part of the contracted channel represented by the specified bottom width.
Q_e is discharge obstructed by the embankment.
Q_u is discharge in the part of the uncontracted or approach channel represented by the specified bottom width.
r is a coefficient used to relate scour in a long contraction to scour at an abutment or pier.
$\boldsymbol{R}_p$ is pier Reynolds number.
S is dimensionless slope of the energy grade line near the bridge.
u_* is shear velocity.
V is average velocity of the section.
V_o is velocity of the approach flow just upstream from the bridge pier or abutment.
V_c is critical velocity.
V_c' is approach velocity at which scour at the pier is initiated.
y is average depth of the section.
y_c is depth of flow in the contracted channel.
y_{ca} is depth of abutment scour, including contraction scour.
y_o is depth of flow just upstream from the bridge pier or abutment, excluding local scour.
y_{oa} is depth of flow at the abutment.
y_p is depth of flow at the bridge pier, including local pier scour.
y_r is regime depth of flow.
y_{sa} is depth of abutment scour below the ambient bed.
y_{sc} is depth of contraction scour below the existing bed.
y_{sp} is depth of pier scour below the ambient bed.
y_u is average depth of flow in the uncontracted channel.
τ_c is critical shear stress.
τ_o' is boundary shear stress of the approach flow associated with the sediment particles.
ω is fall velocity of the median grain size of the bed material.
ν is kinematic viscosity of water.
α is angle of the approach flow referenced to the bridge pier, in degrees.
θ is angle of inclination of an embankment to the flow, in degrees; $\theta < 90°$ if the embankment points downstream.
ϕ is a coefficient based on the shape of the pier nose.
ρ_s is density of the sediment particles.
ρ is density of water.

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ABSTRACT

The Bridge-Scour Data Management System (BSDMS) supports preparation, compilation, and analysis of bridge-scour data. The BSDMS provides interactive storage, retrieval, selection, editing, and display of bridge-scour data sets. Bridge-scour data sets include more than 200 site and measurement attributes of the channel geometry, flow hydraulics, hydrology, sediment, geomorphic-setting, location, and bridge specifications.

This user's manual provides a general overview of the structure and organization of BSDMS data sets and detailed instructions to operate the program. Attributes stored by the BSDMS are described along with an illustration of the input screen where the attribute can be entered or edited. Measured scour depths can be compared with scour depths predicted by selected published equations using the BSDMS. The selected published equations available in the computational portion of the BSDMS are described. This manual is written for BSDMS, version 2.0. The data base will facilitate: (1) developing improved estimators of scour for specific regions or conditions; (2) describing scour processes; and (3) reducing risk from scour at bridges.

BSDMS is available in DOS and UNIX versions. The program was written to be portable and, therefore, can be used on multiple computer platforms. Installation procedures depend on the computer platform, and specific installation instructions are distributed with the software. Sample data files and data sets of 384 pier-scour measurements from 56 bridges in 14 States are also distributed with the software.

INTRODUCTION

Channel-bed scour around bridge foundations is the leading cause of failure among more than 487,000 bridges over water in the United States. Field measurements of scour at bridges are needed to improve the understanding of scour processes and to improve the ability to predict scour depths. Cooperative investigations initiated in the late 1980's and the 1990's between the U.S. Geological Survey (USGS), Federal Highway Administration (FHWA), and numerous State Departments of Transportation have collected more than 380 scour measurements during floods at 56 bridges in 14 States. Those measurements are summarized and analyzed in Landers and Mueller (1995).

This report describes the Bridge Scour Data Management System (BSDMS) that was developed by the USGS, in cooperation with the FHWA, to support preparation, compilation, and analysis of these bridge-scour measurement data. Users may interactively store, retrieve, select, update, and display bridge-scour and associated data. Interactive processing makes use of full-screen menus and fill-in forms; and an instruction panel provides information on how to interact with the program. An optional assistance panel provides descriptions of the more than 200 items in a BSDMS data set for each bridge-scour site. Data-set items cover all information in a detailed scour measurement. Bridge-scour data are stored in binary Bridge Scour Data (BSD) files, which are given the file-name suffix ".bsd". Program options permit comparison of observed scour depths with computed scour-depth estimates from published prediction equations. The program was written to be portable to DOS-based personal computers and UNIX workstations.

BSDMS is an important element in forming a national bridge-scour data base from historical measurements and from ongoing investigations. The purpose of this user's manual is to describe the structure of scour data sets in BSDMS and to fully document the operation of BSDMS with all its features. The data base will facilitate: (1) developing improved estimators of scour for specific regions or conditions; (2) describing scour processes; and (3) reducing risk from scour at bridges.

STRUCTURE OF DATA SETS

Bridge-scour data are stored in BSDMS as data sets that are defined for each bridge-scour site in the data base. A data set contains all scour-related data for a particular bridge, including all measurements of contraction, general, and local-scour data at abutments and any number of piers. Separate data sets are used for parallel bridges where measurements are recorded for each bridge. Each data set has four categories: site data, scour-measurement data, flood-event data, and channel-geometry data. Site data are location, stream-characteristic, datum, and bridge data. Scour-measurement data are defined for local pier scour, local abutment scour, contraction scour, and general scour. Flood-event data are peak stage and discharge, hydrograph, and debris data. Channel-geometry data are the essential cross-sectional data from which scour depths are measured. For each bridge site, there may be several scour measurements for one or more flood events. BSDMS is designed to store all of the essential information from a detailed scour measurement; however, most data sets contain only the information collected in limited-detail measurements. Each attribute of each data set is described in the assistance panel that may be viewed interactively during data entry or editing. *Help information* for each attribute is also listed in Appendix A of this document.

PROGRAM USAGE

BSDMS is available in DOS and UNIX versions. The program was written to be portable and, therefore, can be used on multiple computer platforms. Installation procedures depend on the computer platform, and specific installation instructions are distributed with the software. Sample data files and data sets of 384 pier-scour measurements from 56 bridges in 14 States are also distributed with the software.

User Interface

Program interaction takes place in a screen 80 characters wide by 24 characters high. Figure 1 shows the basic screen layout. Each screen consists of a list of available commands displayed at the bottom of the screen and one or more boxed-in areas that are referred to as panels. Commands are used to obtain additional information and to move between screens. There are three types of panels—data, assistance, and instruction. The data panel displayed at the top of the screen is always present. Data panels contain menus, forms, tables, and text to permit user interaction with the program. An assistance panel may be present depending on user or program assignments. When present, the assistance panel is displayed below the data panel (usually as the middle panel) and contains textual information, such as help messages, valid range of values, and details on program status. The instruction panel is displayed above the available commands when the user is expected to interact with the program. When present, the instruction panel contains information on what keystrokes are required to interact with the program.

Each screen can be identified by a name and the path selected to reach the screen. The screen name appears in the upper left corner of the data panel, where the words “screen name” appear in figure 1. The first screen displayed by the program is named “Opening screen”. All subsequent screens are named based on the menu option or program sequence that caused the current screen to be displayed. Screen names are followed by “(path)”, a string of characters consisting of the first letter(s) of the menu options selected in order to arrive at the current screen. In some cases, descriptive text may follow the path to further help identify the screen. The path can aid in keeping track of the position of the current screen in the menu hierarchy. For example, “Open (FO)” indicates that the menu option Open was selected previously and that the path to this screen from the “Opening screen” consisted of two menu selections—File and Open.

Commands

The screen commands and their associated keystrokes are described in figure 1. A subset of the screen commands is available for any given screen. Most commands can be executed by pressing a single function key. (The designation for a function key is “F#” where # is the number of the function key.) All of the commands can be executed in “command mode”. Command mode is toggled on and off by pressing the semicolon (;) key[1]. In command mode, any command can be executed by pressing the first letter of the command name; for example, “o” or “O” for the Oops command. When commands are discussed in this report, the command name is spelled out with the function key or keystroke given in parentheses. For example, Accept (F2) is the most frequently used command.

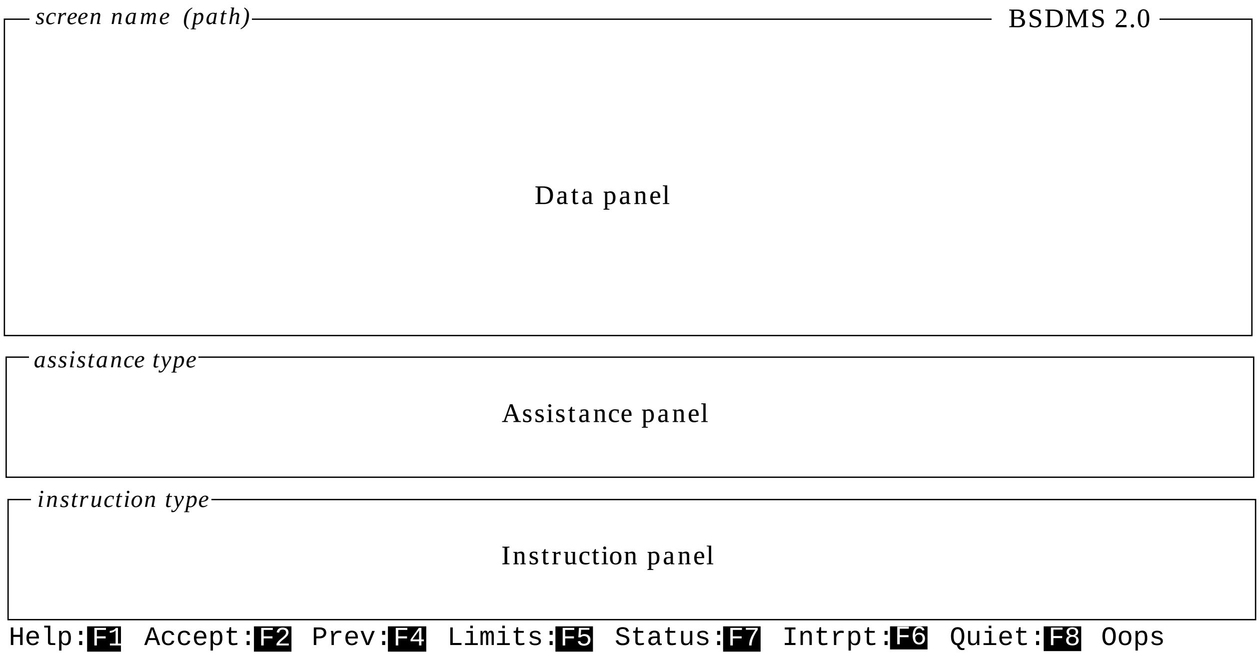
Use Help (F1) and Limits (F5) to obtain additional information about the current screen and use Status (F7) to obtain information on the state of the program. Use Quiet (F8) to close the assistance panel. To move between screens, use Accept (F2), Prev (F4), Intrpt (F6), Dnpg (;d), or Uppg (;u). To reset the values in the data panel, use Oops (;o).

Data Panel

There are four types of data panels—menu, form, table, and text. Menus offer a choice of two or more options. Data values are entered or modified in one or more data fields of a form or table. General or specific information, program progress, messages, and results of analyses may be displayed in a text data panel. The data panel appears at the top of the screen, as shown in figure 1. There are 16 rows in the data panel when the assistance panel is closed and 10 rows when the assistance panel is open.

A single option is selected from a menu that consists of two or more options. There are two ways to select a menu option. Either press the first letter (not case sensitive) of the menu option; if more than one menu option begins with the same letter, press in sequence enough characters to uniquely identify the option; or use the arrow keys to move the cursor to the option and then execute Accept (F2).

[1] On some systems the F3 key and (or) the escape key (Esc) may also work.



Command	Associated keystrokes[1]	Description
Help	F1 *or* ;h	Displays help information in the assistance panel. The help information is updated as the user moves from field to field in the data panel or to a different screen. The program automatically closes the assistance panel if a screen is displayed for which no help information is available.
Accept	F2 *or* ;a	Indicates that you have "accepted" the input values, menu option currently highlighted, or text message in the data panel. Selection of this command causes program execution to continue.
Oops	F3o *or* ;o	Resets all data fields in an input form to their initial values.
Dnpg	F3d *or* ;d	Displays next "page" of text in data panel. Available when all of the text cannot be displayed at one time.
Uppg	F3u *or* ;u	Redisplays previous "page" of text in data panel. Available after execution of Dnpg (F3d).
Prev	F4 *or* ;p	Redisplays a previous screen. Any modifications in the data panel are ignored. Which screen is the previous one may be ambiguous in some cases.
Limits	F5 *or* ;l	Displays valid ranges for numeric fields and valid responses for character fields. As with the Help command, information on field limits is updated as the user moves from field to field in the data panel or to a different screen by using the arrow keys or the Enter (Return) key.
Intrpt	F6 *or* ;i	Interrupts current processing. Depending on the process, returns the program to the point of execution prior to the current process or advances to the next step in the process.
Status	F7 *or* ;s	Displays program status information.
Quiet	F8 *or* ;q	Closes the assistance panel. Available when the assistance panel is open.

[1]The function keys will execute the commands on most computer systems. On all computer systems, the semicolon key (";") followed by the first letter (upper or lower case) of the command can be used to execute the commands. The F3 function key may not be available on some systems.

Figure 1. Basic screen layout and commands for BSDMS.

Forms may contain any number and combination of character, numeric, file name, or option fields. Character fields may be a variable entry, such as a descriptive text string (case sensitive), or they may require a specific entry, such as "yes" or "no" (not case sensitive). The text string "none" in a field indicates that the field is currently undefined. Option fields are activated and deactivated by positioning the cursor in the option field and pressing any key, such as the space bar. Use arrow keys to move up, down, and laterally between fields. The Enter (Return) key is used to move forward through fields. Use Accept (F2) to accept the entered and modified data and continue with the program. Executing Oops (;o) sets all fields in the current screen to their initial values. Executing Prev (F4) will cause the data values entered on the current screen to be ignored and the previous screen to be redisplayed.

Tables may contain any number and combination of character, numeric, and file name columns. As with forms, character fields may require a specific entry or a variable entry. Use arrow keys to move up, down, and laterally between fields. The Enter (Return) key is used to move forward across rows and to the next row. Some tables may contain more rows than can be displayed in the 10 or 16 rows of the data panel. In these cases, the table is divided into multiple screens. Use Accept (F2) to move forward through each of the screens for the table and to continue with the program after the last screen of the table. Executing Oops (;o) sets all fields in the current screen to their initial values. Executing Prev (F4) will cause the data values entered on the current screen to be ignored and the previous screen to be redisplayed. Executing Intrpt (F6) will cause the data values entered on the current screen to be ignored and the remaining screens in the table to be skipped. Use Quiet (F8) to close the assistance panel and view the 16 lines of the data panel.

A text data panel may contain a warning or error message, a tabular list of data, a progress message for an activity that may take more than a few seconds, or other general information. Execute Accept (F2) to continue to the next screen. In cases where the displayed text requires more lines than the number available in the data panel, the Prev (F4), Dnpg (;d), and Uppg (;u) commands may be available to move forward and backward (scroll) through the screens. Note that the up and down arrows also may be used to move through the screens. Intrpt (F6) may be available to permit skipping the remaining screens of text.

Assistance Panel

The assistance panel provides information to help the user enter data in the data panel. The panel appears in the middle of the screen below the data panel. A name corresponding to the type of assistance being provided displays in the upper left corner of the panel, where the words "assistance type" appear in figure 1. The Help (F1), Limits (F5), and Status (F7) commands open the assistance panel. The program may open the assistance panel to display status information. Help and Limits provide information about the current screen and data fields; and Status provides information about the current process. Use Quiet (F8) to close the assistance panel.

Assistance panels display four lines at a time. In cases where the assistance information is greater than four lines, the cursor moves into the assistance panel. Use the up and down arrow keys to scroll through the information. If available, the Page Down and Page Up keys may be used to page through the information. Use the command mode toggle (;) to put the cursor back in the data panel.

Instruction Panel

The instruction panel provides information on how to interact with the current screen, such as how to enter data or how to advance to another screen. This panel appears at the bottom of the screen just above the screen commands (fig. 1). The instruction panel is present whenever the program requires input from the user. Up to four lines of text are displayed in an instruction panel. If an invalid keystroke is entered, the information in the instruction panel is replaced with an error message. In this case, the panel name (upper left corner) changes from the usual "INSTRUCT" to "ERROR." Once a valid keystroke is entered, the Instruct panel is redisplayed.

Special Files

Three files are associated with the interaction between the user and the program. System defaults that control how the program operates can be overridden by setting parameters in the optional TERM.DAT file. A session record is written to the BSDMS.LOG file each time the program is run; all or portions of this file can be used as input to the program at a later time. Error and warning messages, as well as some additional information, may be written to the file ERROR.FIL.

System Defaults—TERM.DAT

Certain aspects of the appearance and operation of the program are controlled by parameters within the program. These parameters specify things such as the computer system type, graphic output type, terminal type, program response to the Enter key, and colors. Each parameter is set based on the preferences of users who tested the program. The preset values can be overridden by creating a TERM.DAT file in the directory where the program is initiated (the current working directory). The available parameters and the format of the TERM.DAT file are described in Appendix C. If a TERM.DAT file does not exist in the current directory, the message "optional TERM.DAT file not opened, defaults will be used" is displayed briefly when the program starts. If the TERM.DAT file is present, the message "reading users system parameters from TERM.DAT" is displayed.

Session Record—BSDMS.LOG

The keystrokes entered during a program session are recorded in the BSDMS.LOG file. Each time the program is run, a BSDMS.LOG file is created; if one already exists in the current directory, it is overwritten. All or part of this file can be used as input to the program as a means of repeating the same or similar tasks. To do this, first save the BSDMS.LOG file under a different name. Modify the file to contain only the sequence of commands that need to be repeated. Then, at any point in a subsequent program session, press "@"; a small file name panel appears; type the name of the log file and press the Enter key. Appendix C describes the use and format of the BSDMS.LOG file.

Error and Warning Messages—ERROR.FIL

Any error or warning messages produced during a program session are written to the ERROR.FIL file. Each time the program is run, an ERROR.FIL file is created; if one already exists in the current directory, it is overwritten. Diagnostic and summary reports also may be written to this file. Examine ERROR.FIL if an unexpected program response is encountered.

PROGRAM OVERVIEW

To start the program, type *"bsdms"* at your *operating-system prompt.* You will see the *Opening Screen* as shown in figure 2. The *data panel* contains the *Opening Screen* menu options, and the *instruction panel* explains how to select from the menu items. The *assistance panel* is not open in figure 2. The following options are available:

File Choose the File option to *open*, *close*, or *build* a BSD file.

Select *Select* data sets from the open BSD file to be placed in the *working buffer.* Data sets can be chosen based on user-specified criteria, or data sets can be chosen from a list of those available.

