UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHANNEL GEOMETRY, FLOOD ELEVATIONS, AND FLOOD MAPS, LOWER TOUTLE AND COWLITZ RIVERS, WASHINGTON, JUNE 1980 TO MAY 1981

By R. E. Lombard

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4080

Tacoma, Washington
1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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ILLUSTRATIONS

METRIC (SI) CONVERSION FACTORS

Multiply	By	To obtain
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

CHANNEL GEOMETRY, FLOOD ELEVATIONS, AND FLOOD MAPS, LOWER TOUTLE AND COWLITZ RIVERS, WASHINGTON, JUNE 1980 TO MAY 1981

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ABSTRACT

The mudflows triggered by the eruption of Mount St. Helens on May 18, 1980, deposited upwards of 15 feet of sediment in the channels of the lower Toutle and Cowlitz Rivers, and appreciably raised the potential water-surface elevations for any immediate major flood. On the basis of backwater analysis of data from a river survey on June 19, 1980, a major flood discharge of 86,500 cubic feet per second would have caused water-surface elevations on the Cowlitz River that are higher than those predicted for the pre-eruption channel by approximately 6.2 feet at Castle Rock, 8 feet at Lexington, and 5.6 feet at Kelso and Longview. These predicted water-surface elevations were lowered by 7.8 feet (which is lower than the pre-eruptive elevation), 5 feet, and 4 feet, respectively, when dredging operations, begun in June 1980, were completed on the Cowlitz River in May 1981 by the U.S. Army Corps of Engineers. Areas of Castle Rock, Lexington, and Kelso that would have been inundated by such a major flood before the dredging operation would be free of flooding after dredging if the channel remained unchanged. After dredging in the lower Toutle River between June 1980 and April 1981, the predicted water-surface elevation for a discharge of 47,600 cubic feet per second was reduced by approximately 17 feet at the Interstate 5 crossing. Periodic river surveys between June 1980 and May 1981 indicate, however, that new sediment is often deposited, sometimes in appreciable amounts, by storm runoff from the mudflow-laden Toutle River basin and erosion of dredged spoil materials. A high flow in December 1980 deposited an average of 10 feet of sediment in the Cowlitz River at Castle Rock.

INTRODUCTION

The mudflows that accompanied the eruption of Mount St. Helens on May 18, 1980, deposited upwards of 15 feet of sediment in the Toutle River near its mouth and in the Cowlitz River upstream and downstream from the Toutle River. The deposits in the Cowlitz River extended about 2 miles upstream from the Toutle River, about 20 miles downstream to its mouth, and on into the Columbia River. Those deposits in the channels, and lesser but deep deposits on the flood plains, seriously reduced the flood-carrying capacity of these streams, thus placing several adjoining communities and transportation routes in increased jeopardy of inundation from future floods. The eruption also deposited immense volumes of erodible material in the upper Toutle River that potentially could be transported into the lower reaches of the Toutle and Cowlitz Rivers to further reduce channel capacity (Lombard and others, 1981).

The lower Cowlitz River is situated in Cowlitz County in southwest Washington (fig. 1). About 55 percent of the county population (1980) resides in the cities of Kelso, Longview, and Castle Rock. Kelso (pop. 11,150), the county seat, and Longview (pop. 31,100) are located on a broad, flat flood plain at the confluence of the Columbia and Cowlitz Rivers. The two cities are approximately 50 miles north of Portland, Oreg., in southwest Cowlitz County. The town of Castle Rock (pop. 2,170) is located on the east bank of the Cowlitz River about 10 miles north of Kelso (Washington State, Office of Financial Management, 1982), about 3 miles downstream from the Toutle River. The small unincorporated community of Lexington (population unknown) is located on the west bank of the Cowlitz River about 3 miles north of Kelso.

The climate in the vicinity is characterized by mild wet winters and warm summers. Maritime airmasses generally dominate the area throughout the year with an annual precipitation of 45 inches. The majority of the rainfall occurs between October and March (U.S. National Oceanic and Atmospheric Administration, 1965). The economic activity in the area centers around the region's lumber industry and the Port of Longview.

Prior to the mudflows the lower Toutle and Cowlitz Rivers had well-defined channels, confined at most of the communities and a few other places by artificial levees. The levees constructed along the Cowlitz River afforded protection from flood peak discharges up to 138,000 ft^3/s for the cities of Castle Rock, Kelso, and Longview (Federal Insurance Administration, 1979a, 1979b, 1979c). A series of drainage ditches and pump stations remove interior surface runoff. The Cowlitz River is the main source of potable water for all of the communities.

The mudflows following the eruption did not significantly inundate levee-protected areas within any of the major communities along the Cowlitz River. However, sediment deposits appreciably reduced the channel capacity between those levees for subsequent floods and damaged or restricted operations of water supply and waste-disposal systems. Should the levees be breached or overtopped nearly all of the commercial development and public utilities in the major communities could suffer flood damage. Approximately 60 percent of the residential areas could also be damaged.

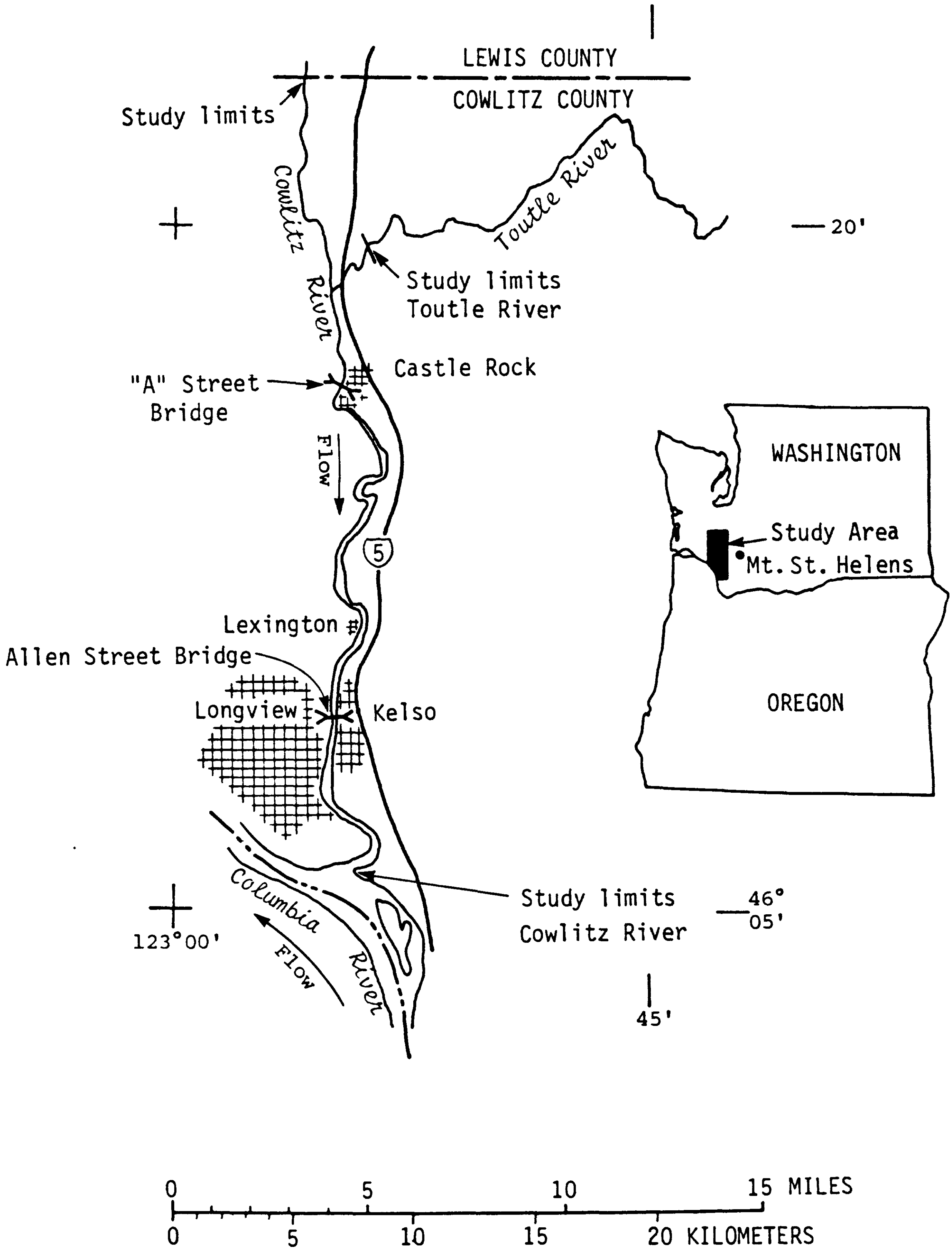

FIGURE 1.--Study limits, lower Cowlitz and Toutle Rivers.

From May 21 to May 24, 1980, shortly after the eruption and mudflows, the U.S. Geological Survey made reconnaissance surveys of the lower Cowlitz River channel. On May 26, 1980, post-eruption water-surface or flood profiles computed for selected high-water flows were transmitted to the Federal Emergency Management Agency for their evaluation of the flood hazard. Within 6 days after the eruption, the U.S. Geological Survey installed a gaging station to measure river stage on the North Fork Toutle River at Kid Valley and transmit the stage via satellite to the National Weather Service in Vancouver, Wash.; the Cowlitz County Sheriff's Office; and the Washington District Office, U.S. Geological Survey. Additional gages were constructed on the Toutle and North and South Fork Toutle Rivers to transmit stages by satellite in the ensuing weeks and months. If flooding had occurred, data transmitted from these gages would have provided several hours of warning to the residents along the Cowlitz River.

To reduce the increased flood hazard, the U.S. Army Corps of Engineers began dredging operations near the mouth of the Cowlitz River on about June 10, 1980, and progressively expanded the operation upstream as quickly as equipment could be made available. Those operations ended in the lower Cowlitz River in May 1981, but were continued in the lower Toutle River into the fall of 1981.

Flood control on the Cowlitz River has also been aided by two reservoirs, Mayfield and Riffe, located on the Cowlitz River upstream of the Toutle River, 20 miles and 30 miles northeast of Castle Rock, respectively. Storage began in 1962 in Mayfield and 1968 in Riffe. They have a combined flood storage volume of 360,000 acre-feet and have been extensively used to mitigate flood magnitudes in the lower Cowlitz River since the mudflow.

The sediment deposits in the lower Cowlitz and Toutle Rivers caused considerable concern by local, county, and Federal agencies that a rainstorm could cause serious flooding and damage before protective measures could be implemented and completed. Accordingly, immediately after the eruption, the U.S. Geological Survey entered into a program of monitoring channel changes and estimating their effects on the flood hazards. A previous report (Lombard and others, 1981) describes the channel and flood-plain conditions of the lower Cowlitz and Toutle Rivers and the flood hazards that existed shortly before and after the mudflows. This report continues the chronology of channel changes and their potential effects on flood elevations for the period from June 19, 1980 (date of the first detailed river survey after dredging began), to May 11, 1981 (after dredging of the Cowlitz River was terminated). The report documents (1) the physical changes to the channels and flood plains that resulted from dredging and subsequent sediment deposits, and (2) the potential effects of these changes on flood elevations and inundation areas.

Physical changes to the channels were determined by periodic, detailed surveys of channel and flood-plain cross sections. Eleven surveys of the Cowlitz River and five surveys of the Toutle River were conducted during the period. Generally, surveys of the Cowlitz River included about 50 cross sections, and those of the Toutle River about 12 cross sections. Each USGS survey of the rivers was completed rapidly, usually within 2 days, using two small crews equipped with boats, fathometers, and engineer levels.

Flood elevations and areas of inundation were estimated using a step-backwater analysis model (Shearman, 1976) and cross-section data. The model was calibrated for the water-surface elevations and river discharges on each date of the river surveys. The water-surface elevations, computed for selected magnitudes of flood discharge by the model, were used to prepare water-surface profiles for the river. Flood-inundation maps for the computed flood elevations were prepared by locating the ground intercepts of those elevations on topographic maps and forming flood boundaries by connecting the intercept points.

The backwater analyses were based upon the assumptions that the stream channels and flood plains would remain unchanged during the passage of the flood wave and that water with extraordinary concentrations of suspended sediment would exhibit the same hydraulic characteristics as normal floodwater. Changes that can affect the water-surface elevation during a flood include the cross-sectional area, mean depth, bed elevation and form, distance between cross sections, and the hydraulic roughness (Manning's n). Because channel changes do occur during floods and because high sediment concentrations can apparently affect certain hydraulic parameters (for example, fluid density, depth, velocity distribution), the computed flood elevations given in this report can only be considered as estimates. All elevations in this report are referenced to the National Geodetic Vertical Datum of 1929 (NGVD).

ACKNOWLEDGMENTS

Appreciation is expressed to the U.S. Army Corps of Engineers, Portland District, who furnished some cross-section data, base maps, dredging figures, and other useful information.

CHANNEL GEOMETRY

Prior to the mudflows, the lower Toutle and Cowlitz Rivers had well-defined, stable channels, confined in places by artificial levees. Figure 2 shows the changes that were caused in the Cowlitz River channel at Kelso and Longview by the May 1980 mudflow deposit in the pre-eruption channel (surveyed in about 1978) and by dredging of the deposit between June 1980 and May 1981. In Kelso and Longview the sediment deposits were confined by levees. Dredges were generally able to clear and maintain the channel there, but the channel filled noticeably each time dredging operations stopped.

