Channel Conditions in the Lower Toutle and Cowlitz Rivers Resulting from the Mudflows of May 18, 1980

GEOLOGICAL SURVEY CIRCULAR 850–C

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By R. E. Lombard, M. B. Miles, L. M. Nelson, D. L. Kresch, and P. J. Carpenter

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FOREWORD

On May 18, 1980, after more than a month of earthquakes and eruptions, Mount St. Helens, in southwestern Washington, exploded in a volcanic eruption more violent than any in the conterminous United States during the 20th century. A lateral blast of hot gas and rock particles devastated an area of about 150 square miles on the northern side of the mountain knocking down trees to a distance of 15 miles. Several minutes later, a giant ash cloud rose to about 60,000 feet. Winds then carried the ash cloud across the United States, with heavy fallout and deposition in eastern Washington and parts of Idaho and Montana. Earlier, smaller eruptions deposited ash in western Washington and parts of Oregon and Canada.

The hydrologic effects of the May 18 eruption have been both widespread and intense. During the eruption, a massive debris avalanche moved down the north flank of the volcano depositing about 3 billion cubic yards of rock, ice, and other materials in the upper 17 miles of the North Fork Toutle River valley. The debris deposits are about 600 feet thick in the upper reaches of the valley. Following the avalanche, runoff from the melted glaciers and snow, and possible outflow from Spirit Lake, caused an extraordinary mudflow in the North Fork Toutle River. The mudflow shattered and uprooted thousands of trees, destroyed most of the local bridges, and deposited an estimated 25,000 acre-feet of sediment in the Cowlitz River channel. A considerable amount of additional sediment was conveyed through the lower Cowlitz into the Columbia River where it deposited and formed a shoal that blocked the shipping channel. Mudflows also occurred in the South Fork Toutle River and in tributaries on the east flank of Mount St. Helens which enter Swift Reservoir.

As part of a concerted Geological Survey effort to study the volcanic event and to identify potential hazards, Survey hydrologists have mounted an intensive program to document the hydrologic effects of the eruptions. The major initial hydrologic findings are reported in this circular series. Quick, useful assessment was made possible only because the Survey has long conducted extensive water-resources investigations in the affected areas of Washington, Oregon, and Idaho. Hence, there was a well-defined basis for identification and documentation of the types and magnitudes of hydrologic changes.

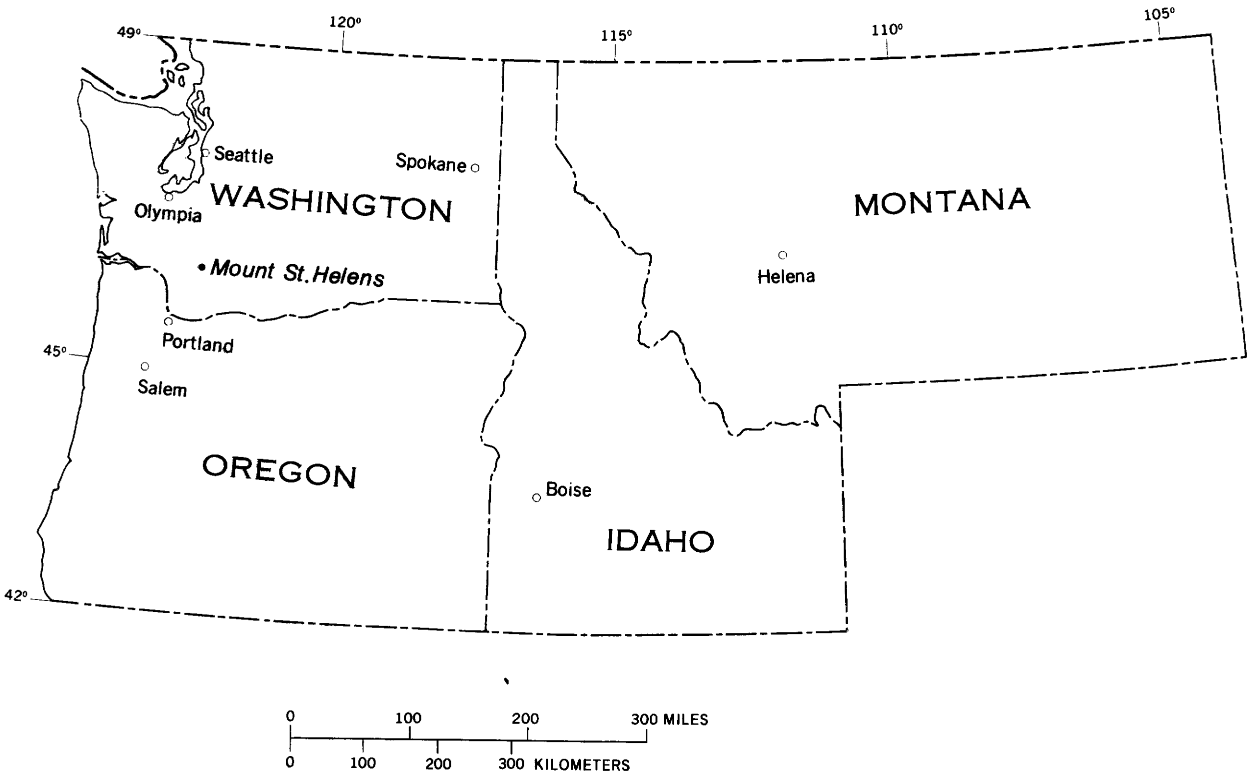
The Geological Survey Circular 850, "Hydrologic Effects of the Eruptions of Mount St. Helens, Washington, 1980," consists of individually published short chapters that emphasize data collection activities, field observations, and initial comparisons of pre- and post-eruption conditions. The series will cover hydrologic events occurring on May 18 in the Toutle and Cowlitz River; physical alteration of the Toutle River system; the chemical and physical quality of precipitation, streams, and lakes affected by volcanic ash fall; ash-leaching studies; and Mount St. Helens glaciers.

