Stream Stability and Scour Assessments at Bridges in Massachusetts

By Gene W. Parker, Lisa Bratton, and David S. Armstrong

U.S. GEOLOGICAL SURVEY
Open-File Report 97-558

Prepared in cooperation with the
MASSACHUSETTS HIGHWAY DEPARTMENT
BRIDGE SECTION

Marlborough, Massachusetts
1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For addtional information write to:

Chief, Massachusetts-Rhode Island District
U.S. Geological Survey
W ater Resources Division
28 Lord Road, Suite 280
Marlborough, MA 01752

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286, Federal Center
Denver, CO 80225-0286

PREFACE

This Open-File report in CD-ROM format documents the hydrologic and geomorphic data gathered from visits to 2,361 bridge sites in Massachusetts. The report is the culmination of a concerted effort by dedicated personnel and volunteers for science of the U.S. Geological Survey and of the Massachusetts Highway Department who collected, compiled, verified, and organized the data, and who typed, edited, assembled, and programmed the report into the electronic format you see. In addition to the authors, who had primary responsibility for ensuring that the information contained herein is accurate, complete, and adheres to U.S. Geological Survey policy and established guidelines, the following individuals contributed significantly to the collection, processing, and tabulation of the data:

Erick M. Boehmler
Megan E. Bohlen
Seth H. Bock
Robert G. Breault
Robert P. Bultman
Robert G. Casey
Linda Y. Comeau
Scott M. Craig
Kirstin Depitro
Timothy H. Diehl
Shannon G. Dionne
Joseph Donahue
Maura R. Ducharme
Brendan P. Finn
Erin L. Galvin
Benjamin P. Gresser
Erin A. Haight
Mark C. Hanson
Noel M. Hurley, Jr.
Carl D. Johnsen
Victoria J. Kelley
Mary H. Kruger
Tracy A. Kruger
Charles R. Leighton
George J. Lemay
Melanie R. Lombardo
Theodore P. Lyman
Peter J. Murphy
Richard Murphy
Paul Nardone
J. Michael Norris
Marianne F. Orlando
Lance J. Ostiguy
Harlow Pinson
Paul L. Provencher
John C. Rader
Eleanor J. Searles
George M. Sechen, Jr.
Timothy M. Shanahan
Jennifer A. Shields
Joshua B. Smith
Kirk P. Smith
Peter A Steeves
Brett O. Stock
Jeffrey L. Strause
Lora K. Striker
Glen A. Warren
Holly Warren
Linda P. Warren
Anne M. Weaver
Bruce N. Weinstock
Joan S. Whitley
Joseph F. Whitley
Sigrid Wohlrab
Joseph L. Zanca

This CD was programmed by George J. Lemay and Lance J. Ostiguy. This report was prepared in cooperation with the Massachusetts Highway Department under the general supervision of Wayne H. Sonntag, Massachusetts-Rhode Island District Chief and J. Michael Norris, Massachusetts-Rhode Island Associate District Chief.

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STREAM STABILITY AND SCOUR ASSESSMENTS AT BRIDGES IN MASSACHUSETTS

By G.W. Parker, Lisa Bratton, and David S. Armstrong

ABSTRACT

In 1989, the Federal Highway Administration mandated that every state establish a program to evaluate the vulnerability to floods of all bridges over water. The Massachusetts Highway Department entered into a cooperative effort with the U.S. Geological Survey to comply with this mandate. Geomorphic and hydraulic characteristics were collected and were used to assess the processes that affect stream stability and current scour problems and potential near 2,361 bridge sites in Massachusetts. As a result of these assessments, the Massachusetts Highway Department will prioritize the bridge inventory for action regarding scour safety. A data base was prepared that includes the geomorphic and hydraulic data collected during field assessments. In addition to the data base, this report includes the historical development of the bridge scour program, the methods used for data collection during assessments, the methods used for quality assurance and quality control, and how the data base was digitally formatted to be presented on a CD-ROM. A user's guide provides assistance in the use of this electronic data base and report.

INTRODUCTION

Bridge failures are one of the most significant concerns of the transportation industry. Scouring of the streambed around piers and abutments has resulted in more bridge failures during flood events than all other causes (Richardson and others, 1993). Two factors play a role in these bridge failures. The first factor is the natural movement of the stream with time. This stream instability can be general horizontal movement such as stream meandering or a vertical movement such as aggradation or degradation. Meandering also has a vertical component because the meander cuts into the streambed as it moves laterally. The second factor is structurally-induced scour, which occurs along the bridge foundation elements (abutments and piers). For this report, scour is the movement of streambed material as the result of flowing water. Although scour may occur during normal flows, the process is especially active during periods of high energy and turbulence typically found during major floods.

After the 1987 failure of the Schoharie Creek bridge in New York, the Federal Highway Administration (FHWA) mandated every state to examine bridges over water for problems related to stream stability and potential for existing scour (U.S. Department of Transportation, 1991). In 1992, the U.S. Geological Survey (USGS) in cooperation with the Massachusetts Highway Department (MHD) began a project to assess the stream stability and streambed scour in the vicinity of all bridges longer than 20 feet. The information gathered during the assessments will be used by bridge engineers to aid in prioritizing maintenance and repairs. The assessments were made in addition to the standard structural-safety inspections that are routinely completed by the MHD.

Purpose and Scope

The purpose of this electronic report is to furnish the MHD with a compact disk-read only memory (CD-ROM) data base with geomorphic and hydraulic information on 2,361 bridges longer than 20 feet and over water in Massachusetts. The information in the data base was collected over a four year period from 1992 to 1995. This data base will assist the MHD in complying with the FHWA mandate to evaluate the bridge sites for scour problems.

Acknowledgments

The authors wish to acknowledge the personnel of the Massachusetts Highway Department for their cooperation and assistance throughout this investigation. In particular, the authors would like to thank Paul Nardone and Richard Murphy for their assistance in conducting field assessment and project planning. Thanks also go to Joe Donahue and his inspection divers and all the MHD District Bridge Inspection Engineers who provided assistance and information at the difficult, deep water and multi-lane bridge sites. Special thanks go to Peter J. Murphy of the USGS Massachusetts-Rhode Island District, who did the initial compilation of the glossary found at the end of this report. The authors also would like to acknowledge the many private citizens who willingly came forward with descriptions of floods that have occurred at the many bridge sites visited.