At Lexington (fig. 3), located on the west bank of the Cowlitz River about 9 miles upstream from the mouth, the mudflows were also confined to the original channel, but channel capacity had been reduced enough by the mudflows to create a hazard from any subsequent flood. Dredging and construction of a levee on that bank in 1980 largely alleviated the hazard in that area, and on April 14 the channel capacity was larger than the pre-eruption capacity.

Figure 4 shows the channel and west bank flood-plain changes at Castle Rock about 17 miles upstream from the mouth. The town of Castle Rock is protected by a levee along the east bank. During the high water in February 1981, the main channel filled about 9 feet and some of the original mudflow material on the west bank and dredge spoils emplaced on it were washed into the river.

The Toutle River at the Interstate 5 crossing (fig. 5) filled about 15 feet with mudflow deposits from the eruption, on the basis of the June 5, 1980, survey. By the last survey of the period, April 15, 1981, the channel was deeper and had more capacity than prior to the eruption.

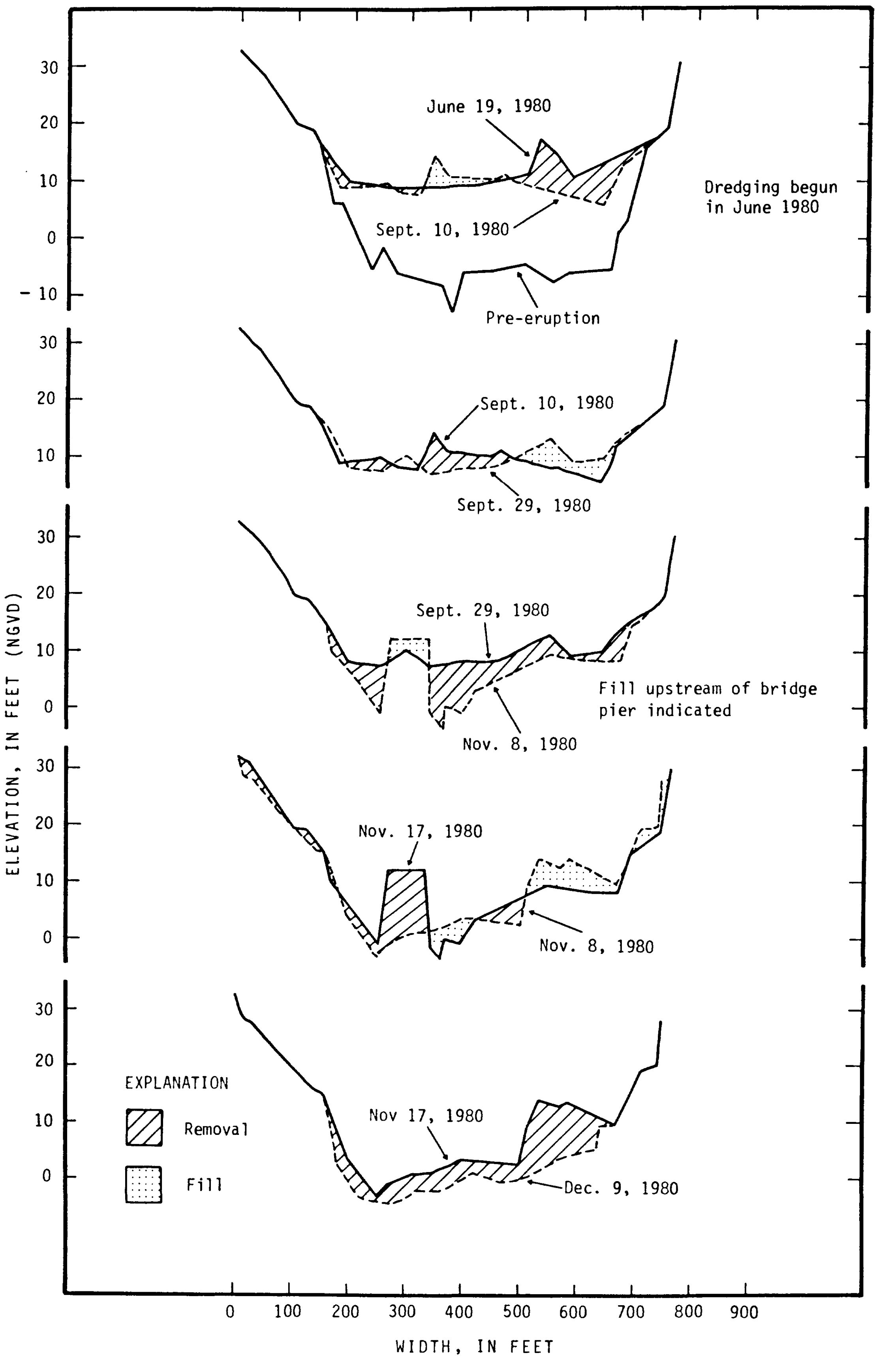

FIGURE 2a.--Changes in channel geometry of the Cowlitz River at Kelso/Longview, Washington.

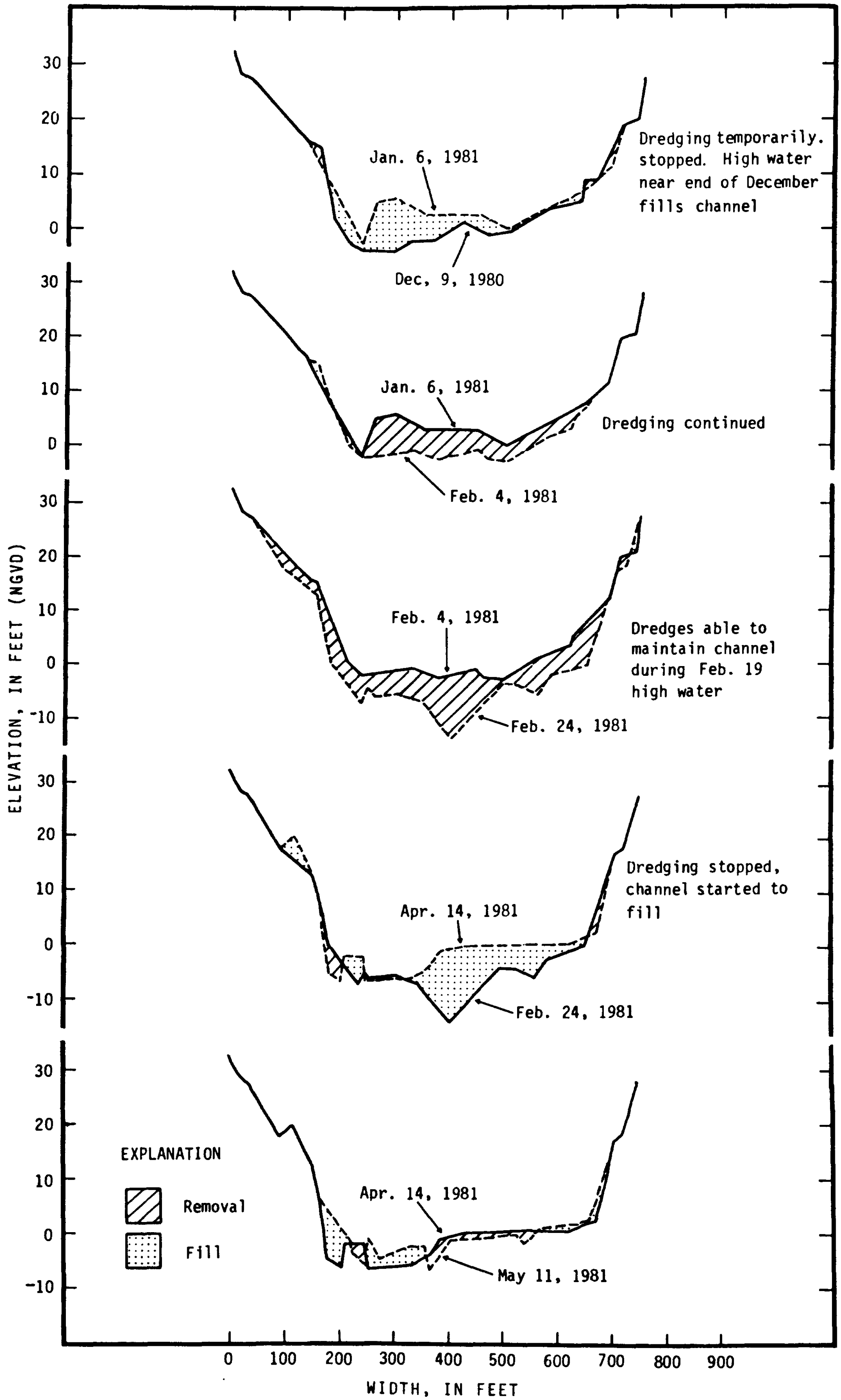

FIGURE 2b.--Changes in channel geometry of the Cowlitz River at Kelso/Longview, Washington.

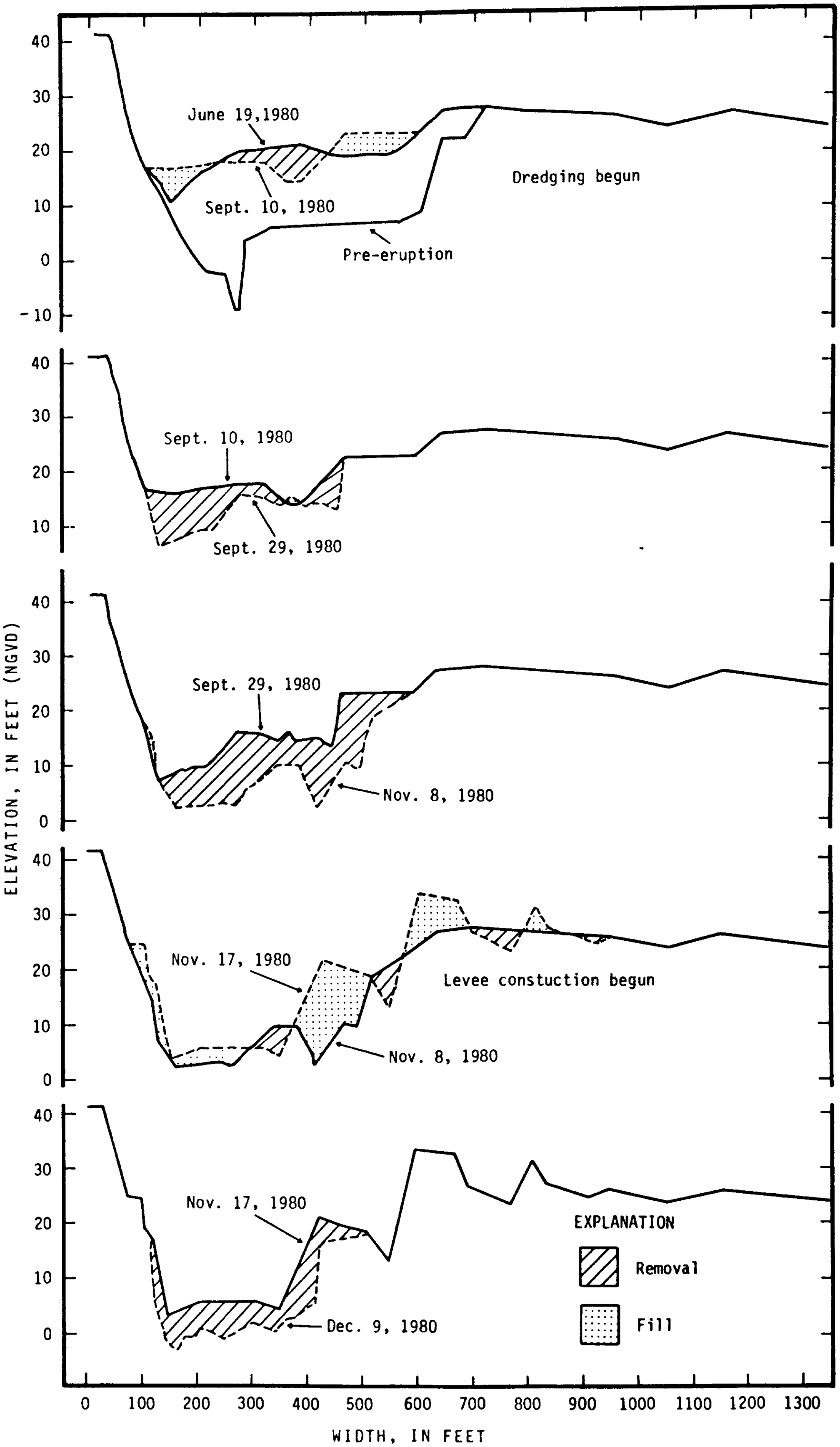

FIGURE 3a.--Changes in channel geometry and the flood plain of the Cowlitz River at Lexington, Washington.