Doyle G. Frederick

Doyle G. Frederick
Acting Director

METRIC CONVERSION FACTORS

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter (m)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/sec)	.02832	Cubic meter per second (m^3/s)



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CHANNEL CONDITIONS IN THE LOWER TOUTLE AND COWLITZ RIVERS RESULTING FROM THE MUDFLOWS OF MAY 18, 1980

By R. E. LOMBARD, M. B. MILES, L. M. NELSON, D. L. KRESCH, and P. J. CARPENTER

ABSTRACT

The volcanic eruption of Mount St. Helens on May 18, 1980, triggered mudflows on the South and North Forks of the Toutle River that deposited up to 15 ft of sediment in the channels of the lower Toutle and Cowlitz Rivers. The thickness of the sediment deposited on the flood plain ranged from almost none just upstream from Kelso to about 10 ft near Castle Rock and the mouth of the Toutle River. Existing levees in Castle Rock, Kelso, and Longview contained the mudflows and prevented flooding of those communities. The mudflow reduced the within-channel flow capacity, except at Kelso and Longview where the effect was minor. The potential exists for unusually high flood levels, up to 10-ft higher than normal, from autumn and winter precipitation. Planned flood-alleviation measures include dredging, additional levees, and sediment-retention structures. A flood-warning system has been established, and the current potential for flooding is being monitored through continued surveillance of the river system.

INTRODUCTION

The explosive volcanic eruption of Mount St. Helens on May 18, 1980, triggered mudflows in several streams that head on the flanks of the volcano. Mudflows that originated in the North and South Forks of the Toutle River were especially significant because of their immense magnitudes and consequent destruction. These two mudflows deposited large volumes of sediment in the North and South Forks of the Toutle River; and in the Toutle, lower Cowlitz, and Columbia Rivers (see fig. 1). In the lower Toutle and Cowlitz River valleys as much as 15 ft of mud and debris were deposited in the river channels, with up to 10 ft on the adjacent flood plains. These deposits destroyed buildings, covered agriculturally productive bottomlands, killed extensive tracts of timber, and seriously reduced the flow carrying capacities of the channels of the Cowlitz and Toutle Rivers. In addition, the volcanic eruption provided immense volumes of erodible material in the upper Toutle River system that potentially could be transported into the lower reaches of the Toutle and Cowlitz Rivers to further impact the channels.

