Bridge-Scour Instrumentation and Data for Nine Sites in Oregon, 1991–94

U.S. GEOLOGICAL SURVEY
Open-File Report 95–366

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Portland, Oregon
1996

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Miscellaneous	
cubic foot per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

Sea level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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By Milo D. Crumrine, Karl K. Lee, *and* Richard L. Kittelson

Abstract

This report is a compilation of bridge-scour instrumentation information, bridge-scour data, and hydraulic data for nine sites studied in Oregon from October 1991 through September 1994. The Alsea Bay scour monitoring site was established to test new bridge-scour monitoring equipment, whereas the eight additional sites were established to monitor scour-hole elevations around piers and footings. These data were collected in cooperation with the Oregon Department of Transportation.

Sonar depth sounders, scour chains, and scour detection arrays were tested during this study; however; all of the bridge-scour data collected were from sonar scour-monitoring devices. Scour was observed at three sites during the period while the nine scour-monitoring sites were in operation. Work on the project is continuing, and includes testing of new scour-monitoring devices in addition to bridge-scour data collection.

INTRODUCTION

Scour around bridge piers and abutments is a serious problem in many rivers and estuaries. Bridge failure is commonly caused by scour, which undermines piers or abutments. Pier failure has caused bridges to collapse; injury and loss of lives have resulted from these failures (Trent, 1989). Determination of maximum scour at piers caused by high water flow is essential for the maintenance of existing bridges and for the design of future bridges. The U.S. Geological Survey (USGS), in cooperation with Oregon Department of Transportation (ODOT), has measured and monitored scour around piers since 1989 (Crumrine, 1990, 1991). The monitoring of scour-critical bridge sites began during the 1992 water year, and has continued through the 1994 water year. In fiscal year 1994, funding from the Federal Highway Administration (FHWA) was provided to ODOT and USGS for the development of new methods to monitor scour around bridges.

Purpose and Scope

This report presents bridge-scour instrumentation information, bridge-scour data, and hydraulic data for nine sites studied in Oregon from October 1991 through September 1994. The two purposes of this study were (1) to monitor scour at bridge piers and footings that were classified as scour critical, and (2) to develop better equipment and methods to monitor bridge scour. The USGS, in cooperation with ODOT, began monitoring selected scour-critical sites during October 1991. A total of 10 sites have been monitored since the project began. Initial monitoring included measurement of scour-hole depths and stream discharge or stage. Subsequent monitoring included the parameters of velocity and median bed-material size, providing sufficient data to verify model-calculated pier-scour estimates at each site.

Important components of bridge-scour monitoring are the ongoing evaluation of both proven and experimental equipment and the improvement of methods used to measure bridge scour. This field of study is relatively new, and information is needed about the accuracy of various types of equipment in specific scour situations. Scour was initially monitored at sites during this study using a sonar device that was modified to enable the sonar signals to be timed and recorded by a datalogger. During fiscal year 1994, new methods were tested, including sonar with a digital output that was readable by computer or datalogger. Other methods being tested in this study to monitor and record maximum scour are scour chains, directional transducer arrays, and piezoelectric bimorph sensor arrays.

Acknowledgments

The authors would like to acknowledge Dave Bryson with the Bridge Section of the ODOT for his support. The authors would also like to thank the FHWA, in particular Tom Krylowski and Brian Roberts, Christopher Dunn, and Bruce Johnson for their overall support in bridge-scour monitoring. We also thank Jerry Price of ETI Instruments for modifying his scour-monitoring package to fit the study needs.

SELECTION CRITERIA FOR BRIDGE-SCOUR MONITORING SITES

Selection of bridge-scour monitoring sites was a combined effort that began with preliminary selection by the ODOT, followed by reconnaissance by USGS personnel.

The Bridge Section of ODOT initially selected the bridges to be monitored by classifying Oregon bridges according to FHWA criteria (Richardson and others, 1993). These bridges classified as “scour-critical” require immediate action, and are replaced, repaired, or monitored as necessary. Plans of these scour-critical sites not suitable for replacement or repair were examined by ODOT to determine if the bridge design characteristics made the bridges vulnerable to scour. Bridges with spread footings or short pilings and those lacking riprap around the piers are most susceptible to scour.

After prospective scour-critical sites were selected, the USGS made reconnaissance surveys to determine if the sites were suitable for monitoring. Each site was inspected during reconnaissance to determine the (1) presence of erodible material, (2) depth of scour holes around piers, (3) exposure of the pier footing, (4) flow angle to the bridge and piers, and (5) best location for the sensors and the instrument shelter. ODOT was contacted, and another candidate site was selected if the prospective scour-monitoring site was not suitable.

INSTRUMENTATION

Most engineering data used in the development of scour equations for the design bridge of supports comes from flume studies. However, field-scour data is generally preferred over flume data, because flume-based scour equations overestimate maximum pier scour for streambed material that is coarser than sand (Richardson and others, 1993).

Before the development of other monitoring methods, scour around bridge piers and footings was measured by using a weight lowered from the bridge railing into the scour hole during high water flow. Field measurements are still made in this manner to verify data collected using other monitoring methods. However, lowering a weight from a bridge can be dangerous and inaccurate because of high water velocities, floating debris, and limited visibility. Sounding the exact bottom of a scour hole can be difficult during high flow, and the measurements made during these times are often inaccurate.

Sonar

The sites in this study were initially monitored using a modified Lowrance or Eagle sonar device. Signals from the transducer were timed and displayed by the sonar, and were timed and recorded by a datalogger. The transducer in a typical installation is mounted above the scour hole and is aimed at the streambed. The transducer is protected from damage from debris by a heavy, metal guard. The sonar unit sends signals to the transducer and datalogger, and the transducer receives the echo and returns the signals back to the sonar unit and datalogger. The time difference between the “send and receive” signals is converted to a distance value by the sonar unit, which displays the distance between the transducer and bottom of the scour hole. The datalogger also computes distance using the send and receive signals, and stores the data (Hayes and Drummond, 1994).

Values stored in the datalogger require further processing to screen erroneous data. Erroneous data can be created during the send-and-receive signal sequence, because the datalogger cannot differentiate between the send and receive signals, and erroneous depth measurement will result if the timing sequence begins with the return signal instead of the send signal. This type of error was eliminated by programming the datalogger to reject signals greater than 20,000 microseconds, a signal time that when converted represents depths greater than expected measurement limits.
A second type of error may occur when the stream is turbid. On those occasions local scour may be occurring, but some sonar signals reflect off suspended particles instead of the bottom of the scour hole.

These errors were eliminated by programming the datalogger to accept only a particular range of signals and to require that five reasonable readings be averaged before storing the data. After an acceptable value was stored in the datalogger, the distance value was converted to the elevation of the scour-hole bottom.

This revised method of recording scour-hole elevations worked well in Oregon streams; however, the system had two disadvantages. First, the sonar devices were modified, making it difficult for other users to obtain an equivalent apparatus. Second, the external processing of the sonar signals by the datalogger does not utilize the advanced signal processing capabilities of the sonar unit.

Recently, the USGS, in cooperation with ODOT and FHWA, began testing low-cost sonar devices that have an output compatible with dataloggers. The new sonar products chosen for testing provide an output in a standard NMEA–0183 (National Marine Engineering Association) format, so data can be stored in a personal computer or datalogger. An interface is necessary to make the NMEA–0183 output compatible with a datalogger. Interfaces developed by Campbell Scientific Instruments (CSI) and by ETI Instruments Inc. were tested. Depth sounders made by Autohelm, and Lowrance Electronics Inc. were used in this study.

Preliminary testing of both sonar devices is in progress. To date, both devices work well and are an improvement over the original sonar scour-monitoring instrument. The sonar method of measuring scour works well in many applications, but is not applicable to every scour-monitoring site. It is not well suited in the following conditions (1) shallow streams, where water is less than 2 feet above the scour hole, (2) where ice jams occur, (3) when the water is very turbid, or (4) where debris can pile up on the sonar transducer. For these reasons, scour-monitoring devices other than sonar were also studied.

Nonsonar Scour-Monitoring Devices

In addition to testing sonar scour-monitoring devices, the USGS, in cooperation with ODOT and FHWA test alternative methods to determine scour levels around bridge footings. The devices selected for study are scour chains and buried-rod devices. Development of this method of monitoring scour continues and no data were available at the time this report was being written.

Scour Chains

A scour chain is a chain attached to an anchor that is driven vertically into a scour hole (figure 1). The chain is cut off near the stream bed, and about 10 feet of small cord is attached to the last link. The elevation of the exposed end of the chain and scour hole is determined by leveling measurements. When scour occurs, the chain links collapse or are pulled horizontally towards the stream bed, and are often buried by bed material. After the high water season, the chain is relocated by “following” the cord back to the chain. The collapsed portion of the chain is dug out to the point where the chain links remain vertical. The length of collapsed chain represents the amount of scour that has occurred at that location. This method of scour measurement is limited to small streams, and scour elevations cannot be continuously monitored using this method. Scour chains were used in the Alsea Bay study to determine sand dune migration within Alsea Bay (Crumrine, 1991). A scour chain was installed at the Cow Creek scour-monitoring site for comparison with the sonar scour monitor (fig. 1).

