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GEOLOGICAL SURVEY

CHANGES IN CHANNEL GEOMORPHOLOGY OF SIX ERUPTION-AFFECTED TRIBUTARIES OF THE LEWIS RIVER, 1980-82, MOUNT ST. HELENS, WASHINGTON

By Holly A. Martinson, Steven D. Finneran, and Lyn J. Topinka

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For additional information
write to:

USDI, Geological Survey, WRD
Pacific Northwest District
1201 Pacific Avenue, Suite 600
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CONVERSION FACTORS

For use of readers who prefer to use inch-pound units, conversion factors for terms used in this report are listed below.

Multiply SI	By	To obtain inch-pound
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Upper Muddy River area looking downstream towards channel cross-sections MD010 and MD020, 1981.

CHANGES IN CHANNEL GEOMETRY OF SIX ERUPTION-AFFECTED TRIBUTARIES OF THE LEWIS RIVER, 1980-82, MOUNT ST. HELENS, WASHINGTON

ABSTRACT

The May 18, 1980, eruption of Mount St. Helens generated a lateral blast, lahars, and tephra deposits that altered tributary channels in the Lewis River drainage basin. In order to assess potential flood hazards, study channel adjustments, and construct a sediment budget for the perturbed drainages on the east and southeast flanks of the volcano, channel cross sections were monumented and surveyed on Pine Creek, Muddy River, and Smith Creek during September and October of 1980. Additional cross sections were monumented and surveyed on Swift Creek, Bean Creek, and Clearwater Creek during the summer of 1981. The network of 88 channel cross sections has been resurveyed annually. Selected cross sections have been surveyed more frequently, following periods of higher flow. The repetitive cross-section surveys provide measurements of bank erosion or accretion and of channel erosion or aggradation. This report presents channel cross-section profiles constructed from the survey data collected during water years 1980-82.

INTRODUCTION

Purpose and Scope

The May 18th and subsequent 1980 eruptions of Mount St. Helens drastically altered an area of about 550 km^2, largely north of the volcano, and all channels draining the volcano. On the south and east sides of the volcano, channels of the Lewis River system were changed primarily by lahars (mudflows or debris flows of volcanic origin) that flowed down major streams originating on Mount St. Helens (Janda and others, 1981, fig. 1; Cummans, 1981). Lahars flowed the entire lengths of Smith Creek, Muddy River, Pine Creek, and Swift Creek, forming deltas upon entering the eastern and western ends of Swift Reservoir into which these streams drain (fig. 1).

Other volcanic processes that modified portions of the Lewis River system include the lateral blast (directed blast of Hoblitt and others, 1981; pyroclastic density flow of Waitt, 1981; and pyroclastic surge of Moore and Sisson, 1981), pyroclastic flows (Rowley and others, 1981), and tephra deposition (Waitt and Dzurisin, 1981; Waitt and others, 1981). Dynamic effects and deposits from these events altered rainfall-runoff relationships (Swanson and others, 1983), channel geometry (Janda and others, 1981; Lisle and others, 1983), and the amount of sediment readily available to stream channels (Janda and others, 1981; Martinson and others, 1982). The blast and airfall deposits destroyed and damaged vegetation, eliminating or reducing transpiration over much of the affected area. Glaciers in the headwaters of streams originating on the flanks of the volcano were affected by removal of mass, surface erosion, and (or) mantling with debris (Brugman and Post, 1981; Brugman and Meier, 1981).

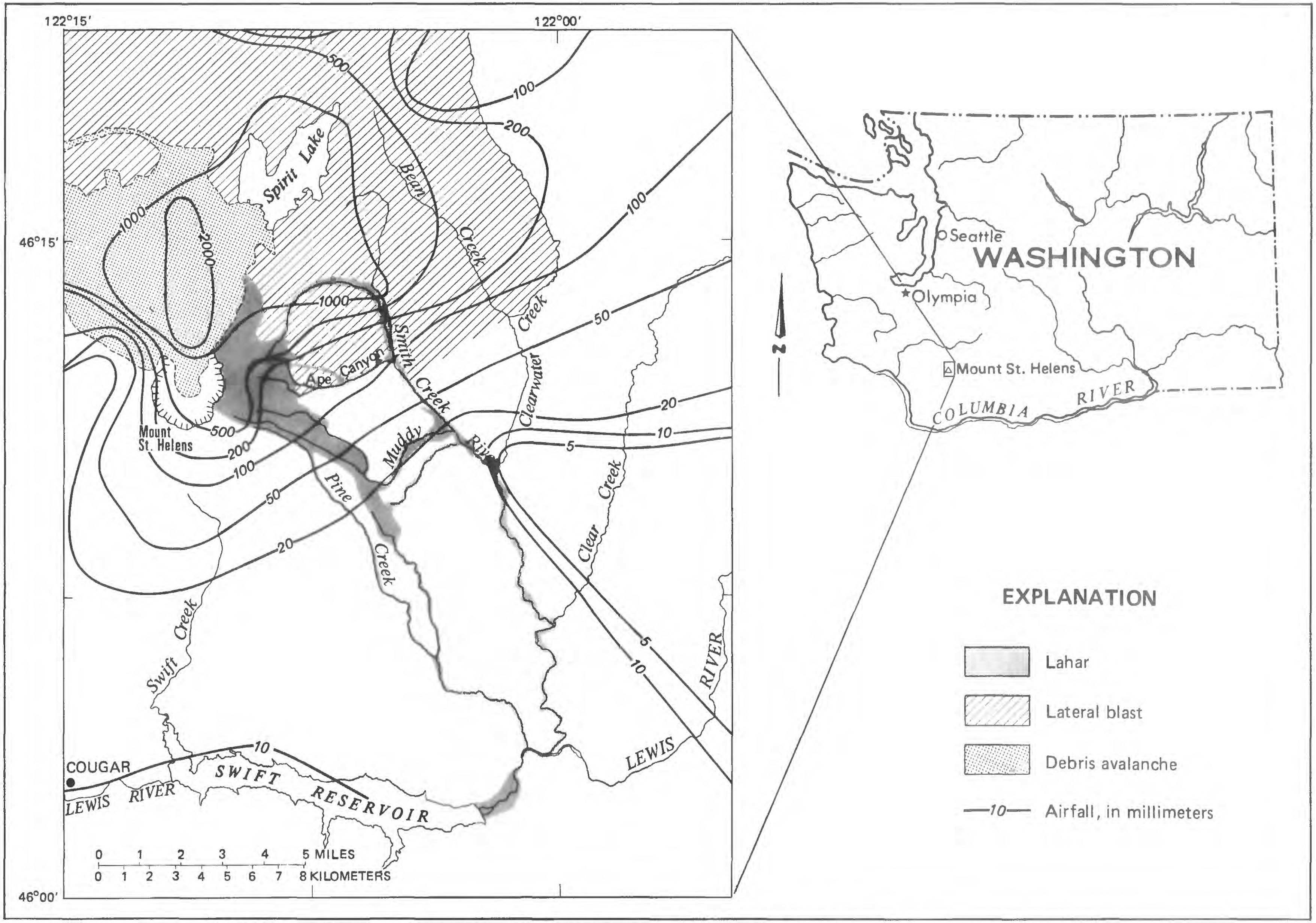

FIGURE 1. – Location of Mount St. Helens, Washington, and channels of the Lewis River system that were altered by the lateral blast, lahars, and May 18th and subsequent 1980 eruptions.

In order to assess potential flood hazards, document storm-induced changes in the morphology of the eruption-altered stream channels, and assist in the development of sediment budgets, 88 monumented channel cross sections were established on six tributaries of the Lewis River system (figs. 2 and 3). Annual or more frequent cross-section surveys provide measurements of bank erosion or accretion and of channel erosion or aggradation. This report presents the cross-section data collected during WY (water years) 1980-82 (September 1980 through September 1982).

Acknowledgments

We gratefully acknowledge the assistance of those who participated in data collection and reduction and in preparation of the report for publication: David M. Bice, Ronald A. Barnes, Steve R. Brantley, Adam W. Burnett, Kenneth A. Cameron, Jeanette E. Dodge, John W. Ewert, Kris K. Gould, Kevin C. Hadley, Hazel E. Hammond, Myrtle A. Jones, Susan E. Key, Jon J. Major, William W. Mast, Patrice D. Mango, Patrick T. Pringle, Sandra J. Pringle, Donald S. Ropiequet, Martha A. Sabol, Trish L. Wahlstrom, and Ginger C. White. Review comments and helpful suggestions for content and organization of the report were provided by K. Michael Nolan, Harvey M. Kelsey, Thomas C. Pierson, Gary L. Gallino, Richard J. Janda, and William W. Emmett.

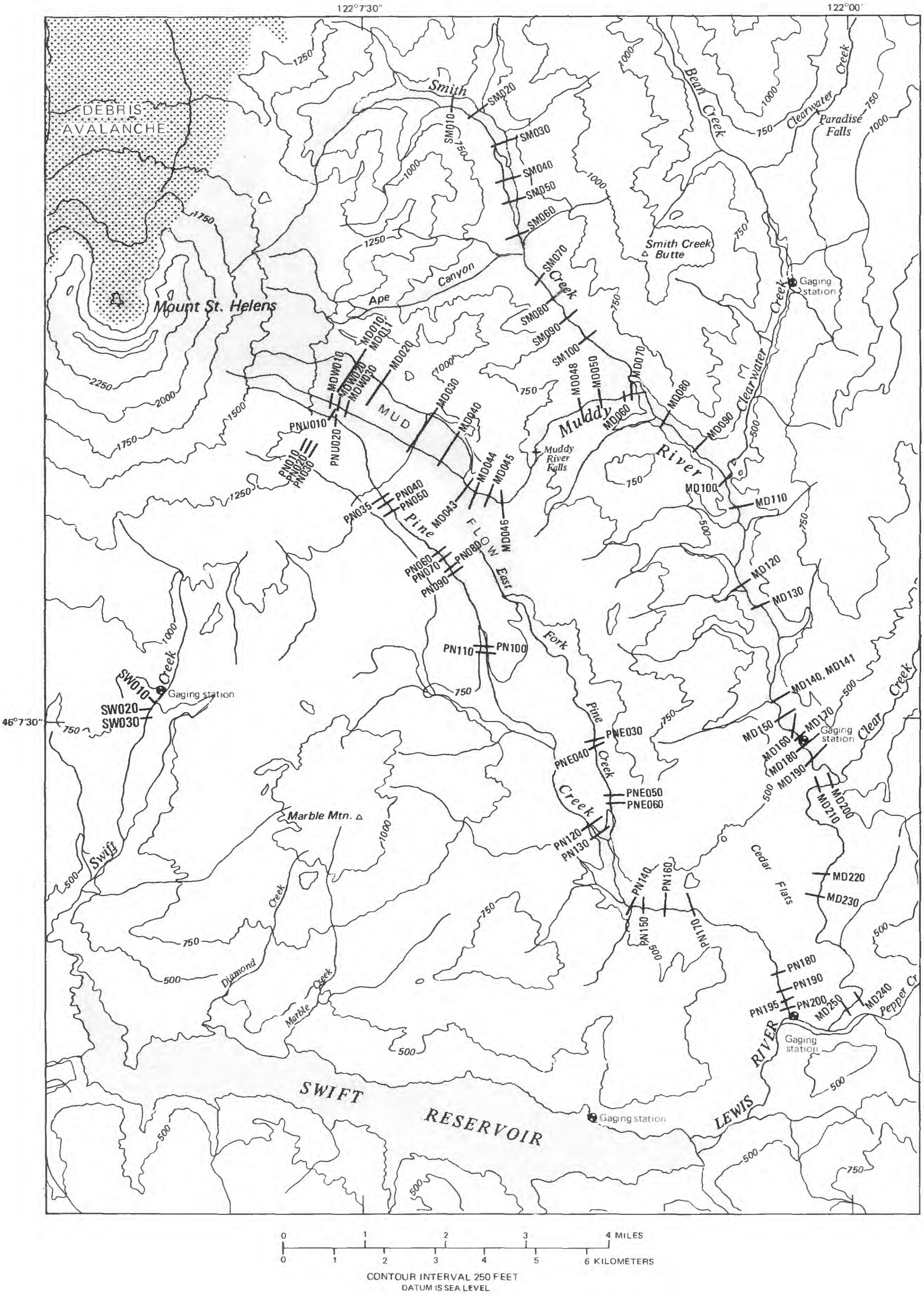

FIGURE 2. – Location of channel cross sections and stream gaging stations on Pine Creek, Muddy River, Smith Creek, and Swift Creek.

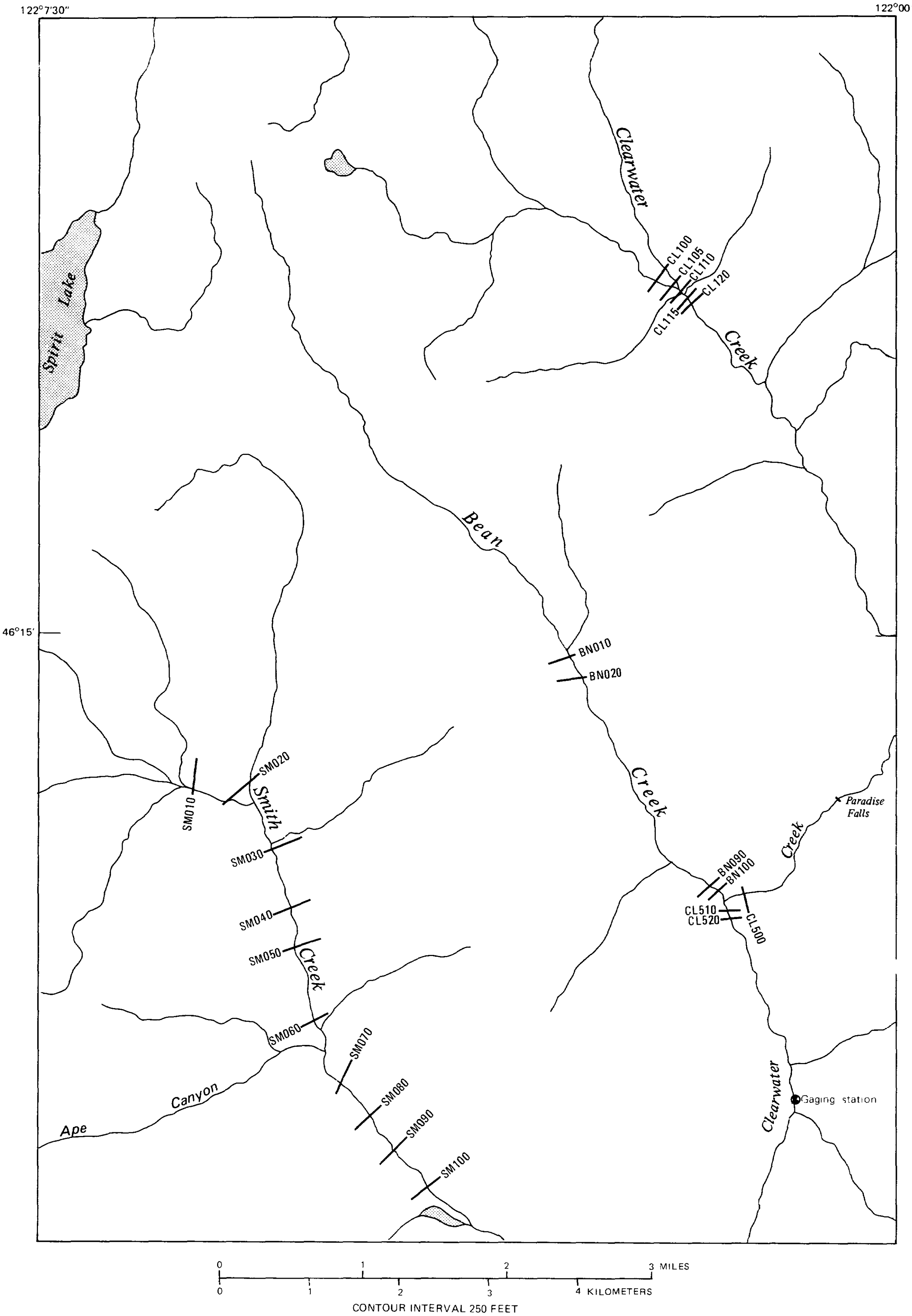

FIGURE 3. – Location of channel cross sections and stream gaging station on Clearwater Creek, Bean Creek and Smith Creek.

DESCRIPTION OF STUDY AREA

Physical Setting

Study streams in the Lewis River system were selected to monitor channel response to the different types and magnitudes of volcanic impacts. The study streams are within a 150° sector northeast and south of Mount St. Helens, and vary in drainage area, length, and gradient of the affected channel (table 1).

The 473-km^2 study area includes streams that originate on the flanks of the volcano and were affected by lahars, as well as streams farther to the east that were affected by only the lateral blast and tephra deposition (fig. 1). The relative severity and extent of lahars that entered tributaries of the Lewis River system on May 18, 1980, generally decreases in a clockwise direction from northeast to south (Janda and others, 1981). Damage from the blast is limited in the study area to portions of the basins northeast to east-northeast of the volcano, and decreases with distance from the volcano. Tephra (airfall) from the May 18th and subsequent 1980 eruptions was carried primarily to the northeast by the prevailing winds. The axis of maximum tephra deposition crosses upper portions of the Smith Creek, Bean Creek, and Clearwater Creek basins, where thickness of deposits decreases with distance from the volcano (Waitt and others, 1981). Volcanic effects on study basins in the Lewis River system are summarized in table 2.

Table 1.--Summary of drainage basin and channel characteristics for study basins

Stream	Drainage area at mouth (km^2)	Channel length (km)	Mean gradient	Elevation at mouth (m)	Relief (m)	Valley trend
Muddy River	[1]351	29.8	0.024	315	2178	NW-SE
Smith Creek	60	11.9	0.020	497	1996	NW-SE
Clearwater Creek	[2]102	21.7	0.018	445	1180	NW-SE
Bean Creek	21	11.3	0.027	523	1063	NW-SE
Pine Creek	62	22.0	0.045	310	2219	NW-SE
Swift Creek	60	13.0	0.133	186	2343	N-S

1 Including Smith Creek, Clearwater Creek, Bean Creek, and Clear Creek.
2 Including Bean Creek.

Table 2.--Summary of eruptive effects on study basins, Lewis River system, Mount St. Helens, Washington

Drainage basin, sub-basin	Channel length affected by lahars[1] (percent)	Drainage basin affected by blast[2] (percent)	Thickness of tephra deposits[3] (mm)
Muddy River Basin[4]	--	30	2-1500
Muddy River[5]	100	1	10-200
Smith Creek	100	81	20-1500
Bean Creek	0	98	70-800
Clearwater Creek[6]	0	44	70-400
Clear Creek	0	0	2-150
Pine Creek Basin	--	1	10-200
East Fork Pine Creek	100	1	10-20
Main Fork Pine Creek	80	1	10-200
Pine Creek[7]	100	1	10-15
Swift Creek	100	1	10-200

1 Extent of lahars determined from maps prepared by Janda and others, 1981; Pierson, 1983.

2 Boundary of the blast-affected area taken from U.S. Geological Survey 1:100,000 scale series map of Mount St. Helens and Vicinity, 1981.

3 Thickness of tephra deposits determined from isopach maps of Waitt and others, 1981. Total thickness of deposits is dominated by the May 18, 1980, directed blast (pyroclastic-density flow) and air-fall deposits.

4 At the mouth of Muddy River, including Smith Creek, Clearwater Creek, Bean Creek, and Clear Creek.

5 At the mouth of Muddy River, excluding Smith Creek, Clearwater Creek, Bean Creek, and Clear Creek

6 Excluding Bean Creek.

7 Downstream from confluence of East Fork and Main Fork Pine Creek.

Hydrologic Setting

Climate

Mount St. Helens is located on the western side of the Cascade Range in southwestern Washington. Mean annual precipitation is 3.3 m or more near the volcanic summit and decreases to 2.2 to 3.0 m away from the mountain to the east and south (Gullidge, 1970). Most precipitation occurs during the winter rainy season, which begins about October, peaks in December or January, and declines into the spring. Seventy-five percent of the annual precipitation occurs during October through March. Most rainfall occurs as showers of light to moderate intensity rather than as heavy rains. The freezing level varies widely. The midwinter snowline is typically between about 800 and 1000 m above sea level. Average annual snow accumulation varies from zero at lower altitudes to more than 8 m above 1,500 m; density of the snowpack increases from about 25 to 45 percent water equivalent between early winter and April (Gullidge, 1970).

Post-eruption water-discharge and suspended-sediment measurements

Water-discharge and suspended-sediment data are scant for the ungaged period immediately after the eruption for all study basins. Suspended-sediment concentration data for the ungaged period are summarized in table 3. Highest post-eruption suspended-sediment concentrations measured at Muddy River and Pine Creek were 178,000 mg/L (milligrams per liter) and 108,000 mg/L, respectively. These samples were collected on November 7, 1980, from streamflow generated during the first large storm runoff (ungaged) following the eruption.

Table 3.--Summary of miscellaneous (ungaged) post-eruption suspended-sediment concentrations, Muddy River, Clearwater Creek, and Pine Creek, Mount St. Helens, Washington

Stream	Period of record	Number of measurements	Suspended-sediment concentration (mg/L)	Remarks
Muddy River	08/29/80	1	1,170	[1]WY 1980
	10/09 - 12/23/80	22	1,940 - 178,000	[1]WY 1981
Clearwater Creek	11/06 - 11/21/80	3	1,520 - 5,240	[2]WY 1980
Pine Creek	06/06 - 08/29/80	3	215 - 8,900	[3]WY 1980
	10/09 - 12/23/80	23	95 - 108,000	[3]WY 1981

[1] Samples collected at a site 8.9 kilometers upstream from mouth of Muddy River.
[2] Samples collected near mouth of Clearwater Creek.
[3] Samples collected at a site 0.2 kilometers upstream from mouth of Pine Creek.

Gaging stations were installed during the summer of 1981 on Muddy River, Clearwater Creek, and Pine Creek for measurement of post-eruption water and suspended-sediment discharge (figs. 2 and 3). Locations and drainage areas for the post-eruption gaging stations are summarized in table 4. Peak flows and suspended-sediment concentrations measured at post-eruption gaging stations on Muddy River, Clearwater Creek, and Pine Creek also are summarized in table 4.

Table 4.-- Summary of post-eruption water-discharge and suspended-sediment measurements at gaging stations on Muddy River, Clearwater Creek, and Pine Creek, water year 1982, Mount St. Helens, Washington

Stream: Station number	Peak water discharge		Peak sediment concentration		
	Date	Instantaneous discharge (m^3/s)	Date	Instantaneous discharge (m^3/s)	Concentration (mg/L)
Muddy River:[1]					
14216350	2/20/82	303	10/06/81	88	82,500
Clearwater Creek:[2]					
14216300	2/20/82	233	02/16/82	--	3,980
Pine Creek:[3]					
14216900	2/20/82	112	10/06/81	25	69,200

1 Stream gaging station is located 7.9 km upstream from the mouth. Drainage area above the gaging station is 212 km^2.
2 Stream gaging station is located 4.4 km upstream from the mouth. Drainage area above the gaging station is 85.4 km^2.
3 Stream gaging station is located 0.2 km upstream from the mouth. Drainage area above the gaging station is 58.8 km^2.

Hydrographs of daily mean discharge for WY 1982 at the Muddy River and Pine Creek gages (figs. 4 and 5) show that significant storm runoff occurred on October 6, November 21, and December 5, 1981, and January 24, February 20, and April 13, 1982. Peak and daily mean discharges for these storms are summarized for Muddy River, Clearwater Creek, and Pine Creek in table 5. These high flows coincide with periods of high flow for the North Fork Toutle River at Kid Valley during WY 1982. Gaging station records in the Toutle River system, where water-discharge measurements have been collected since the summer of 1980, indicate that notably high flows also occurred during the 1981 water year, on December 25, 1980, and February 19, 1981. Because these flows reflect regional storms, proportionally high flows probably occurred along Muddy River and Pine Creek at the same times.

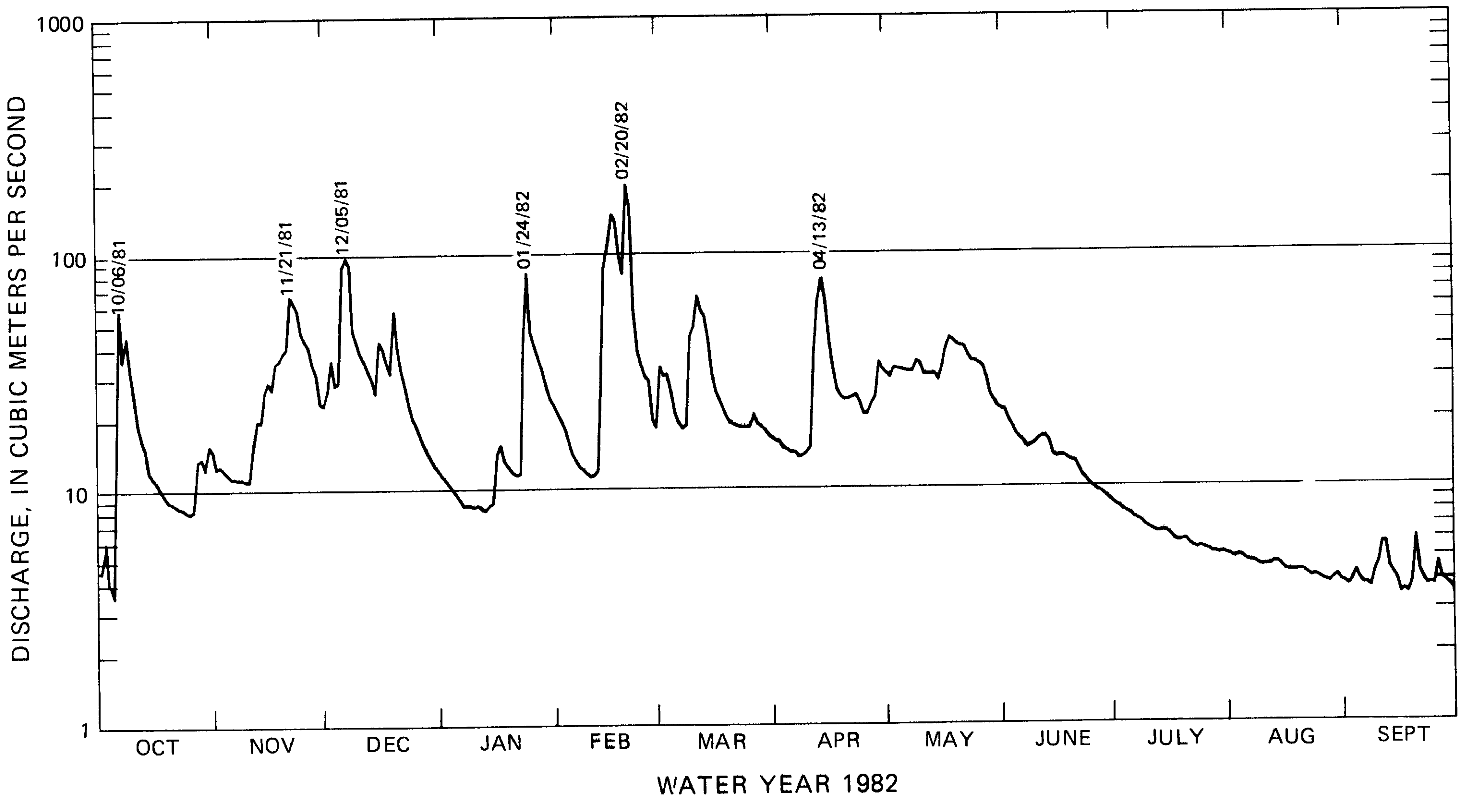

FIGURE 4. – Annual hydrograph of daily mean discharge for Muddy River above Clear Creek, Washington, water year 1982.

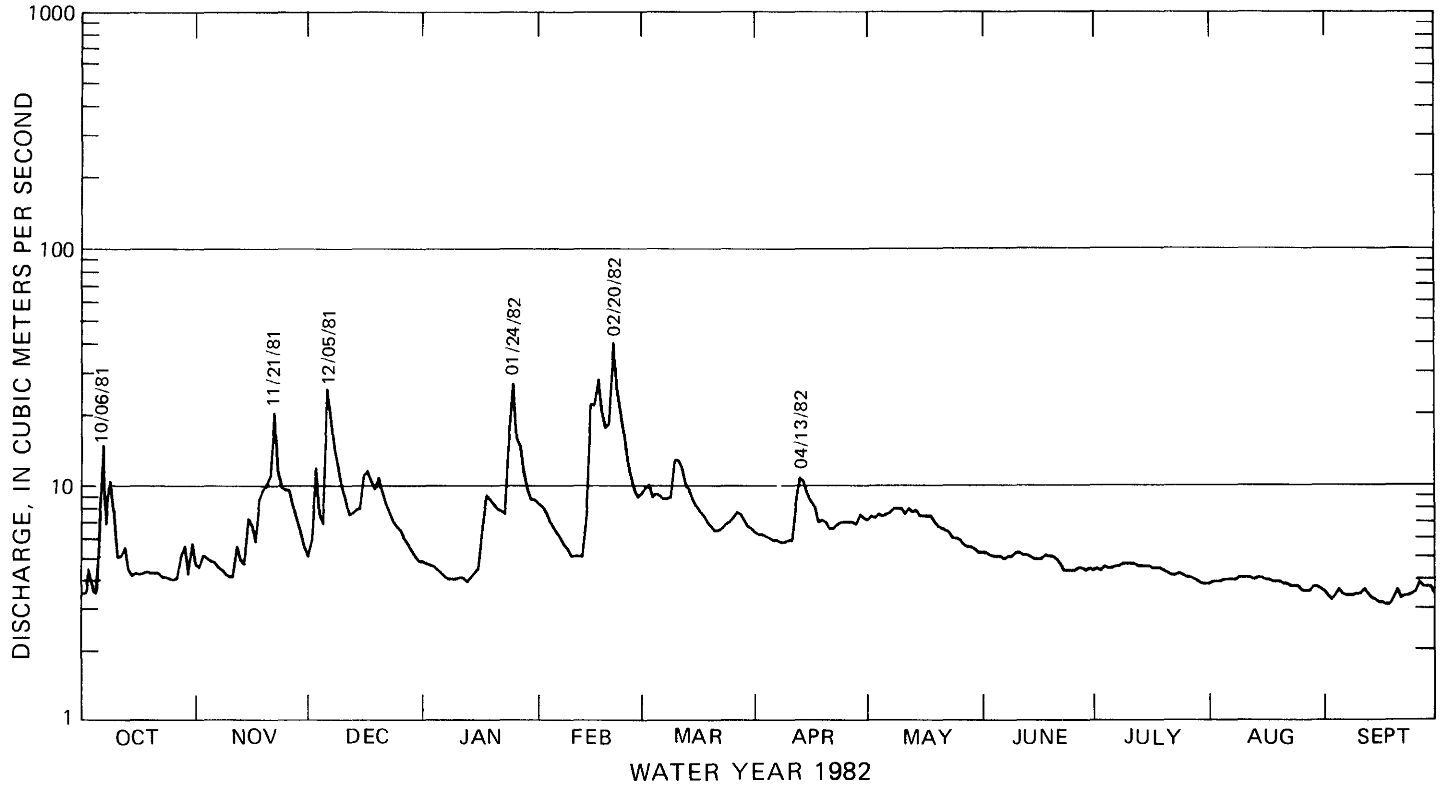

FIGURE 5.– Annual hydrograph of daily mean discharge for Pine Creek near Cougar, Washington, water year 1982.

Table 5.-- Peak and corresponding daily mean discharges for periods of storm runoff, Muddy River, Clearwater Creek, and Pine Creek, water year 1982, Mount St. Helens, Washington

[Values are in cubic meters per second]

Date	Muddy River		Clearwater Creek		Pine Creek	
	Peak	Daily mean	Peak	Daily mean	Peak	Daily mean
10/06/81	101.1	57.8	--	22.7	34.0	15.5
11/21/81	116.4	65.4	--	20.0	28.3	19.8
12/05/81	98.3	87.2	--	55.2	42.5	25.0
01/24/82	147.8	81.6	25.8	19.8	40.8	26.2
02/20/82	303.0	193.0	233.0	118.0	112.1	39.1
04/13/82	100.2	76.5	27.0	25.2	10.7	10.4

METHODS OF DATA COLLECTION

Selection of Cross-section Locations

A total of 88 cross sections was established in clusters of two or more on Muddy River, Smith Creek, Bean Creek, Clearwater Creek, Pine Creek, and Swift Creek. Clusters of two to six cross sections were located to provide data on a range of channel environments, such as river bends, straight reaches, pools, and riffles (figs. 2 and 3). Cross sections were established in clusters, rather than randomly located, in order to define study reaches where adjustments in riparian conditions, channel slope, channel pattern, and streambed material could be studied in conjunction with changes in cross-section geometry, to define reaches for sediment budget computations. Cross sections also were located above and below the confluence of major tributaries. Usually, one or more cross sections were located at or near pre-eruption stream gaging stations and at bridge sites, where pre-eruption survey data are available. Some cross sections on Smith and Clearwater Creeks were located to coincide with cross sections measured photogrametrically from imagery taken during June and July, 1980. The spacing of these sections is about four cross sections per kilometer. For most other clusters of sections, spacing between sections ranges from about 16 cross sections per kilometer to about three cross sections per kilometer, depending on width of the channel.

The network of cross-section measurement sites established during the summer and fall of 1980 on Lewis River tributaries has been modified slightly. Occasionally, local bank erosion, channel avulsion, deposition during floods, gullying, shallow-seated landslides, or salvage logging destroyed both cross-section endpoint monuments. When this occurred, new monumented cross sections were established close to the same location, and, where possible, new surveys were tied to landmarks or reference marks from previous surveys. In some cases this was not possible and cross section relocation was only approximate, with no elevation control. A few cross sections were added to the initial network to increase areal coverage of channel adjustments or to obtain additional measurements in critical areas.

Each cross section in the Lewis River basin was assigned a unique 5- or 6-character alphanumeric identifier. The first two or three characters of the identifier are letters that indicate the specific tributary drainage basin in which the cross section is located, such as "MD" for Muddy River or "PN" for Pine Creek. The last three digits are the cross-section number in the study basin. Cross-section numbers increase in a downstream direction.

Location of channel cross sections and descriptions of endpoint monuments are on file at the Mount St. Helens National Volcanic Monument Headquarters (U.S. Forest Service) in Amboy, Washington, and at the David A. Johnston Cascades Volcano Observatory (U.S. Geological Survey) in Vancouver, Washington.

Surveying Methods

Cross sections usually span the valley floor and were located by establishing a line of sight perpendicular to the channel or valley floor. Cross sections may not have remained perpendicular to the channel as the channel shifted. The endpoints of the cross sections were monumented with metal fenceposts or sections of steel reinforcing bar. The alignment of the monuments with respect to magnetic north was measured. Channel cross sections were surveyed using electronic distance measuring equipment and a theodolite. The instruments were set up on line with the monuments, which served as reference marks for horizontal and vertical control. Where deep gullies or vertical banks precluded precise surveying, a few points on the cross section were measured with hand level and tape. Maximum depth of the channel was estimated where channels were too deep to be waded.

The theodolites used are accurate to about 6 seconds. The precision of electronic distance measurements is generally about 0.05 m per kilometer and is affected by factors such as atmospheric conditions, ground moisture and stability at the instrument station, rod placement, length of shots, and steepness of terrain.

Frequency of Surveys

The network of cross sections was surveyed annually during periods of low streamflow. Single cross sections from about half of the clusters were surveyed additional times each year following significant winter storms. The cross-section network is summarized in table 6.

Table 6.--Description of cross-section network on Lewis River System, 1980-82, Mount St. Helens, Washington

Drainage basin, sub-basin	Number of cross-section clusters	Total number of cross sections[1]	Number of cross sections surveyed after storms	Numbering scheme
Muddy River				
Muddy River	11	32	1-9	MD010-MD250
Smith Creek	3	10	1-3	SM010-SM100
Clearwater Creek	2	8	0	CL100-CL520
Bean Creek	2	4	0	BN010-BN100
Clear Creek	0	0	0	--
West Muddy Channel	1	3	0	MDW010-MDW030
(TOTAL)	(19)	(57)	(2-12)	--
Pine Creek				
Main Fork Pine	7	22	1-3	PN010-PN200
East Fork Pine	2	4	0-1	PNE030-PNE060
Upper East Pine	1	2	0	PNU010-PNU020
(TOTAL)	(10)	(28)	(1-4)	--
Swift Creek	1	3	0	SW010-SW030

[1] Surveyed annually during low flow.

CROSS-SECTION DATA

Field measurements, consisting of slope distance and corresponding vertical angle readings, were converted to horizontal distance and relative elevation and referenced to monuments with fixed station distance and elevation. An arbitrary elevation was assigned to the reference monument. Cross-section survey data were stored and manipulated electronically. Surveys were plotted and superimposed on earlier surveys to show channel changes.

Longitudinal profiles showing the locations of cross sections and survey data in a graphical format are presented at the end of the report (figs. 6-17). An index of cross-section survey sites precedes the survey data for each tributary drainage. Cross sections in each tributary drainage are presented in upstream to downstream order. Plots are viewed looking downstream. All cross sections in a reach or cluster are plotted with the same scale and vertical exaggeration. Scale and (or) vertical exaggeration vary from reach to reach. For some cross sections, a portion of the profile is also plotted at an enlarged scale and (or) different vertical exaggeration to show detailed changes in and near the channel.

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CROSS SECTIONS AND
LONGITUDINAL PROFILES

INDEX TO MUDDY RIVER CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

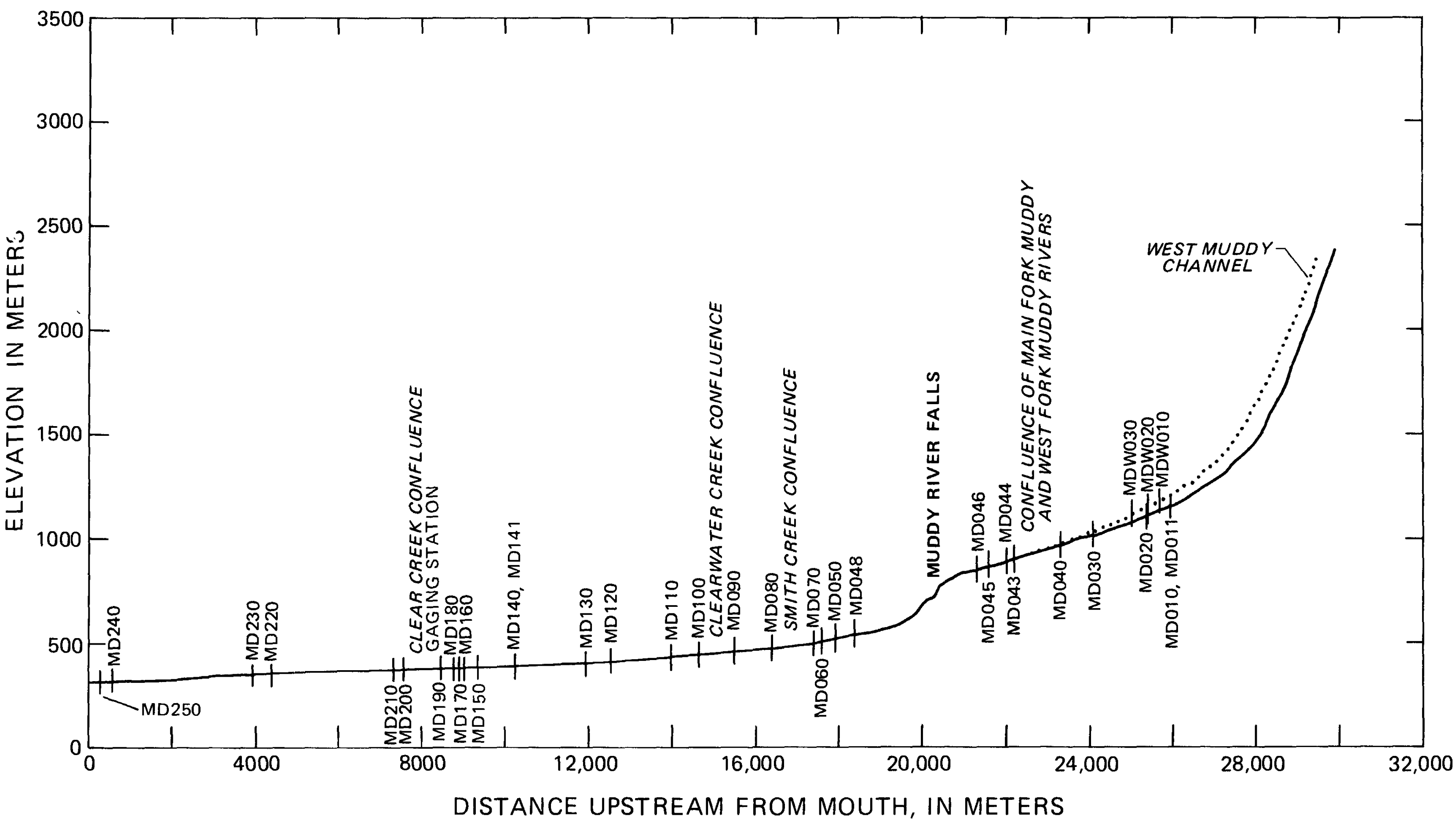


FIGURE 6. -- Longitudinal profile of Muddy River, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic maps, 7.5-minute series, Mount St. Helens SE and Mount St. Helens NE quadrangles.

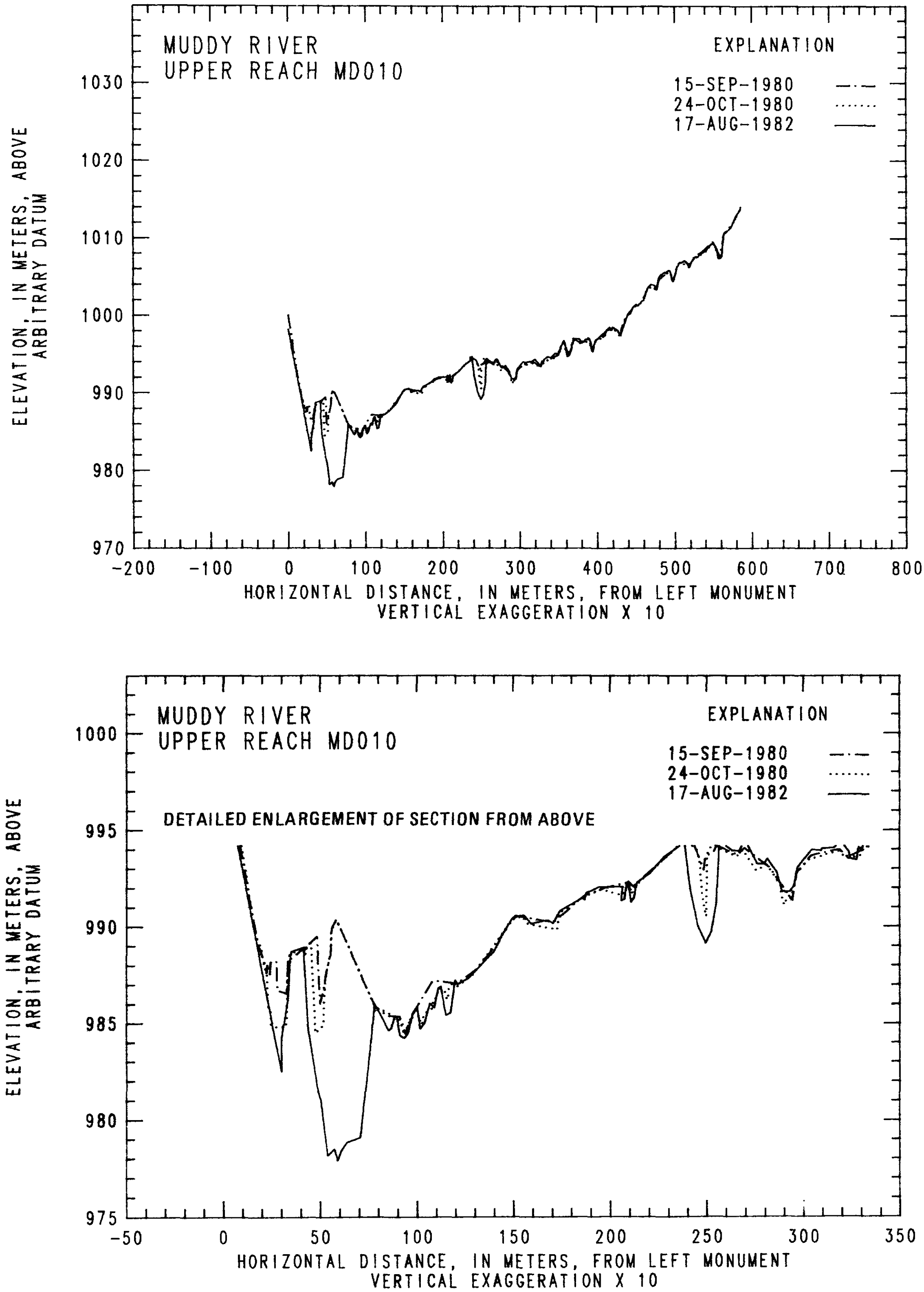
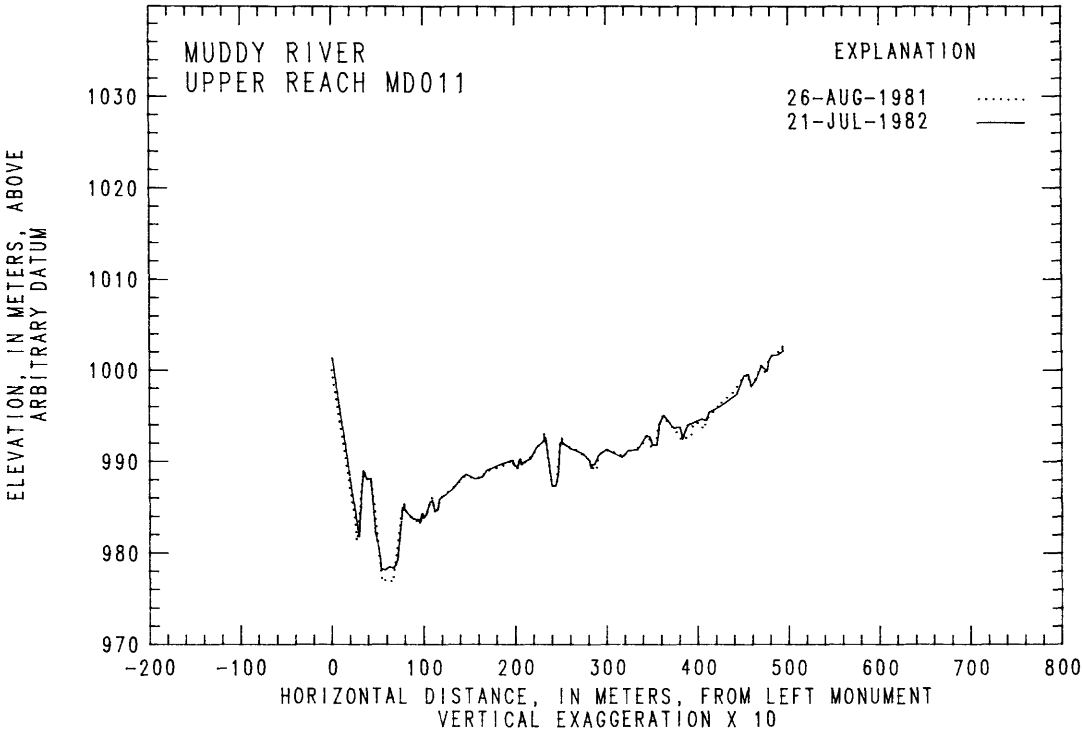


FIGURE 7. – Cross-section profiles for selected sites, Muddy River.



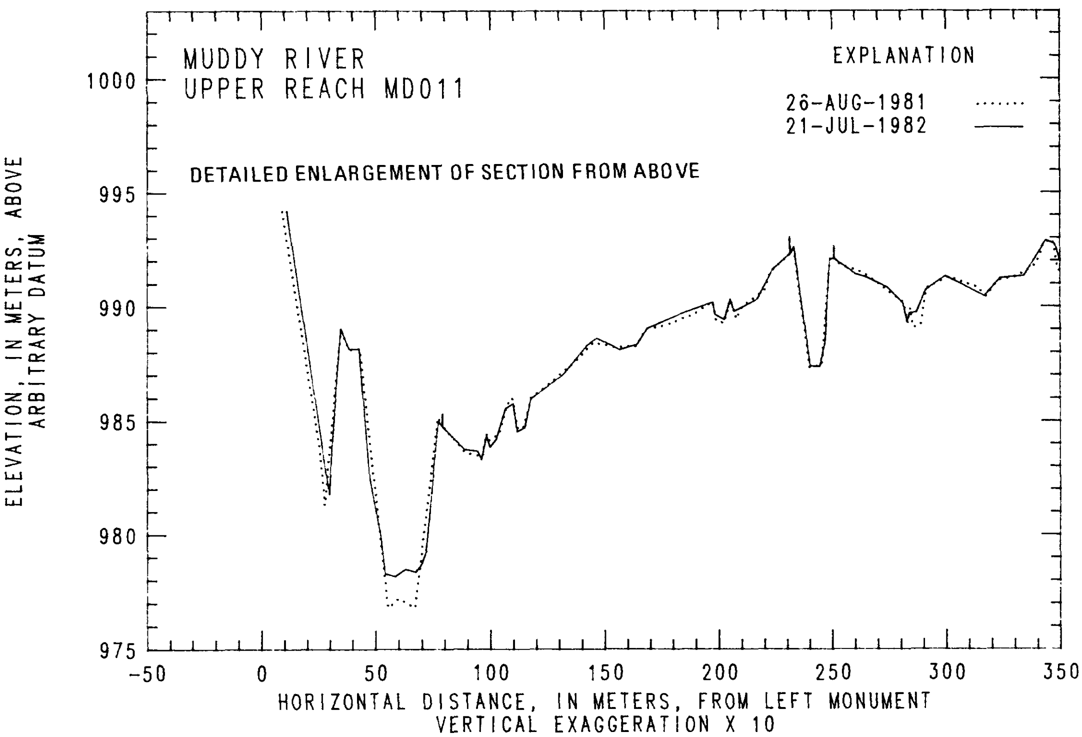
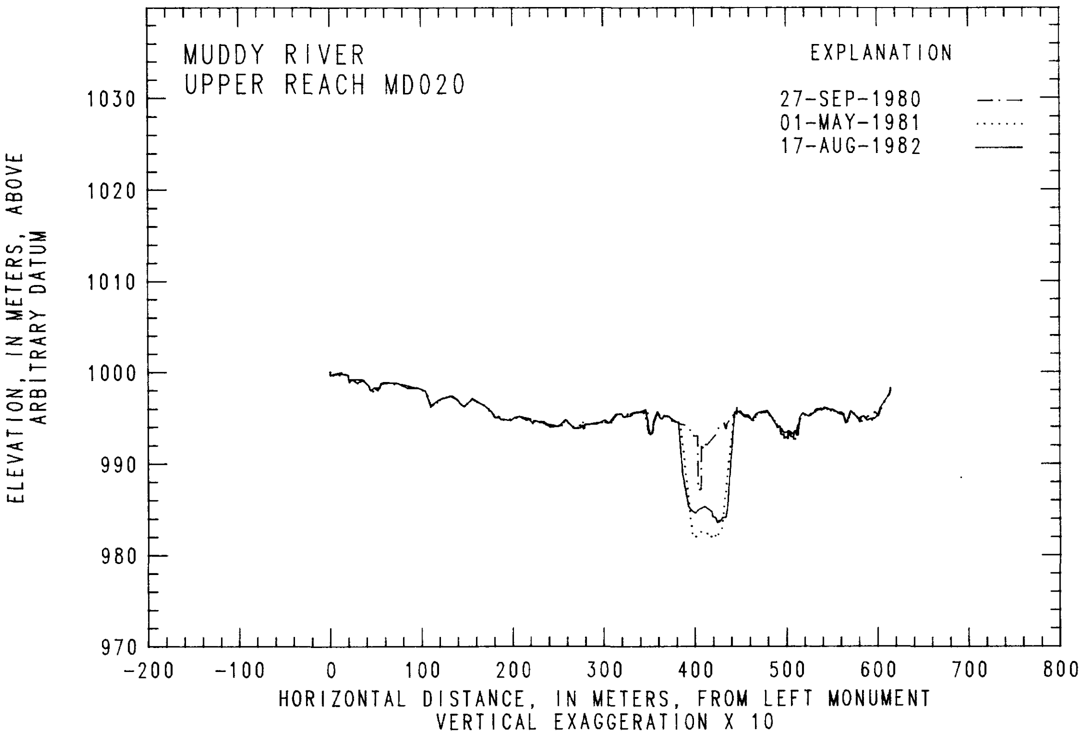


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



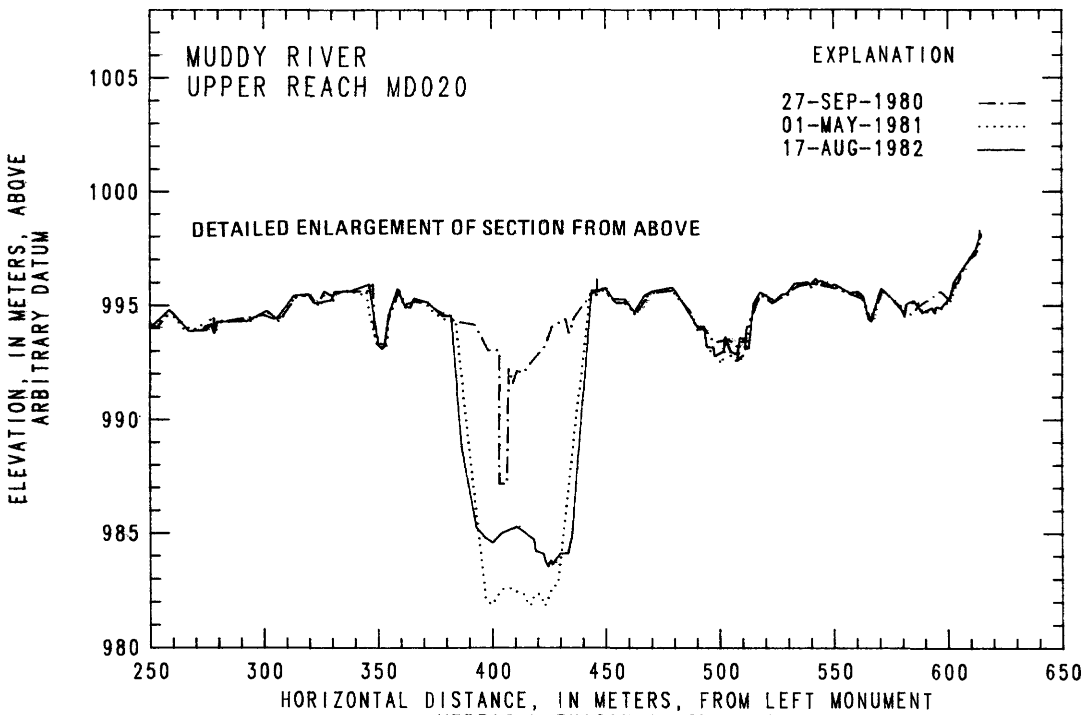
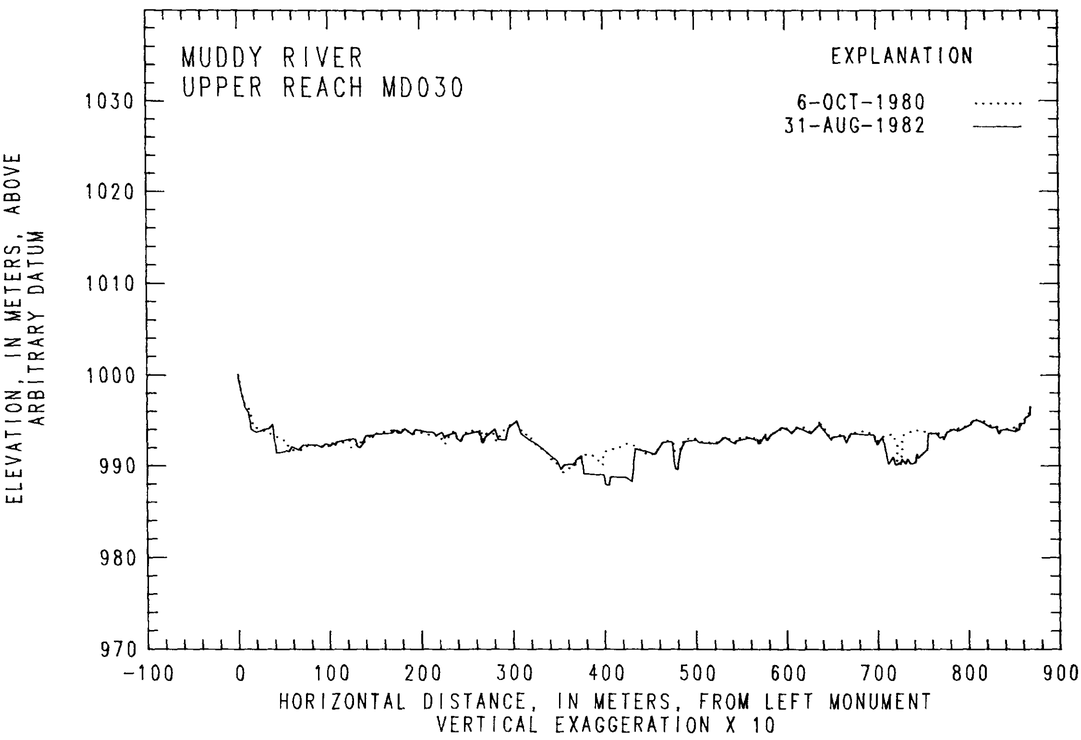


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



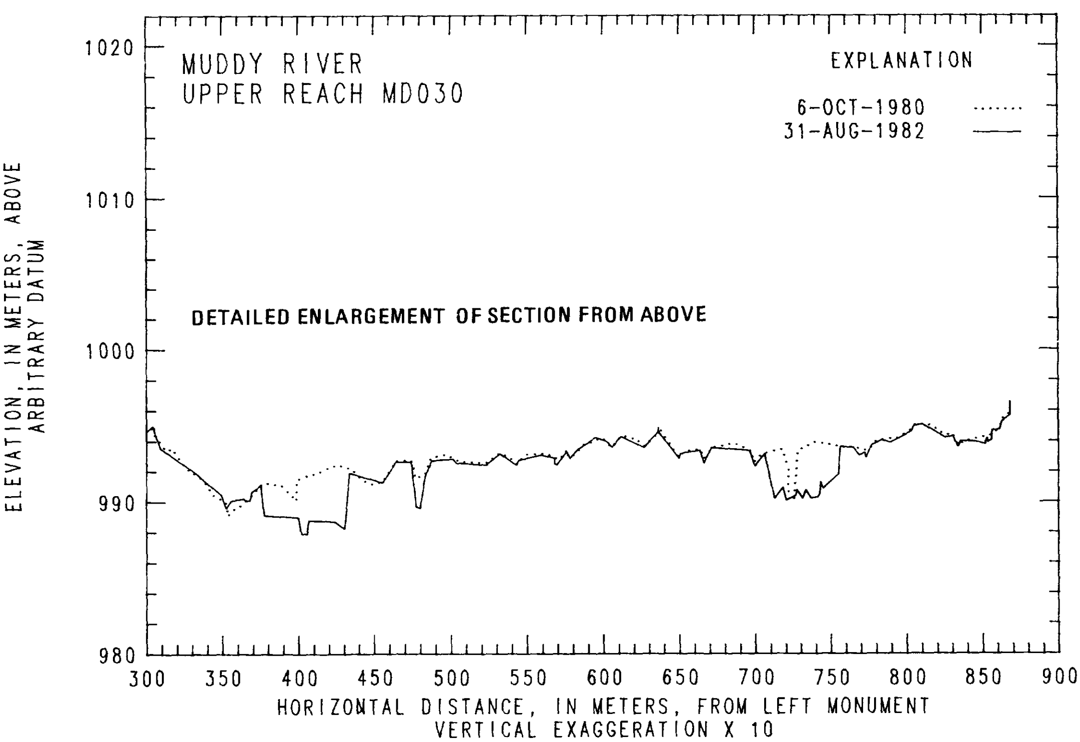
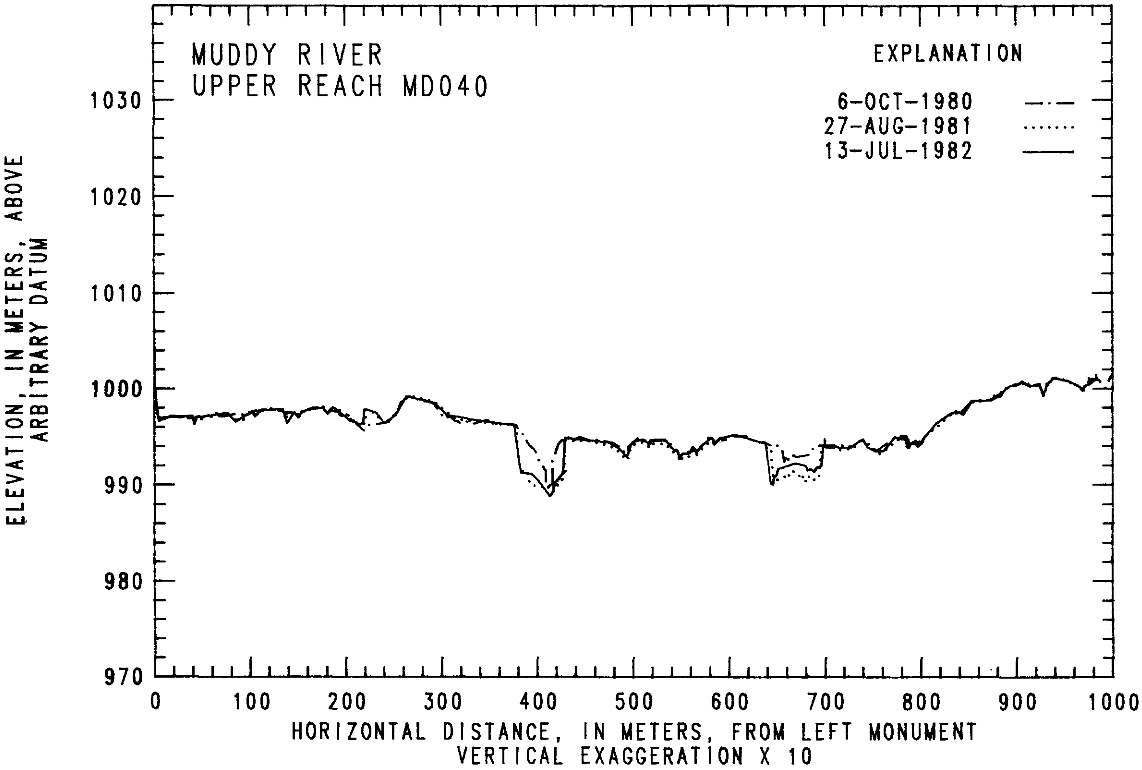


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



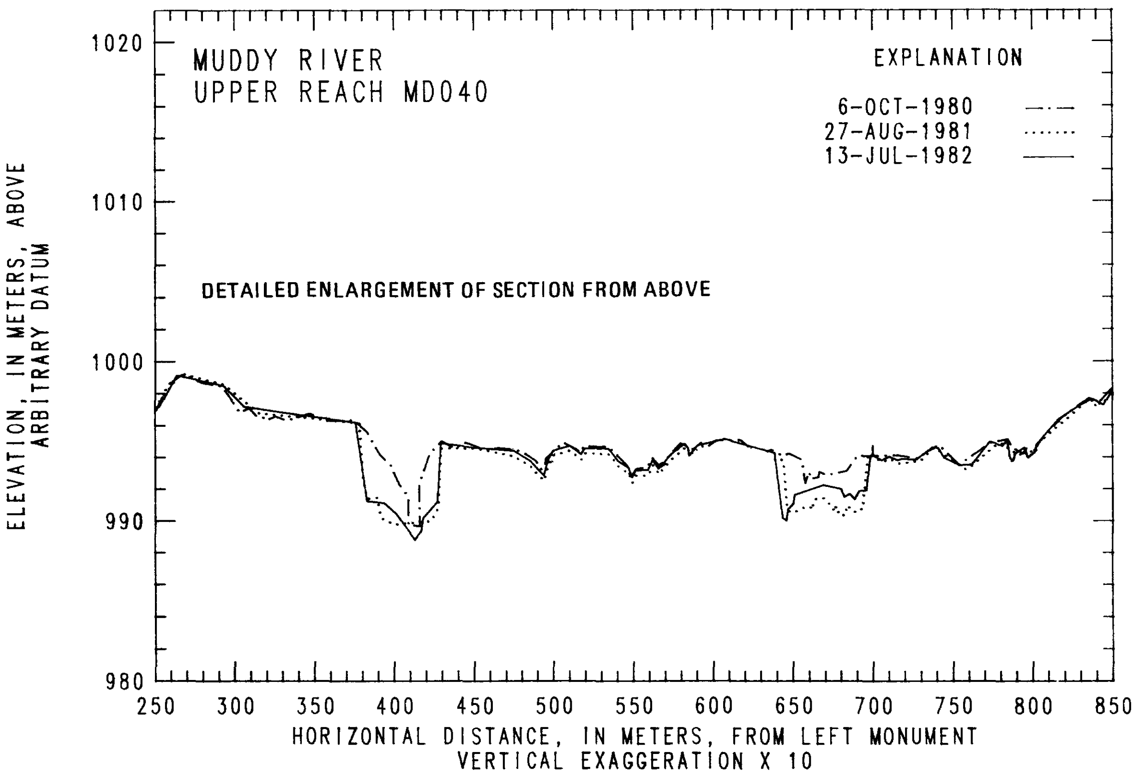


FIGURE 7. —Cross-section profiles for selected sites, Muddy River – continued.