The potential for significant flooding was immediately evident. More than 40,000 people live in the areas affected by the mudflow deposits and Interstate Highway 5, the major north-south highway in western Washington, was at risk. Flood mitigation measures were begun immediately and included such activities as channel dredging, levee raising, reservoir construction, and flood warning systems.

This report describes: (1) changes in the channels and flood plains of the lower Toutle and Cowlitz Rivers as a result of the May 18–19, 1980, mudflows; (2) the flood hazards that existed in the Cowlitz River immediately after the mudflows; (3) the flood mitigation system created. Information on the morphologic changes resulting from the mudflows was obtained by field surveys and observations of May and early June 1980. Potential flood stages and inundated limits reported herein were defined by the Geological Survey from computer models for channel conditions observed following the mudflow deposition. Even though the flood potential obviously would be altered by the flood mitigation activities and possibly by subsequent mudflows, they are reported here to document the magnitude of the hazard that existed immediately after the eruption.

THE MUDFLOWS

Mudflows are large masses of water saturated rock debris of various sizes that move downslope as

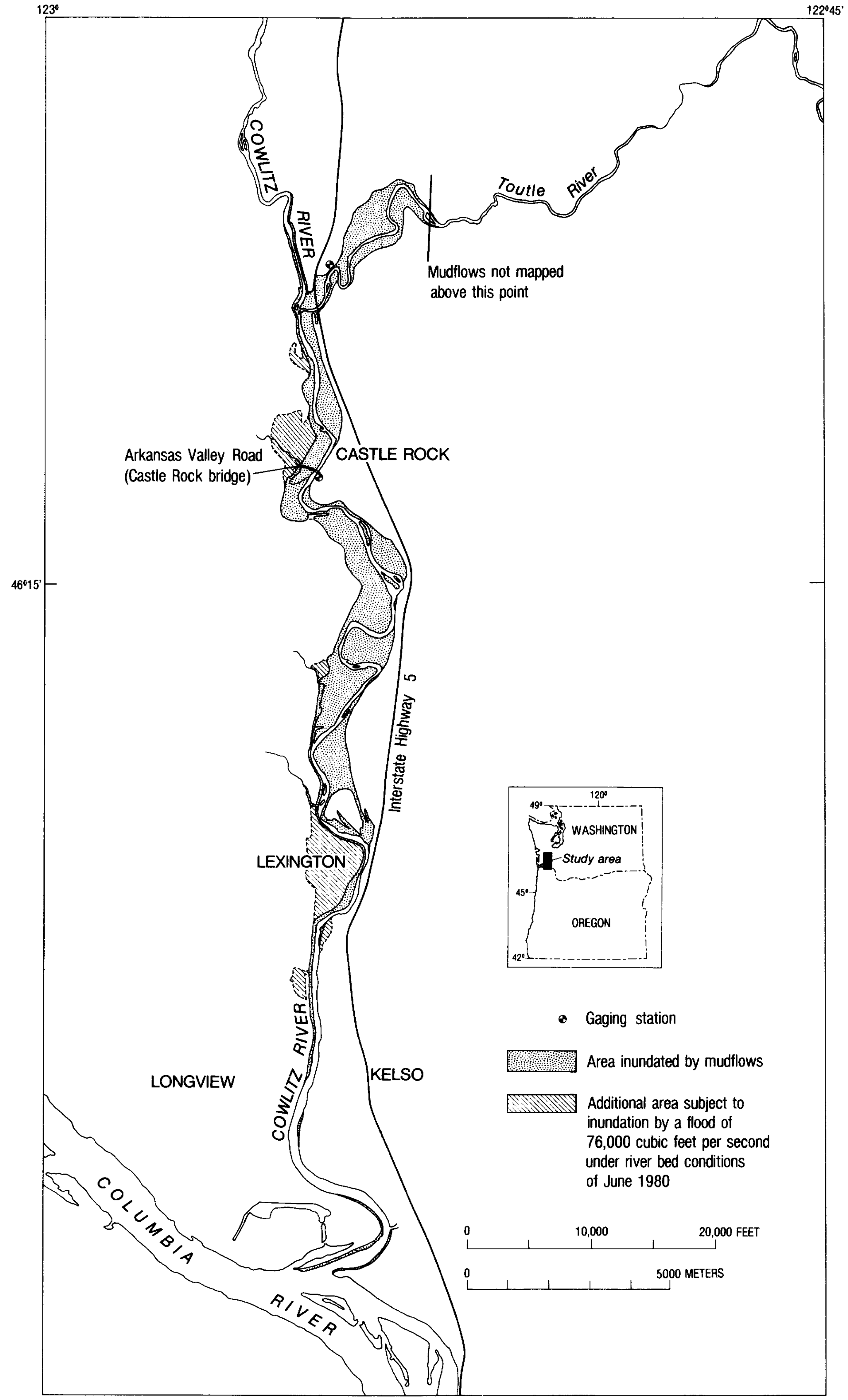

FIGURE 1. - Extent of inundation by mudflows of May 18, 1980, along the lower Toutle and Cowlitz Rivers.