Buried-Rod Devices

Buried-rod scour-monitoring devices are arrays of sensors attached to a rod buried in the scour hole in the vicinity of a bridge footing or abutment. Three types of driven rod devices are being tested: (1) piezoelectric arrays, (2) tilt-switch arrays, and (3) vibrating-switch arrays. These devices are in the developmental stage and have not been tested.

Piezoelectric Array

Piezoelectric material produces a voltage when stress is applied. This phenomena was first discovered in 1880 using quartz crystalline material. Piezoelectric material is placed at half-foot intervals onto a drive point, which is driven into a scour hole. When local scour occurs, water velocity and bed-material movement around the exposed piezoelectric sensors create stress on the sensors. The sensors react by giving off a voltage that can be measured and recorded by a datalogger. Piezoelectric sensors not exposed by scour would not be stressed and would not produce a voltage. Scour elevation can be determined by identifying the piezoelectric sensors producing voltage signals.

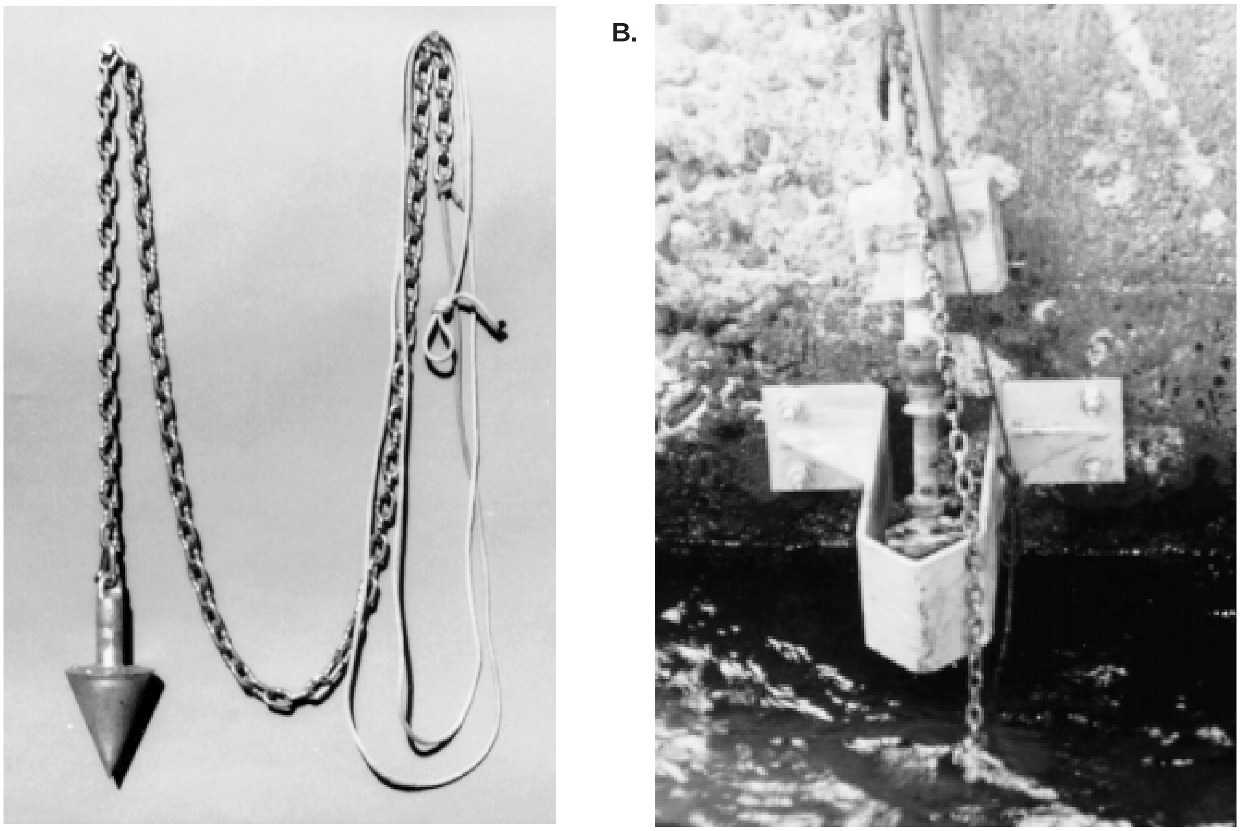


Figure 1. (A) Scour chain attached to driving point and nylon cord.
(B) Scour chain installed at the Cow Creek scour-monitoring site. (During normal operation, the scour chain is lying along the streambed and is not extended upward as shown in this photograph. Also shown in this photograph are the sonar transducer and transducer guard.)

Tilt-Switch Array

The tilt-switch array is similar in design to the piezoelectric array, except that tilt switches are used in place of piezoelectric material. The switches have exposed levers that when driven into a scour hole are in the “up” position. When scour occurs and water and bed material moves past a switch lever, the lever is pushed downwards or sideways causing electrical contact to be broken. This change in electrical contact causes a corresponding monitoring light to turn off. The advantages of this system are (1) the device is inexpensive, and (2) the lights can be placed where a bridge engineer can easily observe them. The drawback of the tilt switch array, like the scour chain, is that the device detects only maximum scour and has to be reset after high water flows.

Vibrating-Switch Array

The vibrating-switch array closely resembles the tilt-switch array, except that the switches activate when the switch levers are vibrated. The advantage over the tilt-switch array is that this device does not have to be reset and can detect when infilling occurs in the scour hole. The vibrating-switch array is inexpensive, and switch closure signals could be monitored by a datalogger if desired.

DATA COLLECTION

Bridge-scour data were collected following guidelines established by FHWA (Richardson and others, 1993) and by techniques developed during bridge-scour studies (Crumrine, 1991; Decker, 1989). Water-surface elevation, velocity, channel geometry, and bed-material data were collected using USGS Techniques for Water-Resources Investigations recommended procedures (Buchanan and Somers, 1974; Kennedy, 1983; Carter and Davidian, 1968, Guy and Norman, 1970).

Sites

In this study, eight scour-critical bridge-scour sites were monitored, and one additional site was instrumented in an estuary where new methods of bridge-scour monitoring were tested (figure 2). The sites are listed and described in the order they were established.The bridge-scour monitoring sites were equipped with (1) scour-hole monitoring sonar device, (2) stage-measuring sonar (if there was not a gaging station nearby), and (3) a datalogger to record the data. Monthly visits were made to (1) retrieve the data, (2) measure scour elevations, (3) measure river stage, (4) measure approach velocities, (5) collect bed-material samples to determine median bed-material size, and (6) locate and record high-water elevations.

Bridge-Scour Data Collection

The type of scour that was measured at the bridge-scour sites is classified as total scour, which is a combination of general, contraction, and local scour (Jarrett and Boyle, 1986). General scour or fill is caused by the degradation or aggradation of the streambed under normal conditions. Contraction scour is caused by bridge abutments and piers constricting streamflow, thereby increasing stream velocity and potential for scour of the streambed. Local scour is caused by local disturbances of the flow, such as vortices and eddies around piers and abutments. Local scour can be caused by two types of scour: (1) clear-water scour, which is scouring that occurs around piers and abutments when general and contraction scour are not, or (2) live-bed scour, which is caused by high flows when general and contraction scour occur simultaneously (Richardson and others, 1993).

Scour at each site was continuously monitored during the high-water season using a sonar depth sounder. The sonar transducer was mounted to either a pier or footing and was directed toward the deepest part of the scour hole. The depth sounder measured the distance between the transducer and the stream bed at the scour hole. These measurements were relayed to a datalogger, which converted the distance data to streambed elevations and stored the data. A summary of data collected is shown in table 1.

Continuously monitored data were verified using monthly field measurements during the high-water season. Field scour-elevation measurements were made by either probing the scour hole with a surveying rod or by lowering a weight from the bridge and measuring the distance between a reference point and the bottom of the scour hole. Attempts were made to measure scour elevations during high water, when live-bed scour occurs. Very few field measurements were made during live-bed scour conditions, because this scour occurs only for a short period of time during extreme high flow conditions.