EDit EDit existing data sets or enter new data sets.

Write Save new or edited data sets to the open BSD file.

Purge Erase from the open BSD file any bridge-site data sets that are currently in the working buffer.

Compute Compute scour depths based on selected published scour-prediction equations for comparison with measured scour depths.

```
┌Opening screen──────────────────────────────────────────────────BSDMS 2.0┐


              U.S. Geological Survey, Water Resources Division
                 BSDMS - Bridge Scour Data Management System
                           Version 2.0, May 1994
 Select an option.

 File   - open/close/build a BSD file       Compute  - calculate scour
 Select - select bridge scour sites         Output   - produce output file
 EDit   - enter/edit bridge sites           Document - view documentation info
 Write  - save edited sites                 Archive  - import/export data
 Purge  - remove selected bridge sites      EXit     - to operating system


┌INSTRUCT──────────────────────────────────────────────────────────────────┐
                     Select an option using arrow keys
                  then confirm selection with the F2 key,  or
                      Type the first letter of an option.
 Help:F1  Accept:F2
```

Figure 2. BSDMS opening screen.

Output Output selected data items to an ASCII output file for sites in the working buffer.

Document View text screens documenting general program information, operation, data-set structure, and references.

Archive Import and export data sets. Exported data sets are written to a formatted ASCII file that can be imported into a different BSD file.

EXit Exit the program and return to the operating system.

The Return option is included on almost all menu screens other than the *Opening Screen* menu. It functions to return you to the previous menu.

File Management

File Data sets of bridge-scour measurement sites are stored in and accessed from a Bridge Scour Data (BSD) file. To open an existing BSD file, select *Open* under the *File* option on the *Opening Screen*. When entering the name of an existing BSD file, be sure to include the ".**bsd**" extension, as well as the path if the BSD file is not located in the directory at which BSDMS was initiated. Select *Build* under the *File* option on the *Opening Screen* to create a new BSD file. Only one BSD file may be used at any given time.

A data set is saved once it has been written to a BSD file. Only data sets saved to a specific BSD file can be retrieved when that specific BSD file has been opened. The national.bsd (natpc.bsd for the DOS version) file is the repository for all bridge-scour data sets reviewed under the National Scour Program. You may wish to make working BSD files that are smaller than national.bsd by use of the *Archive* option.

Retrieving Data Sets

Select An existing data set must be placed in the working buffer before *Edit*, *Compute*, or *Output* options can be performed. Up to 24 data sets can be selected from the BSD file and placed in the working buffer. There are two ways to retrieve an existing data set from an open BSD file (fig. 3).

(1) Scan option: Choose the *Select>Scan* (SS) option to view a list of all data sets in the open BSD file. Select the data sets you wish to place in the working buffer.

(2) Find option: The *Select>Find* (SF) option allows you to conduct a search of the open BSD file for data sets that fulfill specified data-element values or value ranges. Data sets may be selected based on several location, site, and scour measurement attributes. After the search is executed, data sets that meet the criteria will be added to the working buffer. The user may then choose a site from the buffer with which to work.

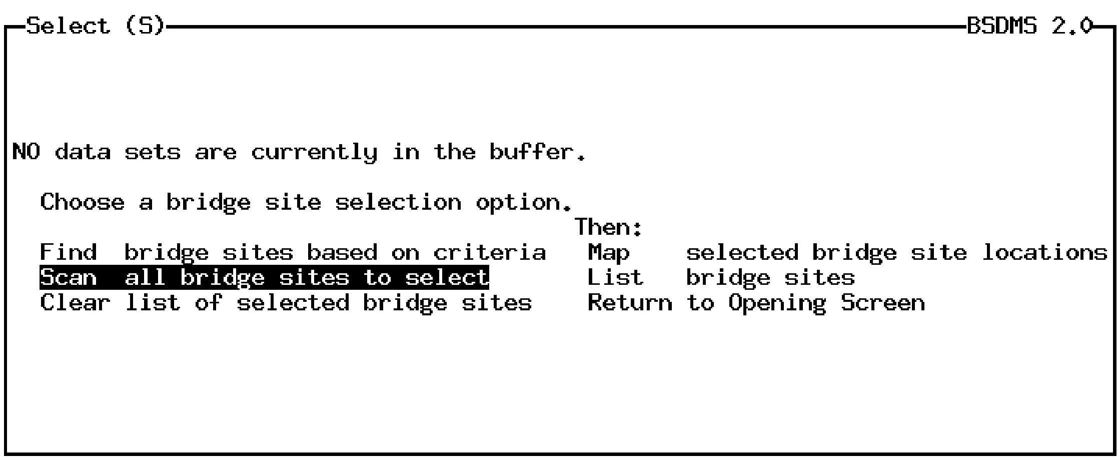


Figure 3. Select options screen.

Editing a Data Set

EDit

Choose *EDit* from the *Opening Screen* to create a new data set (after first opening an existing BSD file or after choosing *Build* under the *File* option on the *Opening Screen*). Menus will then allow the user to move through the desired form fill-in screens and enter new data. Edit an existing data set by first retrieving the data set from an open BSD file to the working buffer. After a data set is placed in the working buffer, it may be modified by choosing *EDit* from the *Opening Screen*.

Parallel bridges should be stored as separate data sets. To avoid re-entering data that is common to both bridges, establish a data set with the variables that are common to both bridges. After writing the data set to the BSD file, re-edit the data set and change the site description enough to make it unique. Write this data set to the BSD file again, selecting "*New*" when you are prompted with a warning about overwriting the existing data set.

Saving a Data Set

Write

After editing a new or existing data set, save for future use by "*Writing*" to an open BSD file. If a BSD file is not open, an opportunity will be given to open an existing BSD file or to build a new one. Edited data sets need to be written to a BSD file before selecting *Output* or *Compute*.

Calculation of Scour by Published Equations

Compute

Choosing the *Compute* option from the *Opening Screen* will display a menu screen of the available options (fig. 4). The *Compute* routine uses the data sets in the working buffer to compute scour using published prediction equations for comparison with observed values. The prediction equations are described in Appendix B. The *Compute* routine allows the user to enter or change values for variables used in the equations. Any values entered or modified in the *Compute* routine will not be stored as part of the data set. The *Compute* routine retrieves the data saved in the BSD file for those sites in the working buffer. Therefore, an active data set should be saved (written to the BSD file) before selecting *Compute*. The computations are written to a user-specified output file. The output file contains the input data, predicted scour, and differences between predicted and observed scour for each data set in the buffer. The output file is accessible after *Returning* from the *Compute* screen or after opening a new output file.

```
Compute (C)                                                  BSDMS 2.0

                    Select an option

                    Output      - file name
                    Abutment    - scour computations
                    Pier        - scour computations
                    Contraction - scour computations
                    Return      - to Opening Screen
```

Figure 4. Compute options screen.

Output Options

Output

The *Output* option allows you to produce output for all data sets that have been placed in the working buffer. Selecting the *Output* option on the *Opening Screen* brings up the screen shown in figure 5, where specific categories of the data sets may be selected for output. Output is written to an ASCII file specified by the user on the output option screen. The output is written in a report-style format with data group and variable names provided. All of the selected data groups for each data set (site) are listed together. Options to produce tabular output of selected variables are planned for a future release of the BSDMS.

Importing and Exporting Data Sets

Archive

To transfer data sets from one BSD file to another, the data sets should first be exported using the *Archive>Export* function. Then, close the first BSD file and open or create the BSD file to which you are transferring the data sets. Import the data sets to the second BSD file using the *Archive>Import* function. Because binary file structure is not standard among different types of computer platforms, use of the *Archive* option is necessary to move BSD file data from one computer platform to another.

Graphical Output Option

There are several menus in BSDMS with an option to view a graphical representation of data. On UNIX workstations where the X Window System is used, a separate window will be opened containing the desired plot. The plotting window must be left open if you wish to view additional plots. The program will end without warning if the user closes the window and later tries to view another plot during the same run of BSDMS. Graphical output is available for mapping locations of selected sites on a State outline map of the continental United States, for plotting channel geometry, pier geometry, and hydrographs (fig. 6).

```
Output (0)                                                        BSDMS 2.0
 Select the data groups you wish to output to a file.

      Site Data              Scour Data          Flood Data          Channel Data
 Location      Abutment      Pier                Peak                Description
 Elevation     Pier          Abutment            Hydrograph          Geometry
 Stream        Contact       Contraction         Debris
 Bridge                      General

 Enter name of output file:
 [                                                                 ]
```

Figure 5. Output options screen.

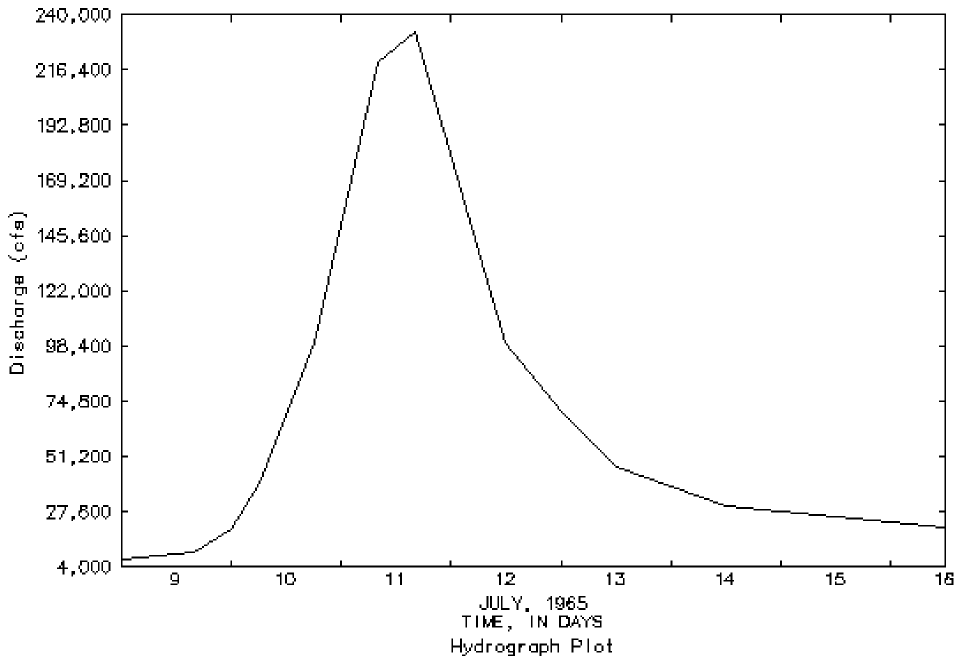


Figure 6. Sample hydrograph.

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APPENDIX A—LISTING OF DATA-ENTRY SCREENS AND HELP INFORMATION

The appearance of the data-entry screens and the on-line help information for each data attribute are listed in the following pages for user reference. Data sets are broken into *site data*, *scour-measurement data*, *flood-event data*, and *channel-geometry data*.

SITE DATA

The site data include descriptions of the location, elevation data, stream characters and structural data for the bridge, including piers and abutments.

Location Data

Location data include site characteristics such as name, State, and highway route number. Figure A-1 shows the first data screen for location data. Users are prompted for a text site description of up to 48 lines on a second location data screen.

```
┌Location - ***1 of 2*** (EdSiL)──────────────────────────────────BSDMS 2.0┐
│Site Description > Pearl River at westbound U.S. 98 nr Columbia, MS        │
│County           > Marion                                                 │
│State            > MS                                                     │
│                                                                          │
│  Latitude  (ddmmss)  >     311414                                        │
│  Longitude (dddmmss) >     895054                                        │
│                                                                          │
│  Station id (integer)>  2489000         Route Class     >        2       │
│  Route Number        >       98         Route Direction >        4       │
│  Service Level       > 1                Mile Point      >    118.5       │
└──────────────────────────────────────────────────────────────────────────┘
```

Figure A-1. Location data screen.

Descriptions of location data attributes are given in table A-1.

Table A-1. Location data-attribute descriptions

Attribute	Help Information
Site description	Enter site description for a bridge in the form: (Stream name at highway number at/near town-name), using additional modifiers, as necessary, for specificity. Up to 48 characters may be used. Example: **Schoharie Creek at I-90 near Amsterdam, NY**.
County	Enter county where bridge is located. If the bridge is on border of two counties, list both counties (for example, **Rankin/Hinds**).
State	Enter the two letter US postal code for the state. One must be entered. **AL**, **AK**, **AZ**, **AR**, **CA**, **CO**, **CT**, **DE**, **DC**, **FL**, **GA**, **HI**, **ID**, **IL**, **IN**, **IA**, **KS**, **KY**, **LA**, **ME**, **MD**, **MA**, **MI**, **MN**, **MS**, **MO**, **MT**, **NE**, **NV**, **NH**, **NJ**, **NM**, **NY**, **NC**, **ND**, **OH**, **OK**, **OR**, **PA**, **RI**, **SC**, **SD**, **TN**, **TX**, **UT**, **VT**, **VA**, **WA**, **WV**, **WI**, **WY**
Latitude	Units: degrees/minutes/seconds Limits: -900000 to 900000 Input latitude as a six digit number (ddmmss).
Longitude	Units: degrees/minutes/seconds Limits: -1800000 to 1800000 Enter longitude as a seven digit number (dddmmss).
Station identification number	Enter the 8-digit USGS station number, if applicable.

Table A-1. Location data-attribute descriptions—Continued

Attribute	Help Information
Route class	Enter appropriate number (for concurrent routes, use highest class of route). **0**-Unknown, **1**-Interstate highway, **2**-U.S. numbered highway, **3**-State highway, **4**-County highway, **5**-City street, **6**-Federal lands road, **7**-State lands road, **8**-Other
Route number	Code route number. For concurrent routes, code number of highest class route. If concurrent routes are the same classification, code lower route number. Code **0** for bridges on roads without route numbers.
Route direction	Code direction of the bridge, if one-directional. **0** - not applicable, **1**-North, **2**-East, **3**-South, **4**-West
Service level	Code the appropriate number. **1**-Mainline, **2**-Alternate, **3**-Bypass, **4**-Spur, **6**-Business,**7**-Ramp, Wye, Connector, etc., **8**-Service and/or unclassified frontage, **0**-none of the above
Mile point	Enter milepoint location reference, precision to thousandths of a mile. Include decimal point. Milepoint should reference beginning of the structure in the direction of increasing mileage.
Description of the bridge site	Describe location of bridge (for example, **6 miles southwest of Mayberry**). Describe terrain features, scour counter-measures, relief or main channel openings and their relative location, upstream or downstream bridges or structures that affect flow or scour. Use up to 48 lines.

Elevation Data

Elevation data include the type of datum, difference between that datum and mean sea level, and descriptions of reference points or bench marks.

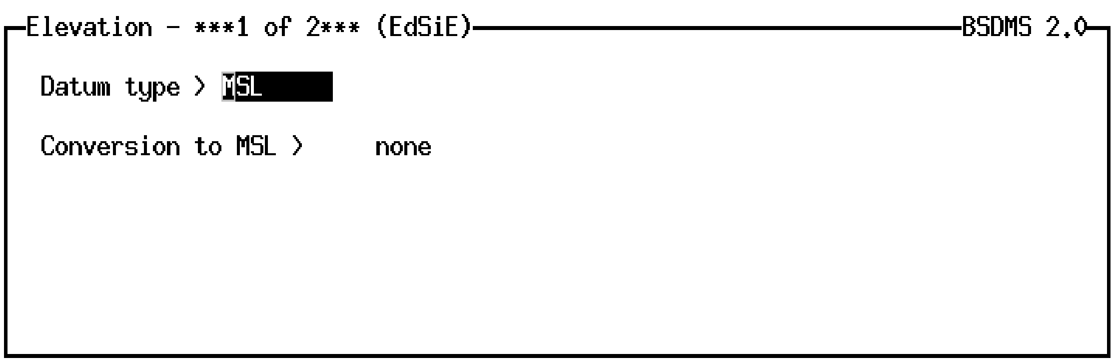


Figure A-2. Elevation-data screen.

Description of elevation-data attributes are given in table A-2.

Table A-2. Elevation data-attribute descriptions

Attribute	Help Information
Datum type	<u>Valid</u>: **Local**, **Gage**, **MSL**. Name the type of datum that elevations are referenced in this data set.
Conversion to MSL	<u>Units</u>: **ft** Limits: **none** Enter the correction, if known, for converting the local datum to MSL. To input a negative number, it must be input as **0-X** where (-X) is the number to be entered.
Description of reference points and bench marks	Describe the datum and reference points or bench marks used in determining any elevations at the bridge.

General Stream Data

General stream data include drainage area, slope armoring, debris, and stage of geomorphic channel evolution.

```
General (EdSiSG)                                          BSDMS 2.0

  Drainage area     >  5720.0
  Slope in Vicinity > 0.000189
  Flow impact       >  LEFT
  Channel evolution >  UNKNOWN
  Observed armoring >  UNKNOWN
  Debris Frequency  >  OCCASIONAL
  Debris Effect     >  LOCAL
```

Figure A-3. General stream-data screen.

Descriptions of general stream-data attributes are given in table A-3.

Table A-3. General stream-data attribute descriptions

Attribute	Help Information
Drainage area	<u>Units</u>: square miles limits: min = **0.0** Enter the contributing drainage area of the stream at bridge.
Slope in vicinity	<u>Units</u>: **ft/ft** <u>Limits</u>: decimal value Enter the slope in the vicinity of the bridge. Slope may be measured from surveyed channel or water-surface profile or map.
Flow impact	<u>Valid</u>: (**U**)nknown, (**S**)traight, (**L**)eft, (**R**)ight Specify which bank receives the impact of the flow; if neither, use (**S**).

Table A-3. General stream-data attribute descriptions—Continued

Attribute	Help Information
Channel evolution	Valid: (**U**)nknown, (**P**)remodified, (**C**)onstructed, (**D**)egradation, (**T**)hreshold, (**A**)ggradation, (**R**)estabilization Information is located at the bottom of this table in three columns. For each channel evolution descriptor, Characteristic Forms and Geobotanical Evidence are listed on the following page, followed by Dominant Fluvial and Hillslope processes.
Observed armoring	Extent of armoring, if any. Valid: (**U**)nknown, (**H**)igh, (**P**)artial, (**N**)one Gravel-bed streams typically have a surficial 'armor' layer of particles of larger (>8mm) and more uniform size than subsurface materials. Extent of armoring is here a reference to spatial continuity and apparent durability.
Debris frequency	Enter the frequency of woody debris accumulations. Count only those large enough to significantly affect the scour at the bridge. Valid: (**U**)nknown, (**N**)one, (**R**)are (>5 yr), (**O**)ccasional (2 to 5 yr), (**F**)requent (<2 yr)
Debris effect	What types of scour does the debris affect? Valid: (**U**)nknown, (**N**)one, (**L**)ocal, (**C**)ontraction, (**B**)oth

Parameters regarding the stage of geomorphic channel evolution are described in tables A-4 and A-5.