DATA COLLECTION AND FIELD PROCEDURES

Historical Data

Selected historical data were collected from the MHD office files to assist in the planning of the field assessments. Information collected included bridge location, name of the waterway, bridge length, bridge type, bridge department number, bridge key number, bridge identification number (BIN), and the latitude and longitude of the bridge. Information on previously observed scour problems also were recorded. Other information included number of spans, year the structure was built, average daily traffic, rip rap or other foundation protection, and other data pertaining to the bridge structure. If available, the map showing the bridge location was copied from the files. The bridge plans were reviewed when available to provide data on the foundation type, low chord elevation, channel-bed elevation, boring information, benchmark location, flood history and whether or not the bridge is over a tidal waterway. Topographic maps were reviewed to provide information on the possibility of flow regulation and locations of dams, confluences, and USGS surface-water gaging stations. These data were collected for planning purposes only and are not included in the CD-ROM data base. The historical data are available for inspection at the USGS Massachusetts-Rhode Island District office in Marlborough, Massachusetts.

The historical data were used to familiarize the field assessor with background information on each bridge site, and to assist in the location and identification of bridges. Lists of bridges to be assessed were provided to assessment teams. Field assessors would then review the historical data, determine bridge locations, and plan trip routes. Recent MHD dive inspection reports were reviewed to determine water depths and to identify site problems.

Field Assessments

The general techniques used for field assessments were similar for most bridge sites. However, some bridge sites or channel reaches having specific or unique problems required different techniques. Sites assessed ranged from 20-foot long, arch bridges over small mountain brooks to mile-long, suspension bridges over major tidal waterways. The following is a description of the typical approach and methods used for a stream stability and scour assessment.

A general convention was used in descriptions of the bridge and channel and to describe the orientation and location of physical attributes such as scour and confluences. This convention used the words right and left to refer to directions that would be reported by an observer facing downstream. Distances were measured upstream and downstream from the bridge. Frequent references are made to distances of one or two bridge lengths upstream or downstream of the bridge, where one bridge length is defined as the distance between bridge abutments. Measurement accuracy was 0.5 foot for distances of linear measurements and 5 degrees for angular measurements. Other characteristics were described by making a selection from a list of predetermined ranges of measurements or descriptive choices. Unusual channel characteristics were detailed in descriptive comment fields.

When the depth of the water was less than 4 feet, channel depths were measured using a graduated range pole, or a measuring tape or tagline with a weight attached. When the depth of water was greater than 4 feet, channel depths were measured using a boat and a bathymetric sounding device. Measuring tapes and optical range finders were used to determine horizontal distances. An inclinometer was used to measure vertical angles, and a compass was used to measure horizontal angles. For tall bridges having deep water, a total station and bathymetric sounding device were used in conjunction with a computer and software package that would digitally record the surveyed locations and elevations.

Assessments usually progressed from the bridge deck to the upstream area, to the under bridge area, to the downstream area, and, finally, back to the bridge deck. The field assessment form was divided into sections called summary, deck, upstream, under bridge, piers, debris, downstream, cross-section, and sketch. Assessments were conducted by wading, using hip boots or waders, or by using boats. The boats used were either a canoe, an inflatable boat, a kayak, a float tube, or a motor boat. Channel cross sections were typically measured along the downstream side of the bridge from the left abutment to the right abutment. The cross section was referenced to the low chord of the bridge structure or to mean sea level. A stage of reach evolution describes the state of the channel as being undisturbed, constructed, stable, aggredational, vertically unstable, horizontally unstable, or vertically and horizontally unstable. The stage of reach evolution was interpreted after weighing all of the geomorphic and hydraulic evidence of stream stability. Additional documentation of site characteristics included video tape recordings or photographs, and plan-view sketches of the assessment area.

The procedures for tidal bridges were the same as for non-tidal bridges, with a few exceptions. These exceptions include the additional measurement of attack angles for the tidal inflow and outflow, and the recording of the time that the various parts of the assessment were completed to compensate for the changing of the depth of water as the result of tides.

Videos, Photographs, And Sketches

The assessments of geomorphic and hydraulic conditions were by video tape recordings (videos) or photographs, and plan-view sketches of the site. Verbal descriptions of site conditions were included in the videos to supplement written descriptions made during the field assessments. The videos and sketches were used extensively for quality assurance and quality control of individual assessments. Computer images of individual video frames, photographs and sketches were digitally captured and included in the CD-ROM data base.

Field Procedures

Videos or photographs were made during the field assessments to identify and describe the important site characteristics and features of each bridge site. Upstream and downstream views of the bridge and channel were recorded. Videos also documented of scour, geomorphic conditions of the stream channel and banks, exposed footers or undermining of piers and abutments, and any obvious structural problems. A final 360-degree pan of the entire assessment area from the bridge deck was made at the end of each field assessment to re-emphasize important features or processes

All videos were made at the time of the field assessment except in a few cases where revisits were necessary to provide better image frames or to complete a set of standard image frames for the assessment reports. In a few cases, still photographs were taken during the assessment. Still cameras were used only as backups for the videos during cases of equipment failure.

Sketches also were completed at the time of assessment using standardized symbols (fig. 1). Each sketch provides a plan view of the location and orientation of the bridge with respect to the channel, including location of wing walls, bed and bank protection, and piers. The sketches also may include identification of land use, location of structures in the floodplain, depth of water in the channel, location of the thalweg and debris, and location and depth of scour.

Office Procedures

Videos collected during field assessments are stored at the USGS Massachusetts-Rhode Island District office in Marlborough, Mass. The videos have been have been used for quality assurance and quality control reviews of the assessments, and for examination of local site conditions before starting detailed scour studies. Videos have also been used for prioritization of scour-critical bridges.