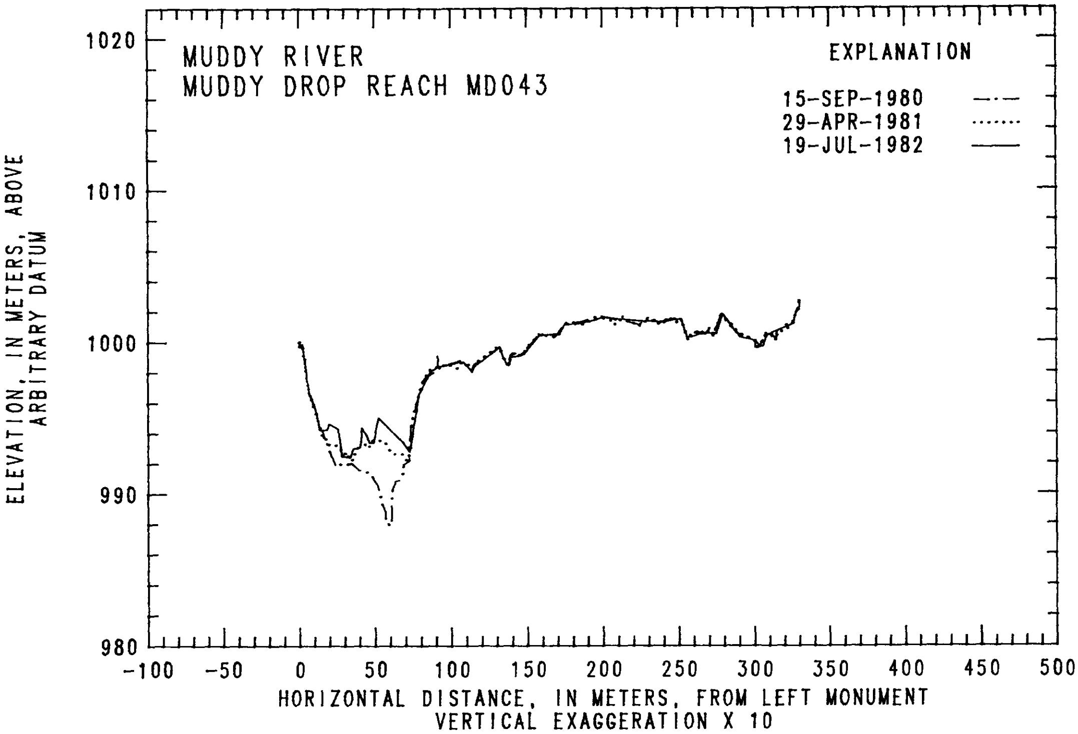


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

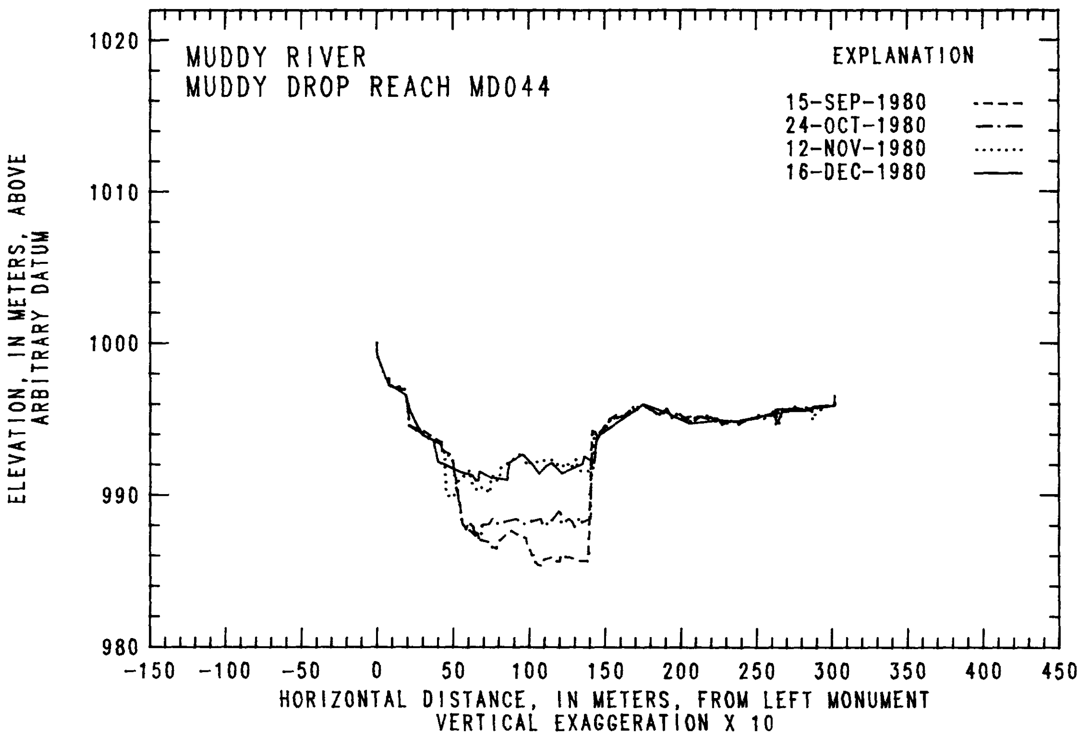
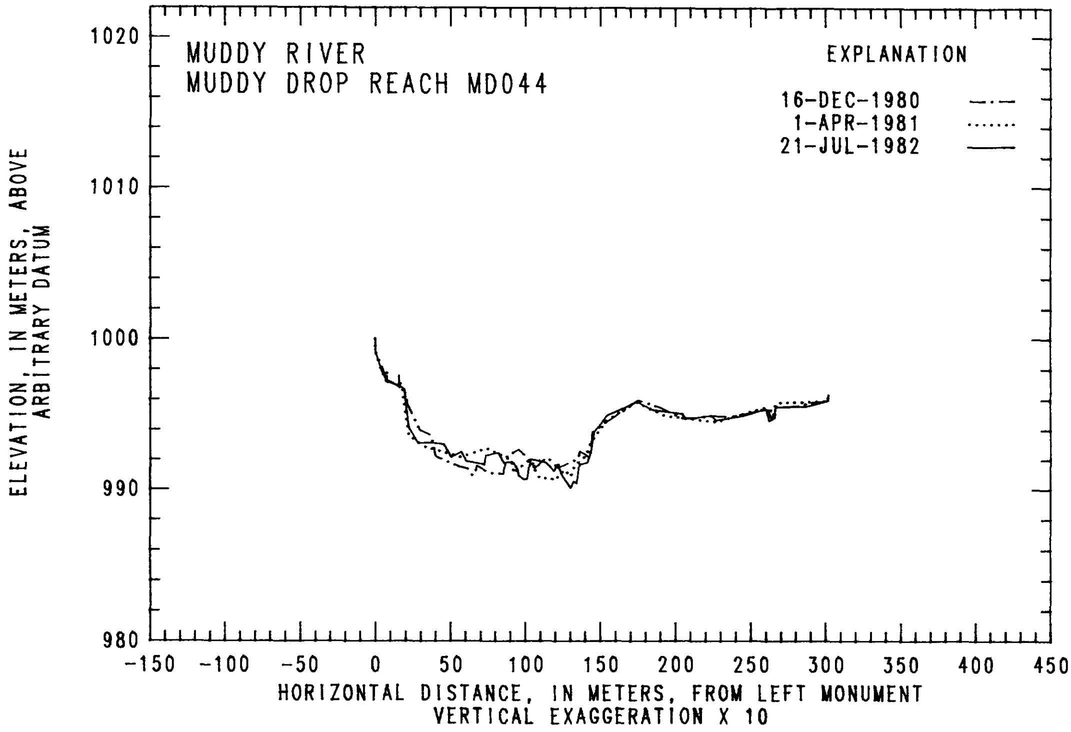


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



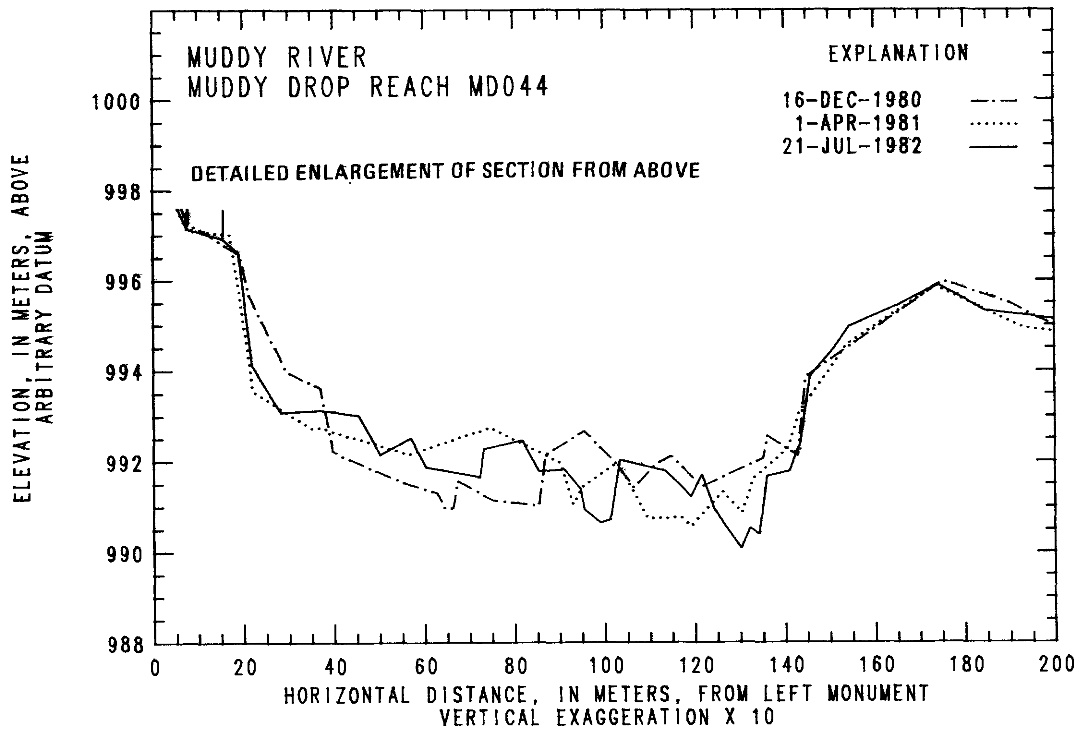
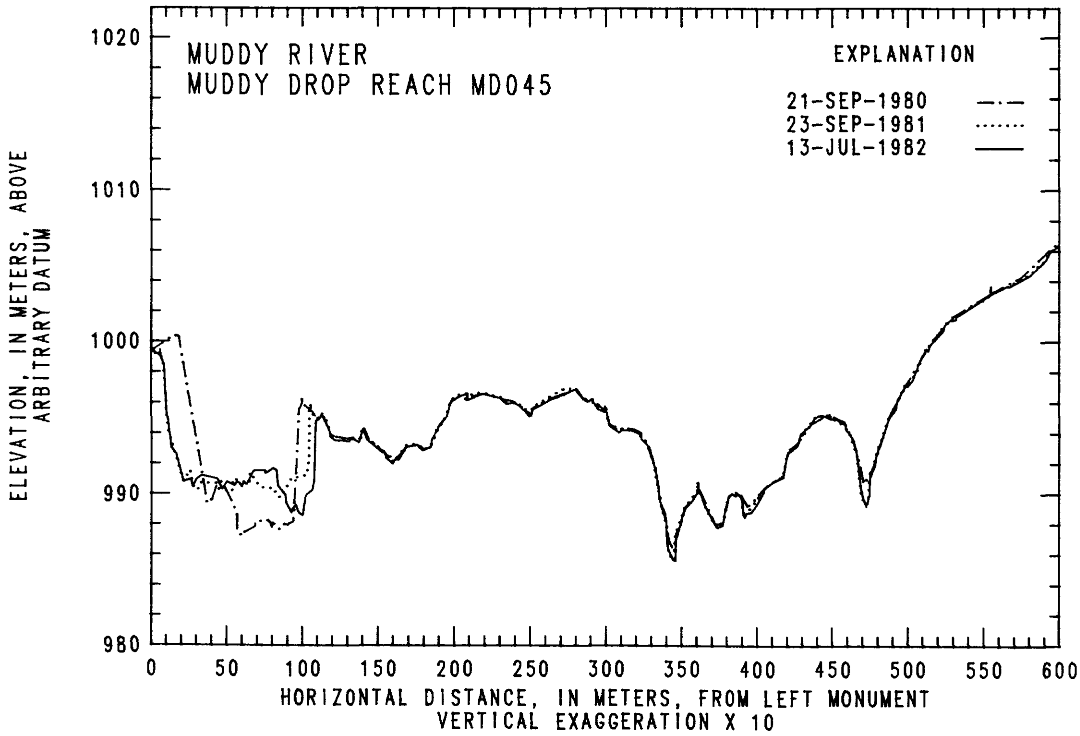


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



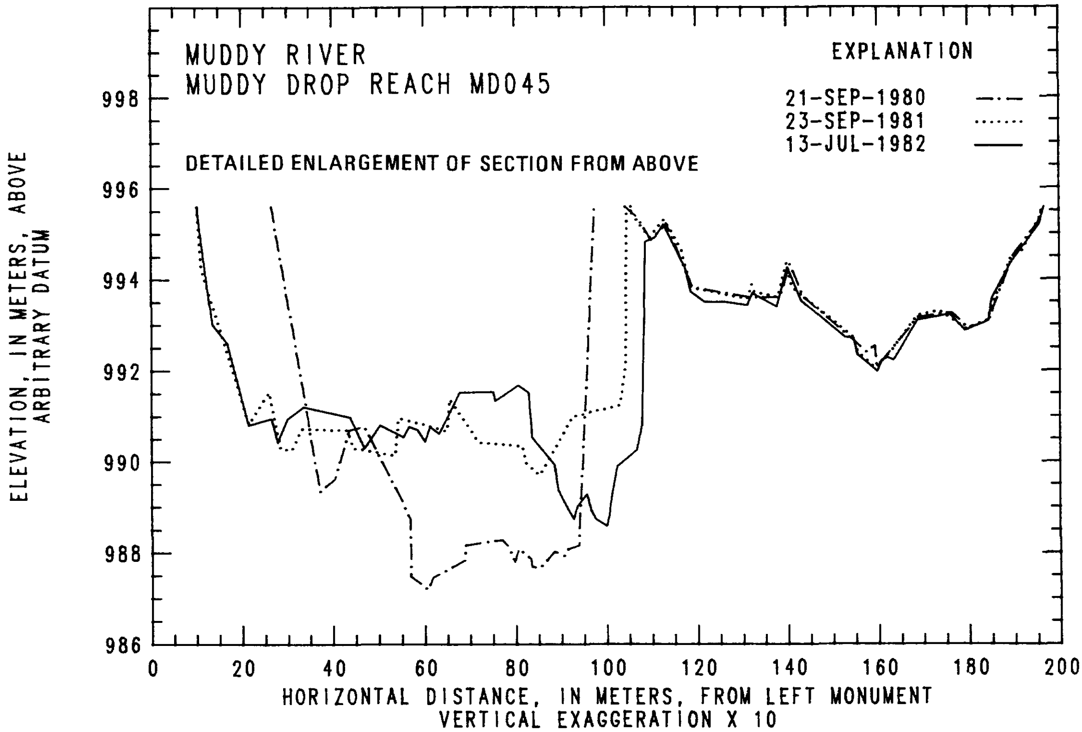
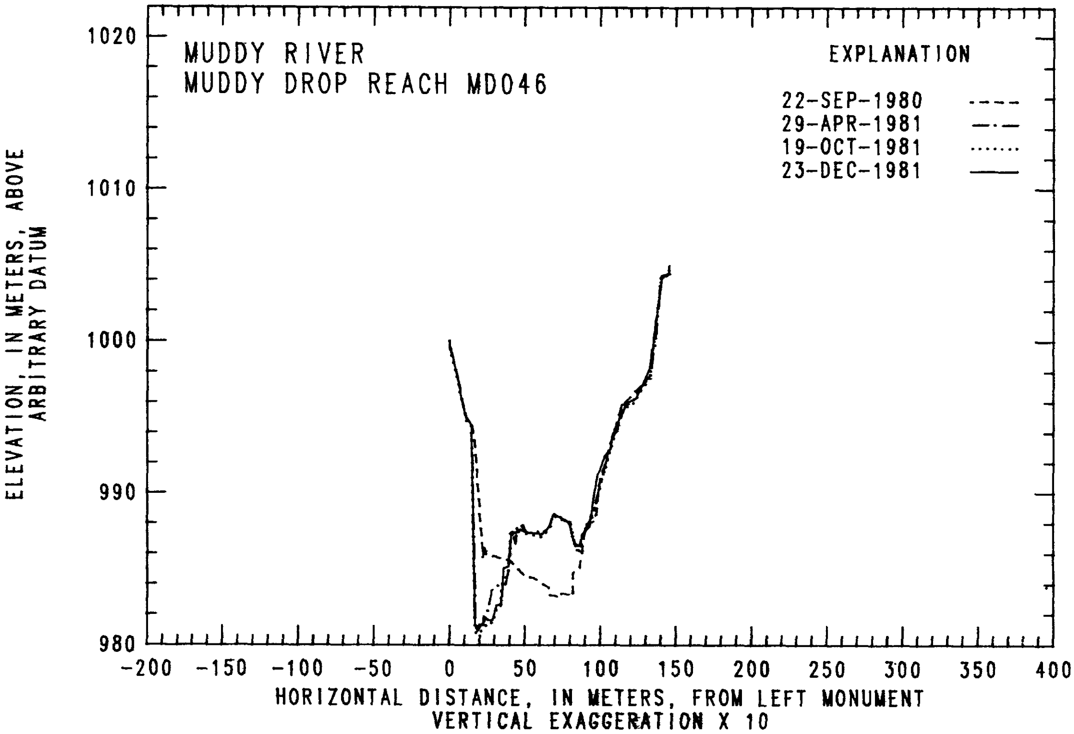


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



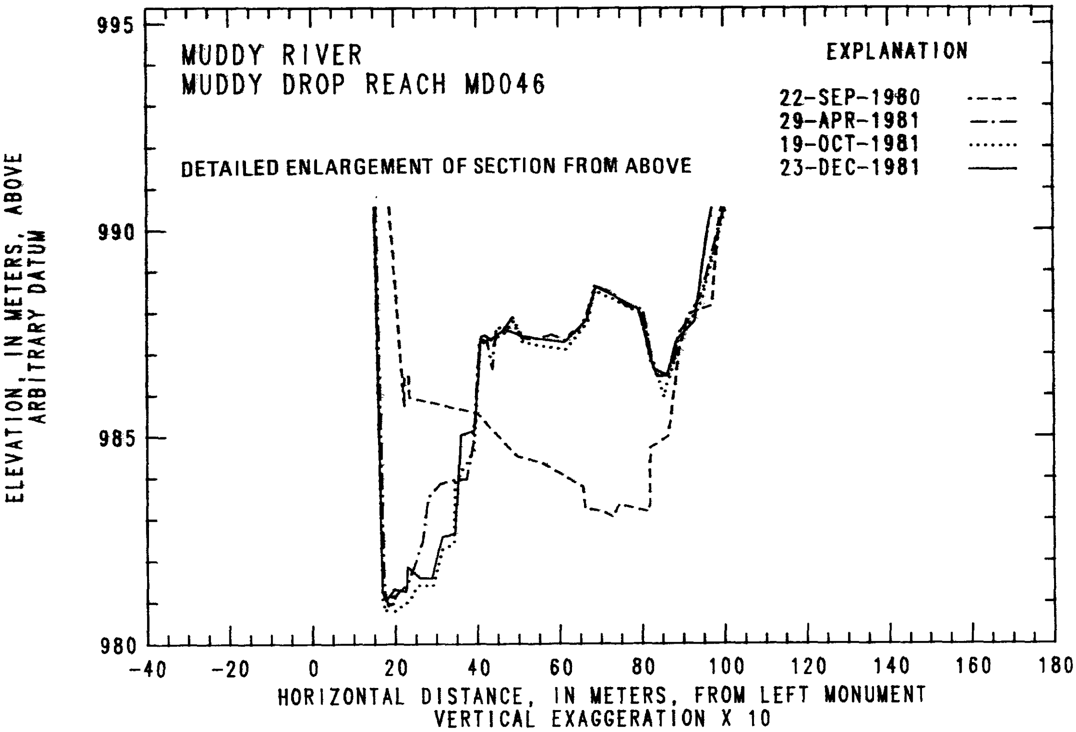


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

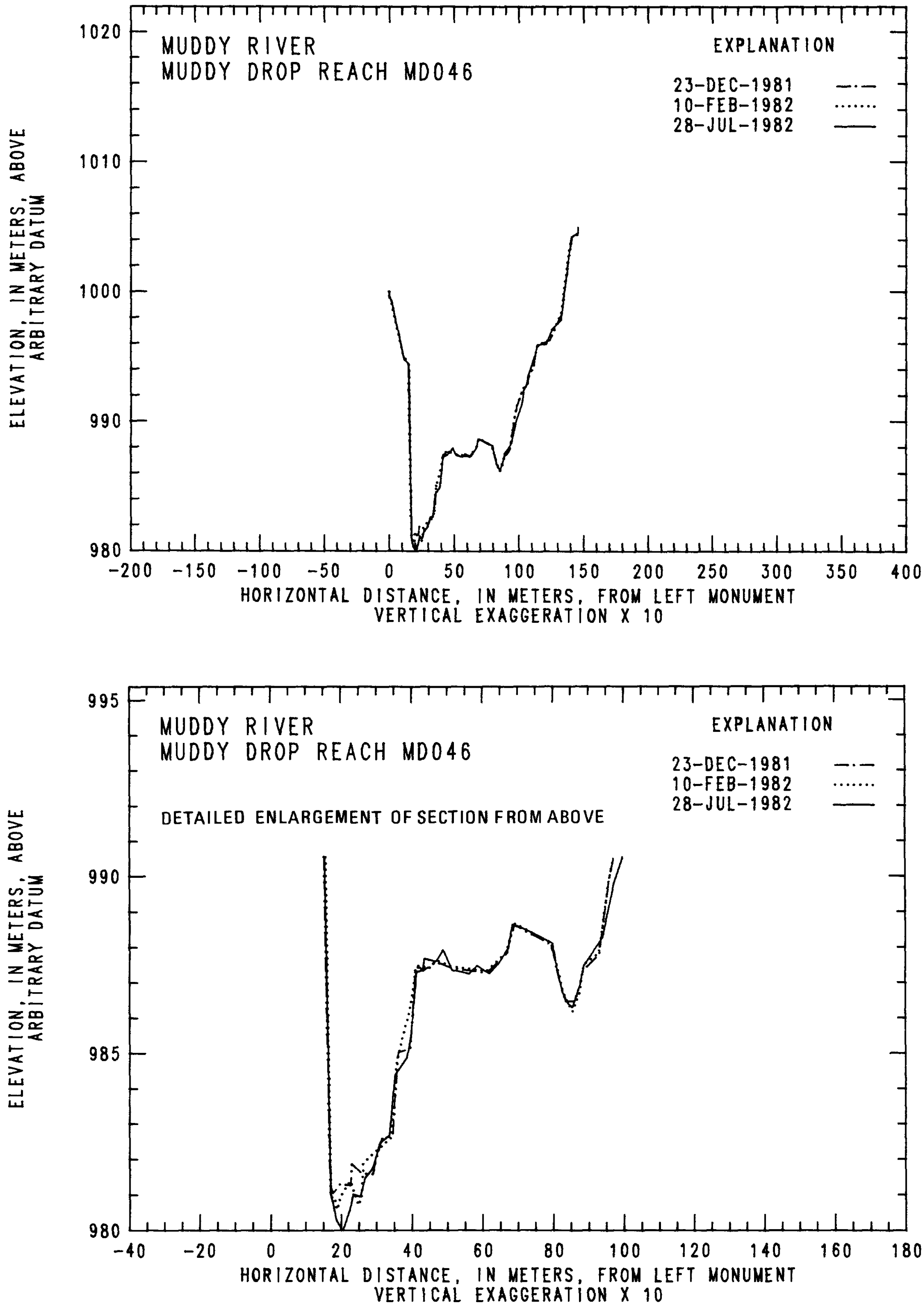


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

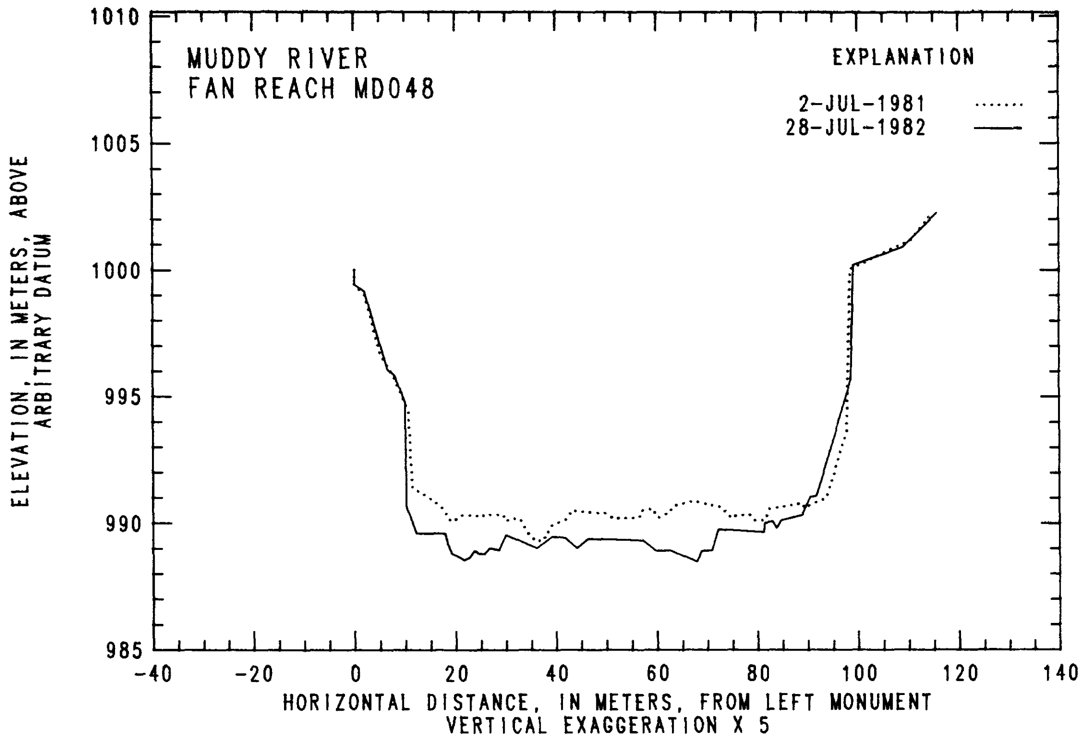


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

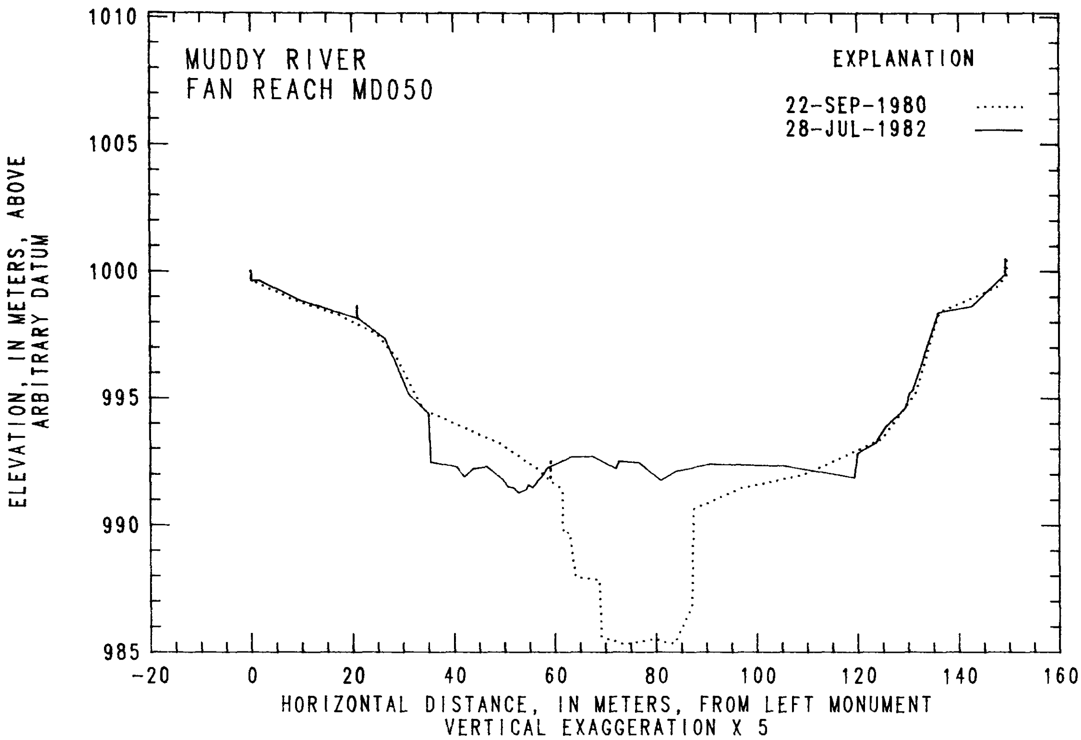


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued

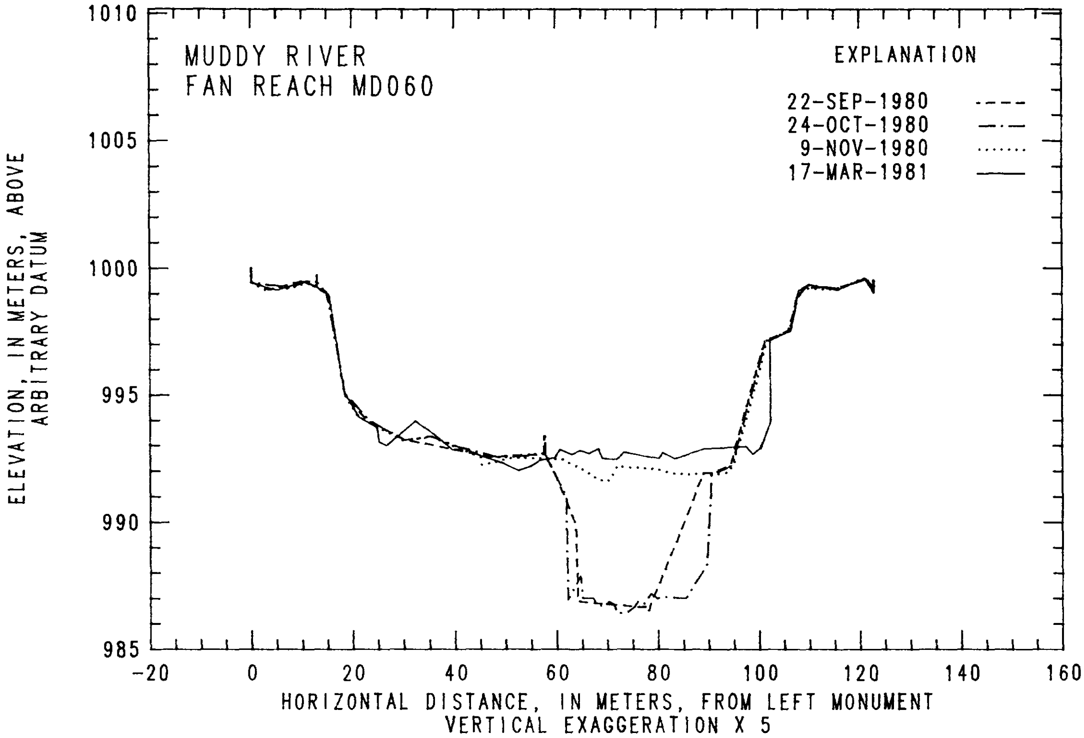
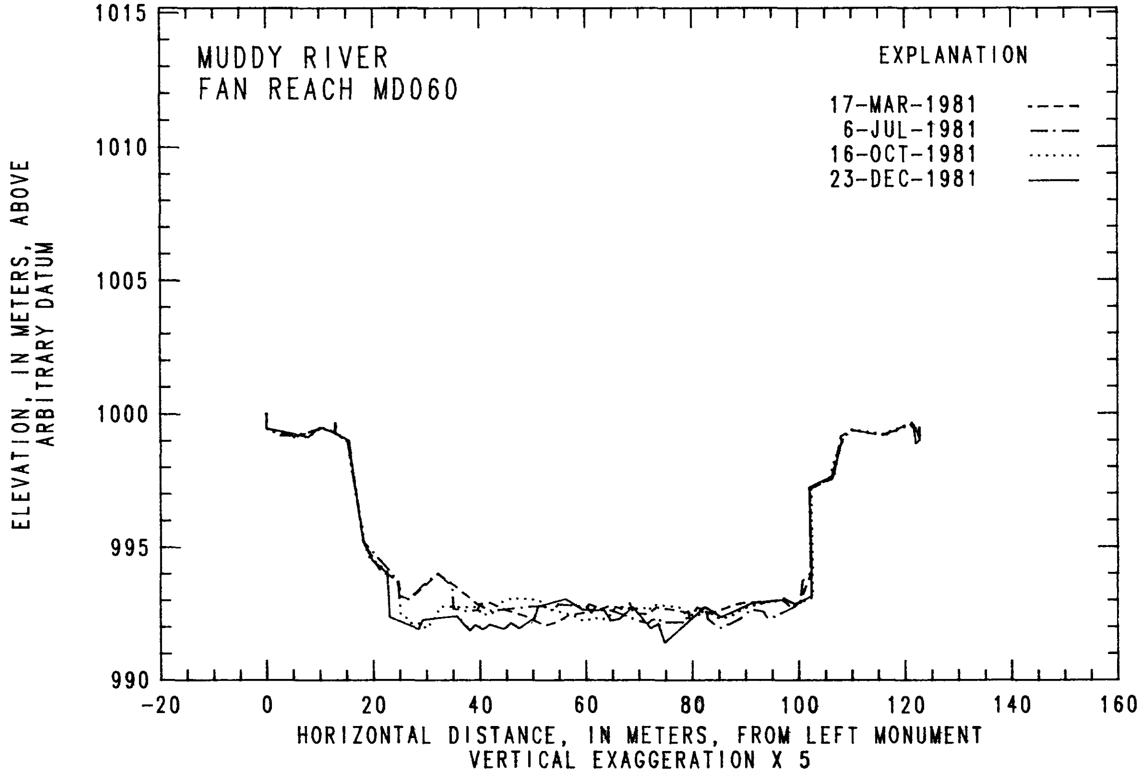


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



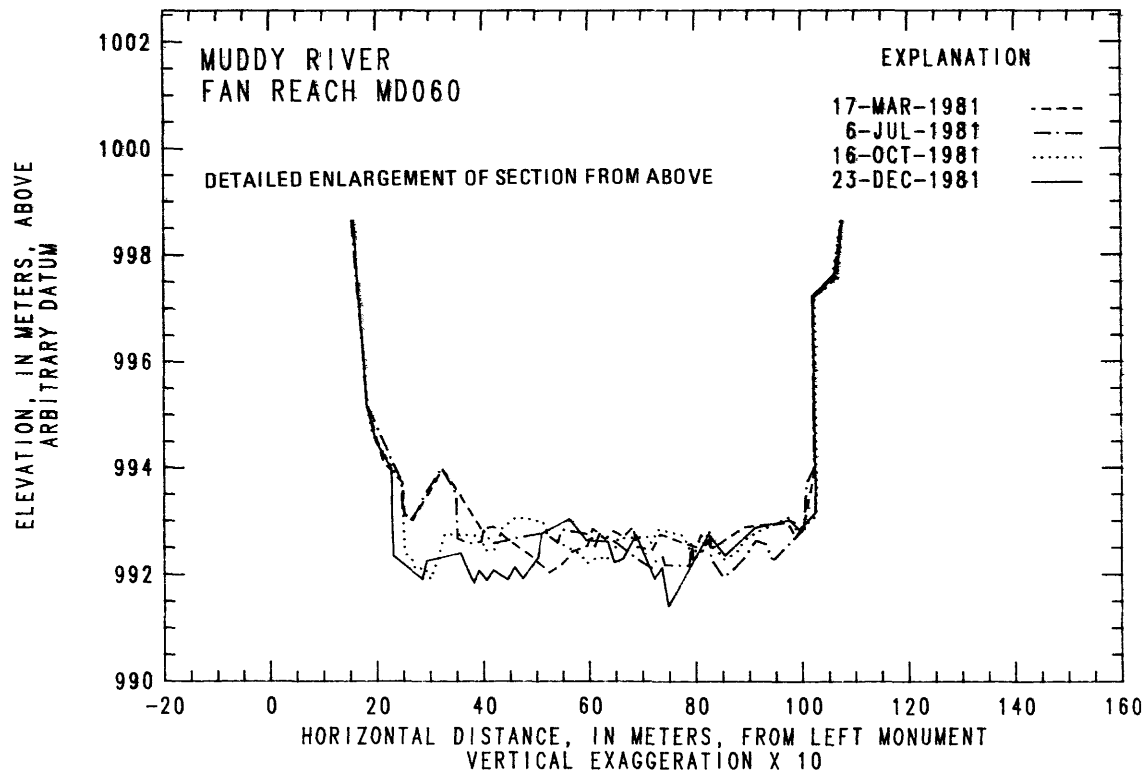
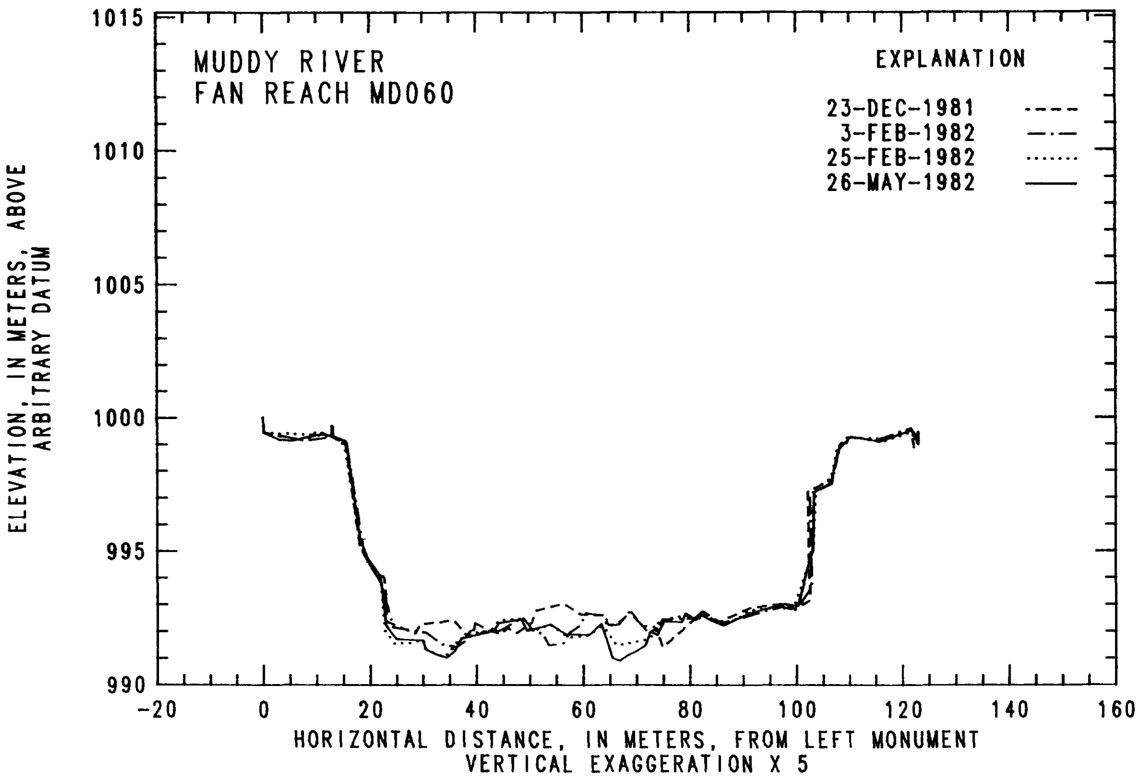