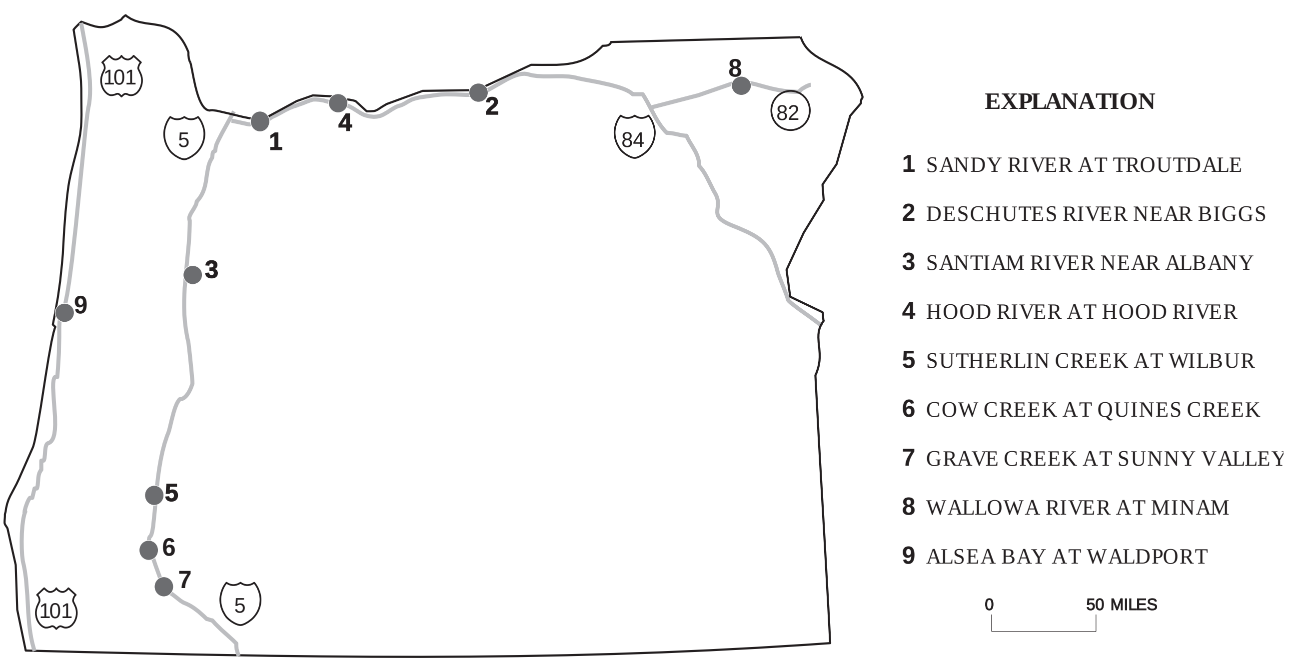


Figure 2. Locations of bridge-scour monitoring sites in Oregon.

Table 1. Bridge-scour monitoring site information at selected bridge-scour sites in Oregon, 1991–94

Sites	Period of record	Stage Record	Was local scour recorded ?	Scour-hole levels near bottom of the footing ?
453241122230400 Sandy River at Troutdale, Oregon	October 1991 through September 1994	Gaging station (14142500)	Yes	Yes
Deschutes River near Biggs, Oregon	October 1991 through September 1992	Gaging station (14103000)	No	No
Santiam River near Albany, Oregon	October 1991 through September 1992	Gaging station (14189000)	No	No
4319051232044 Sutherlin Creek at Wilbur, Oregon	October 1992 through September 1994	At site and gaging station (14312170)	Yes	No
424651123161500 Cow Creek at Quines Creek, Oregon	October 1992 through September 1994	At site and gaging station (14309000)	Yes	No
4238091232300 Grave Creek near Sunny Valley, Oregon	October 1992 through September 1994	At site and gaging station (14308990)	No	No
454238121302300 Hood River at Hood River, Oregon	October 1992 through September 1994	Gaging station (14120000)	No	No
453720117431200 Wallowa River at Minam, Oregon	October 1993 through September 1994	At site and gaging station (13331500)	No	No
442558124041402 Alsea Bay at Waldport, Oregon	September 1994 through October 1994	At site	Yes	No

Hydraulic-Data Collection

Hydraulic data were collected for evaluating pier-scour equations at selected scour monitoring sites. The hydraulic data collected beginning in the 1993 water year consisted of stage, velocity, channel geometry, and bed-material size (tables 2 and 3).

Stage Data

Stage was continuously monitored during the high-water season at sites that were not near a streamflow gaging station. The stage-monitoring device used at these sites were a downward-looking sonar unit that measured the distance between the transducer, mounted near the bridge deck, and the water. Data from these units were stored with scour data in a datalogger. Verification of water-surface elevations were made during periodic visits to the site. Stage data for sites without a continuous stage-monitoring device were obtained by checking high-water marks and by comparison with nearby gaging stations.

Velocity Data

Mean approach water velocity was measured at each bridge-scour monitoring site, either by wading or using a boat, beginning in the 1993 water year. Stream velocity was measured at an approach section upstream from the bridge and at the upstream side of the bridge. During high flow, water velocity was measured from the bridge alone and is adjusted to mean approach velocity.

Channel Geometry and Bed-Material Data

Surveys to determine channel geometry and bed slope were made at sites a distance of three channel widths upstream from the bridge, at the bridge, and near the downstream side of the bridge. Bed material samples were taken at each of the cross sections and were analyzed for particle sizes greater than sand (.062 millimeters). Median bed-material size (D50) was derived from the bed-material analysis.

Table 2. Summary of observed hydraulic properties at selected bridge-scour monitoring sites in Oregon, 1992–94

Station	Date	Observations on date of visit		
		Water-surface elevation, in feet above mean sea level	Elevation of monitored scour hole, in feet above mean sea level	Velocity of approach, in feet per second
4319051232044				
Sutherlin Creek at Wilbur, Oregon	04/06/93	450.4	--	--
	05/06/93	448.9	443.6	--
	08/17/93	447.3	444.7	--
	10/26/93	447.6	444.5	--
	12/10/93	447.9	444.6	1.77
	01/10/94	449.0	444.5	2.68
	03/10/94	447.7	444.8	2.08
	04/13/94	447.5	444.7	1.78
Estimated data for period of peak flow	01/19/93	451.5	443.5	3.60
424651123161500				
Cow Creek at Quines Creek, Oregon	12/08/92	1,545.6	1,544.2	--
	01/04/93	1,545.5	1,544.1	--
	03/30/93	1,545.6	1,544.4	--
	05/16/93	1,544.4	1,543.4	--
	06/10/93	1,546.4	1,544.3	--
	08/17/93	1,545.8	1,544.5	--
	10/28/93	1,545.4	1,544.5	--
	12/09/93	1,546.1	1,544.0	2.25
	01/27/94	1,545.2	1,544.2	1.38
	03/09/94	1,545.2	1,544.3	1.37
	04/12/94	1,545.2	1,544.3	1.42
Estimated data for period of peak flow	01/24/93	1,549.0	1,539.0	2.25
4238091232300				
Grave Creek near Sunny Valley, Oregon	12/08/92	1,173.0	1,170.1	--
	12/15/92	--	1,169.9	--
	01/14/93	1,172.8	1,169.8	--
	03/30/93	1,172.8	1,169.6	--
	05/06/93	1,172.7	1,170.0	--
	06/10/93	1,172.6	1,169.7	--

Table 2. Summary of observed hydraulic properties at selected bridge-scour monitoring sites in Oregon, 1992–94 (Continued)

Station	Date	Observations on date of visit		
		Water-surface elevation, in feet above mean sea level	Elevation of monitored scour hole, in feet above mean sea level	Velocity of approach, in feet per second
4238091232300 (Continued)				
Grave Creek near Sunny Valley, Oregon	08/17/93	1,172.7	1,169.9	--
	10/27/93	1,172.3	1,169.6	--
	12/09/93	1,173.0	1,169.6	1.06
	01/11/94	1,172.8	1,169.8	1.03
	01/27/94	1,172.4	1,170.1	0.54
	03/09/94	1,172.4	1,170.3	0.52
	04/12/94	1,172.2	1,169.6	0.37
Estimated data for period of peak flow	01/18/93	1,175.5	1,169.5	3.00
454238121302300				
Hood River at Hood River, Oregon	03/11/93	75.5	67.2	--
	03/18/93	76.8	67.2	--
	01/04/94	77.8	68.1	6.20
	01/20/94	76.6	--	--
	02/24/94	77.8	66.6	--
	03/29/94	76.6	--	--
	04/27/94	76.6	67.8	--
Estimated data for period of peak flow	01/03/94	80.0	66.0	7.50
453241122230400 Sandy River at Troutdale, Oregon				
Estimated data for period of peak flow	01/04/94	19.0	5.5	--
	02/23/94	20.2	10.5	--
453720117431200 Wallowa River at Minam, Oregon				
	12/15/93	2,827.8	2,826.8	2.06
	01/19/94	2,827.6	2,826.6	1.98
	02/23/94	2,827.7	2,826.5	1.90
	03/28/94	2,828.0	2,826.7	2.40
	04/26/94	2,829.0	2,826.6	4.30
Estimated data for period of peak flow	05/12/94	2,831.1	2,826.5	5.50

Table 3. Particle-size distribution of bed material sampled at selected bridge-scour monitoring sites in Oregon, 1993–94.