Four standard views for each bridge were selected from the videos or photographs to be included in each bridge assessment report. These four views are the following:

1. the upstream bridge face,
2. the upstream channel looking upstream from the bridge,
3. the downstream bridge face, and
4. the downstream channel looking downstream from the bridge.

Individual digital images were captured from selected frames from the videos selecting the best possible view of the 4 standard views. Images were saved to files at 320 x 240 dots per inch resolution in a standard digital image format. The image files were transferred to the CD-ROM data base. A scanner was used to capture digital images of the plan-view sketches and photographs. Some captured images were adjusted for brightness and sharpness, to delete extraneous lines, and to clarify written details on the sketches. Photograph and sketch images were saved to files in standard digital image format at the same resolution as was used for the video images. The image files were transfer to the CD-ROM data base.

Electronic Assessment Form

Field Procedures

Shortly after the field assessment, the field data were entered into an electronic assessment form using laptop computers. Data and comments were checked for correctness during data entry. The electronic assessment form simulated the paper field forms used during the field assessments. The first page of the form contains information on bridge site identification and specific information that can be gathered from the bridge deck. The subsequent pages were for data collected upstream of the bridge site, in the under-bridge area, and from the downstream area. Additional pages were for debris, piers and bridge cross section. The final pages were for description of the stage of channel evolution and description of the video tape taken of the bridge site at the time of assessment.

Office Procedure

After the data was typed into the electronic form, the form was saved onto a floppy disk for temporary storage. The data were transferred from the temporary storage disk and merged into a master electronic data base at the office. Detailed explanations of the specific data fields incorporated in the data base can be found in the Glossary at the end of this report. The ‘MA SCOUR NO.’ is a data field calculated using an algorithm provided by the Massachusetts Highway Department (Paul Nardone, written comm., 1997). The algorithm uses information from the data base to calculate a number that ranges from 0 to 9. The numeric range has 0 being associated with a site having many observable or potential problems and 9 being associated with a site having no observable or potential problems. For more information about the ‘MA SCOUR NO.’, please contact Paul Nardone at the Massachusetts Highway Department, Bridge Section, 10 Park Plaza, Boston, Massachusetts.

Quality Assurance and Quality Control

Quality assurance and quality control were important aspects of the project because of the number of personnel and quantity of data being collected. The data collection phase of the study covered 4 years and the number and backgrounds of personnel varied continuously. Training and quality reviews were constant activities required to maintain a consistent quality of data collection.

Training

In addition to academic and practical experience in geomorphic and hydraulic processes, all field assessors attended the Federal Highway Administrations training program on stream stability and bridge scour. All project personnel received local training on identifying and describing geomorphic and hydraulic processes before they were approved as primary assessors. Many assessors also attended a bridge safety inspection course. Assessors were also encouraged to take local university courses explaining scour processes. Some of the assessors attended research conferences related to bridge scour and stream stability.

Group Reviews and Multiple Assessments

Monthly assessment-technique-review meetings were held with project staff to discuss all aspects of the field assessments and to review work conducted at individual assessment sites. Each Spring, the entire project staff would conduct a group assessment of a selected bridge. Periodically, selected bridge sites were also assessed by multiple individuals. These multiple assessments assured that all assessors were consistent in their techniques of detection, description and measurement of scour and stream stability.

Review and Validation of Data Base

The data base manager made spot checks on field assessment data prior to incorporation into the master data base. This enabled the detection and correction of systematic errors in field data entry. An intensive, one-time quality check was made by the primary assessors to verify the data in the master data base was correct and consistent. A validation check was made by running a program on the data base which tested all data fields for valid entries. Data fields that had invalid entries were identified for review and correction. A final complete technical review of the entire master data base was accomplished by experienced field assessors. Comment and data fields were examined to determine if any errors, omissions, or inconsistencies existed. When errors, omissions, or inconsistencies were found, they were corrected. Comment fields were not corrected for grammar

Global Positioning System Procedures

The MHD maintains records of the latitude and longitude of the 2,361 bridges over water. These locations were accurate only within 0.5 mile or were in error. The USGS and MHD agreed to include corrected bridge location as a field in the data base. The location of each bridge was determined to an average accuracy of 30 feet through the use of a Global Positioning System (GPS). GPS signals were recorded from a minimum of four satellites, to meet this accuracy. Latitude and longitude data were collected at both ends of open bridges and at one end of closed bridges. At dual, divided-highway bridges, such as Interstate highways, only one of the two bridges was located. Location data were periodically downloaded to a computer for further processing.

The latitude and longitude location data for each bridge site required additional processing to meet the required accuracy. This processing required that the bridge location data be corrected using GPS data collected at a reference location. For this project, the reference-location data were provided by the University of Rhode Island in Kingston, Rhode Island. Once the latitude and longitude were processed, the corrected location data were recorded in the master data base.

The GPS information from the master data base was used to create a map coverage in a Geographic Information System (GIS). This GIS coverage was initially used for quality control checks on bridge locations. Where necessary, revisits to bridge sites were made to collect additional GPS location data. The GIS bridge-location coverage was combined with hydrography and road coverages to create the town maps at the front of this CD-ROM report.

CD-ROM USERS GUIDE

The CD-ROM Stream Stability and Scour data base consists of nine sections of geomorphic- and hydraulic-characteristic information, descriptive comments, and images collected during the field assessments. The information available on each page is detailed in the sections named SITE SUMMARY, GENERAL CONDITIONS, UPSTREAM, UNDER BRIDGE, PROTECTION AND DEBRIS, PIER 1-6, DOWNSTREAM, CROSS SECTION, and SITE SKETCH. Many of the terms and procedures used on these sections and in this text are defined in the Glossary at the end of this report. The database is divided onto 2 CD-ROMS with Massachusetts Highway Districts 1, 2, and 3 (western and central Massachusetts) on one CD-ROM, and Massachusetts Highway Districts 4 and 5 (eastern Massachusetts) on the other CD-ROM.

General Users Information

The minimum equipment required to access the CD-ROM report and data base are a personal computer (PC) that can run Windows 3.1 or Windows 95, a 256 color video monitor, 4 megabytes of ram and a CD-ROM drive. For optimum visual display of maps and data, the video display should be set to 256 colors, 1024 pixels, and large fonts. Any printer options available in the application will be sent to the default printer.