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



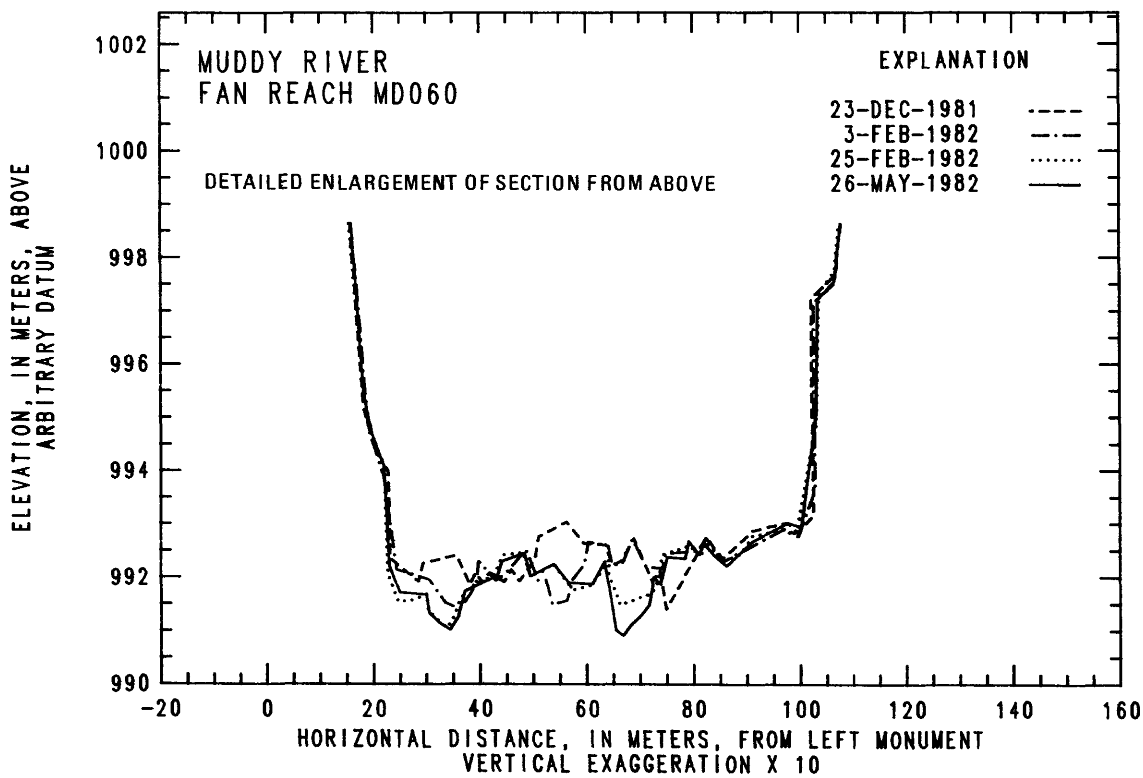


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

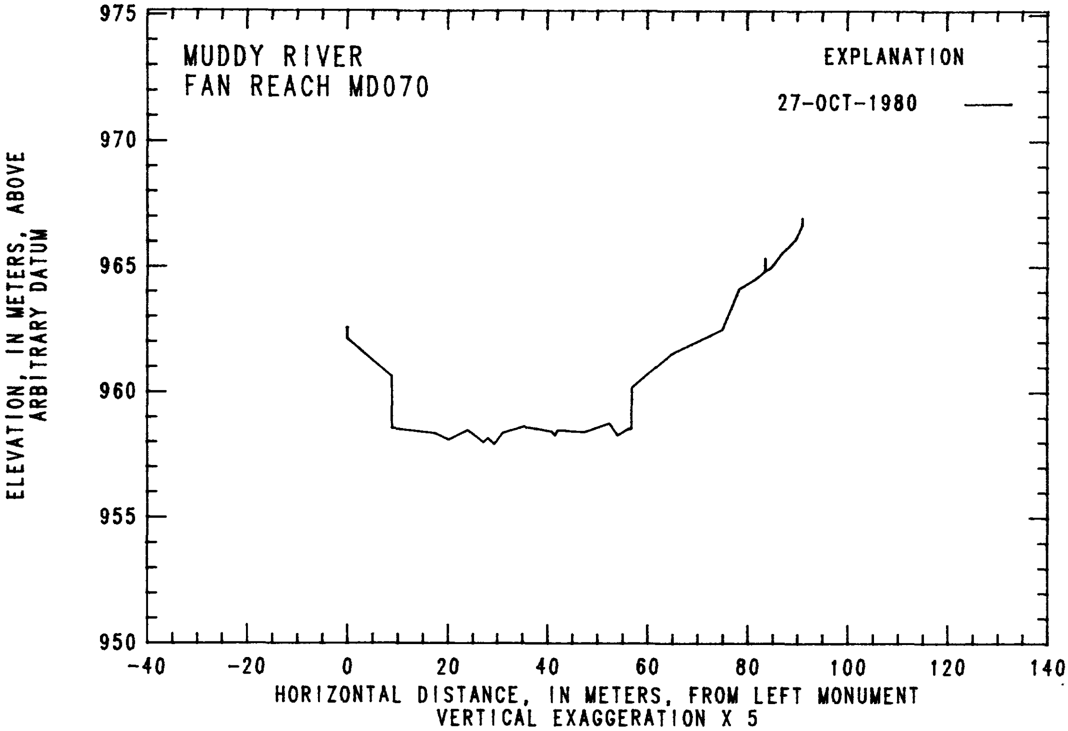


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

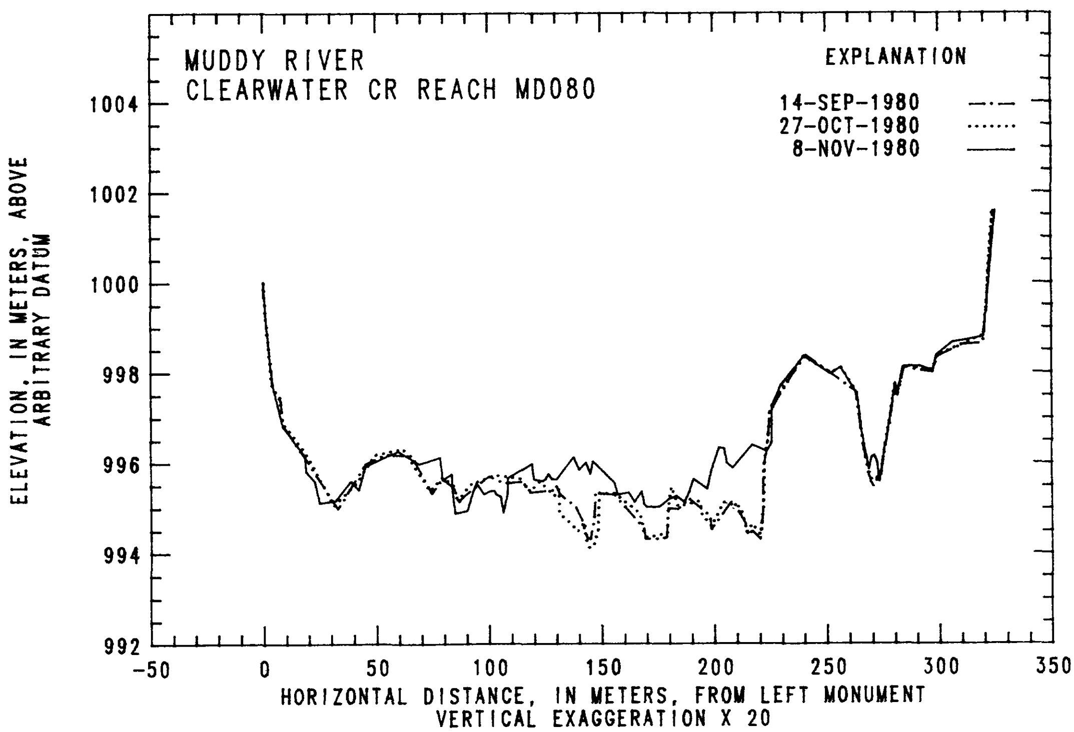


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

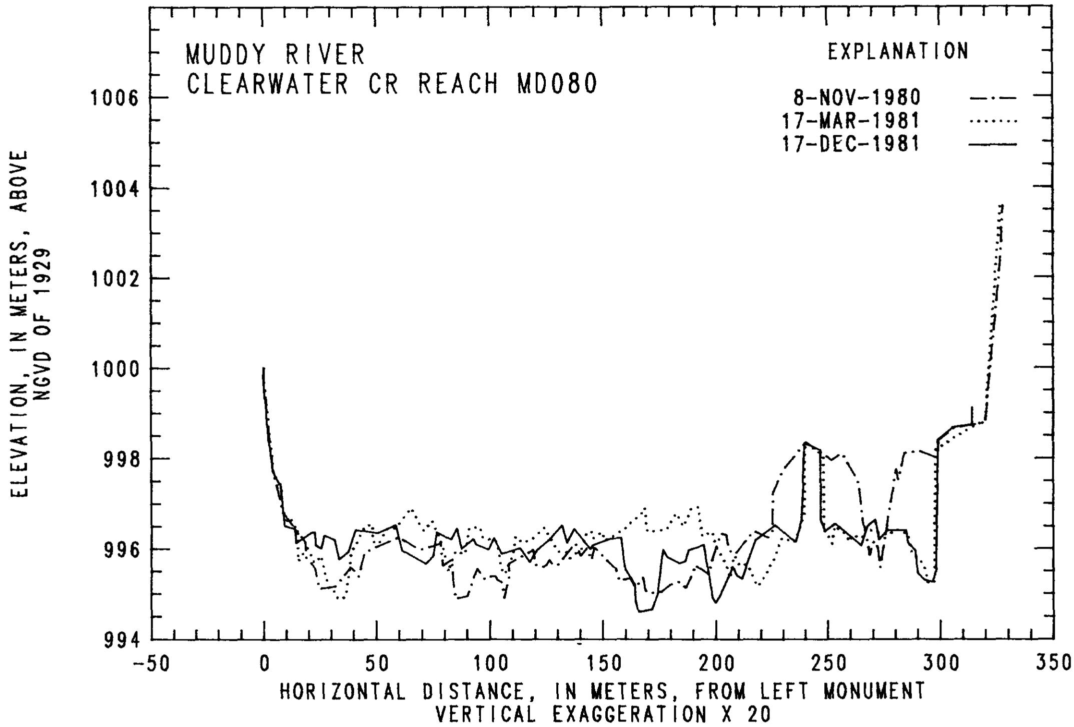


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

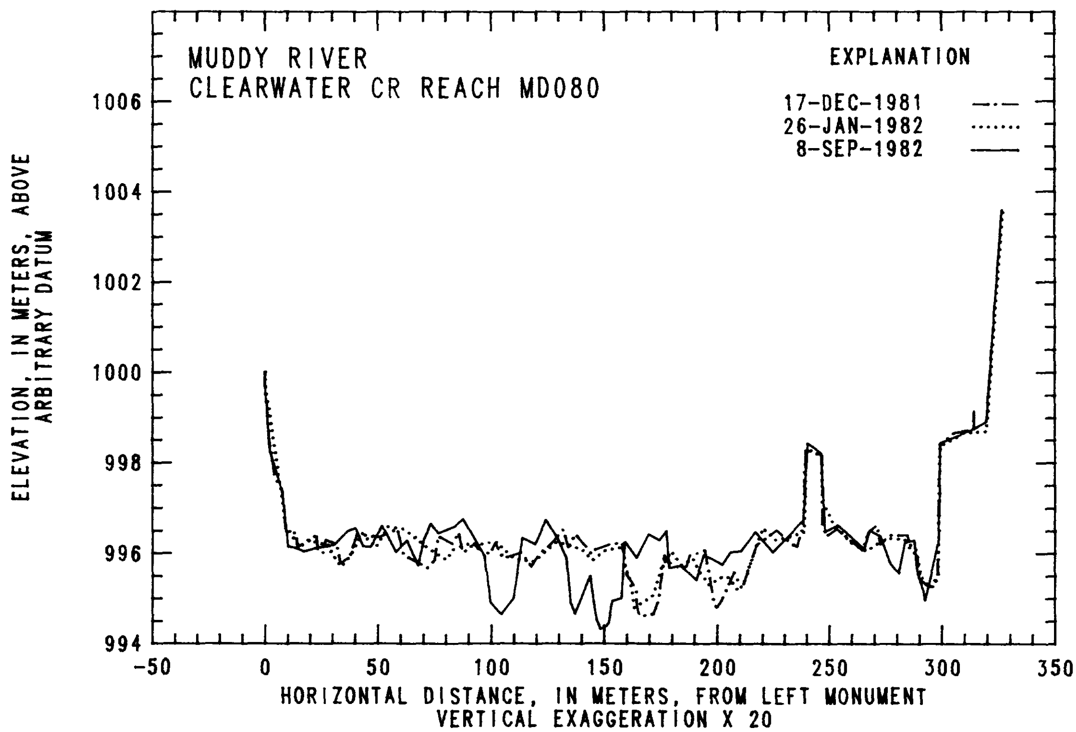


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

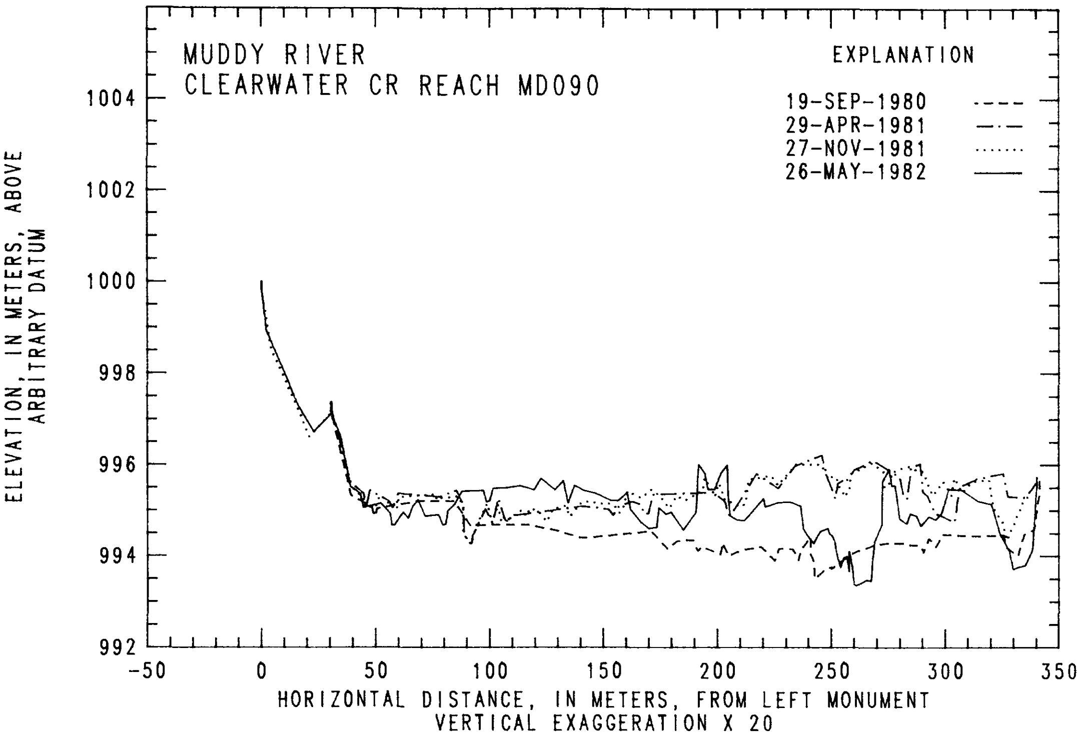


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

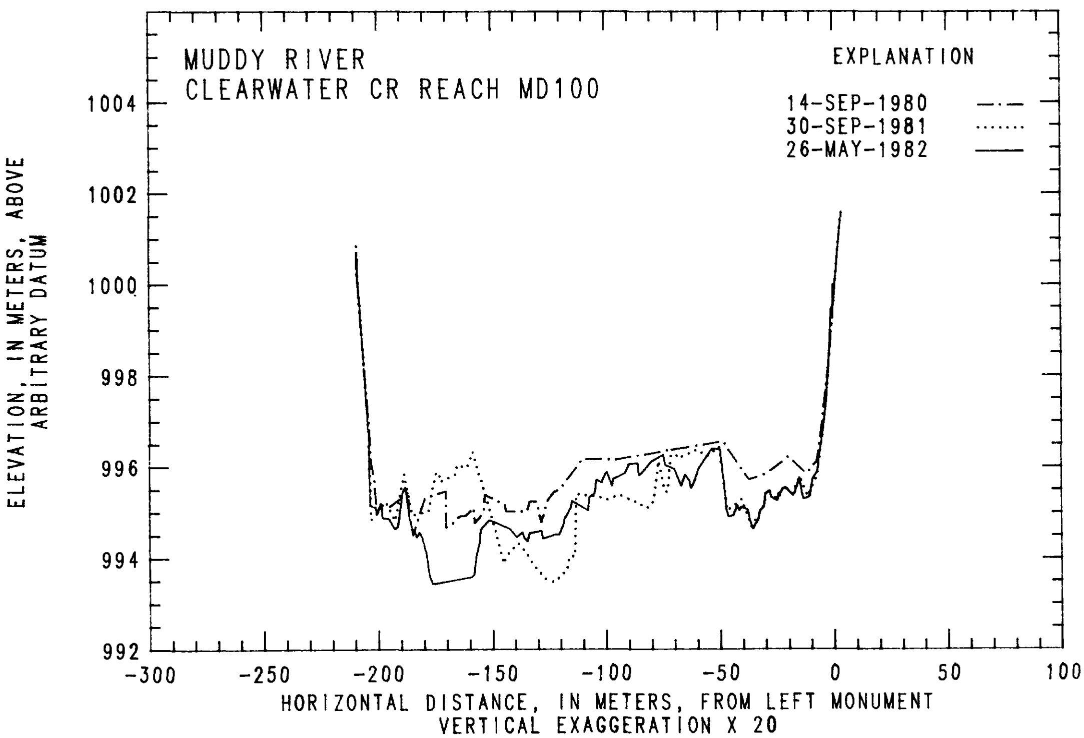


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

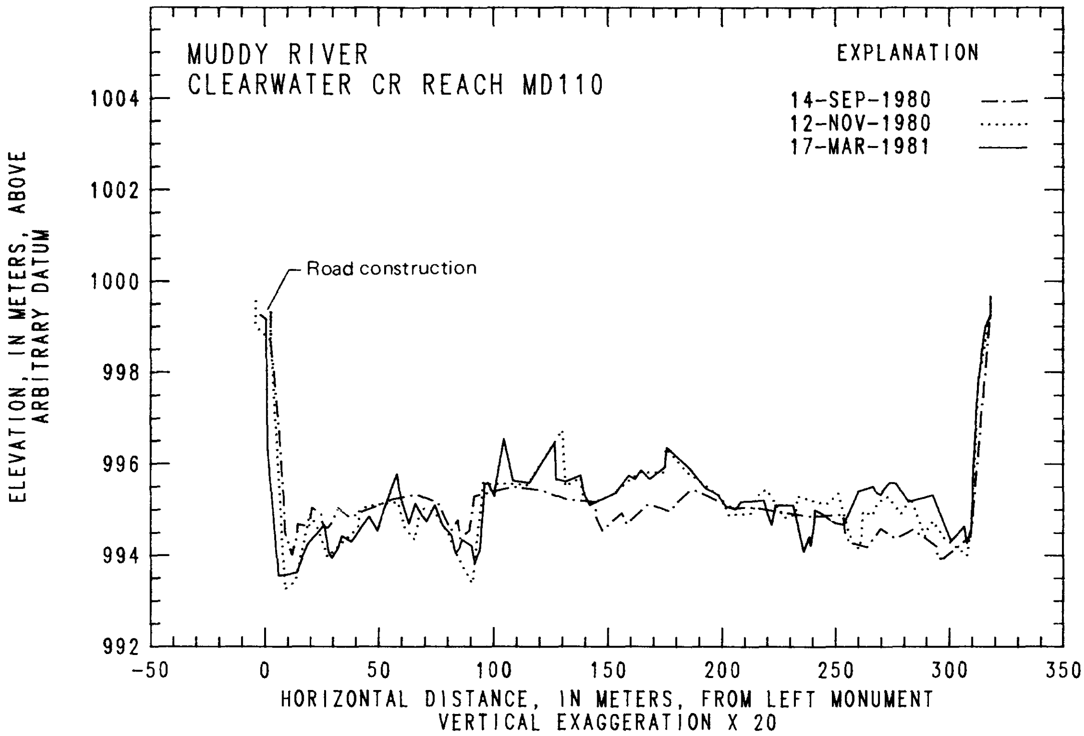


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

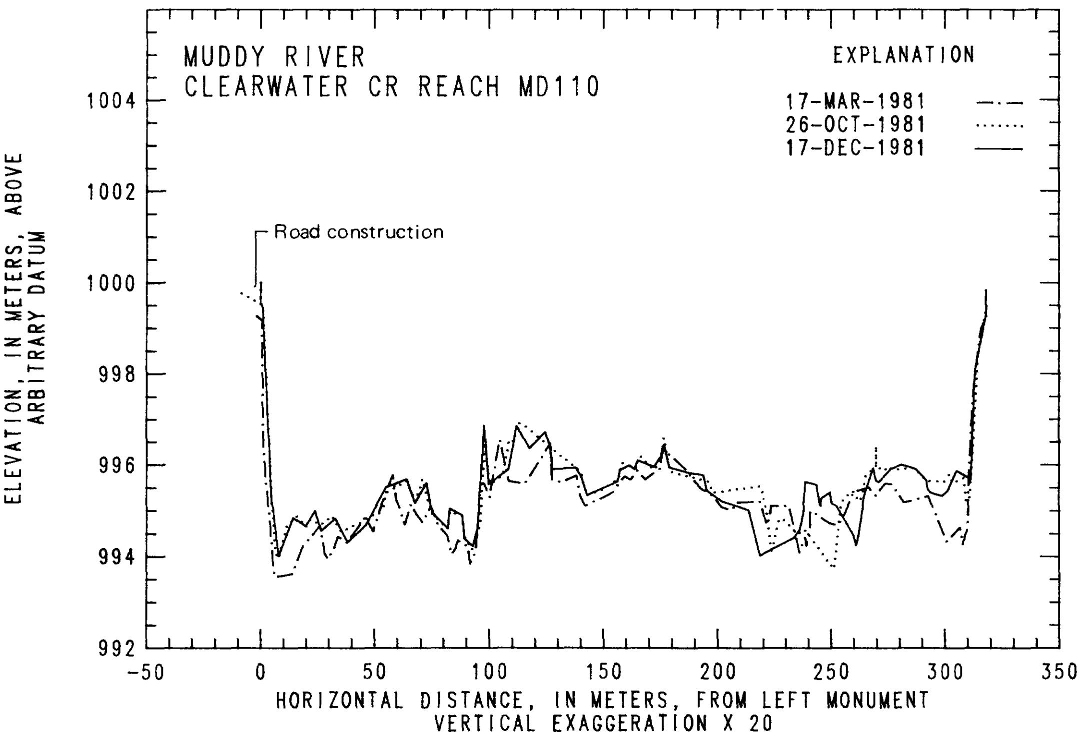


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

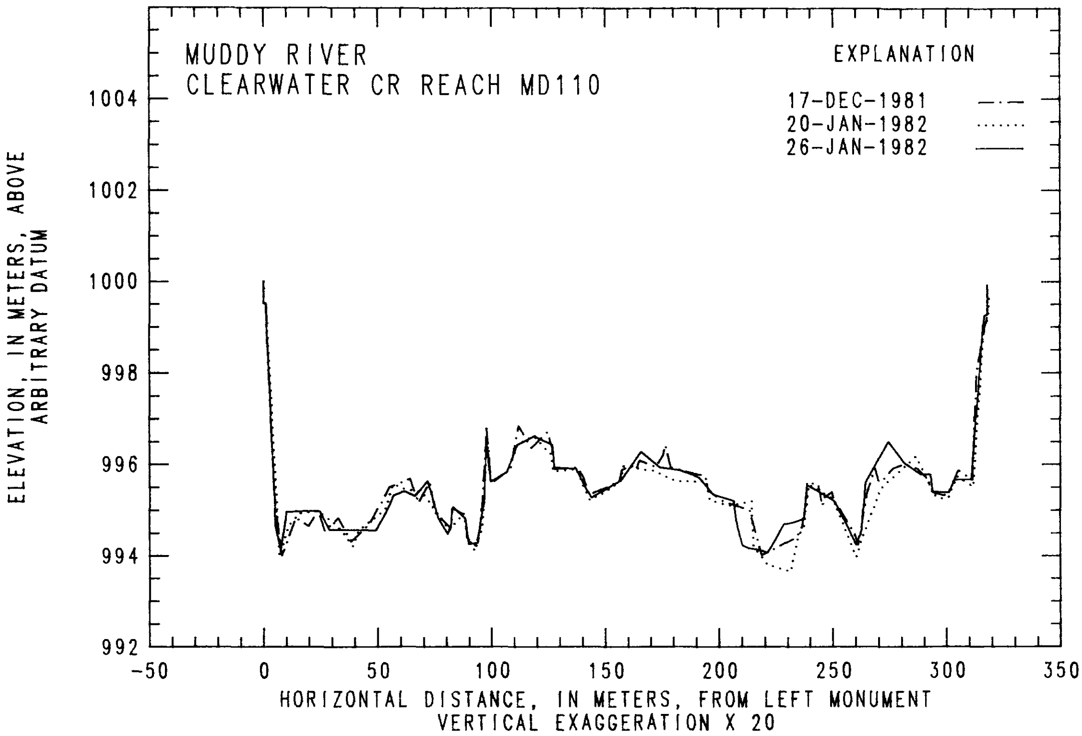


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

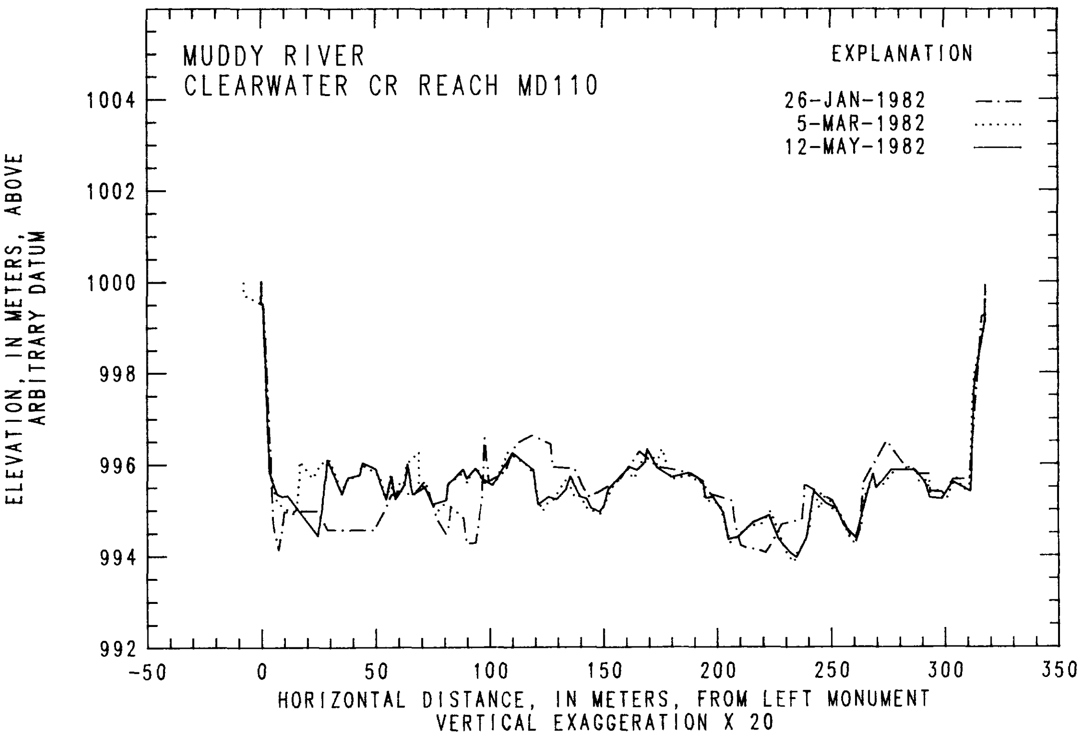


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

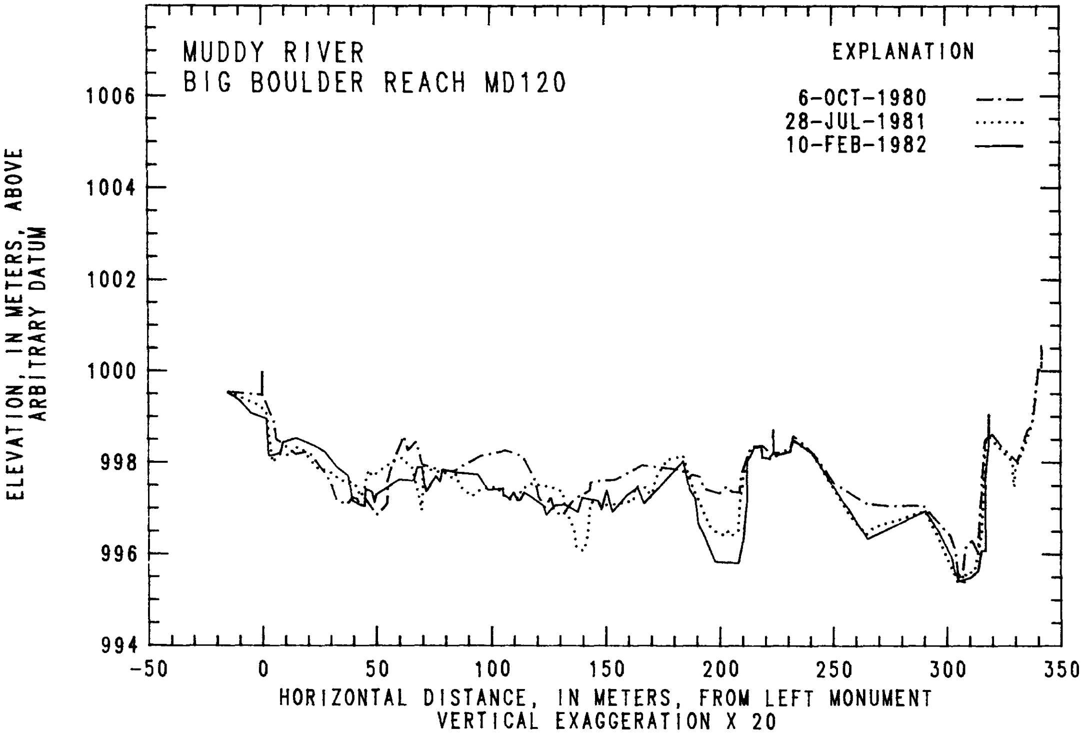


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

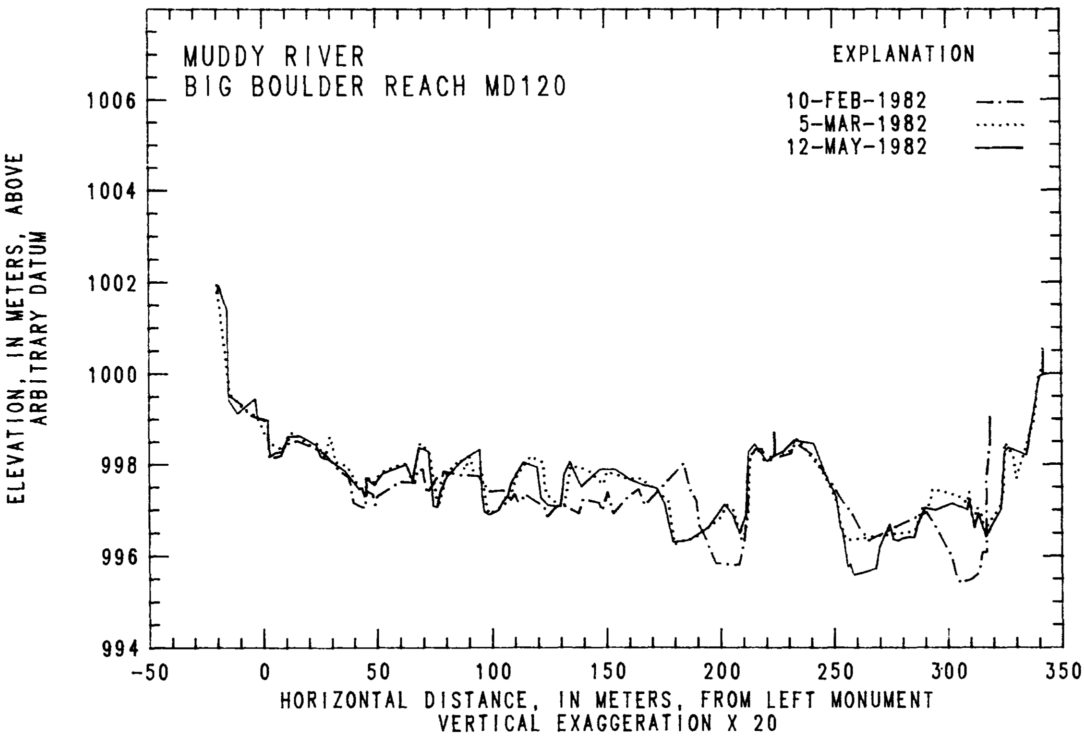


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

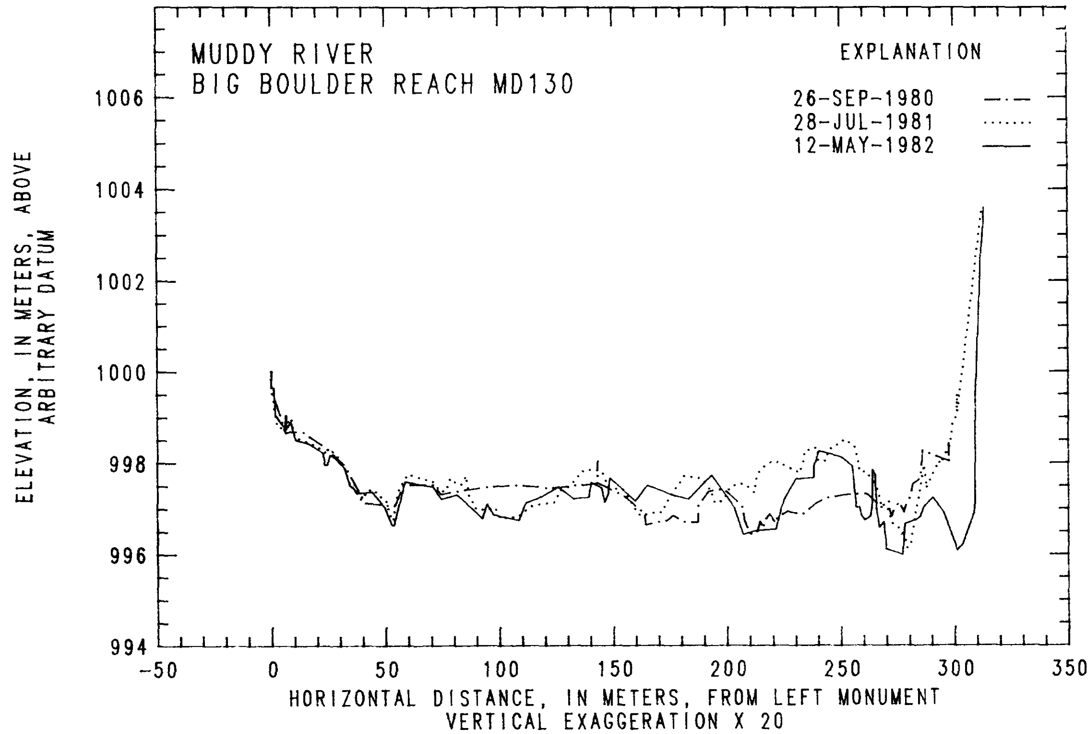


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

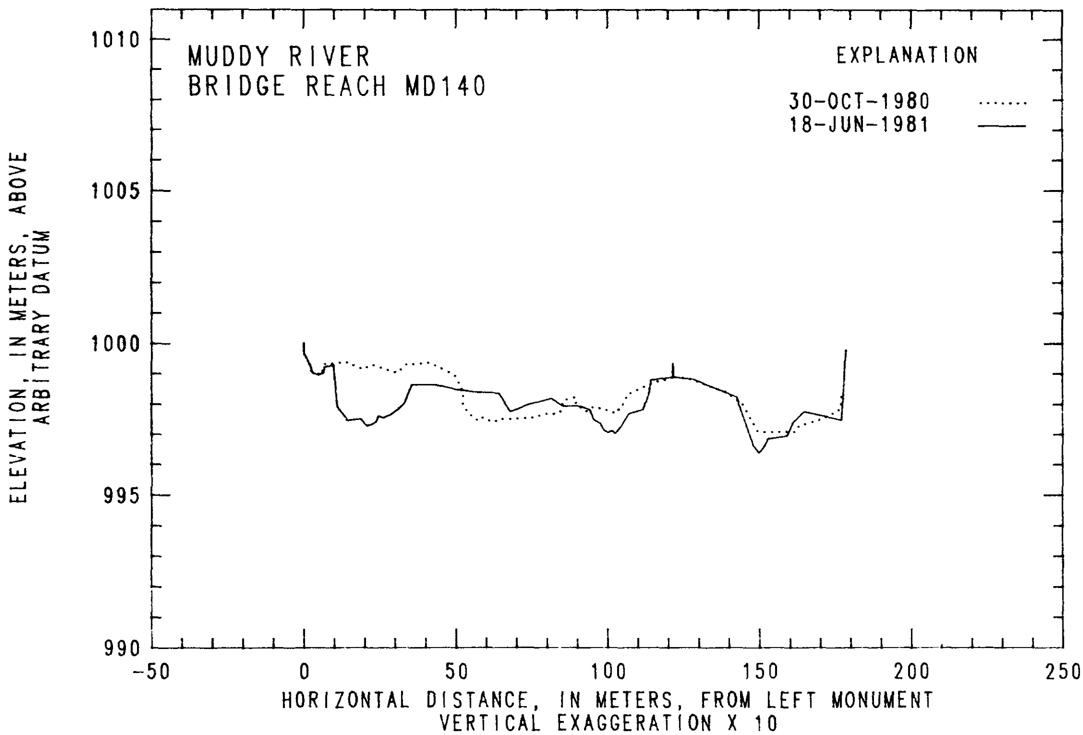


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

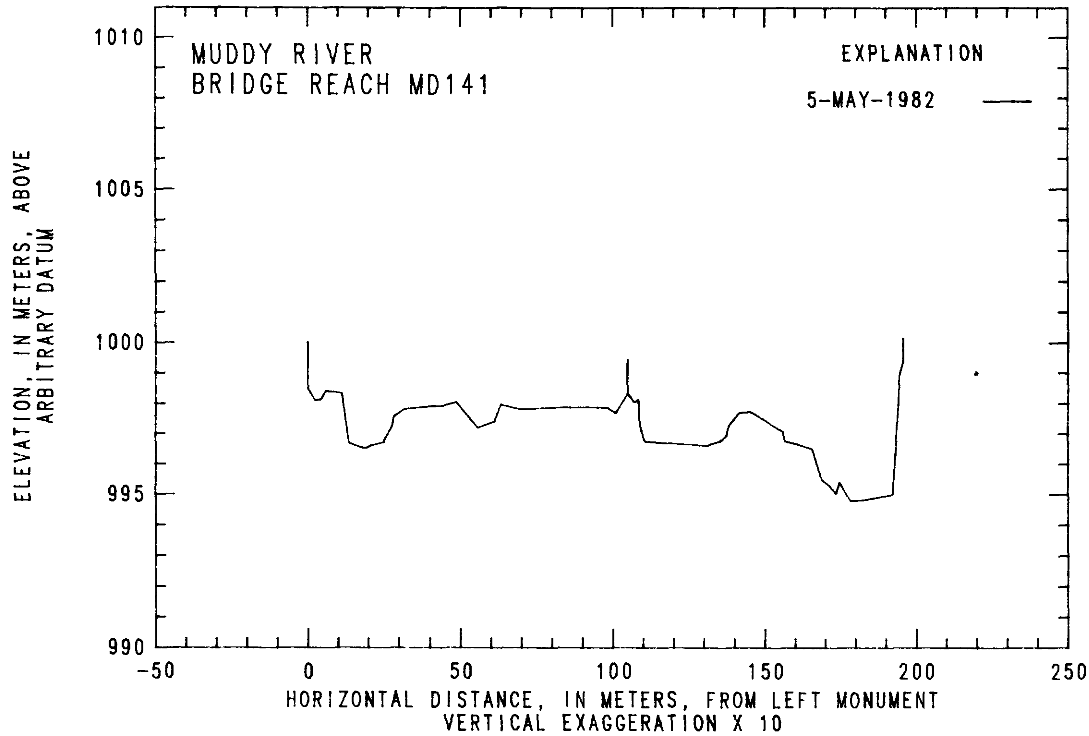


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

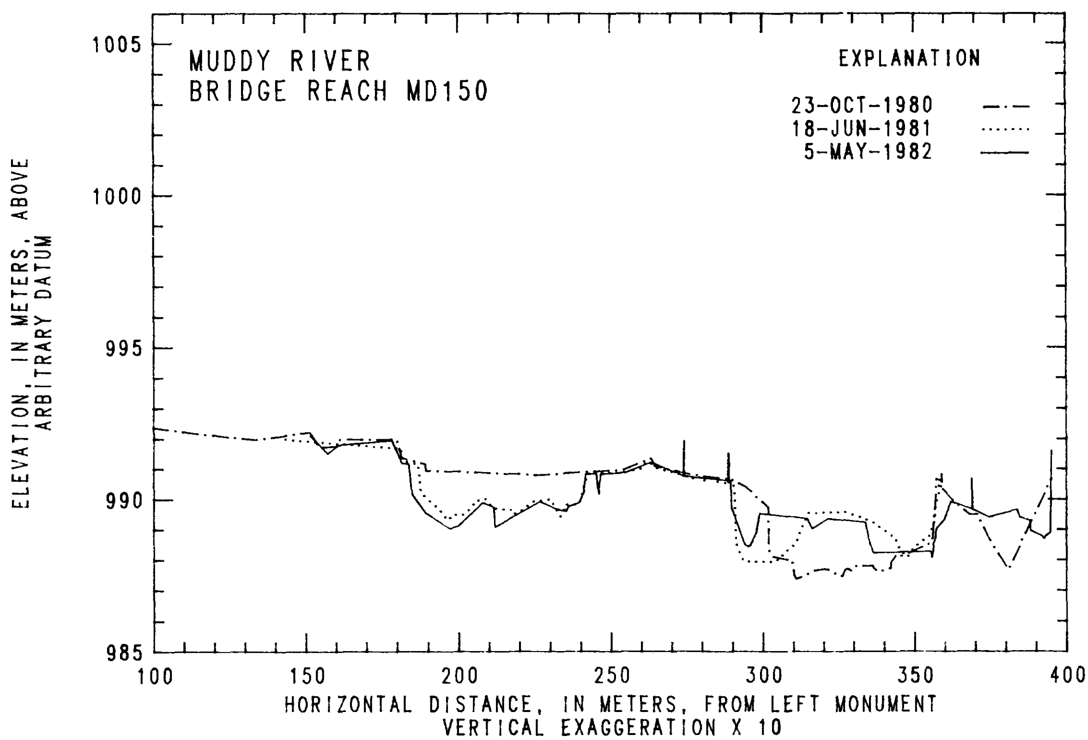
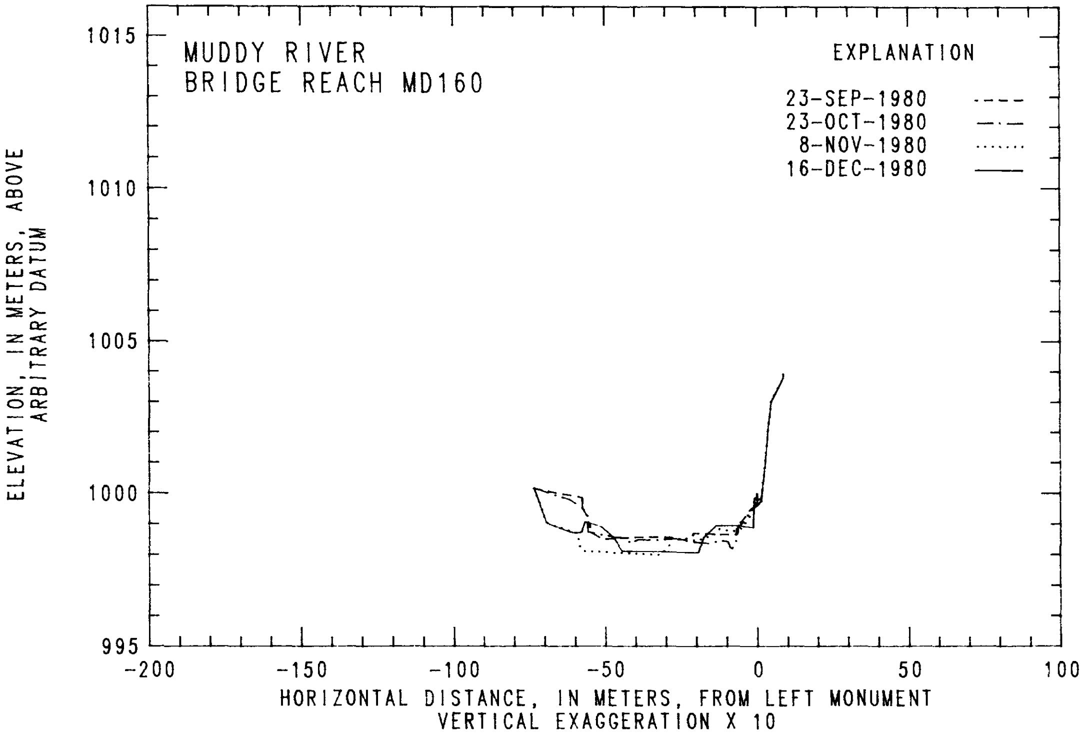


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



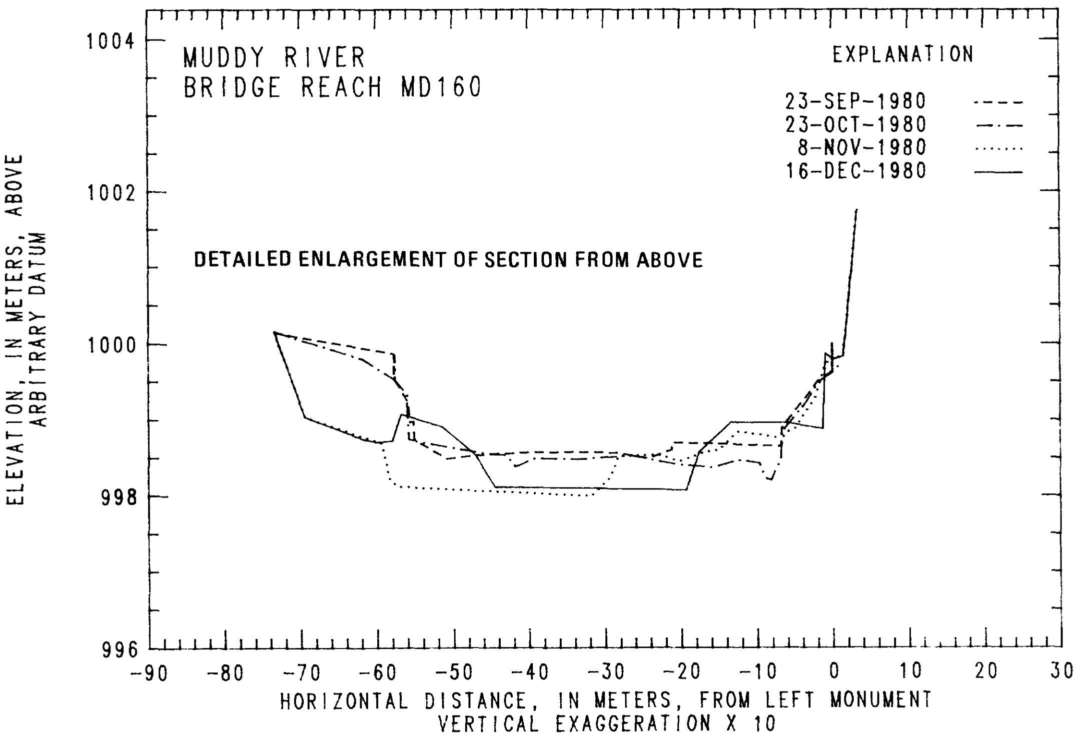
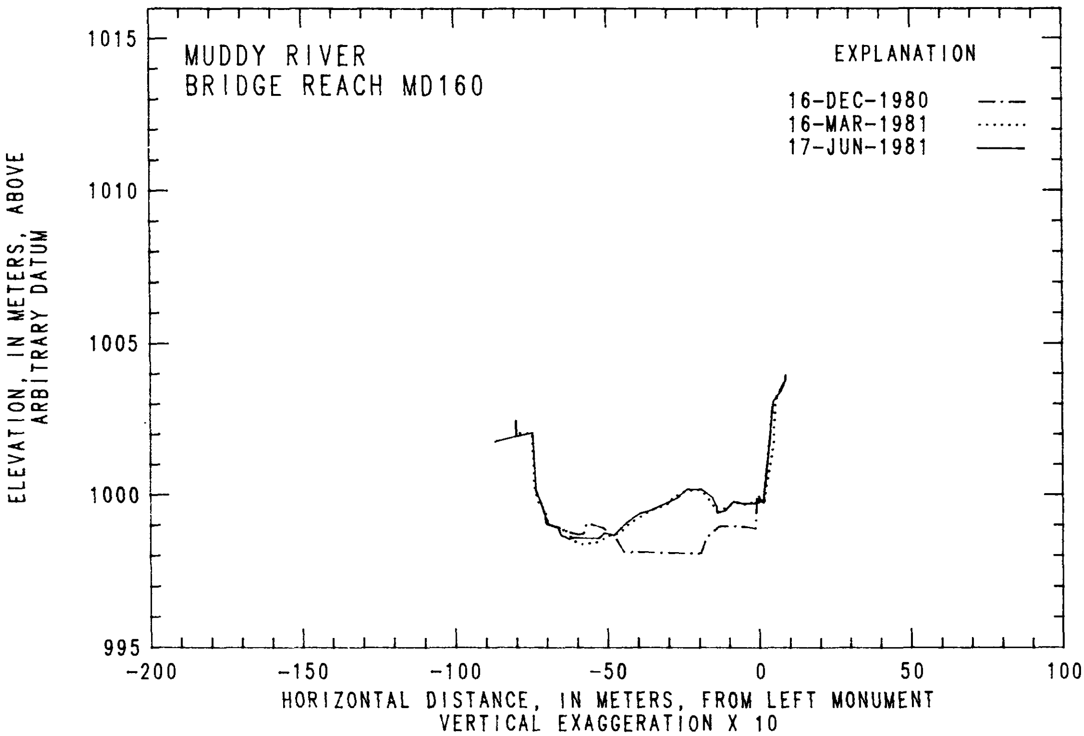


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.