Station	Date	Percent of particles finer than listed size, in millimeters												
		128	64	32	16	8	4	2	1	0.5	0.25	0.125	0.625	Less than 0.625
453241122230400 Sandy River at Troutdale, Oregon	09/12/94	100.0	89.4	53.8	35.1	24.8	19.4	17.4	15.2	10.3	1.3	0.2	0.1	0.0
4319051232044 Sutherlin Creek at Wilbur, Oregon	10/26/93	100.0	100.0	97.9	84.0	71.1	60.3	50.0	39.3	32.2	27.5	26.2	25.7	25.3
424651123161500 Cow Creek at Quines Creek, Oregon	10/28/93	100.0	74.9	63.0	45.1	33.4	24.8	17.3	9.1	2.4	0.7	0.2	0.1	0.0
4238091232300 Grave Creek near Sunny Valley, Oregon	10/27/93	100.0	70.6	17.7	10.2	5.7	2.9	1.7	1.0	0.5	0.2	0.1	0.0	0.0
454238121302300 Hood River at Hood River, Oregon	01/14/94	100.0	44.6	9.8	1.7	1.4	1.3	1.2	1.1	1.0	0.7	0.3	0.1	0.0
453720117431200 Wallowa River at Minam, Oregon	03/28/94	100.0	46.5	21.5	11.1	7.3	5.4	3.9	2.0	0.8	0.3	0.2	0.1	0.0

BRIDGE-SCOUR SITES

Sandy River at Troutdale

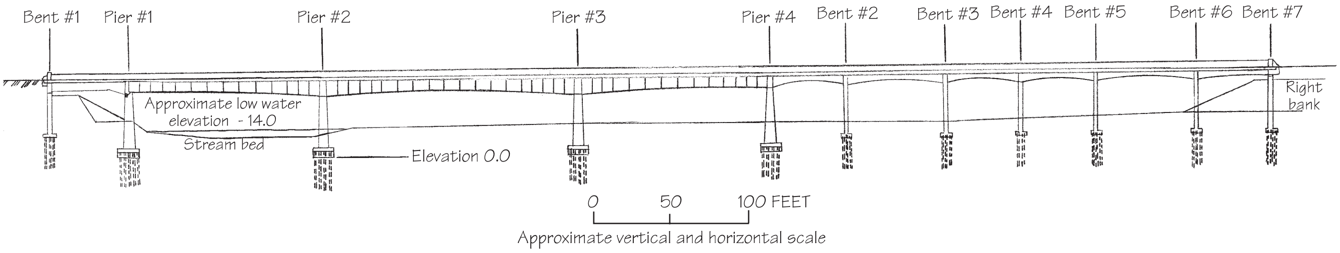
The Sandy River at Troutdale, Oregon, bridge-scour monitoring site is located at pier 2 on the Interstate Highway 84 eastbound bridge (6875), (figs. 3 and 4). This site was also selected for a previous bridge-scour study (Crumrine, 1990). Continuous scour monitoring began at this site in October 1991 at pier 2A; two scour holes located at the upstream corners of pier 2A were monitored (fig. 4). In October 1992 the scour-monitoring site was changed to the scour hole located at the upstream side of pier 2B. Both sites 2A and 2B had live-bed scour at times during high flow (fig. 5).

The Sandy River at Troutdale site is equipped with a sonar depth sounder and stage-monitoring sonar device, which are connected by a datalogger to process and store the data. The datalogger at the first site, pier 2A, was connected by a modem to download data and monitor scour elevations, via computer, from the office. The site at pier 2B was selected as a test site for a new sonar device, which has an output (NMEA–0183) that connects to the datalogger or laptop computer. Data from the new sonar device will be compared with data from the older sonar unit, also located at this site. The site was selected as a long-term scour-monitoring site, and will operate until the end of the 1999 water year.

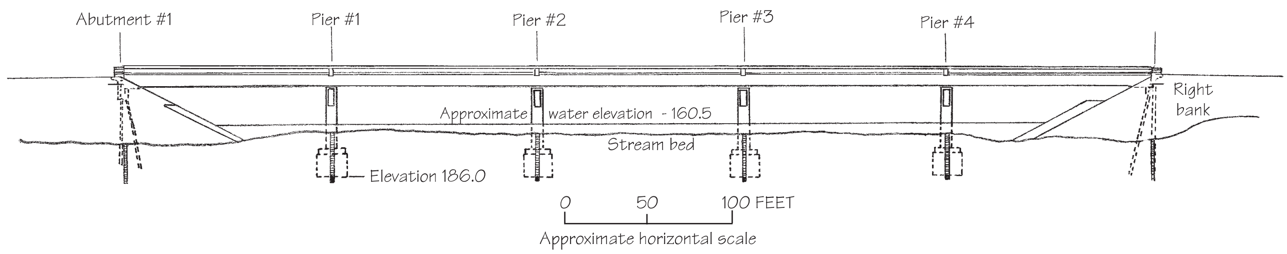
Deschutes River near Biggs

The Deschutes River near Biggs, Oregon, bridge-scour monitoring site was located at pier 4 of the Interstate Highway 84 bridge (332C) (fig. 3). This site was equipped with a sonar depth sounder and a datalogger. Water stage was determined by a staff gage at the site and by a gaging station 1 mile upstream. This site was included in an earlier bridge-scour study (Crumrine, 1990). Continuous scour monitoring began at this site in October 1991 and ended in the summer of 1992. No scour has been observed at this site.

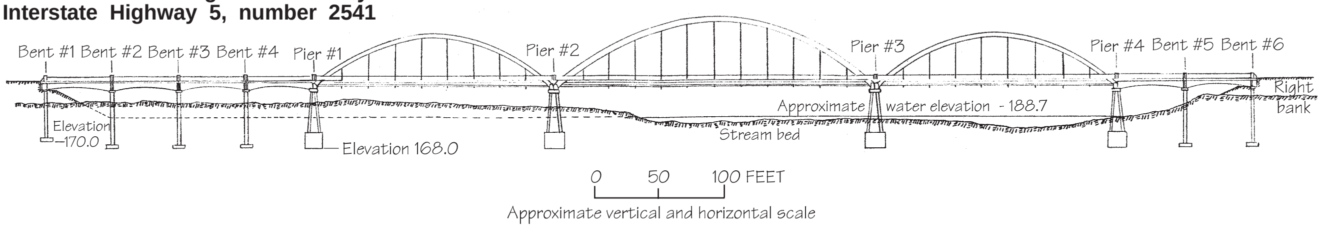
Sandy River Bridge at Troutdale
Interstate Highway 84, number 6875



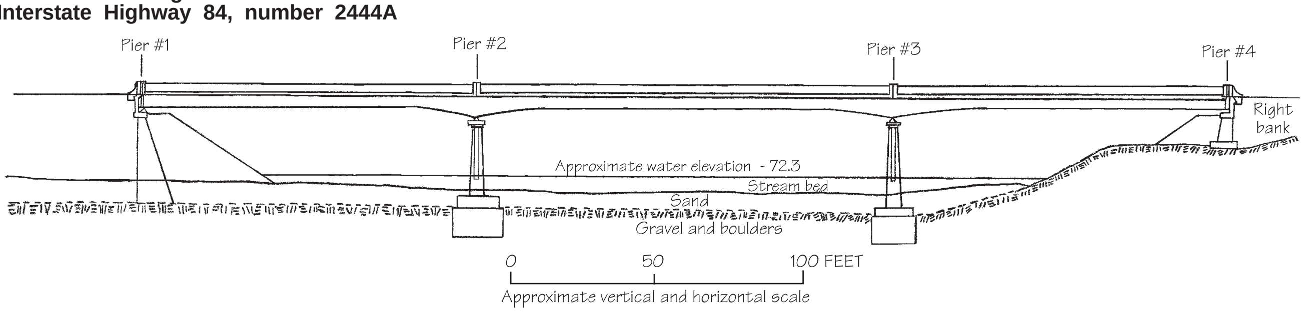
Deschutes River Bridge near Biggs
Interstate Highway 84, number 332C



Santiam River Bridge near Albany
Interstate Highway 5, number 2541



Hood River Bridge at Hood River
Interstate Highway 84, number 2444A



Sutherlin Creek Bridge at Wilbur
Interstate Highway 5, number 7628

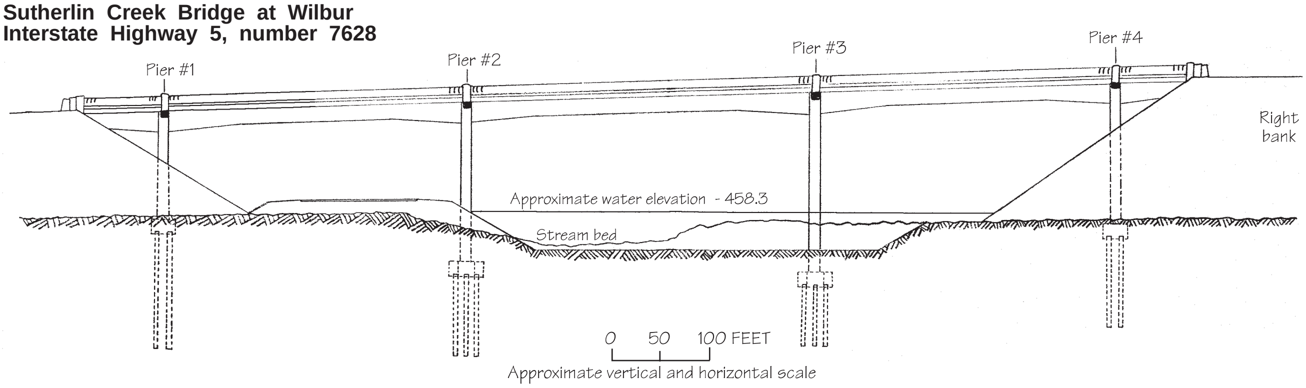
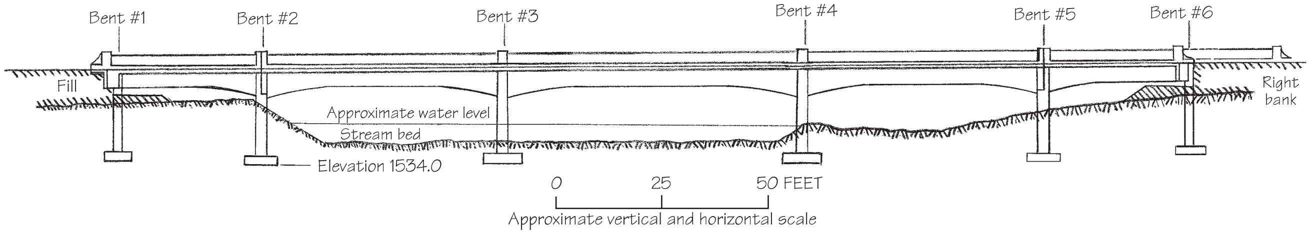
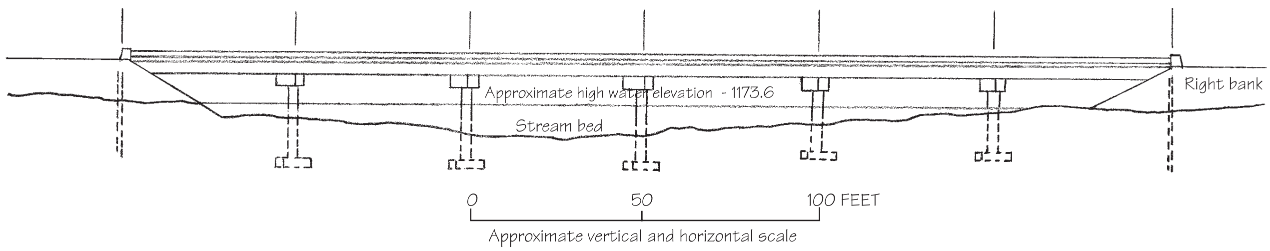