To run the CD-ROM application for the Stream Stability and Scour data base:

1) For Windows 95:

a) Put the CD-ROM for the appropriate area of Massachusetts into the CD-ROM drive.

b) Select Start with the left mouse button.

c) Select Run.

d) Type “your CD Drive letter”:\sbrts\bridges.exe and select OK.

For example, if your CD Drive is D: then you would type:

“D:\sbrts\bridges.exe”.

2) For Windows 3.1:

a) Put the CD-ROM for the appropriate area of Massachusetts into the CD-ROM drive.

b) Select File Run in the Program Manager

c) Type “your CD Drive letter”:\sbrts\bridges.exe and select OK.

For example, if your CD Drive is D: then you would type:

“D:\sbrts\bridges.exe”.

This CD-ROM has been produced in accordance with the ISO 9660 CD-ROM Standard and is therefore capable of being read on any platform that has the appropriate CD-ROM driver software.

The CD-ROM was prepared on June 26, 1997:
Department of Interior
U.S. Geological Survey - WRD
Massachusetts-Rhode Island District
Marlborough, MA 01752.

Prepared by George Lemay, USGS, Marlborough, MA 01752

For questions about this CD-ROM, contact: glemay@usgs.gov or phone: (508) 490-5062.

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Accessing the Database Using the CD-ROM Application

Names for all windows in this CD-ROM will be referred to by the window title bar and in this report in uppercase letters with single quotes (example: 'MENU'). All command buttons described in this report are written in **bold** *italics* with single quotes (example: '***Report*** '). Command buttons can be used with a mouse or "fast keys". "Fast keys" are a method of activating a command button by simultaneously depressing two keys, the "Alt" key and the letter key underlined on a command button's label.

After an automatic sequence of windows introducing the Stream Stability and Scour Assessments at Bridges in Massachusetts CD, the program will halt at a window called 'MENU'. Control of the program is allowed only at the end of the automatic window sequence.

‘MENU’ Window

The ‘MENU’ window provides a main link to other windows. The operator may select from the following choices:

a) ‘***Report***’ -- This button allows the user to view the various windows of the report text.

b) ‘***District 1, 2, and 3***’ and ‘***District 4 and 5***’ -- Selecting the appropriate button will bring the user to a window called ‘MASSACHUSETTS HIGHWAY DISTRICTS’. If the button selected is not appropriate with the CD being used, a warning box will be displayed. From the ‘MASSACHUSETTS HIGHWAY DISTRICTS’ window, the users can go through a series of more detailed maps to select and view assessment data for a bridge site.

c) ‘***Data for bridge***’-- This button will display a window with a request box giving the user an opportunity to enter a bridge department identification number. Acceptance of the bridge department identification number will open a window to view the data for that bridge site.

d) ‘***Quit***’,-- Use this button to exit the CD program. The program also can be terminated by depressing the *‘X’* button located in the uppermost top right corner of the title bar ‘STREAM STABILITY AND SCOUR ASSESSMENTS AT BRIDGES IN MASSACHUSETTS’ window.

MASSACHUSETTS HIGHWAY DISTRICTS' Window

The 'MASSACHUSETTS HIGHWAY DISTRICTS' Window requests the user to select a highway district from a map of Massachusetts. The active districts for each CD-ROM are shaded in green and have bold highway district numbers. The ***'Menu'*** button can be used to return to the 'MENU' window. When a district is selected, the program pauses while it loads the 'MASSACHUSETTS HIGHWAY DISTRICT (1,2,3,4,OR 5)' window containing a detailed map of the chosen district.

‘MASSACHUSETTS HIGHWAY DISTRICT (1,2,3,4, OR 5)’ Window

On the ‘MASSACHUSETTS HIGHWAY DISTRICT (1,2,3,4, OR 5)’ window, the user views all the towns in which assessments were made in that district. Towns are marked with a labeling code of the first three characters of the bridge department identification number. Indexes for the town codes are listed to the left and right of the district map. Selecting a town location on the map will open a window showing a more detailed town map and locations of all the bridges assessed. At this point, the user can select a labeled bridge. Selection of a labeled bridge will open a ‘HIGHWAY DISTRICT-DATA-’ window showing stream stability and scour assessment data for the bridge. Bridge department identification numbers that are labeled yellow are non-tidal sites, while bridge department identification numbers labeled in light blue are tidal sites. The town maps also provide other information such as lines of transportation and hydrologic features. Due to screen and map size limitations, these features are unlabeled. The unlabeled features are distinguished by color. The Interstates are depicted in dark blue. The state routes and U.S. routes are red. The paved and unpaved roads are black. And the Massachusetts Turnpike is green. Rivers, streams, lakes, and ponds are depicted in light blue.

The user may return to the current district map by selecting the ***‘District (1,2,3,4, or 5) Map’*** button. Selecting either ‘***District 1, 2, and 3’*** or ***‘District 4, and 5’*** button will bring the user back to the ‘MASSACHUSETTS HIGHWAY DISTRICTS’ window where a new district can be selected from the map.

‘HIGHWAY DISTRICT-DATA-‘ Windows

The assessment data are presented on nine ‘HIGHWAY DISTRICT-DATA-‘ windows. Information contained on these windows are generally described in the list below:

a) SITE SUMMARY .... date of assessment, and bridge location

b) GENERAL CONDITIONS .... overall channel assessment

c) UPSTREAM......................... upstream channel data

d) UNDER BRIDGE .... channel data in close proximity to the bridge

e) PROTECTION & DEBRIS.... fluvial protection and debris information

f) PIERS 1- 6 .... data for up to 18 piers can be examined

g) DOWNSTREAM .... downstream channel data

h) CROSS SECTION .... bed profiles usually on the downstream side

i) SITE SKETCH .... a plan view sketch of the assessment area

On each window, buttons are available for the user to browse through the remaining ‘HIGHWAY DISTRICT-DATA-‘ windows. These buttons are: ***‘Site Summary’***, ***‘General’***, ***‘Upstream’***, ***‘Under’***, ***‘Protection’***, ***‘Piers’***, ***‘Downstream’***, ***‘Cross Section’***, or ***‘Site Sketch’***. A ***‘Print’*** button is present on all windows to print the assessment data in the current window.