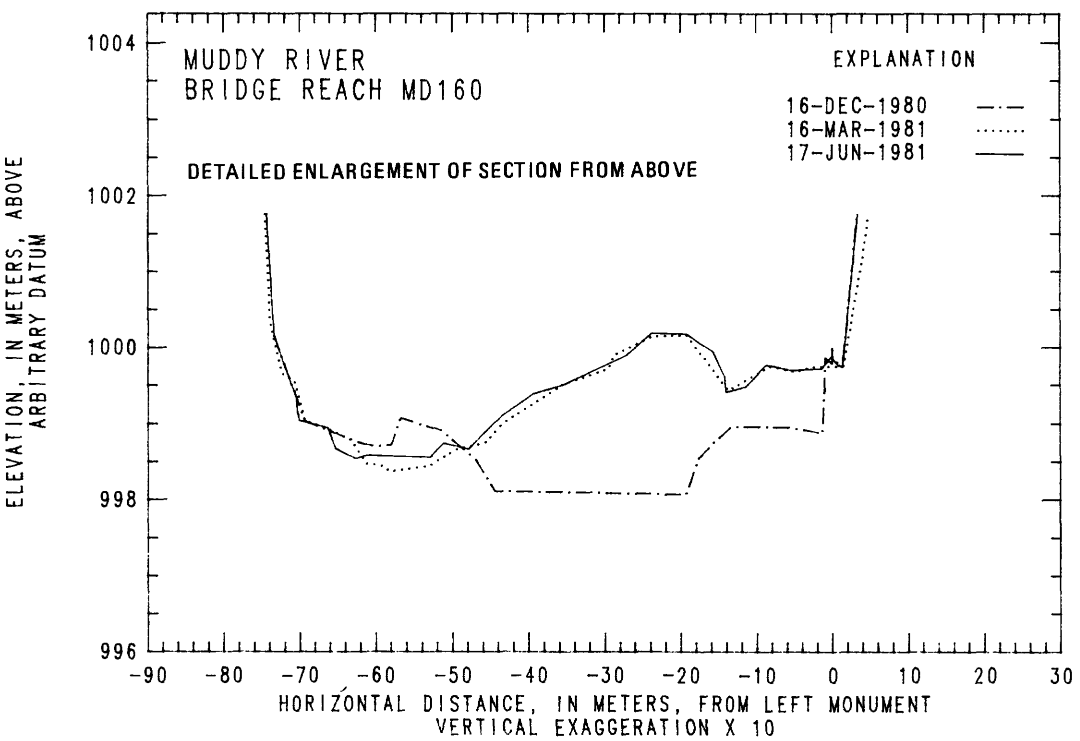


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

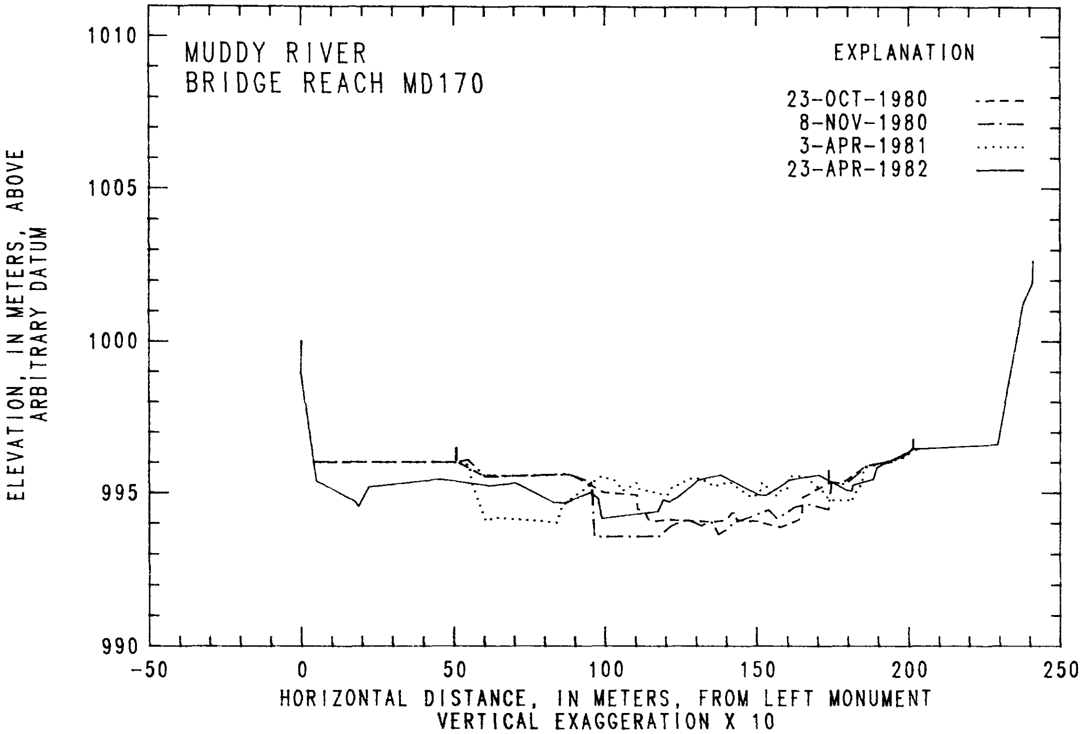


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

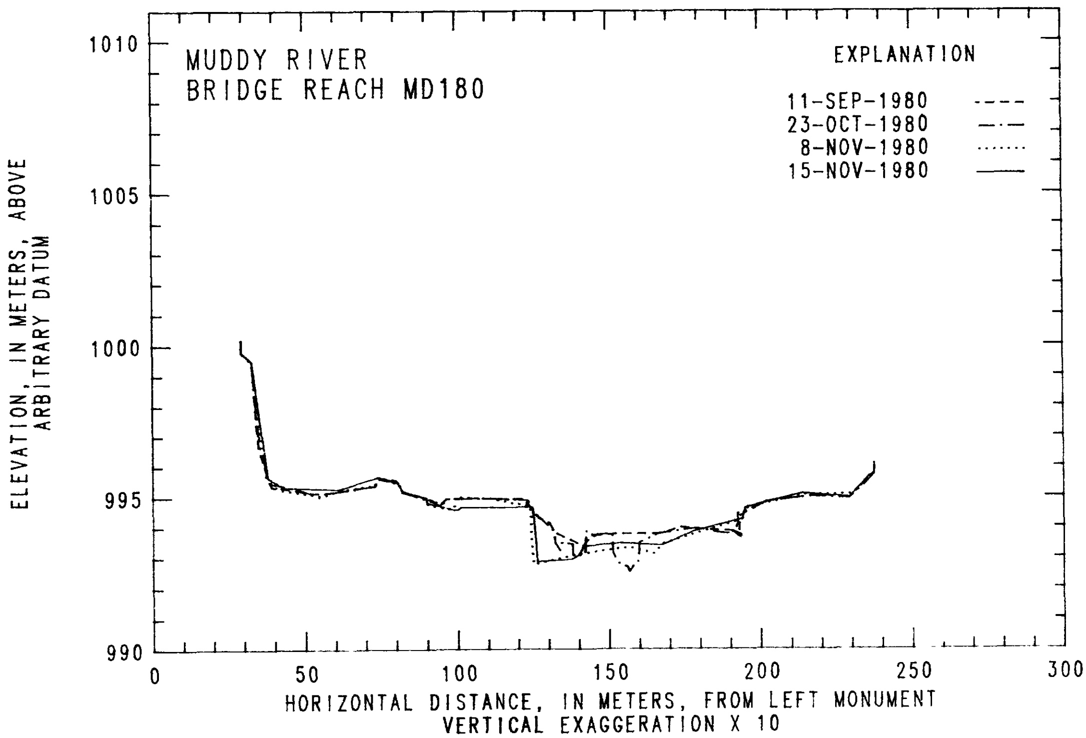


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

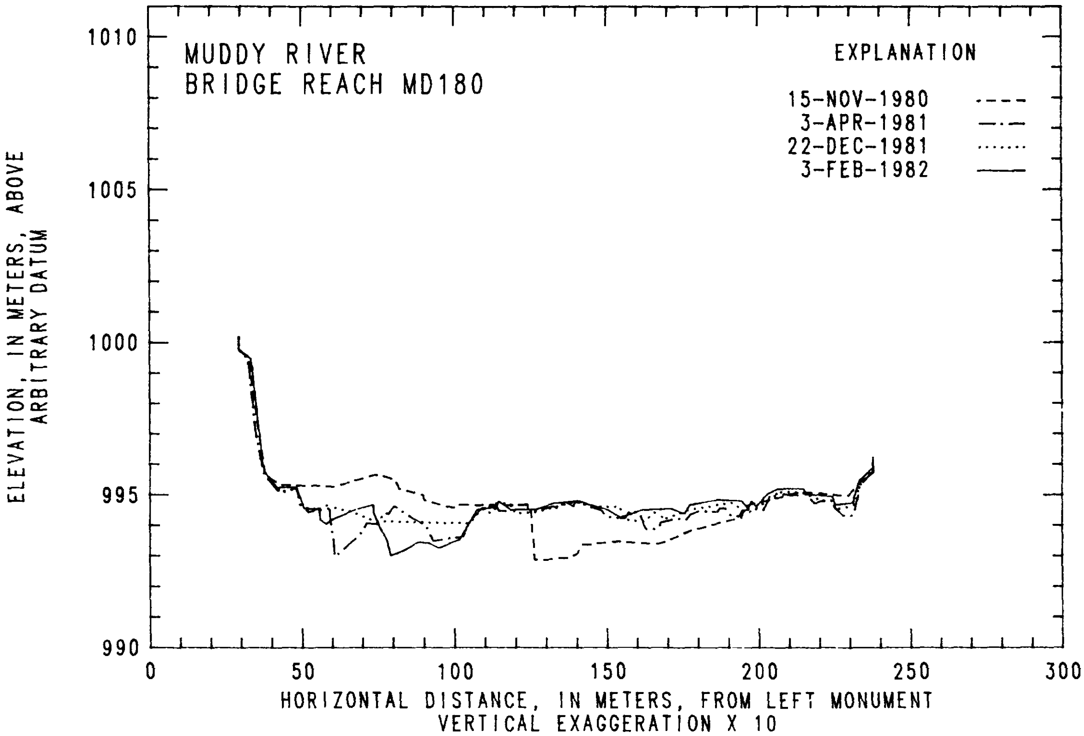


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

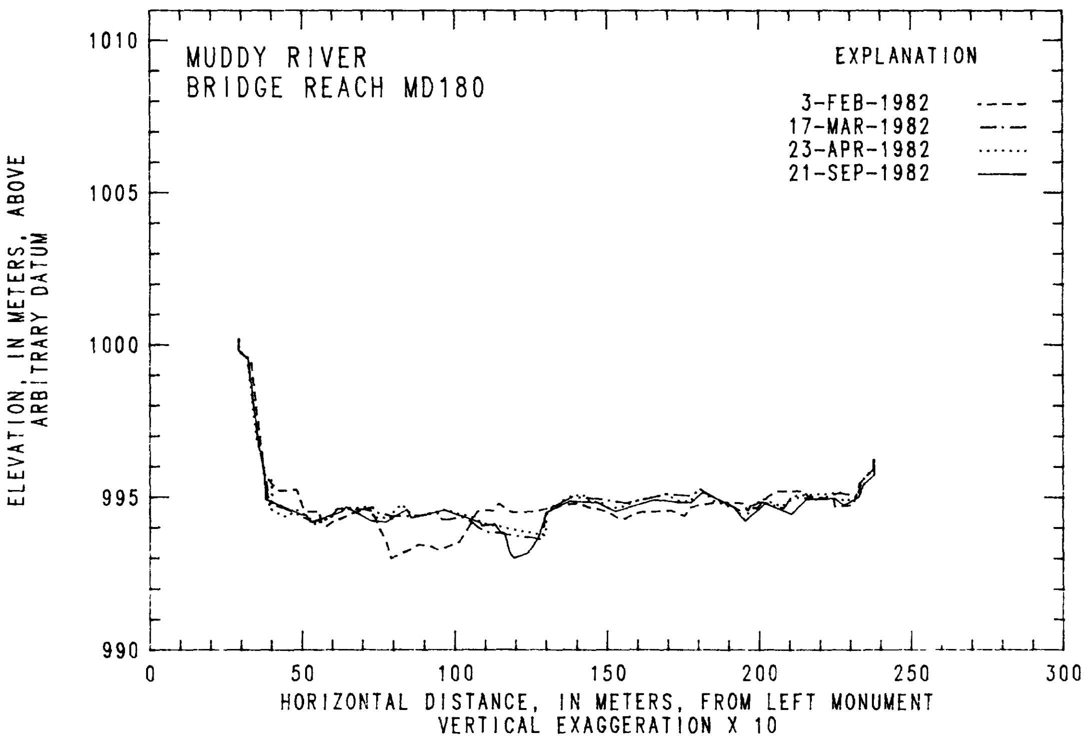


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

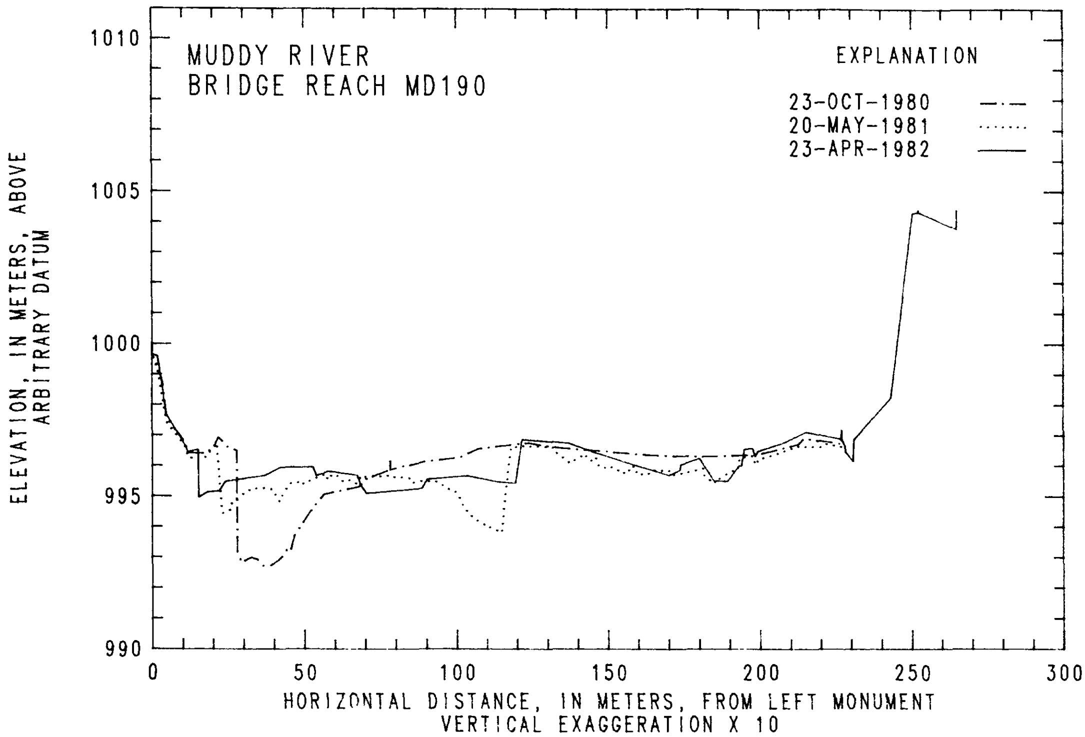


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

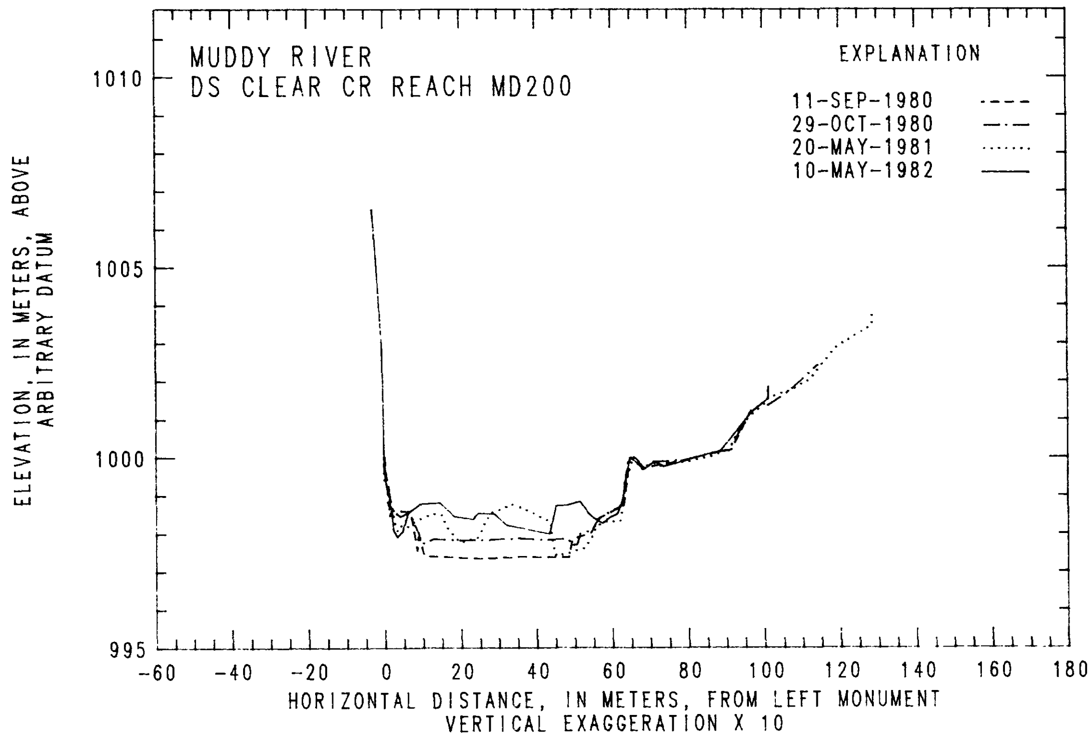


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

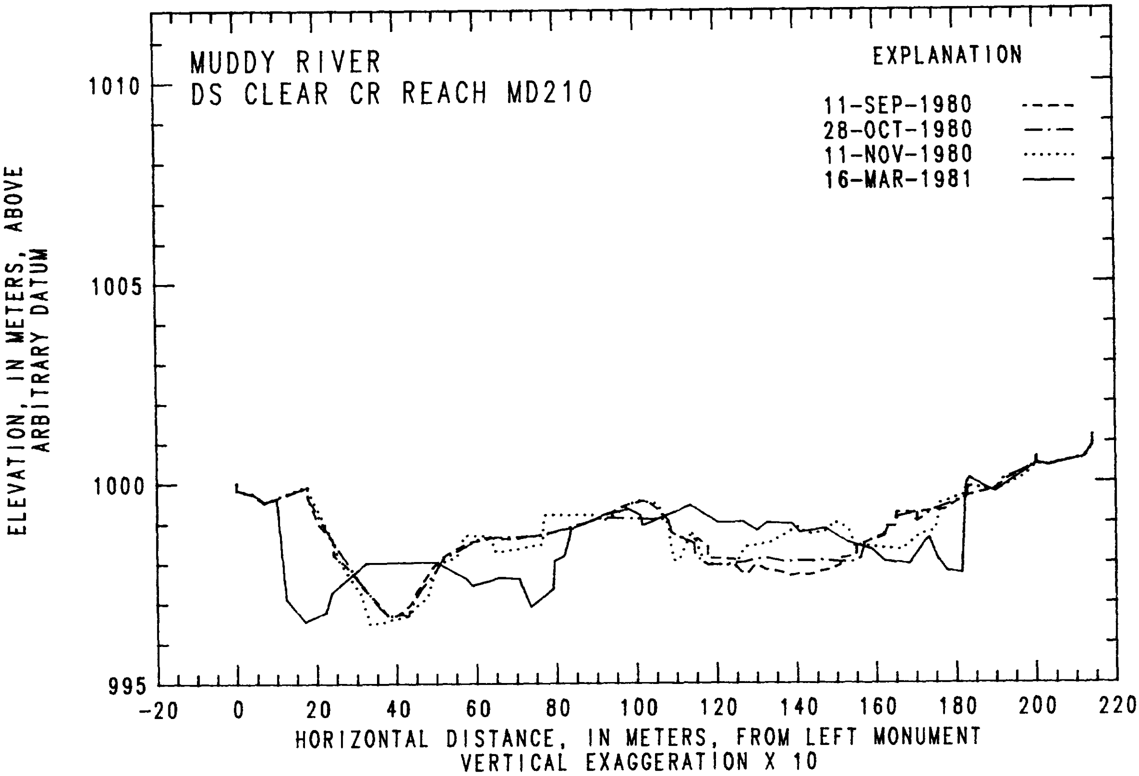


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

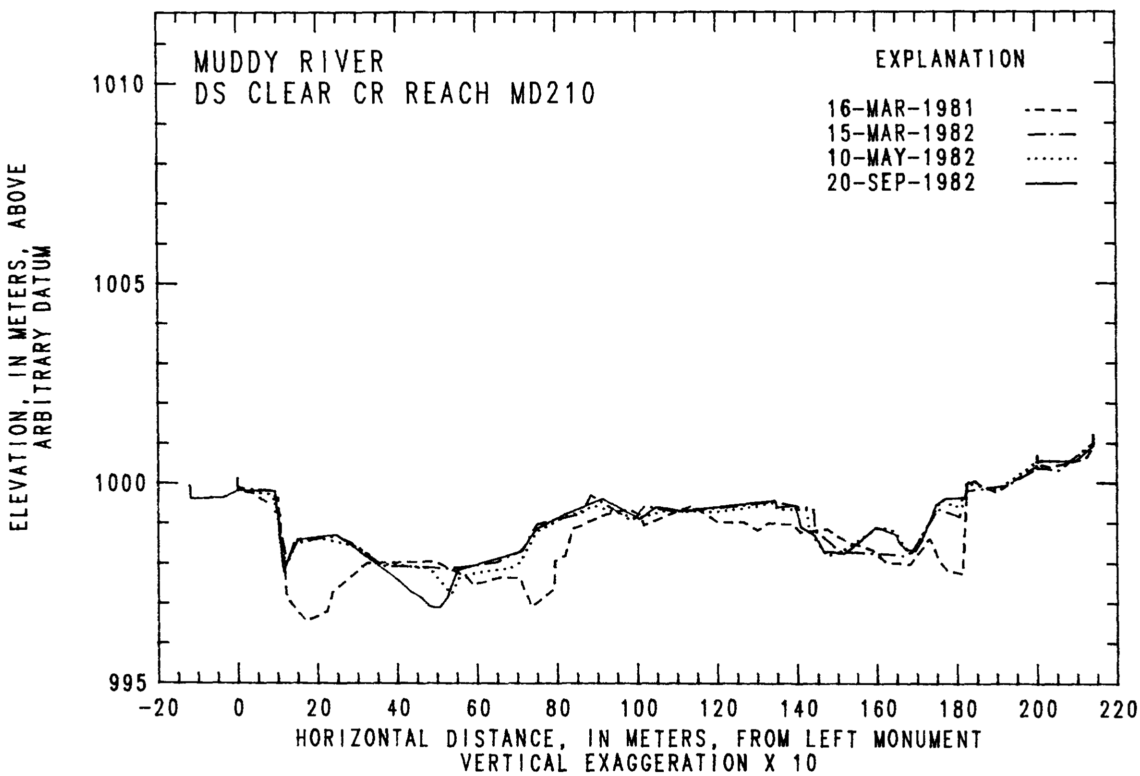


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

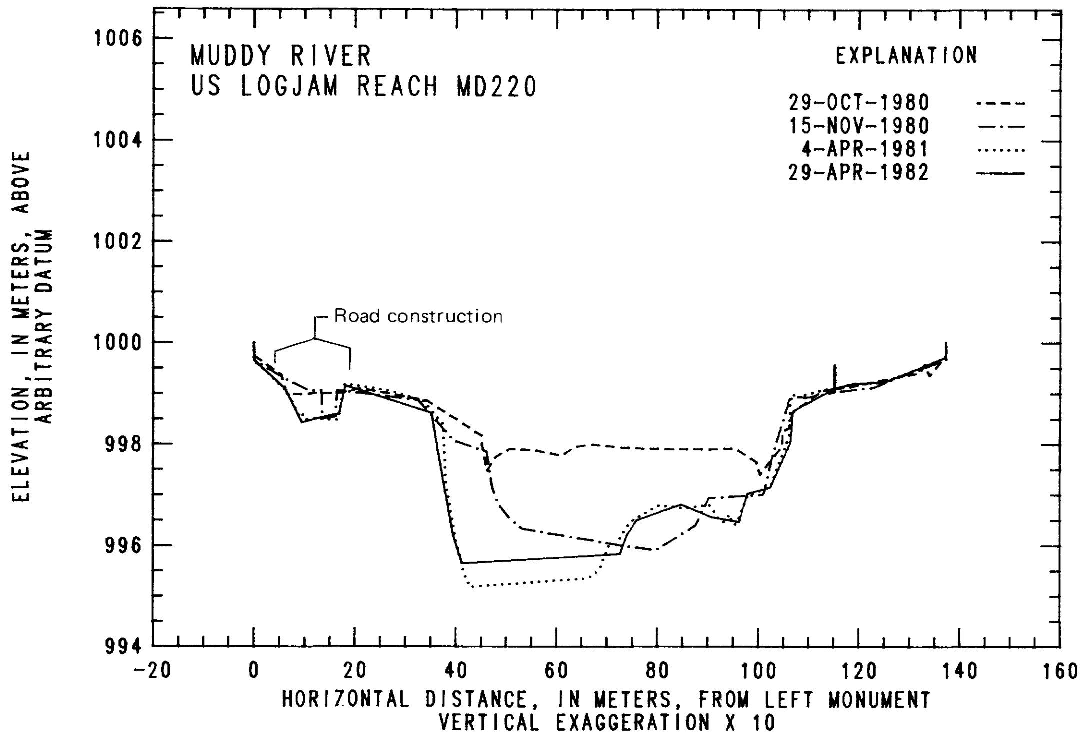


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

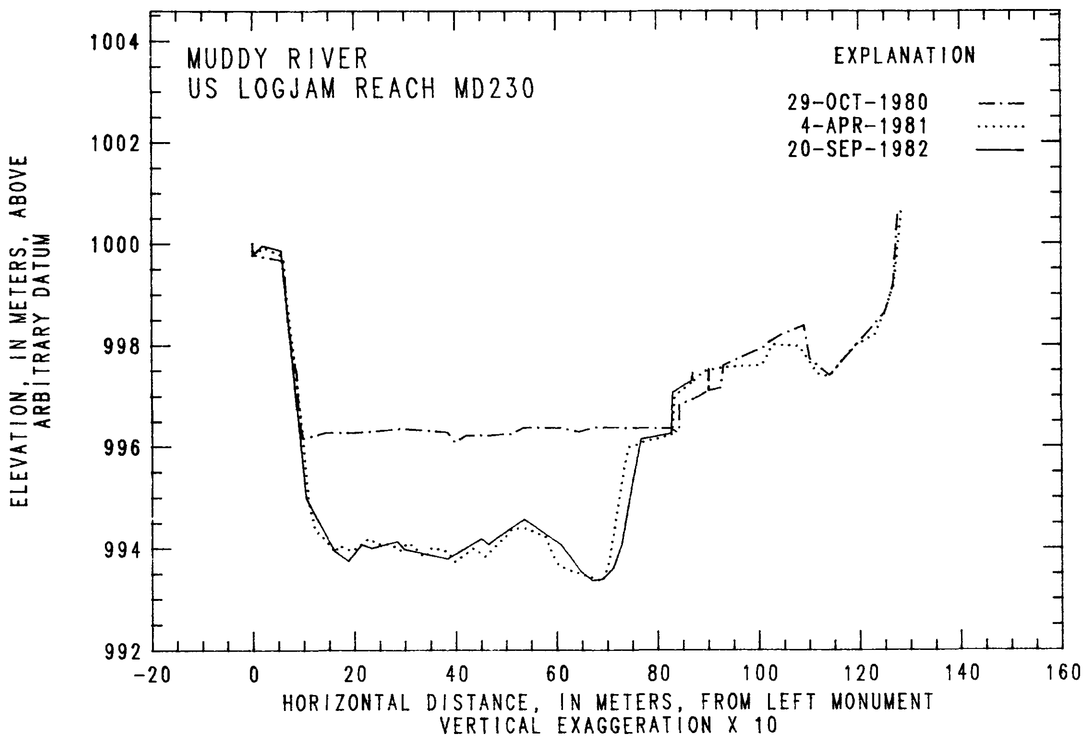


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

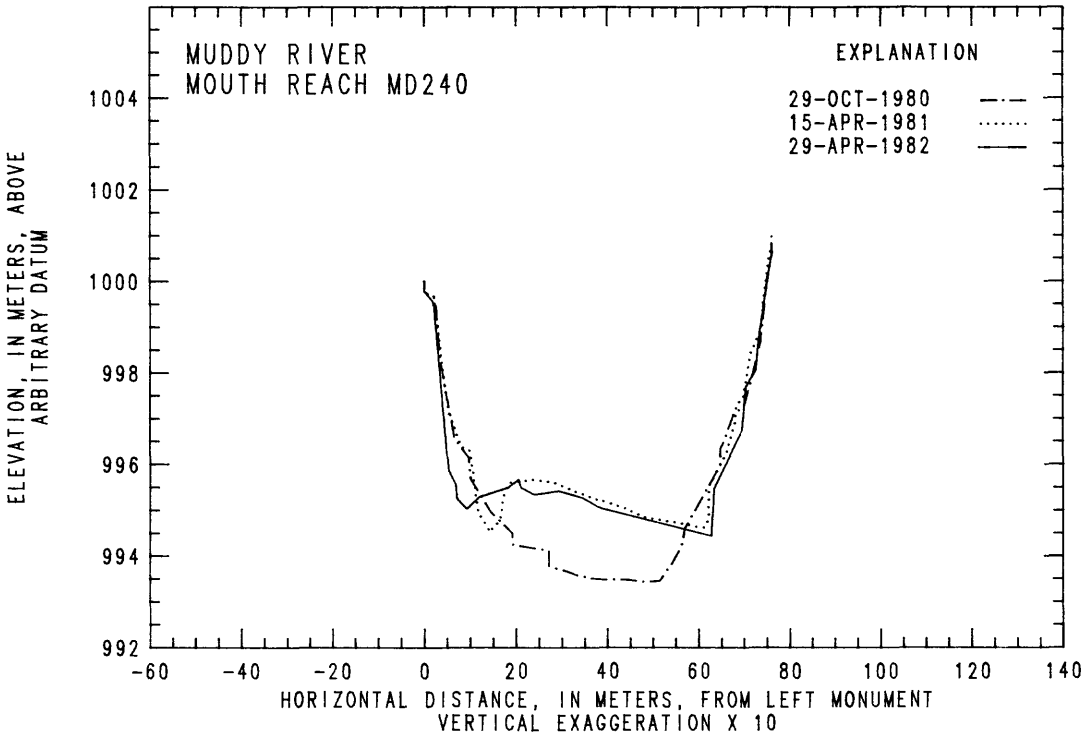


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

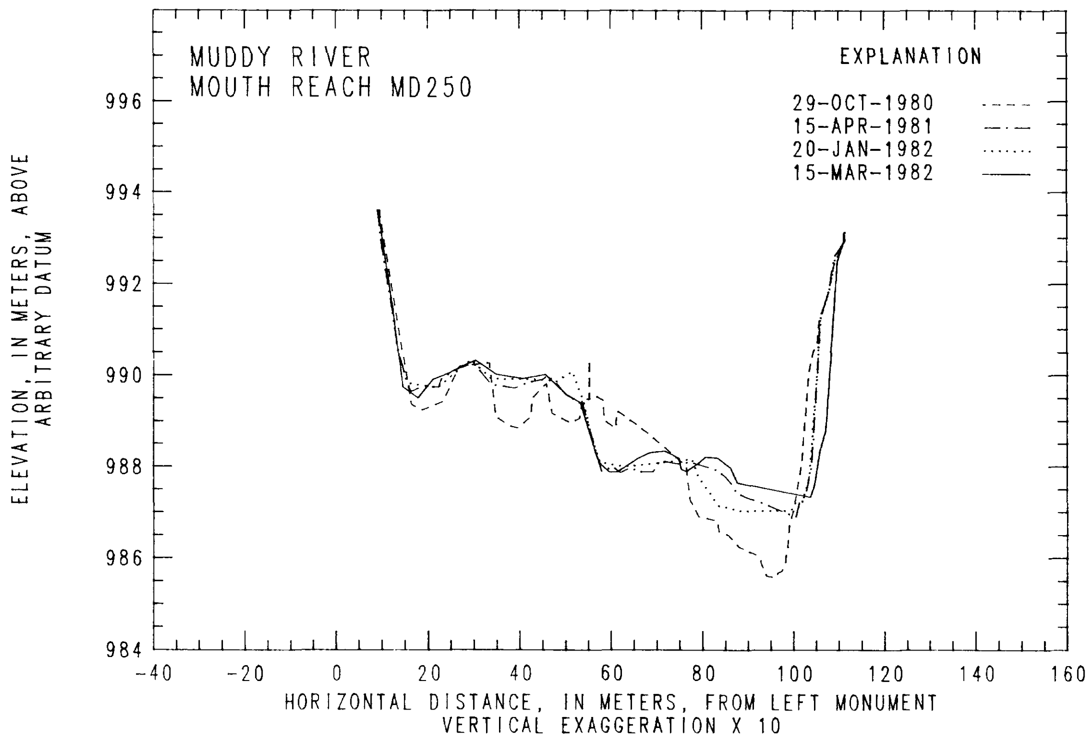


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

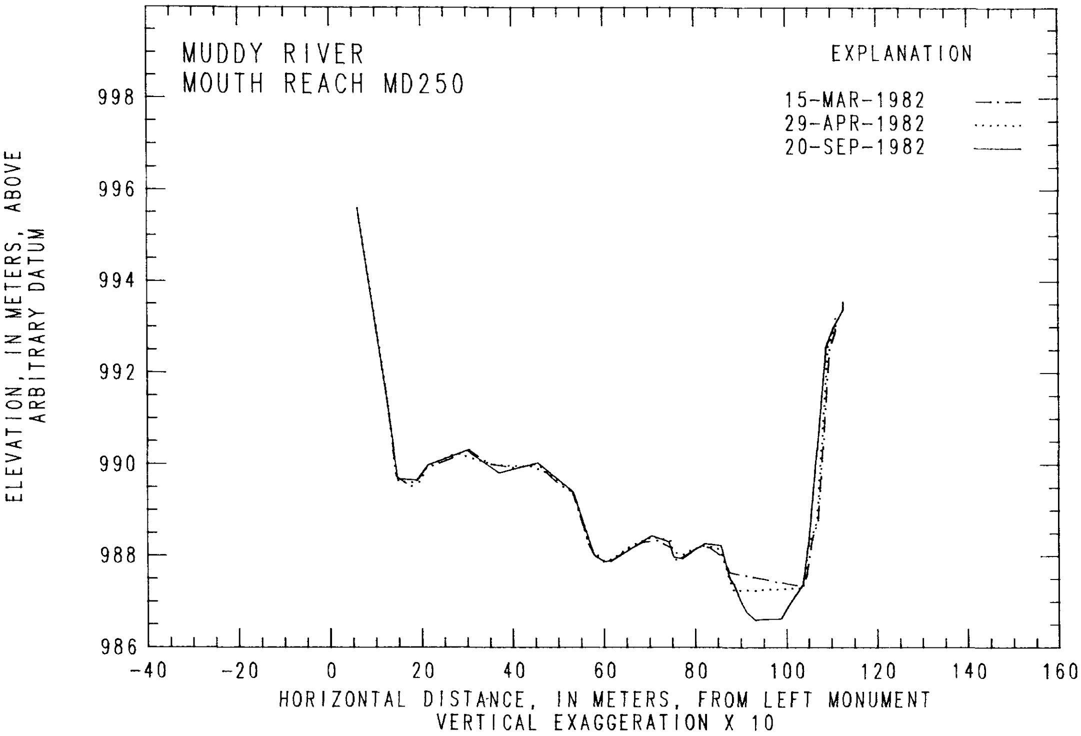


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

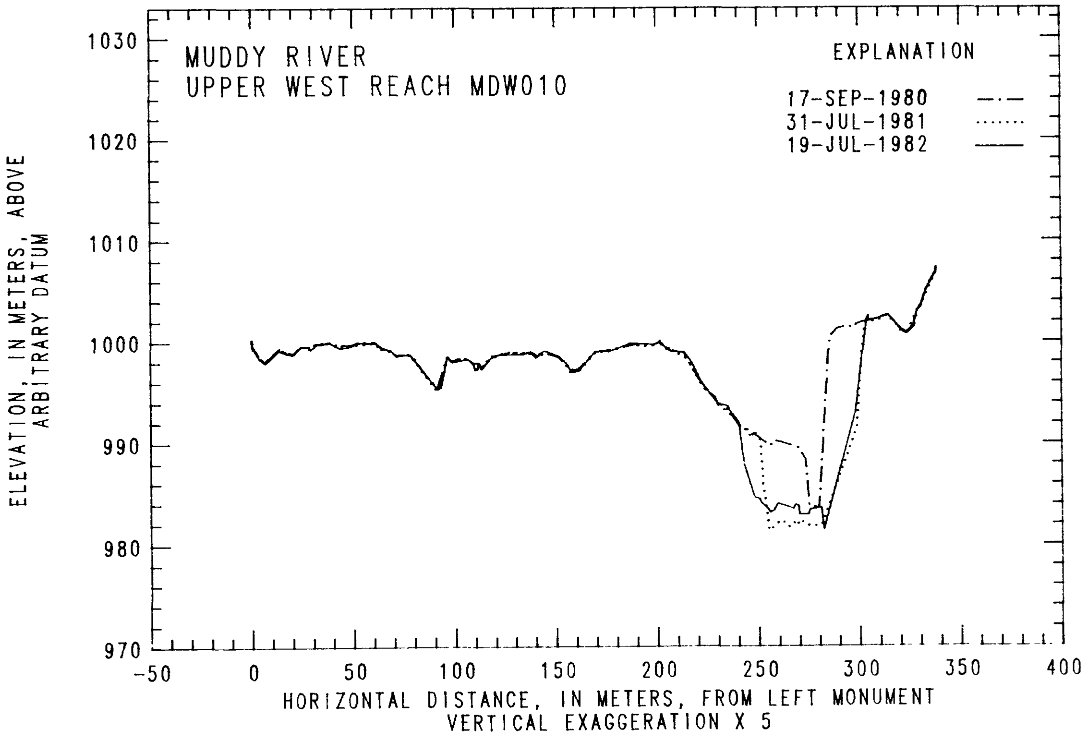


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

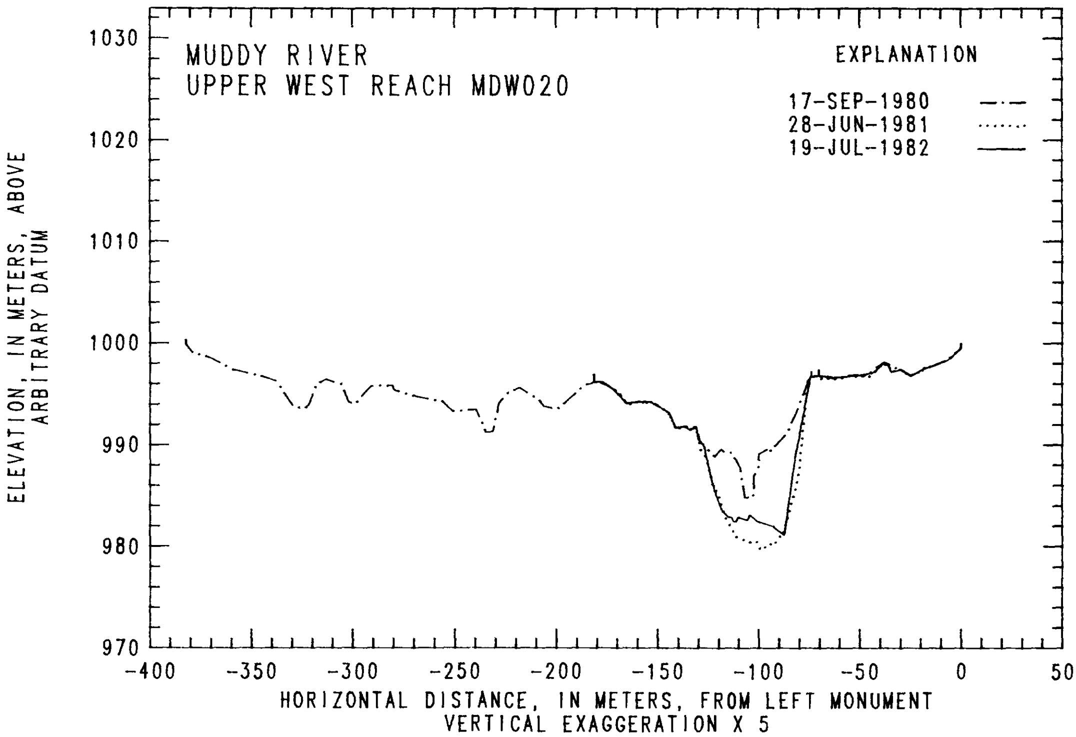


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

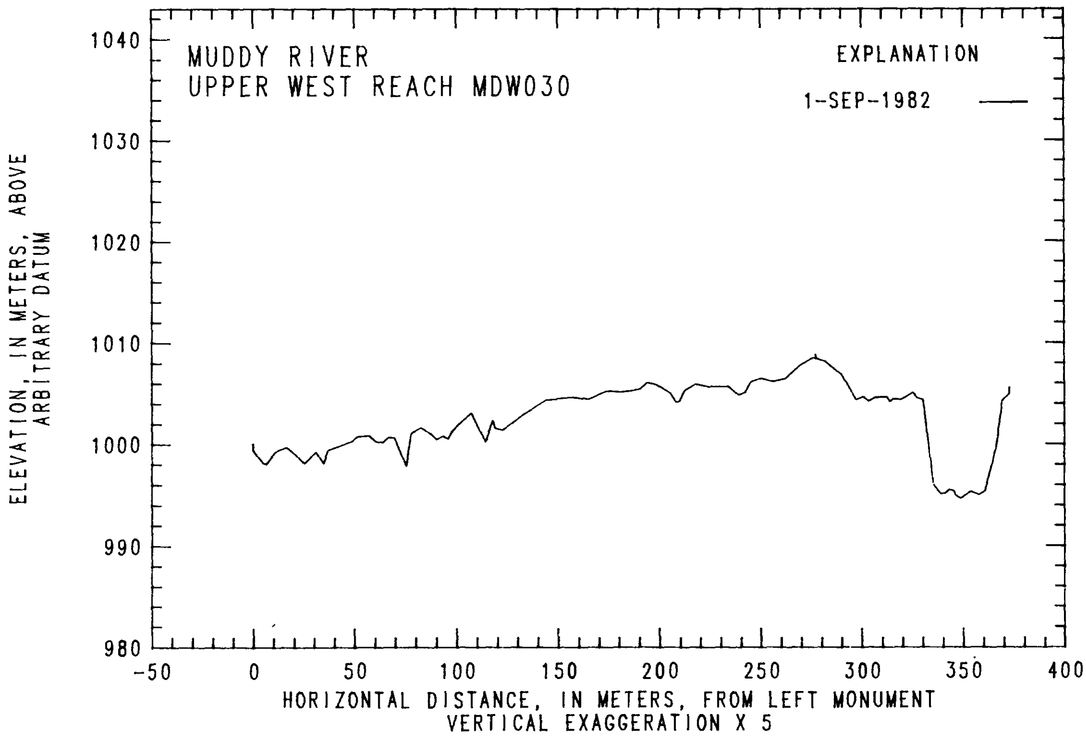


FIGURE 7. – Cross-section profiles for selected sites, Muddy River – continued.

INDEX TO SMITH CREEK CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

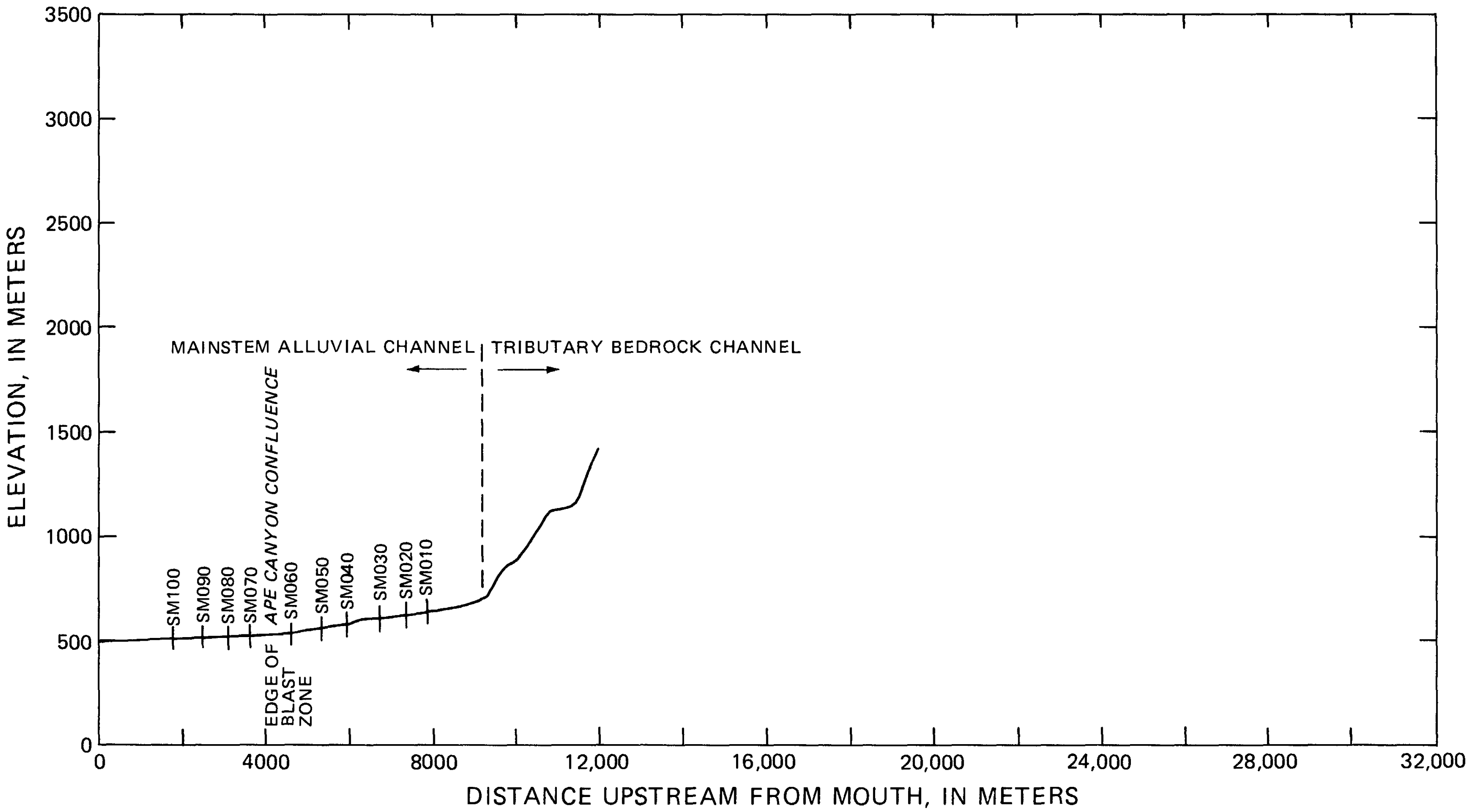


FIGURE 8. – Longitudinal profile of Smith Creek, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic map, 7.5-minute series, Mount St. Helens NE quadrangle.

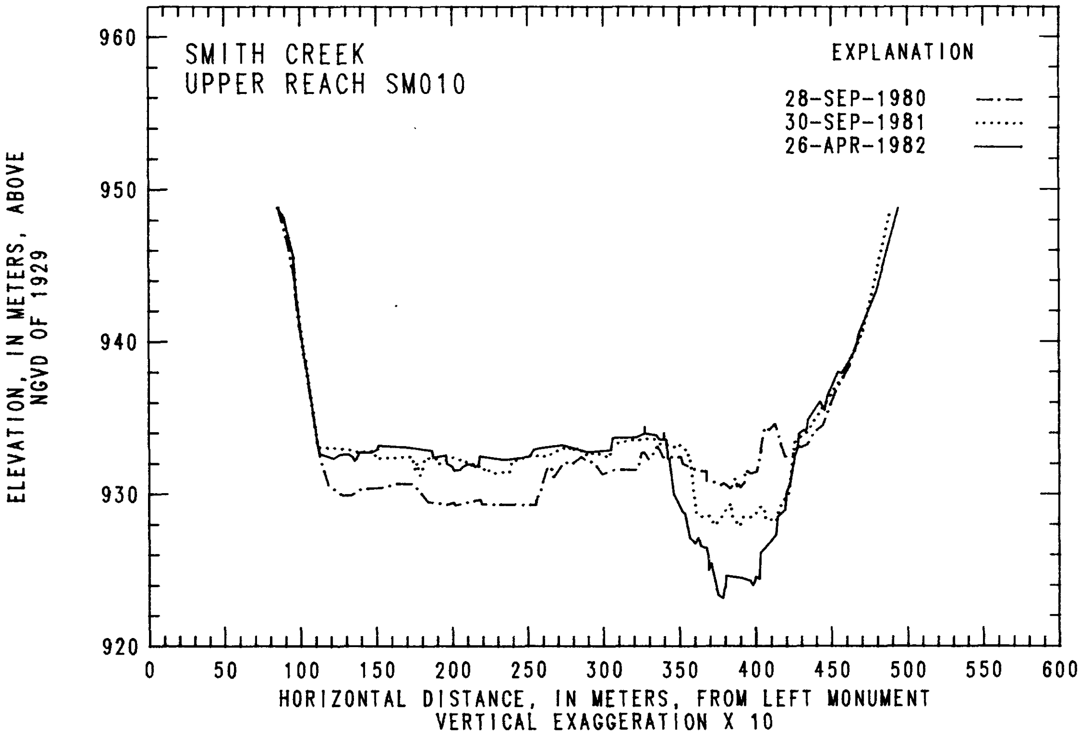


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek.

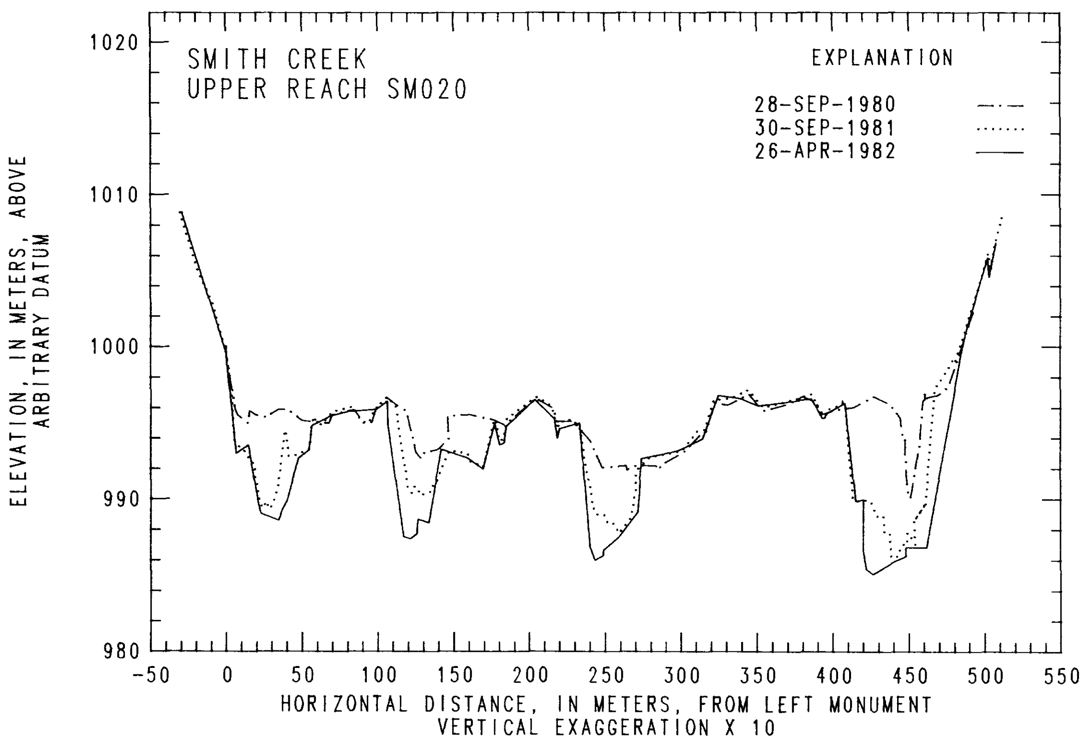
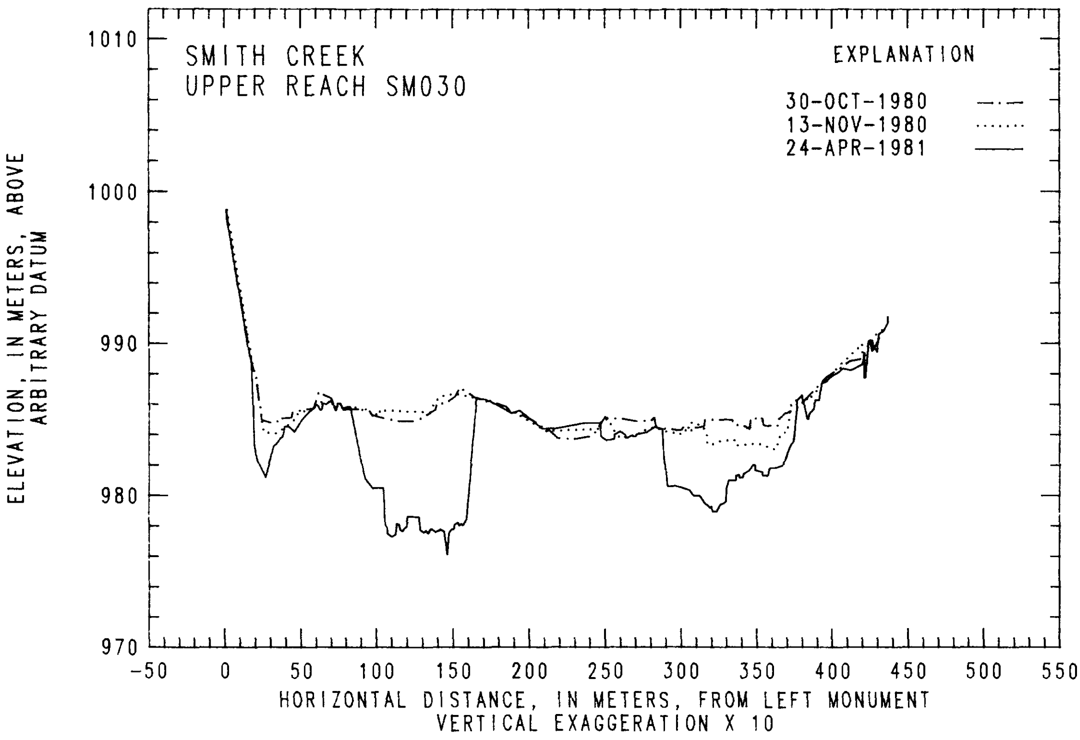


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.



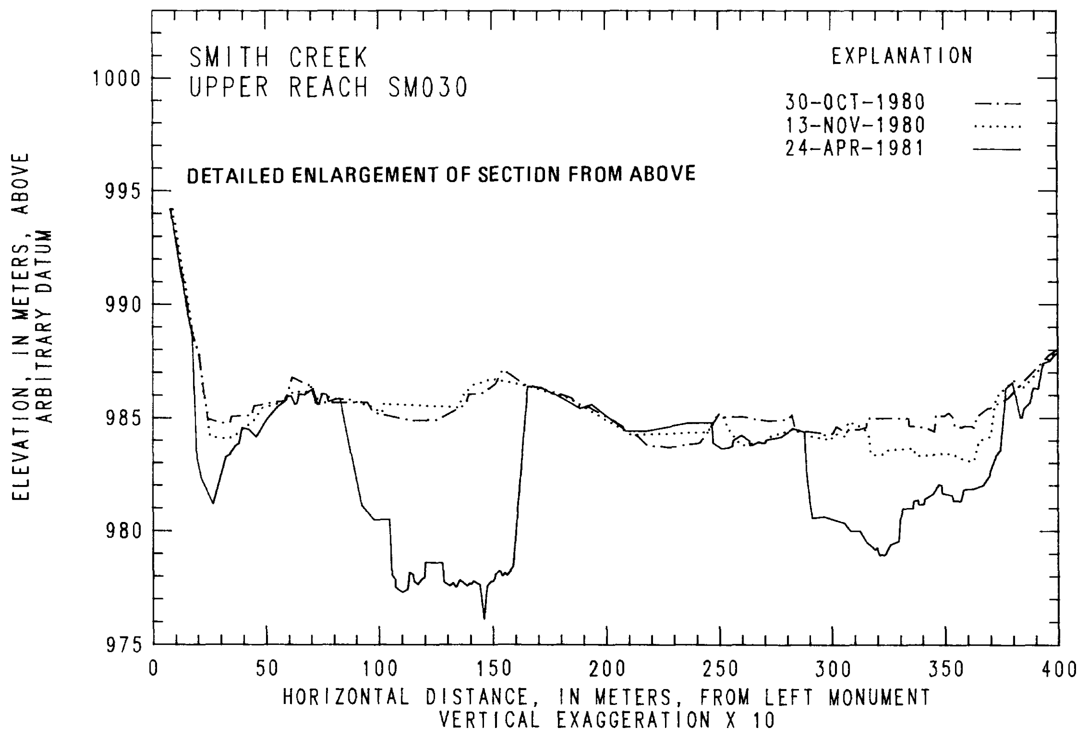
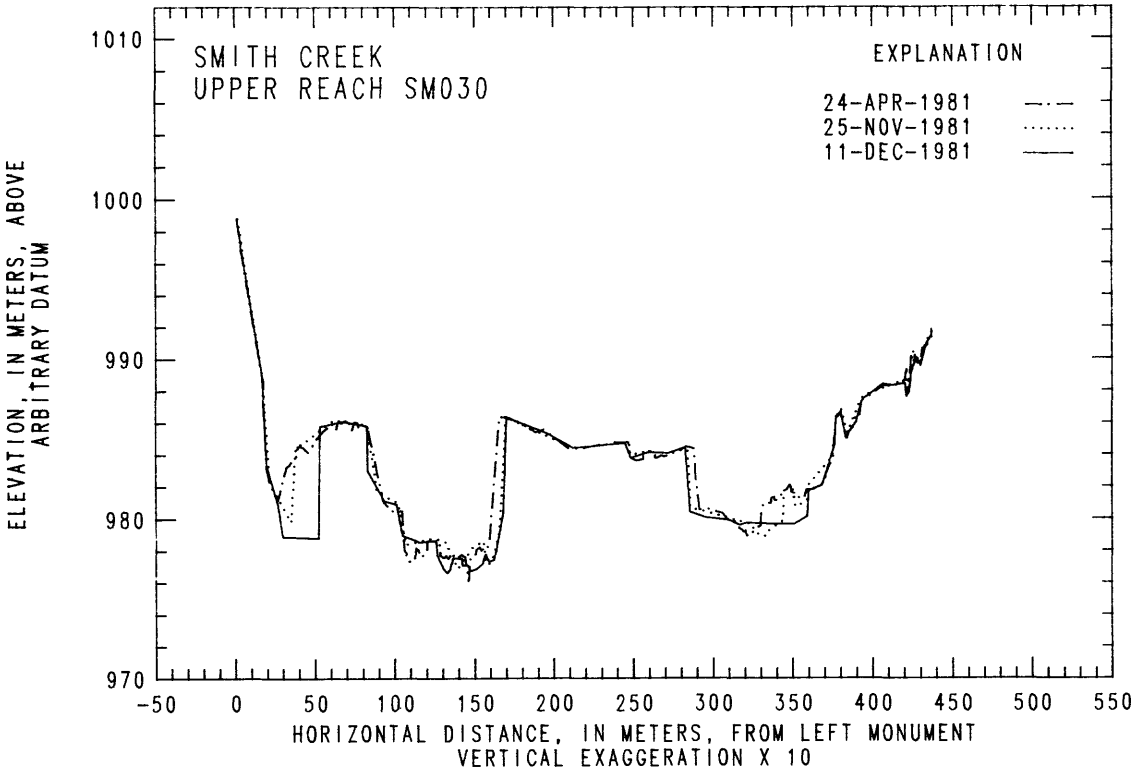


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.



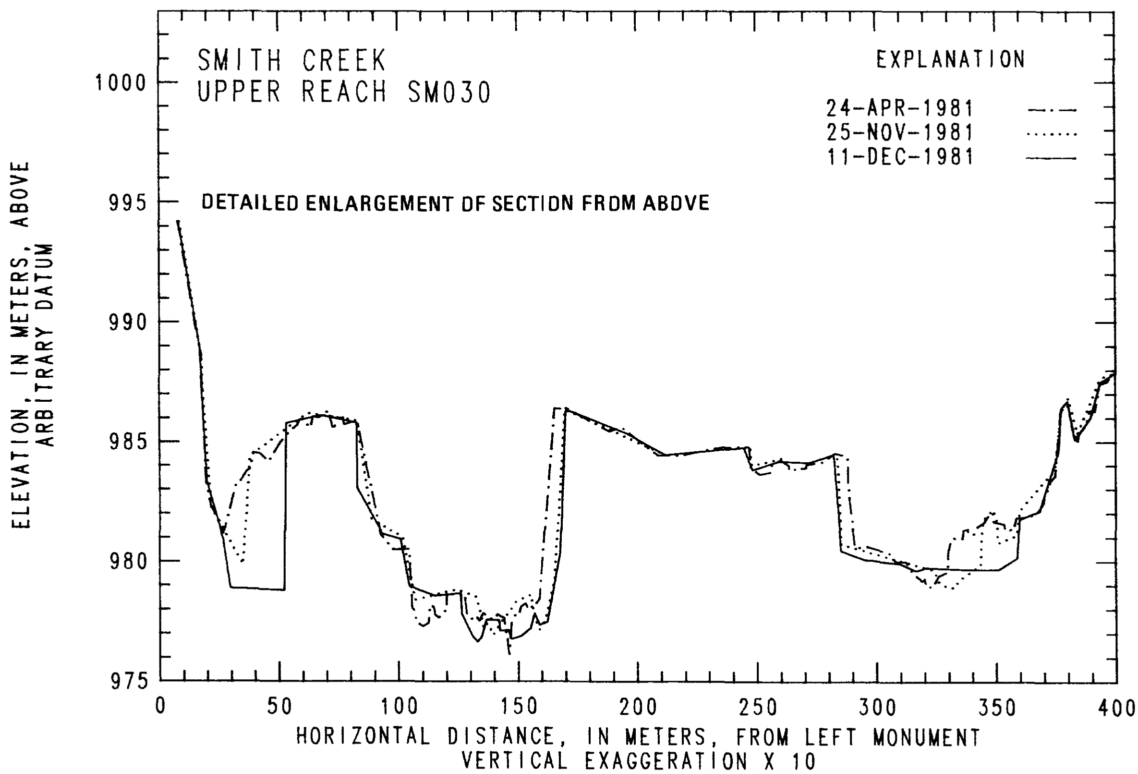
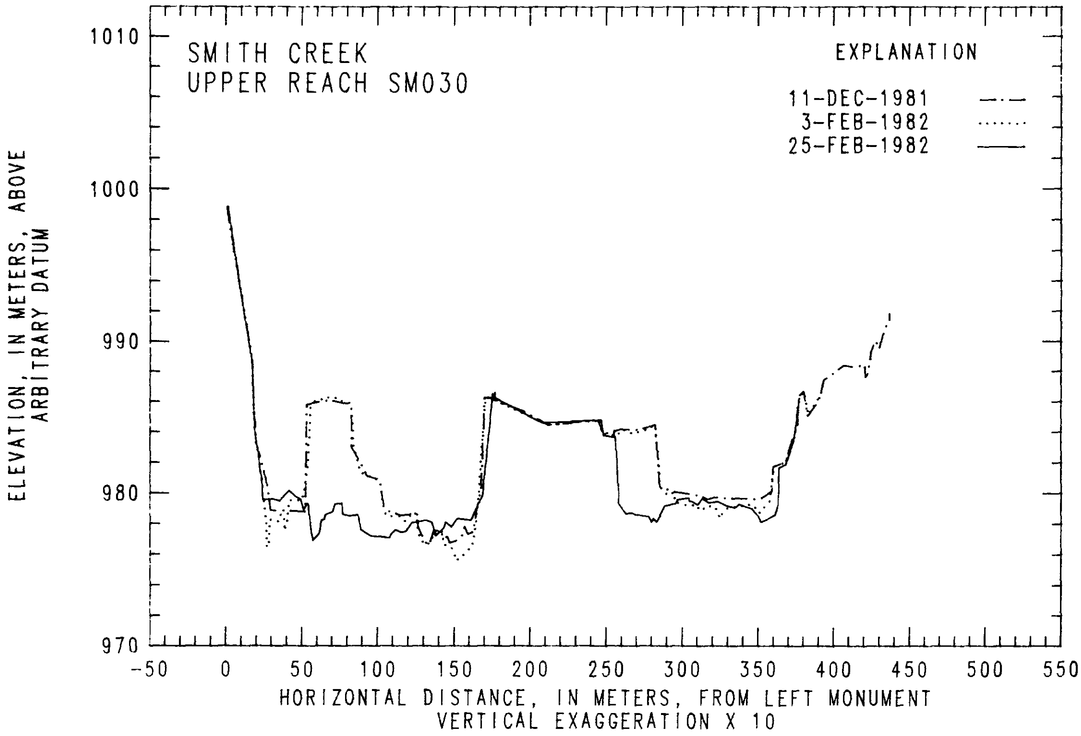


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.



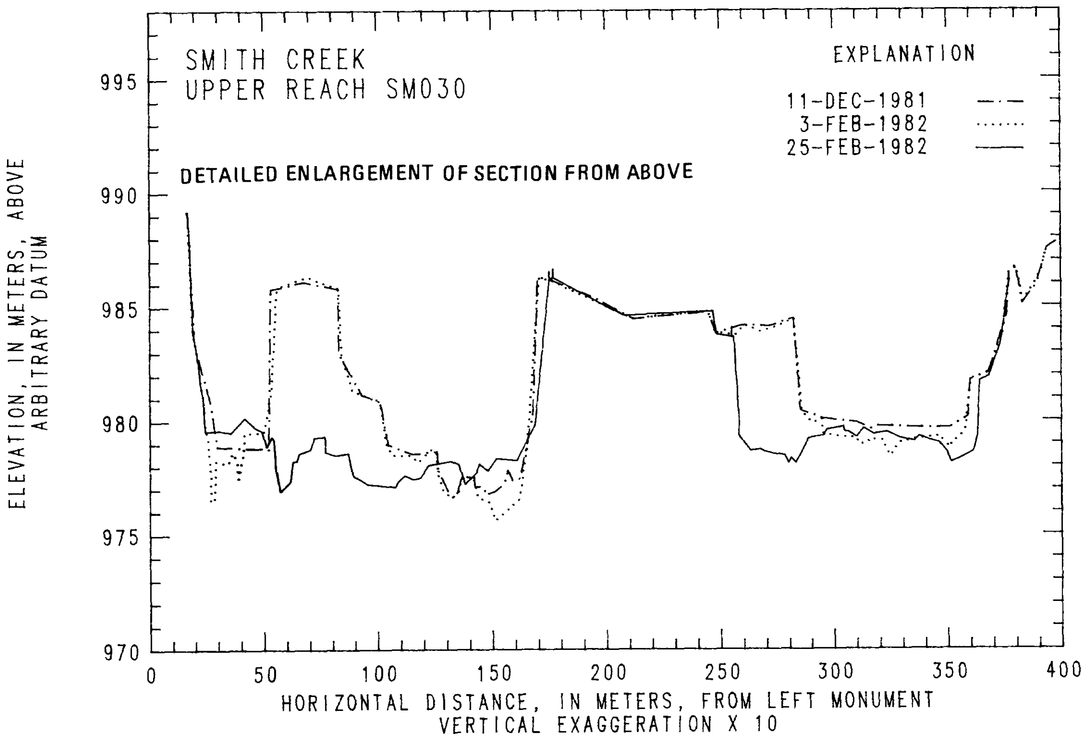
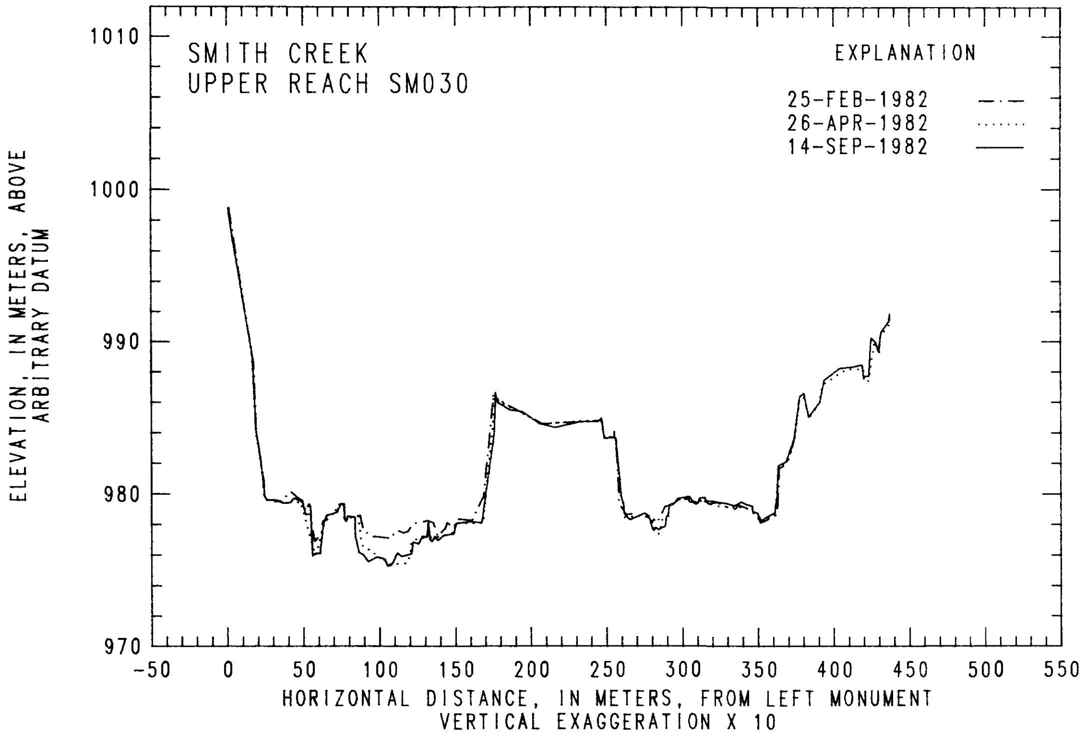


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.



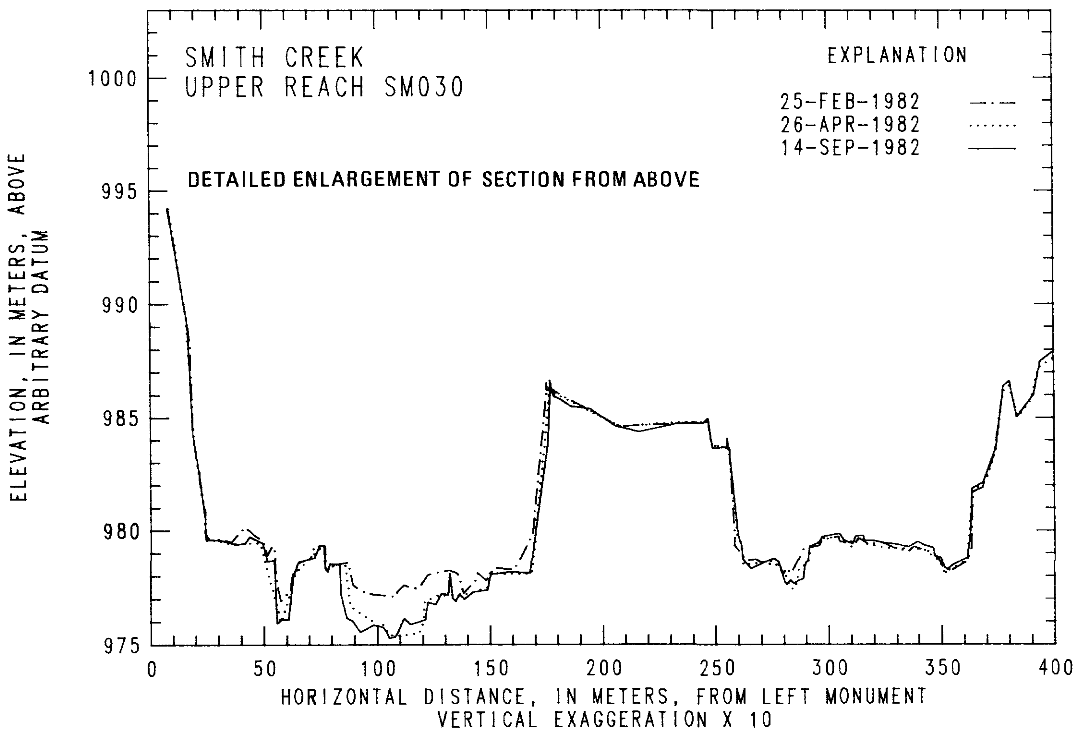


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

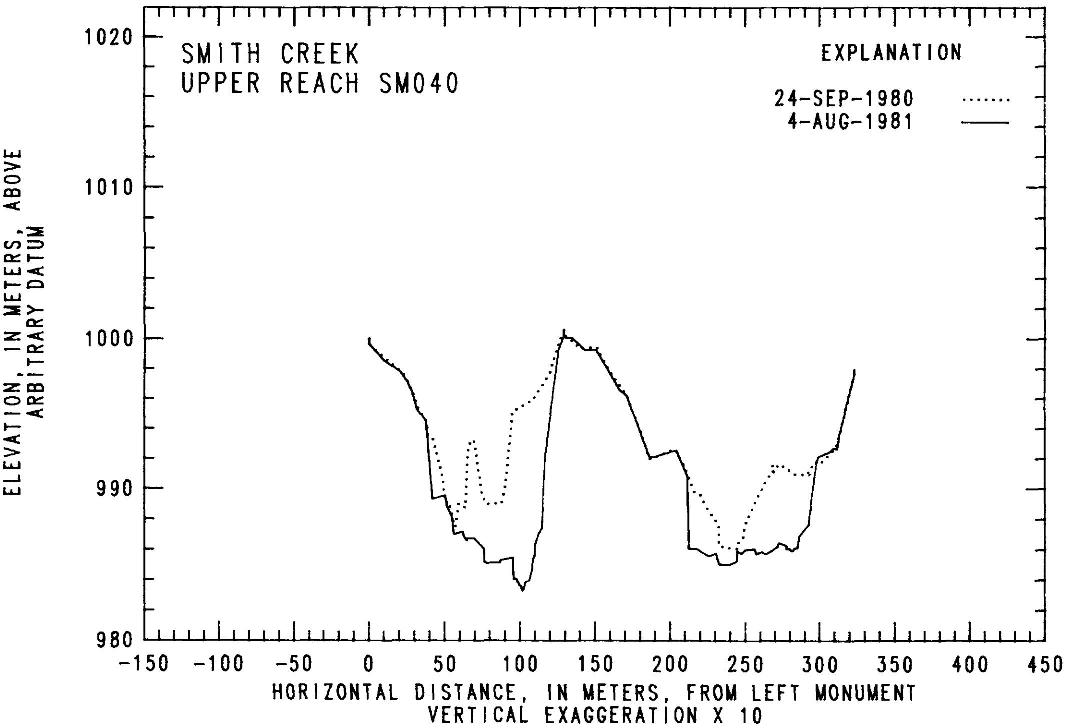


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

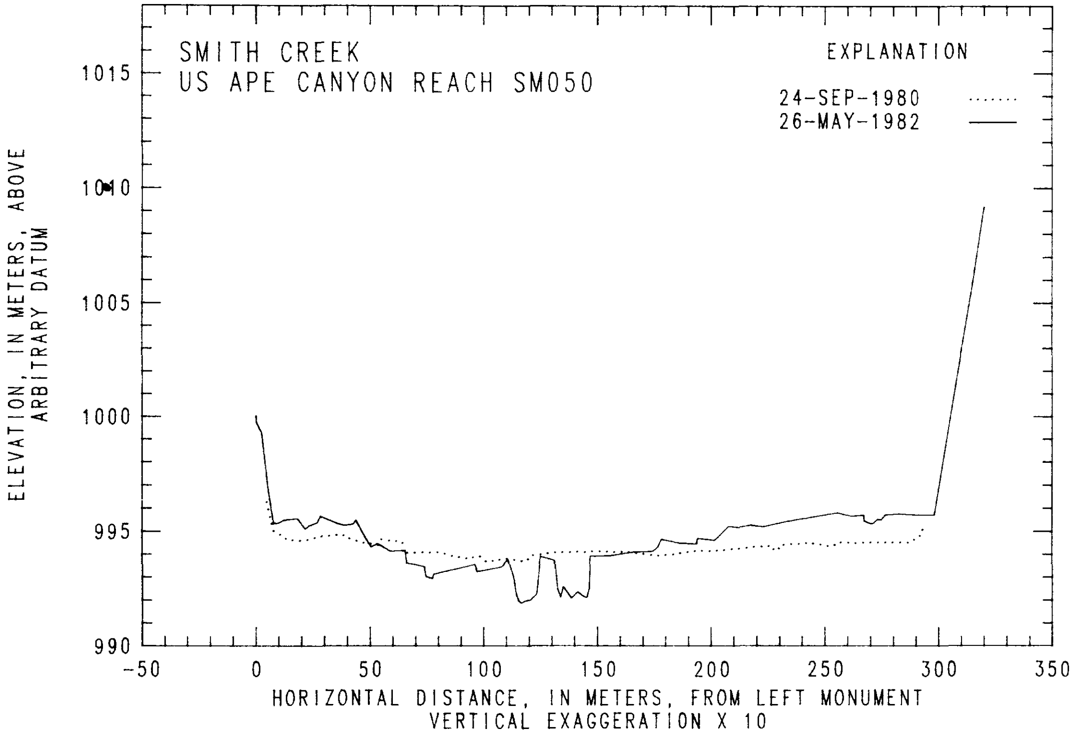


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

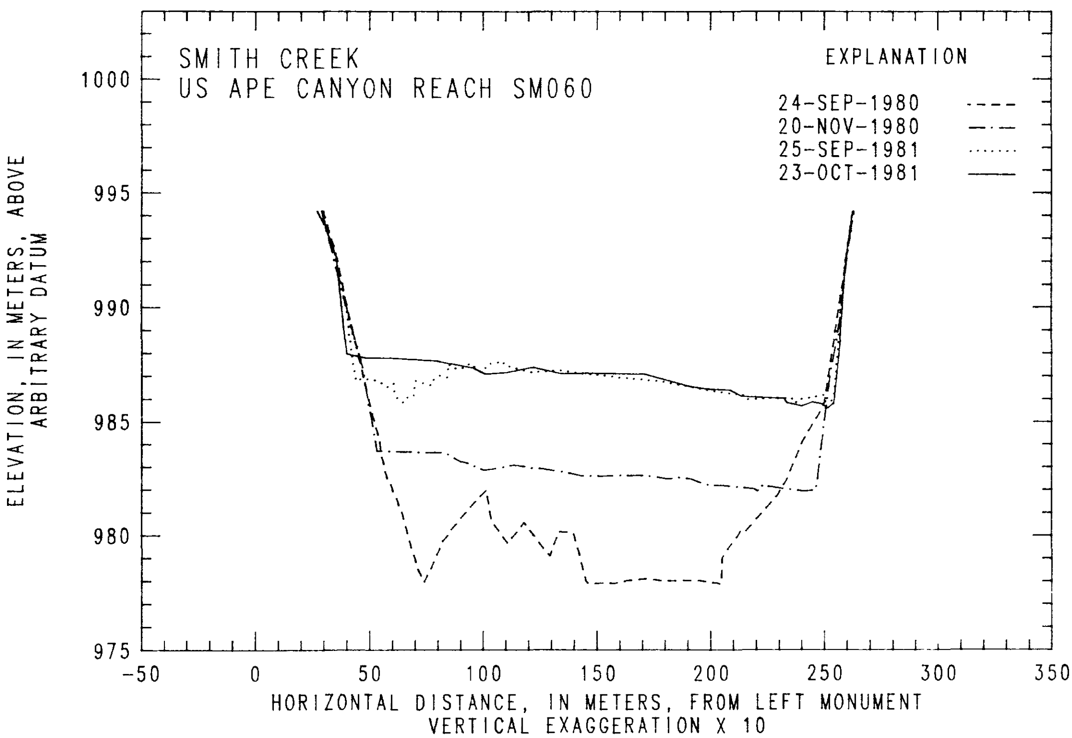
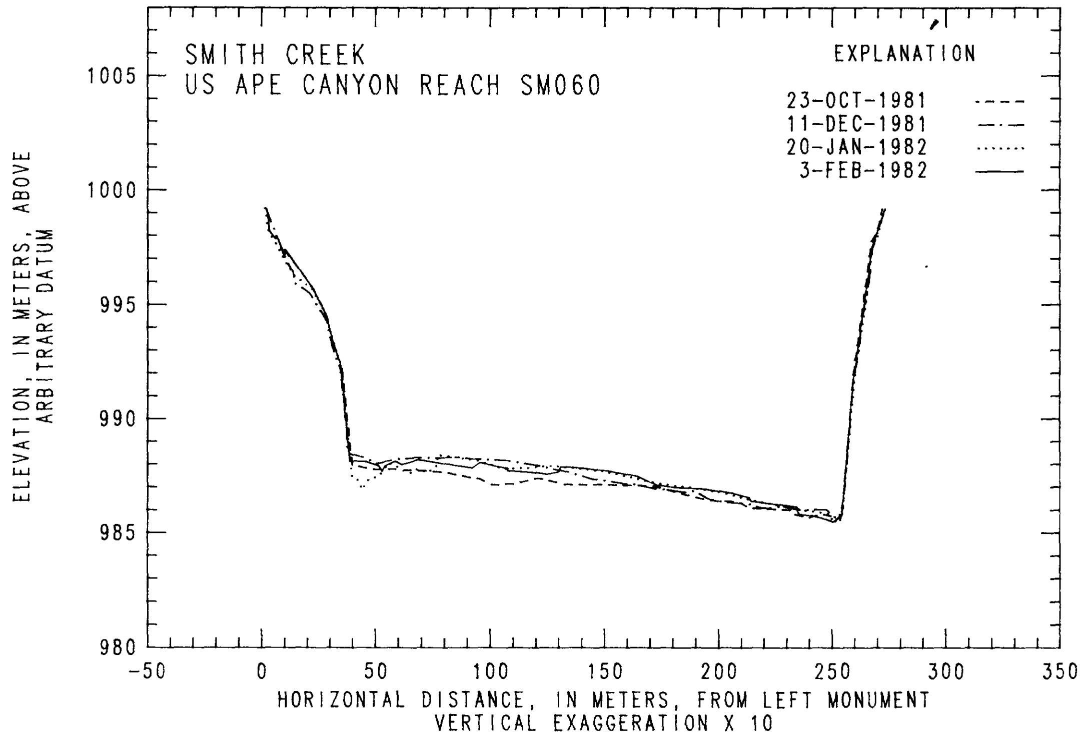


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.