Figure 3. Schematic drawings of bridges selected for bridge-scour monitoring in Oregon.

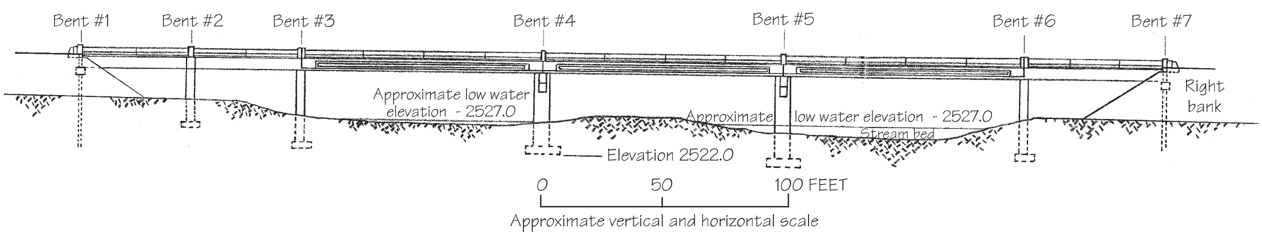
Cow Creek Bridge at Quines Creek
Interstate Highway 5, number 6782



Grave Creek Bridge at Sunny Valley
Interstate Highway 5, number 6493A



Wallowa River Bridge at Minam
State Highway 82, number 1038A



Alsea Bay Bridge at Waldport
Federal Highway 101, number 1746B

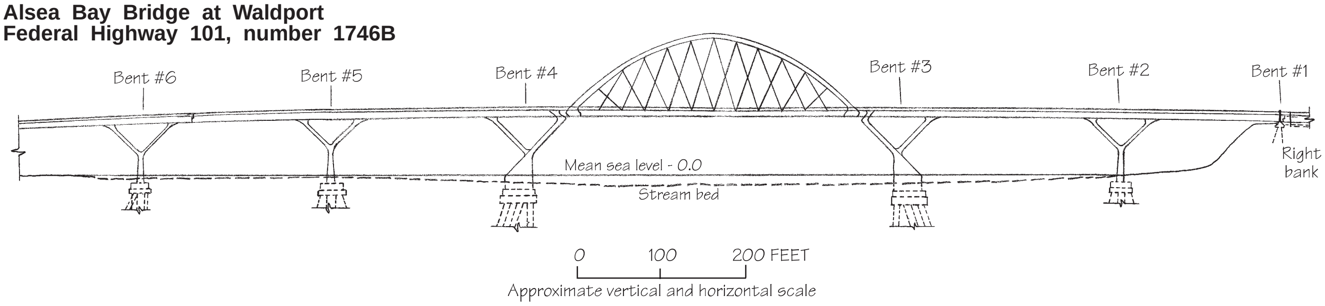


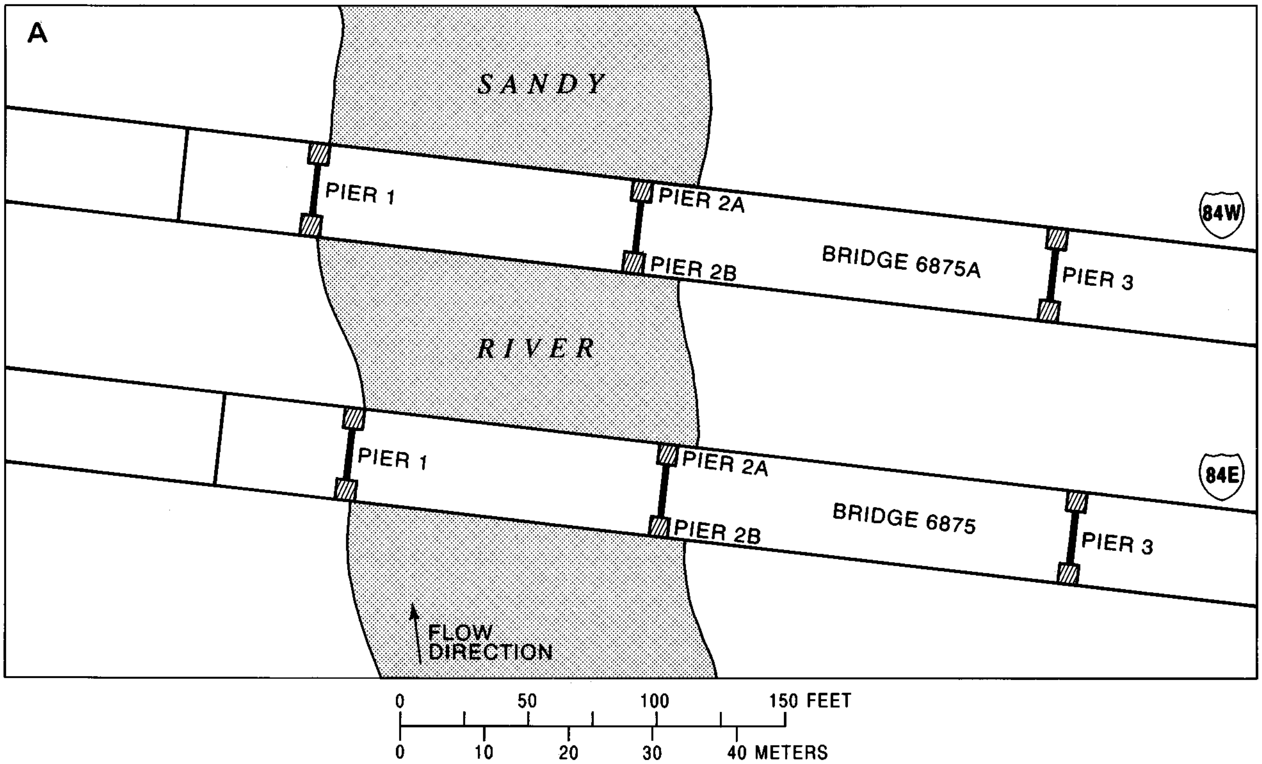
Figure 3. Schematic drawings of bridges selected for bridge-scour monitoring in Oregon—Continued.

Santiam River near Albany

The Santiam River near Albany, Oregon, bridge-scour monitoring site was located on Interstate Highway 5 northbound bridge (2541) (fig. 3). Attempts to monitor scour at the upstream end of the pier, beginning October 1991, failed because of entrained air in the water due to turbulence in the vicinity of the scour hole. Sonar devices are ineffectual when air bubbles are in the water, because sonar signals are absorbed by the air bubbles, so the reflected signal does not return to the transducer. It is probable that there was scour at this site; however, no scour was measured.