Table A-4. Channel-evolution attribute descriptions

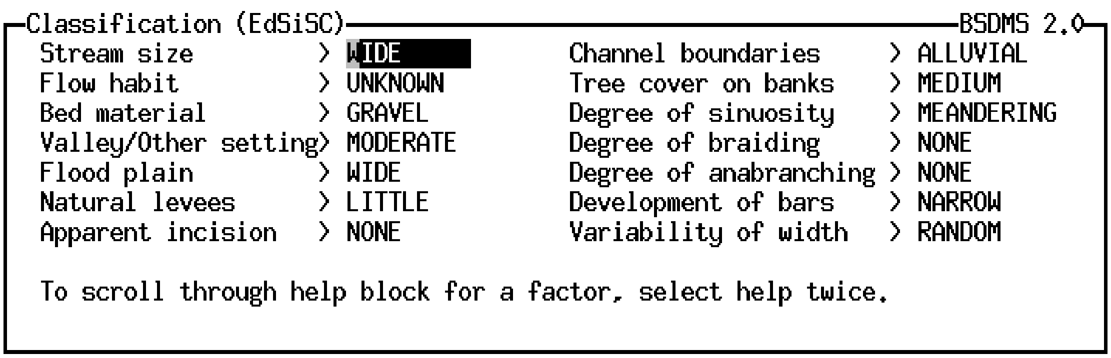
Descriptor	Characteristic Forms	Geobotanical Evidence
Premodified	stable, alternate, channel bars; convex top-bank shape; flow line high relative to the top of the bank; channel straight or meandering.	vegetated banks to flow line
Constructed	trapezoidal cross section; linear bank surfaces; flow line lower relative to the top bank.	removal of vegetation
Degradation	heightening and steepening of banks; alternate bars eroded; flow line lower relative to top of bank.	riparian vegetation high relative to flow line and may lean towards channel.
Threshold	large scallops and bank retreat; vertical face and upper-bank surfaces; failure blocks on upper bank; some reduction in bank angles; flow line very low relative to top bank.	tilted and fallen riparian vegetation
Aggradation	large scallops and bank retreat; vertical face, upper bank, and slough line; flattening of bank angles; flow line low relative to top bank; development of new flood plain.	tilted and fallen riparian vegetation; re-establishing vegetation on slough line; deposition of material above root collars of slough line vegetation
Restablization	stable, alternate channel bars; convex, short vertical face, on top bank; flattening of bank angles; development of new flood plain; flow line high relative to top bank.	re-establishing vegetation extends up slough line and upper bank; deposition of material above root collars of slough line vegetation, some vegetation establishing on bars.

Table A-5. Additional channel-evolution attribute descriptions

Descriptor	Fluvial	Hillslope
Premodified	sediment transport-mild aggradation; basal erosion on outside bends; deposition on inside bends	none
Constructed	none	none
Degradation	degradation, basal erosion on banks	pop-out failures
Threshold	none	none
Aggradation	aggradation; development of meandering thalweg; initial deposition of alternate bars; reworking of failed material on lower banks	slab, rotational and pop-out failures; low-angle slides of previously failed material
Restablization	aggradation; further development of meandering thalweg; further deposition of alternate bars; reworking of failed material; some basal erosion on outside bends; deposition on flood plain and bank surfaces	low-angle slides, some pop-out failures near flow line

Stream-Classification Data

A standing geomorphic stream-classification is a valuable method of stream site characterization. This stream classification is based on a report by Lagasse and others (1991).


```
Classification (EdSiSC)                                              BSDMS 2.0
  Stream size          > WIDE          Channel boundaries     > ALLUVIAL
  Flow habit           > UNKNOWN       Tree cover on banks    > MEDIUM
  Bed material         > GRAVEL        Degree of sinuosity    > MEANDERING
  Valley/Other setting> MODERATE       Degree of braiding     > NONE
  Flood plain          > WIDE          Degree of anabranching > NONE
  Natural levees       > LITTLE        Development of bars    > NARROW
  Apparent incision    > NONE          Variability of width   > RANDOM

  To scroll through help block for a factor, select help twice.
```

Figure A-4. Stream-classification data screen.

Descriptions of stream-classification data attributes are given in table A-6.

Table A-6. Stream-classification data attribute description

Attribute	Help Information
Stream size	Valid: (**S**)mall = < 100-ft wide (**M**)edium = 100- to 500-ft wide (**W**)ide = > 500-ft wide Description: Stream depth tends to increase with size, and potential for scour increases with depth. The size of a stream can be indicated by channel width. The width of a stream is measured along a perpendicular drawn between its opposing banks, which are defined by either their form or as the riverward edge of a line of permanent vegetation. For sinuous meandering streams, width is measured at straight reach or at the inflection points between bends, where it tends to be most consistent. For multiple channel streams, width is the sum of the widths of individual, unvegetated channels.
Flow habit	Valid: (**U**)nknown (**E**)phemeral (**F**)lashy (**P**)erennial The flow habit of a stream may be ephemeral, perennial but flashy, or perennial. An ephemeral stream flows briefly in direct response to precipitation, and as used here, includes intermittent streams. A perennial stream flows all or most of a year, and a perennial but flashy stream responds to precipitation by rapid changes in stage and discharge. Perennial streams may be relatively stable or unstable, depending on other factors, such as channel boundaries and bed material.
Bed material	Valid: (**U**)nknown, (**CL**)ay-silt, (**SI**)lt, (**SA**)nd, (**G**)ravel, (**CO**)bbles Clay = d <0.004 mm Silt = 0.004 < d < 0.062 mm Sand = 0.062 < d < 2 mm Gravel = 2 < d < 64 mm Cobbles = d > 64 mm Description: Streams are classified according to the dominant size of the sediment on their beds, as silt-clay bed, sand bed, gravel bed, and cobble or boulder bed. For these bed material designations, rough approximations derived from visual observation are acceptable.
Valley/other setting	Valid: (**L**)ow relief valley, < 100-ft deep (**M**)oderate relief, 100- to 1,000-ft deep (**H**)igh relief, > 1,000-ft deep (**N**)one = No relief, Alluvial fan (**U**)nknown Description: Valley relief is used as a means of indicating whether the surrounding terrain is generally flat, hilly, or mountainous. For a particular site, relief is measured (usually on a topographic map) from the valley bottom to the top of the nearest adjacent divide. Relief greater than 1,000 ft is regarded as mountainous, and relief in the range of 100 to 1,000 ft as hilly. Streams in mountainous regions are likely to have steep slopes, coarse bed materials, narrow floodplains and be non-alluvial, for example, supply-limited transport rates. Streams in regions of lower relief are usually alluvial and exhibit more problems because of lateral erosion in the channels.
Floodplain	Describe the flood plain width. Acceptable input: (**L**)ittle or none = <2X CHANNEL WIDTH (**N**)arrow = 2-10X CHANNEL WIDTH (**W**)ide = >10X CHANNEL WIDTH (**U**)nknown Description: Floodplains are described as nearly flat alluvial lowlands bordering a stream that is subject to inundation by floods. Many geomorphologists prefer to define a floodplain as the surface presently under construction by a stream that is flooded with a frequency of about 1-1/2 years. According to this definition, surfaces flooded less frequently are terraces, abandoned floodplains, or flood-prone areas. However, flood-prone areas are considered herein as part of the floodplain. Floodplains are categorized according to width relative to channel width.

Table A-6. Stream-classification data attribute description—Continued

Attribute	Help Information
Natural levees	Describe the natural levees (if any). Acceptable input: (**L**)ittle or none (**C**)oncave bank principally (**B**)oth banks well developed (**U**)nknown Description: Natural levees form during floods as the stream stage exceeds bankfull conditions. Sediment is then deposited on the floodplain due to the reduced velocity and transporting capacity of the flood in these overbank areas. Streams with well-developed natural levees tend to be of constant width and have low rates of lateral migration.
Apparent incision	Describe the apparent incision if it exists. Acceptable input: (**N**)one = no apparent incision (**A**)pparent = if incision probably exists (**U**)nknown Description: The apparent incision of a stream channel is judged from the height of its banks at normal stage relative to its width. For a stream whose width is about 100 feet, bank heights in the range of 6 to 10 feet are about average, and higher banks indicate probable incision. Incised streams tend to be fixed in position and are not likely to bypass a bridge or shift in alignment at a bridge. Lateral erosion rates are likely to be slow, except for western arroyos with high, vertical, and clearly unstable banks.
Channel boundaries	Describe the channel boundaries. Acceptable input: (**A**)lluvial (**S**)emi-alluvial (**N**)on-alluvial (**U**)nknown Description: Although precise definitions cannot be given for alluvial, semi-alluvial, or non-alluvial streams, some distinction with regard to the erosional resistance of the earth material in channel boundaries is needed. An alluvial channel is in alluvium, a non-alluvial channel is in bedrock or very large material (cobbles or boulders) that do not move except at very large flows, and a semi-alluvial channel has both bedrock and alluvium in its channels.
Tree cover on banks	Describe the tree cover on the banks. (**L**)ow = <50 percent of bankline (**M**)edium = 50 to 90 percent of bankline (**H**)igh = >90 percent of bankline Description: Mature trees on a graded bank slope are convincing evidence of bank stability. In most regions of the United States, the upper parts of stable banks are vegetated, but the lower part may be bare at normal stage, depending on bank height and flow regime of the stream. Where banks are low, dense vegetation may extend to the water's edge at normal stage. Where banks are high, occasional slumps may occur even on stable graded banks.
Degree of sinuosity	Describe the degree of sinuosity of the channel (**ST**)raight = 1-1.05 (**SI**)nuous = 1.06-1.25 (**M**)eandering = 1.26 - 2.0 (**H**)igh > 2.0 Description: Sinuosity is the ratio of the length of a stream reach measured along its center line, to the length measured along the valley center line or along a straight line connecting the ends of the reach. The valley center line is preferable when the valley itself is curved. Straight stream reaches have a sinuosity of one and the maximum value of sinuosity is about four. Inasmuch as the sinuosity of a stream is rarely constant from one reach to the next, a very refined measurement of sinuosity is not warranted.

Table A-6. Stream-classification data attribute description—Continued

Attribute	Help Information
Degree of braiding	Describe the degree of braiding of the channel. (**N**)one = Not braided, <5 percent (**L**)ocally = Locally braided, 5 to 35 percent (**G**)enerally = Generally braided, >35 percent Description: A braided stream is one that consists of multiple and interlacing channels. In general, a braided channel has a large slope, a large bed-material load in comparison with its suspended load, and relatively small amounts of silts and clays in the bed and banks. Multiple channels are generally formed as bars of sediment are deposited within the main channel, causing the overall channel system to widen. However, braided streams may occur with a graded state that is neither aggrading nor degrading.
Degree of anabranching	Describe the degree of anabranching of the channel. (**N**)ot anabranched, < 5 percent (**L**)ocally anabranched, 5 to 35 percent (**G**)enerally anabranched, >35 percent Description: An anabranched stream differs from a braided stream in that the flow is divided by islands rather than bars, and the islands are relatively large in relation to the channel width. The anabranches, or individual channels, are more widely and distinctly separated and more fixed in position than the braids of a stream. An anabranch does not necessarily transmit flow at normal stage, but it is an active and well-defined channel, not blocked by vegetation.
Development of bars	Valid: (**U**)nknown, (**N**)arrow, (**W**)ide, or (**I**)rregular (characteristic width) This attribute describes the development of point and alternate bars in terms of their characteristic width. A point bar with an unvegetated width greater than the width of flowing water at the bend is considered to be wider than average (Wide). Development of bars data is used with variability of channel width data to assess lateral channel stability. Point bars occur along the convex banks of channel bends. If the concave bank is eroding slowly, the point bar will grow slowly and vegetation will become established on it. The unvegetated part of the bar will appear as a narrow crescent. If the bank is eroding rapidly, the unvegetated part of the rapidly growing point bar will be wide and conspicuous. However, in areas where vegetation is quickly established, as in rainy southern climates, cut banks at bends may be a more reliable indication of instability than the unvegetated width of point bars. Alternate bars typically occur in straighter channel reaches and are distributed periodically on alternating sides of the channel. Their characteristic width is much less than the width of flowing water.
Variability of width	Valid: (**U**)nknown, (**E**)quiwidth, (**W**)ider, (**R**)andom The variability of unvegetated channel width, in connection with bar development is a useful indication of the lateral stability of a channel. A channel is considered to be of uniform width (equiwidth) if the unvegetated width at bends is not more than 1-1/2 times the average width at the narrowest places. In general, equiwidth streams having narrow point bars are the most stable laterally, and random-width streams having wide irregular point bars are the least stable. Vertical stability, or the tendency to scour, cannot be assessed from these properties. Scour may occur in any alluvial channel. In fact, the greatest potential for deep scour might be expected in laterally stable equiwidth channels, which tend to have relatively deep and narrow cross sections and bed material in the size range of silt and sand.

Stream-Roughness Data

Stream-roughness data include Manning's 'n' roughness coefficients for the channel and overbanks.

```
Roughness (EdSiSR)                                                BSDMS 2.0
 Enter values for Manning's 'n'

                     Left Overbank   Main Channel   Right Overbank
 High                      none            none            none
 Typical                   0.18            0.03            0.18
 Low                       none            none            none
```

Figure A-5. Stream-roughness data screen.

Descriptions of stream-roughness data attributes are given in table A-7.

Table A-7. Stream-roughness data attribute description

Attribute	Help Information
Manning's 'n'	Units: none Limits: min = 0.0, max = 0.25 Enter the Manning's coefficient for the indicated section. Try to use coefficients which are representative for the study reach.

Bed-Material Data

Bed-material data include sediment sample characteristics, sampling date, and sample type.

```
Bed-material (EdSiSB)                                                     BSDMS 2.0
Sample <-Date-> Type                                          Spec.
No.     Yr Mo Dy Sampler       D95    D84    D50    D16    Grav.  Shape Cohesion
    1 1991 10  4 BMH-60        5.8   0.36   0.25   0.16    2.65   none NONCOHES
    2 1991 10  4 BMH-60       0.28   0.19   0.14  0.092    2.65   none NONCOHES
    3 1991 10  4 BMH-60       17.3   10.4    2.1   0.35    2.65   none NONCOHES
    4 1991 10  4 BMH-60       15.0   10.0    2.0   0.33    2.65   none NONCOHES
    5 1991 10  9 BMH-60       0.86    0.5   0.32   0.13    2.65   none MILD
    6 1991 10  9 SHOVEL       20.0   15.0    6.9   0.39    2.65   none NONCOHES
    0    0  0  0              none   none   none   none    2.65   none UNKNOWN
    0    0  0  0              none   none   none   none    2.65   none UNKNOWN
```

Figure A-6. Bed-material data screen.

Descriptions of bed-material data are given in table A-8.

Table A-8. Bed-material data attribute description

Attribute	Help Information
Sample number	Enter the number of the bed material sample if it does not correspond to the existing number.
Date	Enter the date of the bed material sample. Use the full year designation (**1991** instead of '91) and integers for the month and day.
Type sampler	Enter the type of sampler used for bed material sample, limit 10 chars. BM-54, BMH-60, RBMH-80, BMH-53, SHIPEK If a surface hand sample, designate HAND (GRID, or AREAL ...)
D95	Units: mm Limits: min = 0.0 Enter the D95 value for the bed material. Ninety-five percent of the sample (by weight) is finer than the D95 grain size.
D84	Units: mm Limits: min = 0.0 Enter the D84 value for the bed material. Eighty-four percent of the sample (by weight) is finer than the D84 grain size.
D50	Units: mm Limits: min = 0.0 Enter the D50 value for the bed material. Fifty percent of the sample (by weight) is finer than the D50 grain size.
D16	Units: mm Limits: min = 0.0 Enter the D16 value for the bed material. Sixteen percent of the sample (by weight) is finer than the D16 grain size.
Specific gravity	Units: none Enter the specific gravity of the bed material. The default is 2.65 (sand).
Shape	Particle shape factor used here is defined as S= c/sqrt(ab), that is the ratio of the shortest axis length (c) to the square root of the product of the longest (a) and the intermediate (b) axis lengths. Particle shape may influence hydraulic forces on coarse gravel or cobble-bed streams. Flatter particles may be able to form a more tightly imbricated armor layer than more spherical particles.
Cohesion	Valid: (**U**)nknown, (**N**)on-cohesive, (**M**)ildly cohesive, (**C**)ohesive, (**L**)enses of non-cohesive in cohesive material, (**A**)lluvial non-cohesive overlay on cohesive material. Description: Cohesion is a measurement of the force which holds the bed material together as a body which deforms plastically at varying water contents. It is due to the ionic attraction between clay particles and adsorbed water.

Bridge-Site Data

Bridge-site data include parameters such as bridge length, width, and elevations.

```
Bridge - ***1 of 3*** (EdSiB)                                      BSDMS 2.0

 Structure Number > 118.5A

 Length                >    785.0       Plans on file?    X
 Width                 >       32       Parallel bridges? X
 Lower low chord elev. >    159.8         Continuous Abutments  > NO
 Upper low chord elev. >    167.4         Distance/center lines >     75.0
 Overtopping elevation >     none         Distance/pier faces   >     51.0
 Skew to flow          >      0.0         Upstream/Downstream?  > UP
 Guide banks           > ELLIPTICAL
```

Figure A-7. Bridge-site data screen.

Descriptions of bridge-site data attributes are given in table A-9.

Table A-9. Bridge-site data attribute description

Attribute	Help Information
Structure number	Enter the official structure number. This should be the State Department of Transportation number as entered in the NBIS, and unique to that bridge. Dual bridges with closed medians have a single structure number.
Length	<u>Units</u>: ft <u>Limits</u>: min = 0.0 Enter the length of the bridge (abutment to abutment).
Width	<u>Units</u>: ft <u>Limits</u>: min = 0 Enter the width, railing to railing, of the bridge deck, to the nearest foot.
Lower low chord elevation	<u>Units</u>: ft, gage datum The lower low chord elevation is the low point on the bridge superstructure (excluding the piers). It is the elevation at which the free water surface begins to be contracted and is significant in evaluating pressure flow conditions.
Upper low chord elevation	<u>Units</u>: ft, gage datum The upper low chord elevation is the high point on the underside of the superstructure. It is the elevation at which there will be no free surface flow through the bridge opening and is significant in evaluating pressure flow conditions.
Overtopping elevation	<u>Units</u>: ft, gage datum <u>Limits</u>: min = 0.0 The overtopping elevation is the minimum elevation at which the bridge or nearby roadway embankment will be overtopped by flood waters.
Skew to flow	<u>Units</u>: degrees <u>Limits</u>: 0, 90 The bridge skew is the acute angle the bridge makes with a line perpendicular to the flow. If the bridge is perpendicular to the flow, its skew is 0. The skew is positive if the bridge is rotated clockwise from the perpendicular to flow and negative if the bridge is rotated counterclockwise.
Guide banks	Guide banks (also referred to as spur dikes) guide approach flows through the opening, to reduce abutment scour potential and increase bridge conveyance efficiency. <u>Valid entries are</u>: (**U**)nknown, (**S**)traight, (**E**)lliptical, (**N**)one, or (**O**)ther.