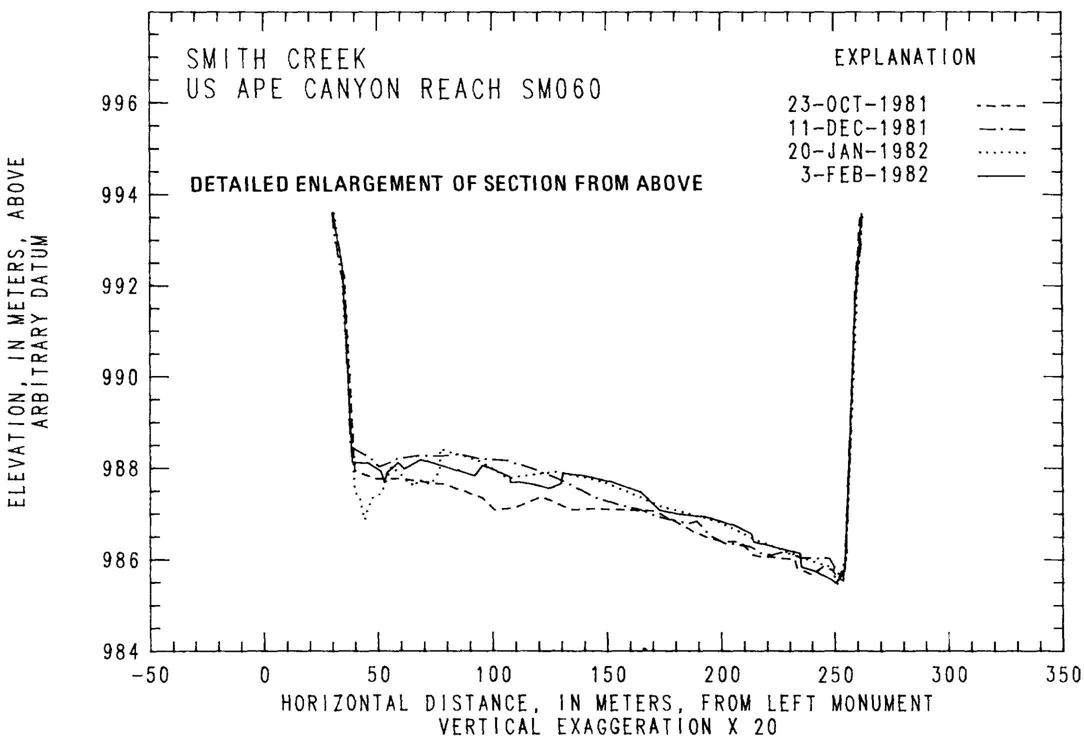


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

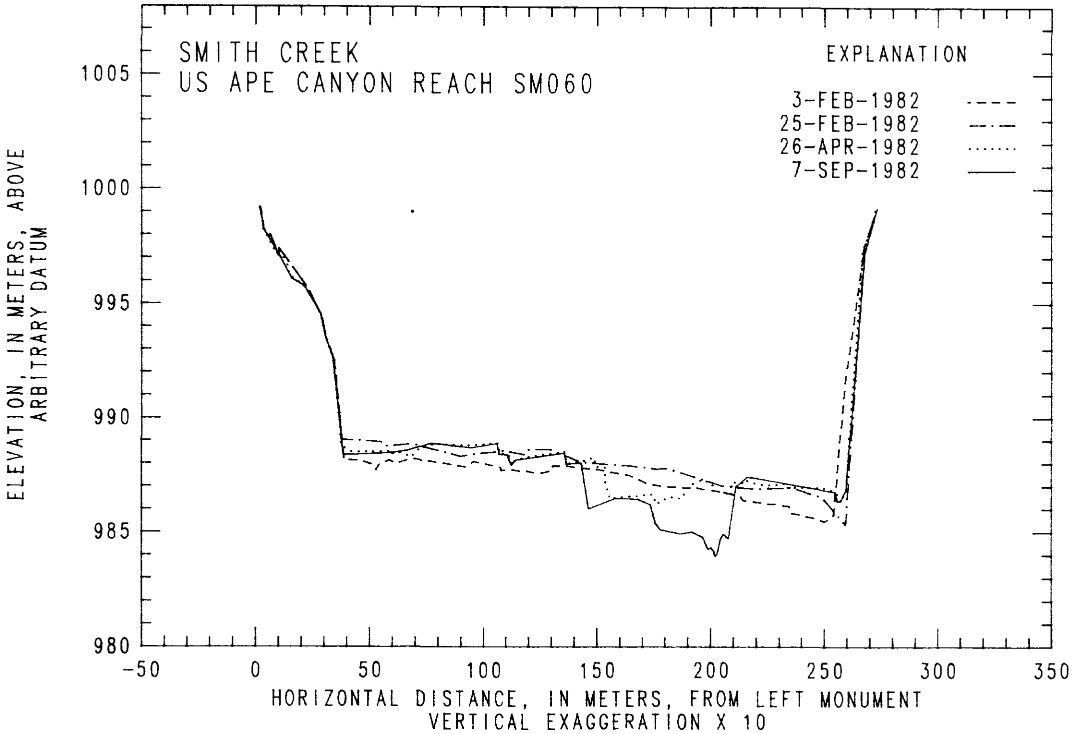


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

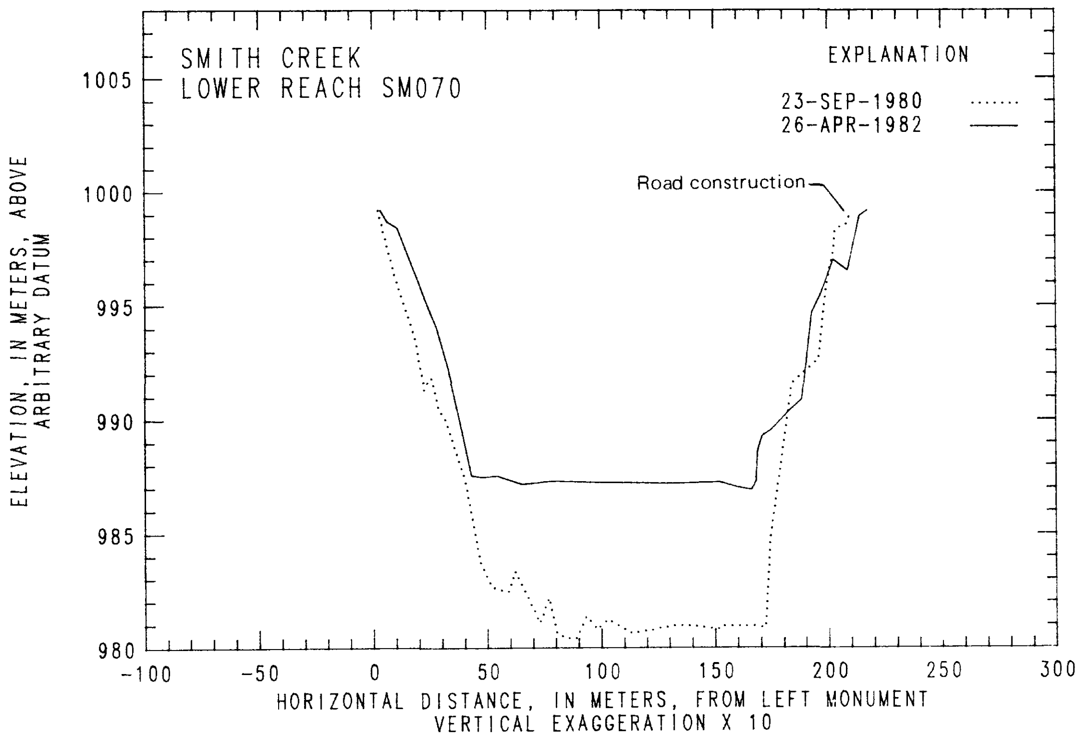


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

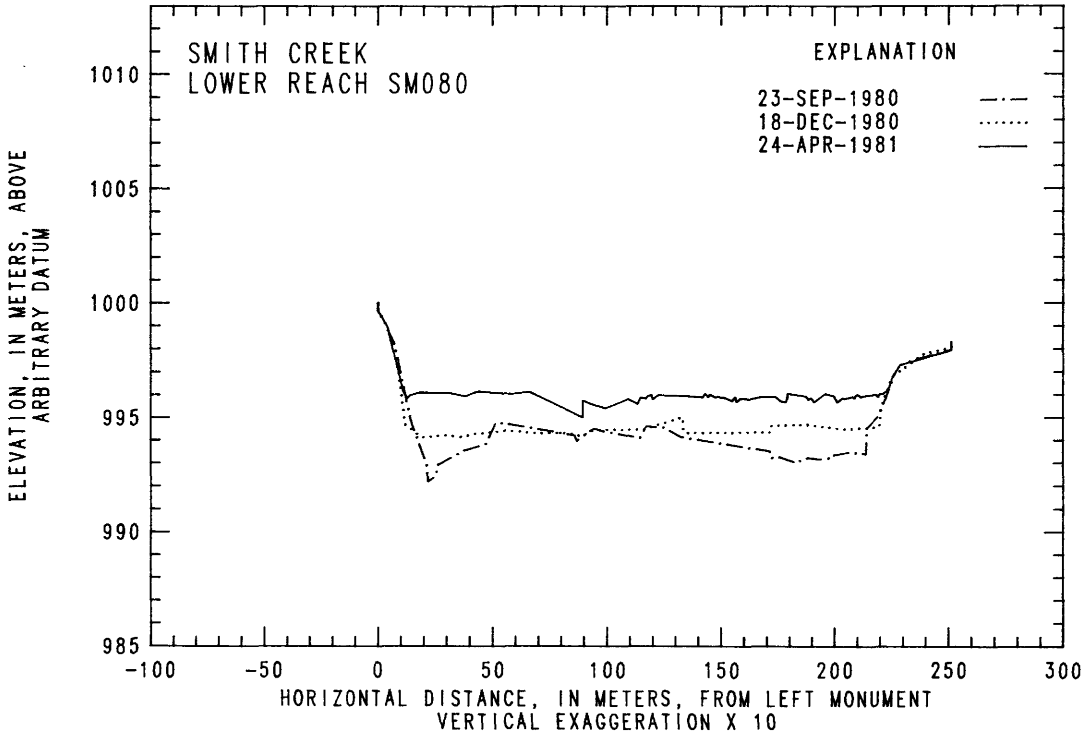


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

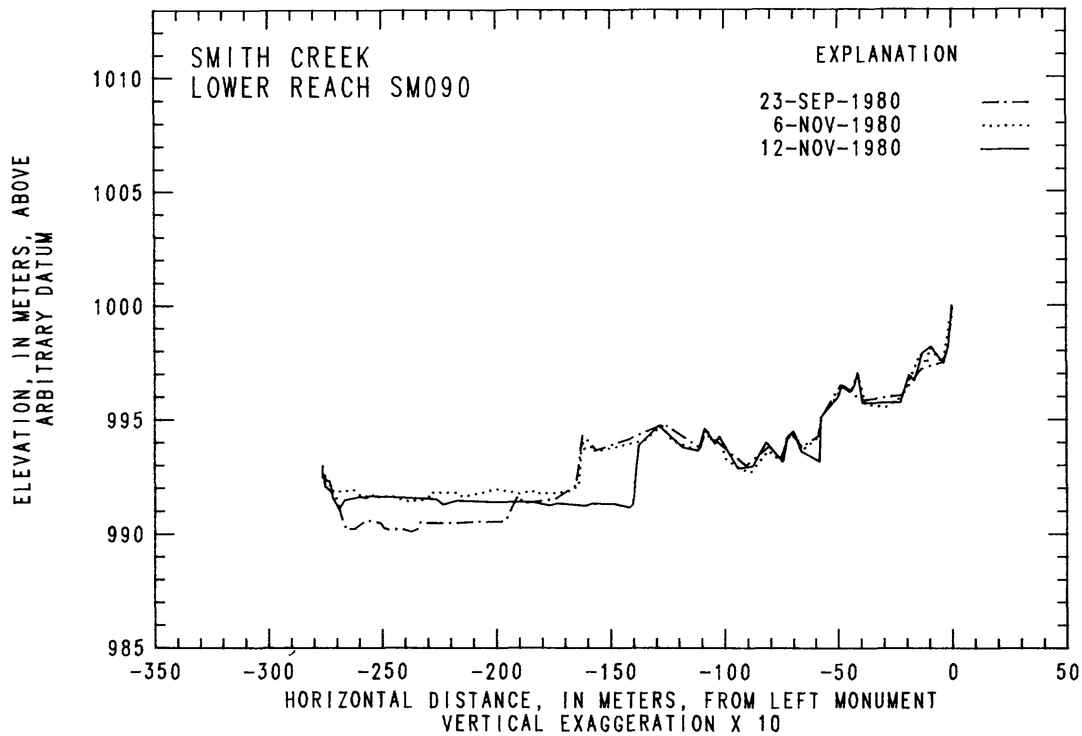


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

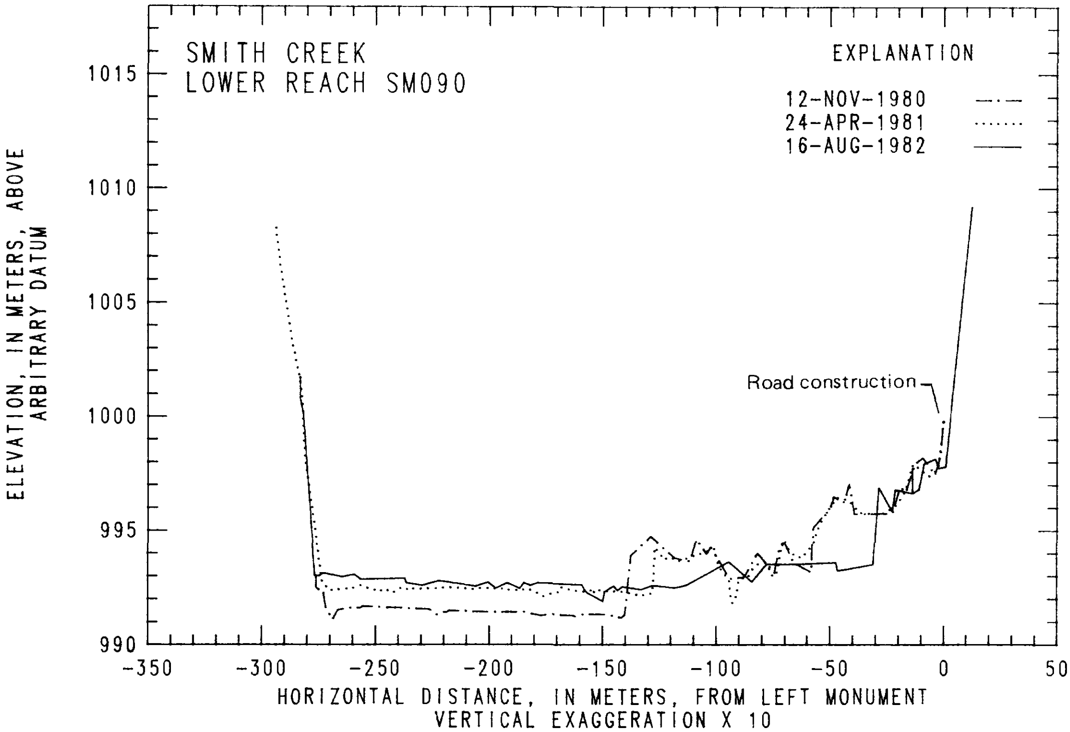


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

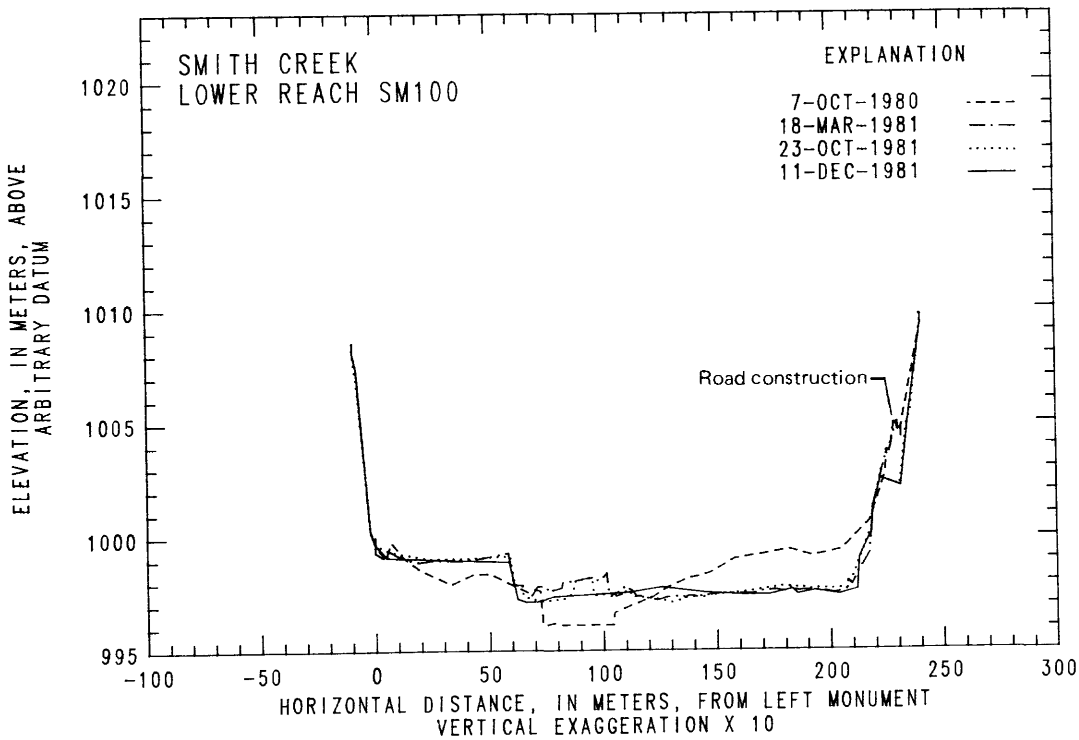


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

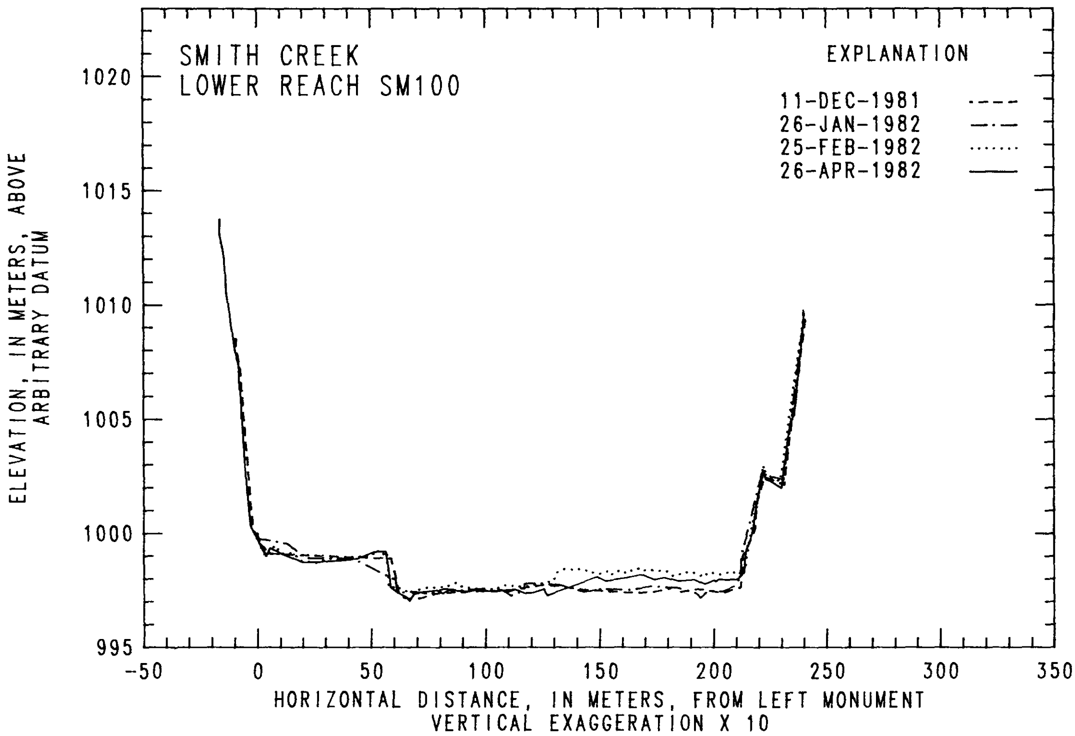


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

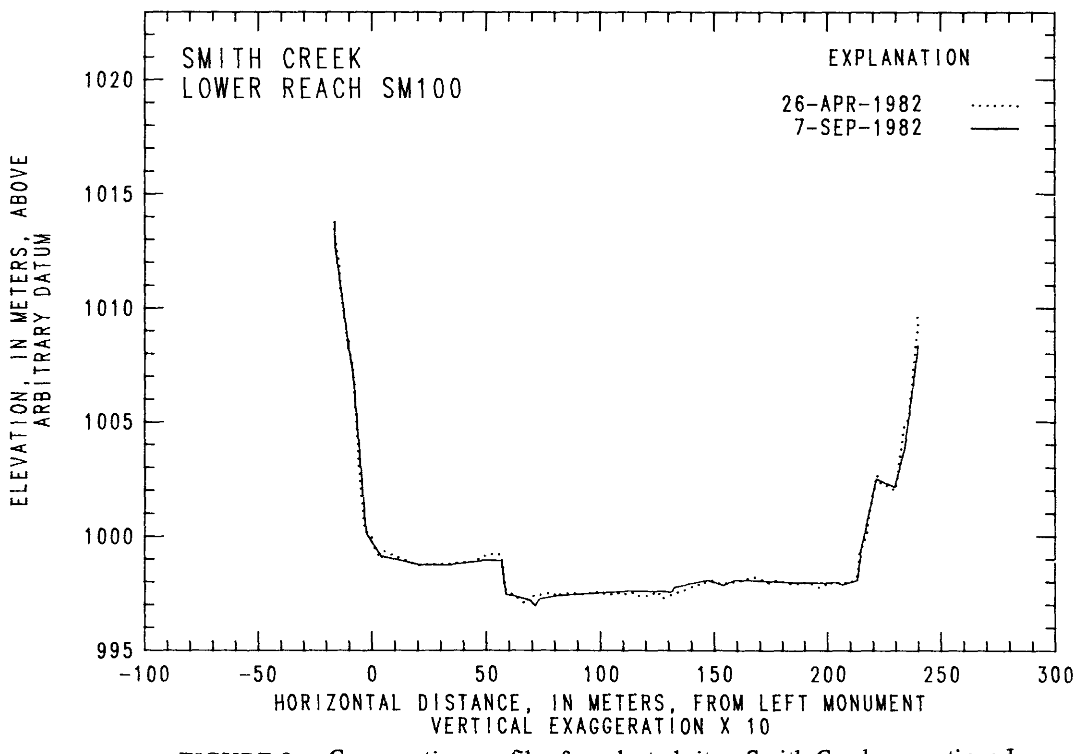


FIGURE 9. – Cross-section profiles for selected sites, Smith Creek – continued.

INDEX TO CLEARWATER CREEK CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

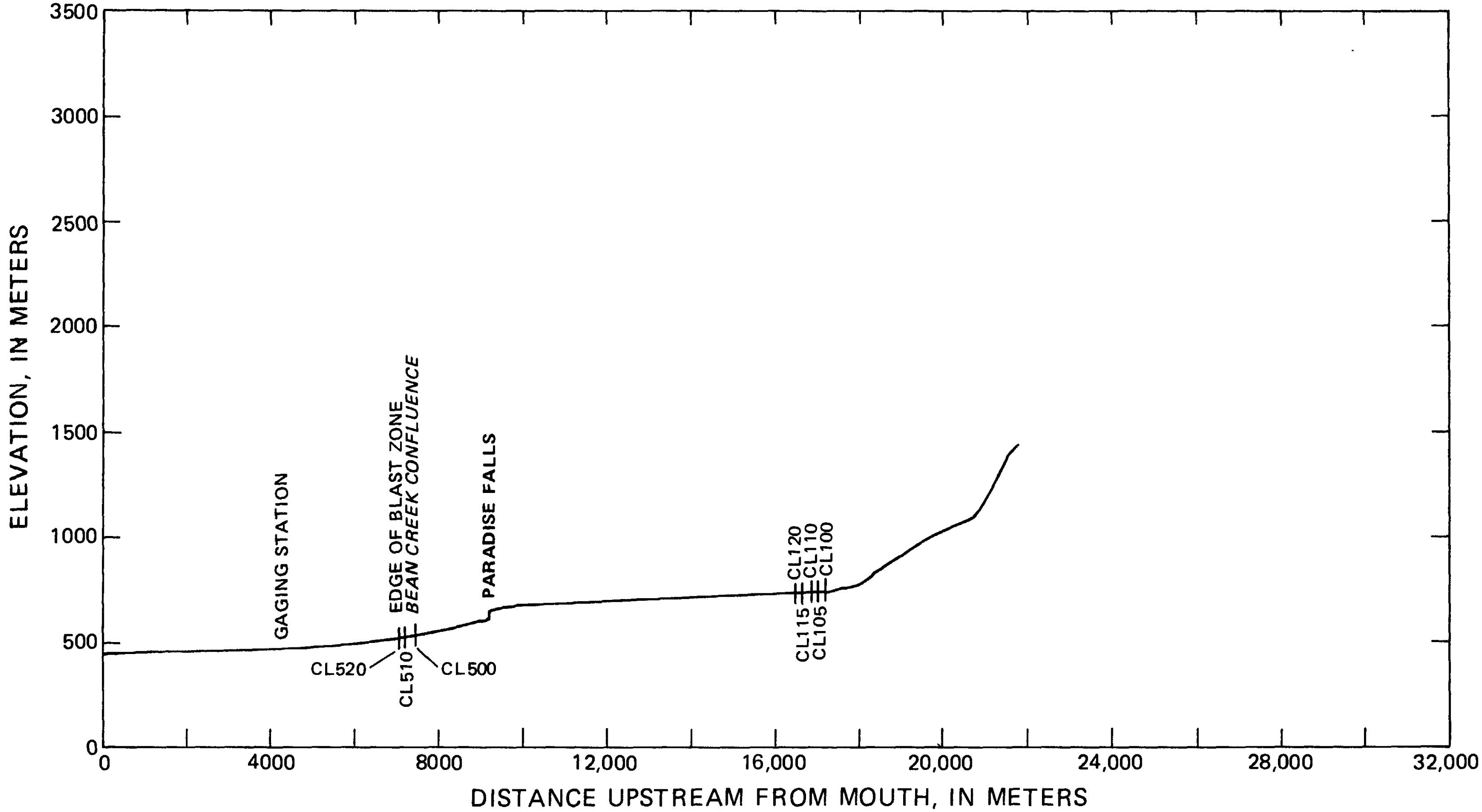


FIGURE 10.– Longitudinal profile of Clearwater Creek, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic maps, 7.5-minute series, Mount St. Helens NE and Spirit Lake SE quadrangles.

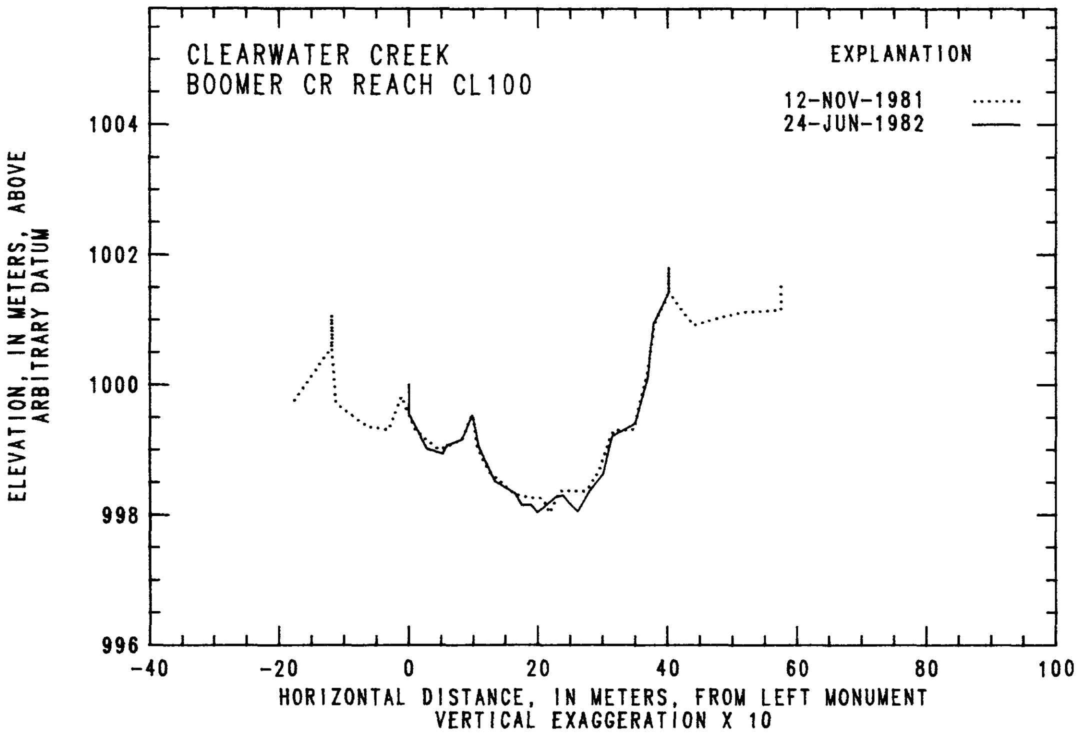


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek.

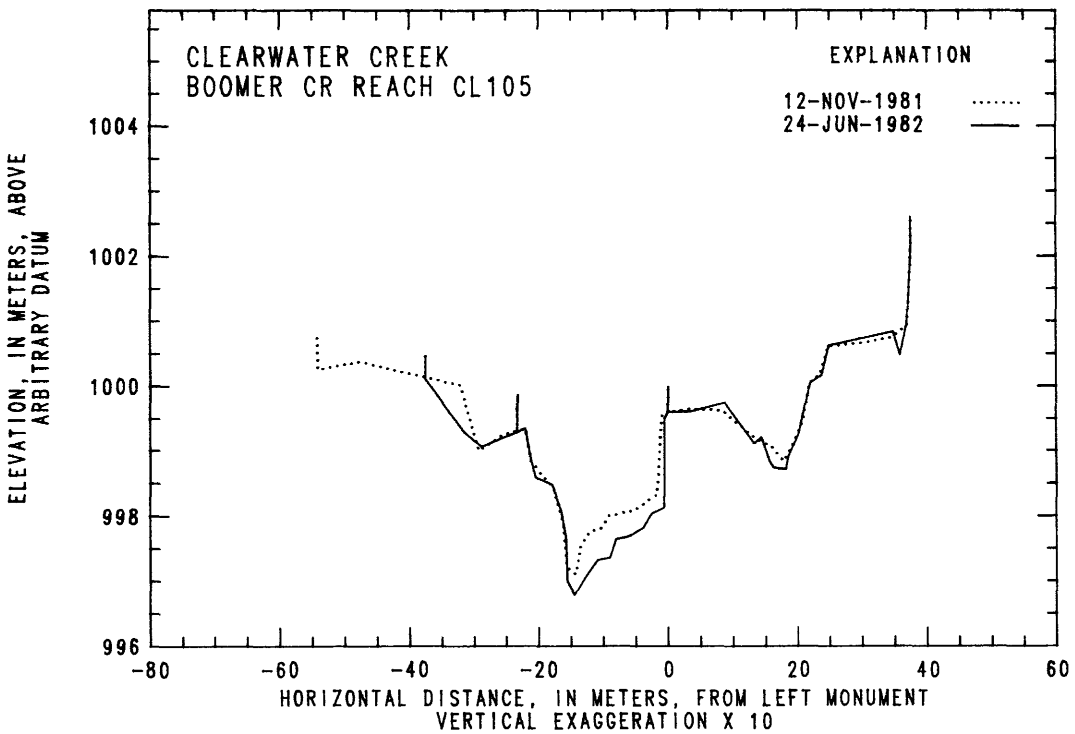


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

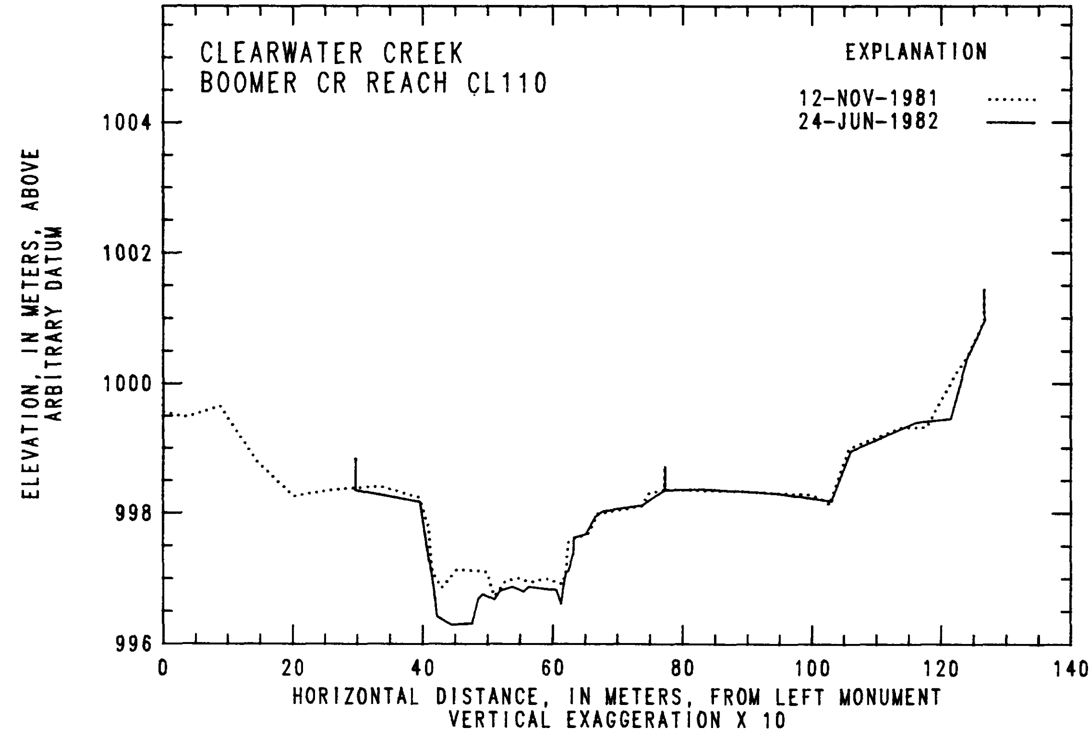


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

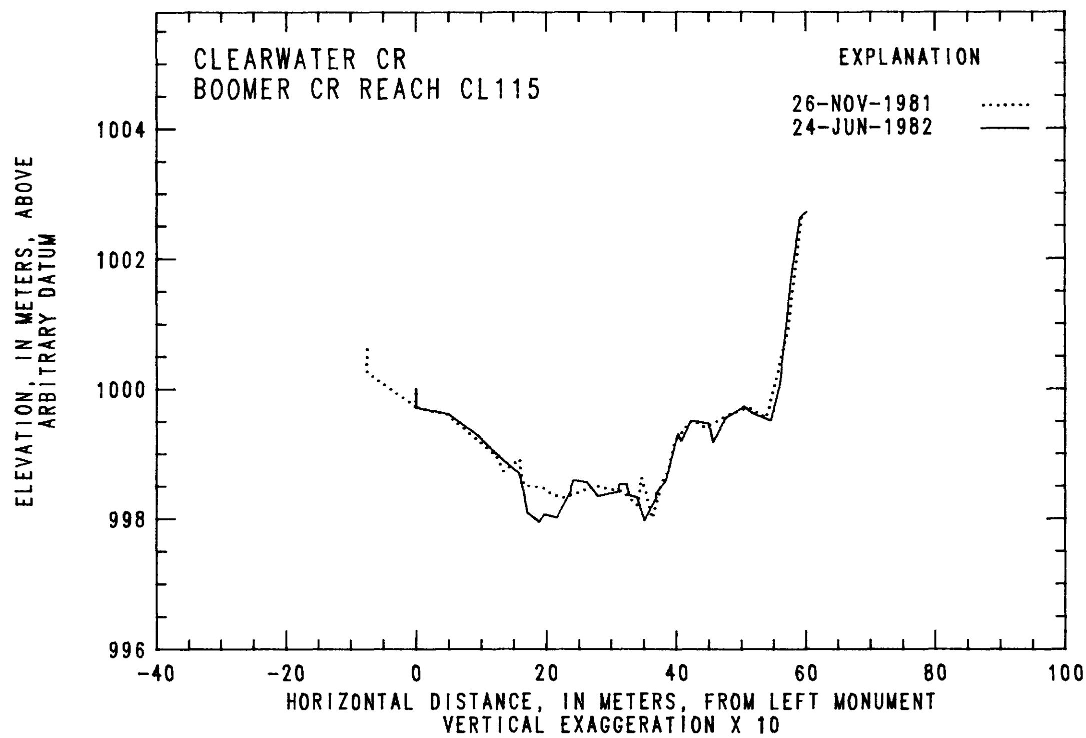


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

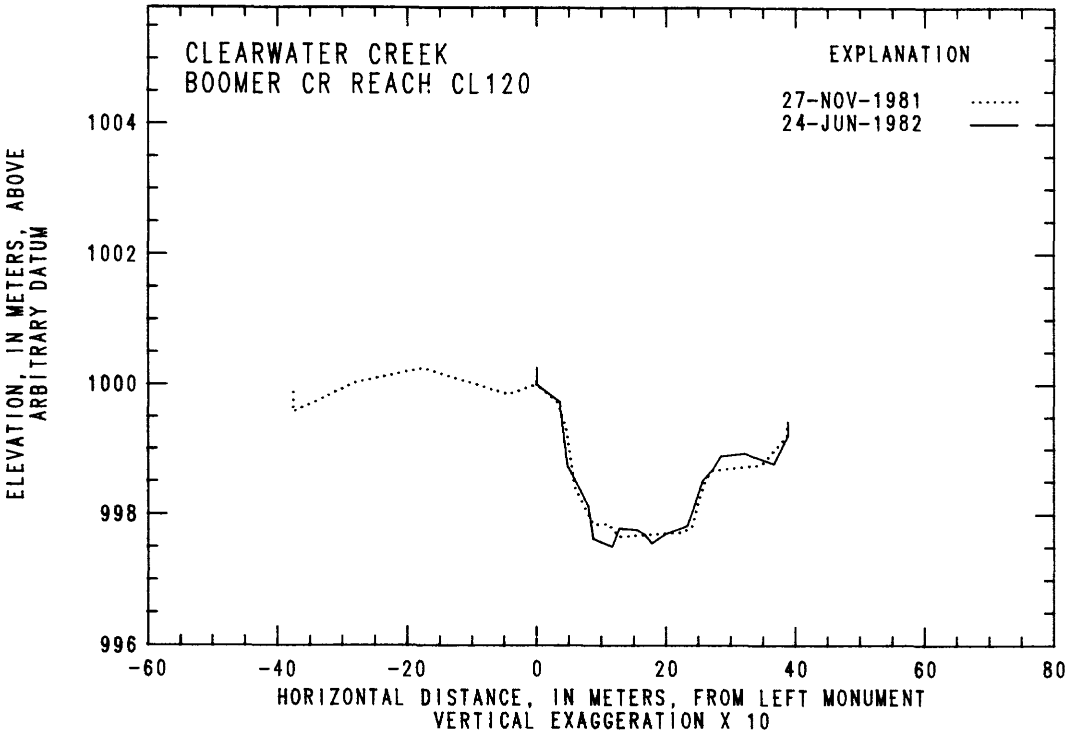


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

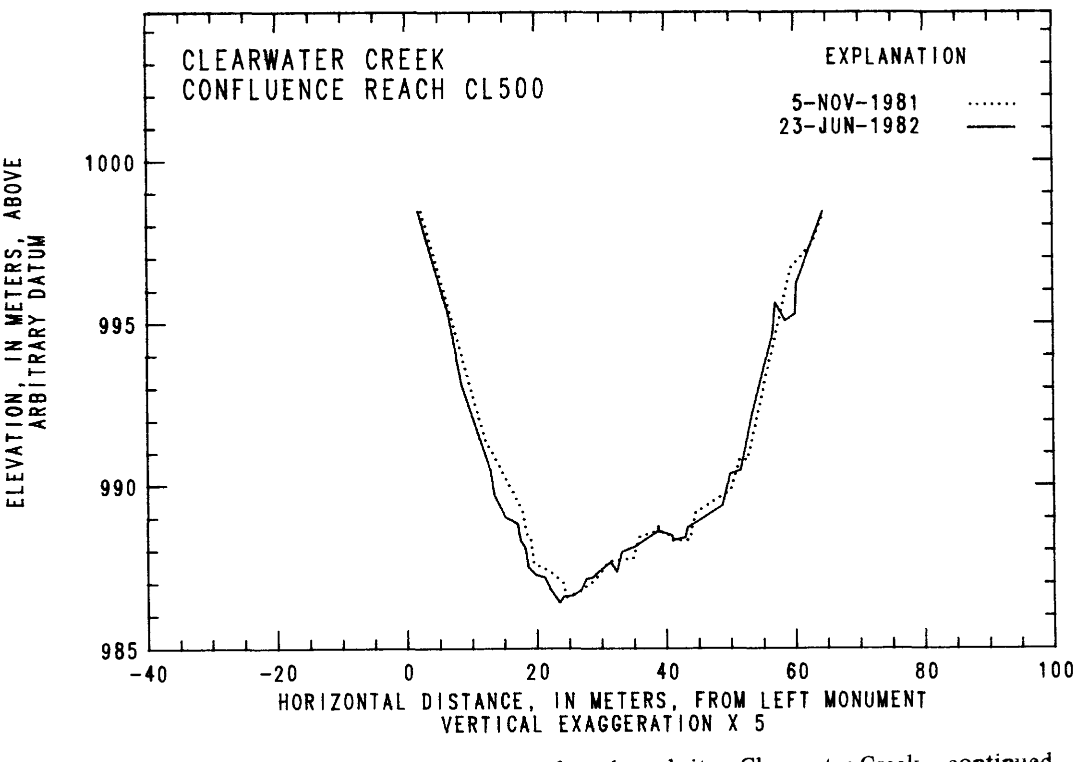


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

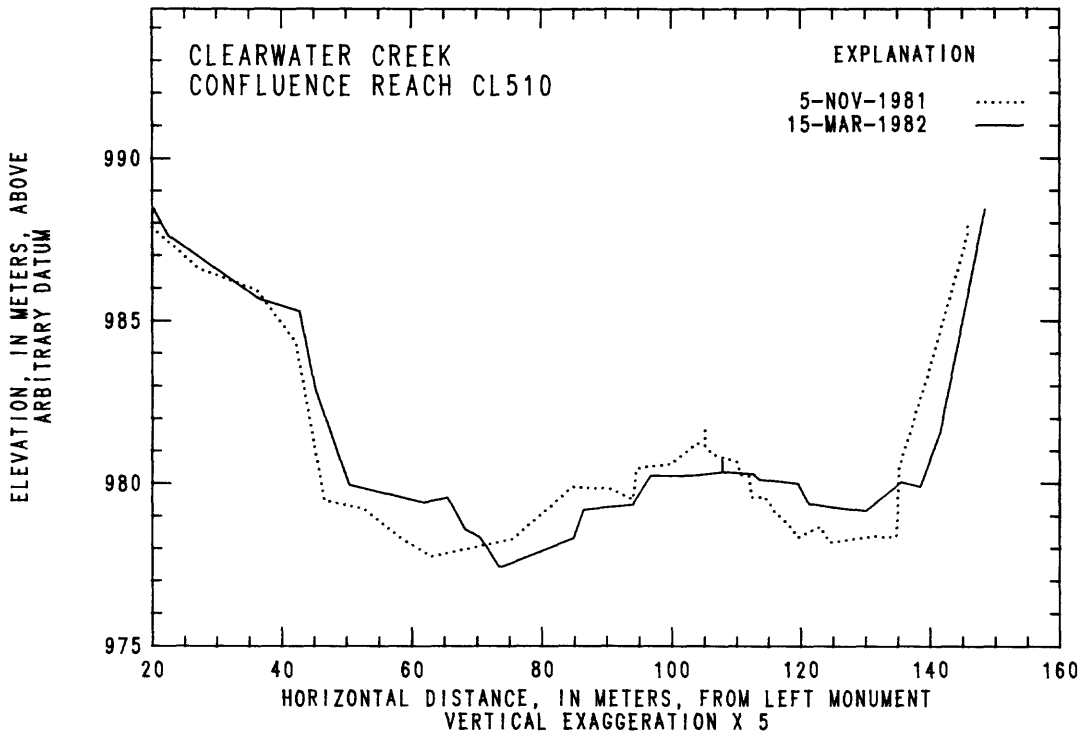


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

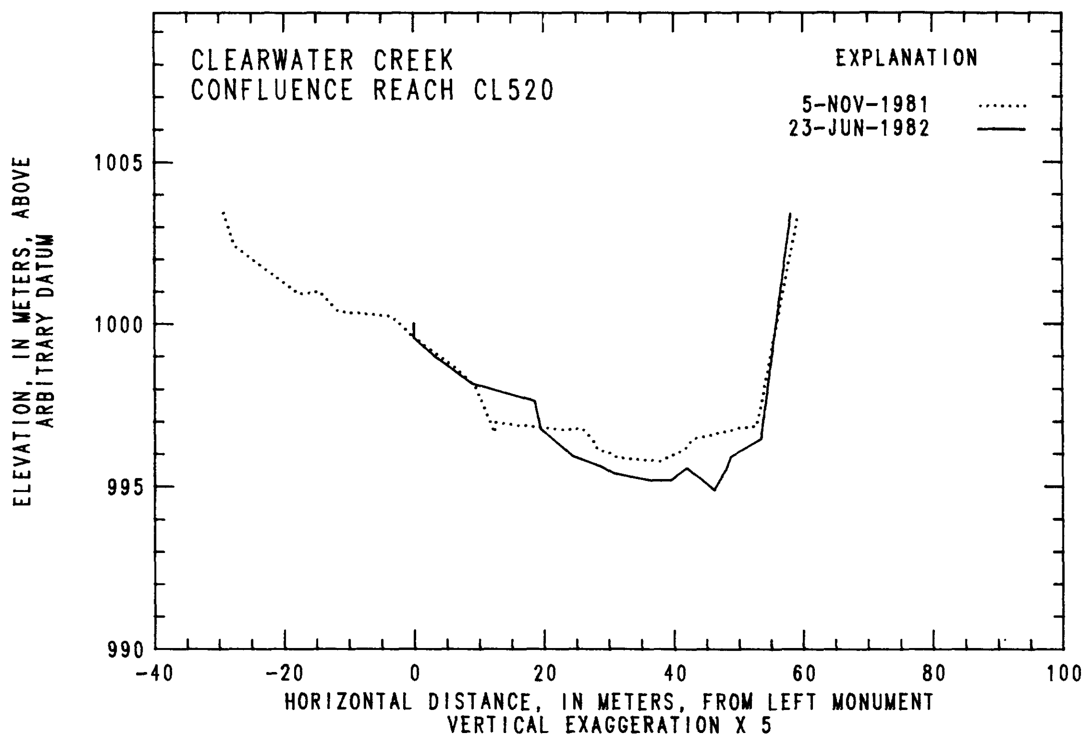


FIGURE 11. – Cross-section profiles for selected sites, Clearwater Creek – continued.

INDEX TO BEAN CREEK CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

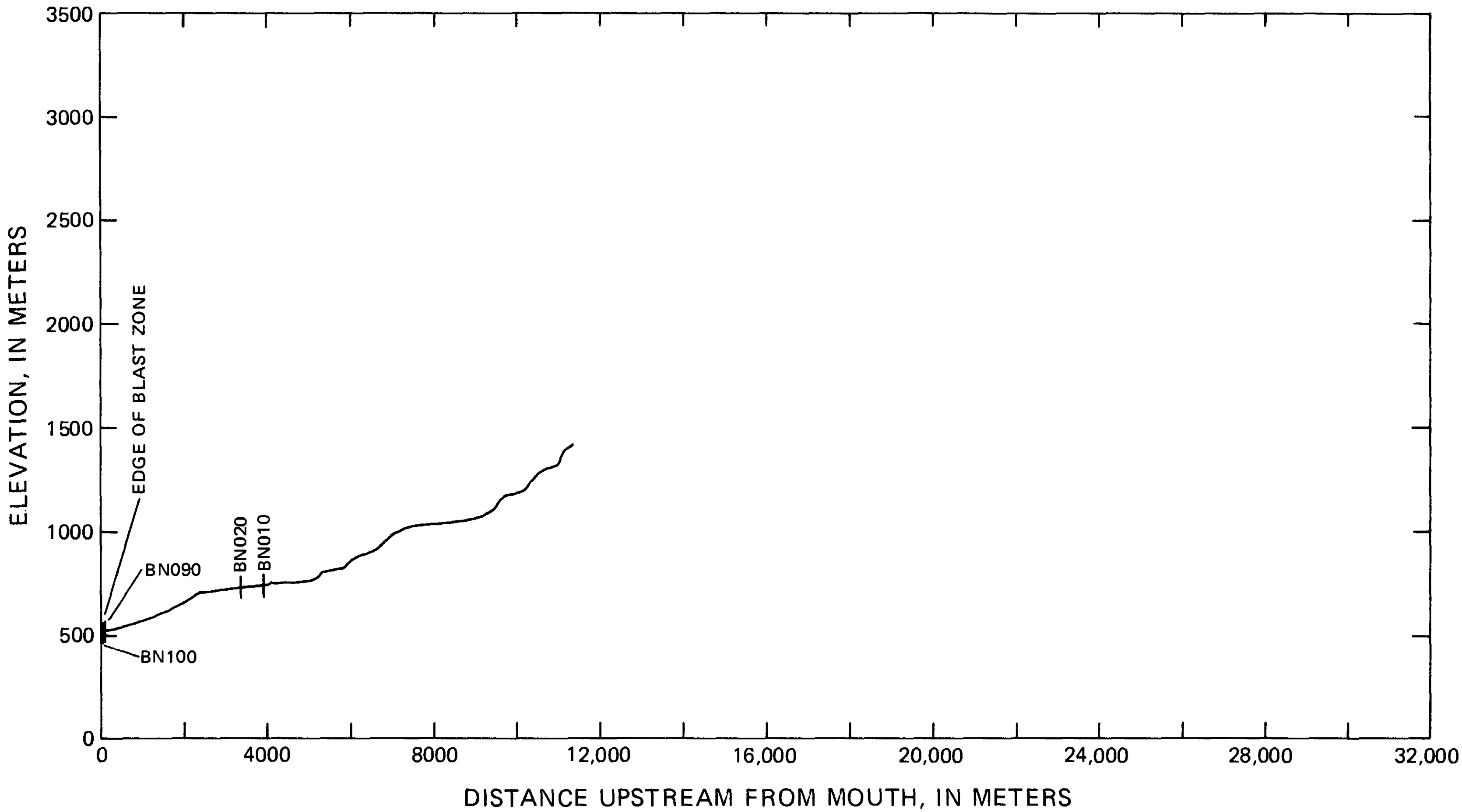


FIGURE 12.– Longitudinal profile of Bean Creek, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic map, 7.5-minute series, Mount St. Helens NE quadrangle.

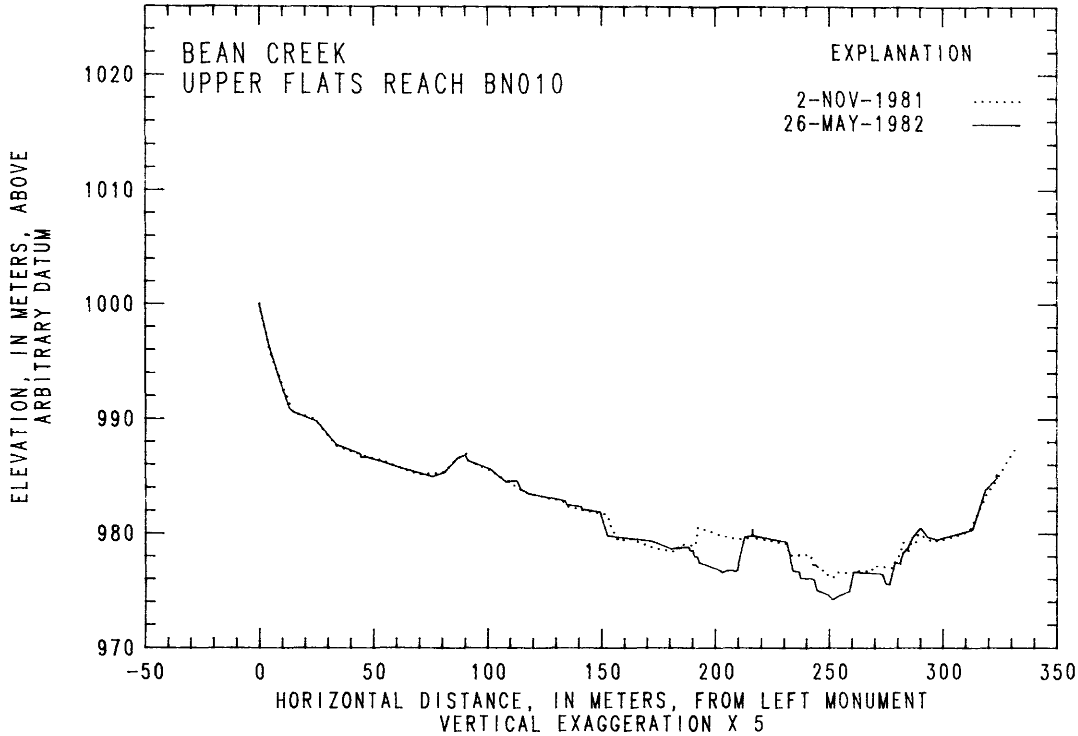


FIGURE 13. –Cross-section profiles for selected sites, Bean Creek.

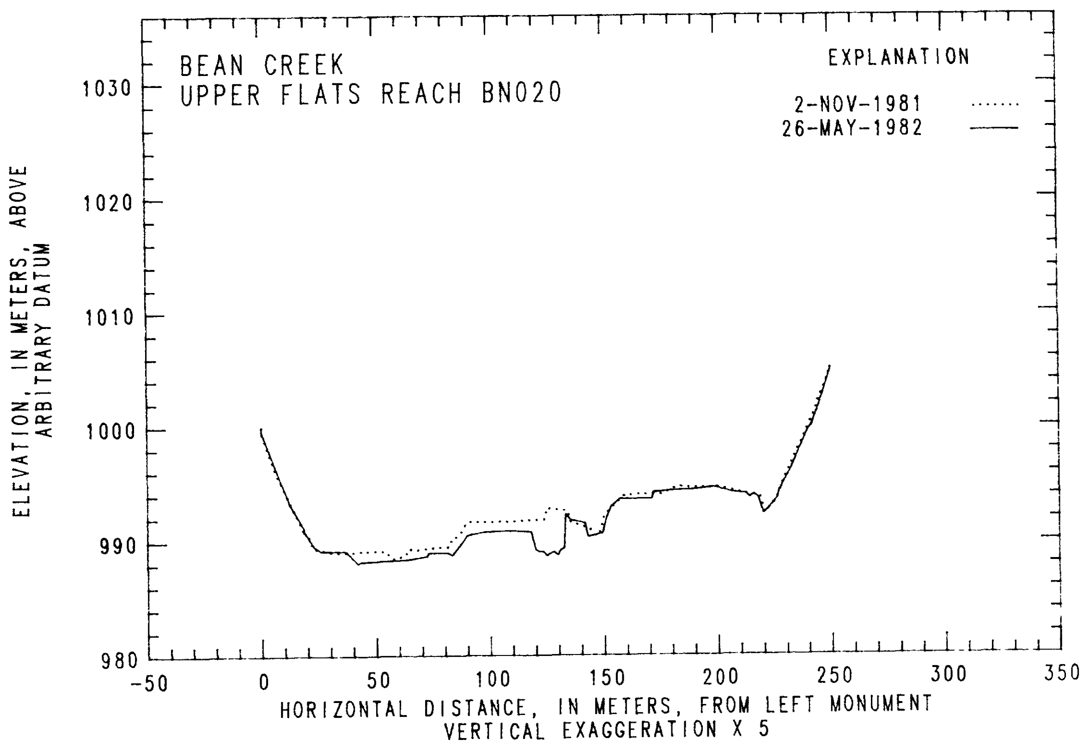


FIGURE 13. –Cross-section profiles for selected sites, Bean Creek. – continued

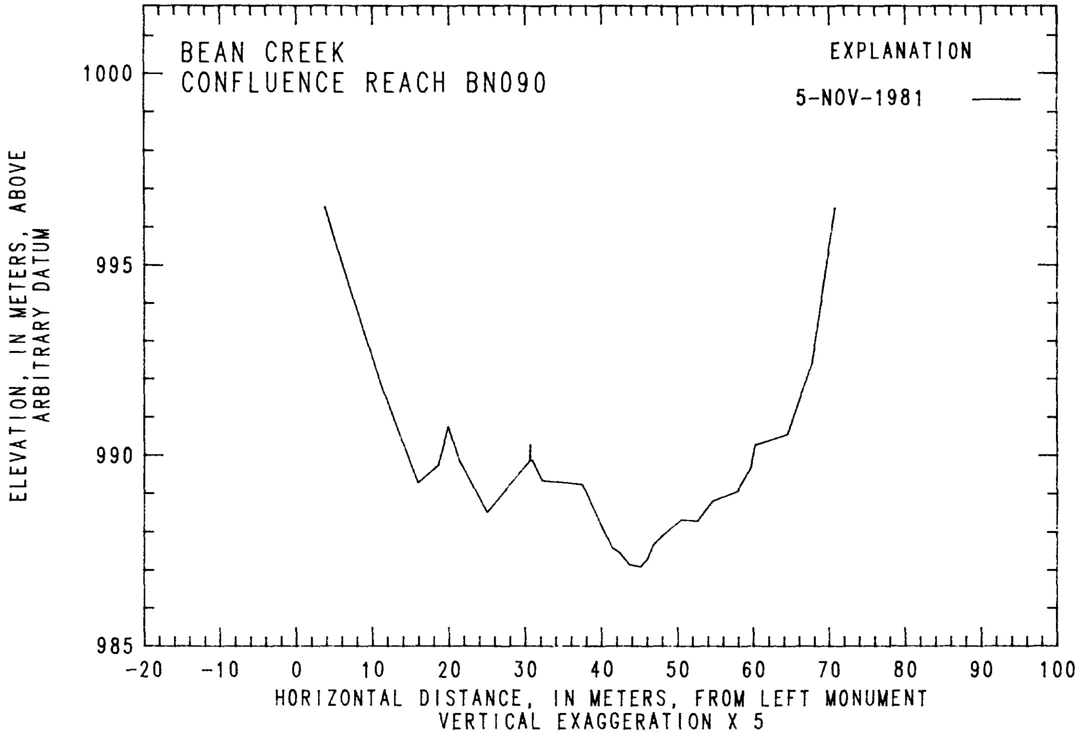


FIGURE 13. – Cross-section profiles for selected sites, Bean Creek – continued.