Hood River at Hood River

The bridge-scour monitoring site at the Interstate Highway 84 bridge over Hood River (bridge number 2444A) at Hood River, Oregon, is unique in that the



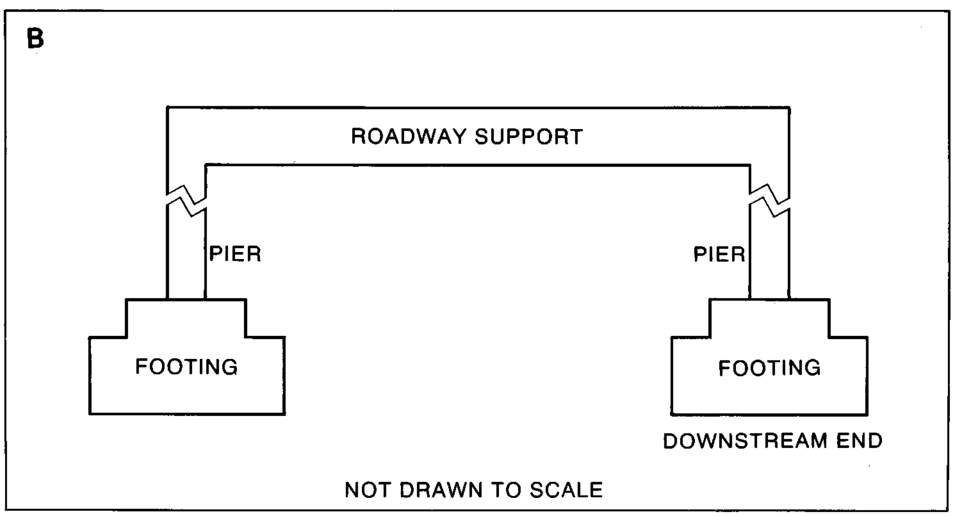


Figure 4. Configuration (A) and pier design (B) of Sandy River bridges 6875 and 6875A near Troutdale, Oregon.

major scour hole was located at the downstream end of pier 3 (fig. 3). Usually maximum scour occurs at the upstream edge of a bridge pier or footing, but in this case the bridge is situated at an angle to the flow. The pier wall instead of the upstream edge of the pier obstructs the flow. This site was instrumented with a sonar depth sounder and a datalogger, which was connected to a phone modem. Stage data were provided by stage observation at the site and by a gaging station located upstream. Continuous data collection began in October 1992 and ended in the summer of 1994. No significant scour was observed during the period when this scour-monitoring site was in operation.

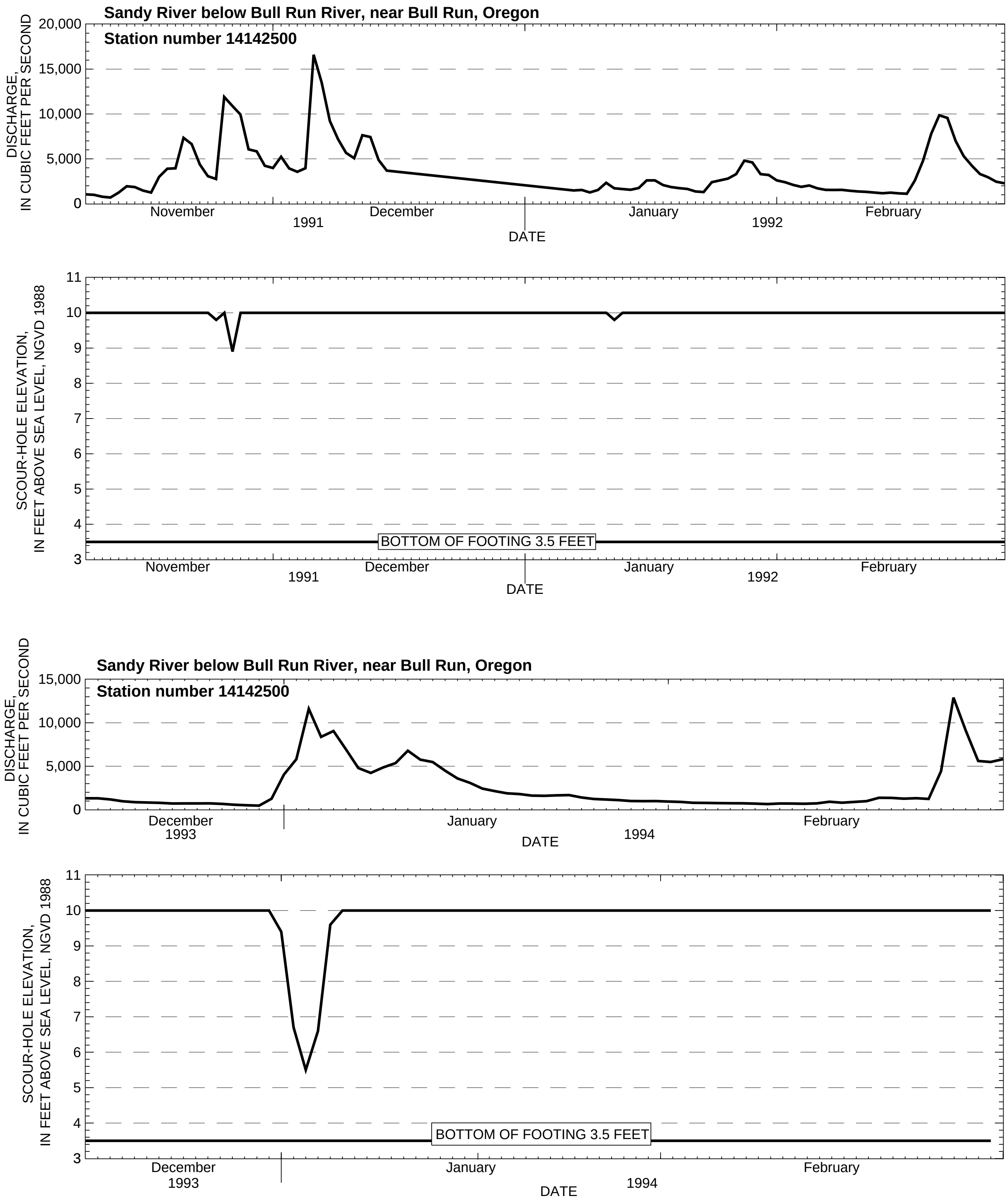


Figure 5. Daily mean discharge and scour-hole elevation at pier 2A of the Interstate 84 bridge (number 6875) over Sandy River near Troutdale, Oregon, November 1991–February 1992, and December 1993–February 1993. Sea level for this site is the National Geodetic Vertical Datum of 1988.

Sutherlin Creek at Wilbur

The Sutherlin Creek bridge-scour monitoring site was located at the Interstate Highway 5 bridge over Sutherlin Creek (bridge number 7628), at pier 3 (fig. 3). Continuous monitoring of stage and scour-hole elevations at this site began October 1992 and ended after the high-water season in 1994. Scour data recorded during high water that indicated that there was scour to the top of the footing (fig. 6). The sonar scour record also showed debris movement into and out of the scour hole. This site was equipped with a sonar depth sounder, down-looking stage transducer, and datalogger. This was the first site at which a stage transducer was used; therefore, a small stilling well was installed to verify the stage transducer data.

Cow Creek at Quines Creek

The Cow Creek at Quines Creek bridge-scour monitoring site was located at the Interstate Highway 5 bridge over Cow Creek (bridge number 6782) at bent 3 (figs. 3 and 7). This site was instrumented with a sonar depth sounder and down-looking stage transducer connected to a datalogger. The stage monitor was verified using an upstream gaging station. Local scour was recorded during high water at this site during the 1993 water year (fig. 8). During the 1994 water year, a scour chain was installed to test the scour-chain method of determining maximum scour. No scour was observed by the scour chain or the depth sounder. Continuous monitoring of stage and scour-hole elevations began October 1992 and ended after the high-water season in 1994.

Grave Creek at Sunny Valley

The Grave Creek bridge-scour monitoring site was located at the Interstate Highway 5 bridge spanning Grave Creek (bridge number 6493A) at bent 5 (figs. 3 and 9). This site was instrumented with a sonar depth sounder and down-looking stage transducer, both of which were connected to a datalogger. Continuous monitoring of stage and scour-hole elevations at this site began October 1992 and ended after the high-water season in 1994. There was no local scour recorded during high water at this site.