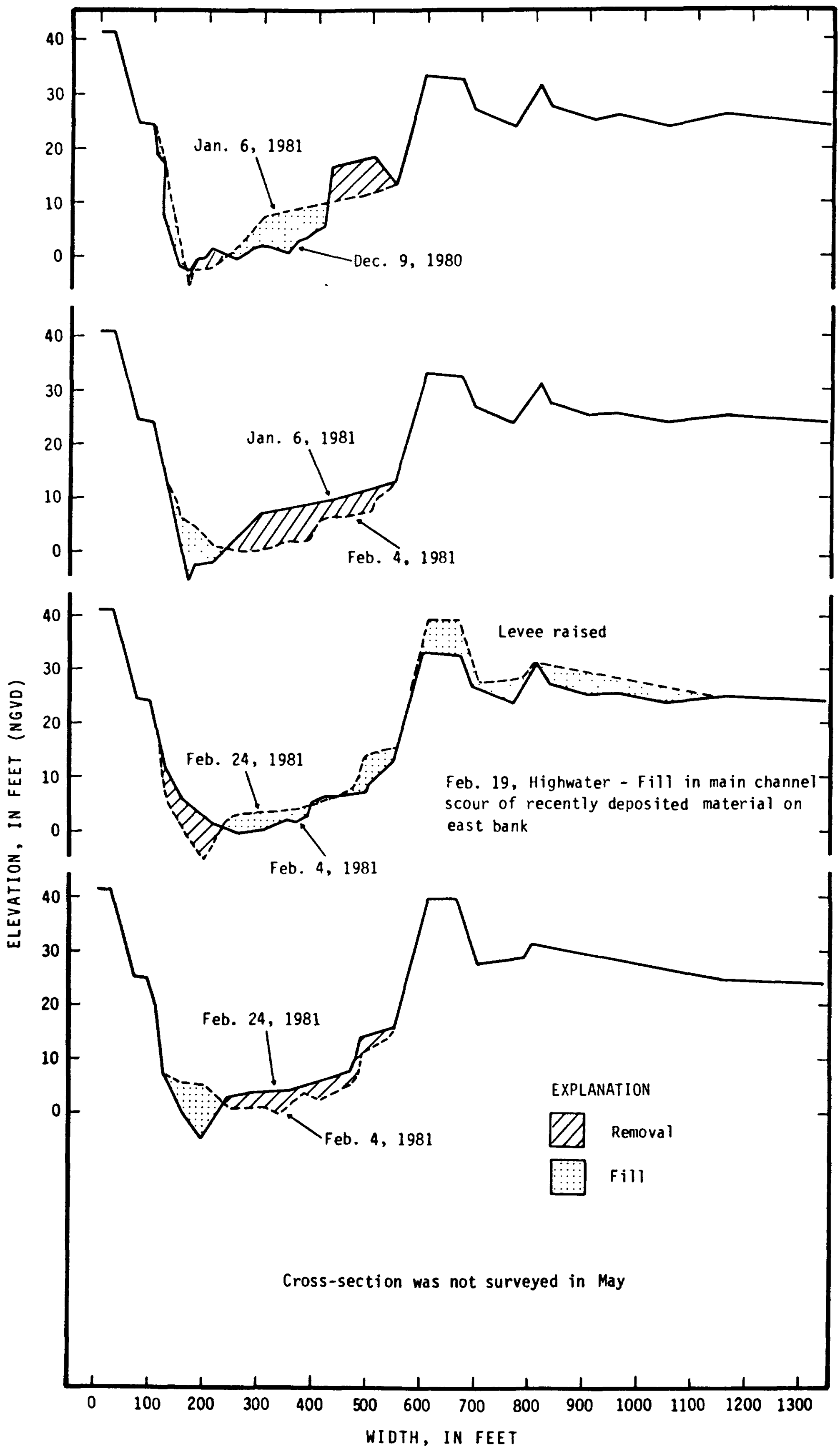

FIGURE 3b.--Changes in channel geometry and the flood plain of the Cowlitz River at Lexington, Washington.

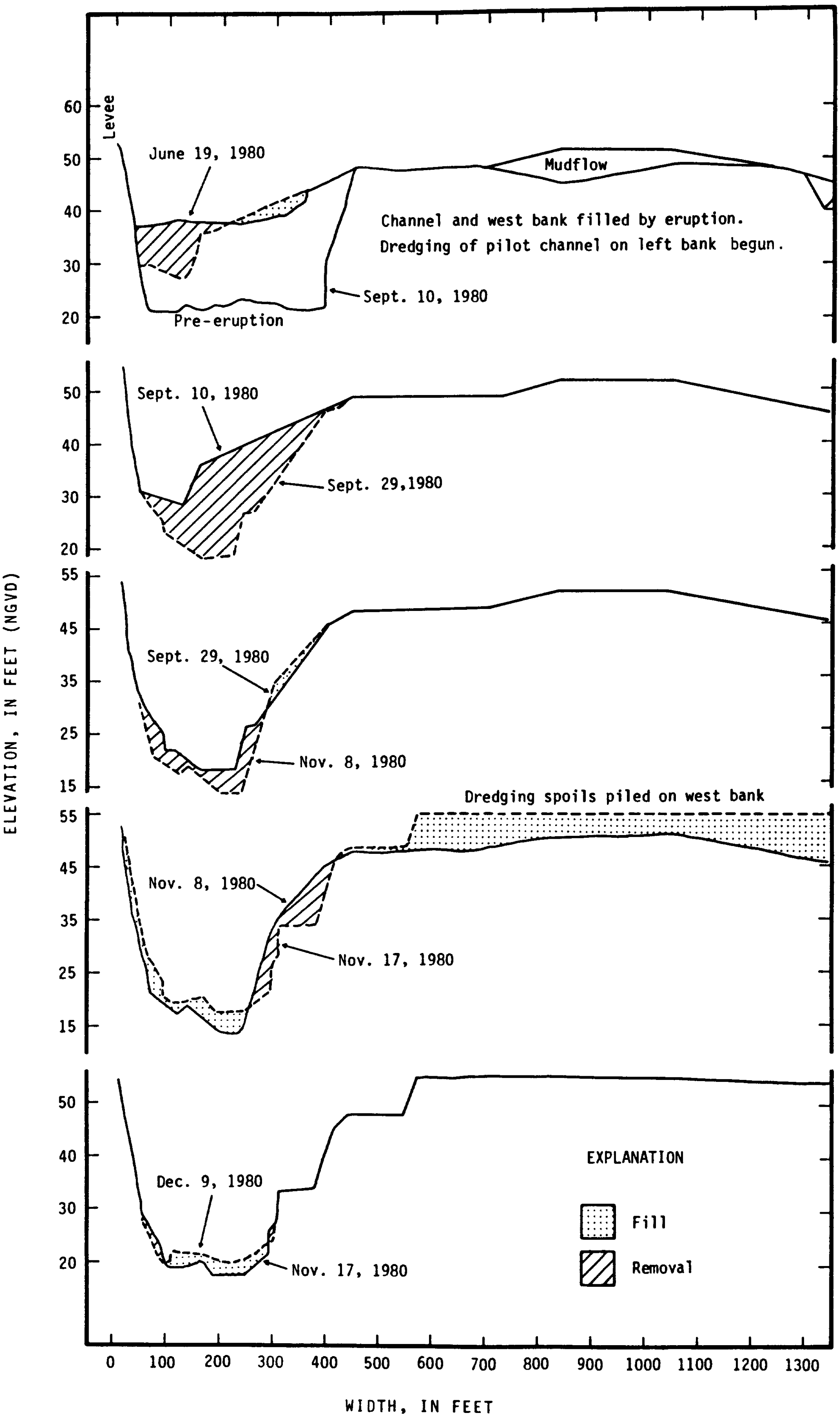

FIGURE 4a.--Changes in channel geometry and the flood plain of the Cowlitz River at Castle Rock, Washington.

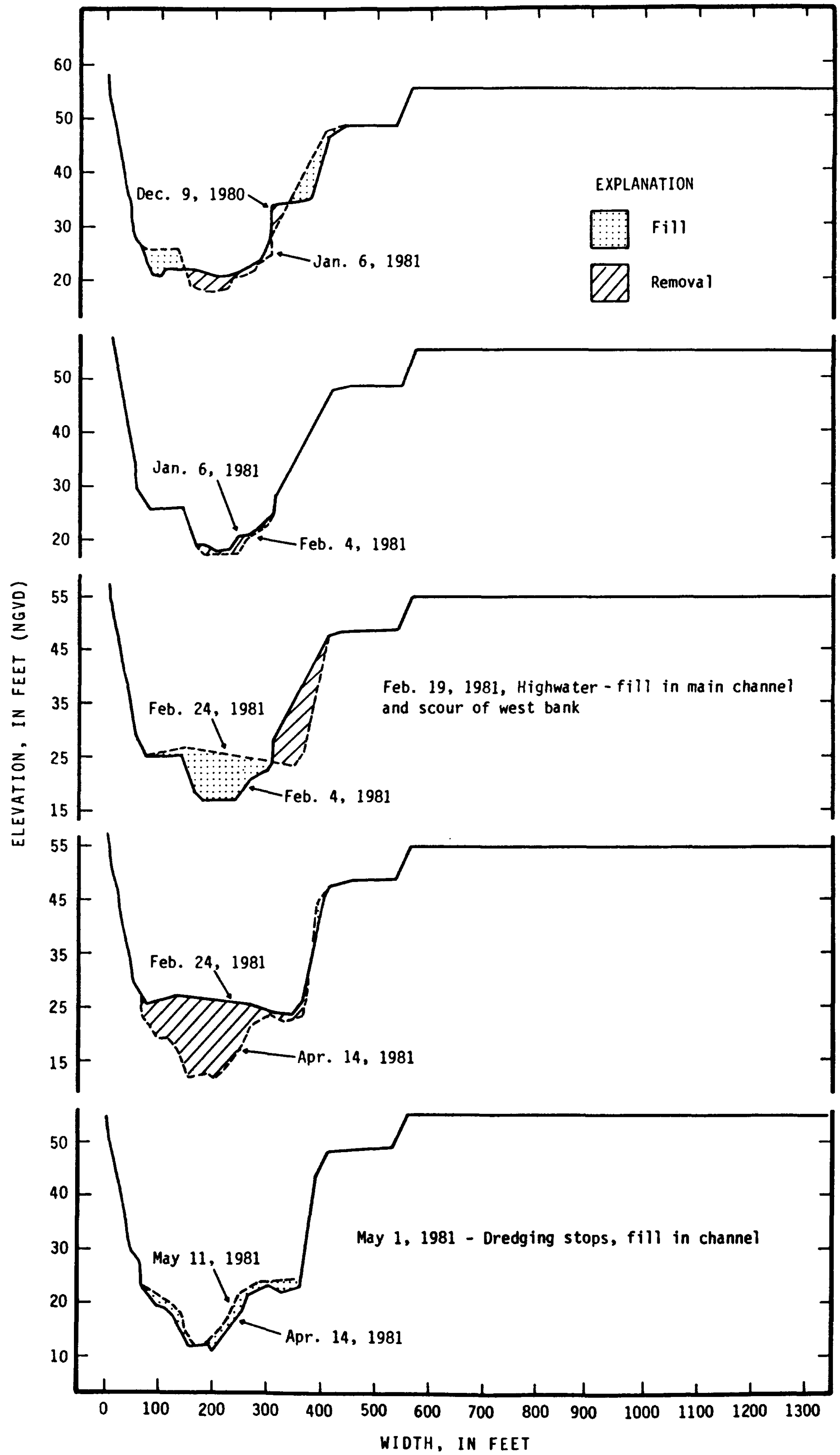

FIGURE 4b.--Changes in channel geometry and the flood plain of the Cowlitz River at Castle Rock, Washington.

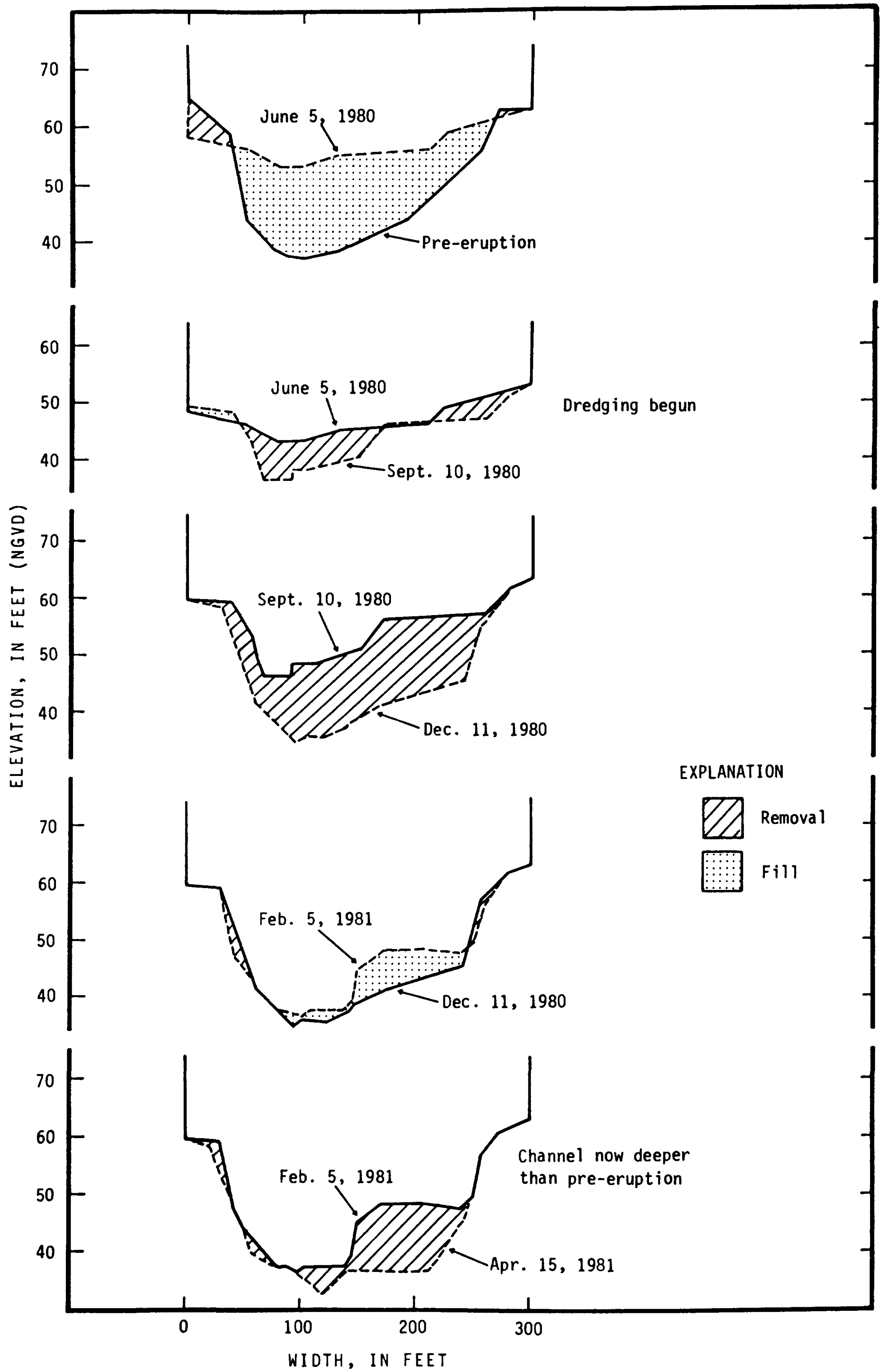

FIGURE 5.--Changes in channel geometry of the Toutle River at Interstate 5 crossing, Washington.