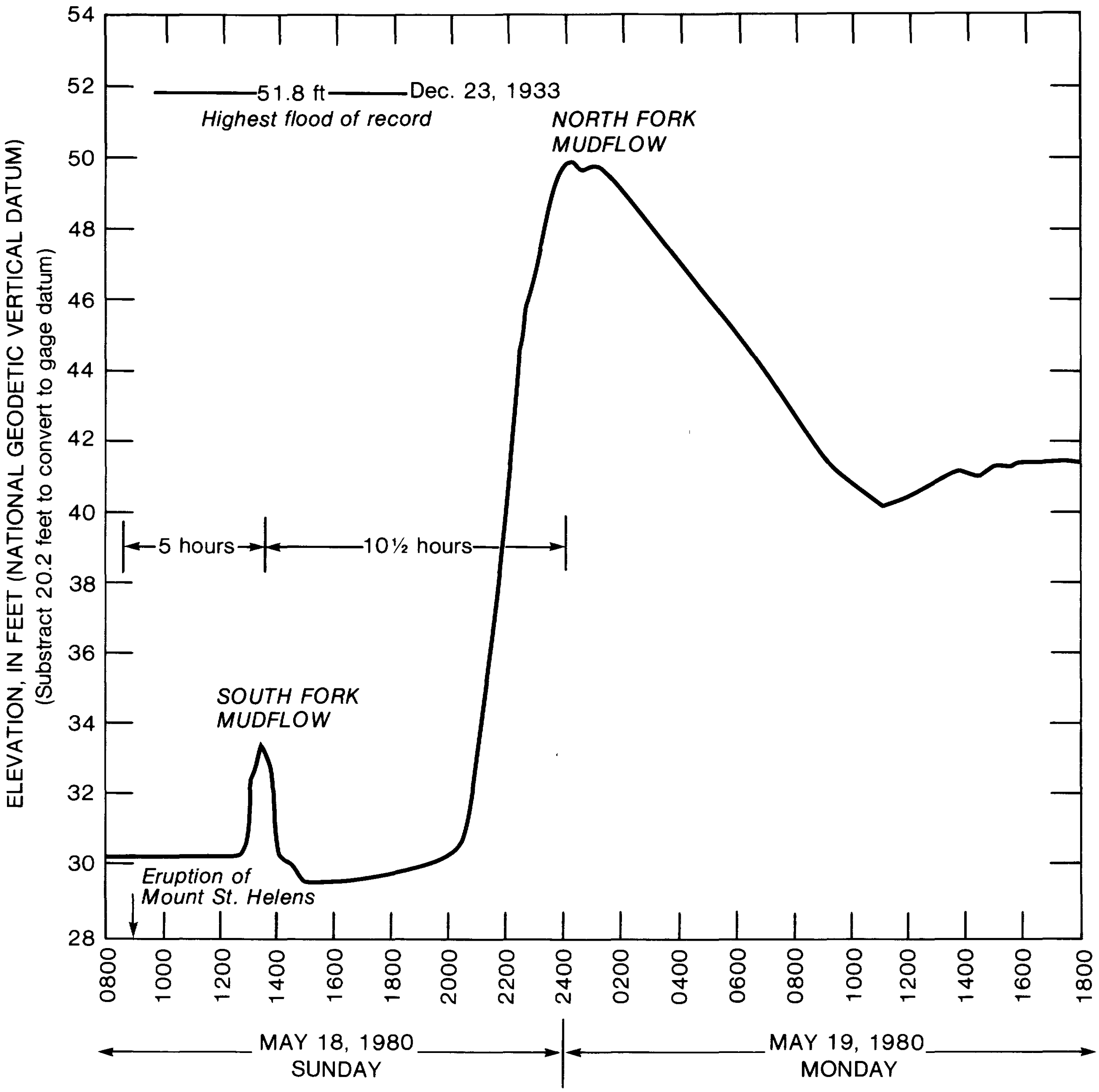

FIGURE 2. - River stage, Cowlitz River at Castle Rock, Washington, May 18–19, 1980.

fluids under the influence of gravity. Stratigraphic evidence indicates that mudflows have commonly occurred when Mount St. Helens erupts (Crandall and Mullineaux, 1978). The explosive eruption of May 18 triggered large mudflows in the Toutle and Lewis River drainage systems, and small mudflows in the Kalama River system (Cummans, 1981).

Two large mudflows originated in the Toutle system, which moved on through the lower Cowlitz River into the Columbia River. The first came from the South Fork Toutle River; the second from the North Fork (Cummans, 1981). Figure 2 shows the timing of the mudflows in the Cowlitz River as Castle Rock, Washington. At noon on May 18, the river stage at the Castle Rock Bridge was 30.2 ft. The peak stage of the South Fork mudflow occurred at about 1:30 p.m. (1330) when the stage reached 33.4 ft. The level then quickly dropped, returning to 30.2 ft by 2:15 p.m. (1415). The South Fork mudflow was confined entirely within the channel of the Cowlitz River, but the associated deposition is unknown, because channel conditions were soon altered by the larger North Fork mudflow.