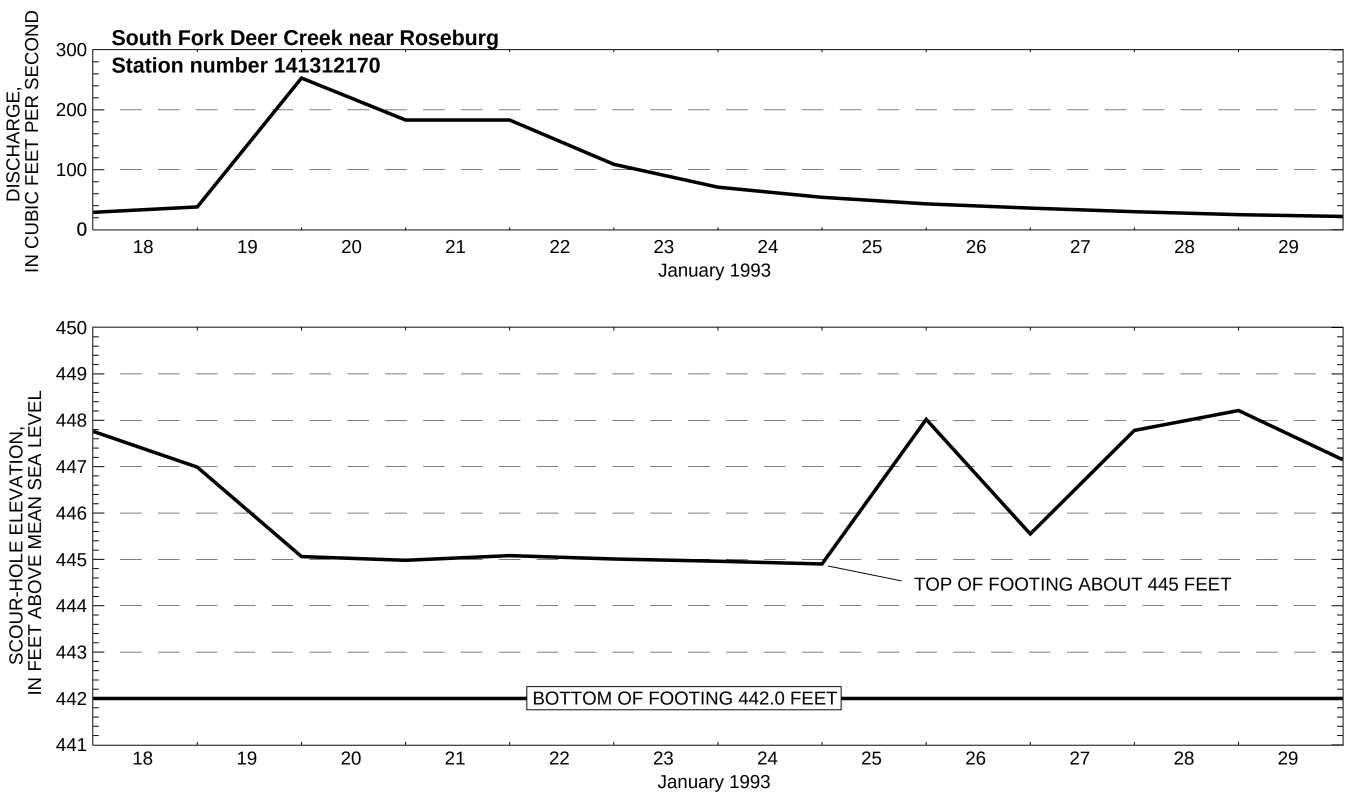


Figure 6. Daily mean discharge and scour-hole elevation at pier 3 of the Interstate Highway 5 bridge over Sutherlin Creek at Wilbur, Oregon, January 18–29, 1993.

A

B

C

Figure 7. (A) Cow Creek bridge with attached scour-monitoring apparatus.
(B) Pier of Cow Creek bridge with attached scour-monitoring apparatus.
(C) Scour-monitoring and recording equipment.

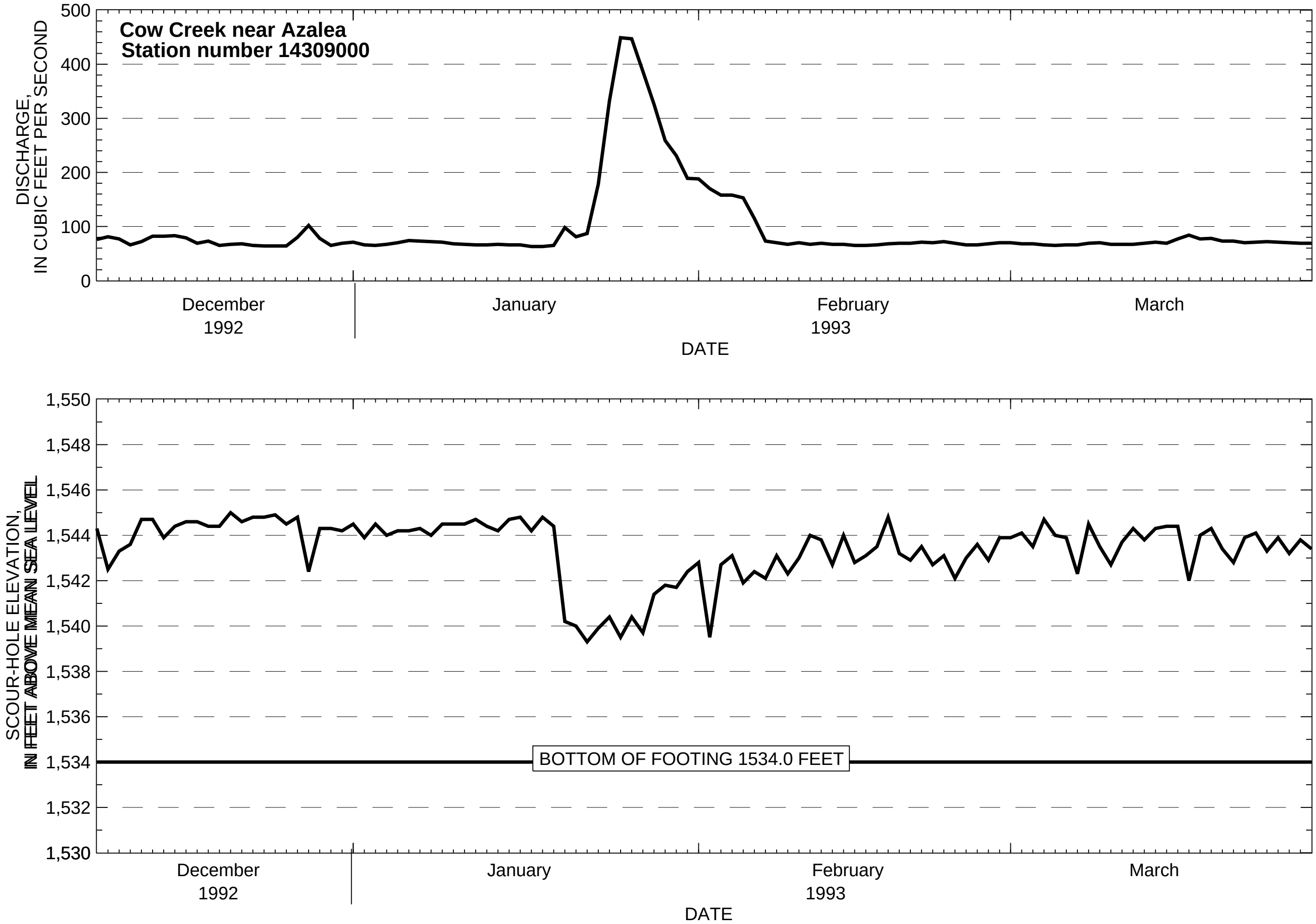


Figure 8. Daily mean discharge and scour-hole elevation at bent 4 of the Interstate Highway 5 bridge (number 6782) over Cow Creek near Quines Creek, Oregon, December 1992–March 1993.

Wallowa River at Minam

The Wallowa River at Minam bridge-scour monitoring site was located at the Oregon Highway 92 bridge over the Wallowa River, at the confluence of the Wallowa and Minam Rivers (bridge number 1038A), at Minam, Oregon (fig. 3). This site was equipped with a sonar depth sounder, down-looking stage transducer, and datalogger. Continuous monitoring of stage and scour-hole elevations at this site began October 1993. Maximum potential for scour usually occurs at this site between March and June, during spring runoff. This site was temporarily inactivated during the period from April 29, 1994 to August 24, 1994, when the bridge railing was being replaced. No local scour was recorded at this site, and the lack of data may be attributed to peak flows occurring during the period when the scour-monitoring instrumentation was removed. This site was selected as an ongoing scour-monitoring site and will be in operation until the end of the 1999 water year.

Figure 9. Scour-monitoring equipment on the Grave Creek bridge pier.

Alsea Bay at Waldport

The Alsea Bay bridge-scour monitoring site is located at bent 4 of the Oregon Highway 101 bridge (bridge number 1746B) over Alsea Bay at Waldport, Oregon (figs. 4 and 10). This site was selected as a testing site for new bridge-scour monitoring equipment, because local scour occurs during each tide cycle. This site was monitored previously between 1988 and 1990 (Crumrine, 1991). The new site equipment was installed September 1994 and monitors water-level and scour-hole elevations using the original sonar method and the ETI Instruments monitor with a Lowrance 350A sonar unit. To date, the ETI Instruments scour-monitoring package appears to provide more consistent data (fig. 11). Instrumentation at this site will be removed at the end of the 1995 water year, unless a further evaluation of new scour-monitoring methods is needed.

SUMMARY

Monitoring scour at bridge supports has begun only recently, and methods and techniques are still being developed. This study, in cooperation with ODOT, began in October 1991 and uses a depth sounder sonar device modified to output depth readings to a datalogger. Since the beginning of the study, nine sites have been monitored for scour, and new sonar monitoring methods have been tested. New methods being developed include the use of scour chains and three driven-rod devices (piezoelectric, tilt switch, and vibrating switch). Changes in scour-hole elevations during high water were observed at three of the nine scour-monitoring sites.

Beginning in October 1993, data were collected at scour-monitoring sites that can be used for computation of scour-hole elevations. These data include scour-hole elevations, bed-material size, stream-geometry surveys, water-velocity measurements, and measurements of maximum river stage. New sonar scour-monitoring methods were also tested at the regular scour-monitoring sites and at Alsea Bay at Waldport beginning October 1994.

This report provides data collected to date. The study is continuing, with a projected finish date of September 1999. Additional data and results of new scour-monitoring methods will be published at a later date.