FLOOD CONDITIONS BEFORE AND AFTER DREDGING

Flood Elevations and Profiles

Hydraulic characteristics of the lower Cowlitz and Toutle Rivers were analyzed to compute potential flood elevations on the lower Toutle and Cowlitz Rivers prior to dredging (June 1980), during the course of the dredging operation, and after dredging (May 1981). The last hydraulic analysis for the lower Toutle River was in April 1981. Elevations were computed for a number of different discharges to allow the effect on different flood magnitudes to be examined. The largest discharge studied along the Cowlitz River was 86,500 ft^3/s. Prior to the eruption and mudflow this discharge had been equaled or exceeded at Castle Rock only twice in the 53 years since 1927 and only once since 1969 when Riffe (Davisson) Lake became operational for flood control (U.S. Geological survey, 1958, 1963, 1971-80). It is also the discharge that had been used as the 100-year flood for Federal Emergency Management Agency flood studies (Federal Insurance Administration, 1979a, 1979b, 1979c, and 1980) along the lower Cowlitz River prior to the eruption.

A comparison of elevation-discharge relations for the Cowlitz River for post-eruption and post-dredging conditions at Kelso, Longview, Lexington, and Castle Rock (figs. 6-8) shows the effects of dredging and levee work. For the survey of June 19, 1980, water-surface elevations computed by backwater analysis showed that Castle Rock and Lexington were in jeopardy of being inundated if a major flood were to occur. Kelso and Longview were not in great jeopardy if the levees remained effective. The risk that a major flood would occur in the immediate future was low, however, because the mountain snow was melted and the area was entering the driest time of the year (average monthly precipitation for July is only 0.75 inch). Assuming that the channel was stable at the end of dredging on May 11, 1981, a flood discharge of 86,500 ft^3/s would cause no flooding in any of those communities.

If channel conditions had been left as they were at the beginning of dredging, riverbanks at Lexington and Castle Rock (figs. 7 and 8) would be topped by flows of 22,000 and 28,000 ft^3/s, respectively. Annual peak discharges have exceeded 22,000 ft^3/s at Castle Rock in all but 2 years since 1927, and have exceeded 28,000 ft^3/s in all but 3 years. The town of Castle Rock, which is on the east bank and protected by a levee, would be flooded if flows exceeded 60,000 ft^3/s and overtopped the levee. Annual peak discharges have equaled or exceeded 60,000 ft^3/s at Castle Rock in 20 of the years since 1927 and in 4 years since 1969. The levees along Kelso and Longview (fig. 6) would contain a flood discharge of 86,500 ft^3/s in the channel, and those cities were protected as long as channel capacities were not further reducted. Although none of the historic flood peaks had occurred during the summer months, fall and winter storms were of obvious concern.

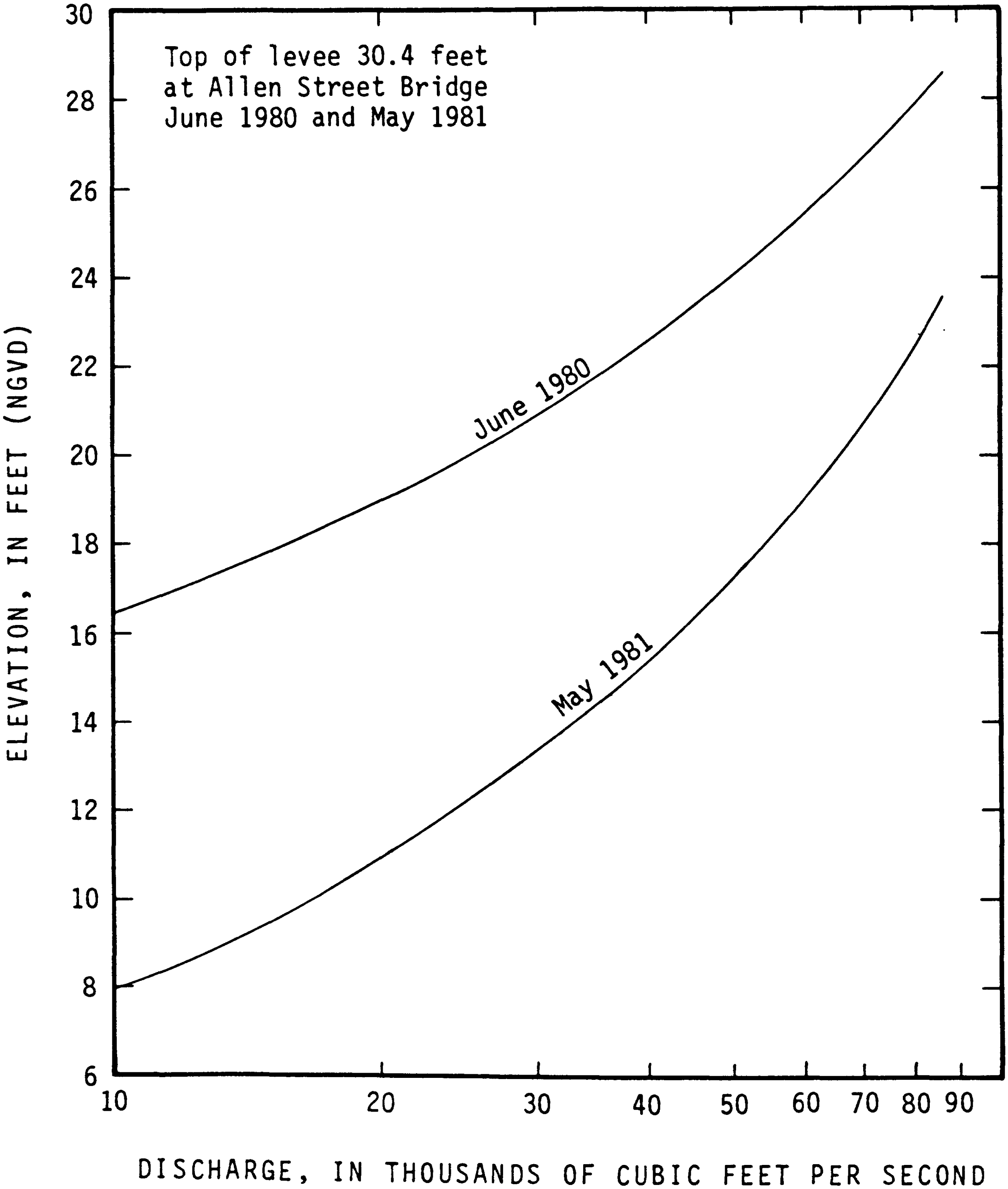

FIGURE 6.--Relation between water-surface elevation and discharge, Cowlitz River at Kelso/Longview, Washington.

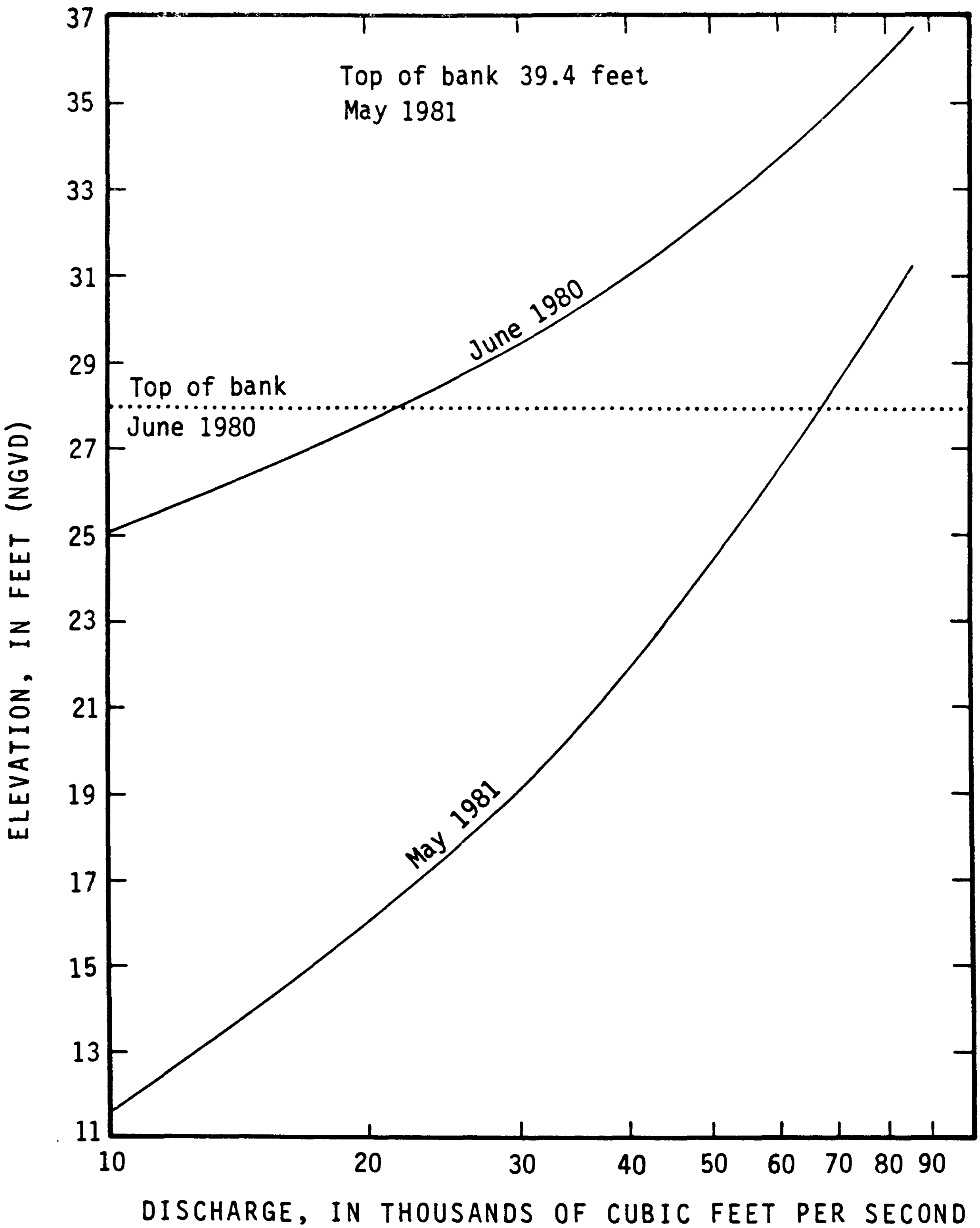

FIGURE 7.--Relation between water-surface elevation and discharge, Cowlitz River at Lexington, Washington.

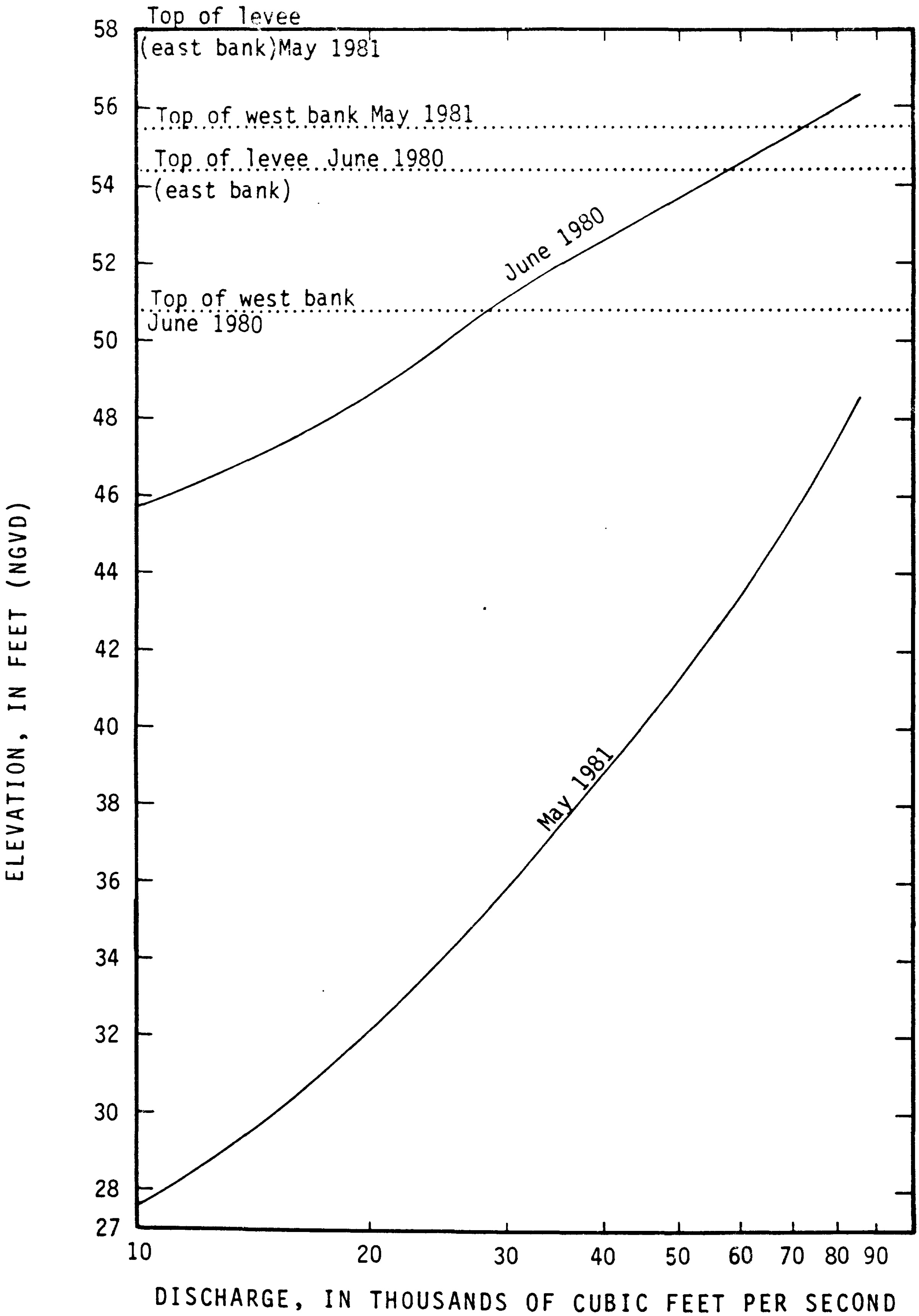

FIGURE 8.--Relation between water-surface elevation and discharge, Cowlitz River at Castle Rock, Washington.