Table A-9. Bridge-site data attribute description—Continued

Attribute	Help Information
Plans on file	Toggle field using the space bar. (**X**)= Yes **( )**= No or Unknown Toggle field Yes if bridge design plans are available for this bridge. Otherwise, toggle field No ( ).
Parallel bridges	Toggle field using the space bar. (**X**)= Yes **( )**= No or Unknown Is the bridge part of a dual bridge? That is, is there a separate parallel bridge immediately upstream or downstream? Enter parallel bridges as two separate bridge sites. Toggle **Yes**, and see help under fields that pop up.
Continuous abutments[1/]	Are the abutments continuous through the parallel bridge opening? (**Y**)es (**N**)o. Enter parallel bridges as two separate bridge sites. You may change the *Site Description* (EdSiL) to a unique description, and *Write* the data set, choosing '*New*' at prompt.
Distance/center lines[1/]	<u>Units</u>: ft <u>Limits</u>: min = 0.0 Stream distance between the center lines of the roadways. See *Editing Data Sets* under Documentation>Data_set (DD) for information on storing parallel bridges as separate data sets.
Distance/pier faces[1/]	<u>Units</u>: ft <u>Limits</u>: min = 0.0 Stream distance between the downstream face of upstream bridge piers and upstream face of the downstream bridge piers. See *Editing Data Sets* under Documentation>Data_set (DD) for information on storing parallel bridges as separate data sets.
Upstream/ downstream[1/]	<u>Valid</u>: (**UN**)known, (**UP**), (**D**)own Code (**U**)pstream if this is the upstream of the parallel bridges, code (**D**)ownstream if this is the down stream of the two bridges. See *Editing Data Sets* under Documentation>Data_set (DD) for information on storing parallel bridges as separate data sets.

[1/]These attributes appear only if the "Parallel bridges?" field is toggled to (X)=Yes.

A second bridge-site data entry screen is shown in figure A-8.

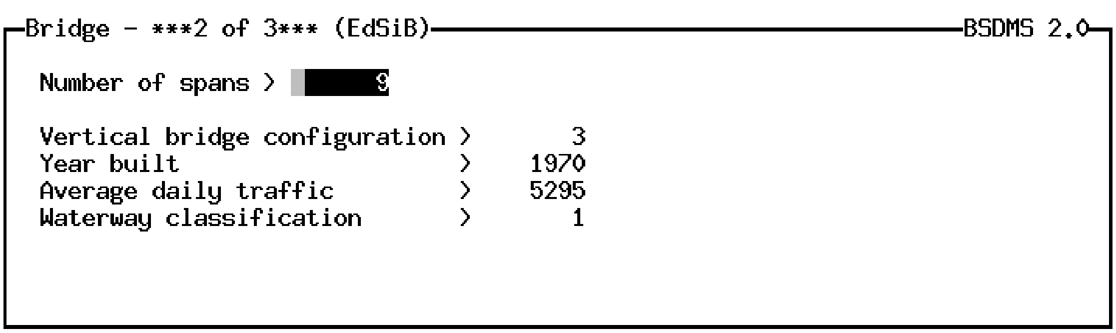


Figure A-8. Additional bridge-site data screen.

Descriptions of additional bridge-site data attributes are given in table A-10.

Table A-10. Additional bridge-site data attribute descriptions

Attribute	Help Information
Number of spans	Enter the total number of spans the bridge has. (number of piers + 1) For long bridges this includes major unit spans.
Vertical bridge configuration	Code the appropriate number to describe vertical bridge configuration. **0** - Unknown, **1** - Horizontal, **2** - Sloping, **3** - Curvilinear
Year built	Code the year of construction of the structure. If the year built is unknown, provide an estimate.
Average daily traffic	Enter the average daily traffic volume for the route. Note that if this bridge carries only one direction of a route, the ADT should be for this bridge's direction only, not for the entire route.
Waterway classification	Enter the appropriate number for the waterway classification. **0** - Unknown, **1** - Main channel, **2** - Relief opening, **3** - Relief opening carrying tributary
Bridge description	Enter a brief description of the bridge noting any distinguishing characteristics of the bridge, the pier reference system used, materials and design information, and etc.

Abutment Data

Abutment-data parameters describe the physical characteristics of each abutment.

```
Abutment - ***1 of 2*** (EdSiA)                                BSDMS 2.0

  Left Abutment:   Highway Station >  7688.0
  Right Abutment:  Highway Station >  8471.0

  Left abutment skew to flow  >   0
  Right abutment skew to flow >   0

  Abutment/Contracted Opening type > III
```

Figure A-9. Abutment-data screen.

Descriptions of abutment-data attributes are given in table A-11.

Table A-11. Abutment-data attribute descriptions

Attribute	Help Information
Left abutment: highway station	Enter the highway station for the center line of the left abutment. Right and left determined from downstream-looking perspective.
Right abutment: highway station	Enter the highway station for the center line of the right abutment. Right and left determined from downstream-looking perspective.
Left abutment skew to flow	Enter the skew of the left abutment with respect to the flow. Skew is zero degrees for an abutment parallel to the flow, positive degrees for clockwise skew, and negative degrees for counterclockwise skew.
Right abutment skew to flow	Enter the skew of the right abutment with respect to the flow. Skew is zero degrees for an abutment parallel to the flow, positive degrees for clockwise skew, and negative degrees for counterclockwise skew.
Abutment/ contracted opening type	Valid: Unknown, **I**, **II**, **III**, **IV**, **Other** Type I - Vertical embankments and vertical abutments, with or without wingwalls Type II - Sloping embankments and vertical abutments without wingwalls Type III - Sloping embankments and sloping spillthrough abutments Type IV - Sloping embankments and vertical abutments with wingwalls Other - If above definitions are not adequate For further definition, see User's Manual for WSPRO (Shearman, J.O., 1989)

Figure A-10 shows a second abutment-data screen.

```
Abutment - ***2 of 2*** (EdSiA)                              BSDMS 2.0
  Abutment slope          >    2.0
  Embankment slope        >    3.0
  Left abutment length    >   none
  Right abutment length   >   none
  Embankment skew to flow >    0.0

  Wingwalls? >

  Distance from Left abutment to channel bank  >   170.0
  Distance from Right abutment to channel bank >    95.0
```

Figure A-10. Additional abutment-data screen.

Descriptions of additional abutment-data attributes are given in table A-12.

Table A-12. Additional abutment-data attribute descriptions

Attribute	Help Information
Abutment slope	Units: ft/ft Limits: min = 0.0 Enter the slope (horizontal/vertical) of the face of the abutment. Vertical = 0.0; 2:1 (27 degree) = 2.0
Embankment slope	Units: ft/ft Limits: min = 0.0 Enter the slope (horizontal/vertical) of the embankments. Vertical = 0.0; 2:1 (27 degree) = 2.0
Left abutment length	Units: ft Limits: min = 0.0 Enter the length of the left abutment in the direction of flow.
Right abutment length	Units: ft Limits: min = 0.0 Enter the length of the right abutment in the direction of flow.
Embankment skew to flow	Units: Degrees Limits: -89.0 : 89.0 Enter skew (acute angle) of bridge and embankments to the flow of the river. Use a negative angle if the LEFT (when looking downstream) embankment points downstream. Use a positive angle if the LEFT embankment points upstream.
Wingwalls	Toggle field On (**X**) or Off **( )** using the space bar. Toggle field On if abutment has wingwalls, otherwise, toggle field Off.
Enter wingwall angle	Units: degrees Limits: 0 to 90 Wingwall angle, in degrees. Wingwall in line with abutment is 90 degrees. Wingwall perpendicular to abutment is 0 degrees.
Distance from left abutment to channel bank	Units: ft Limits: min 0.0 Enter distance from left abutment to the left channel bank. That is, the distance the abutment is set back from the channel bank. If abutment sits at the channel bank, enter 0.0001.
Distance from right abutment to channel bank	Units: ft Limits: min = 0.0 Enter distance from the right abutment to the right channel bank. That is, the distance the abutment is set back from the channel bank. If abutment sits at the channel bank, enter 0.0001.

Pier-Location Data

Pier-location data include factors such as the location and spacing of piers.

```
Location (EdSiPL)                                                    BSDMS 2.0
                                                   <For Pile Bent Piers>
Pier   Bridge                  Highway  Pier         Number    Pile
ID     Station    Alignment    Station  Type         of Piles  Spacing
6       7980.0         0.0     7980.0   GROUP               2      17.0
5       8110.0         0.0     8110.0   GROUP               2      17.0
4       8240.0         0.0     8240.0   GROUP               2      17.0
           0.0         0.0        0.0   UNKNOWN             0      none
           0.0         0.0        0.0   UNKNOWN             0      none
           0.0         0.0        0.0   UNKNOWN             0      none
           0.0         0.0        0.0   UNKNOWN             0      none
```

Figure A-11. Pier-location data screen.

Descriptions of pier-location data attributes are given in table A-13.

Table A-13. Pier-location data attribute descriptions

Attribute	Help Information
Pier identifier	Enter a unique identifier for the pier being described. Use up to 4 alpha-numeric characters. If letters are used, they must be uppercase.
Bridge station	Enter the distance along the bridge center line from the left abutment to the pier at the center line.
Alignment	Enter the alignment, in degrees, of the pier relative to the bridge alignment. Enter zero degrees if pier is aligned perpendicular to bridge alignment, positive degrees if pier is skewed clockwise, or negative degrees if pier is skewed counterclockwise.
Highway station	Units: ft Limits: min = 0.0 Enter the highway stationing for the center line of the pier.
Pier type	Describe the type of piers on the bridge. Valid: **UNKNOWN**, **SINGLE** column piers, or **GROUP** for multi-column (pile bent) piers.
Number of piles	Enter the number of columns or piles for each pier if the pier is a pile bent (or has multiple columns)
Pile spacing	Enter the spacing, center to center, of the piles or columns.

Pier-Shape Data

Pier-shape data include information on the pier shape and on the pier footing or pile cap.

```
Shape - ***1 of 2*** (EdSiPS)                                BSDMS 2.0
Pier         Pier   Pier       Pier Shape    Pier    Pier
ID          Width   Shape          Factor   Length   Protection
6             4.0   CYLINDER         none     21.0   NONE
5             4.0   CYLINDER         none     21.0   NONE
4             4.0   CYLINDER         none     21.0   NONE
```

Figure A-12. Pier-attributes data screen.

Descriptions of pier-shape data attributes are given in table A-14.

Table A-14. Pier-shape data attribute descriptions

Attribute	Help Information
Pier identifier	Pier identifier cannot be changed on this screen. Make notes in comment section.
Pier width	Units: ft Limits: min = 0.0 Enter the actual pier width. For tapered piers, enter a representative width. Pier width will also be entered for each scour measurement.
Pier shape	Describe the shape of the pier nose. Valid: (**U**)nknown, (**C**)ylindrical, (**SQ**)uare, (**R**)ound, (**SH**)arp, (**L**)enticular
Pier-shape factor	If you wish to specify a pier shape factor for some reason, you may do so here. Usually this should be left blank.
Pier length	Units: ft Limits: min = 0.0 Enter the actual length of the pier.
Pier protection	Note whether scour countermeasures are in place at the pier. Valid: (**U**)nknown, (**N**)one, (**R**)iprap, (**O**)ther

Figure A-13 shows the second screen under pier “shape”, where footing and foundation data are recorded.

```
Shape - ***2 of 2*** (EdSiPS)                                    BSDMS 2.0
          Pier  <----------Foot or Pile Cap---------->
Pier    Found-  <---Elevations--->                      Pile Tip
ID        ation       Top    Bottom     Width     Shape Elevation
6     PILES         122.1     118.1      11.2  SQUARE        82.0
5     PILES         122.3     118.3      11.2  SQUARE        81.0
4     PILES         122.1     118.1      11.2  SQUARE        79.0
```

Figure A-13. Additional pier-attributes data screen.

Descriptions of additional pier attributes are given in table A-15.

Table A-15. Additional pier-shape attribute descriptions

Attribute	Help Information
Pier identifier	Pier identifier cannot be changed, make notes in comment section.
Pier foundation	Describe the foundation type of the pier. Valid: (**U**)nknown, (**PO**)ured footing, (**PI**)les
Foot or pile cap elevation-top	Units: ft, gage datum Limits: none Enter elevation of the top of the footing or pile cap.
Foot or pile cap elevation-bottom	Units: ft Limits: min = 0.0 Enter the elevation at the bottom of the footing or pile cap.
Foot or pile cap width	Units: ft Limits: min = 0.0 Enter width at the footing or pile cap.
Foot or pile cap shape	Describe shape of the footing or pile cap. Valid: (**U**)nknown, (**SQU**)are, (**R**)ound, (**SQR**)nd (square with rounded corners), **Other.**
Pile tip elevation	Units: ft, gage datum Limits: None Enter minimum pile tip elevation. If a minimum elevation was specified for construction, enter this.
Pier description	Provide a brief comment on any feature which may affect the scour characteristics. Note design and materials characteristics not already specified, etc.

SCOUR-MEASUREMENT DATA

Scour-measurement data include pier-scour, abutment-scour, contraction-scour, and general scour data.

Pier-Scour Data

Pier-scour data include local pier-scour measurement attributes.

```
Add - 1 of 2 (EdScPA)                                              BSDMS 2.0
 For Pier scour measurement being added, enter the following:

                                         Year  Mon  Day  Hr  Min
 Pier ID >              Date of measurement > none   no   no  no   no

 Upstream/Downstream indicator > no
 Scour depth                   >     none  Approach flow velocity >     none
 Scour depth accuracy          >     none  Approach flow depth    >     none
 Scour hole side slope         >     none  Effective pier width   >     none
 Scour hole top width          >     none  Skewness to flood flow >     none
```

Figure A-14. Pier-scour data screen.

Descriptions of pier-scour data attributes are given in table A-16.

Table A-16. Pier-scour data attribute descriptions

Attribute	Help Information
Pier identifier	Valid pier identifier are taken from *Pier Site* data previously entered. Scour values may only be entered for piers which have been defined under the *Site* screens.
Date of measurement	Enter the date of pier-scour measurement using the full year (example, **1991** instead of '91), integers for the month and day, and 24-hr time for the hour of the day of measurement. Enter as close as possible the minute the measurement was taken.
Upstream/downstream indicator	Indicate if scour measurement was taken upstream or downstream from pier. **1** = Upstream **2** = Downstream **0** = Unknown
Scour depth	Units: ft. Limits: min. = 0.0 Enter measured local scour depth at the pier. Local scour is measured as maximum distance between bottom of scour hole and projected average bed level around the scour hole at the time of measurement.
Scour accuracy	Units: ft Limits: min. = 0 Enter estimated accuracy (±) of scour measurement. This important variable should be provided by the measurer. A rough estimate is preferable to no entry.
Scour-hole side slope	Units: ft/ft Limits: min. = 0.0 Enter average side slope for scour hole. Use an X:1 slope format entering only the X value.
Scour-hole top width	Units: ft Limits: min = 0.0 Enter the width of the top of the scour hole.
Approach flow velocity	Units: ft/sec Enter average approach velocity of the stream just upstream of (or estimated as just on either side of) flow acceleration zone around pier.
Approach flow depth	Units: ft Enter scour hole approach flow depth for the time of the measurement. This may be estimated as flow depth at the scour hole, minus the measured local scour (in ft).
Effective pier width	Units: ft Enter effective pier width at the time of measurement. Effective pier width accounts for debris and nonuniform pier geometry, but does NOT account for pier SKEW to approach flow.
Skewness to flood flow	Units: Deg. Enter the pier skewness to flood flow for the time of the measurement.

Additional local-pier scour attributes are shown on the data screen in figure A-15.

```
Add - 2 of 2 (EdScPA)                                      BSDMS 2.0

 Sediment transport >  UNKNOWN      Dune scour crest         >    none
 Bed Material       >  UNKNOWN      Bed material size - D50  >    none
 Sand bed form      >  UNKNOWN      Bed gradation - Sigma    >    none
 Dune scour trough  >     none      Debris effect            >  UNKNOWN
 Description of scour measurement (4 lines):
```

Figure A-15. Additional pier-scour data screen.

Descriptions of additional pier-scour data attributes are given in table A-17.

Table A-17. Additional pier-scour data attribute descriptions

Attribute	Help Information
Sediment transport	Enter the sediment transport characteristic of the stream. Valid: **CLEAR** water, **LIVE** bed, or **UNK**nown Clear-water scour and live bed scour are the two conditions of local scour. Clear-water scour occurs when there is no transport of bed material into the scour hole from upstream. That is, critical shear stress for the bed material is not exceeded in the approach section, but is exceeded at the pier due to the flow-acceleration and vortices induced by the piers. Live bed scour occurs when bed material is being transported into the scour hole from upstream. NOTE that a condition with high suspended sediment load (very muddy), may be 'CLEAR-water scour' if it does not carry bed load. Channels of sand and finer materials are usually live-bed. Bridges over coarse bed material streams often have clear water scour at the lower part of a hydrograph, live bed scour at the higher velocities and then clear water scour on the falling stages. Response should indicate conditions at time of measurement.
Bed material	Valid: (**C**)ohesive, (**N**)on-cohesive, (**U**)nknown Cohesion is a measurement of the force which holds the bed material together as a body which deforms plastically at varying water contents. It is due to ionic attraction between clay particles and absorbed water.
Sand-bed form	For live-bed streams, bed configuration at time of measurement. Valid: (**R**)iffle, (**D**)une, (**T**)ransition, (**A**)ntidune, or (**U**)nknown Live-bed scour depth in a stream with a dune bed-load transport fluctuates with the passage of dune crests and troughs. In this case, maximum depth of scour, at the passing dune trough, may be about 30 percent larger than equilibrium scour depth. For live-bed scour with a plain bed configuration, the maximum depth of scour is equal to the equilibrium depth of scour. With antidunes occurring upstream and in the bridge crossing, the maximum depth of scour may be about 20 percent greater than the equilibrium depth of scour, based on flume experiments.
Dune-scour trough	Units: ft Limits: min = 0.0 If applicable and measured, enter the depth of scour at the passage of the dune trough.
Dune-scour crest	Units: ft Limits: min = 0.0 If applicable and measured, enter the scour depth at the passage of the dune crest.
Bed-material size - D50	Units: mm Limits: min = 0.0 Enter **D50** applicable for this measurement. This should represent the channel D50 for sand beds and a selected sedimentary environment (for example, head of a major bar) for gravel beds. Alternatively, for gravel-bed streams, a channel D50 may be entered.
Bed gradation - Sigma	Units: none Limits: min = 1.0 Gradation is typically indicated by the geometric standard deviation of the sizes (sigma), defined as the square root of D84/D16.
Debris effect	Qualify the extent of the effects of debris on this measured scour. Valid: (**U**)nknown, (**I**)nsignificant, (**M**)oderate, (**S**)ubstantial
Description of scour measurement	Enter a brief comment about the scour measurement noting any information that may have affected the reading.