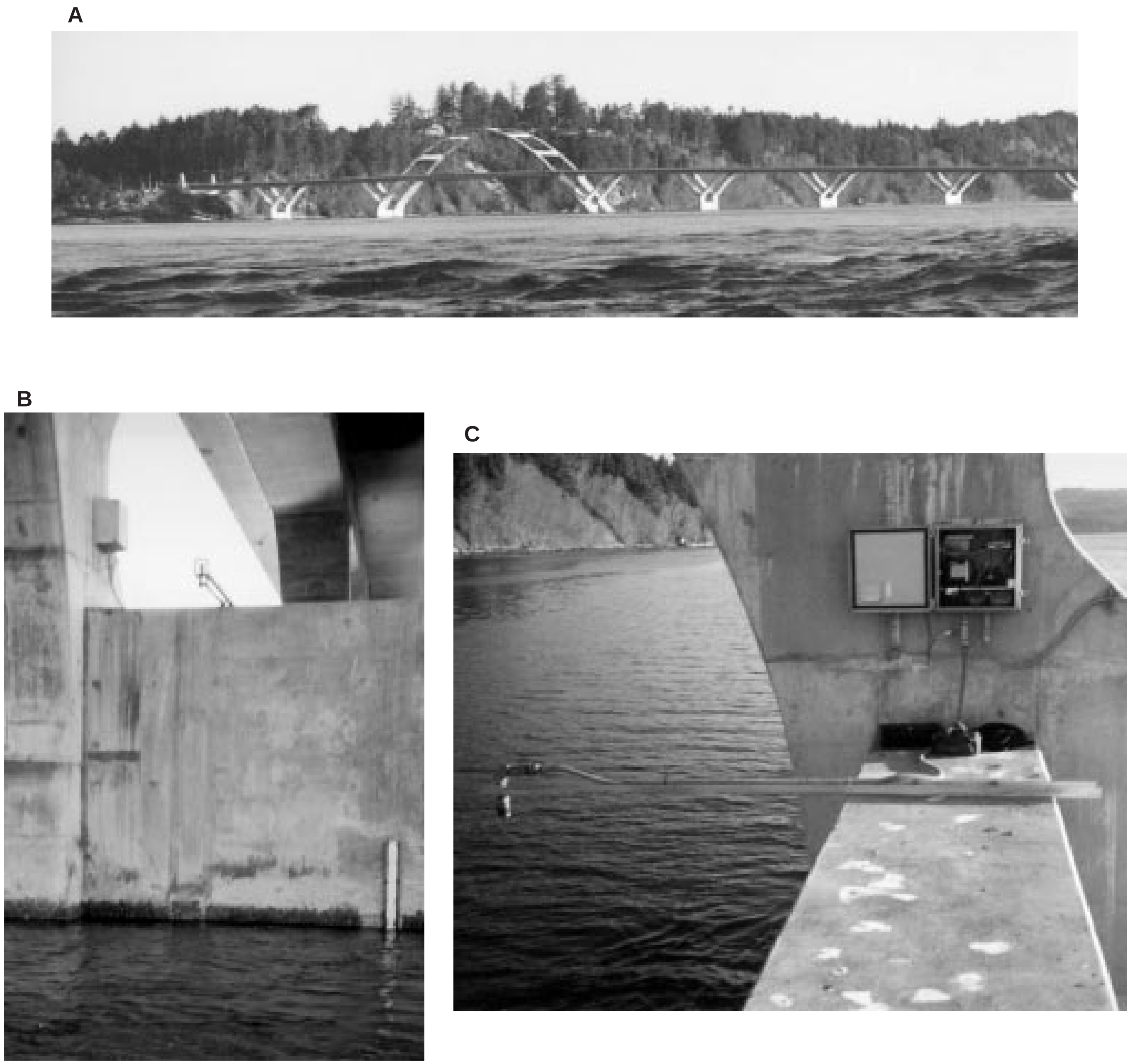


Figure 10. (A) The Alsea Bay bridge, Waldport, Oregon.
(B) Staff gage and scour-monitoring equipment on the Alsea Bay bridge.
(C) Data-recording and monitoring equipment on the Alsea Bay bridge.

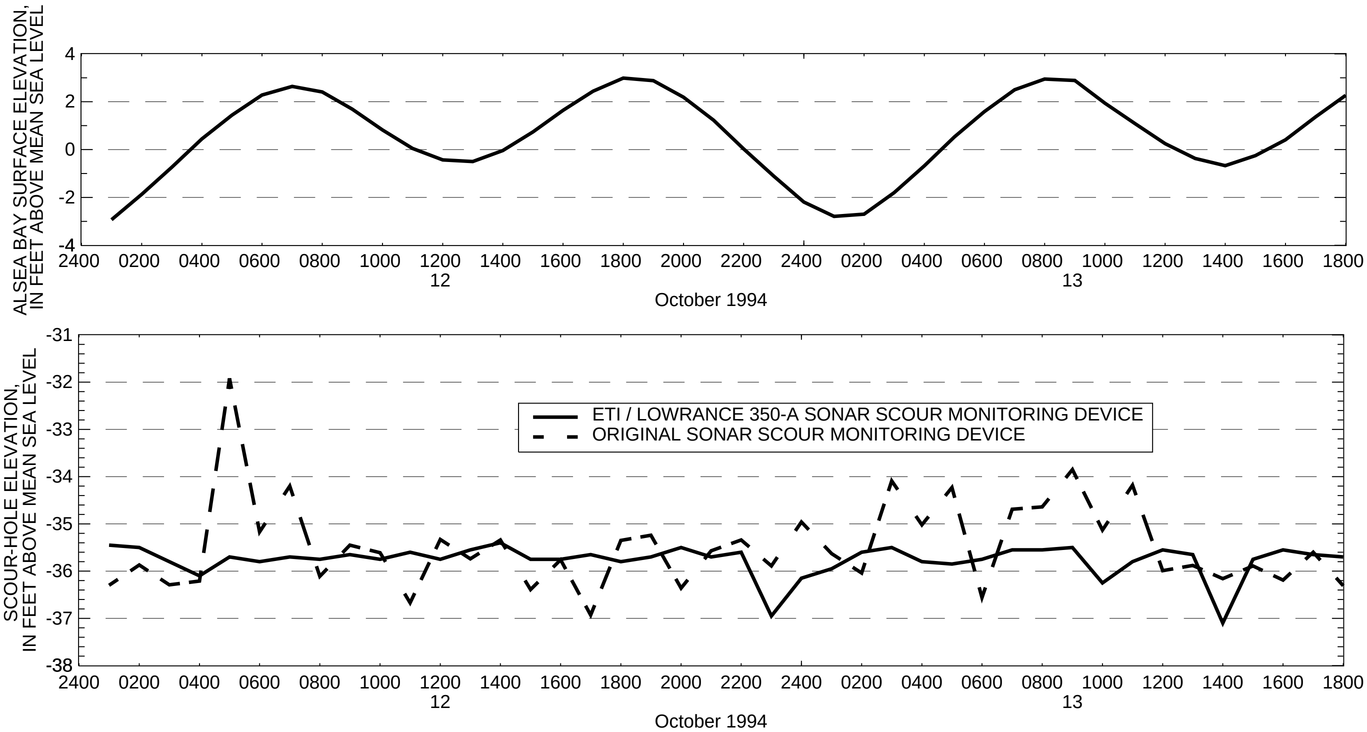


Figure 11. Hourly water level and scour-hole elevation from two scour-monitoring devices on the southeastern corner of bent 4 of the Highway 101 bridge (number 1746B) over Alsea Bay at Waldport, Oregon, October 12–13, 1994.

REFERENCES CITED

Buchanan, T.J., and Somers, W.P., 1974, Stage measurement at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A7, 28 p.

Carter, R.W., and Davidian, J., 1968, General procedure for gaging streams: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A6, 13 p.

Crumrine, M.D.,1990, Results of a reconnaissance bridge-scour study at selected sites in Oregon using surface geophysical methods, 1989: U.S. Geological Survey Water-Resources Investigations Report 90–4199, 44 p.

Crumrine, M.D., 1991, Bridge-scour data for the Highway 101 Bridge over Alsea River Estuary at Waldport, Oregon, 1988–90: U.S. Geological Survey Open-File Report 91–531, 48 p.

Decker, D.A., 1989, Demonstration Project No. 80, in Bridge Inspection Techniques and Equipment, *in* Proceedings of The Bridge Scour Symposium, October 17–19, 1989: McLean, Virginia, U.S. Federal Highway Administration Report FHWA–RD–90–035, p. 227.

Guy H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter C2, 59 p.

Hayes, D.C., and Drummond, F.E., 1994, Use of fathometers and electrical-conductivity probes to monitor riverbed scour at bridge piers: U.S. Geological Survey Water-Resources Investigations Report 94–4164, 17 p.

Jarrett, R.D., and Boyle, J.M., 1986, Pilot study for collection of bridge-scour data: U.S. Geological Survey Water-Resources Investigations Report 86–4030, 46 p.

Kennedy, E.J., 1983, Computation of continuous records of streamflow: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chapter A13, 53 p.

Richardson, E.V., Harrison, L.J., Richardson, J.R., 1993, Evaluating scour at bridges (2d ed.): U.S. Federal Highway Administration Hydraulic Engineering Circular 18, 132 p.

Trent, R.E., 1989, Two-dimensional flow modeling of Schoharie Creek at the Thruway Bridge, *in* Proceedings of the Bridge Scour Symposium, October 17–19, 1989: McLean, Virginia, U.S. Federal Highway Administration and U.S. Geological Survey, p. 232–255.

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