At about the same time (1:30 p.m. (1330) on May 18) that the first mudflow peaked at Castle Rock, a second larger mudflow was developing on a massive debris deposit in the devastated upper part of the North Fork Toutle River valley (Cummans, 1981). This massive and highly destructive mudflow moved more slowly than the South Fork mudflow, with the peak stage at Castle Rock (fig. 2) occurring around 12 midnight (2400) on May 18. The peak stage of the second mudflow was 49.8 ft, 16.4 ft higher than the first mudflow. The North Fork mudflow spilled over the flood plain, leaving deep deposits of sand, volcanic ash, and gravel-size pumice on the flood plain and in the channel. The aerial extent of the inundation is shown in figure 1.

As shown in figure 2, the shape of the hydrograph beginning at about 11:00 a.m. (1100) on May 19 is indicative of massive sediment deposition in the channel following the North Fork mudflow. The deposition raised the riverbed, and reduced the capacity of the channel to convey water. For example, at 8:00 a.m. (0800), on May 18, a flow of 6,160 cubic feet per second occurred at a river stage of 30.1 ft. In contrast, at 8:00 a.m. (0800) on May 20 (not shown), a similar flow of 6,140 cubic feet per second occurred at a river stage of 42.4 ft – 12.3 ft higher than before the mudflows.