The SITE SUMMARY window contains several additional buttons. One of these buttons, ‘***Print all Pages’*** allows printing of all assessment data windows for the currently displayed bridge site. A ‘***District Map (1,2, 3, 4, or 5)***’ button is available for each highway district on the instatlled CD. The ‘***Display new bridge’*** button functions exactly as the ‘***Data for bridge’*** button mentioned above. ‘***Select a new Bridge by Town’*** button is another means of locating a bridge record without having to use the district maps. To select a bridge record by using a town’s name, select the ***‘Select a Bridge by Town’*** button located near the bottom right of the SITE SUMMARY window.

‘SELECT A BRIDGE BY TOWN’ Window

The ‘SELECT A BRIDGE BY TOWN’ window is divided into two or three sections depending upon which CD is being used. The CD for Massachusetts Highway Districts 1,2, and 3 has only two sections, while the CD for Massachusetts Highway Districts 4 and 5 has three sections. This difference is due to the lack of tidal streams in Massachusetts Highway Districts 1, 2, and 3.

The center gray section contains the town name for the bridge site selected. Select the bridge department identification number from the lists adjacent to the center section to choose another bridge site in the same town. The lists include the site vicinity and route locations next to the bridge department identification numbers. A slide bar on the right of the lists can be used to display bridge sites in the town that are not shown in the window. Non-tidal bridge sites are listed above the center section. This section is labeled RIVER SITE. The tidal bridge sites are listed below the center section. This section is labeled OCEAN SITE. The CD-ROM for Massachusetts Districts 1, 2, and 3, only the section RIVER SITE appears in the ‘SELECT A BRIDGE BY TOWN’ window.

To choose a bridge site in a different town, select the button called ***‘New Town’***. The ***‘New Town’*** button opens a small request box displayed above the center of the current window. The box allows the user to type in a town name. If the entered town name is misspelled, is on the other CD, or did not have any bridge sites assessed, the ‘SELECT A BRIDGE BY TOWN’ window will display the next town alphabetically available.

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GLOSSARY

Abutment:	A substructure supporting the end of a single span or the extreme end of a multi-span superstructure and, in general, retaining or supporting the approach embankment.
Abutment Angle:	The angle of the abutment face referenced to the horizontal, as measured with a inclinometer.
Abutment Exposure:	The amount of exposure along the abutment is identified as none, footer exposed, undermined, settled, or failed.
Abutment Scour:	The amount of erosion along an abutment is identified as none, slight, moderate and severe.
Aggradation:	The general and progressive buildup of the longitudinal profile of a channel bed as the result of sediment deposition. Aggradation can be natural or man-induced.
Alluvial fan:	A fan-shaped deposit of material at the place where a stream issues from a narrow valley of high slope onto a plain or broad valley of low slope. An alluvial cone is made of the finer materials that were suspended in the flow while a debris cone is a mixture of all sizes and kinds of material.
Alluvium:	The unconsolidated material deposited in water by a stream.
Anabranch:	The individual channel of an anabranched stream.
Anabranched stream:	A stream whose flow is divided at normal and lower stages by large islands or, more rarely, by large bars; individual islands or bars are wider than about three times the water width; channels are more widely and distinctly separated than in a braided stream.
Angle of approach:	The angle of approach is the measured angle of a stream's flow as it approaches a bridge and referenced to the angle of the flow exiting away from the bridge.
Apron:	The protective material laid on a streambed to resist scour.
Approach:	The channel bank and stream bed area upstream of the bridge.
Armor:	The surfacing of the channel bed, banks, bridge piers and abutments, or road embankments which resist erosion and scour.

Armoring:	(a)The natural process whereby an erosion-resistant layer of relatively large particles is formed on a streambed due to the removal of finer particles by stream flow, (b) the placement of a man-made or natural covering to resist erosion.
Attack Angle:	The angle by which flow enters the area under the bridge and impacts and referenced to the abutment or pier walls. The direction in which the flow is diverted or pushed towards is determined as either the left bank or the right bank.
Average annual flood:	The maximum flood discharge that is not exceeded on average, every year
Average depth:	The depth obtained by dividing the cross-sectional area of flow normal to the flow direction by the top width of the stream channel.
Backwater:	The increase in water surface elevation above normal elevation induced by a natural contraction, a bridge, or other structure that obstructs or constricts the stream channel.
Backwater profile:	The water surface elevation profile of the water backed up by a channel blockage.
Backwater area:	The low-lying land adjacent to a stream that becomes flooded by a backwater.
Banks:	The side slopes of a channel which confine average annual flood.
Bank angles:	The average angles above the horizontal of the side slopes of a channel up to the 'top of bank'. The bank angle is measured using a compass equipped with a clinometer.
Bank erosion:	The bank erosion data field corresponds to the intensity of the fluvial erosion observed along the banks and is denoted by: none, mass wasting, light fluvial erosion, heavy fluvial erosion. Mass wasting occurs when a bank is heavily eroded and the bank material loses its cohesiveness and the bank collapses as slump blocks. Light fluvial erosion is characterized by slight but noticeable sediment removal from the banks of generally low to medium gradient streams. Heavy fluvial erosion is usually manifested by the formation of cutbanks and pointbars, tree root exposure, or undermined banks.