Abutment-Scour Data

Abutment-scour data include local abutment scour data attributes.

```
Add - 1 of 2 (EdScAA)                                              BSDMS 2.0

 For Abutment scour measurement being added, enter the following:

                                          Year  Mon  Day  Hr  Min
 Abutment > none      Date of measurement > none  no   no  no   no

 Upstream/Downstream   >  0
 Scour depth           >     none   Velocity measured at abutment>    none
 Scour depth accuracy  >     none   Approach flow depth at abut. >    none
 Sediment transport    >  UNKNOWN
```

Figure A-16. Abutment scour-data screen.

Descriptions of abutment scour-data attributes are given in table A-18.

Table A-18. Abutment scour-data attribute descriptions

Attribute	Help Information
Abutment	Specify abutment for which this scour measurement is being added. Valid: **LEFT** **RIGHT**
Date of measurement	Enter date of the abutment scour measurement using the full year (for example, **1991** instead of ‘91), integers for the month and day, and 24-hour time for the hour of the day the measurement. Enter as close as possible the minute the measurement was taken.
Upstream/downstream	Indicate if measurement was taken upstream or downstream from the abutment. **1** = Upstream **2** = Downstream **0** = Unknown
Scour depth	Units: ft Limits: min. = 0.0 Enter the measured local scour depth at the abutment. Local scour is measured as maximum distance between bottom of scour hole and projected average bed level around the scour hole at the time of measurement.
Scour-depth accuracy	Units: ft Limits: min. = 0 Enter estimated accuracy (±) of the scour measurement. This important information should be provided by the measurer. A rough estimate is preferable to no entry.
Sediment transport	See *Help Information* in EDScPA table
Velocity measured at abutment	Units: ft/sec Enter the velocity measured at the upstream side of the abutment for this abutment scour measurement.
Approach flow depth at abut.	Units: ft Enter the scour hole approach flow depth for the time of the measurement. This may be estimated as the flow depth at the scour hole, minus the measured local scour (in feet).

Additional local abutment scour-measurement attributes are shown on the data screen in figure A-17.

```
Add - 2 of 2 (EdScAA)                                              BSDMS 2.0

Bed Material          >  UNKNOWN    Bed material size - D50   >     none
Sand bed form         >  UNKNOWN    Bed gradation - Sigma     >     none
Embankment Length     >     none    Debris effect             >  UNKNOWN
Obstr. flow velocity  >     none
Description of Abutment scour measurement (4 lines):
```

Figure A-17. Additional abutment scour-data screen.

Descriptions of additional abutment scour-data attributes are given in table A-19.

Table A-19. Additional abutment scour-data attribute descriptions

Attribute	Help Information
Bed material	See *Help Information* in EDScPA table.
Sand-bed form	See *Help Information* in EDScPA table.
Embankment length	Units: ft Limits: min = 0.0 Embankment length is 'A', the wetted length of the embankment and abutment obstructing flow for this measurement. The length should be projected to be perpendicular to the flow.
Obstructed flow velocity	Units: ft/sec Limits: min = 0.0 The obstructed flow velocity is the average of the velocity blocked by the embankment, computed as (Q blocked)/(area blocked), where the area blocked is projected normal to the flow.
Bed-material size - D50	See *Help Information* in EDScPA table.
Bed gradation - Sigma	See *Help Information* in EDScPA table.
Debris effect	See *Help Information* in EDScPA table.
Description of abutment-scour measurement	See *Help Information* in EDScPA table.

Contraction-Scour Data

Contraction-scour data include contraction scour measurement attributes.

```
Add - 1 of 2 (EdScCA)                                                BSDMS 2.0
 For Contraction scour measurement being added, enter the following:
                                         Year  Mon  Day  Hr
              Date of scour measurement > none   no   no  no
       Date of uncontracted measurement > none   no   no  no
Disch., uncontracted channel>     none  Scour depth accuracy      >     none
Discharge, contract. channel>     none  Channel contraction ratio >     none
Width, uncontracted channel >     none  Eccentricity              >     none
Width, contracted channel   >     none  Pier contraction ratio    >     none
Scour depth                 >     none  Approach flow velocity    >     none
                                        Contract. channel velocity>     none
```

Figure A-18. Contraction scour-data screen.

Descriptions of contraction scour-data attributes are given in table A-20.

Table A-20. Contraction scour-data attribute descriptions

Attribute	Help Information
Date of scour measurement	Enter date of contraction scour measurement using the full year (for example, **1991** instead of '91), integers for the month and day, and 24-hour time for the hour of the day the measurement.
Date of uncontracted measurement	The 'uncontracted' cross-section measurement may represent data used to determine datum from which contraction scour was measured.
Discharge for uncontracted channel	<u>Units</u>: integer cubic feet per second Enter discharge for the portion of the uncontracted section in the approach which is actively transporting bed load.
Discharge, contract. channel	<u>Units</u>: integer cubic feet per second Enter discharge for portion of contracted section at the bridge which is actively transporting bedload for scour measurement.
Width, uncontracted channel	<u>Units</u>: integer ft. Enter width of flow actively transporting bedload in uncontracted section upstream of bridge.
Width, contracted channel	<u>Units</u>: integer ft. Enter width of flow actively transporting bedload in contracted section at bridge.

Table A-20. Contraction scour-data attribute descriptions—Continued

Attribute	Help Information
Scour depth	Contraction scour depth is the difference between average channel-bed elevation of contracted channel and a reference elevation that represents average channel-bed elevation of a hypothetical uncontracted channel at a bridge. Reference surface should characterize mean bed elevation of an uncontracted section at location of contraction scour measurement. Reference surface can be established by passing a line through the average elevation of uncontracted sections, located upstream and downstream of contracted section. Ideally, contracted and uncontracted sections would be measured concurrently. Effects of local scour should be removed by excluding locally scoured areas when determining average contracted bed elevation. Cross sections that have some subareas with live-bed, and others with clear-water bed-load transport conditions require separate analysis of those subareas (typically channel and overbank areas). Pre- and/or post-flood measurements of uncontracted upstream and downstream sections are often used to establish a contraction scour reference surface. Live-bed contraction scour measurements using this reference surface may be useful if sufficient data support assumption that the geometry of the approach and exit sections change relatively little during high flow. Clear-water contraction scour occurs when sediment is not transported into the scour hole so that geometry of uncontracted section will remain the same after the flood has passed. Therefore, post-flood surveys can be used to measure clear-water contraction scour, although real-time flood measurements of hydraulic characteristics are still desirable. Post-flood surveys should extend downstream beyond the influence of deposited scour-hole material.
Scour-depth accuracy	Units: ft Limits: min = 0.0 Enter estimated accuracy of the scour measurement.
Channel-contraction ratio	Channel-contraction ratio describes the degree of hydraulic contraction at a bridge section as compared with the approach section. Channel-contraction ratio is a measure of the proportion of the total flow that enters the contraction from the sides of the channel. It can be computed from the equation m=(Q-q)/Q, where Q is the total discharge, and q is the discharge in that segment of the approach section determined by projecting the contracted section width up to the approach. The equation is also written as $m=[\ 1-(K_{q}/K_{1})\ ]$, where K_q is the conveyance of that segment of the approach section that conveys q, and K_1 is the total conveyance of the approach section. Reference: Matthai, H.F., Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A4.
Eccentricity	Eccentricity is ratio of conveyances K_a/K_b, where K_a and K_b are the conveyances of the segments of approach section on either side of the K_q segment (see channel-contraction help), or on either side of projected bridge opening width. K_a is always the smaller of the two conveyances. These conveyances are proportional to the flow that must deviate from its natural course to enter the bridge opening. Reference: Matthai, H.F., Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A4.

Table A-20. Contraction scour-data attribute descriptions—Continued

Attribute	Help Information
Pier-contraction ratio	Units: none Limits: 0.0-1.0 Pier-contraction ratio is an area ratio. The total submerged area of the piers or piles projected on a plane defined by the bridge opening section is defined as A_p. The ratio of A_p to the gross area of the bridge opening section is the Pier Contraction Ratio. Reference: Matthai, H.F., Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A4.
Approach flow velocity	Units: ft/sec Limits: min = 0.0 Enter average flow velocity of the approach section, before contraction has an effect.
Contracted channel velocity	Units: ft/sec Limits: min = 0.0 Enter average flow velocity of the contracted channel, in the bridge opening. Enter average flow velocity of contracted channel, in the bridge opening.

Additional contraction scour measurement attributes are shown on the data screen in figure A-19.

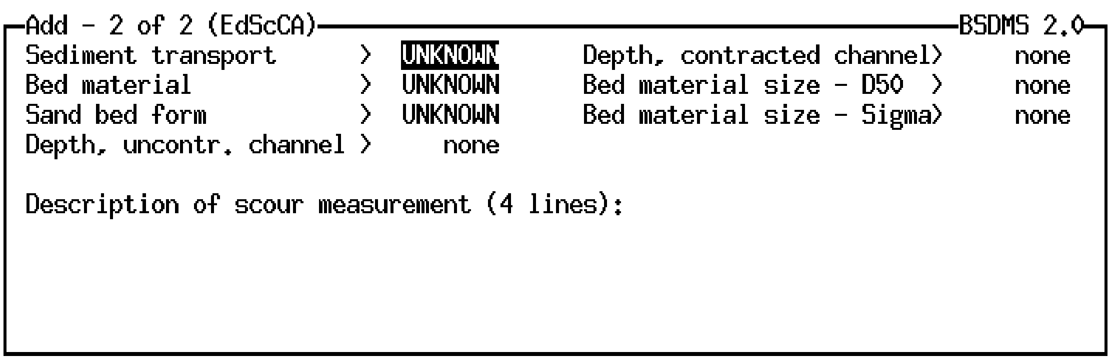


Figure A-19. Additional contraction scour-data screen.

Descriptions of additional contraction scour-data attributes are given in table A-21.

Table A-21. Additional contraction scour-data attribute descriptions

Attribute	Help Information
Sediment transport	See *Help Information* in EDScPA table.
Bed material	See *Help Information* in EDScPA table.
Sandbed form	See *Help Information* in EDScPA table.
Depth, uncontracted channel	<u>Units</u>: ft <u>Limits</u>: min = 0.0 Enter depth of flow in the main channel. This should represent average depth of flow which is actively transporting bed load in the uncontracted section upstream of the bridge.
Depth, contracted channel	<u>Units</u>: ft <u>Limits</u>: min = 0.0 Enter the depth of flow in the contracted section at the bridge. This should represent the average depth of flow which is actively transporting bed load in the contracted section upstream of the bridge.
Bed-material size - D50	See *Help Information* in EDScPA table.
Bed-material size - Sigma	See *Help Information* in EDScPA table.
Description of scour measurement	See *Help Information* in EDScPA table.

General Scour Data

General scour data include general scour measurement attributes.

```
Add - 1 of 2 (EdScGA)                                          BSDMS 2.0
 For General scour measurement being added, enter the following:

                                 Year  Mon  Day  Hr  Min  Sec
Date of scour measurement      > none   no   no  no   no   no
Date of comparison measurement > none   no   no  no   no   no

 Scour depth              >      none      Approach flow velocity >     none
 Scour depth accuracy     >      none      Approach flow depth    >     none
```

Figure A-20. General scour-data screen.

Descriptions of general scour-data attributes are given in table A-22.

Table A-22. General scour-data attribute descriptions

Attribute	Help Information
Date of scour measurement	Enter date of the general scour measurement using the full year (for example, **1991** instead of '91), integers for the month and day, and 24-hour time for the hour of the day the measurement. Enter as close as possible the minute and second the measurement was taken.
Date of comparison measurement	Enter date of the comparison scour measurement using the full year (for example, **1991** instead of '91), integers for the month and day, and 24-hour time for the hour of the day the measurement. Enter as close as possible the minute and second the measurement was taken.
Scour depth	Enter general scour depth for this measurement, in feet. General scour in the study reach is not caused by the bridge crossing. It may be long-term degradation or due to changes in sediment supply or a long, natural channel contraction.
Scour-depth accuracy	Units: ft Limits: min. = 0 Enter estimated accuracy of the scour measurement.
Approach flow velocity	Units: ft/sec Limits: min = 0.0 Enter average flow velocity of the approach section.
Approach flow depth	Units: ft Enter average depth of flow (in feet) of the approach section.
Description of general scour measurement	Enter a brief comment about the scour measurement noting any information that may have affected the reading.

FLOOD-EVENT DATA

Peak flow and hydrograph data associated with scour measurements may be entered in the flood data section.

```
File (EdFF)                                                    BSDMS 2.0
(-Hydrograph->      Name of File
Number   Type       Containing Data
 █        none
          none
          none
          none
          none
          none
          none
          none
```

Figure A-21. Flood-data screen.

Descriptions of flood-event data attributes are given in table A-23.

Table A-23. Flood-event data attribute desciptions

Attribute	Help Information
Hydrograph number	Enter lowest available integer, **1** to **10**, as the number for the hydrograph. Both a *Number* and a *Type* must be specified to define a hydrograph that can then be edited. NOTE: Be sure to enter a new number or an existing hydrograph will be overwritten!
Hydrograph type	Enter type of hydrograph the data represents. Valid: (**S**)tage, (**D**)ischarge Entry of a valid type of hydrograph combined with an identifier (1st field) will define a hydrograph
Name of file containing data	Enter filename and path for the file that contains data for existing hydrographs. File format is: date/time (6 integers) and stage or discharge (1 real) per row, free format. <Year mo da hr mi sec stage/discharge> Example: **1993 06 10 15 20 00 7772**. To create a hydrograph, enter a hydrograph number and type. Leave the 'Name of File...' field blank, and hit 'Accept' (**F2**). Then select Edit to key in data.

The additional flood-data screen is shown in figure A-22.

```
Edit (EdFE)                                                    BSDMS 2.0
 For hydrograph ID 1 DI, edit/enter Date, Time and Discharge values.
 Year Mo Dy Hr Mn Se      Discharge (cfs)
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
 none no no no no no            none
```

Figure A-22. Additional flood-data screen.

Descriptions of additional flood-event data attributes are given in table A-24.

Table A-24. Additional flood-event data attributes descriptions

Attribute	Help Information
Hydrograph date	Enter date of hydrograph using the full year (for example, **1991** instead of '91), integers for the month and day, and 24-hour time for the hour of the day the measurement. Enter as close as possible the minute and second the measurement was taken.
Stage	Enter Stage value for this date and time. A value of 0.0 will be stored as 1.0E-7 to avoid an internal error.
Discharge	Enter Discharge value for this date and time. A value of 0.0 will be stored as 1.0E-7 to avoid an internal error.

CHANNEL-GEOMETRY DATA

The channel-geometry data from which scour depth is measured may be recorded. A description of important aspects of the channel geometry may be recorded in the data screen shown in figure A-23.

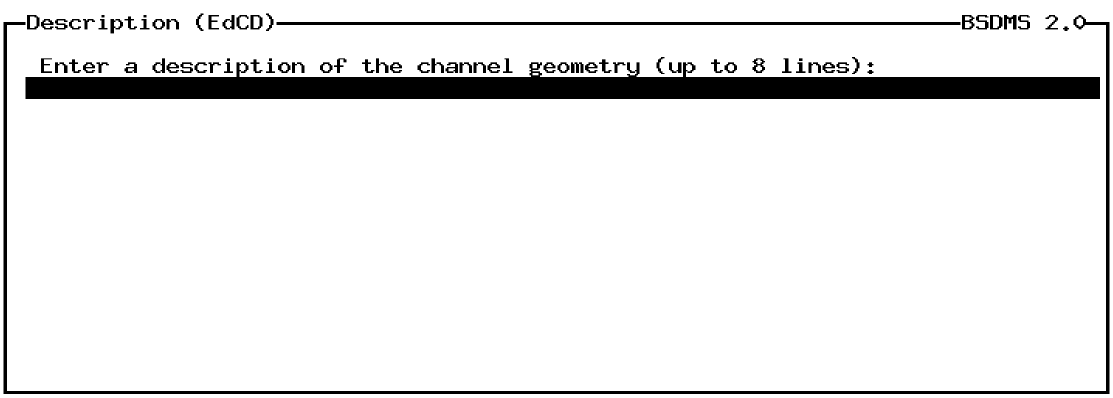


Figure A-23. Channel-data screen.

Descriptions of channel-geometry data attributes are given in table A-25.

Table A-25. Channel-geometry data attribute descriptions

Attribute	Help Information
Description	Channel geometry is stored as station and elevation, with distance from bridge and skew to channel specified for each section. Use the lines to describe characteristics of the channel geometry which are particularly important or dynamic.

Channel-geometry data may be entered from a file using the data screen shown in figure A-24.

```
File (EdCF)------------------------------------------------BSDMS 2.0
Enter date of measurement and name of file containing data for measurement.

Year  Mo  Dy  Hr  Mi   Name of File
none  no  no  no  no
none  no  no  no  no
none  no  no  no  no
none  no  no  no  no
none  no  no  no  no
none  no  no  no  no
none  no  no  no  no
```

Figure A-24. Additional channel-geometry data screen.

Descriptions of channel-geometry data attributes are given in table A-26.

Table A-26. Additional channel-geometry data attribute descriptions

Attribute	Help Information
Measurement date	Enter date of channel measurement using the full year (for example, **1991** instead of ‘91), integers for the month and day, and 24-hour time for the hour of the day the measurement. Enter as close as possible the minute the measurement was taken.
Filename	Enter filename (including path) where channel geometry data for this measurement can be accessed. If channel geometry data is to be entered by hand, leave this field blank, but be sure to specify the date of the measurement.