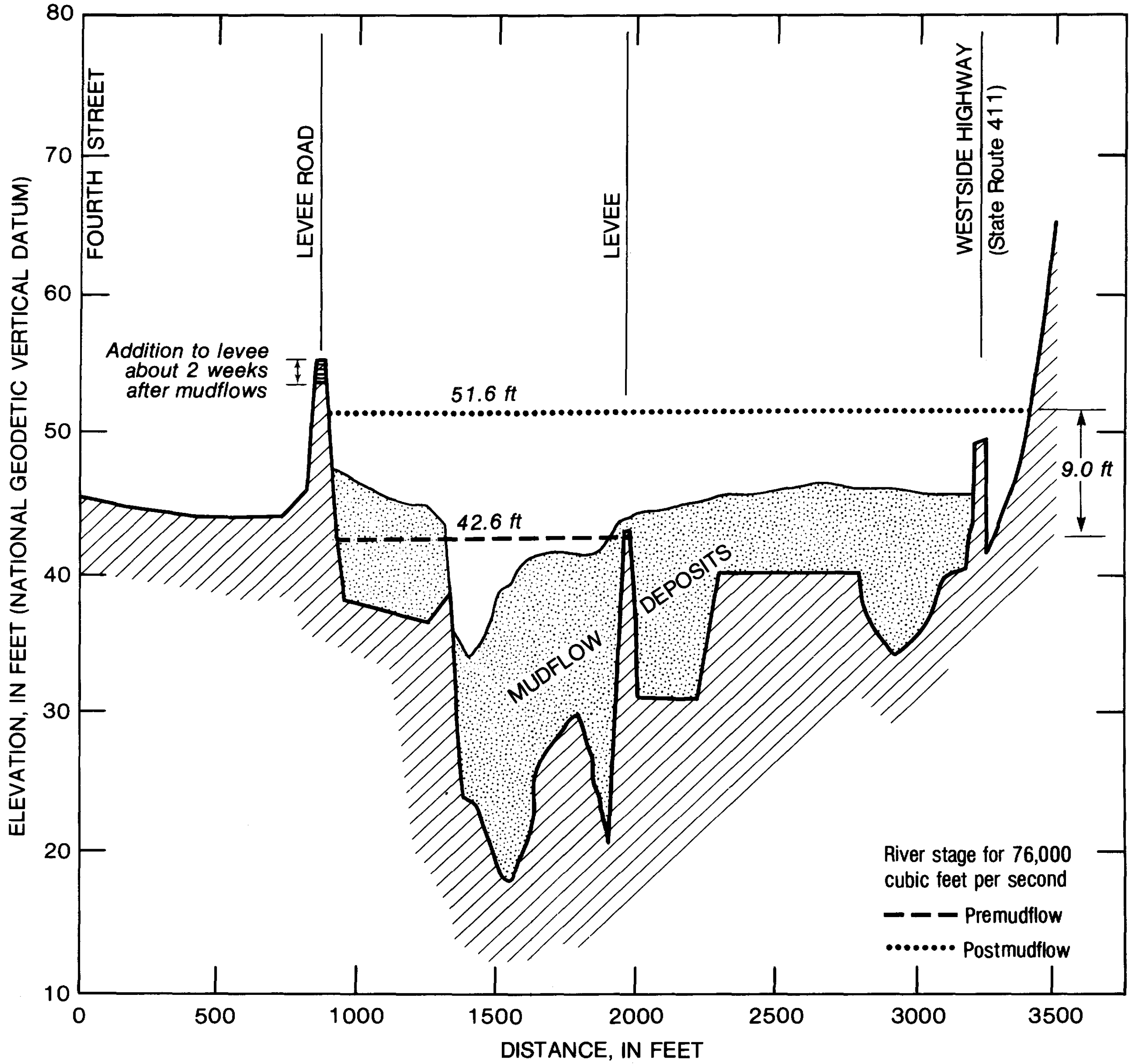

FIGURE 3. – Channel and valley conditions near Castle Rock, Washington, prior to and after the mudflows of May 18, 1980. The cross section is located 1,400 ft downstream from the Castle Rock Bridge.

EFFECT OF MUDFLOWS ON CHANNEL AND FLOOD PLAIN

Prior to the mudflows, the lower Toutle and Cowlitz Rivers had well-defined channels, confined in places by artificial levees. Figure 3 compares the pre- and postmudflow character of a cross section through the Cowlitz River and flood plain, 1,400 ft downstream from the Castle Rock Bridge. At this location, the North Fork mudflow was contained by the east bank (left hand side) levee, but overtopped the west side levee, leaving thick deposits of sediment between the levee and the Westside highway. Particularly evident in the cross section are: (1) the great thickness of deposits within the channel, and (2) the smoothing of the overbank profile on the west bank. The average depth of sediment deposited over the entire cross section was 9.3 ft. Within the channel (levee to levee), deposition raised the low point (thalweg) by 16.3 ft.

In the Castle Rock area, the North Fork mudflow failed to top the 1.5-mile long east bank levee which was built to protect the city; in places, however, the flow came within inches of the top. At many other locations along the Toutle and lower Cowlitz Rivers, the mudflows were not contained by levees or roads and, hence, overflowed and left considerable deposits on the flood plain (fig. 1). In general, the thickness of the overbank deposits decreased in a downstream direction.