Bank height:	The vertical distance between the toe of the bank, where it meets the bottom of the stream bed, and the top of the bank. The bank height is measured, using a graduated range rod, by sighting a geomorphic indicators of the top of bank.
Bank material:	Corresponds to a lithologic description of the bank material such as sand, silt/clay, gravel, cobble, boulder, bedrock, alluvium, or man-made. If the bank is armored, the material under the protection is considered as the bank material, not the protection.
Bank other than abutment:	A bank other than the abutment is termed a bank if there is a natural accumulation of sediment along the abutment wall under the bridge. In order to be termed a bank, the average annual flood must not reach above the natural bank.
Bank protection:	The engineering works like rip rap for the purpose of protecting streambanks from erosion.
Bank walls:	The engineering works, usually concrete walls, for the purpose of replacing the natural bank material.
Bank width	The bank width is a linear measurement across the channel between the geomorphic indicators of the top of bank. The bank width defines the width of the water surface during an average, annual flood.
Bank, left/right:	The left/right bank is the side of the channel on the left/right as viewed facing in a downstream direction.
Bar:	An elongated deposit of alluvium within a channel, not permanently vegetated.
Base flow:	The condition when all the discharge in a channel is from ground water.
Bed:	The bottom of the stream channel bounded by banks.
Bed form:	A relief feature on the bottom of a channel, such as a ripple, dune or bar.
Bed layer:	A flow layer, several grain diameters thick (usually two), immediately above the bed.
Bed load:	The sediment that is transported in a stream by rolling, sliding, or skipping along the bed or very close to it; the load is considered to be within the bed layer.

Channel reach: The length along a stream where the channel cross section does not change significantly.

Channel widening: An increase in channel width caused by lateral erosion of the channel banks.

Channel width: The horizontal distance across a channel, normal to the flow, between the points of intersection of the water surface and the banks during the flow conditions at the time of the assessment.

Check dam: A low dam or weir across a channel used to control stage or degradation.

Choking (of flow): The constriction of flow which causes a backwater effect.

Cobble: A piece of rock or mineral with an average diameter greater than 64 millimeters and less than 256 millimeters.

Comment fields: A field for descriptive comments beyond what is normally detailed that elaborates on the type, location, morphology, bounds, and other descriptive elements of a specific area being observed.

Confluence: The junction of two or more streams or a man-made pipe joining a stream. Confluences may be flowing or intermittent.

Constriction: A natural or artificial control section, such as a bridge crossing, a narrow channel reach or a dam, through which the upstream water surface elevation is related to discharge.

Constructed bank: A channel bank that is protected from lateral erosion by rip-rap, concrete walls, gabions, or other structures.

Contraction: The effect of channel constriction on flow streamlines.

Contraction scour: The erosion as the result of increased velocity of flowing water that has occurred as the result of contracting of the river flow through a narrow opening. The erosion occurs most frequently when associated with flood events.

Countermeasure: A measure intended to prevent, delay or reduce the severity of hydraulic problems.

Crib: A frame structure filled with earth or stone ballast, designed to deflect the stream flow away from a bank or embankment.

Crossing/crossover: The relatively shallow reach of a stream between bends.

Cross-section:	The flow area normal to the direction of flow in a channel.
Culvert:	A drainage structure beneath an embankment.
Current:	Flowing water through a channel.
Cut bank:	The concave, nearly vertical, side slope of a stream.
Cutoff:	A natural or artificial channel across the neck of a meander loop.
Debris/ drift:	The floating or submerged material, such as logs, brush or trash, transported by a stream.
Debris capture efficiency:	The debris capture efficiency is indicative of the bridge's ability to prevent debris from passing through the bridge opening, thereby capturing the debris at the bridge at a low, medium, or high rate.
Debris potential:	The debris potential corresponds to the potential for forest litter, slumping trees, and woody brush, to enter the channel and is described as low, medium, or high. The debris potential also depends on the amount of erosion and undermining along the banks and on the vegetation cover on the banks.
Debris stack:	The fallen trees, brush or trash that is deposited in a channel or near the bridge opening, typically upstream of piers and abutments, and that reduces the available flow area at the bridge.
Deflected flow:	The flow that is redirected towards piers, abutments or channel banks due to debris in the channel or by an impact point on channel banks.
Degradation(bed):	A general and progressive lowering of the channel bed due to scour.
Delta:	An alluvial deposit, usually triangular, and at the mouth of a river.
Depth of scour:	The vertical distance a streambed is lowered below a reference elevation by scour, usually below the thalweg elevation.
Discharge:	The volume rate of water flowing in a channel, usually measured in cubic feet per second or cubic meters per second.
Distance:	The distance to the middle of a feature is measured from the upstream or downstream bridge face to the middle of the feature.
Eddy current:	A vortex or whirlpool motion of the water flowing at the edge of the main current, such as the circular movement that occurs alongside the main flow when the main flow becomes separated from the bank.

Erosion: The displacement of soil or rock particles as the result of the force of wind or water.

Erosion Protection: The channel and bridge area is more often protected from erosion with rip rap then other types of protection. The rip rap comes in a variety of diameters such as less than 9 inches spherical, 9 - 16 inches spherical and greater than 16 inches spherical. Other types of protection may include retaining walls and concrete aprons. This type of protection is indicated as poured concrete or man-made. Protection may also be described as being absent.

Fetch: The horizontal distance in the direction facing into the wind, over which the wind generates waves.

Fine sediment: See silt.

Flood plain: A nearly flat, alluvial region bordering a stream, that is subject to inundation by floods.

Footing: The lower portion of a structure which distributes the structures load to the earth or supporting piles.

Froude number: A dimensionless number that represents the ratio of kinetic and gravitational energy. High Froude numbers are indicative of high flow velocity and can indicate high potential for scour.

Flow: See discharge.

Fluvial erosion: The channel-bank erosion that is characterized by particle failure of bank material and stable banks.

Gabion: A basket or compartmented rectangular container made of galvanized steel wire mesh and filled with course gravel or cobbles. It can serve as a filter and as riprap.

General scour: The general erosion of a streambed as the result of flowing water that has occurred over a long period of time and general in area of extent.

Geomorphology The branch of physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary rock and the buildup of erosional debris.

Getaway: The channel bank and stream bed area downstream of the bridge crossing that contribute to the conveyance of flows through that stream reach.

Glacial deposits: The earth material that has been moved, deposited, and sorted as the result of glacial fluvial activity.

Glacial till: The earth material that has been moved but unsorted by glacial activity.

Gravel: An accumulation of pieces of rock or mineral with an average diameter greater than 0.08 inch or 2.5 inches.

Grout: The mortar placed between or around stones or pipe to seal out water.