Channel-geometry data may be entered or edited directly using the data screen shown in figure A-25.

```
Edit (EdCE)--------------------------------------------------------BSDMS 2.0
  Enter/edit the channel geometry values for cross section of 5/5/94 12:00.
NOTE:  Enter the skew and location of this cross-section (see Help)
       in the first row of the Station and Elevation columns.
     Station     Elevation     Coordinate number
         none         none                1
         none         none                2
         none         none                3
         none         none                4
         none         none                5
         none         none                6
         none         none                7
         none         none                8
         none         none                9
         none         none               10
         none         none               11
         none         none               12
```

Figure A-25. Channel cross-section data screen.

Descriptions of channel cross-section data attributes are given in table A-27.

Table A-27. Channel cross-section data attributes

Attribute	Help Information
Station	Enter horizontal station value in feet. The first value in this column is the skew of this section to a perpendicular to the flow. Skew is + (clockwise) or - (counterclockwise).
Elevation	Enter/edit the elevation value. The first value in this column is the upstream (+) or downstream (-) distance from the upstream side of the bridge to this cross section. A value of 0.0 will be stored as 1.0E-7 to avoid an internal error.from the upstream side of the bridge to this cross section.

APPENDIX B—DESCRIPTION OF EQUATIONS

A literature review of bridge-scour equations by McIntosh (1989) found that more than 35 equations have been proposed for estimating local scour at bridge piers. Numerous equations also have been developed for predicting scour at abutments and scour resulting from channel-width contractions. Most local-scour equations are based on research with scale models in laboratory flumes with cohesionless, uniform bed material, and limited field verification (McIntosh, 1989). The contraction-and local-scour equations produce wide ranges of scour-depth estimates for the same set of conditions (Anderson, 1974; Hopkins and others, 1980; Richards, 1991).

Review and evaluation of all published equations were beyond the scope of this study; therefore, a limited number of equations were selected. Consistent notations of variables are used to present and discuss selected equations in this report. Consequently, the notation used herein may not be identical to the notation in the references cited. The variables are defined in the text the first time they are introduced. A complete listing of the symbol variables is provided in the “Symbols” at the front of this report. Many equations are dimensionless; therefore, any units can be used as long as they are consistent. If an equation requires a particular set of units, the units are defined with the equation.

CONTRACTION-SCOUR EQUATIONS

Contraction scour has traditionally been classified as either live-bed or clear-water scour. The live-bed condition occurs when the upstream flow is transporting bedload into the contracted section. The clear-water condition occurs when bedload transport into the contracted section from the upstream flow is negligible. Separate equations have been developed to estimate scour for these two conditions.

Live-Bed Scour

Laursen (1962) used a discharge equation (Manning's equation), a sediment-transport equation (Laursen, 1958), and continuity of discharge and sediment to solve the ratio of depth in a long contraction to a uniform reach. On the basis of these equations and the assumptions associated with them (steady-uniform flow, noncohesive material, and sufficient length of time to achieve equilibrium sediment transport), Laursen developed the following equation:

$$\frac{y_c}{y_u} = \left(\frac{Q_c}{Q_u}\right)^{6/7}\left(\frac{B_u}{B_c}\right)^{6/7\left(\frac{2+a}{3+a}\right)}\left(\frac{n_c}{n_u}\right)^{6/7\left(\frac{a}{3+a}\right)} \qquad (1)$$

where y_c is depth of flow in the contracted channel;

y_u is average depth of flow in the uncontracted channel;

Q_c is discharge in part of the contracted channel represented by the specified bottom width;

Q_u is discharge in the part of the uncontracted or approach channel represented by the specified bottom width;

B_u is bottom width of the active bed in the approach section;

B_c is bottom width of the active bed in the contracted section;

n_c is Manning's roughness coefficient for the part of the contracted channel represented by the specified bottom width;

n_u is Manning's roughness coefficient for the part of the uncontracted or approach channel represented by the specified bottom width; and

a is a coefficient based on the ratio of the shear velocity to the fall velocity in the uncontracted channel.

a	u_*/ω	Mode of bed-material transport
0.25	<0.50	mostly contact bed-material discharge
1.00	0.5-2.0	some suspended bed-material discharge

where u_* is shear velocity, defined as, $\sqrt{gy_uS}$; (g is acceleration of gravity; and S is dimensionless slope of the grade line near the bridge) and

ω is fall velocity of the median grain size of the bed material (Richardson and others, 1991, p. 44, figure 4.2);

According to Laursen (1960, p. 44), "A bridge crossing is in effect a long contraction foreshortened to such an extreme that it has only a beginning and an end." Therefore, the depth of contraction scour at a bridge for live-bed conditions can be derived from equation 1 as

$$y_{sc} = y_u\left(\frac{Q_c}{Q_u}\right)^{6/7}\left(\frac{B_u}{B_c}\right)^{6/7\left(\frac{2+a}{3+a}\right)}\left(\frac{n_c}{n_u}\right)^{6/7\left(\frac{a}{3+a}\right)} - y_u \quad (2)$$

where y_{sc} is depth of contraction scour.

Richardson and others (1991, p. 38) provided two warnings on the use of this equation.

> The Manning's *n* ratio can be significant for a condition of dune bed in the main channel and a corresponding plain bed, washed out dunes, or antidunes in the contracted channel (Richardson and others, 1990). However, Laursen's equation does not correctly account for the increase in transport that will occur as the result of the bed planing out, which decreases resistance to flow and increases velocity and the transport of bed material at the bridge. That is, Laursen's equation indicates a decrease in scour for this case whereas in reality there is an increase in scour depth. Therefore, set the two *n* values equal.
>
> Laursen's equation will overestimate the depth of scour at the bridge if the bridge is located at the upstream end of the contraction or if the contraction is the result of the bridge abutments and piers. At this time, however, it is the best equation available.

Clear-Water Scour

Laursen (1963) developed a relation for scour in a long contraction as a function of channel geometry, flow, and sediment. The relation is based on the proposition that the limiting condition of clear-water scour is a boundary shear equal to the critical tractive force. Laursen assumed that the critical shear stress for noncohesive bed materials could be approximated as

$$\tau_c = 4d_m \quad (3)$$

where τ_c is critical shear stress, in pounds per square foot and

d_m is mean grain size of the bed material, in feet.

This relation is consistent with White (1940) and Shields (1936). Laursen then set the ratio of shear stress in the contracted section to critical shear stress equal to one, and solved for the dimensionless depth of scour,

$$\frac{y_c}{y_u} = 0.13\left(\frac{Q_c}{d_m^{1/3}y_u^{7/6}B_c}\right)^{6/7} - 1 \quad . \quad (4)$$

If the mean diameter of sediment is represented by the more common median diameter, then depth of scour, y_{sc}, yields

$$y_{sc} = \left(\frac{Q_c^2}{120d_{50}^{2/3}B_c^2}\right)^{3/7} - y_u \quad (5)$$

where d_{50} is median grain size of the bed material.

Note: This equation is not dimensionless; y_{sc}, d_{50}, B_c, and y_u are in feet, and Q_c is in cubic feet per second.

Equation 5 is applicable to compute contraction scour at relief bridges for overbank areas beneath bridges. Richardson and others (1993, p. 35) recommend that $1.25d_{50}$ be used for the grain diameter in equation 5 for all conditions. Computational routines in BSDMS use $1.25d_{50}$ to compute clear water-contraction scour, as recommended by Richardson and others (1993, p. 35).

PIER-SCOUR EQUATIONS

Discussions of pier-scour equations should consider how the method of data-collection analysis affect the computed depth of scour. Many papers in the literature lack a good explanation of whether the measured depth of scour represents equilibrium or maximum scour depth. The equilibrium depth of scour is measured after equilibrium sediment transport has occurred and averages the periodic change in bed elevation caused by the movement of bedforms. Equations based on laboratory data are typically developed from and compute equilibrium scour. Some researchers assume that scour measured in the field represents equilibrium conditions; whereas others assume it represents maximum conditions. It is usually impossible to determine the extent to which the equilibrium or maximum condition is represented by a field measurement without continuous monitoring; thus, judgement is required when interpreting field data. The method used to develop the pier-scour equations further complicates the description of which depth of scour is computed by the equations. If a regression analysis is used and additional corrections are not added, the depth of scour computed will not be a maximum scour for all sites, but would be exceeded by approximately half of the data measured. If an envelope curve is drawn above the data and used to develop the equation, then the depth of scour from this equation will, by design, exceed all measured depths of scour. It may be desirable, for design purposes, to use an equation that produces the maximum probable depth of scour, thereby ensuring that the design achieves an acceptable factor of safety. Alternatively, an accurate predictive equation would allow a designer to assign a risk-based factor of safety to a given scour estimate.

Ahmad Equation

Ahmad (1953) concluded from previous work around spur dikes that local scour does not differ with grain size in the range usually found in the alluvial plains of West Pakistan (0.1 to 0.7 mm). He admitted, however, that this conclusion may not be valid for an entire range of bed-material grain sizes. Ahmad (1962) reanalyzed the work of Laursen (1962) with special emphasis on his experience with scour in sand-bed streams in West Pakistan and developed the following equation:

$$y_p = Kq^{2/3} \tag{6}$$

where

$$y_p = y_o + y_{sp} \tag{7}$$

and y_p is depth of flow at the bridge pier, including local pier scour;

y_o is depth of flow just upstream from the bridge pier or abutment, excluding local scour;

y_{sp} is depth of pier scour below the ambient bed;

q is discharge per unit width just upstream from the pier; and

K is a coefficient that is a function of boundary geometry, abutment shape, width of piers, shape of piers, and angle of the approach flow. On the basis of numerous model studies, Ahmad (1962) suggested that the coefficient should be in the range of 1.7 to 2.0 to calculate scour at piers and abutments. For this investigation, it was assumed to be 1.8.

Solving equations 6 and 7 for y_{sp} yields

$$y_{sp} = Kq^{2/3} - y_o \tag{8}$$

Note: Equations 6 and 8 are not dimensionless; y_p, y_{sp}, and y_o are in feet and q is in cubic feet per second per foot.

Equation 8 will be referred to as the “Ahmad equation.”

Blench-Inglis Equation

Inglis (1949) performed numerous experiments on model bridge piers and developed an empirical formula by fitting an equation to the plotted data. Blench (1962) reduced Inglis' (1949) original formula to the form

$$\frac{y_p}{y_r} = 1.8\left(\frac{b}{y_r}\right)^{0.25} \tag{9}$$

where

$$y_r = \left(\frac{q^2}{f_b}\right)^{1/3} \tag{10}$$

and b is width of the bridge pier,

y_r is regime depth of flow, and

f_b is the bed factor.

Blench (1951) stated that the bed factor was related to the nature of the sediment load and defined it as

$$f_b = \frac{V^2}{y} \tag{11}$$

where V is average velocity of the section and

y is average depth of the section.

Equation 11 is not acceptable for estimating the bed factor in the design of regime channels because the velocity will have a direct effect on the width and depth of the channel. Lacey (1936) proposed a rough estimate for the bed factor based on grain size; this relation was modified by other researchers including Blench (1951, 1969). Although the value of the coefficient varies in the literature, a value of 1.9 is common, and will be used herein:

$$f_b = \left(1.9d_{50}\right)^{0.5} \quad . \tag{12}$$

Note: This equation is not dimensionless; d_{50} is in millimeters.

If, in applying regime theory to bridge scour, the average velocity and depth in equation 11 can be approximated by the conditions just upstream of the pier, then equations 7, 9, 10, and 11 can be solved for y_{sp}, and the result is equation 13, which will be referred to as the "Blench-Inglis I equation":

$$y_{sp} = 1.8b^{0.25}q^{0.5}\left(\frac{y_o}{V_o^2}\right)^{0.25} - y_o \tag{13}$$

where V_o is velocity of the approach flow just upstream from the bridge pier or abutment.

However, applying the empirical formula to estimate the bed factor and solving equations 7, 9, 10, and 12 for y_{sp} results in equation 14, which will be referred to as the "Blench-Inglis II equation":

$$y_{sp} = 1.8b^{0.25}\left(\frac{q^2}{1.9d_{50}^{0.5}}\right)^{0.25} - y_o \quad . \tag{14}$$

Note: Because equation 12 was used in the derivation, equation 14 is not dimensionless; y_{sp}, b, and y_o are in feet, q is in cubic feet per second per foot, and d_{50} is in millimeters.

Chitale Equation

A series of experiments on a 1:65 scale model of the Hardings Bridge (Chitale, 1962) was done to determine the influence of the upstream depth and sand diameter on scour around piers. The bed of the flume contained 0.32 mm sand, but four different sands having mean diameters of 0.16 mm, 0.24 mm, 0.68 mm, and 1.51 mm were used in the immediate vicinity of the piers. Each experiment was run until the scour depth reached equilibrium. Chitale (1962, p. 196) observed that

1. maximum depth of scour for aligned flow was always at the nose of the pier. Scour alongside the pier was 5 to 15 percent less;
2. the ratio of scour and flow depth in the channel bears a simple relation to the approach velocity in the channel; and
3. the depth of flow on the upstream channel has an influence on the scour at the pier nose.

Chitale (1962) found that the Froude number provided the best criterion with which to characterize the relative depth of the scour hole, and developed the following equation:

$$\frac{y_{sp}}{y_o} = -5.49\boldsymbol{F}_o^2 + 6.65\boldsymbol{F}_o - 0.51 \qquad (15)$$

where

$$\boldsymbol{F}_o = \frac{V_o}{\sqrt{gy_o}} \qquad (16)$$

$\boldsymbol{F}_o$ is the Froude number of the flow just upstream of the pier and

g is the acceleration of gravity.

Solving equation 15 for y_{sp} results in,

$$y_{sp} = y_o\left(-5.49\boldsymbol{F}_o^2 + 6.65\boldsymbol{F}_o - 0.51\right) \qquad (17)$$

which will be referred to as the “Chitale equation.”

One of the objectives of the model experiments is to determine the influence of sediment size on the depth of scour. The final equation does not account for sediment size; however, a visual analysis of the scatter of data around equation 15 showed that bed-material size can affect the relative depth of scour by as much as a factor of 2 for Froude numbers less than 0.2 but to a lesser extent for Froude numbers greater than 0.2.

HEC-18 Equation

Richardson and others (1975) used all of the available laboratory data for scour at circular piers and developed the following equation:

$$\frac{y_{sp}}{y_o} = 2.0K_1K_2K_3\left(\frac{b}{y_o}\right)^{0.65}F_o^{0.43} \tag{18}$$

where K_1 is a coefficient based on the shape of the pier nose (1.1 for square-nosed piers, 1.0 for circular- or round-nosed piers, 0.9 for sharp-nosed piers, and 1.0 for a group of piers);

K_2 is a coefficient based on the ratio of the pier length to pier width (L/b) and the angle of the approach flow referenced to the bridge pier; and

Angle	L/b=4	L/b=8	L/b=12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

K_3 is a coefficient based on the bed conditions.

Bed condition	Dune height	K_3
Clear-water scour	not applicable	1.1
Plane bed and antidune flow	not applicable	1.1
Small dunes	2-10 feet	1.1
Medium dunes	10-30 feet	1.1-1.2
Large dunes	>30 feet	1.3

Solving equation 18 for y_{sp} yields

$$y_{sp} = 2.0y_oK_1K_2K_3\left(\frac{b}{y_o}\right)^{0.65}F_o^{0.43} \tag{19}$$

which will be referred to as the “Hydraulic Enginary Circular-18 (HEC-18) equation.” Richardson and others (1991) stated that no correction for pier shape should be made if the angle of attack of the approach flow is greater than 5 degrees because, at these greater angles, the pier shape loses its effect.

Froehlich Equation

Froehlich (1988) compiled a several field measurements of local scour at bridge piers. All of the data were collected during sustained high flows and are assumed to represent equilibrium sediment transport through the scour hole. The critical mean-velocity relation presented by Neill (1968) was used to extract only live-bed data from the data set. Linear regression analysis of these live-bed data was used to develop an equation for the maximum relative depth of scour at a bridge pier:

$$\frac{y_{sp}}{b} = 0.32\phi\left(\frac{b'}{b}\right)^{0.62}\left(\frac{y_o}{b}\right)^{0.46}\boldsymbol{F}_o^{0.2}\left(\frac{b}{d_{50}}\right)^{0.08} \tag{20}$$

where b' is width of the bridge pier projected normal to the approach flow

$b' = b\cos(\alpha) + L\sin(\alpha)$;

ϕ is a coefficient based on the shape of the pier nose (1.3 for square-nosed piers, 1.0 for round-nosed piers, 0.7 for sharp-nosed piers);

α is angle of the approach flow referenced to the bridge pier, in degrees; and

L is length of the bridge pier.

Solving equation 20 for y_{sp} results in

$$y_{sp} = 0.32b\phi\left(\frac{b'}{b}\right)^{0.62}\left(\frac{y_o}{b}\right)^{0.46}\boldsymbol{F}_o^{0.2}\left(\frac{b}{d_{50}}\right)^{0.08} \tag{21}$$

which will be referred to as the “Froehlich equation.” Although Raudkivi (1986) showed the standard deviation of the bed material to have a significant influence on the depth of scour, this information was not available for most of the data used to develop equation 20 and was not included in the regression analysis. All of the measured depths of scour were less than the sum of the pier width and the depth of scour computed by equation 21. Froehlich (1988, p. 538) recommended that the depth of scour computed by equation 21 be increased by the width of the pier for design purposes. This will be referred to as the “Froehlich Design equation”.

Inglis-Lacey Equation

The application of the pier-scour equation developed by Inglis (1949) was determined to be difficult because of the effect of local stream geometry on the unit discharge (Joglekar, 1962, p. 184). In addition,

> it has to be remembered that the angle of repose of the bed material in the model and the prototype is the same, hence, the extent of scour in plan in the vertically distorted model is found always relatively greater than in the prototype. This in effect reduces the discharge intensity at the pier due to greater dispersion of flow and hence the depths of scour obtained in the model would be relatively less.(Joglekar, 1962, p. 184)

Data were collected for scour around bridge piers at 17 bridges in India. The discharges at these 17 sites ranged from 29,063 to 2,250,00 ft^3/s, the mean diameter of the bed material ranged from 0.17 to 0.39 mm, and measured flow depths in the scoured areas ranging from 25 to 115 ft (Richards, 1991, p. 35). On the basis of this data, the following formula was developed (Joglekar, 1962, p. 184; Lacey, 1930):

$$y_p = 0.946\left(\frac{Q}{f_b}\right)^{1/3} \quad (22)$$

where

$$f_b = 1.76 d_m^{0.5} \quad (23)$$

and Q is discharge.