The largest discharge studied along the Toutle River was 47,600 ft^3/s. This flow represents a pre-eruption flood of 100-year recurrence interval, as determined from equations given for winter-peak streams in a report evaluating a streamflow-data network in Washington (Moss and Haushild, 1978). It is a discharge that has not been equaled or exceeded (maximum recorded, 43,200 ft^3/s, 1977) during the 50-year period 1930-79 at the former Toutle River near Silver Lake gage (14242500), except by the May 1980 mudflow (U.S. Geological Survey, 1958, 1963, 1971-80).

Prior to dredging, a flow of 40,000 ft^3/s would have come in contact with the bridge structure at Interstate 5 (the main north-south highway in western Washington) where it crosses the Toutle River. Figure 9 shows the effect at the Interstate 5 bridge of dredging in the lower Toutle and in the Cowlitz Rivers. With the channel conditions that existed on April 15, 1981, the computed elevation for a flow of 40,000 ft^3/s was about 16 feet lower than the computed post-eruption (June 5, 1980) elevation.

Figures 10a and 10b compare water-surface profiles and streambed elevations for the lower Cowlitz and Toutle Rivers prior to and just after the mudflows, and also after dredging. Profiles were computed for many different discharges, but for clarity only the profiles for peak flows of 86,500 ft^3/s for the Cowlitz River and 47,600 ft^3/s for the Toutle River are shown. The profiles are constructed of straight lines drawn between the elevations computed for each particular discharge at each cross section of the river channel and flood plain.

Computed flood elevations on the Cowlitz River upstream from its confluence with the Toutle River, which had been raised approximately 11 feet by the mudflows, were lowered by as much as 14 feet by dredging operations between June 19, 1980, and May 11, 1981 (fig. 10). Similarly, computed flood elevations were lowered by about 8 feet at Castle Rock, raised (due to channel constriction) about 1 foot approximately a mile downstream of Castle Rock, and lowered about 5 feet at Lexington and about 4 feet at Kelso and Longview. Corresponding reductions in flood elevations along the Toutle River (fig. 10b) ranged from about 17 feet immediately upstream of Interstate 5 (about 0.3 mile upstream of its mouth) to about 5 feet at the upper study limits (about 1.7 miles upstream of the mouth). The post-eruption (pre-dredging) profiles are based on channel conditions as they existed on June 19, 1980. The post-dredging profiles reflect channel conditions of April 15, 1981, for the Toutle River and May 11, 1981, for the Cowlitz River, and apply for those conditions only.

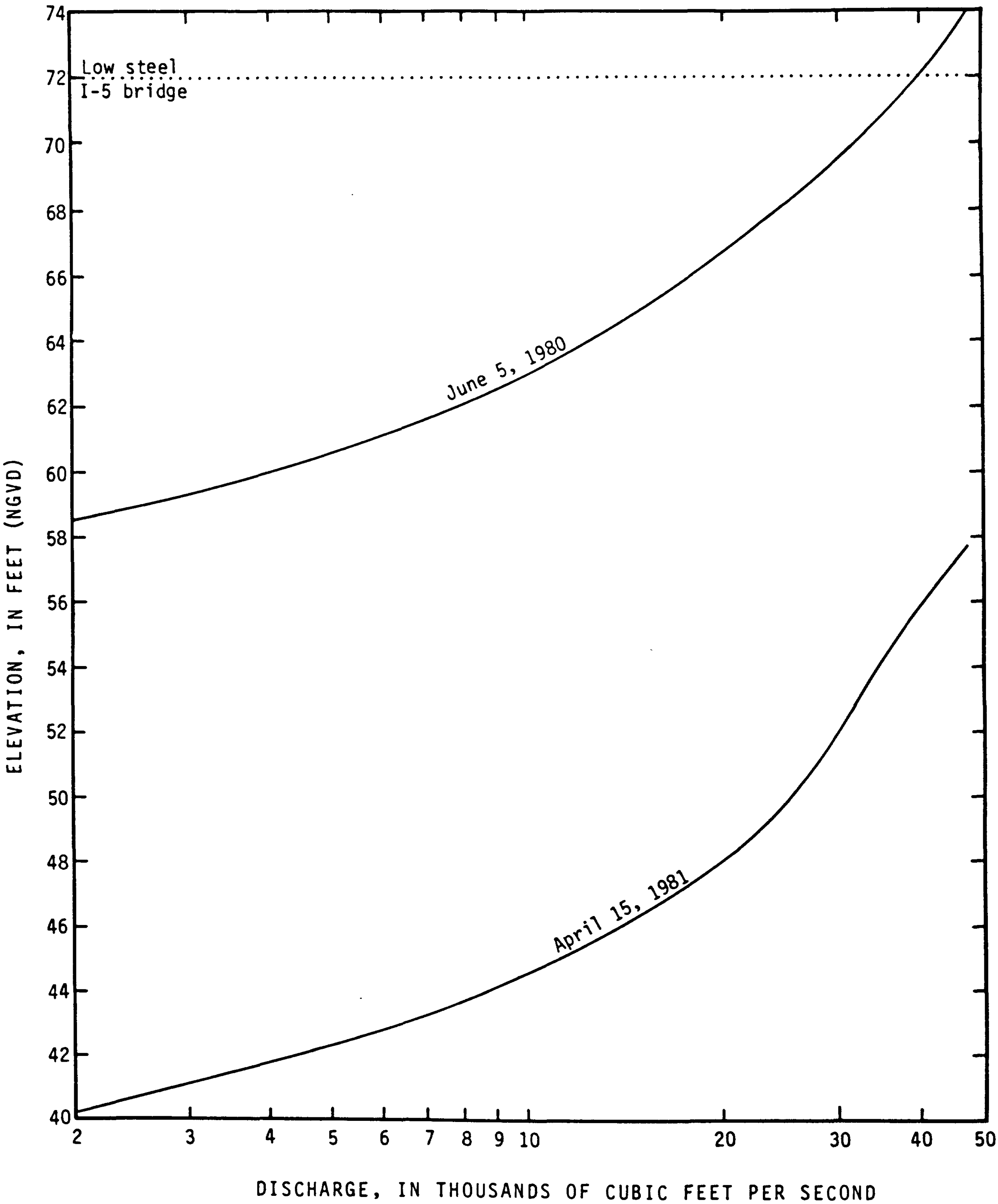

FIGURE 9.--Relation between water-surface elevation and discharge, Toutle River at Interstate 5 crossing.

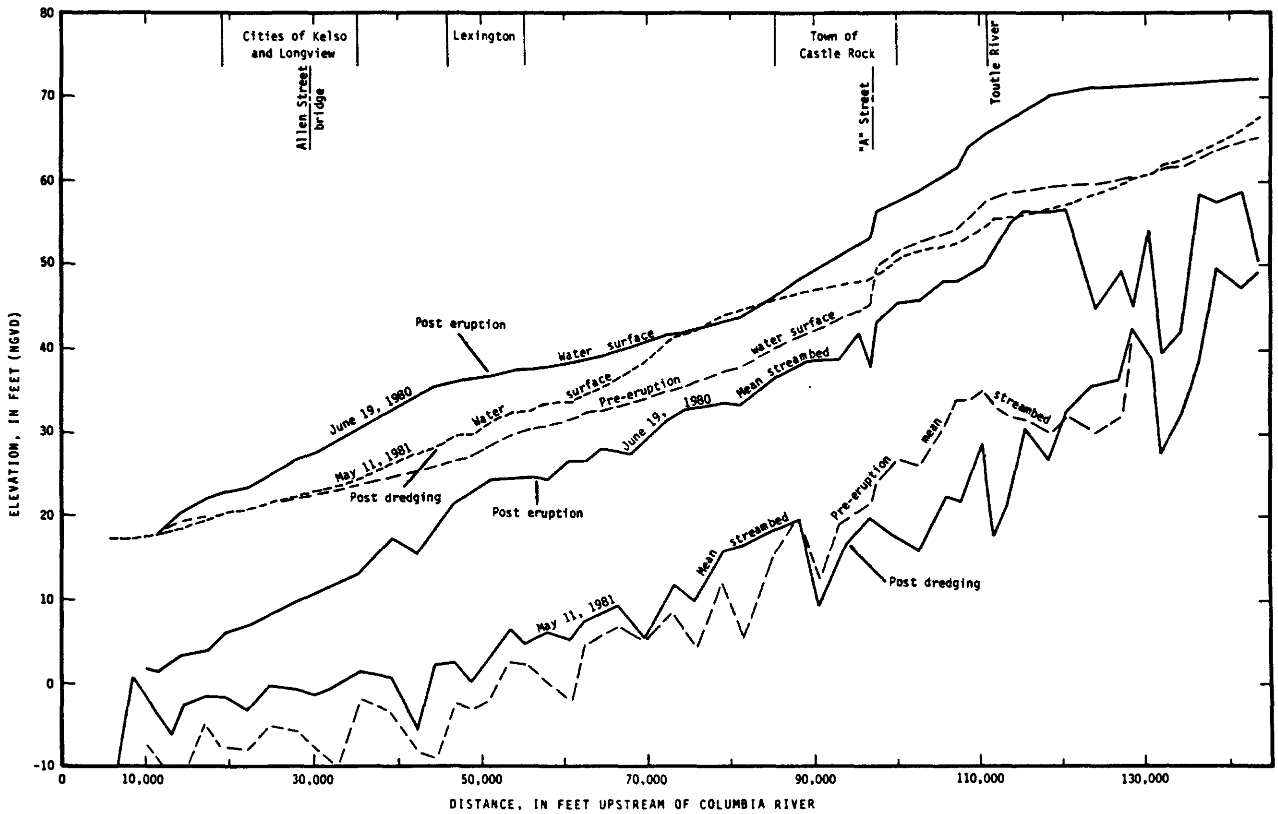

FIGURE 10a.--Flood profiles for discharge of 86,500 ft^3/s along the lower Cowlitz River.