High flow: The flow in a channel at a stage equal to the top of banks or higher.

Hydraulics: The physical science and technology of the static and dynamic behavior of fluids.

Hydrology: The study of the properties, distribution and effects of water in the atmosphere, on the earth's surface and in soil and rocks.

Impact point: The location in a channel where the water collides with the banks or bridge structure and may cause a wearing away of bank or bridge material.

Incised stream: A stream that has cut down through the streambed of the valley floor.

Island: A permanently vegetated area, emergent at non-high stage, that divides the flow of a stream.

Jetty: (a) An obstruction built of piles, rock, or other material extending from a bank into a stream, so placed as to induce scouring or bank building, or to protect against erosion. (b) A similar obstruction to influence stream, lake, or tidal currents, or to protect a harbor.

Meander impact The point in a meander bend where the flow impacts the outer channel bank.

Meandering channel: A channel exhibiting a characteristic process of bank erosion and point bar deposition associated with systematically shifting meanders.

Mid-bar width: The width of the pointbar measured from left bank to right where the bar is widest.

Mid-channel bar: A bar lacking permanent vegetative cover that divides the flow in a channel at low flows.

Migration: Change in position of a channel by lateral erosion of one bank and simultaneous accretion of the opposite bank.

Normal flow: The streamflow prevailing on average during any year.

Normal stage: The water level prevailing on average during any year.

Overflow bridge: An overflow bridge is a smaller bridge or a culvert built as part of the same channel crossing. Overflow structures usually are constructed on a flood plain adjacent to the structure crossing the waterway. The purpose of an overflow structure is to expand the main channel crossing's stability by diverting the flow through the overflow structure during high flow.

Oxbow: The abandoned bow-shaped or horseshoe-shaped reach of a former meander loop that remains after a stream cuts a new, shorter channel across the narrow neck between closely approaching bends of a meander.

Pier: A supporting structural member at the junction of connected bridge spans. Piers have foundations that are set within the material underlying the channel bed.

Pier cross-members: The structural cross-members between piers or between the piles of a bent. The choices for this column are: none, laterals, diagonals or both laterals and diagonals.

Pier fender: A protective fender may be found around the pier in areas of boat traffic. A yes or no is found in this field.

Pier footing: The designation that can be given for the pier footing can be yes, no, or unknown.

Pier length: The pier length from the upstream side of the bridge to the downstream side.

Pier location: The location of the pier relative to the channel. The choices are left flood plain, left top of bank, left bank, main channel left, main channel middle, main channel right, right bank, right top of bank, and right flood plain.

Pier material: The material used to construct a pier, which may be wood, concrete, metal, or stone.

Pier nose incline: The pier nose may be inclined or not. A yes or no is found in this field.

Pier shape: The shape of the pier nose may be round, square, or pointed.

Pier type: The type of pier is a solid pier, columns, or bents.

Pier width: The width of the pier when looking at the bridge face from upstream of the bridge.

Pier, number of piles/columns: The number of multiple piles or columns in a pier.

Pile: A shaft-like linear member that carries load through water or weak layers of soil.

Pile cap:	The uppermost part of a pile that secures the piles in position and provides a bridge seat to receive and distribute the superstructure loads.
Point bar:	An alluvial deposit of sand, gravel, or cobbles that lacks permanent vegetative cover. Point bars usually occur in a channel at the inside of a meander loop.
Pool:	A pool is a reach of water where the water surface is smooth and undisturbed, and generally occurs in a low gradient, deeper reach of the channel.
Pressure flow:	The flow that occurs when stream stages reach the low-chord elevation of the bridge.
Protection condition:	The erosion protection is described in terms of its condition with: good condition, weathered, or slumped. The protection is considered to be "weathered" if some movement has occurred and "slumped" if it is displaced into the channel as the result of flow impact.
Rangefinder:	An electronic instrument that is used in the field for measuring horizontal distances greater than 50 feet.
Range pole:	A graduated, eight-foot long pole that is used in the field for measuring distances less than 16 feet.
Reach:	A segment of stream length where the channel cross section does not change significantly.
Revetment:	Rigid or flexible armor placed to inhibit scour and lateral erosion.
Riffle:	A natural, shallow flow area in the channel bed in which the surface of flowing water is broken by waves or bed material. Riffles usually alternate with pools along the length of a stream channel.
Rip rap:	A layer or facing of cut or broken rock that is placed to protect a bridge or embankment from erosion.

Road approach:	The road approach describes the roadway near the bridge as lower, even, or higher than the bridge deck.
Road approach threat:	A road approach can be threatened by a meander impact, road wash, or other conditions. The impact upstream and impact downstream values are numeric codes that describe the severity of the aforementioned threats as none, slight, moderate, or severe.
Road embankment:	The man-made sides of a road approach.
Roughness coefficient:	The numerical measure of the frictional resistance to flow in a channel, as in the Manning and Strikler formulas.
Sand:	A sediment that has an average particle diameter of between 0.0025 inch and 0.079 inch.
Scour:	The erosion of bed material as the result of flowing water.
Scour length:	The linear distance along the scour hole perpendicular to the scour width.
Scour rating:	The summation of all assigned numerical-index values to specific characteristics as determined by Massachusetts Highway Department (written communication, 1995).
Scour width:	The distance measured across the scour hole from left to right.
Sediment or fluvial sediment:	The loose material derived from rock that is transported, suspended, or deposited by water.
Seepage:	The slow movement of water through small pores and cracks in the bank material.
Sill:	A structure like a very low dam built on the stream bed transverse to the channel. These structures are used to control the bed level.

Silt: The sedimentary material whose average diameter is between 0.00016 inch and 0.0025 inch.

Sinuosity: The ratio between the thalweg length and the valley length of the channel of a stream.

Skew: The angle between the alignment of an abutment or pier and the bankfull flow path of water approaching the abutment or pier.

Sloping abutment: A bridge abutment having a fill slope on the streamward side.

Slump: Down slope sliding of earth material when the toe of a bank erodes and the bank can no longer support the weight above it.

Spread Footing: A footing that is wider than the structure above it.