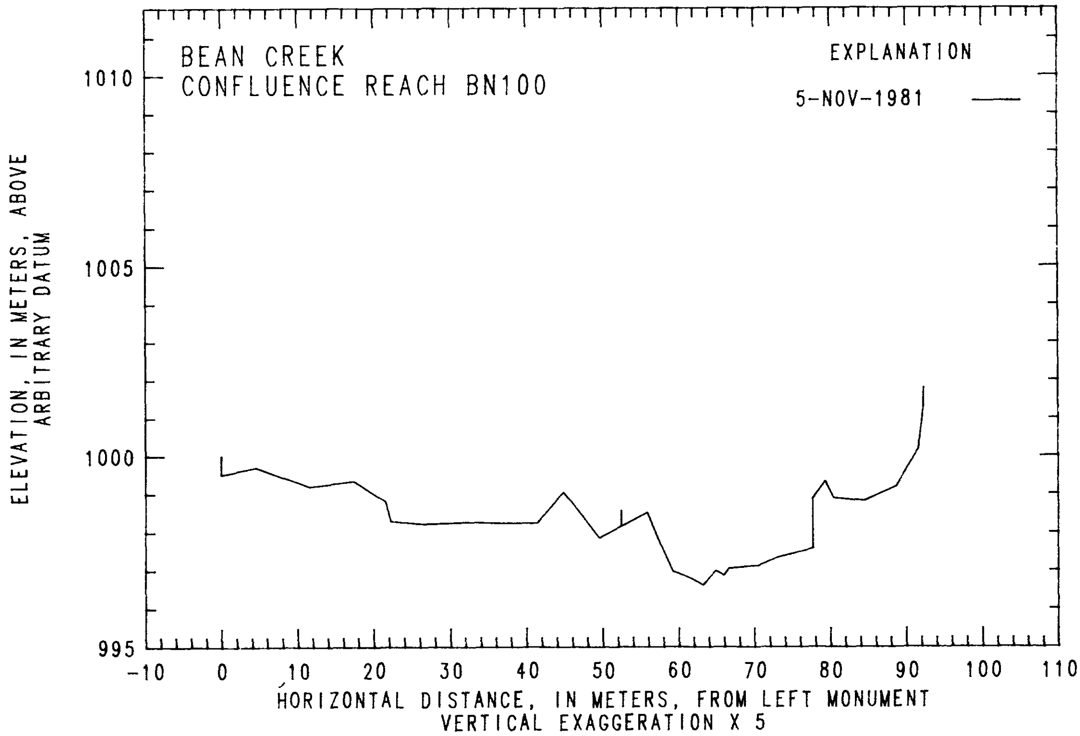


FIGURE 13. – Cross-section profiles for selected sites, Bean Creek – continued.

INDEX TO PINE CREEK CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

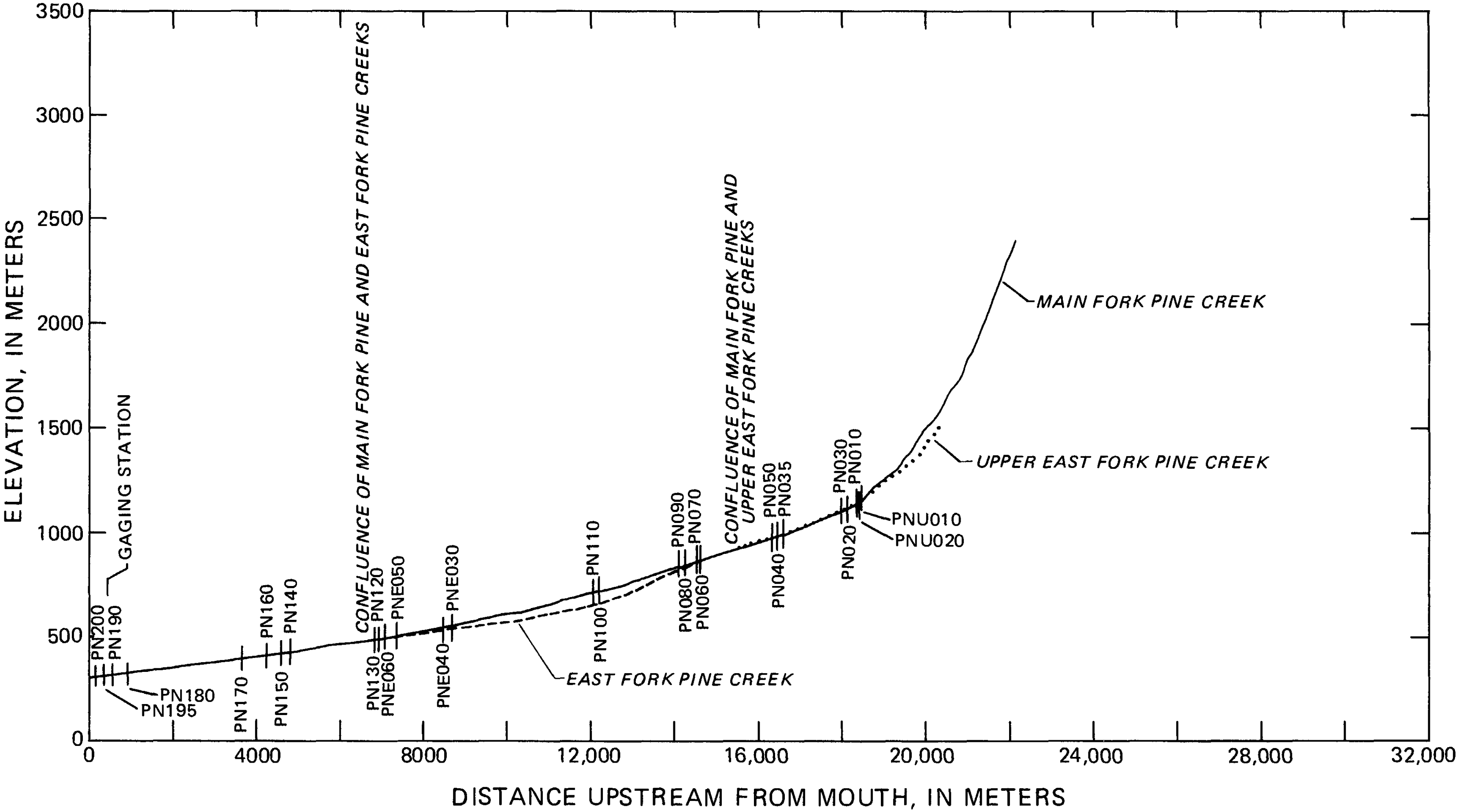
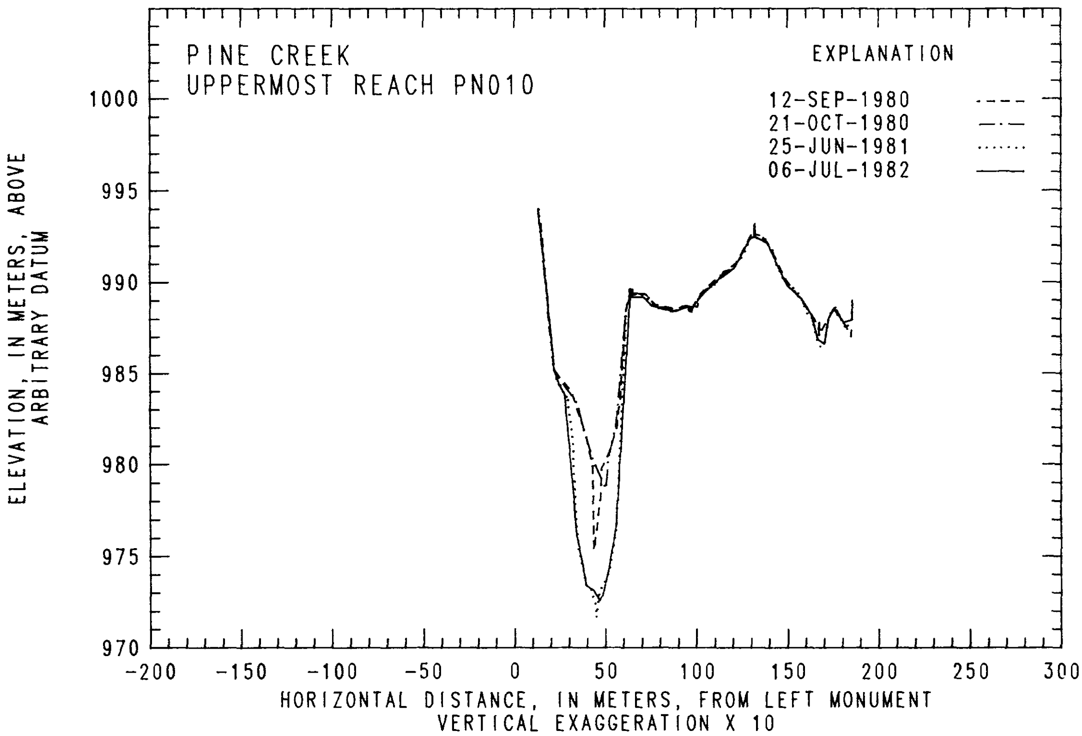


FIGURE 14. – Longitudinal profile of Pine Creek, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic maps, 7.5-minute series, Mount St. Helens SE and Mount St. Helens NE quadrangles.



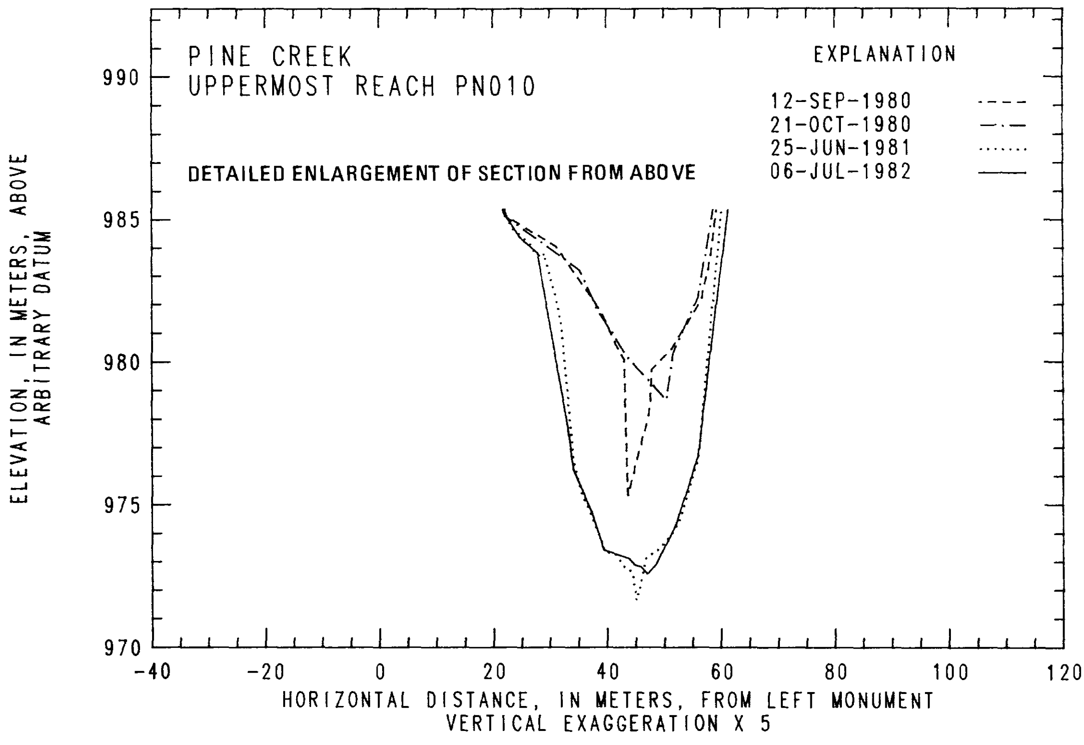
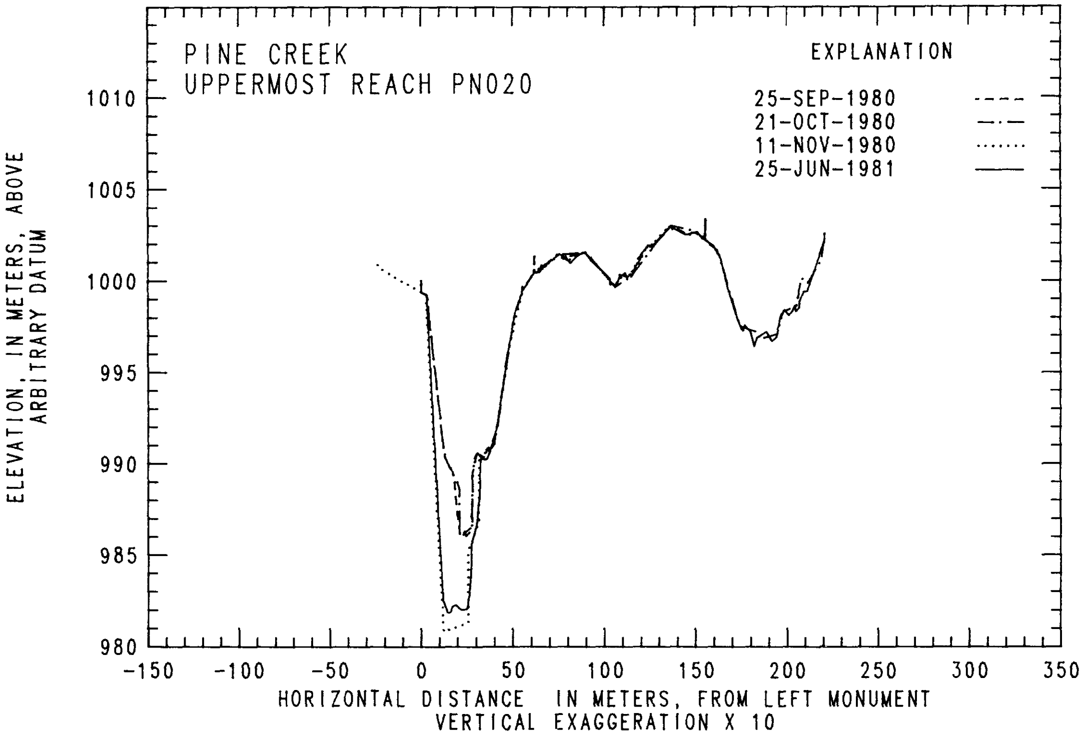


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek.



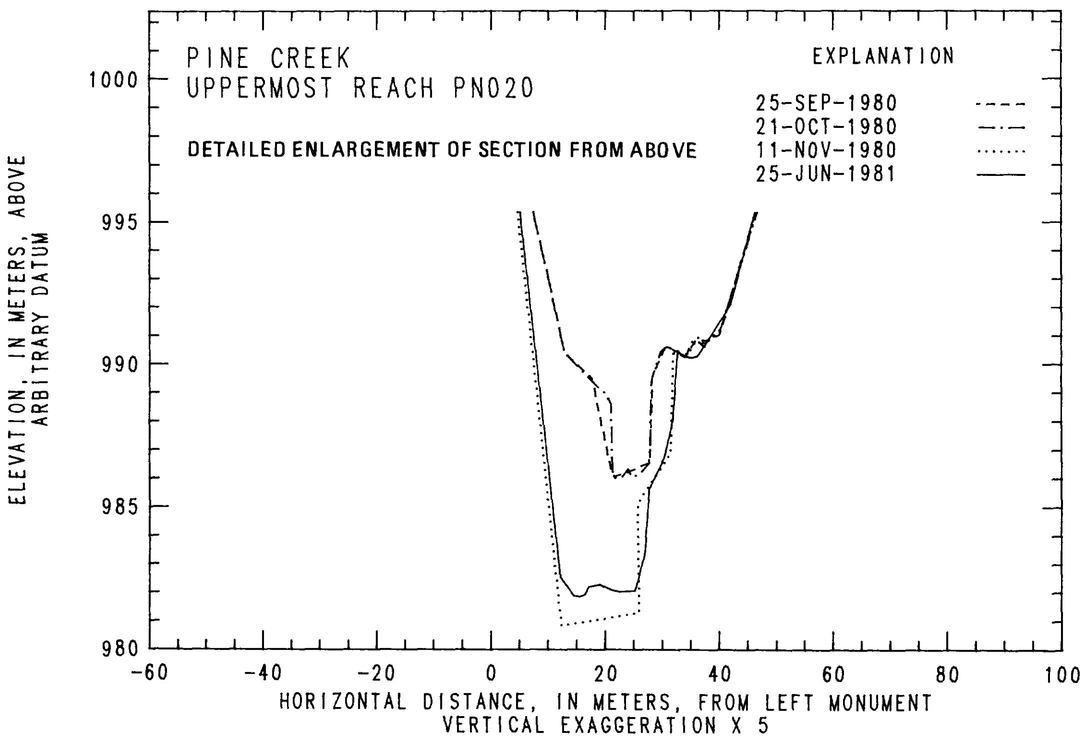
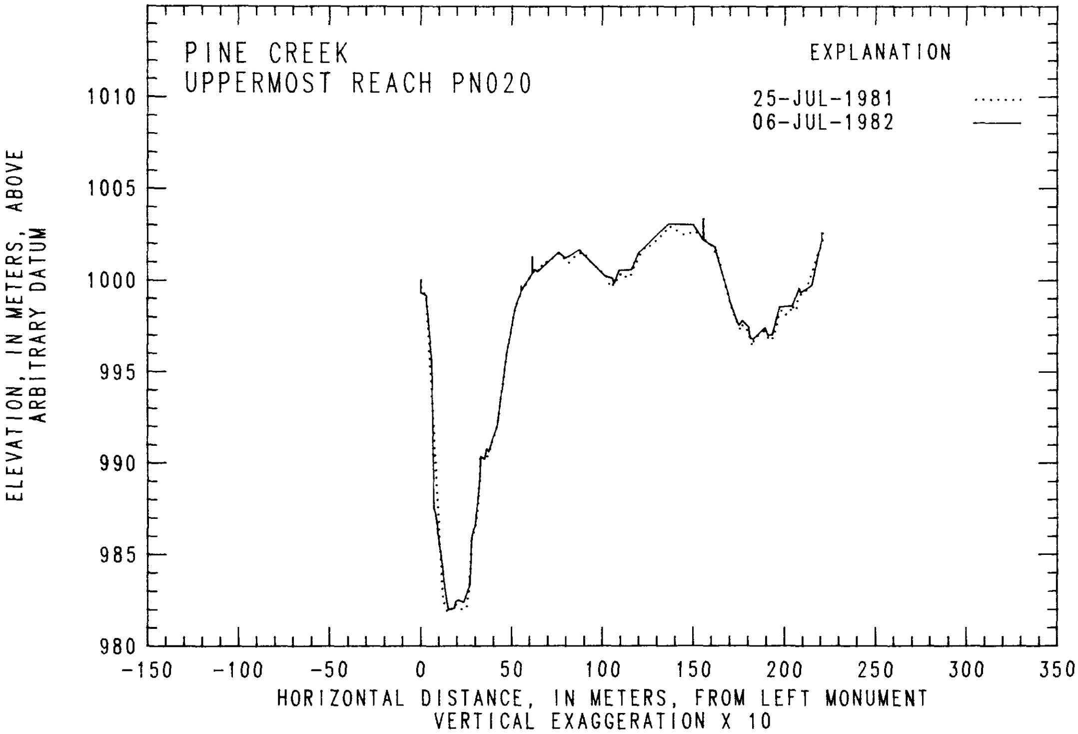


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



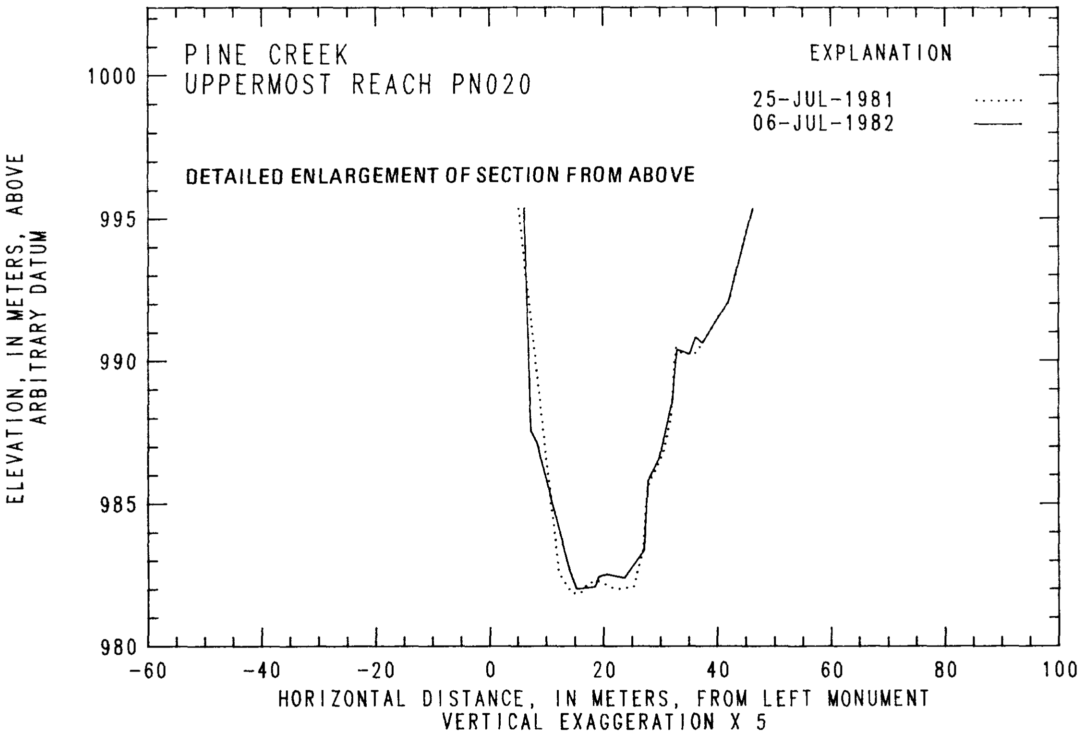


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

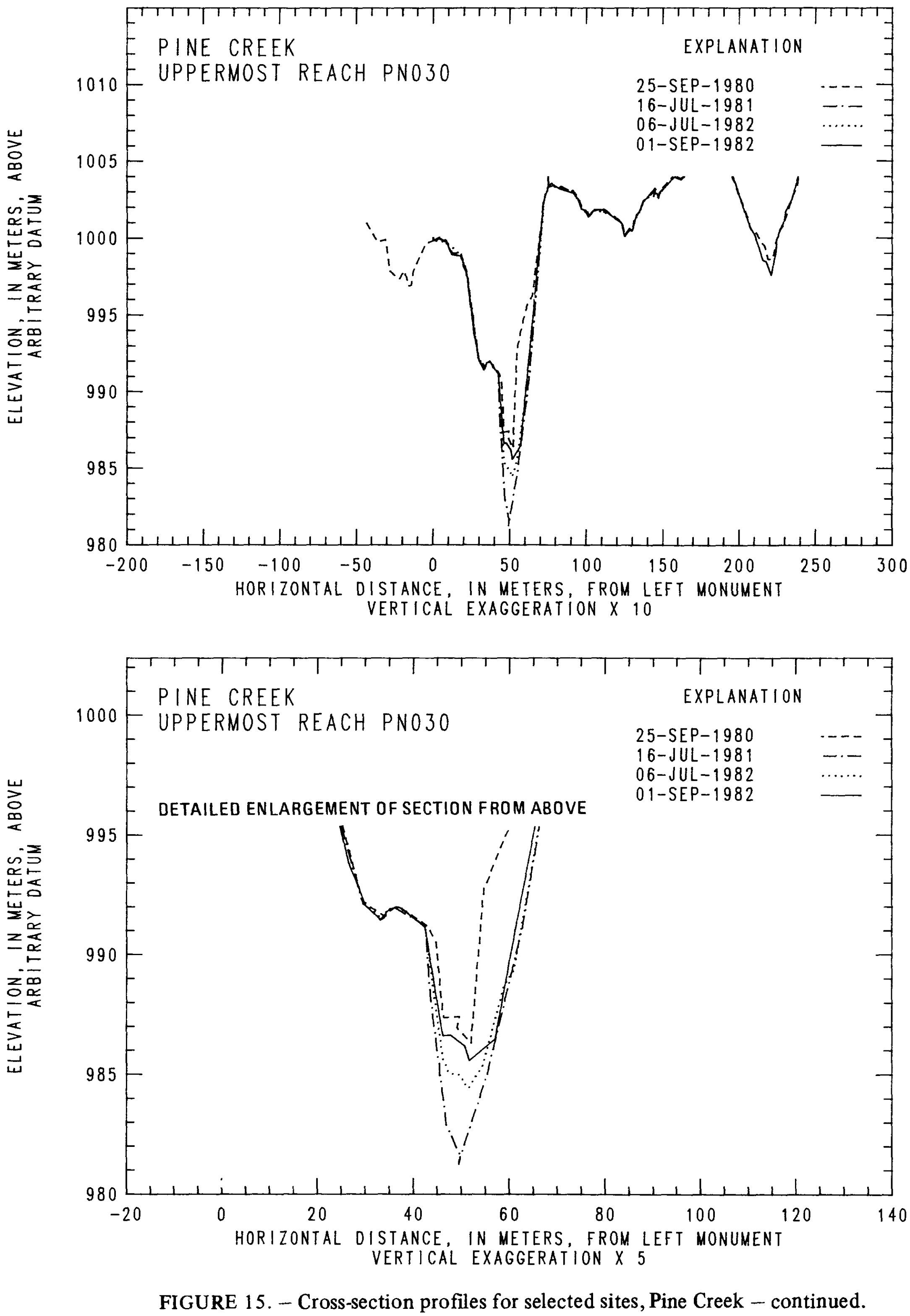
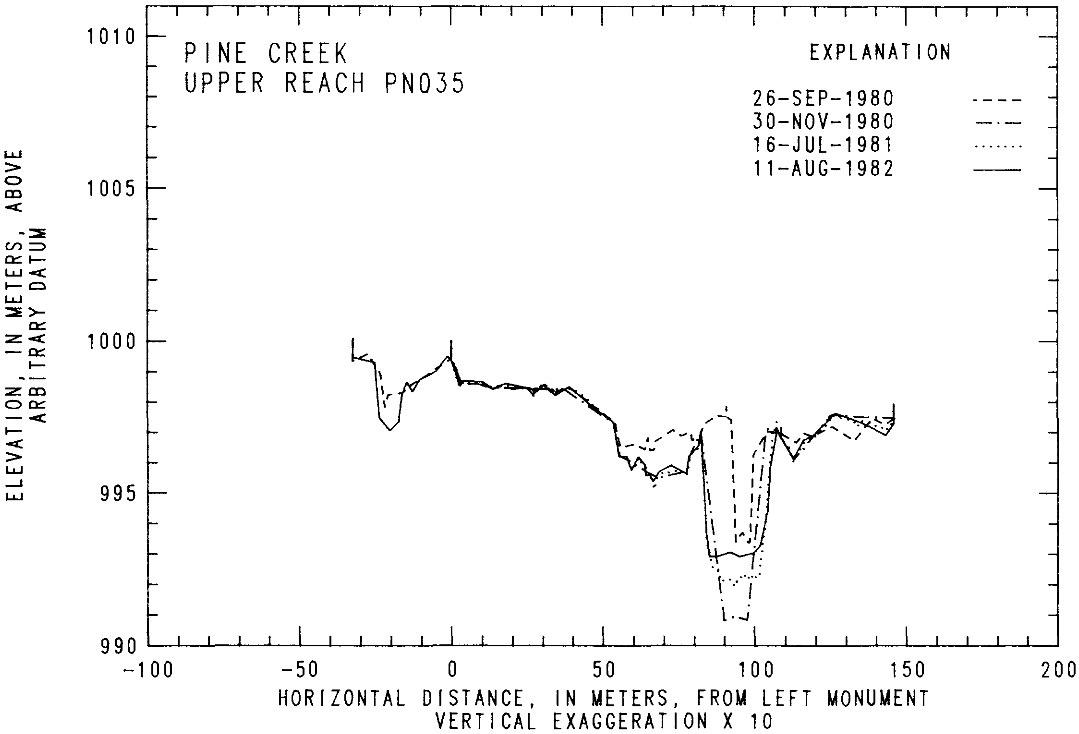


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



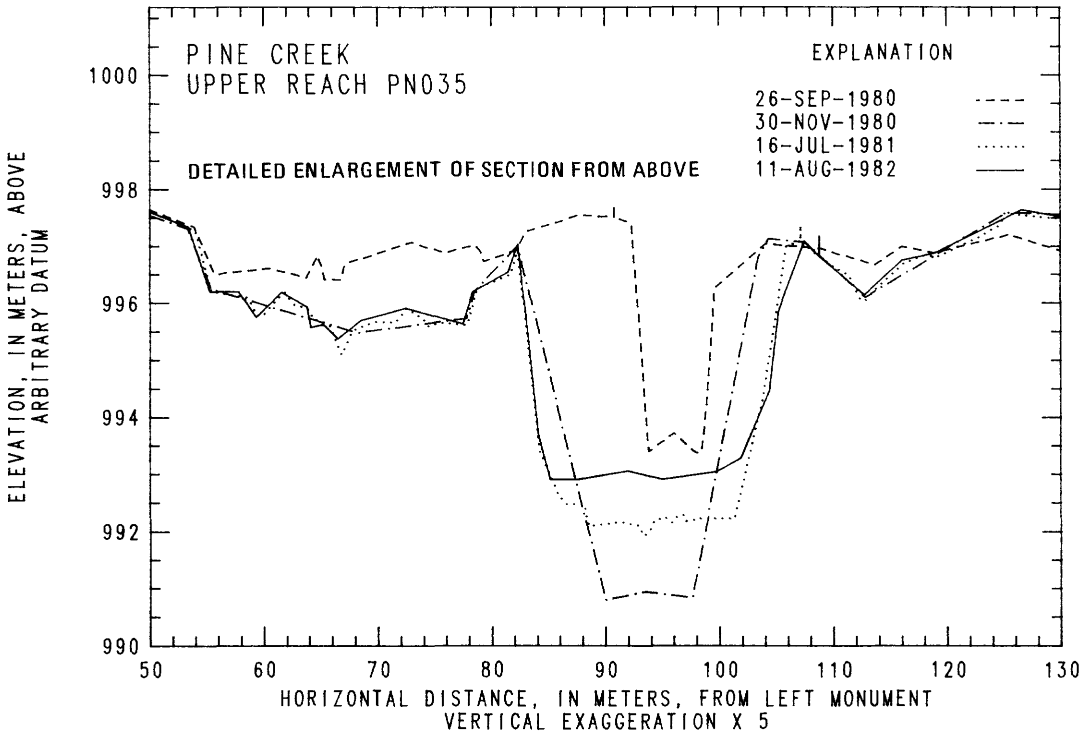
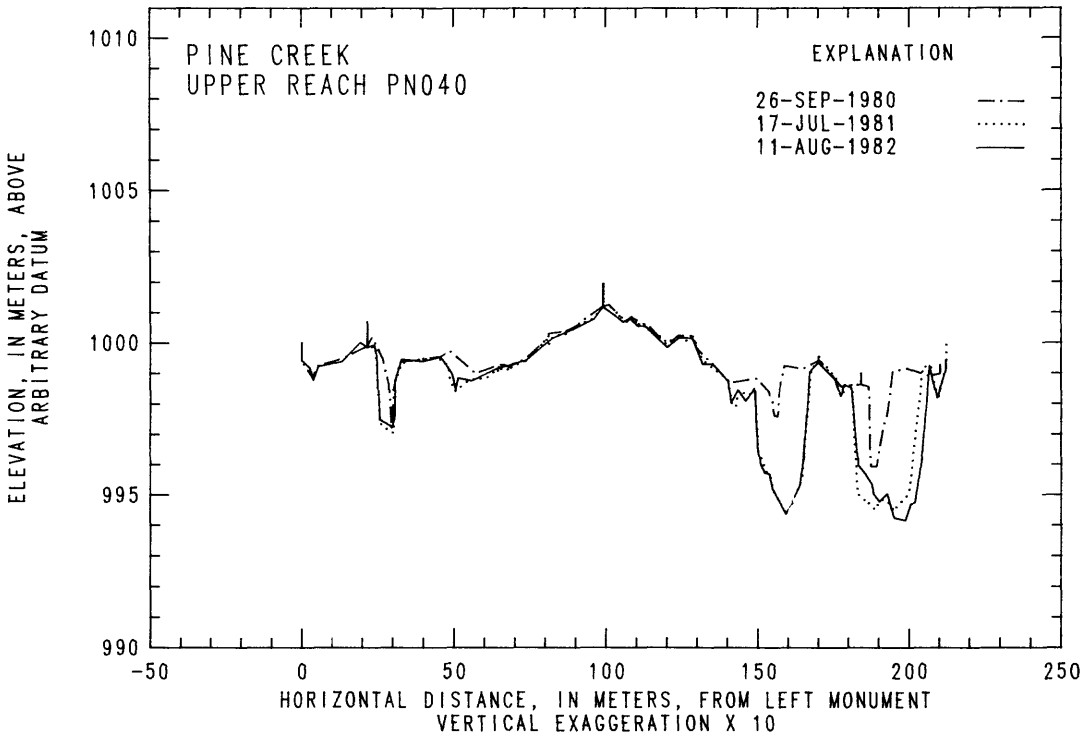


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



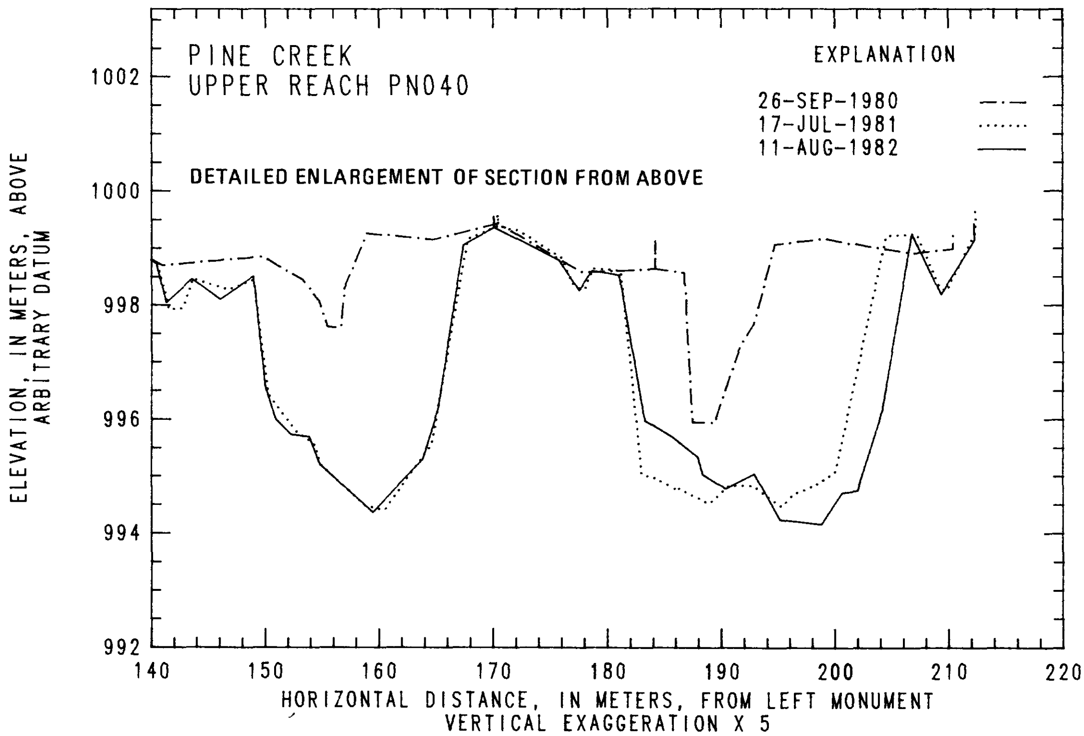
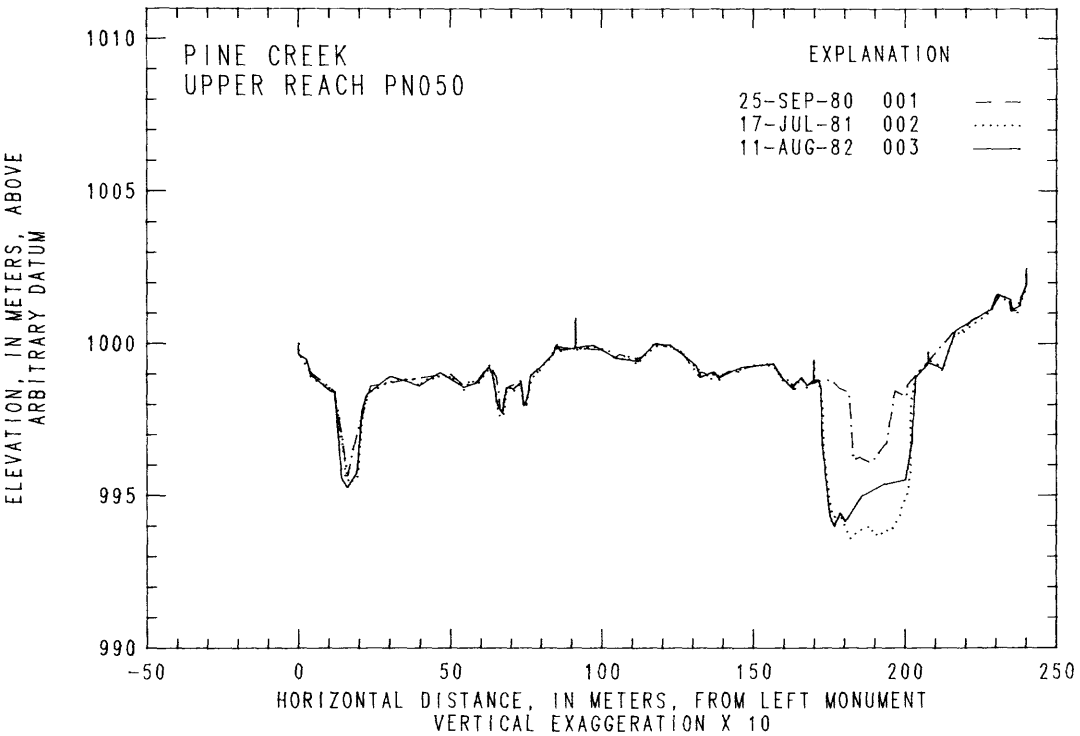


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



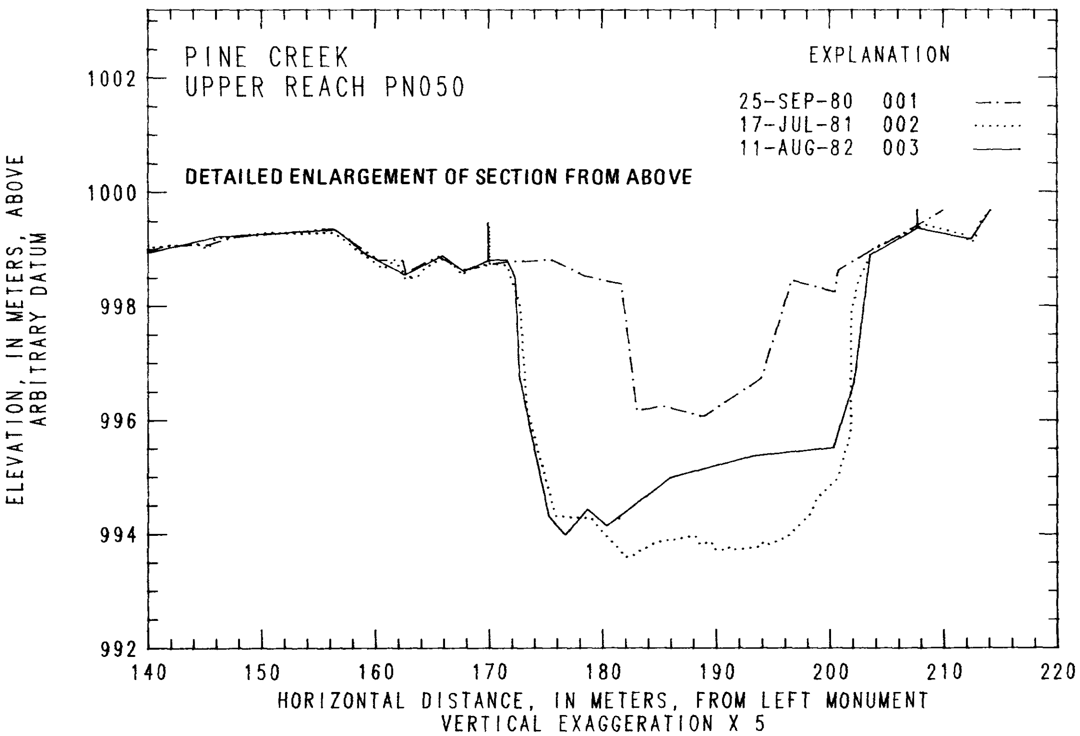


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

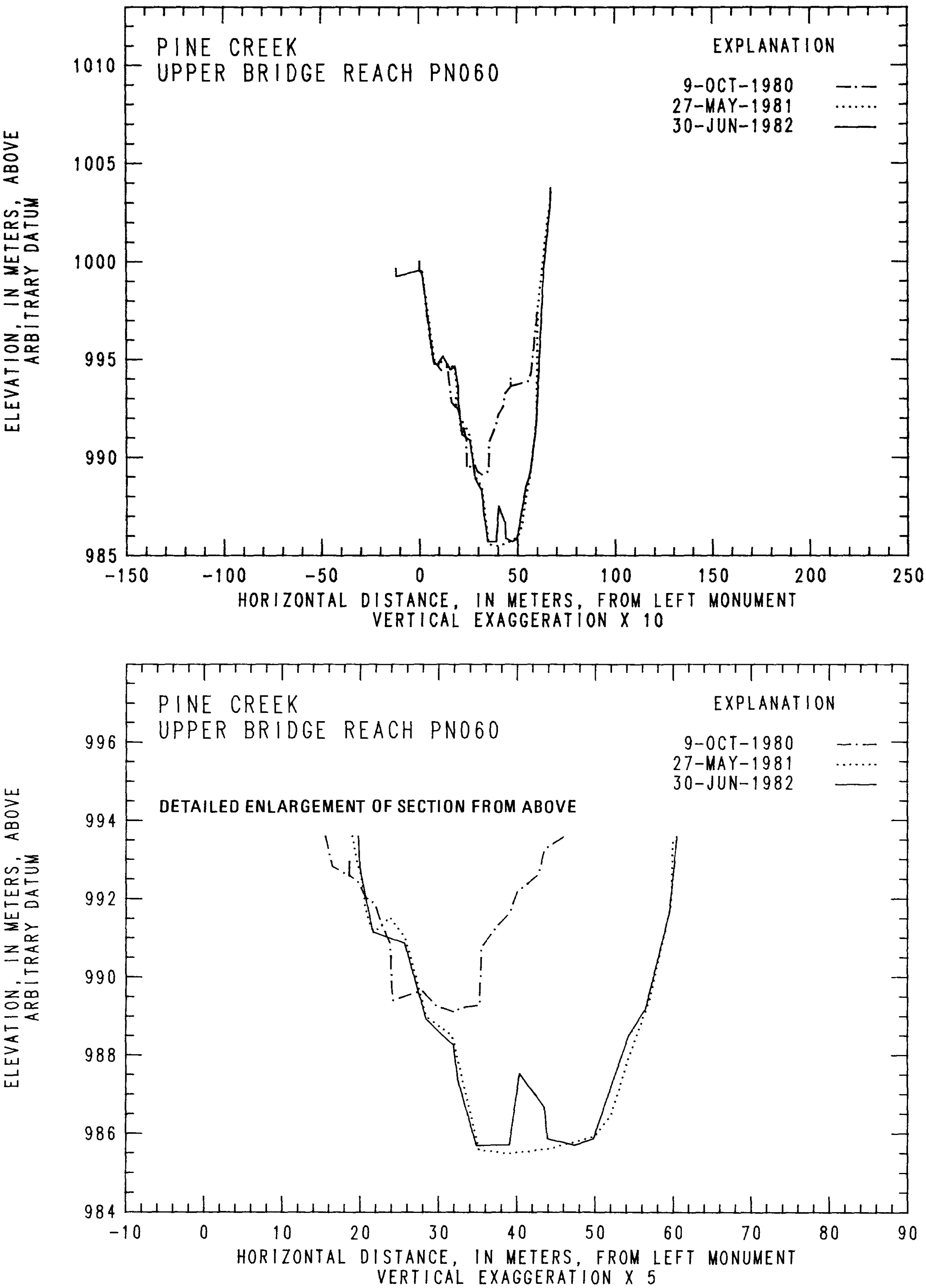
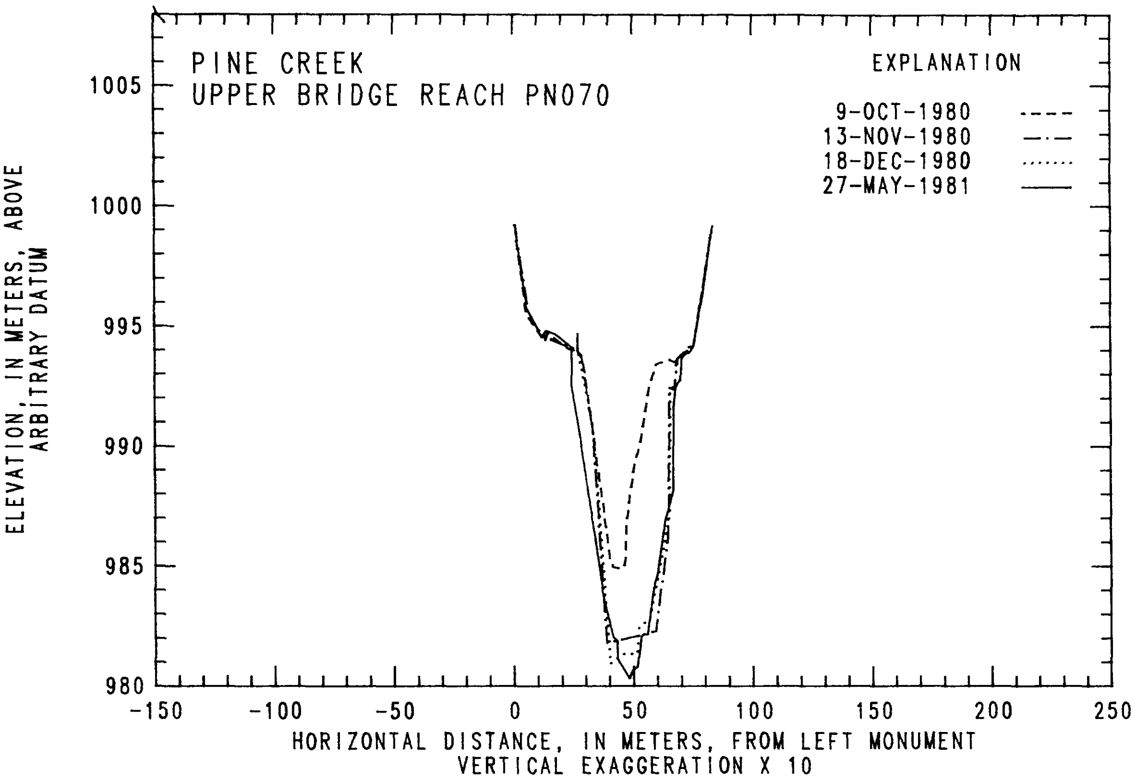


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



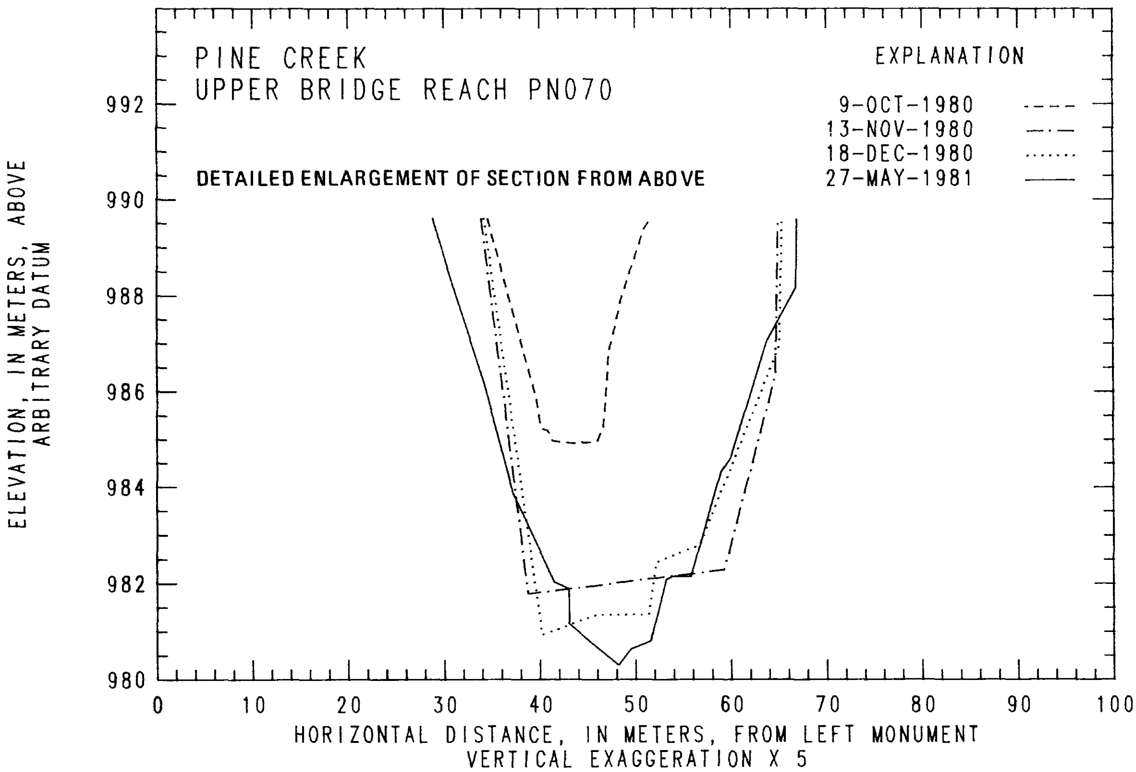
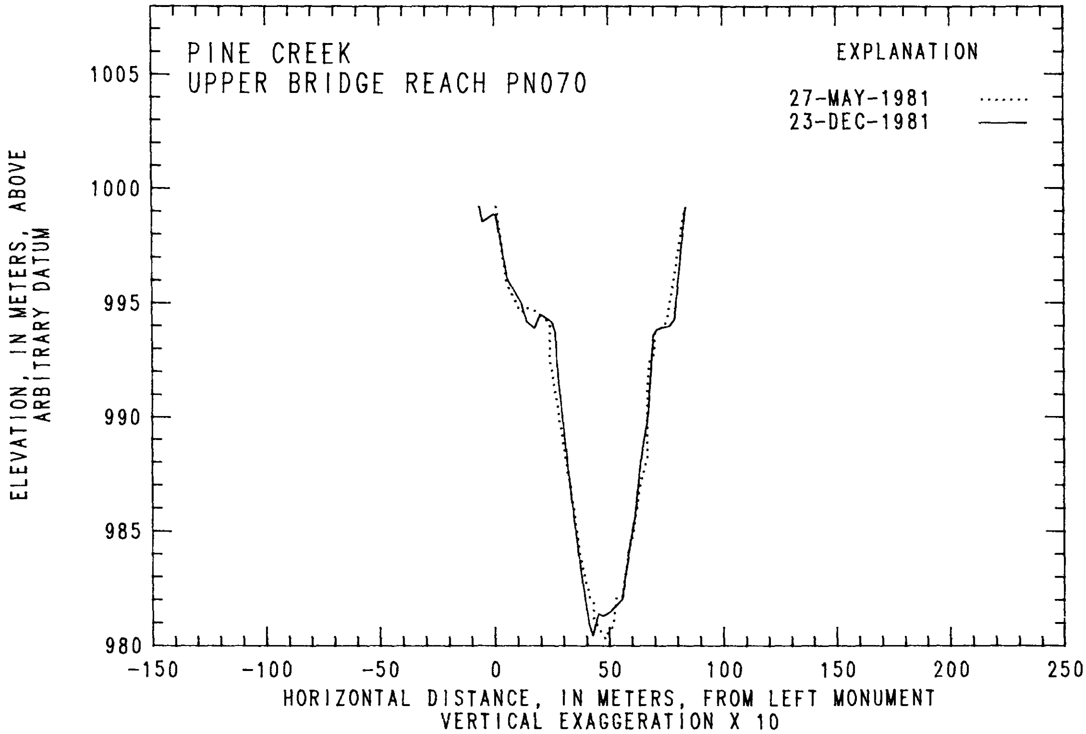


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



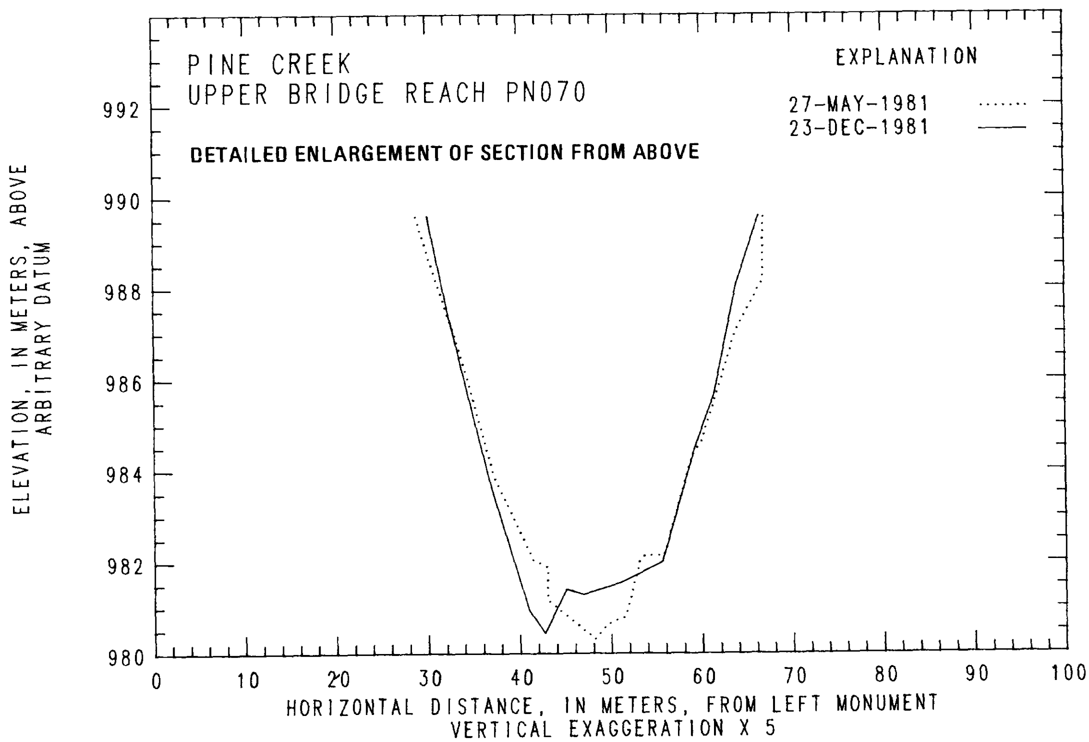
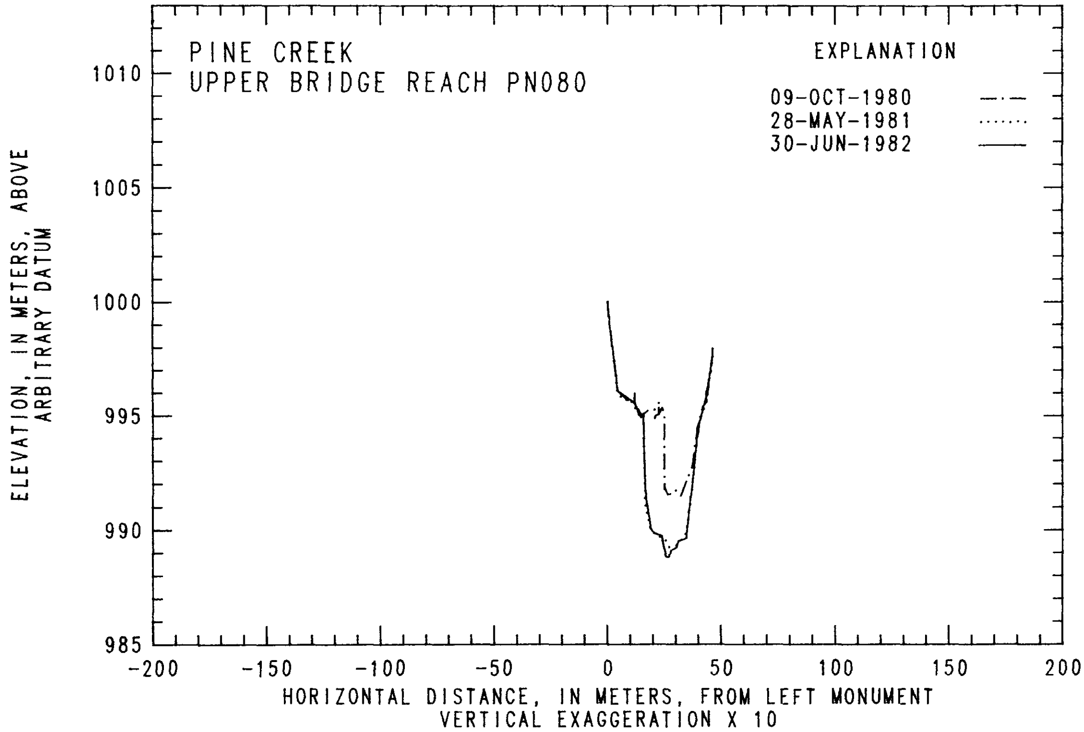