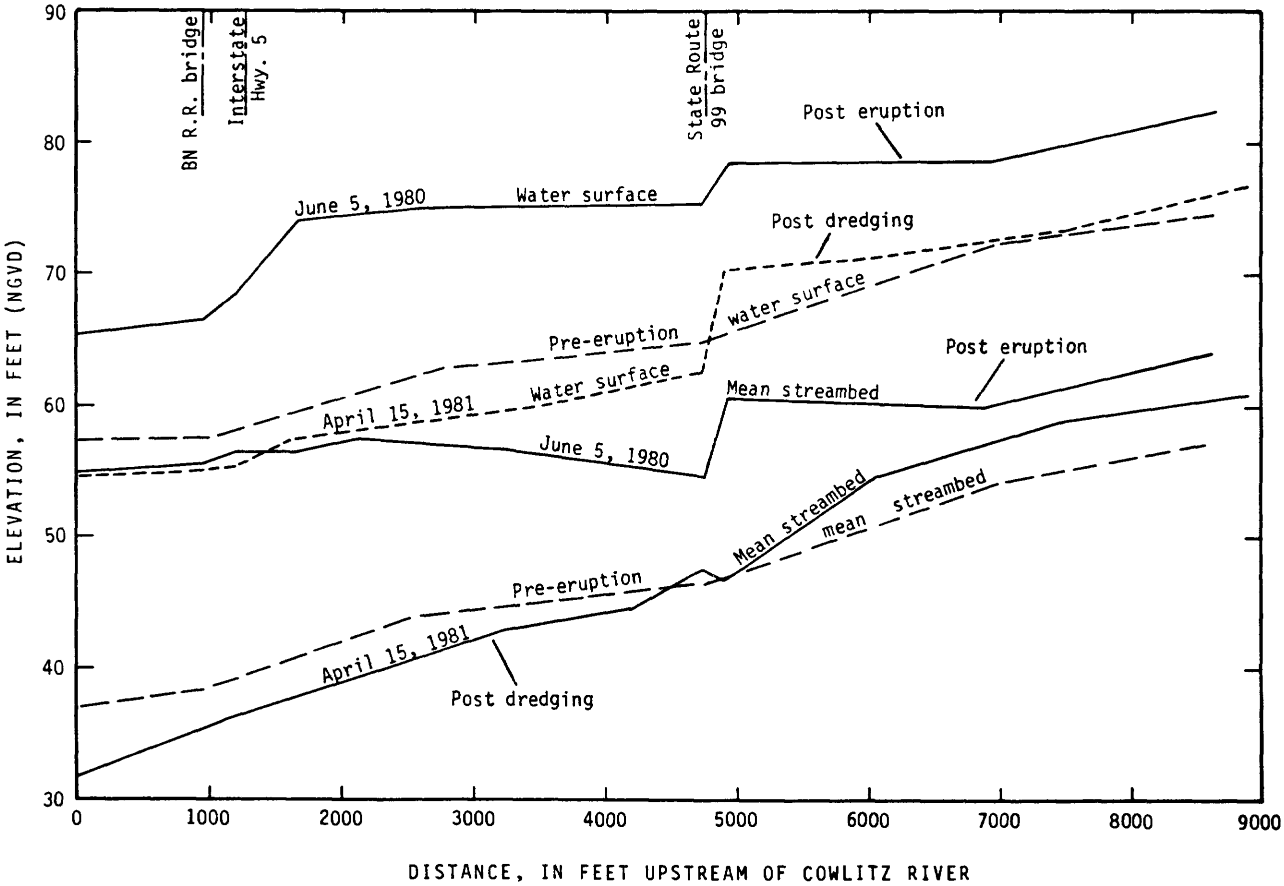

FIGURE 10b.--Flood profiles for a discharge of 47,600 ft^3/s along the Toutle River.

Flood-Inundation Maps

Figures 11-17 show the areas that probably would have been inundated along the lower Cowlitz River if a peak flow of 86,500 ft^3/s had occurred both before and after dredging along the Cowlitz River. Figure 15 similarly shows potential areas of inundation along the lower Toutle River for a peak flow of 47,600 ft^3/s. Included in the inundated areas for non-dredged conditions are a major portion of the business district of the city of Castle Rock, all of the community of Lexington, and a small section of northeast Kelso. Traffic would have been disrupted on the West Side Highway (SR411) along the west bank of the Cowlitz River where floodwater would have either inundated or washed away the highway in several areas. The city of Kelso waterworks plant probably would have been inundated, creating a hardship for the city's residents. On the basis of the conditions of May 11, 1981, all of the aforementioned inundated areas would be free of flooding from similar discharge after dredging.