<u>Note</u>: Equations 22 and 23 are not dimensionless; y_p is in feet, Q is in cubic feet per second, and d_m is in millimeters. Equation 23 is another published variation of equation 12.

Solving equations 7, 22, and 23 for y_{sp} and substituting the median grain size for the mean grain size results in

$$y_{sp} = 0.946\left(\frac{Q}{1.76 d_{50}^{0.5}}\right)^{1/3} - y_o \quad (24)$$

<u>Note</u>: Equation 24 is not dimensionless; y_{sp}, y_o are in feet, Q is in cubic feet per second, and d_{50} is in millimeters.

Equation 24 will be referred to as the "Inglis-Lacey equation."

Joglekar (1962, p. 184) stated, "a representative f_b value has to be used. From bore data, values of f_b for each strata is to be worked out to ascertain that the anticipated depth is not based on the f_b value which is higher than that appropriate at that depth."

Because the total discharge and depth of flow is included but the width of the channel is not, the approach velocity is not defined. This would seem to limit the application of this formula to streams whose geometric and hydraulic features are similar.

Inglis-Poona Equation

Experiments were done at the Central Water and Power Research Station in Poona, India, in 1938 and 1939 to study scour around a single pier. These studies were done in a flume with sand having a mean diameter of 0.29 mm. On the basis of these studies, Inglis (1949) presented this formula (Joglekar, 1962, p. 184):

$$\frac{y_p}{b} = 1.7\left(\frac{q^{2/3}}{b}\right)^{0.78} \tag{25}$$

Making the appropriate substitutions and solving equation 25 for y_{sp} results in

$$y_{sp} = 1.7b\left(\frac{q^{2/3}}{b}\right)^{0.78} - y_o \tag{26}$$

Note: Equations 25 and 26 are not dimensionless; y_p, y_s, y_o, b are in feet, and q is in cubic feet per second per foot.

which will be referred to as the "Inglis-Poona I equation." This relation is not dimensionally homogeneous; therefore, it is unlikely that it is universally applicable to other bridge-scour data.

From this same set of experiments, Inglis (1949) developed a dimensionally homogeneous equation,

$$\frac{y_p}{b} = 1.73\left(\frac{y_o}{b}\right)^{0.78} \tag{27}$$

which, when solved for y_{sp}, yields

$$y_{sp} = 1.73b\left(\frac{y_o}{b}\right)^{0.78} - y_o \tag{28}$$

which will be referred to as the "Inglis-Poona II equation."

Larras Equation

Larras (1963) defined a stable river as one that transports enough material to maintain the bed at a constant level and an unstable river as one that has inadequate sediment transport to maintain the bed at a constant level. According to Hopkins and others (1980),

> Larras concluded that maximum scouring is independent of the water depth and bed material size if the bed is stable, water depth is greater than 30 to 40 times the size of the bed material, and the channel constriction is less than 10% at the bridge site. The scour depth is a function of the maximum width of the pier, its shape, and flow direction.

Larras (1963) analyzed available scour data from various French rivers and model studies and developed the equation that will be referred to as the "Larras equation":

$$y_{sp} = 1.42 K_{S2} b^{0.75} \tag{29}$$

where K_{S2} is coefficient based on the shape of the pier nose (1.0 for cylindrical piers and 1.4 for rectangular piers).

Larras stated that the depth of scour would be greater in unstable riverbeds than for stable riverbeds because of the inadequate supply of bed material to the scoured area in unstable beds. Because Larras's field measurements were only point measurements of scour depth made after a flood had passed, those data may not properly represent the depth of equilibrium scour (Shen and others, 1969). Equation 29 depends only on pier width and is independent of the hydraulics.

Laursen Equation

"The flow at the crossing cannot be considered uniform, but the solutions for the long contraction can be modified to describe the scour at bridge piers and abutments with the use of experimentally determined coefficients" (Laursen, 1962, p. 170). Laursen manipulated equation 1 to develop a formula which could be used to predict scour at abutments. If a live-bed condition is assumed, the formula is,

$$\frac{l_{ae}}{y_o} = 2.75\left(\frac{y_{ca}}{y_o}\right)\left(\left[\left(\frac{1}{r}\right)\left(\frac{y_{ca}}{y_o}\right) + 1\right]^{1.70} - 1\right) \tag{30}$$

where l_{ae} is effective length of an abutment;

y_{ca} is depth of abutment scour including contraction scour; and

r is a coefficient used to relate scour in a long contraction to scour at an abutment or pier.

Numerous flume experiments were done to evaluate the importance of the length-width ratio of the piers, the angle of attack of the stream against the piers, the approach velocity, the depth of flow, and the sediment size. All data on piers were adjusted to represent scour around a rectangular pier aligned with the flow. Laursen (1962) concluded that the abutment-scour equation with $r = 11.5$ and $l_{ae} = b/2$ fit the data reasonably well. Therefore, the Laursen equation for pier scour is,

$$\frac{b}{y_o} = 5.5\left(\frac{y_{sp}}{y_o}\right)\left(\left[\left(\frac{1}{11.5}\right)\left(\frac{y_{sp}}{y_o}\right) + 1\right]^{1.70} - 1\right) \tag{31}$$

Laursen found that the most important aspect of the geometry of the pier was the angle of attack between the pier and the flow, coupled with the length-width ratio of the pier. The shape of the pier is also important if the pier is aligned with the flow. Therefore, the depth of scour from equation 31 must be corrected for pier shape if the pier is aligned with the flow, so as

$$y_{sp} = K_{S1} y_{sp} \tag{32}$$

and for angle of attack if the pier is not aligned with the flow,

$$y_{sp} = K_{\alpha L} y_{sp} \tag{33}$$

where $K_{\alpha L}$ is a coefficient based on the angle of the approach flow referenced to the bridge pier (fig. B-1); and

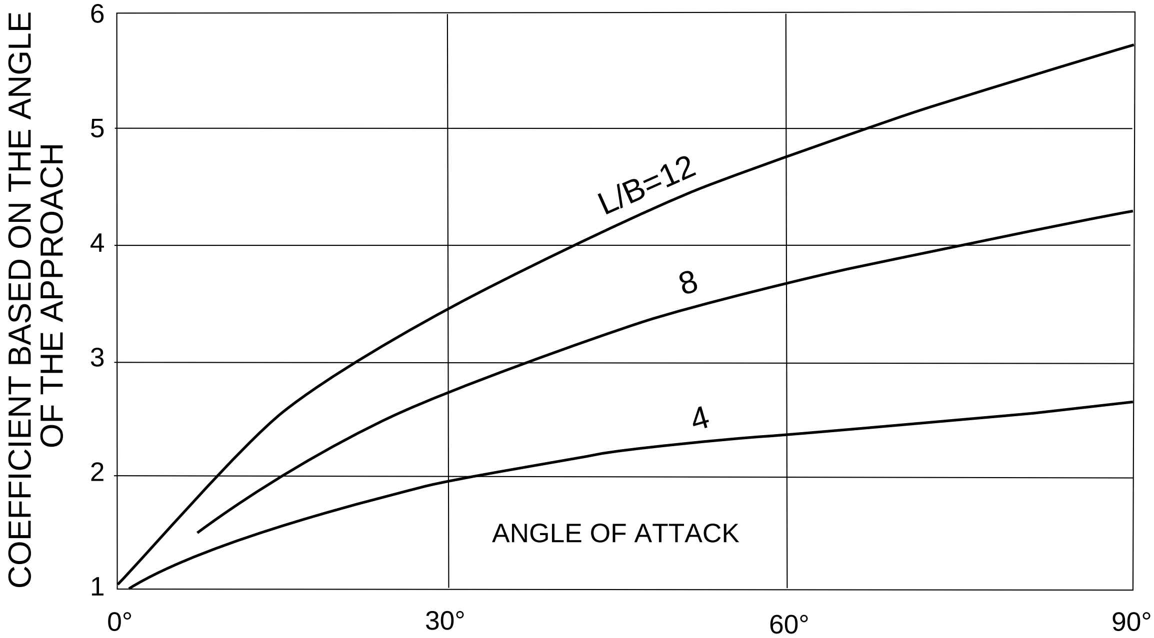


Figure B-1. Effect of angle of attack (from Laursen, 1962, p. 177).

K_{S1} is a coefficient based on the shape of the pier nose (table B-1).

Table B-1. Pier-shape coefficients

[K_{S1}, shape coefficients for nose forms (to be used only for piers aligned with flow); modified from Laursen, 1962, p. 177]

Nose form	Length-width ratio	K_{S1}
Rectangular	—	1.0
Semicircular	1:1	0.90
Elliptic	2:1	0.80
	3:1	0.75
Lenticular	2:1	0.80
	3:1	0.70

Laursen found no significant influence of the velocity or sediment size on the depth of scour for live-bed conditions. Laursen (1962) concluded that the maximum depth of scour was uniquely determined by the geometry and that the width of the scour holes was approximately 2.75 y_{sp}.

Shen Equation

Shen and others (1969) conducted a series of experiments and determined that the basic mechanism of local scour was the vortex systems caused by the pressure field induced by the pier. Further analysis of the vortex systems showed that the strength of the horseshoe vortex system was a function of the pier Reynolds number,

$$\boldsymbol{R}_p = \frac{V_o b}{\nu} \tag{34}$$

where $\boldsymbol{R}_p$ is pier Reynolds number and

ν is kinematic viscosity of water.

According to Shen and others (1969, p. 1925), "Since the horseshoe vortex system is the mechanism of local scour and the strength of the horseshoe vortex system is a function of the pier Reynolds number, the equilibrium depth of scour should be functionally related to the pier Reynolds number."

All known data at the time were used to investigate the influence of the pier Reynolds number on the depth of scour around bridge piers. The analysis showed that the depth of scour rises sharply as the pier Reynolds number increases to a point, then begins to decline as the pier Reynolds number continues to increase. A least-squares regression of the data with a pier Reynold's number less than 50,000 resulted in the following equation:

$$y_{sp} = 0.00073\boldsymbol{R}_p^{0.619} \tag{35}$$

which seems to form an envelope for all data (Shen and other 1969, p. 1931) and will be referred to as the "Shen equation." Evaluation of this equation showed that the effect of pier size prevented the equation from collapsing all of the data into one line, even for a given grain size. A definite separation of the data by sand size also was observed. Therefore, the Shen equation does not adequately account for the pier shape and the size of the bed material. Shen and others (1969) concluded that this equation could be used to provide a conservative estimate of clear-water scour, but that it was too conservative to be used for live-bed conditions. They suggested use of the equations by Larras (1963) and Breusers (1964-1965) for live-bed conditions.

Maza and Sanchez (1964) presented a relation between the ratio of depth of scour to pier width and the pier Froude number. Shen and others (1969) used all the available data in which median grain diameter of bed material was smaller than 0.52 mm in further investigations of the effects of the pier Froude number. They found that, for pier Froude numbers less than 0.2 and fine sands, the depth of scour increased rapidly as the pier Froude number increases; however, for pier Froude numbers greater than 0.2 and coarser sands, the depth of scour increased only moderately for increases in the pier Froude number. Therefore, two equations, which will be referred to as "the Shen-Maza equations," were used to fit the data:

$$y_{sp} = 11.0b\boldsymbol{F}_p^2 \quad for \quad \boldsymbol{F}_p < 0.2 \tag{36}$$

$$y_{sp} = 3.4b\boldsymbol{F}_p^{0.67} \quad for \quad \boldsymbol{F}_p > 0.2 \tag{37}$$

where $\boldsymbol{F}_p$ is pier Froude number, defined as, $\frac{V_o}{\sqrt{gb}}$.

Equation 36 is fundamentally the same equation developed by Maza and Sanchez (1964) and is applicable when the pier Froude numbers are less than 0.2 (Shen and others, 1969). Equation 37 was developed by Shen and others (1969) for pier Froude numbers greater than 0.2. Pier width cancels out equation 36; therefore, equation 36 is based only on velocity, and is unlikely to be generally applicable.

ABUTMENT-SCOUR EQUATIONS

Only abutment-scour equations presented in Richardson and others (1991) are discussed in this report. The Froehlich live-bed abutment-scour equation, however, is the primary equation recommended by Richardson and others (1991) for computing abutment scour. Alternative methods cover several conditions where differing equations are applicable.

Abutment Projecting into a Main Channel Without an Overbank Flow

Liu and others (1961) used dimensional analysis to design a laboratory experiment to study the mechanics of scour at abutments. Two tilting flumes were used in the investigation: one was 160 ft long and 8 ft wide and the other was 80 ft long and 4 ft wide. River sand that had a median diameter of 0.56 mm was used in the 8-ft-wide flume. Two different sands were used in the 4-ft-wide flume, a filter sand that had a median diameter of 0.65 mm and Black Hills sand that had a median diameter of 0.56 mm. Four different abutment configurations were tested: (1) vertical-board, (2) vertical-wall, (3) wing-wall, and (4) spill-through. The depth of scour was measured with respect to the average normal bed surface. Analysis of the major dimensionless parameters by use of data collected for the vertical-wall configuration resulted in the following equation:

$$\frac{y_{sa}}{y_o} = 2.15\left(\frac{l_{at}}{y_o}\right)^{0.4} \boldsymbol{F}_o^{1/3} \qquad (38)$$

where y_{sa} is depth of abutment scour below the ambient bed and

l_{at} is abutment and embankment length measured at the top of the water surface and normal to the side of the channel from where the top of the design flood hits the bank to the other edge of the abutment (Richardson and others, 1991, p. B-7).

Solving equation 38 for y_{sa} results in

$$y_{sa} = 2.15\left(\frac{l_{at}}{y_o}\right)^{0.4} \boldsymbol{F}_o^{1/3} y_o \qquad (39)$$

which can be used to compute live-bed scour at vertical abutments.

Although wing-wall and spill-through abutment configurations were studied and the data were presented, Liu and others (1961, p. 43) did not present an equation with the suitable exponents because, “such an effort is not fully justified due to the limited amount of data.” They did find, however, that the depth of scour for the wing-wall and spill-through abutment configurations generally are less than those for the vertical-wall and vertical-board abutment configurations. Richardson and others (1991, p. B-7) presented the following equation based on Liu and others (1961) for spill-through abutments:

$$\frac{y_{sa}}{y_o} = 1.1\left(\frac{l_{at}}{y_o}\right)^{0.4} \boldsymbol{F}_o^{1/3} \qquad (40)$$

which, when solved for y_{sa}, results in

$$y_{sa} = 1.1\left(\frac{l_{at}}{y_o}\right)^{0.4} \boldsymbol{F}_o^{1/3} y_o \ . \qquad (41)$$

Equation 41 can be used to compute live-bed scour at spill-through abutments.

Liu and others (1961) developed their equations on the basis of equilibrium scour for a dune bed configuration. The maximum depth of scour depends on the bed configuration of the natural stream. Richardson and others (1991, p. B-10) recommend that the equilibrium scour be increased 30 percent for dune bed configurations and 10 percent for antidune bed configurations.

Laursen (1962) manipulated equation 1 to develop the following formula, which can be used to predict live-bed scour at vertical wall abutments:

$$\frac{l_{ae}}{y_o} = 2.75\left(\frac{y_{ca}}{y_o}\right)\left(\left[\left(\frac{y_{ca}}{11.5y_o}\right)+1\right]^{1.70}-1\right) \tag{42}$$

Equation 42 must be solved by an iterative procedure; however, Richardson and others (1991, p. B-8) presented a simplified form,

$$\frac{y_{ca}}{y_o} = 1.5\left(\frac{l_{ae}}{y_o}\right)^{0.48} \tag{43}$$

which can be solved directly for y_{ca} as

$$y_{ca} = 1.5\left(\frac{l_{ae}}{y_o}\right)^{0.48} y_o \ . \tag{44}$$

Laursen’s abutment-scour equations are presented for vertical abutments; however, the following factors are suggested for other abutment types of small encroachment lengths (Richardson and others, 1991, p. B-8):

Abutment type	Multiplying factor
45-degree wing wall	0.90
Spill-through	0.80

Abutment Scour at Relief Bridges

Laursen (1963, p. 100) extended his clear-water contraction-scour equation to abutments, stating:

> The solution for the long contraction serves only as a minimum estimate of the scour to be expected at a relief bridge. However, if the same assumptions can be made concerning the nature of the flow in the clear-water case as in the case with sediment supply by the stream, the solution for the long contraction can be adapted to the case of the abutment (and the case of the pier). The key observations in the case of sediment-transporting flow were that the flow approaching the obstruction dived beneath the surface and passed through the constriction in a somewhat distorted conical scour hole centered at the upstream corner of the abutment, and that the flow approaching the clear opening was little disturbed.

Laursen (1963, p. 102) presented the following equation for computing clear-water scour at vertical abutments,

$$\frac{l_{ae}}{y_o} = 2.75\left(\frac{y_{ca}}{y_o}\right)\left(\frac{\left(\frac{y_{ca}}{12y_o}+1\right)^{7/6}}{\left(\frac{\tau_o'}{\tau_c}\right)^{0.5}} - 1\right) \tag{45}$$

where τ_o' is shear stress for the approach flow associated with the sediment particles and

τ_c is critical shear stress, which can be obtained from figure B-2.