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



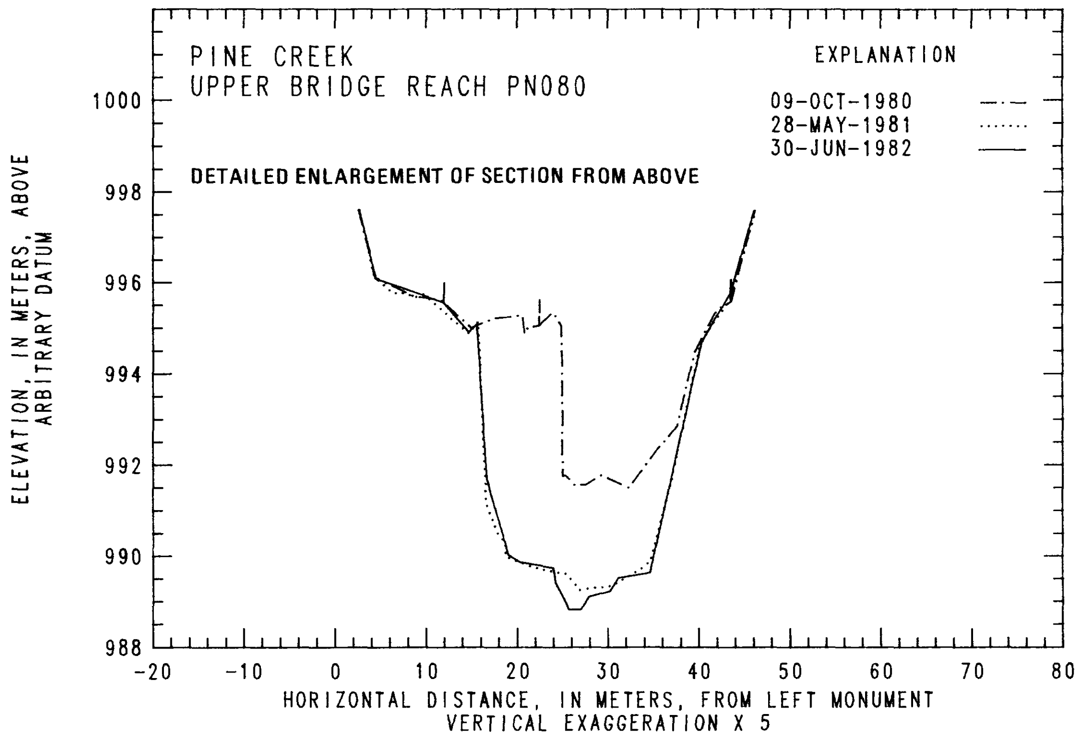
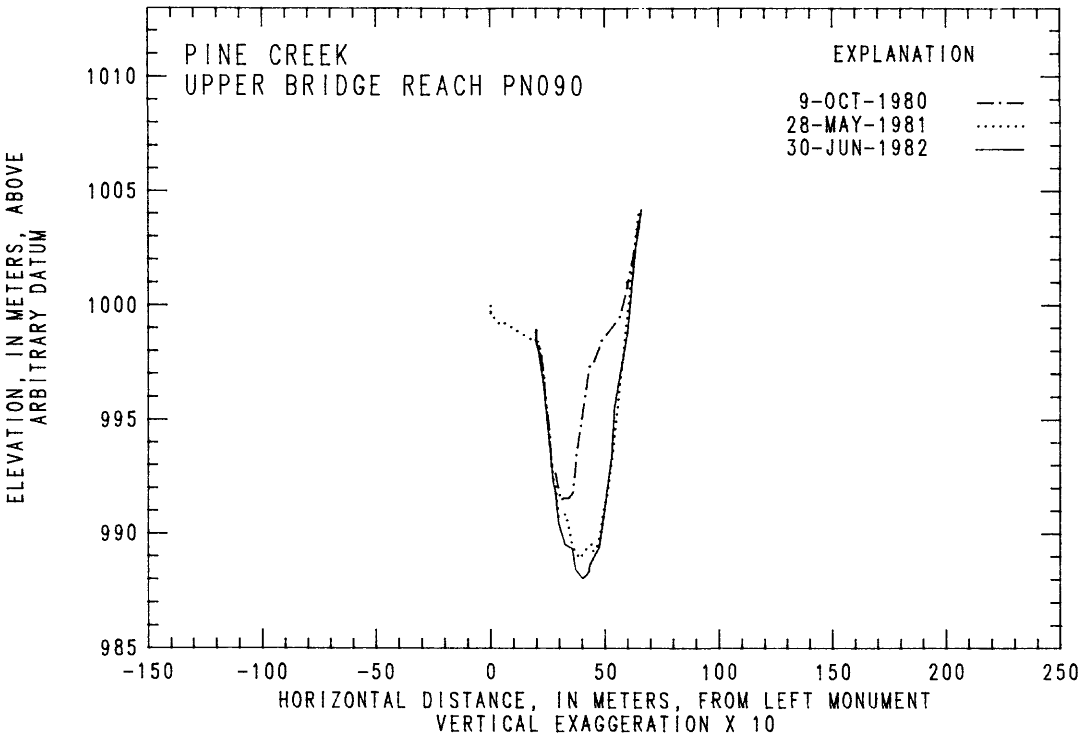


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



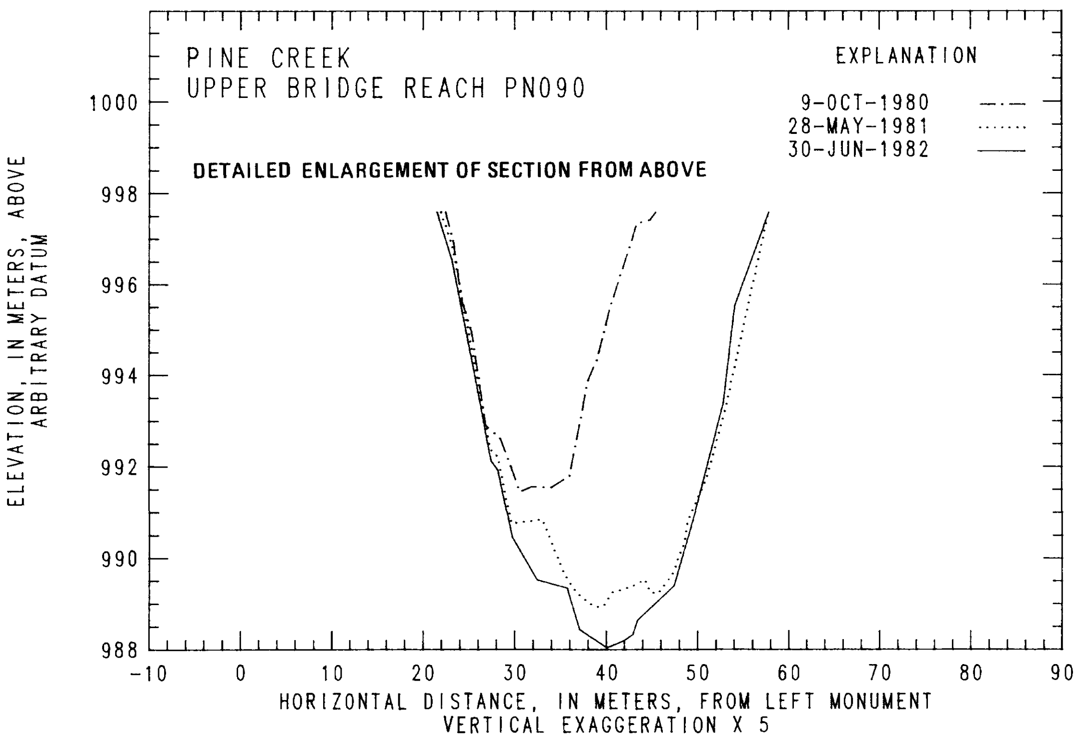


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

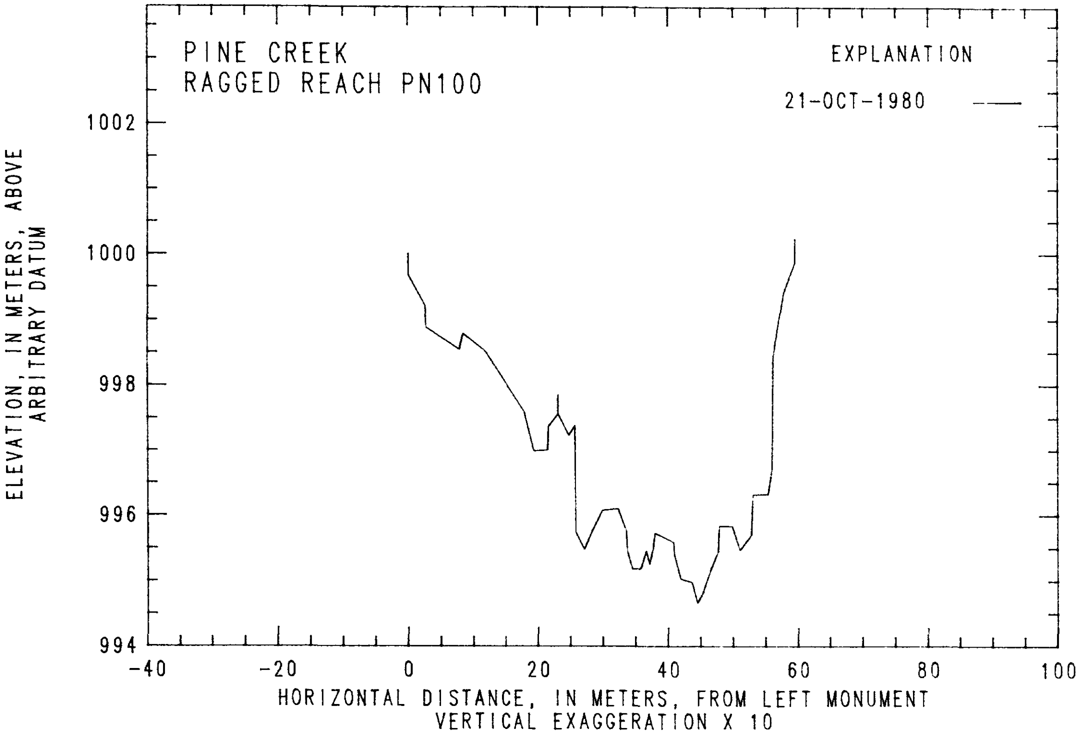


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

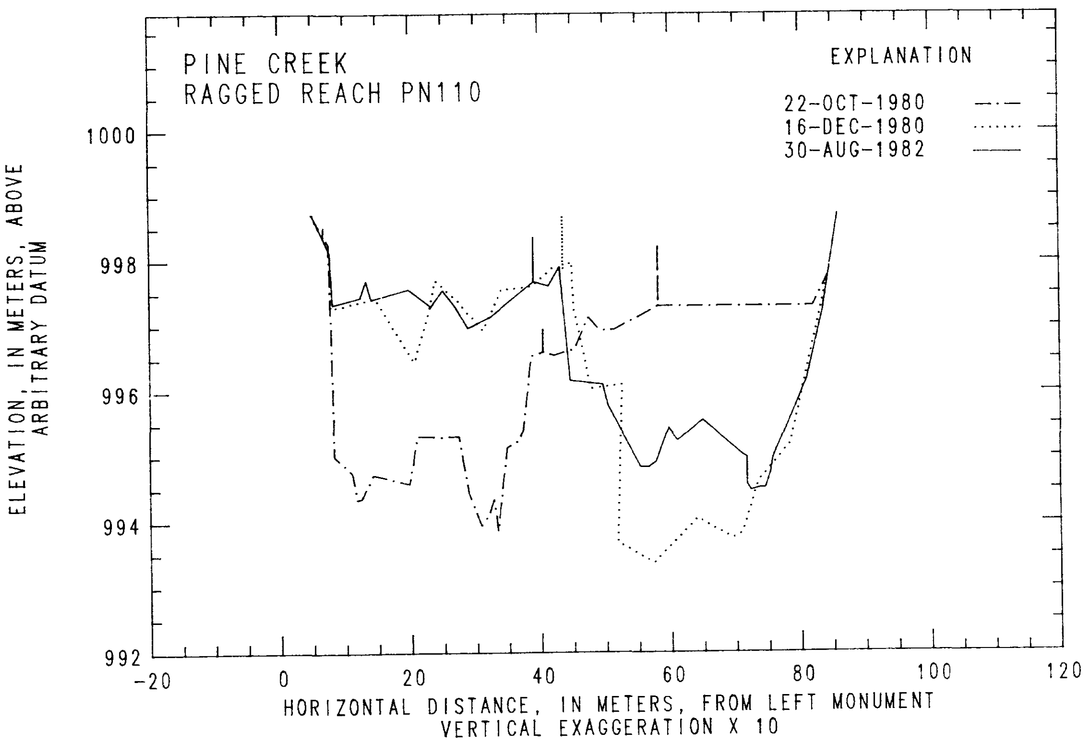
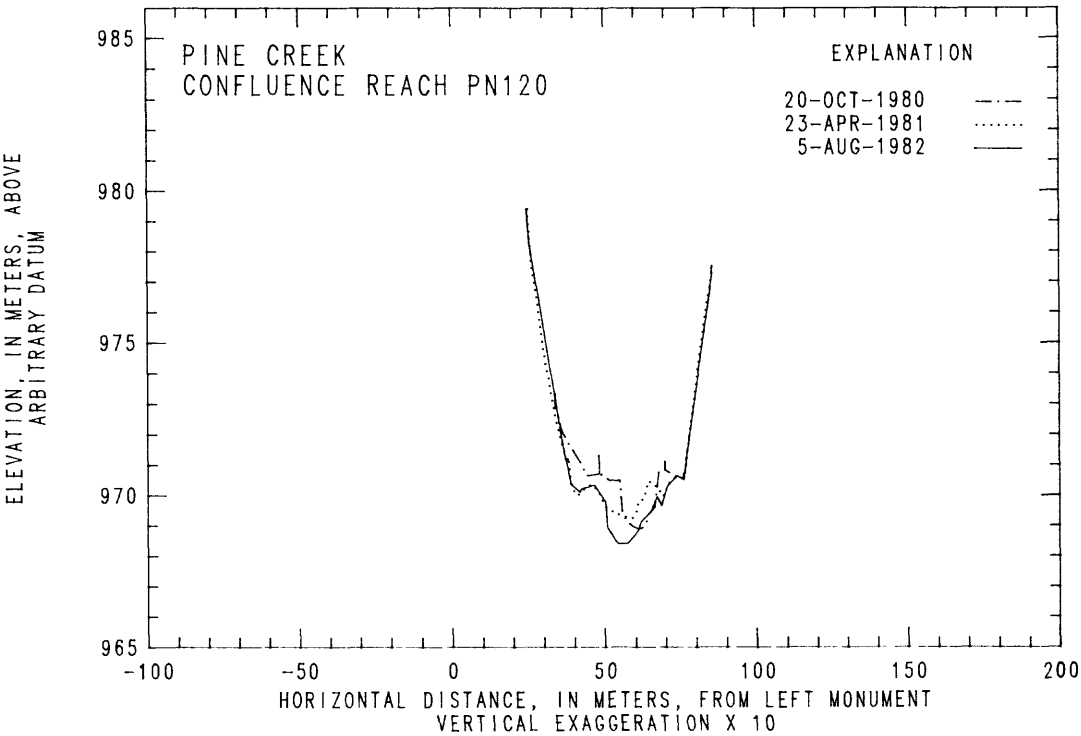


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



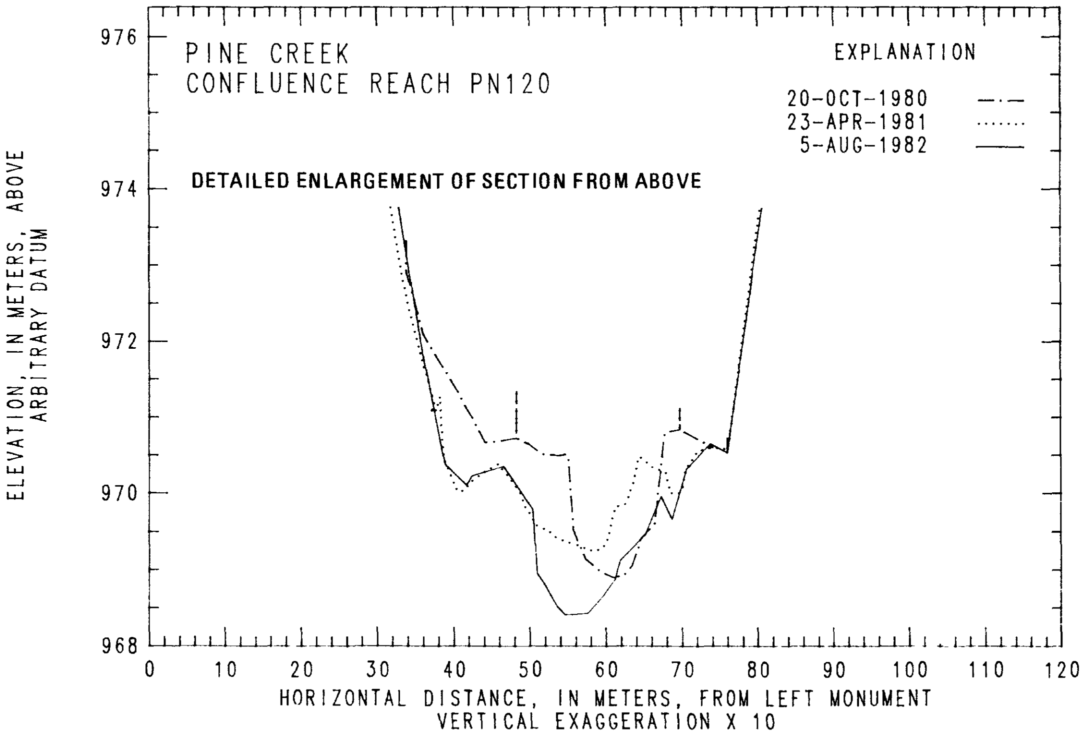
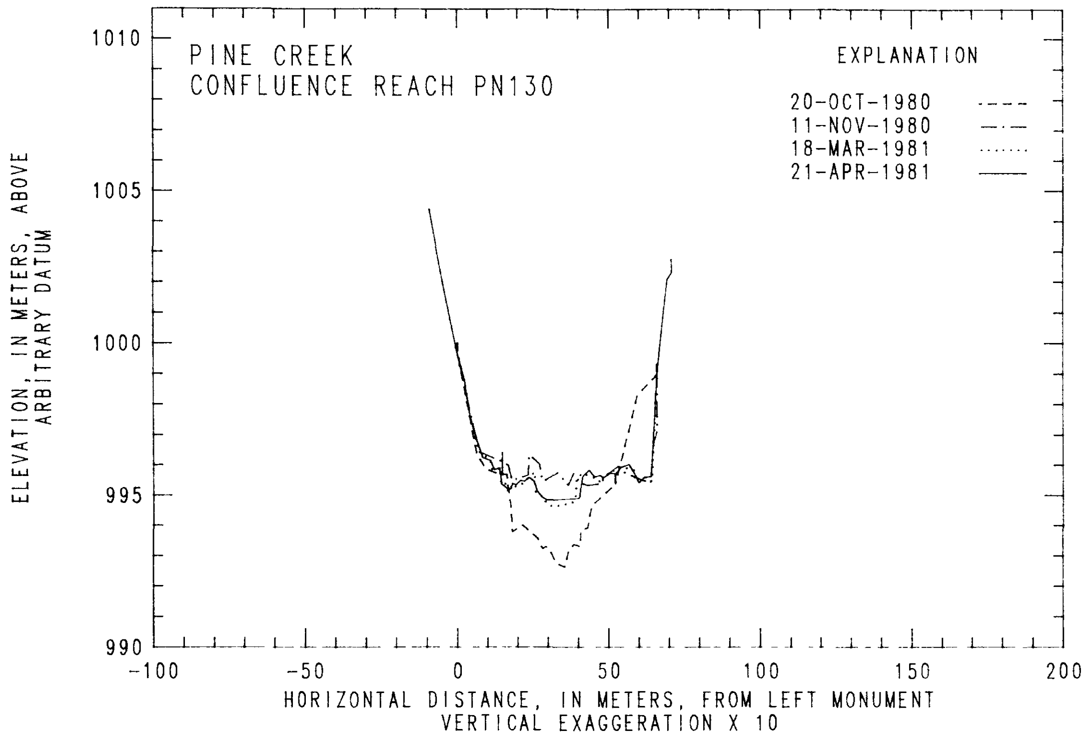


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



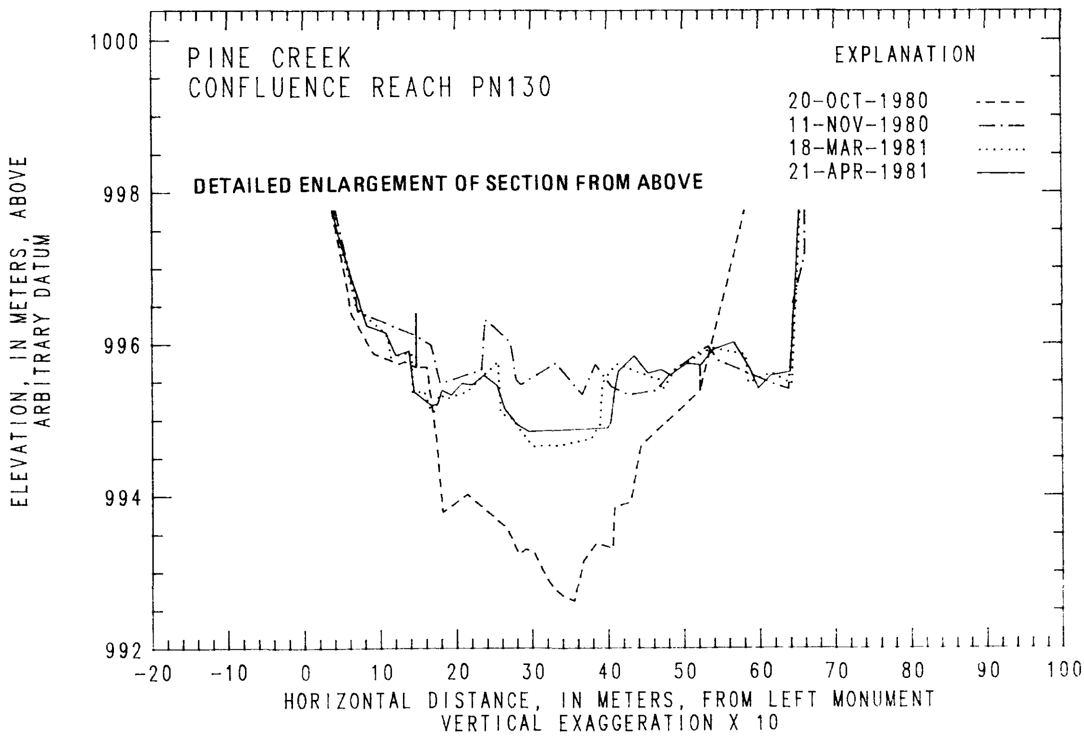
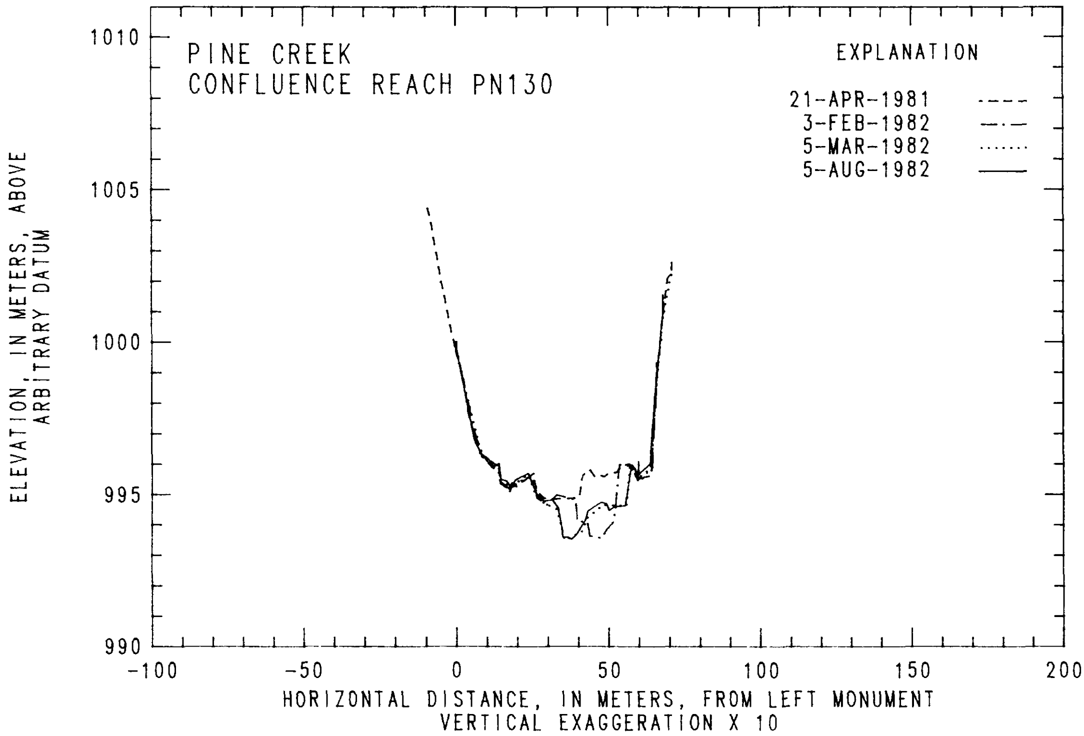


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



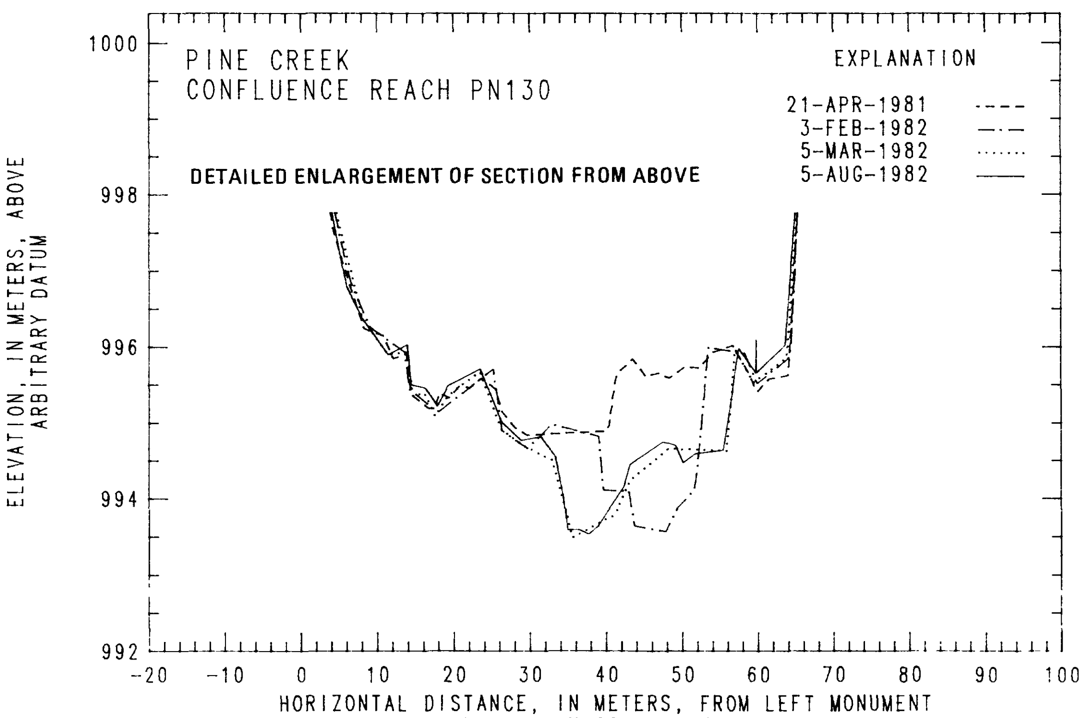


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

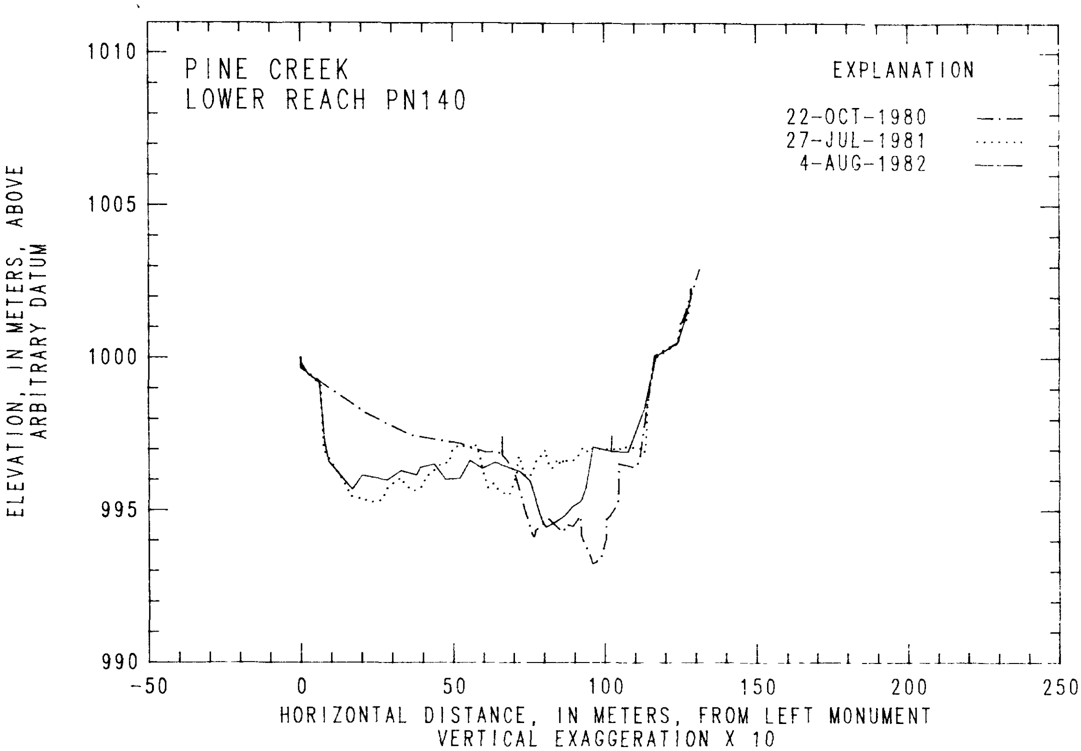


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

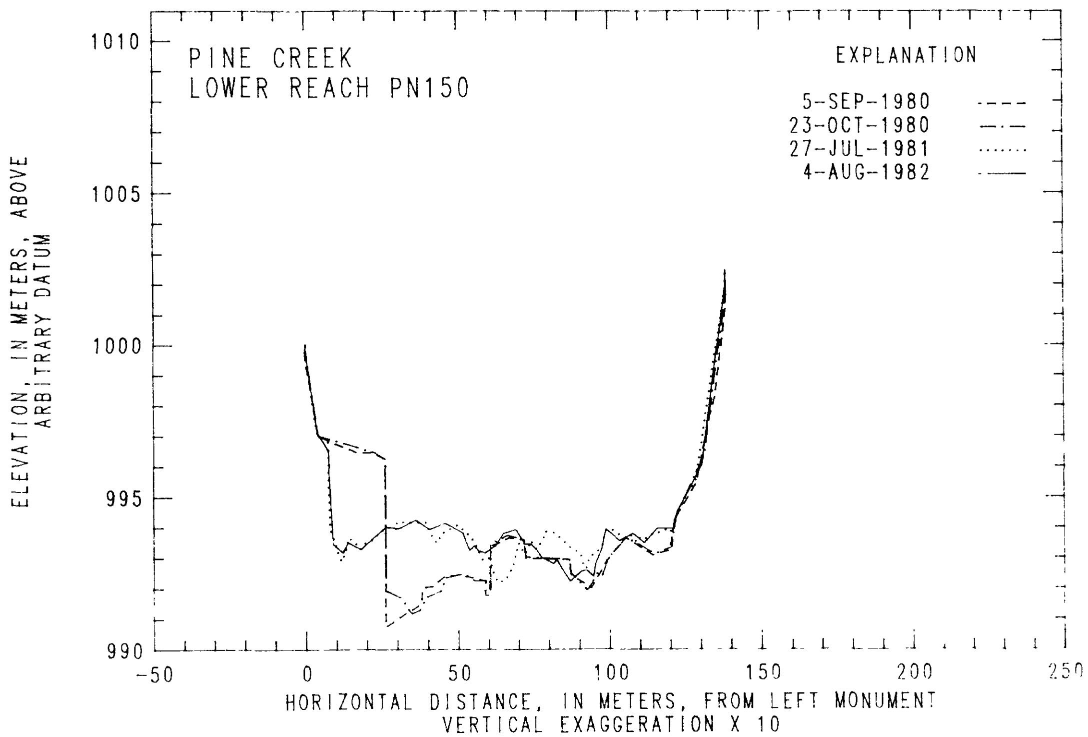
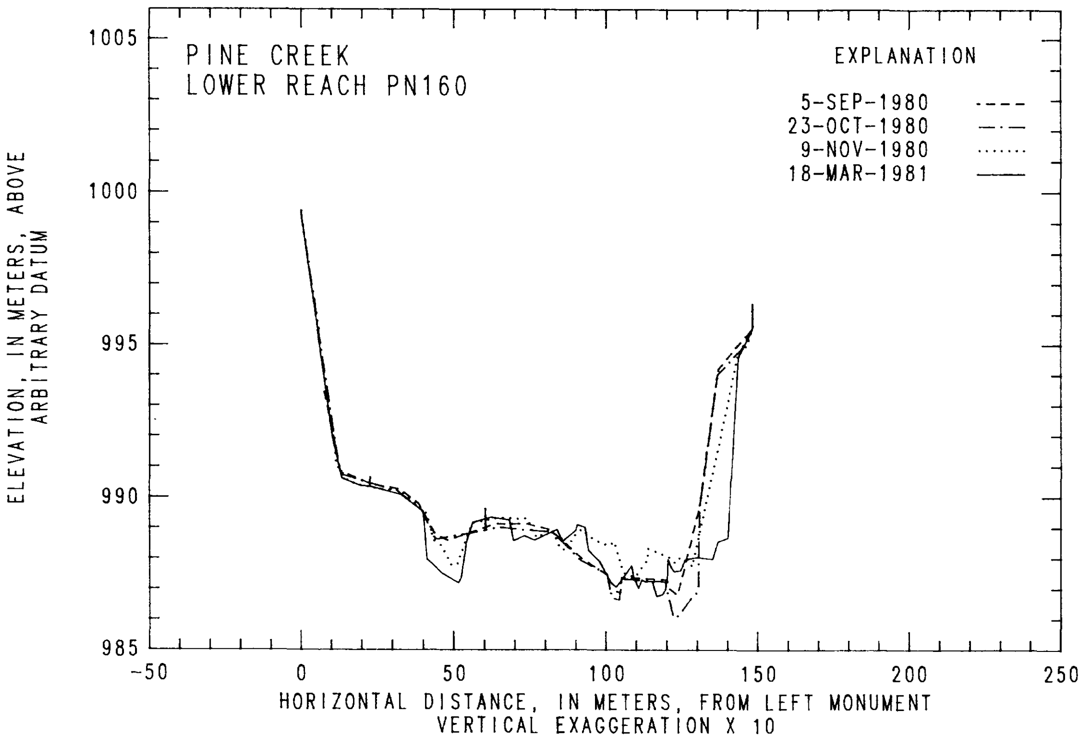


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



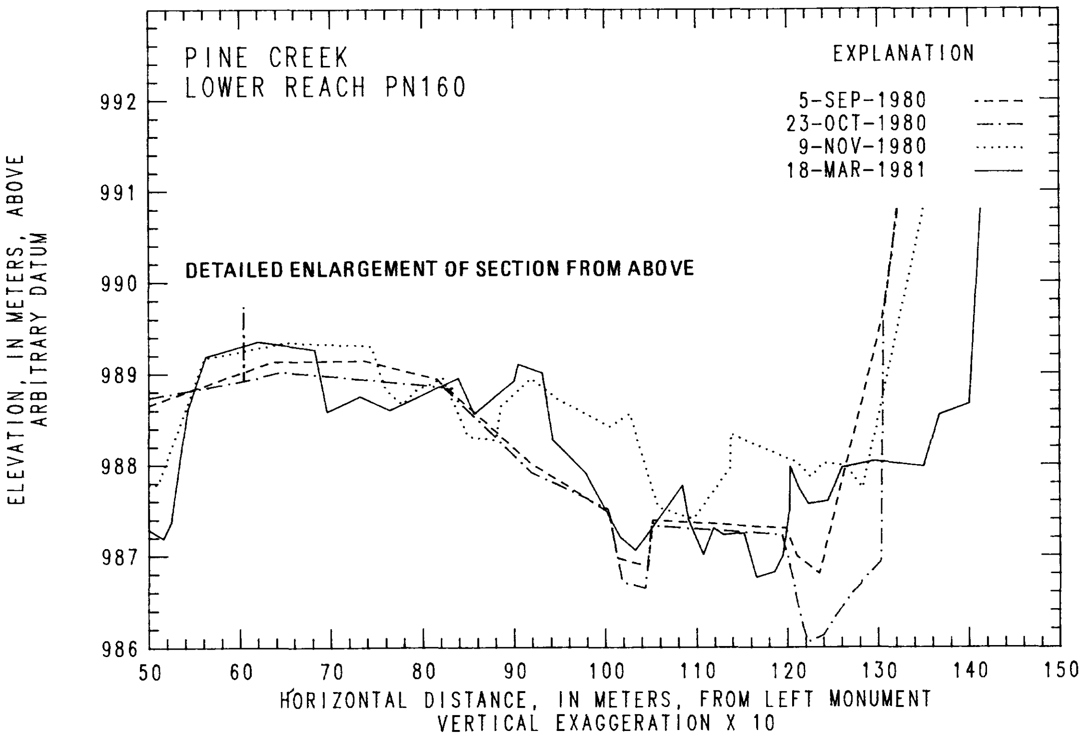
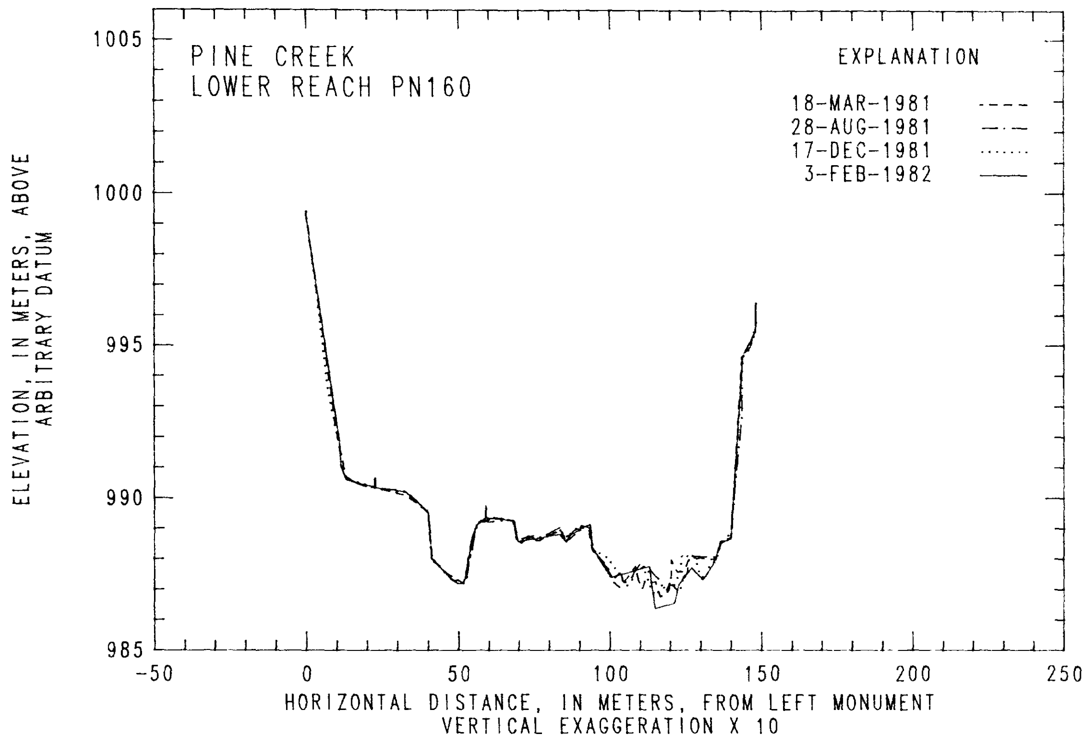


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



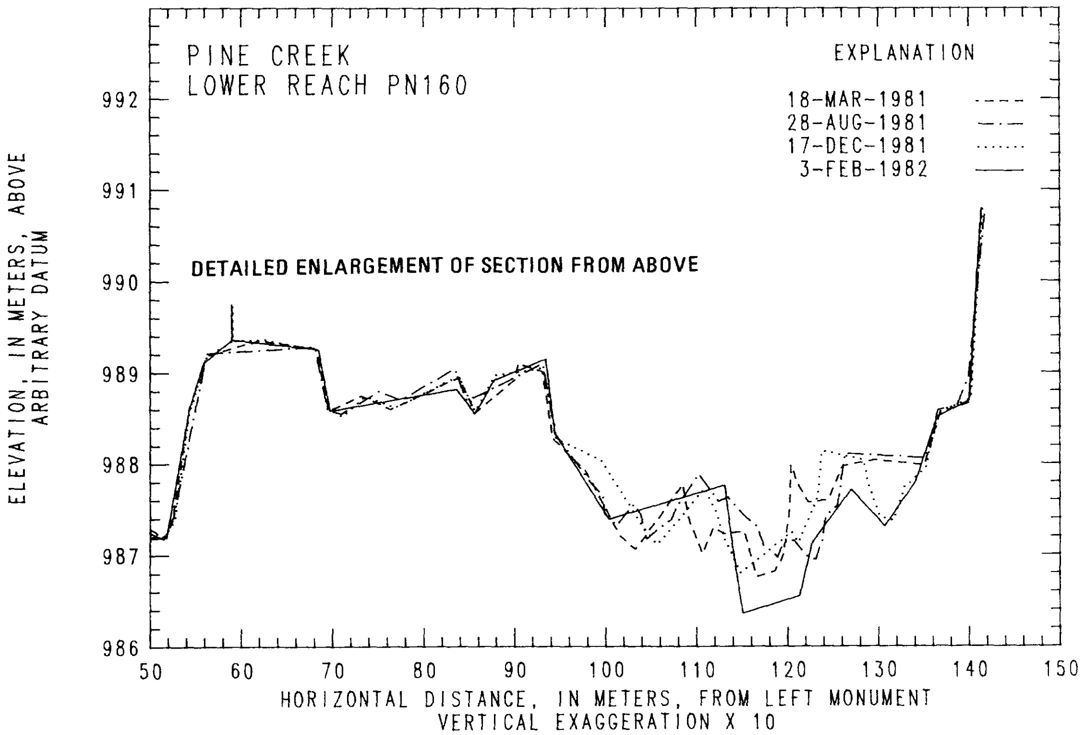
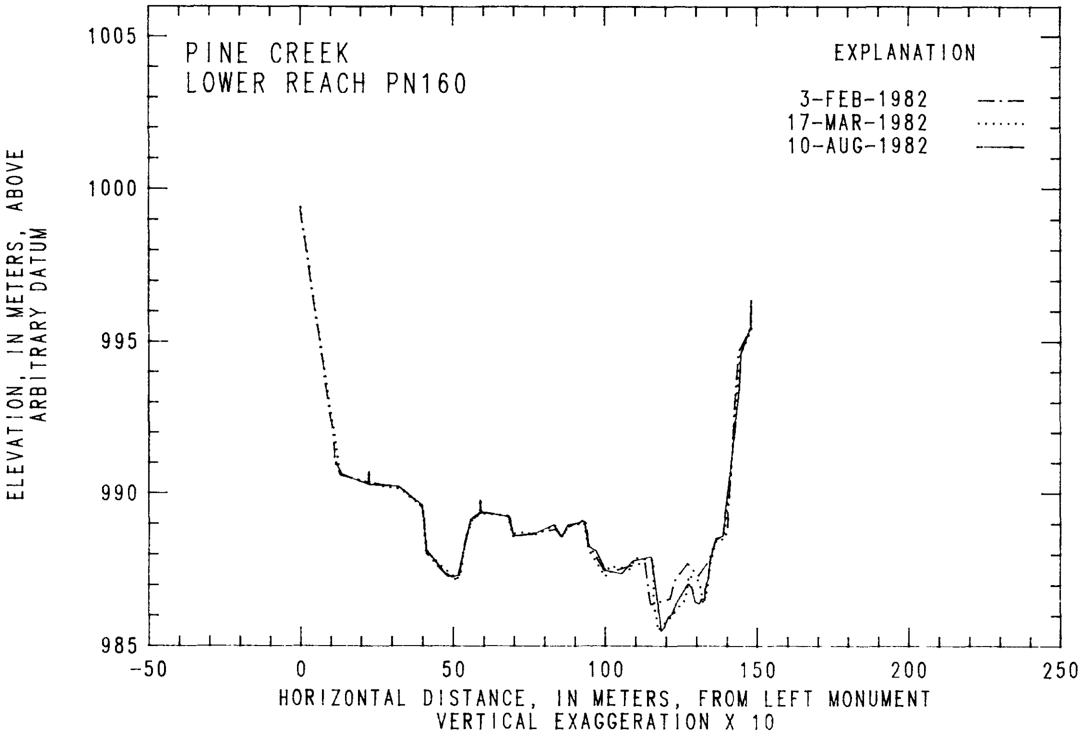


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



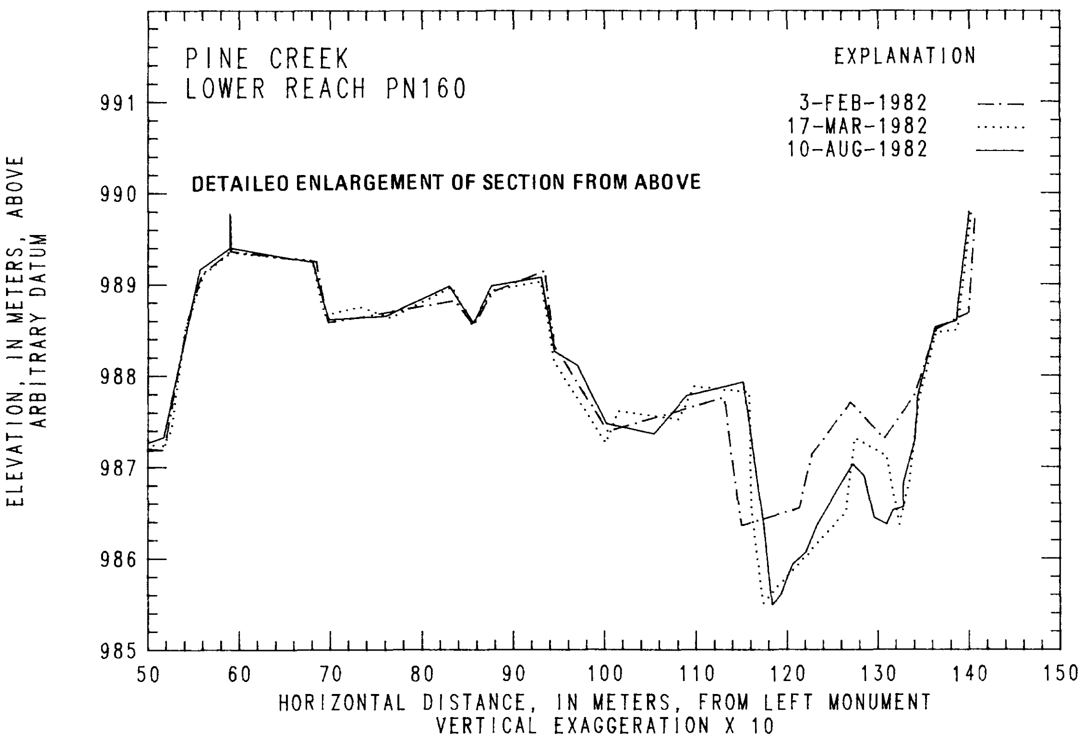


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

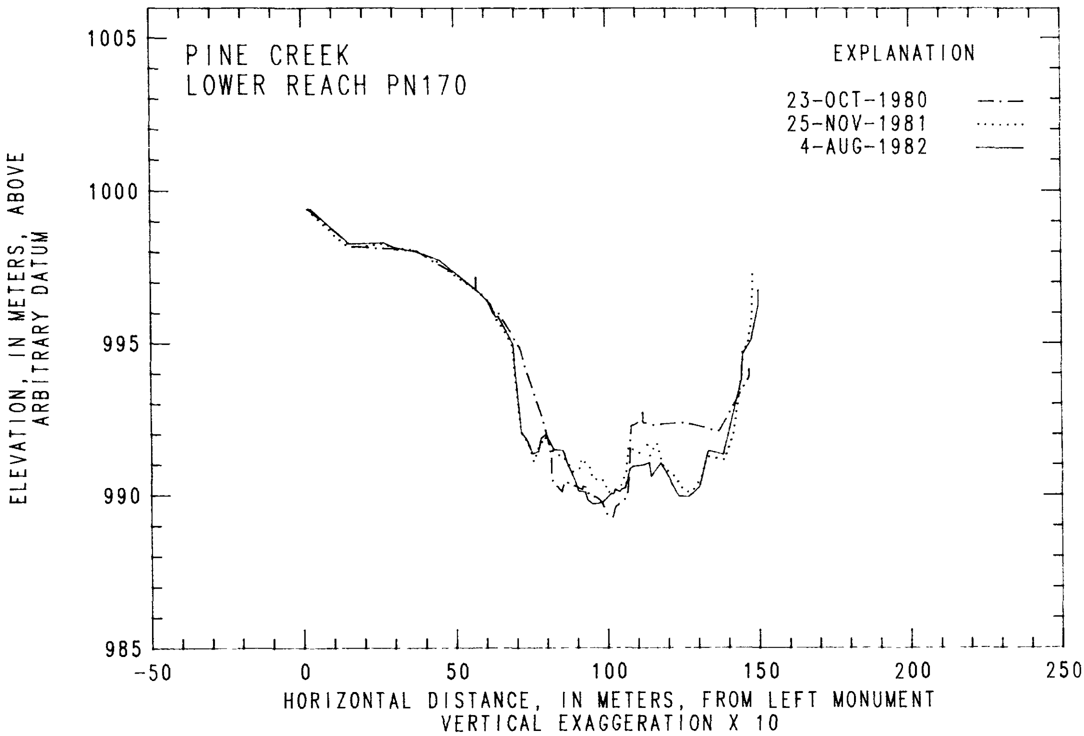


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

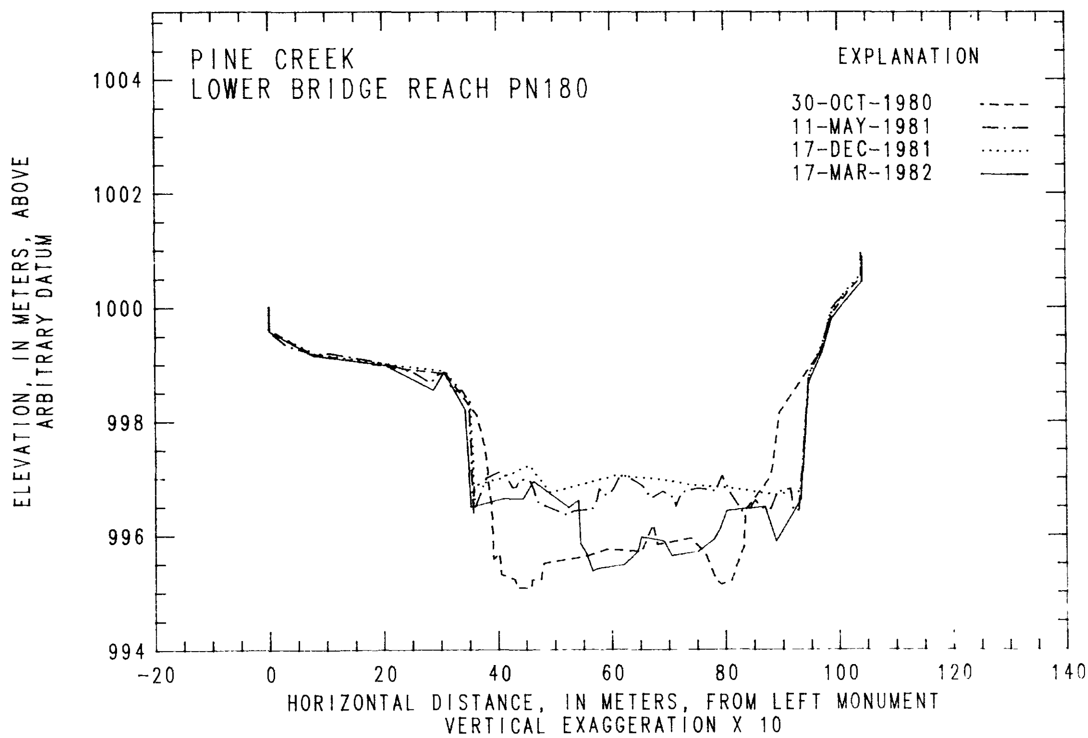


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

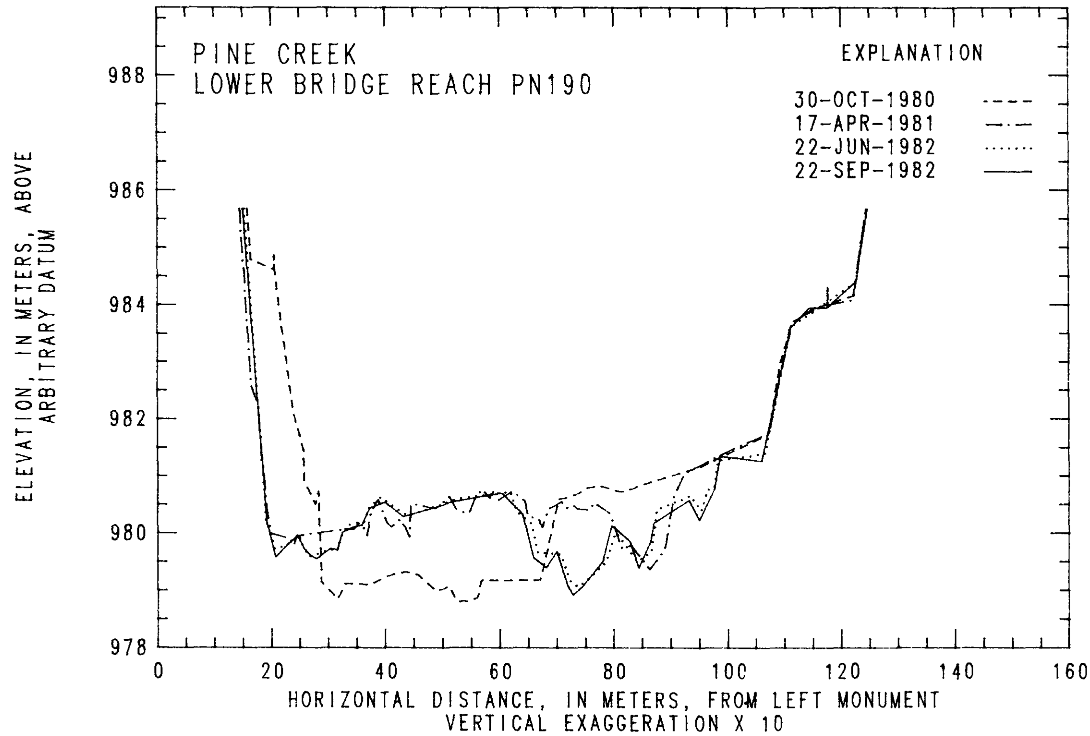


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

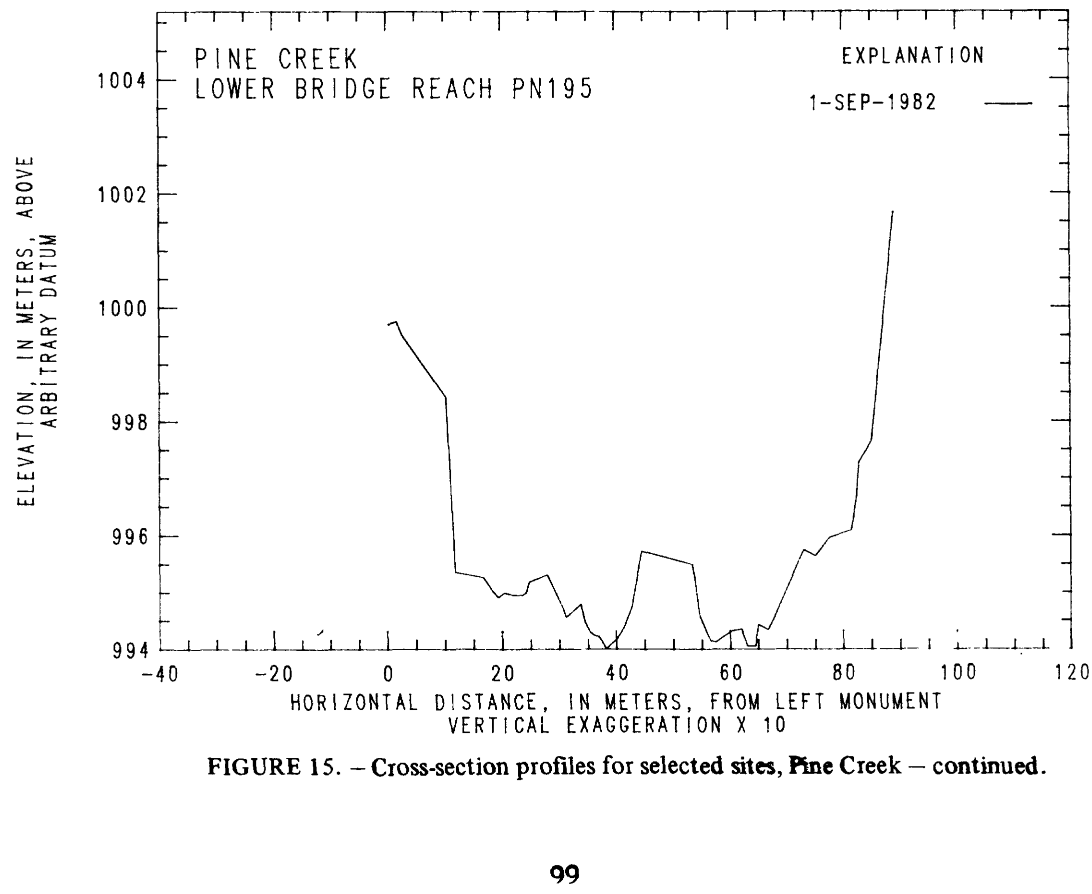
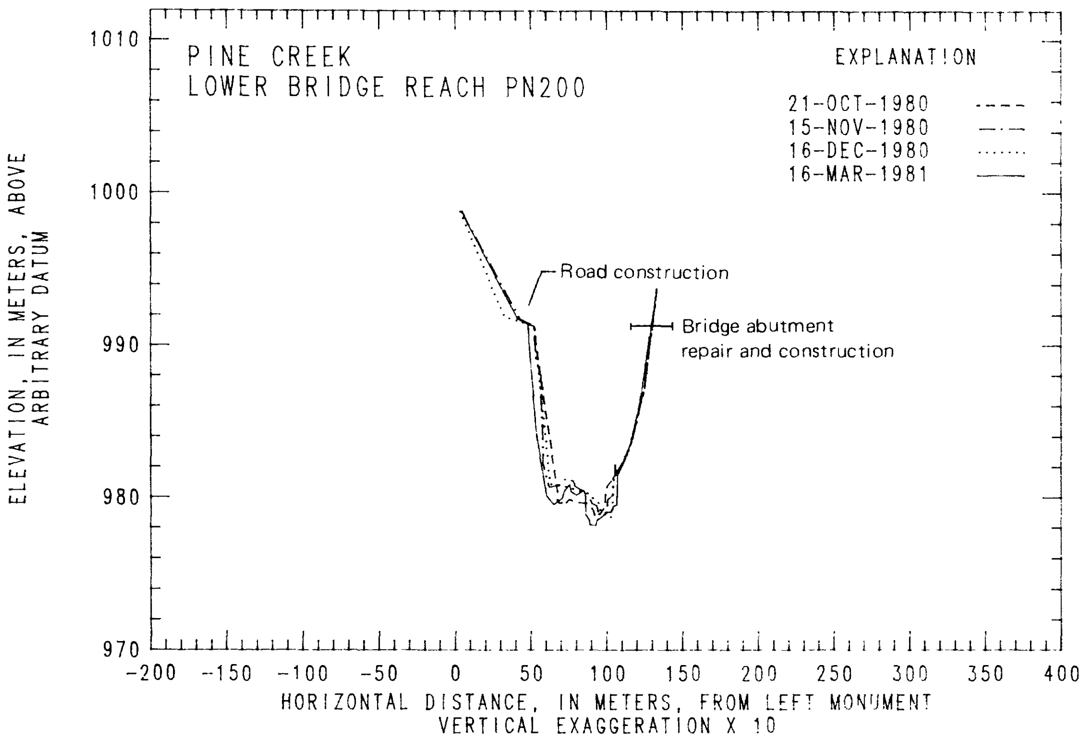