Spur dike/guide bank: A dike extending upstream from the approach embankment at either or both sides of the bridge opening. Guide banks also may extend downstream from the bridge.

Stability/stable: A condition of a stream channel when there is no appreciable change in vertical or lateral channel dimensions over many years.

Stable channel: A channel that transports water and sediment delivered from the upstream watershed without aggradation, degradation, or bank erosion.

Stage: The water-surface elevation of a stream with respect to a reference elevation.

Stage of reach evolution: The stage of reach evolution of the stream reach is a geomorphic classification based on stream stability and denoted as undisturbed, constructed, stable, aggradation, vertically unstable, laterally unstable, or vertically and laterally unstable.

Stone rip rap: The natural cobbles, boulders, or rock dumped or placed as protection against erosion.

Stream: A body of water flowing in a channel.

Streamflow: See discharge.

Streamward: Looking toward the stream laterally from the channel bank.

Structure Type: The structure type is a description that corresponds to the structural specifications of the bridge such as single span, multiple span, single arch, multiple arch, steel culvert, box culvert, or other.

Subcritical, critical, supercritical flow: The open channel flow conditions with Froude number less than, equal to, or greater than unity, respectively.

Superstructure: The part of a bridge structure that primarily receives and supports traffic loads and in turn transfers the loads to the bridge foundation structures.

Surface cover: The type of land-use along the upstream and downstream banks, denoted as: urban, row crop, pasture, forest, wetland, suburb, rangeland, or other. The code for the surface cover overall is based on the predominant type of land-use along all four banks.

Thalweg: The line extending down a channel that follows the lowest elevation of each cross section with flowing water.

Toe location The abutment toes may be described as protruding into the channel (-), setback from(+), or even with the channel. The measurements are made from the top of the banks to the corresponding abutment walls. For tidal bridges, the toe location is measured on both the upstream and downstream sides of the bridge.

Toe of bank: The part of a stream cross section where the lower bank terminates and the channel bottom or the opposite bank begins.

Toe protection: The loose stones laid or dumped at the toe of an embankment, groin, etc., or masonry or concrete wall built at the junction of the bank and the bed in channels or at extremities of hydraulic structures to counteract erosion.

Top of bank: The height of the water level on the bank resulting from the average annual flood. Geomorphic indicators of this top of bank are characteristic features on the banks that are indicative of fluvial processes. The geomorphic indicators can be: the extent of large woody vegetation, a break in slope, a change in the amount of bank erosion, small twigs or leaves carried by the stream lodged against the bank vegetation, or extrapolation of a high water mark from the abutment.

Total scour depth: The arithmetic sum of the respective scour depths that result from general scour, contraction scour, and local scour in a stream channel.

Turbulence: The motion of fluids in which local velocities and pressures fluctuate irregularly in a random manner as opposed to laminar flow where all particles of the fluid move in orderly lines.

Vegetative cover: The tree coverage on the channel banks. Vegetative cover is estimated as a percentage of crown cover that trees occupy from the edge of water to the top of the respective channel banks at the bridge crossing. The choices are 0-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent.

Velocity: The rate of motion of a fluid in a stream channel, or the rate of motion of the objects or particles transported therein. Velocity is usually expressed in feet per second or meters per second.

Water surface: The water surface can be described as being a pool or riffle.

Weephole: A hole in an impermeable wall or revetment to relieve pore pressure in the soil.

Wire mesh: A mesh formed from woven wire and used as an integral part of a countermeasure. Openings are of suitable size and shape to enclose rock or broken concrete or to function on fence-like spurs and retards.

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To Obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter

STANDARD SYMBOLS FOR SKETCHES

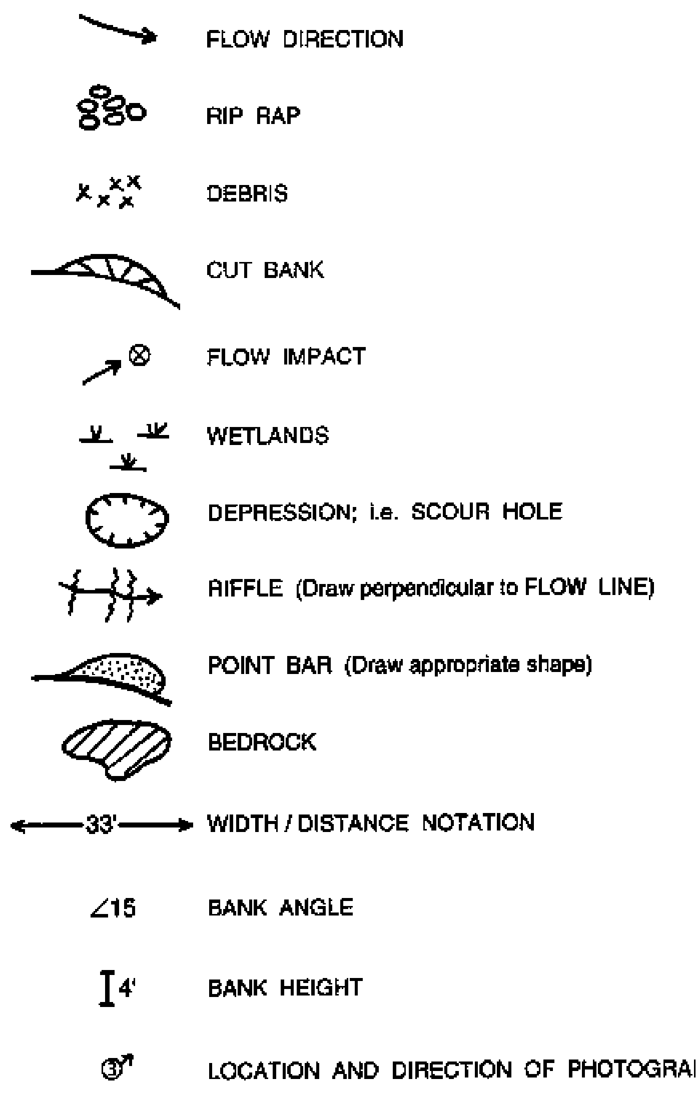

Figure 1