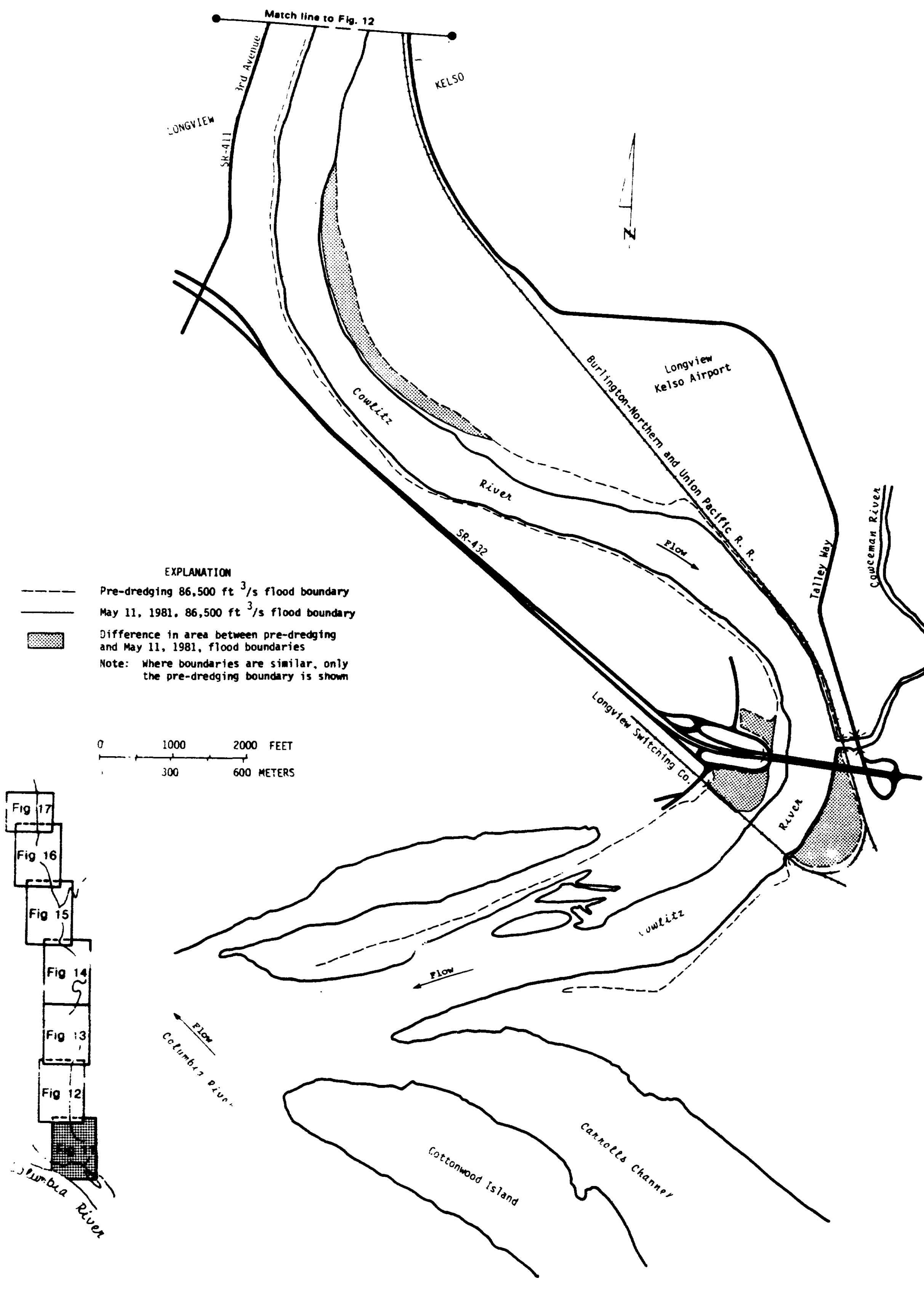

FIGURE 11.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

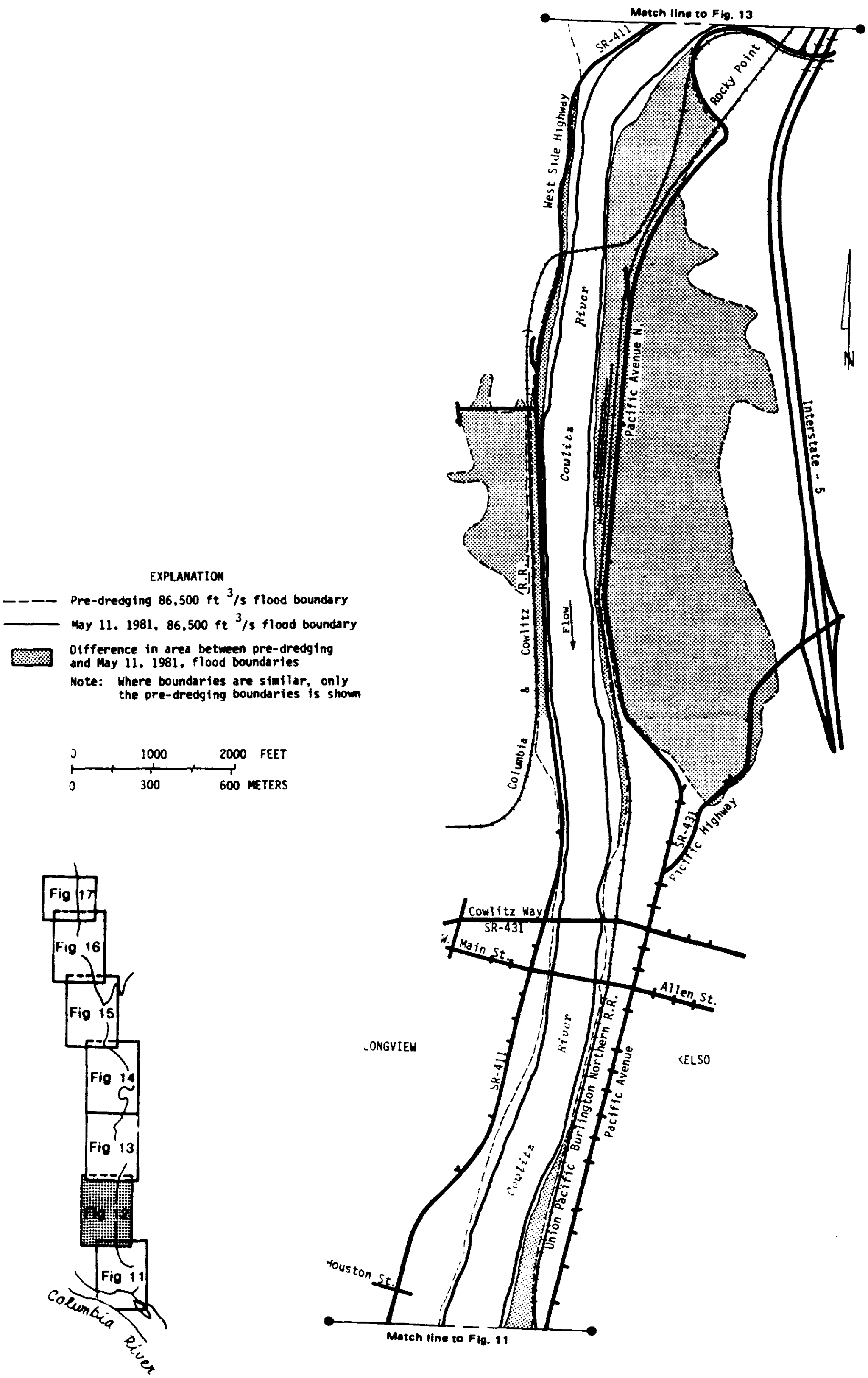

FIGURE 12.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

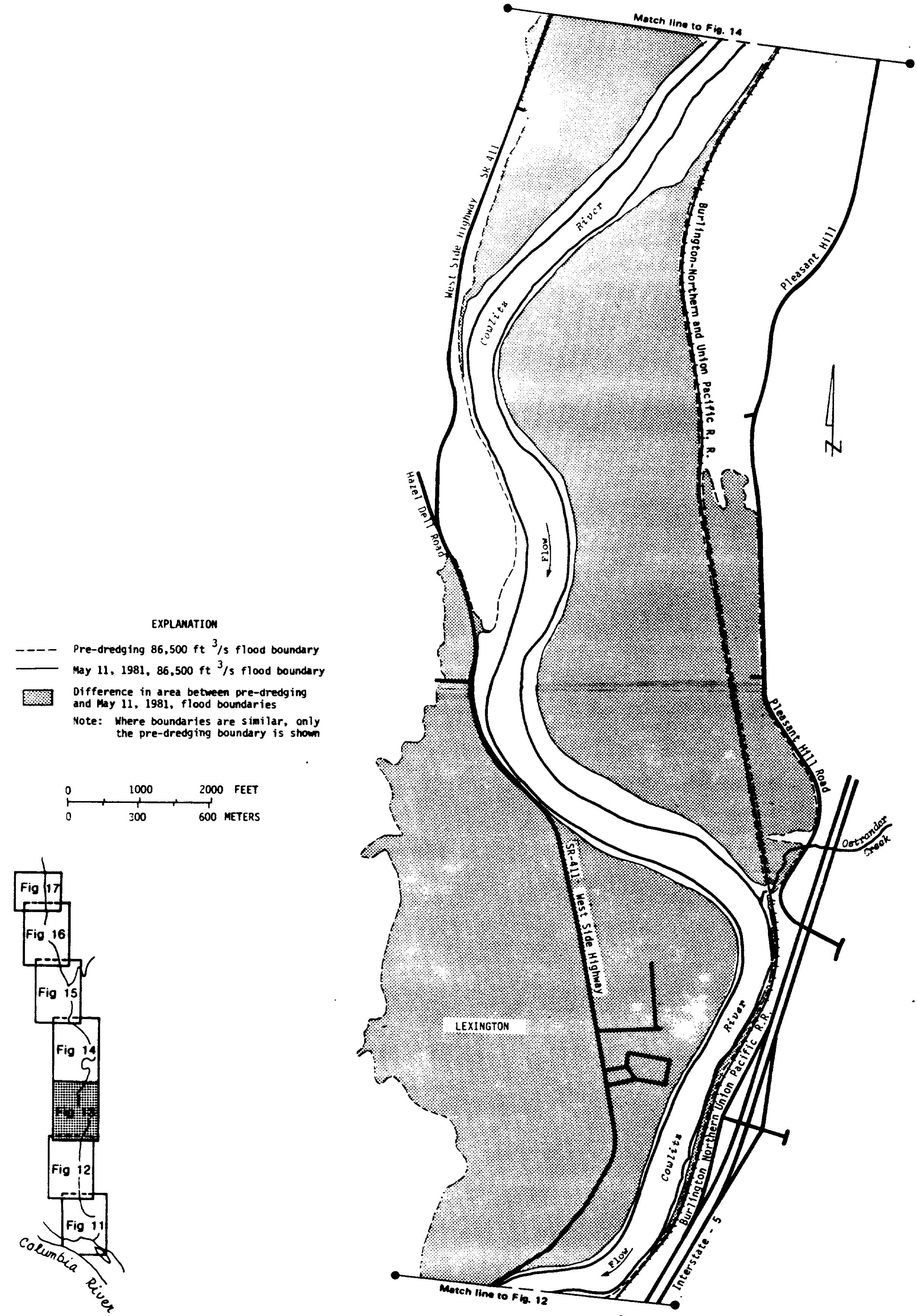

FIGURE 13.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

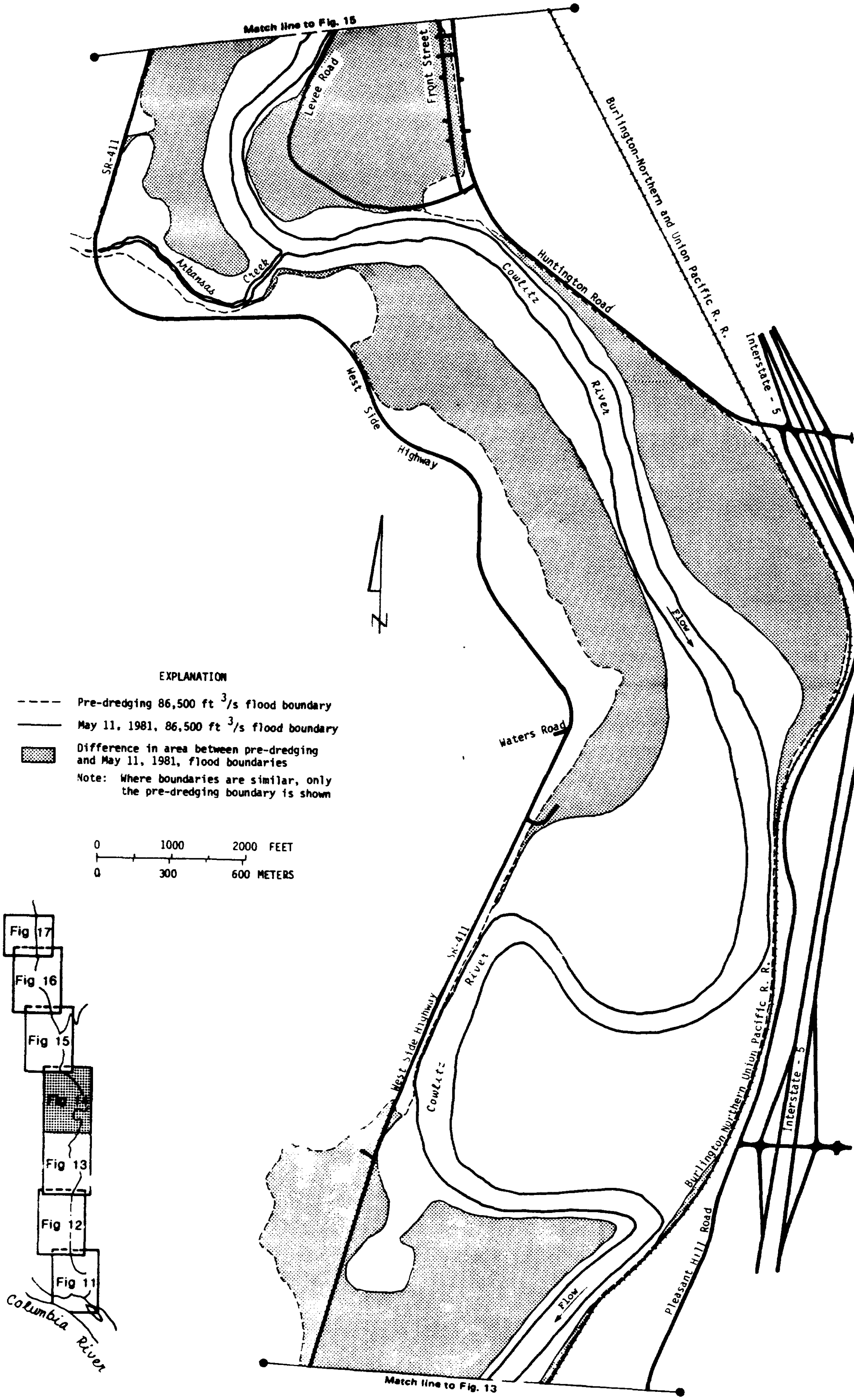

FIGURE 14.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

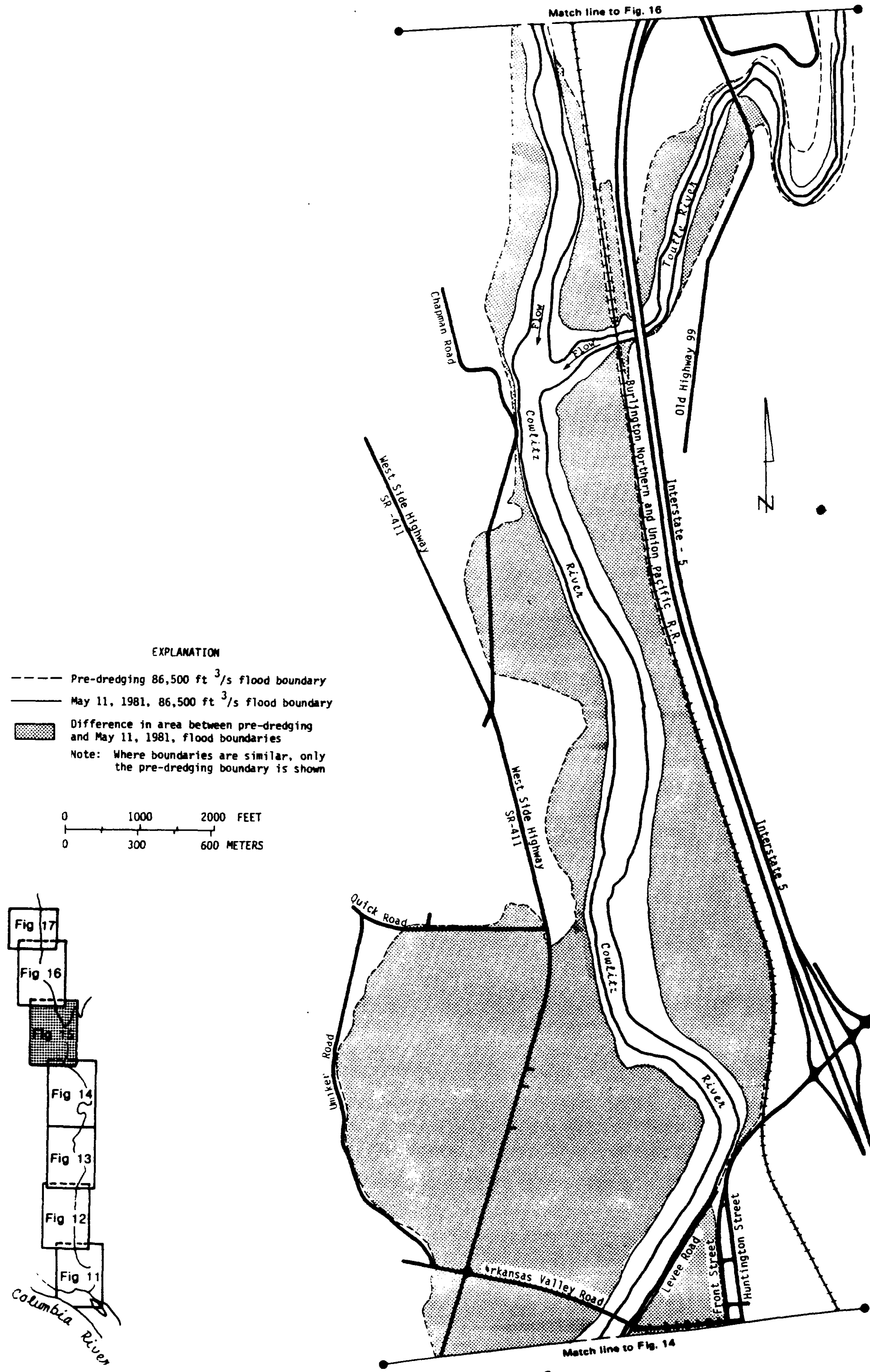

FIGURE 15.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

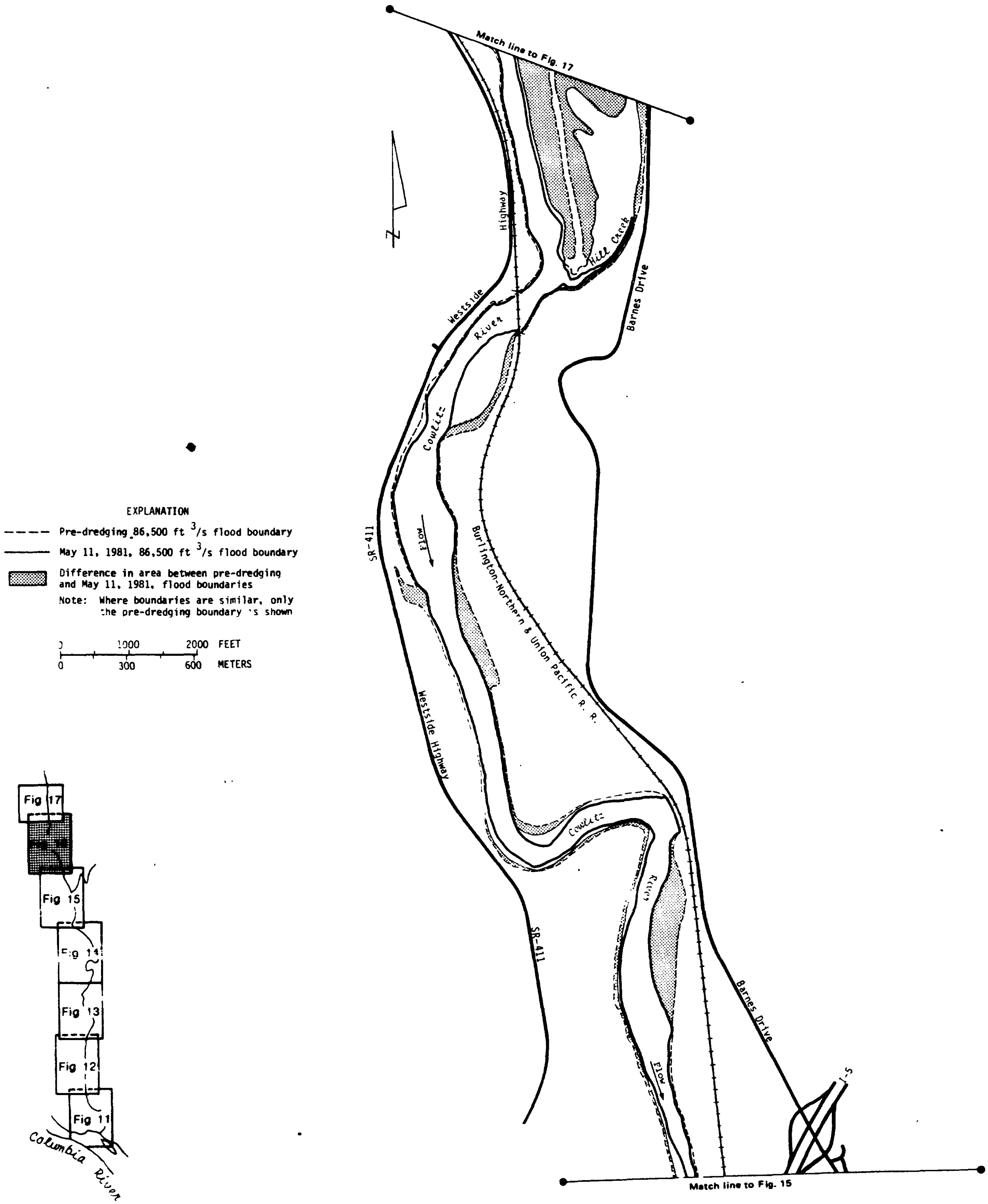

FIGURE 16.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

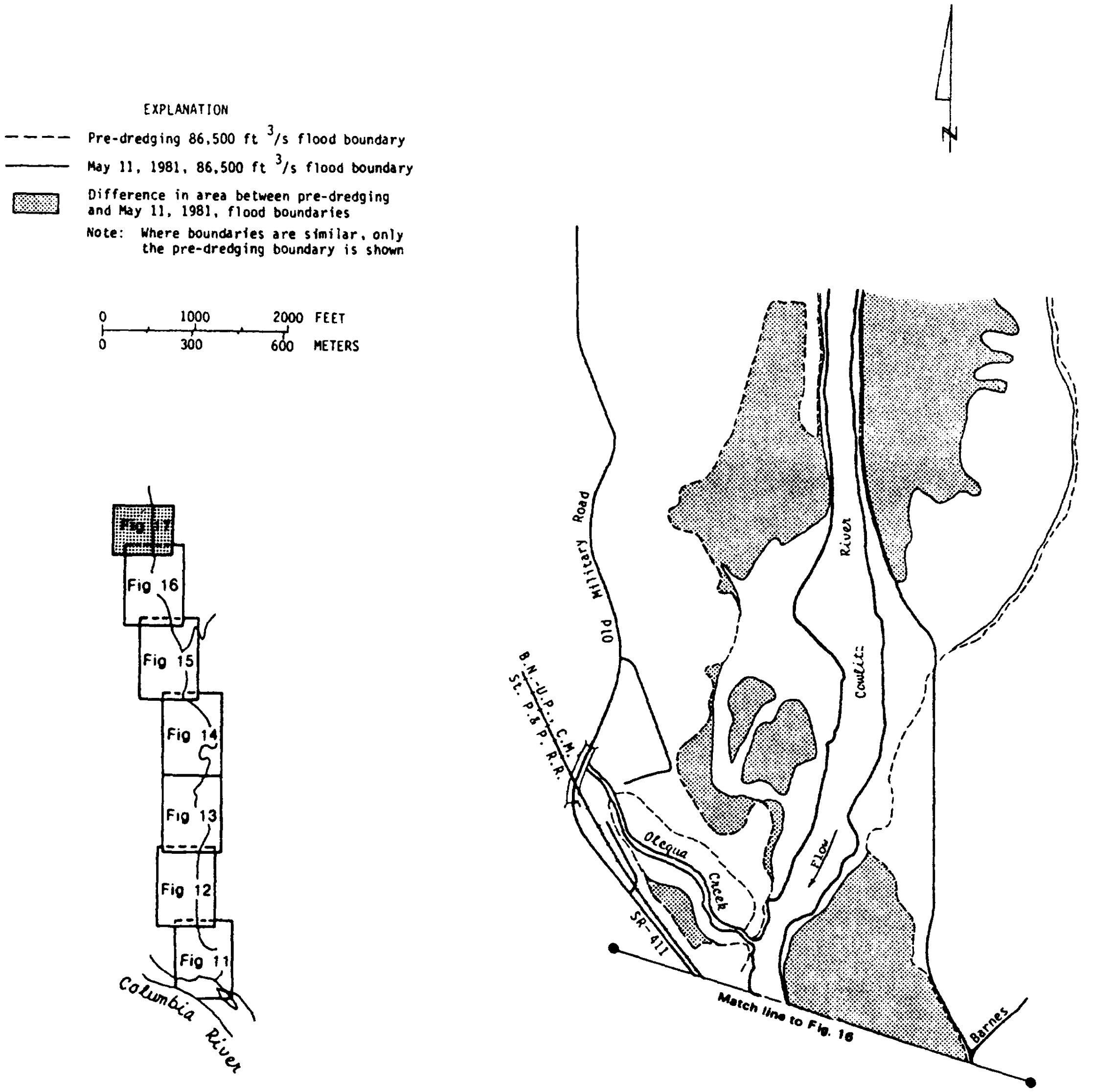

FIGURE 17.--Inundation map for a discharge of 86,500 ft^3/s along the Cowlitz River.

FLOOD-ELEVATION CHANGES DURING DREDGING

Monitoring of potential flood elevations was continued throughout the period because the capacity of the dredged channel could have deteriorated very rapidly during high flows by deposition of new sediments eroded from the upper Toutle River basin and from dredged spoils eroded from the flood plains. Figure 18 shows chronologically the computed flood elevations for a flood discharge of 86,500 ft^3/s at the three major population areas along the Cowlitz River from the date of the eruption until the end of dredging. The initial increases in flood elevation, due to the mudflow deposits following the eruption, were about 6 feet at Kelso/Longview, 8 feet at Lexington, and 6 feet at Castle Rock.

Although dredging operations along the lower Cowlitz River were begun in June 1980, they had little effect on flood elevations until September 1980, after about 17 million cubic yards of sediment had been dredged from the river (U.S. Corps of Engineers, written commun., 1980). The effectiveness of removing the large deposits of sediment from the lower Cowlitz River after September 1980 is shown in figure 18 by the continued reduction in computed flood elevations. The May 11, 1981, computed elevation for a flood of 86,500 ft^3/s at Castle Rock was about 1 1/2 feet lower than the elevation computed for pre-eruption conditions. At Kelso/Longview, and Lexington the elevations were still above those prior to the eruption and mudflow, but only about 1 foot and 2 feet, respectively.