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



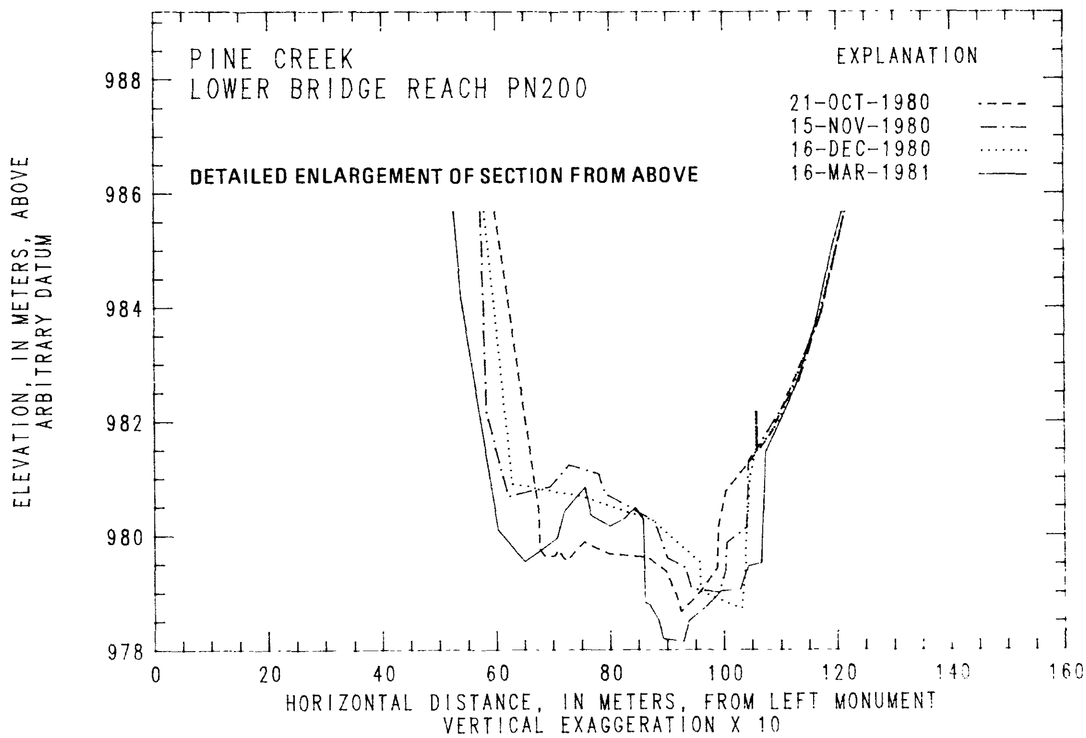
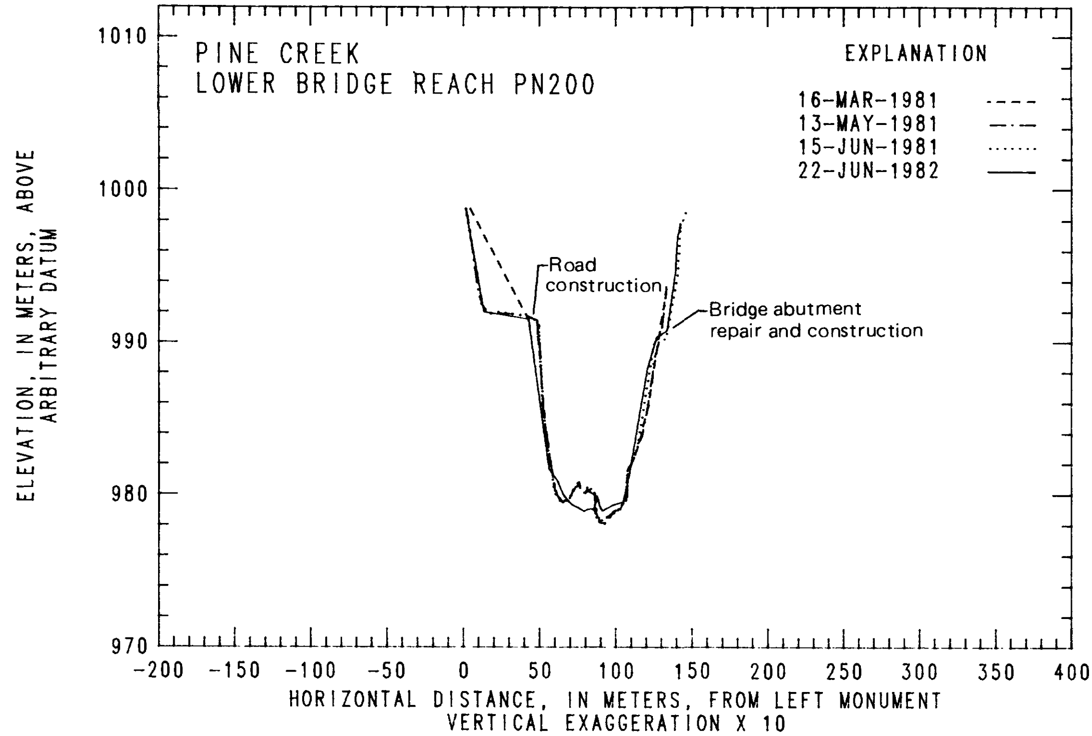


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



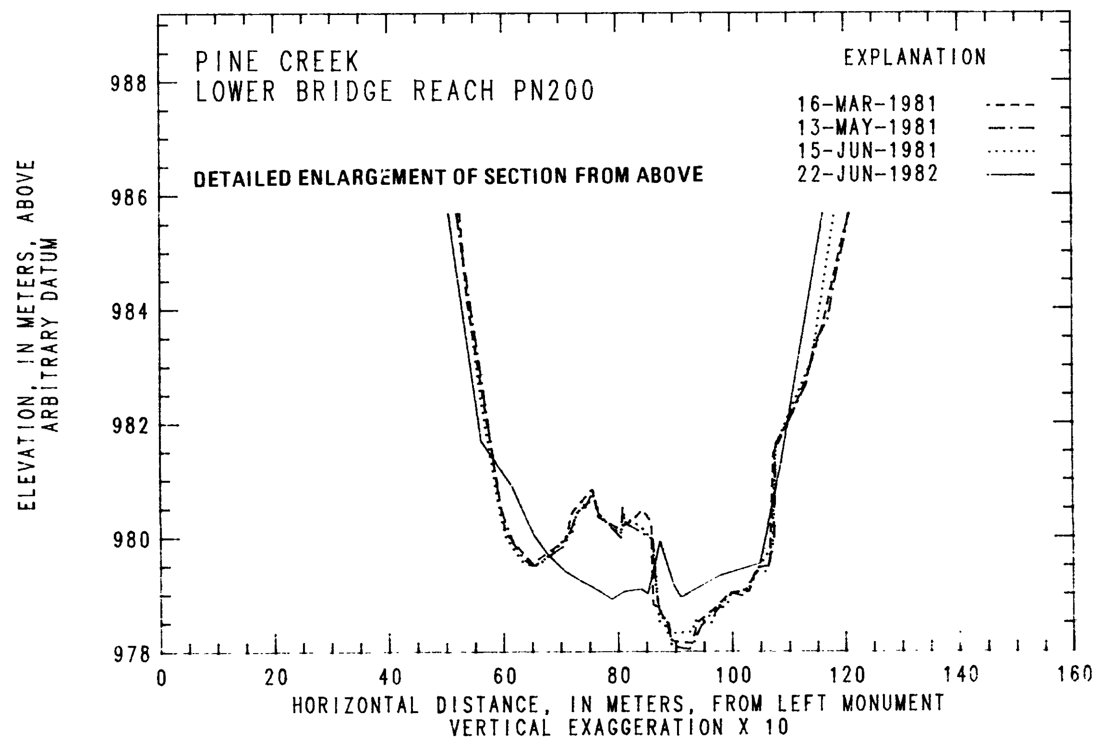
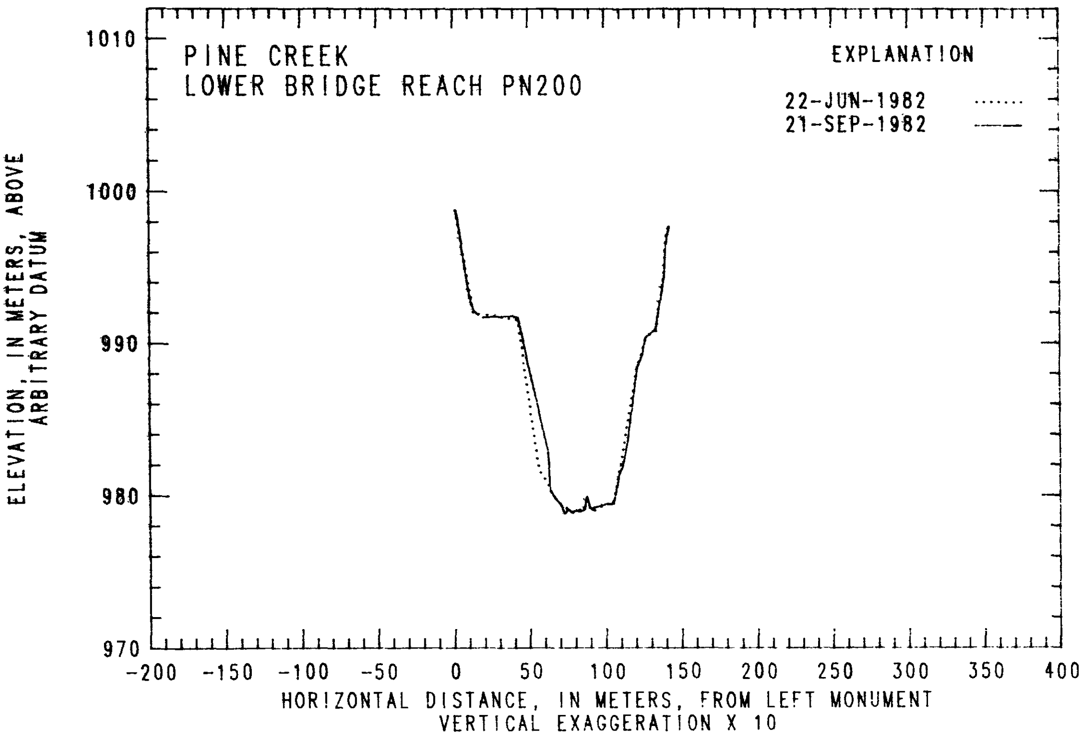


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



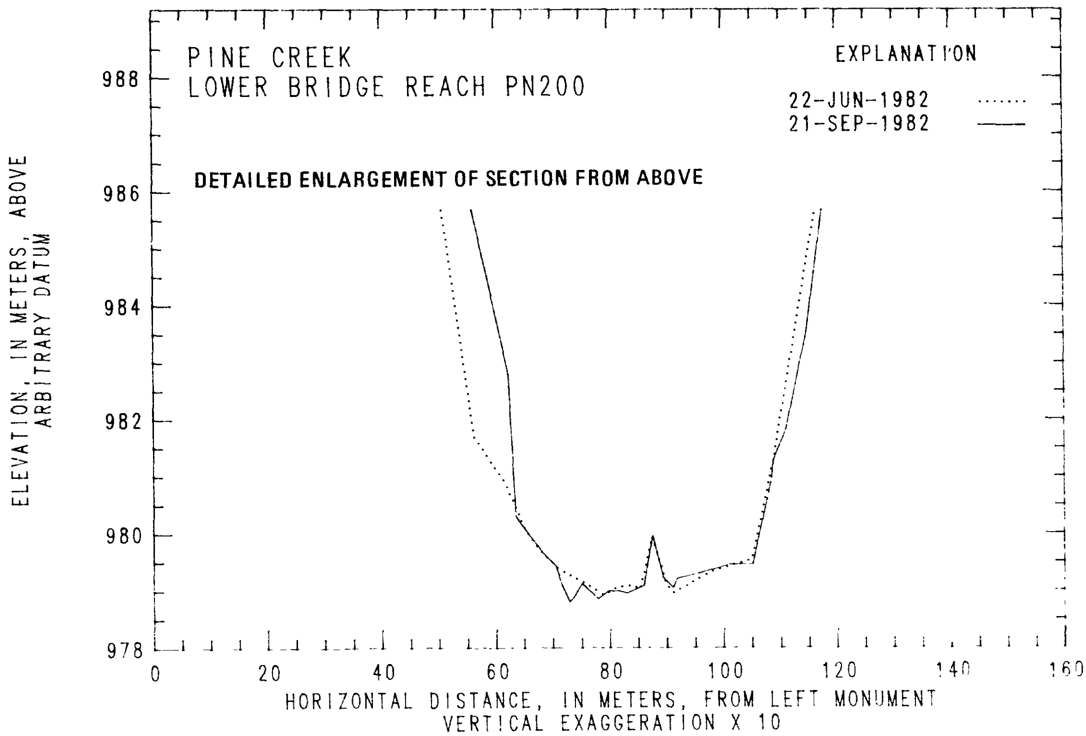
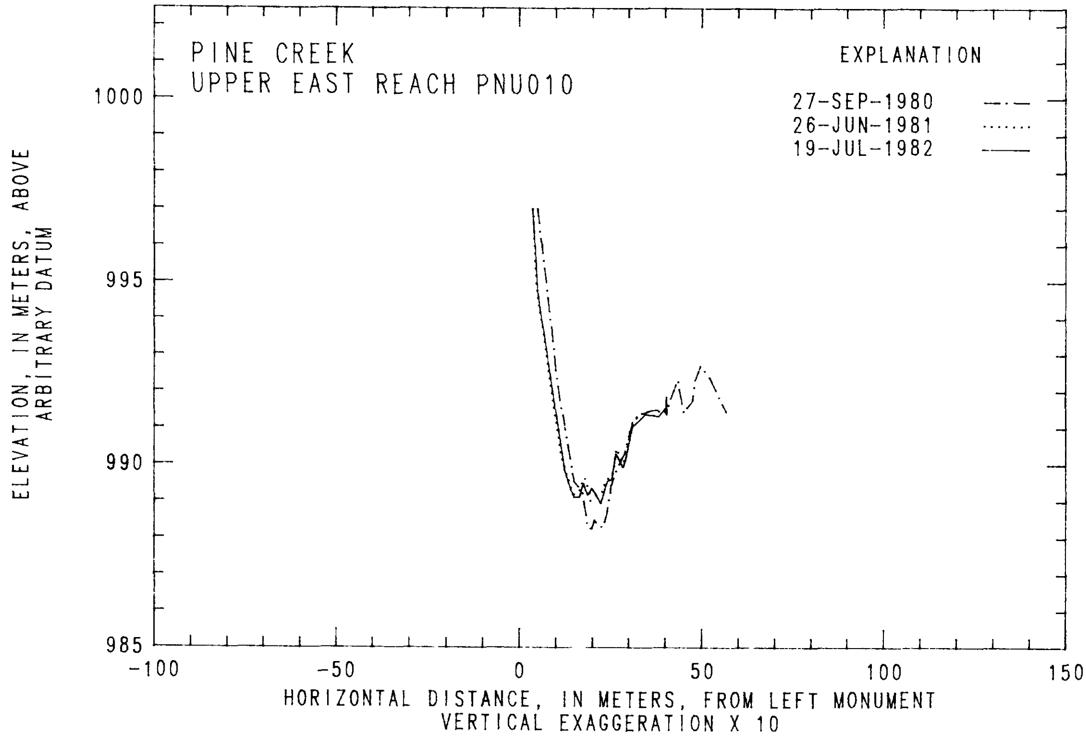


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



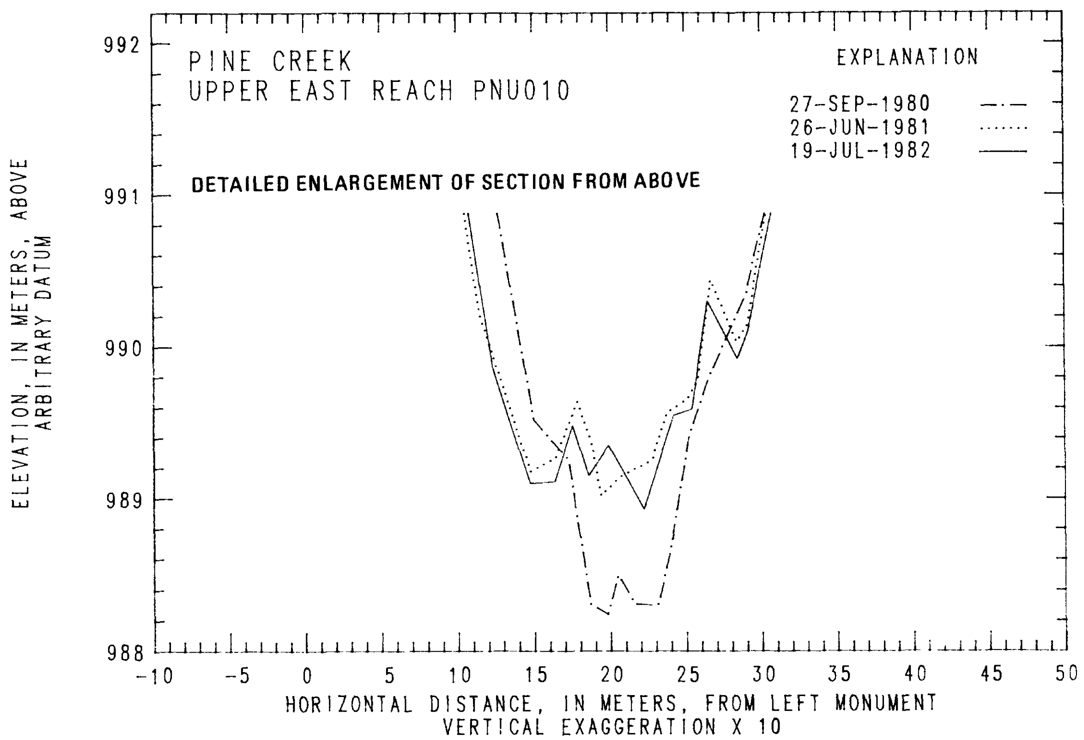
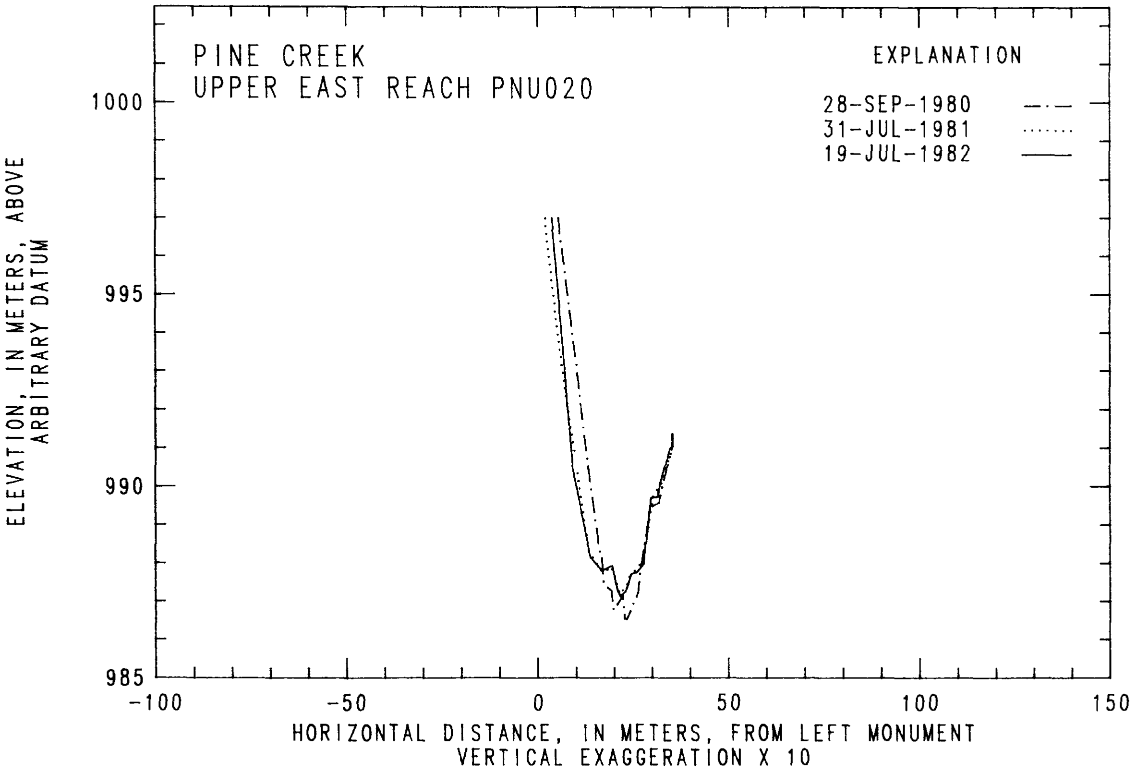


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



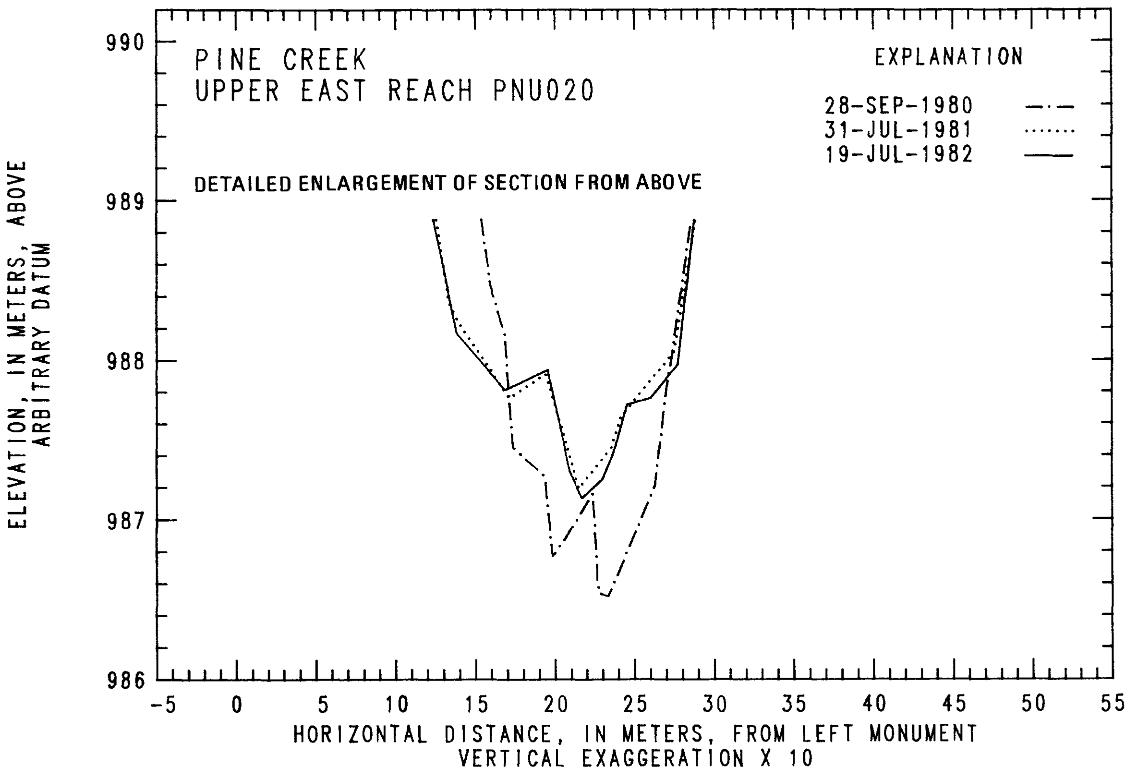
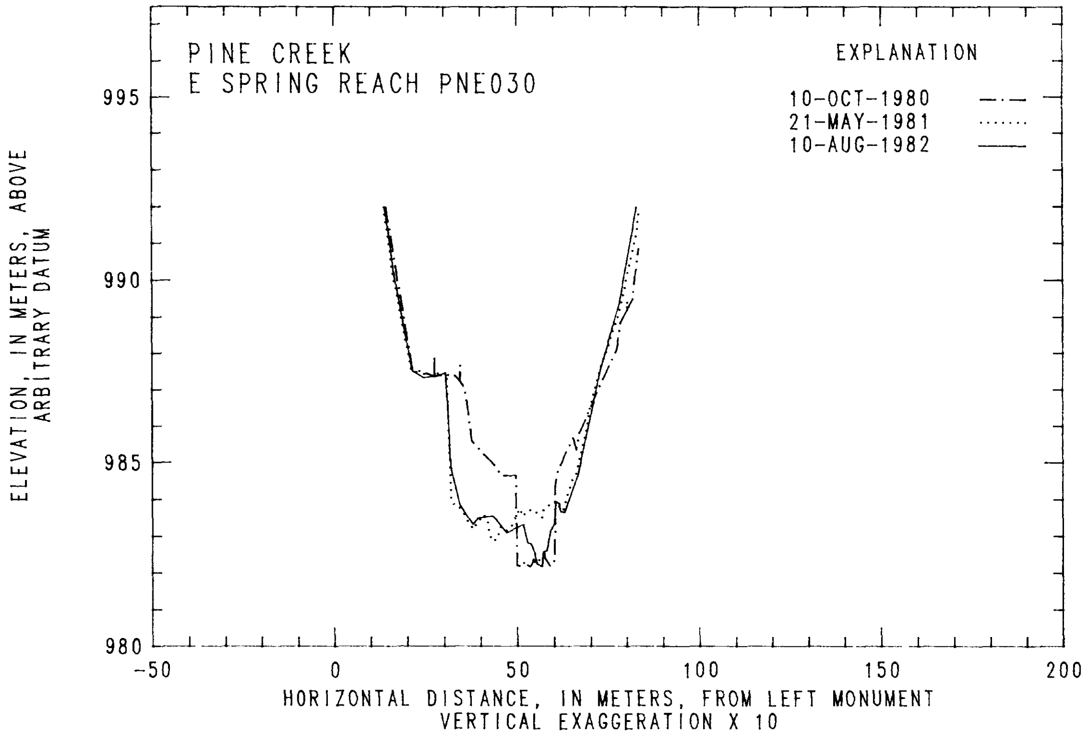


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



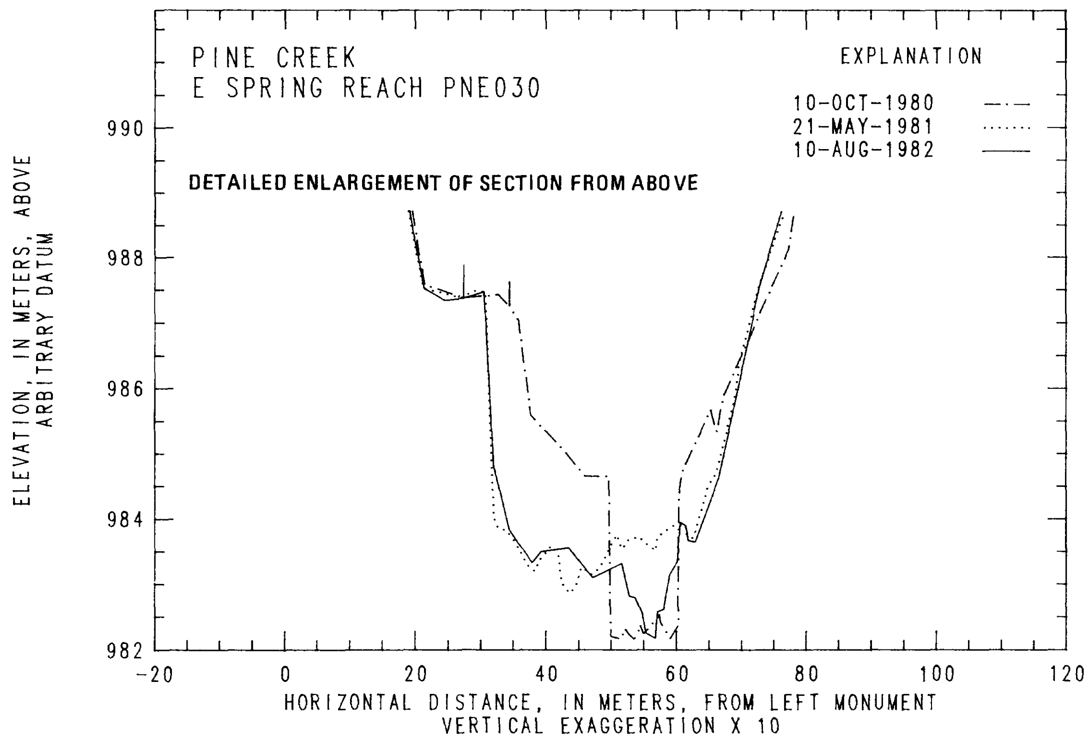
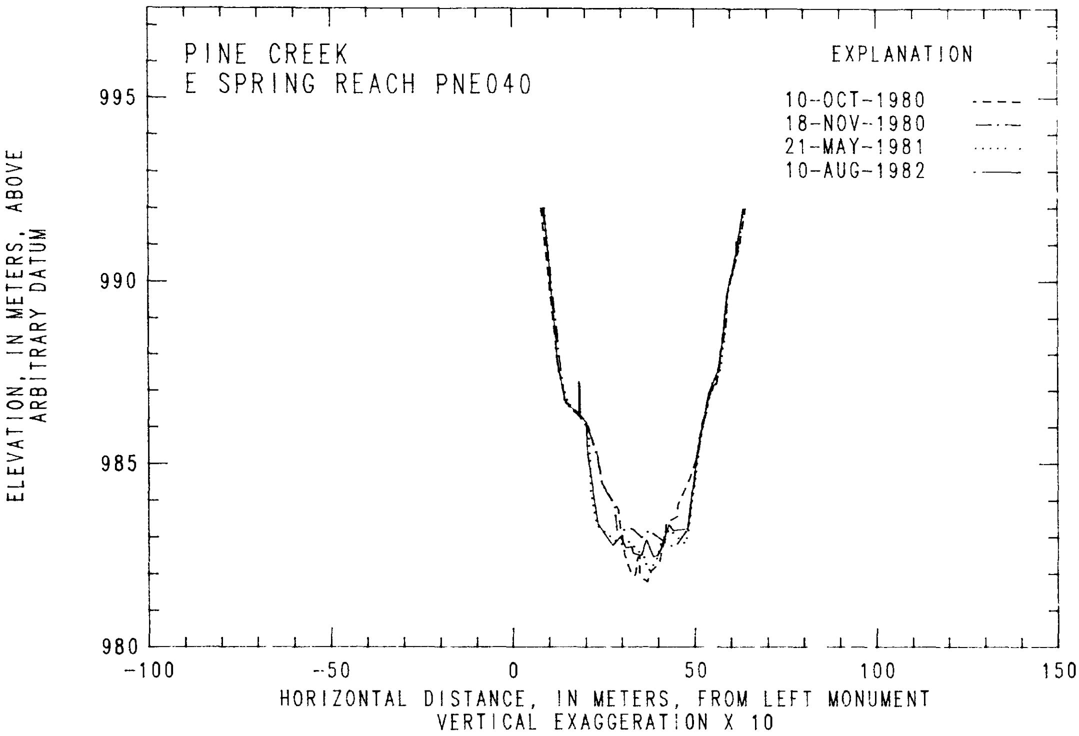


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



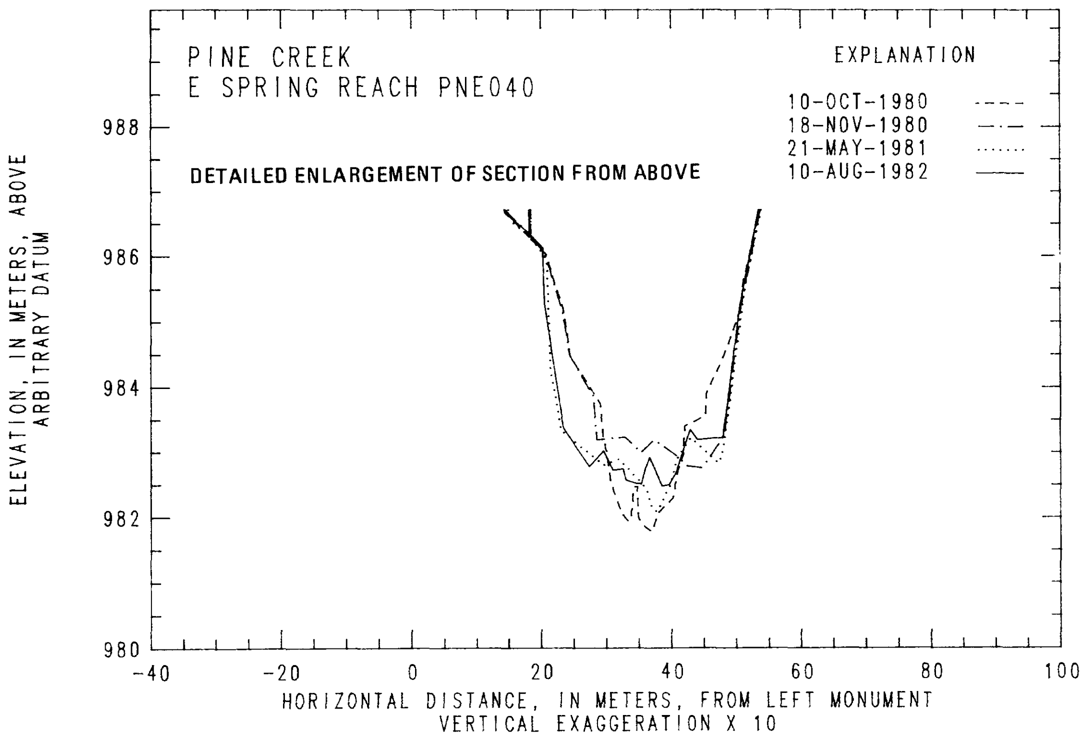
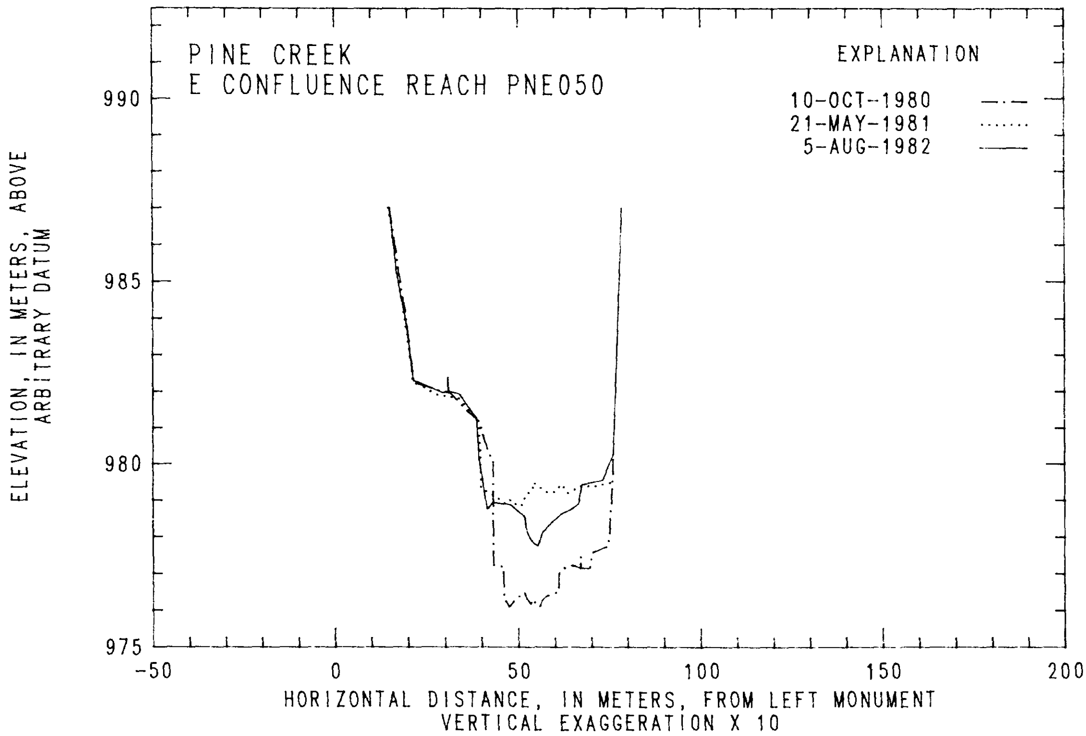


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



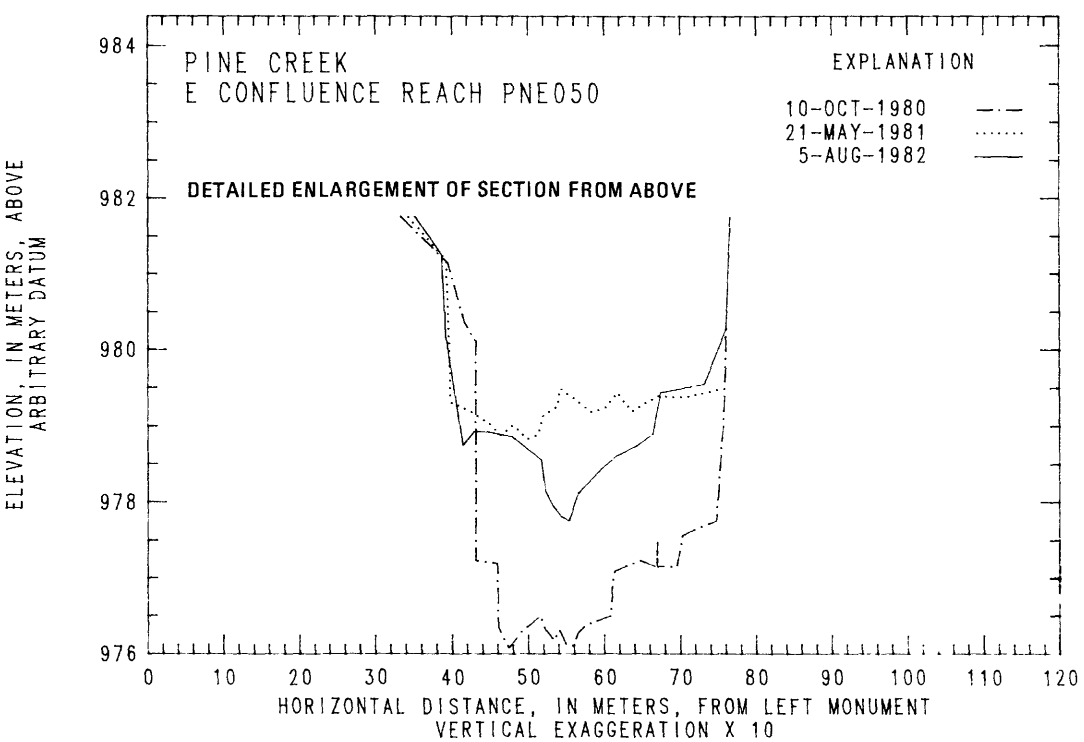
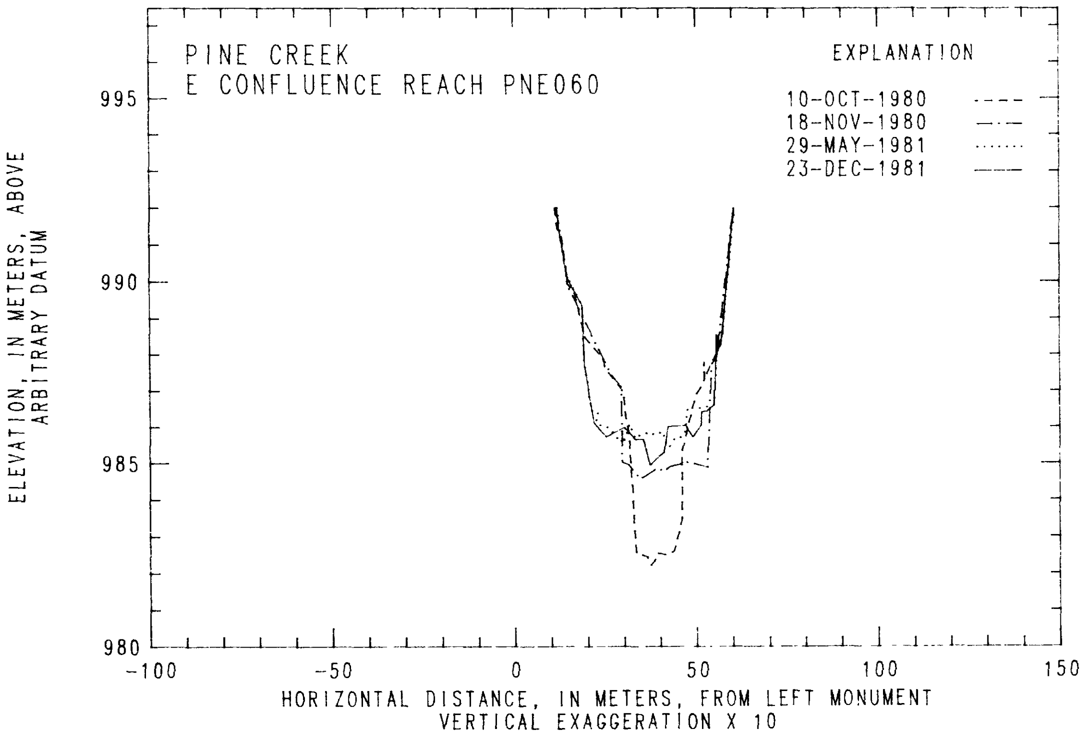


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



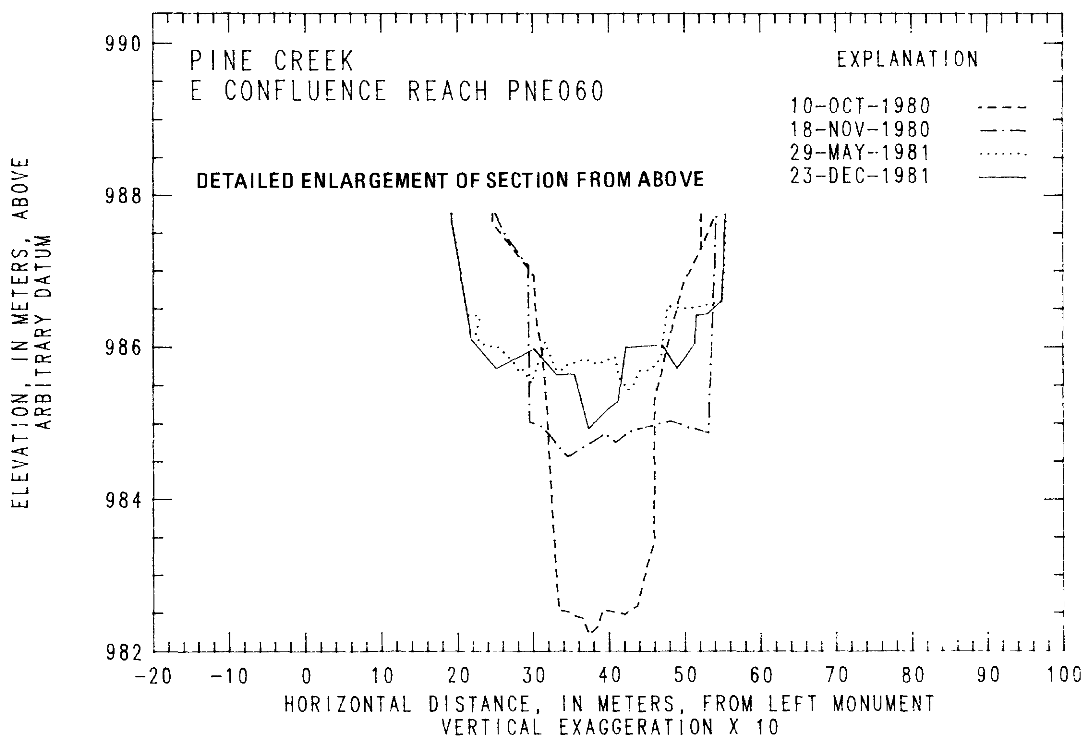
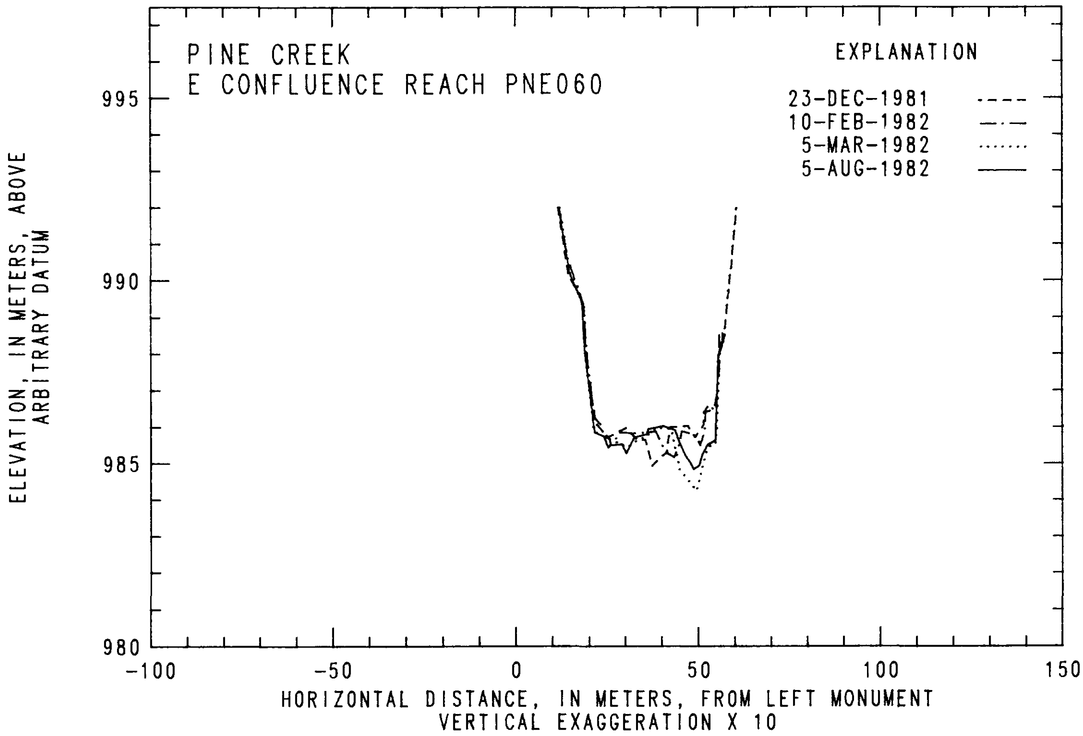


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.



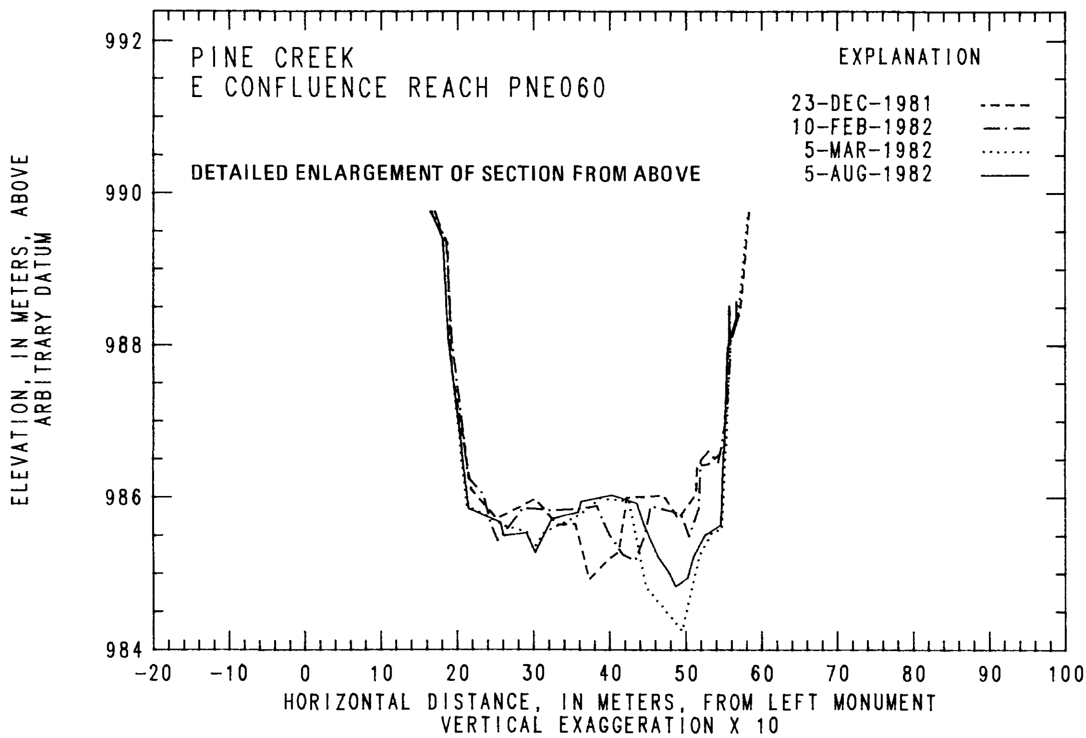


FIGURE 15. – Cross-section profiles for selected sites, Pine Creek – continued.

INDEX TO SWIFT CREEK CROSS-SECTION SITES

As an aid to the reader, listed below are the individual cross-section site numbers with corresponding page number of the plot.

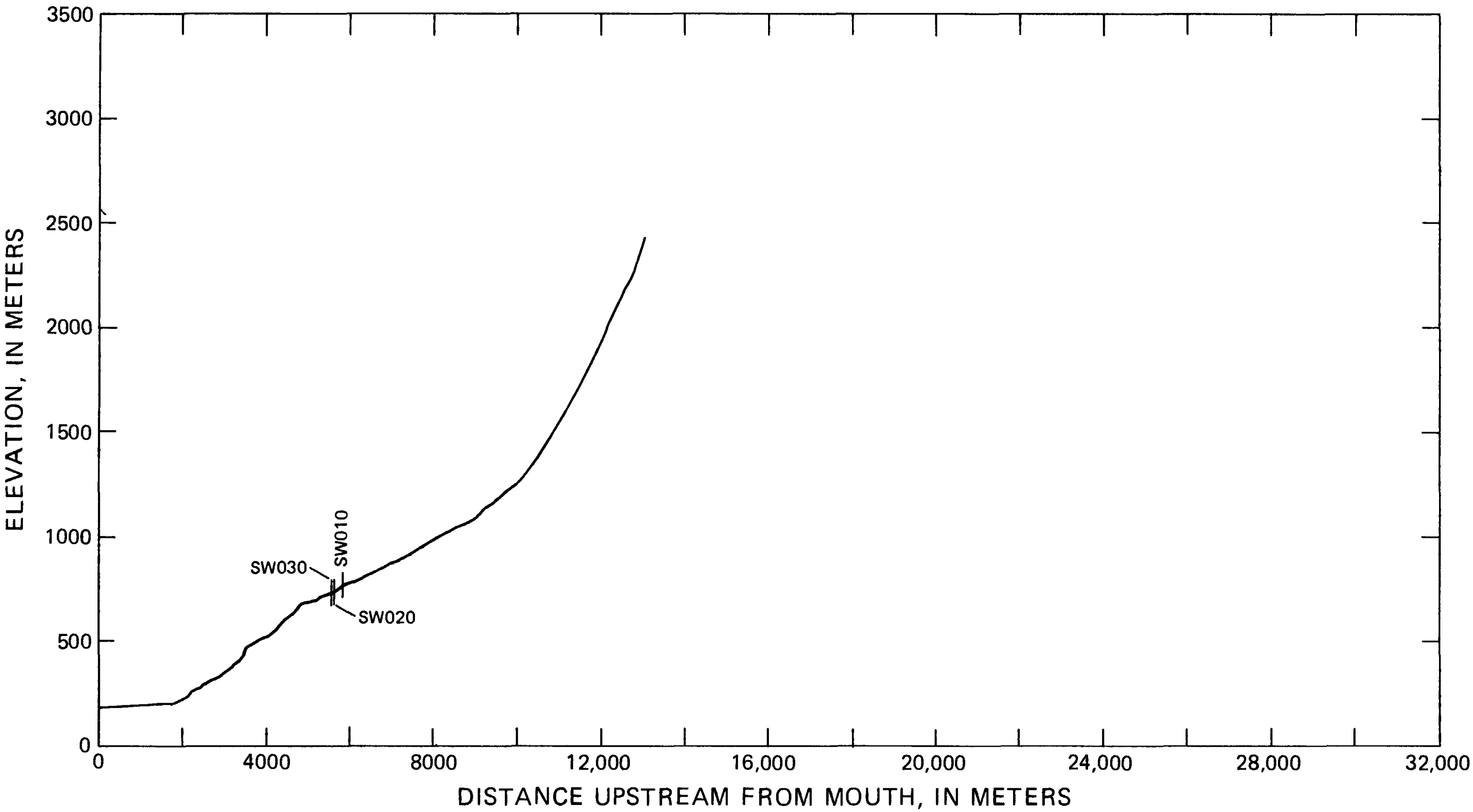


FIGURE 16.– Longitudinal profile of Swift Creek, showing locations of cross-section survey sites. Channel distance upstream from mouth and elevation above sea level are determined from U.S. Geological Survey topographic map, 7.5-minute series, Mount St. Helens SW quadrangle.

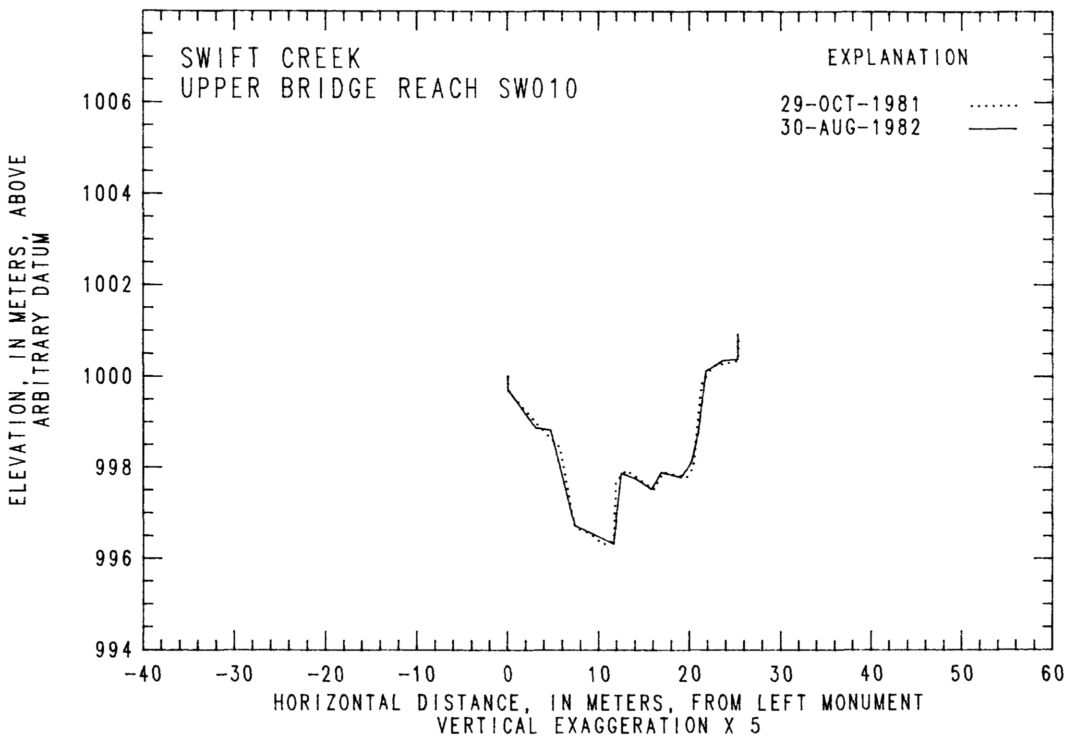


FIGURE 17. – Cross-section profiles for selected sites, Swift Creek.

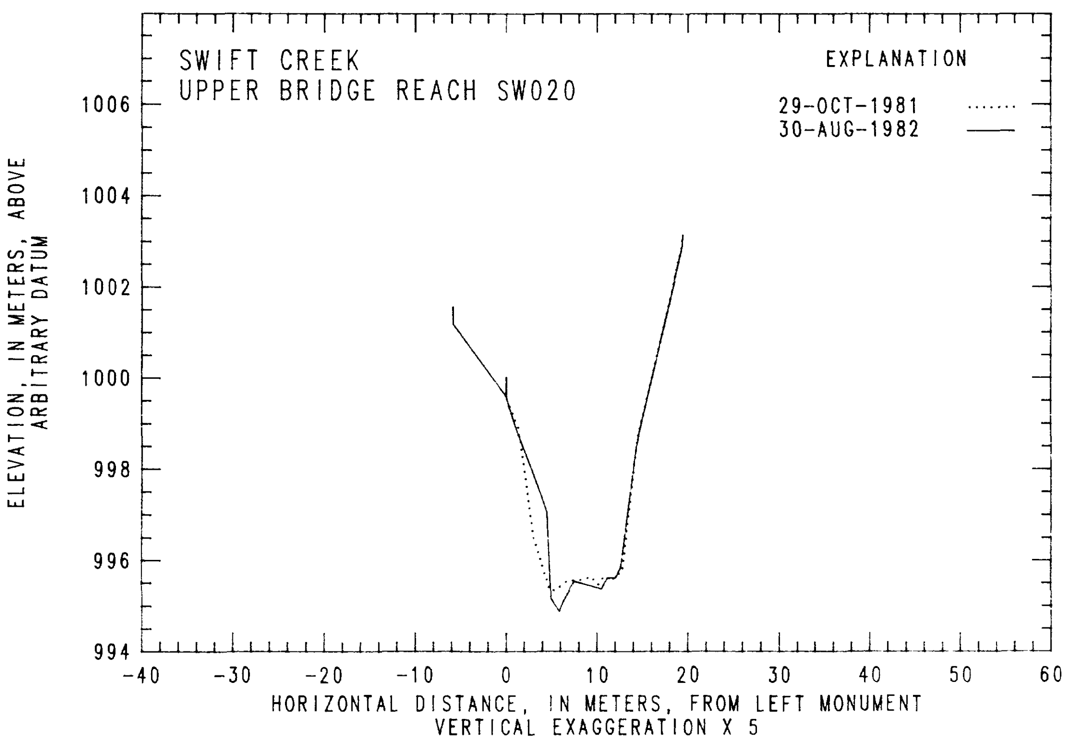


FIGURE 17. – Cross-section profiles for selected sites, Swift Creek – continued.

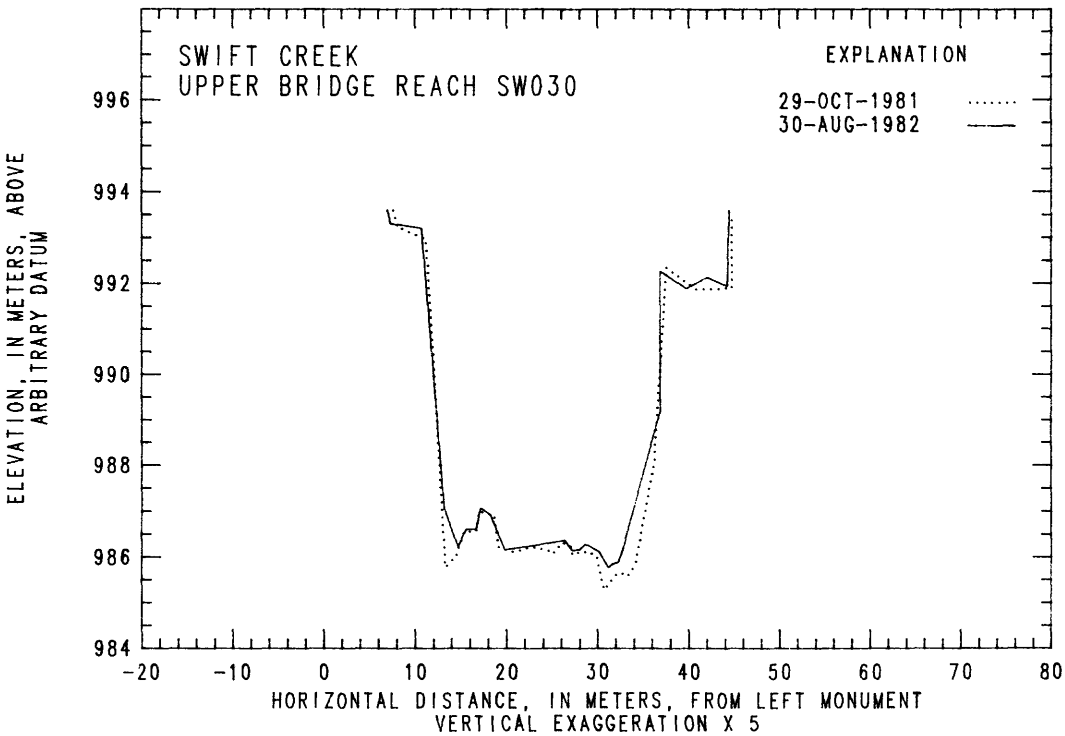


FIGURE 17. – Cross-section profiles for selected sites, Swift Creek – continued.