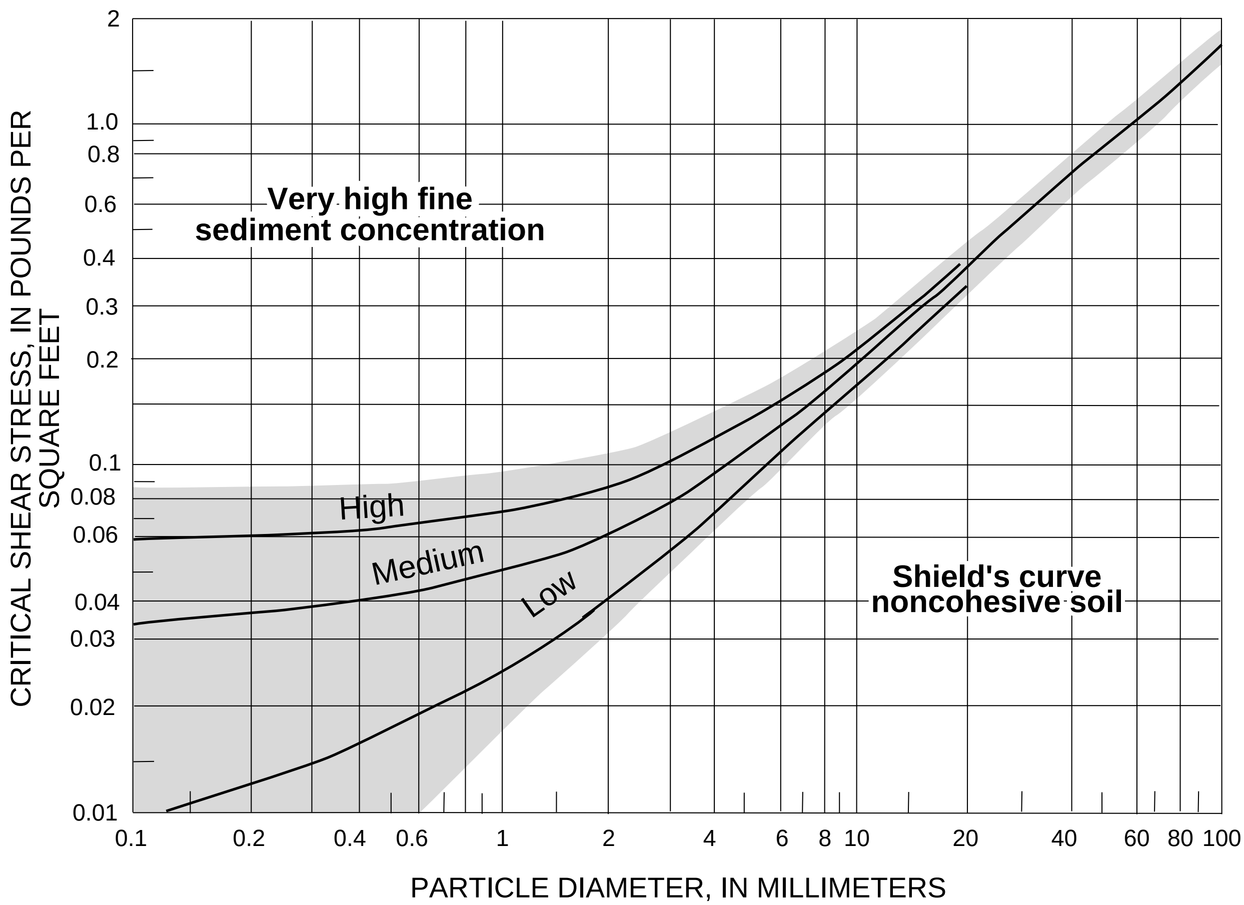


Figure B-2. Critical shear stress as a function of bed-material size and suspended fine sediment.

An iterative solution is required to solve equation 45 for y_{ca}. Laursen (1963, p. 102) assumed a coefficient of 12, based on experience for similar situations in sediment transporting flows. Richardson and others (1991, p. B-8), however, used 11.5 instead of 12.

Laursen's clear-water abutment-scour equation is applicable to abutments at relief bridges. If there is sufficient evidence to suggest that bedload transport will occur, Laursen's live-bed abutment-scour equation can be applied.

Abutment Projecting into a Channel with Overbank Flow

Laursen's equations 42, 44, and 45 can be used to calculate live-bed and clear-water scour when the abutment projects into the main channel and overbank flow is present. The abutment length for this situation should be determined from the following equation (Richardson and others, 1991, p. B-13):

$$l_{ae} = \frac{Q_e}{y_o V_o} \tag{46}$$

where Q_e is discharge obstructed by the embankment.

Abutment Set Back from a Main Channel

Laursen (1962, p. 174) stated, "The effect of setting the abutment back from the normal bank of the stream is difficult to assess. In the laboratory experiments no measurable effect could be noted." If the abutment is set back more than 2.75 times the depth of scour, y_{ca}, Laursen's equations can be used to compute the abutment scour by evaluating the variables on the basis of the flow on the overbank being obstructed by the abutment (Richardson and others, 1991, p. B-14). Typically the overbank flow will not be transporting bed material, and Laursen's clear-water abutment-scour equation should be applied. If there is sufficient evidence to suggest that bedload transport will occur on the overbank, Laursen's live-bed abutment-scour equation can be applied.

Abutment Set at Edge of a Main Channel

When there is no bedload transport on the overbank, the scour for a vertical-wall abutment set at the edge of the main channel can be computed from the following equation proposed by Laursen (1980) (Richardson and others, 1991, p. B-16):

$$\frac{Q_e}{q_{mc} y_o} = 2.75 \frac{y_{ca}}{y_o}\left(\left(\frac{y_{ca}}{4.1 y_o} + 1\right)^{7/6} - 1\right) \tag{47}$$

where q_{mc} is discharge per unit width in the main channel.

An iterative solution is required to solve equation 47 for the depth of scour, y_{ca}.

Long Abutments

Scour data collected at rock dikes on the Mississippi River indicate that equilibrium scour depths for large abutment length to depth of flow ratios (l_{at}/y_o)>25) can be estimated by the following equation (Richardson and others, 1991, p. B-18):

$$y_{sa} = 4\boldsymbol{F}_o^{1/3} y_o\ . \tag{48}$$

Abutments Skewed to a Stream

When abutments are skewed to the direction of flow in the stream, the scour at the abutment angled downstream is reduced because of the streamlining effect of the angle. Conversely, the scour at the abutment angled upstream is increased. The abutment-scour depths computed by use of equations 39, 41, 42, 44, 45, 47, and 48 should be corrected by use of figure B-3, which is patterned after work by Ahmad (1953) (Richardson and others, 1991, p. B-18).

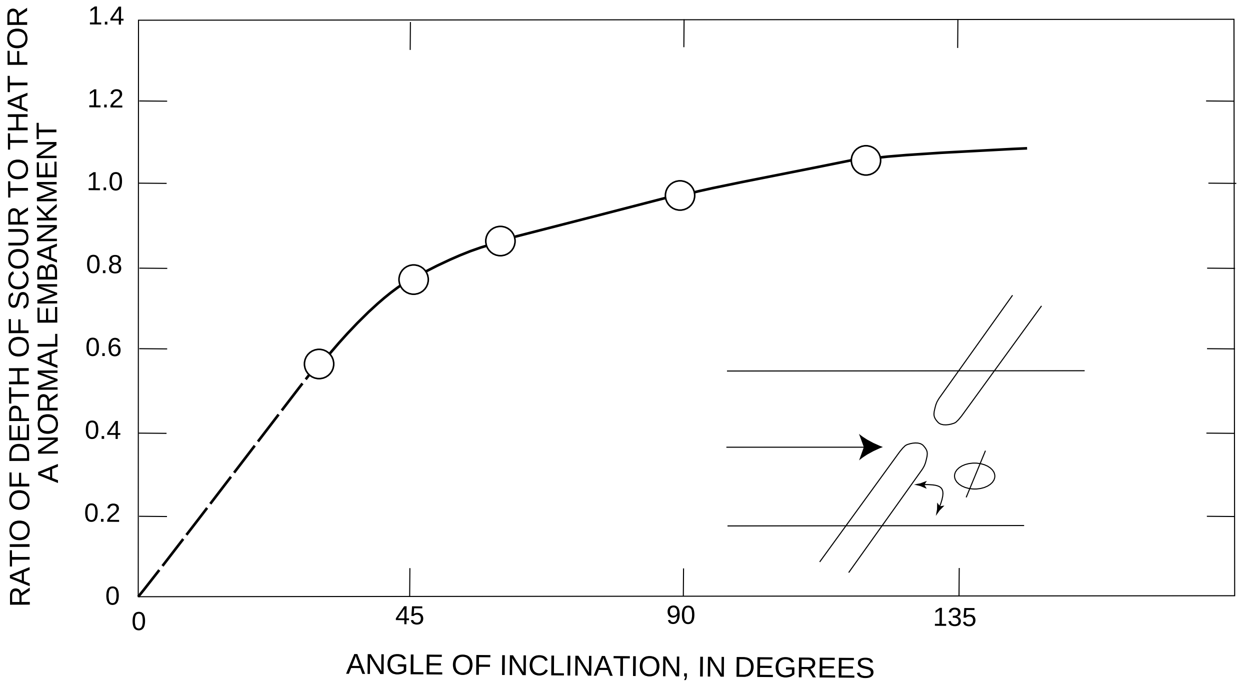


Figure B-3. Scour-estimate adjustment for skew [modified from Richardson and others, 1991, p. B-19].

Froehlich's Live-Bed Equation

Froehlich (1989) used multiple linear regression on 164 clear-water and 170 live-bed laboratory measurements of the maximum depth of local scour at model abutments to develop clear-water and live-bed abutment-scour equations. Because Froehlich's clear-water scour equation requires the standard deviation of the bed-material size distribution (which was not readily available at the selected sites) and because the equation is not currently recommended (Richardson and others,1991, p. 48), this equation was not evaluated in this study. Froehlich's live-bed abutment-scour regression equation is as follows:

$$\frac{y_{sa}}{y_{oa}} = 2.27 K_{sa} K_{\theta} \left(\frac{l}{y_{oa}}\right)^{0.43} \boldsymbol{F}_a^{0.61} \qquad (49)$$

where K_{sa} is a coefficient based on the geometry of the abutment (1.0 for a vertical abutment that has square or rounded corners and a vertical embankment, 0.82 for a vertical abutment that has wing walls and a sloped embankment, and 0.55 for a spill-through abutment and a sloped embankment)

K_{θ} is a coefficient based on the inclination of an approach roadway embankment to the direction of the flow, $K_{\theta} = \left(\frac{\theta}{90}\right)^{0.13}$;

l is length of an abutment, defined as, A_e / y_{oa} ;

A_e is cross-sectional area of the flow obstructed by the embankment;

y_{oa} is depth of flow at the abutment;

$\boldsymbol{F}_a$ is Froude number of the flow obstructed by the abutment, defined as, $\boldsymbol{F}_a = \frac{\left(\frac{Q_e}{A_e}\right)}{\sqrt{g y_o}}$; and

θ is angle of inclination of an embankment to the flow, in degrees; $\theta < 90°$ if the embankment points downstream.

Equation 49 is a linear least-squares regression equation that minimizes the residual error. For design purposes, it may be preferable to compute the maximum scour which could be expected. Analysis of the data showed that the sum of the depth of flow at the abutment and the computed scour from equation 49 is equal to or greater than 98 percent of the observed values. Solving equation 49 for depth of scour, y_{sa}, and including the flow depth as a margin of safety yields

$$y_{sa} = 2.27 K_{sa} K_{\theta} \left(\frac{l}{y_{oa}}\right)^{0.43} \boldsymbol{F}_a^{0.61} y_{oa} + y_{oa} \qquad (50)$$

which is recommended for all abutment configurations (Richardson and others, 1991, p. B-9).

APPENDIX C—SPECIAL FILES

Three files are associated with the interaction between the user and the program. The optional TERM.DAT file is used to change some aspects of how the program operates. The BSDMS.LOG file records keystrokes entered during a program session. Error and warning messages are written to the ERROR.FIL file if problems arise during a program session. The ERROR.FIL file also can contain messages that document the processing sequence of the program.

TERM.DAT

A TERM.DAT file is used to override the default values of parameters that define the configuration of the computer system and the user's preferences. The program looks for a TERM.DAT file in the current directory. The parameters include terminal type, the program response to the Enter key, and graphics options. Table C-1 describes the TERM.DAT parameters showing the default values as set for DOS-based computers, for DG/UX-based (Data General/UNIX) computers, and for other UNIX-based computers. A parameter is overridden by specifying its keyword and the new value in the TERM.DAT file. One record is used to define each parameter—with the keyword beginning in column 1 and the value beginning in column 8.

Table C-1. TERM.DAT parameters

Parameter keyword	Default values			Valid values	Description
	DOS	DG/UX	Other UNIX		
TRMTYP	PC	VT100	VT100	PC VT100 OTHER	Terminal type.
MENCRA	NEXT	NEXT	NEXT	NONE DOWN NEXT	Program response to Enter key.
USRLEV	0	0	0	0 to 2	User experience level: 0=lots, 1=some, 2=none.
GRAPHS	YES	YES	YES	NO YES	Is a software library for graphics generation available?
GKSDIS	1	1100	4	0-9999[a]	GKS code number for workstation type for display terminal.
GKPREC	CHAR	STROKE	CHAR	STRING CHAR STROKE	Text precision.
GKSCFT	1	1	1	-9999 to 9999[a]	Text font for screen.
BCOLOR	BLACK	BLACK	BLACK	WHITE BLACK OTHER	Background color of graphics screen display.
BGRED	0	0	0	0 to 100	Percent red for background of graphics screen display if BCOLOR=OTHER.
BGREEN	0	0	0	0 to 100	Percent green for background of graphics screen display if BCOLOR=OTHER.
BGBLUE	0	0	0	0 to 100	Percent blue for background of graphics screen display if BCOLOR=OTHER.
PBCOLR	WHITE	WHITE	WHITE	WHITE BLACK	Foreground color of graphics screen display.
SYMSIZ	100	100	100	1 to 10000	Symbol size ratio in hundredths.
TXTEXF	133	100	100	0 to 200	Text expansion factor in hundredths.
TXTCHS	0	0	0	0 to 200	Text character spacing in hundredths.

[a]Refer to GKS documentation and README file supplied with the program to determine valid values for these parameters.

The value of the MENCRA parameter and the data panel type control how the program responds when the Enter key is pressed. Table C-2 describes the program response for the various combinations of MENCRA values and data panel type. The default value for the MENCRA parameter is "NEXT".

Table C-2. MENCRA values and corresponding program response

MENCRA	Data panel contents	Program response when Enter is pressed
NEXT	menu	Same as if Accept (F2) were executed: the highlighted menu option is selected and the program advances to the next screen.
	form	For all but the last field on the form, causes the cursor to advance to the next field. For the last field on the form, the response is the same as for Accept (F2)—the program advances to the next screen. (Note: usually the rightmost, lowest field is the "last" field in the form. Occasionally, however, it is not!)
	table	For each row, the cursor advances across the fields in the row. For all but the last row, the cursor advances from the last field in the row to the first field of the next row. For the last row, the cursor advances to the beginning of the last row. (Use Accept (F2) to advance to the next page of the table.)
	text	Same as if Accept (F2) were executed—the program advances to the next screen.
NONE	menu	No effect—it is ignored.
	form	Cursor is advanced to the next field. When the cursor is in the last field, the cursor cycles back to the first field.
	table	For each row, the cursor advances across the fields in the row. For all but the last row, the cursor advances from the last field in the row to the first field of the next row. For the last row, the cursor advances to the beginning of the last row. (Use Accept (F2) to advance to the next page of the table.)
	text	No effect—it is ignored.
DOWN	menu	Same as if the down arrow were pressed: the highlight bar moves to the next menu option. When the highlight bar is on the last menu option, it returns to the first menu option.
	form	Cursor is advanced to the next field. When the cursor is in the last field, the cursor cycles back to the first field.
	table	For each row, the cursor advances across the fields in the row. For all but the last row, the cursor advances from the last field in the row to the first field of the next row. For the last row, the cursor advances to the beginning of the last row. (Use Accept (F2) to advance to the next page of the table.)
	text	No effect—it is ignored.

Figure C-1 shows an example TERM.DAT file that overrides the default BLACK background color of the graphics display. The parameter BCOLOR is set to OTHER and the parameters BGRED and BGBLUE are set to 40 and 60, respectively. The resulting graphics screen display background will be a shade of purple. In addition to the parameters described in table C-1, there are five parameters that can be used to set the foreground and background colors of parts of the program screen on DOS-based computers. These parameters are described in table C-3.

Figure C-1. Example TERM.DAT.

```
BCOLOR OTHER
BGRED  40
BGREEN 0
BGBLUE 60
```

Table C-3. TERM.DAT parameters for color display (DOS-based computers)

Parameter keyword	Default value	Allowable values[a]	Description
CLRFRS	15	0 to 15	Standard foreground color.
CLRBKS	1	0 to 15	Standard background color.
CLRFRE	7	0 to 15	Foreground color for error messages in instruction panel.
CLRBKE	4	0 to 15	Background color for error messages in instruction panel.
CLRFRD	14	0 to 15	Color of first letter of commands in command mode.

[a]0-black, 1-blue, 2-green, 3-cyan, 4-red, 5-magenta, 6-brown, 7-light gray, 8-dark gray, 9-bright blue, 10-bright green, 11-bright cyan, 12-bright red, 13-bright magenta, 14-yellow, 15-white

BSDMS.LOG

A file named BSDMS.LOG is created each time the program is run. This file contains the sequence of keystrokes entered during a program session. It may be used as an input to the program in a later session. To keep the sequence of keystrokes, you must rename the file because the program will overwrite any file named BSDMS.LOG. Keystrokes of nonprinting keys, such as the backspace and function keys, are represented in the file by special codes. Table C-4 lists each code and its definition. Menu options are chosen in one of two ways—either press the first letter(s) of a menu option, or position the cursor with the arrow keys and then Accept (F2). Using the first method will make the log file easier to interpret and modify. Using the letter "x" for making option selections also will help. Table C-5 contains an annotated example log file for a program session that opens a BSD file and gets a summary of the contents of the file.

Table C-4. Codes used for nonprinting characters in a log file

Code	User's keystroke	Associated command	Code	User's keystroke	Associated command
#227	; or Esc[a]		#401	F1	Help
#208	Backspace		#402	F2	Accept
#213	Return or Enter		#403	F3	
#301	↑		#404	F4	Prev
#302	↓		#405	F5	Limits
#303	→		#406	F6	Intrpt
#304	←		#407	F7	Status
#307	Page Up		#408	F8	Quiet
#308	Page Down				

[a]The Escape key is only functional on DOS-based computers.

Table C-5. Description of example log file

Line	Contents	Explanation
1	fotest.bsd	The File option was selected from the Opening screen menu. The Open option was selected from the File (F) screen menu. The file name test.bsd was entered in the Open (FO) screen.
2	#402	Accept, function key F2, was executed, causing the test.bsd file to be opened.
3	s	The Summarize option was selected from the File (F) screen menu.
4	#402	After the summary of the contents of the test.bsd file had been viewed, Accept, function key F2, was executed.
5	rex	The Return option was selected from the File (F) screen menu. The EXit option was selected from the Opening screen menu.

Log files can be used to easily repeat a task, or they can be modified to perform a similar task. A log file may contain all of the keystrokes required for a complete program session, or it may contain the keystrokes for part of a program session. A subset of a session might consist of the keystrokes required to select a particular set of data sets; this log file would be used whenever that set of data was needed.

A log file may be entered at any point in the program by typing "@"; in the small panel that appears, type the name of the log file. The program will run using the input from the file just as if it were being typed in. The program and the log file must be synchronized; if the keystrokes in the log file get out of sync with the program, the program response may produce unpredictable results. A common cause of synchronization problems involves output files. If an output file did not exist when the log file was generated and does exist when the log file is read by the program, the program may ask if it is OK to overwrite the existing file. Because the keystrokes required to answer this question are not in the log file, the program will probably do something unexpected.