Elevations for a large flood (86,000 ft^3/s) after dredging were higher than pre-eruption elevations at some places for two major reasons: first, the effectiveness of flood plains for carrying floodwater had been largely eliminated because the flood plains had been used as storage areas for dredged spoils, thus forcing the channel to carry all floodwaters; and second, additional sediment was continually deposited in the channels.

Additional sediment was transported into the lower Toutle and Cowlitz Rivers from the erodible materials in the upper Toutle River basin even while mudflow sediment was dredged from the Cowlitz River. Most of that additional sediment is transported and deposited during periods of high flow. Some of the additional deposits in the channel are also caused by erosion of the riverbanks and the dredged spoils stored adjacent to the streams. The sediment deposition associated with the moderate high flow that occurred in late December 1980 at Castle Rock is evidenced in figure 18 by an increase in early January 1981 in the computed elevation for a flood of 86,500 ft^3/s.

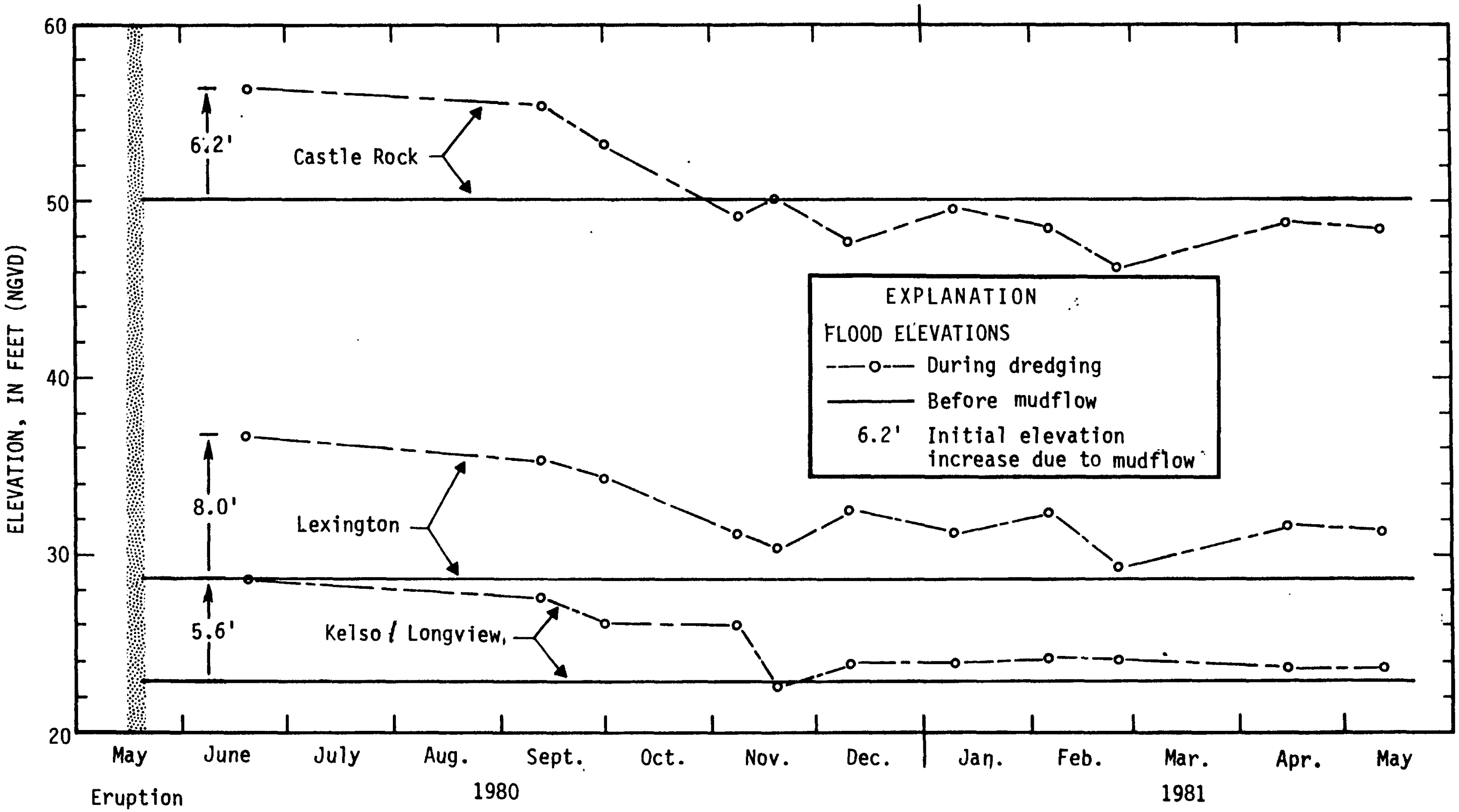

FIGURE 18.--Flood elevations for peak discharge of 86,500 ft^3/s along the Cowlitz River at Castle Rock (at "A' St. bridge), Lexington (about 9 mi upstream from mouth), Kelso / Longview (at Allen St. bridge) at selected times during dredging.

The potential for flooding will be present as long as the massive mudflow deposits in the Toutle River basin remain available for transport into the Cowlitz River. The unleveed riverbanks, which are easily erodible, and the dredged spoils on the adjacent flood plains are also available for channel deposition. The potential for higher flood elevations increases each time a high runoff event and sediment deposition occur if the sediments are not subsequently removed. Figure 19 shows the changes that took place in the Cowlitz River at Castle Rock during the high water in December 1980. On December 26, a flow of 38,100 ft^3/s was measured at an elevation of 37.0 feet. Three days later on December 29, a flow of 28,600 ft^3/s was measured at an elevation of 37.9 feet. The channel had filled an average of 10 feet and the capacity to carry water was significantly reduced. In this case, the newly deposited sediments were removed by dredging soon after the event. After dredging, if not prevented, new deposits can be expected to accumulate with each new high-runoff event, and the chance of flooding will increase accordingly.

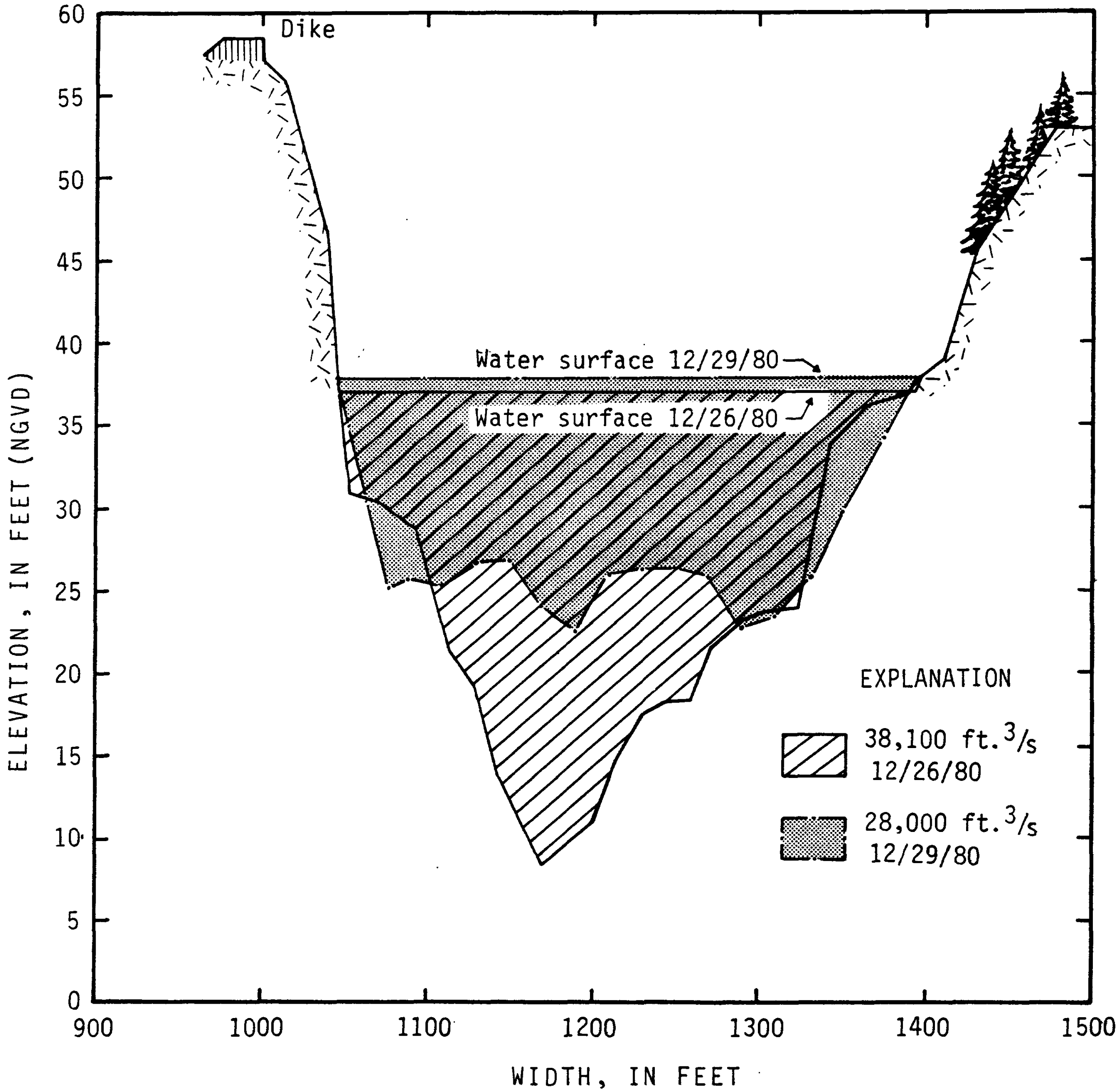

FIGURE 19.--Channel geometry of the Cowlitz River at Castle Rock, Washington, on December 26 and 29, 1980.

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