Downstream from Lexington, few overbank deposits occurred, and in the vicinity of Kelso and Longview (fig. 1), levees completely confined the mudflows to the channel. Part of the North Fork mudflow also moved about 2 ½ miles upstream in the Cowlitz River above the Toutle River

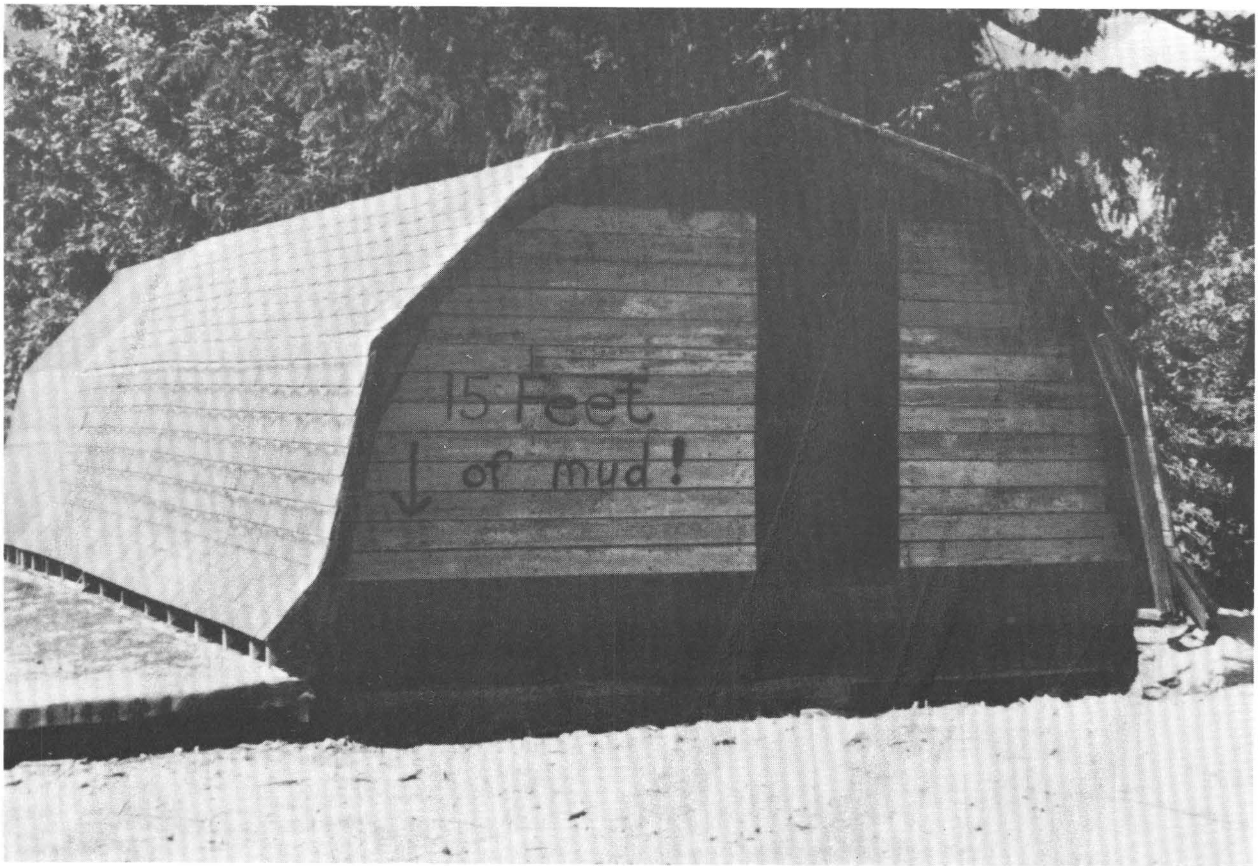

FIGURE 4. - After mudflow deposits of 15 ft, only the loft area of this barn is above ground level. The barn is located on the east bank of the Cowlitz River approximately 1 mile south of Castle Rock.

FIGURE 5. - Mudflow damage to farmhouse located approximately 1 ½ miles south of Castle Rock on the west bank of the Cowlitz River.

FIGURE 6. - Mudflow destruction along the Cowlitz River at a housing subdivision across the river from Castle Rock. Several houses were damaged beyond repair and were subsequently removed.

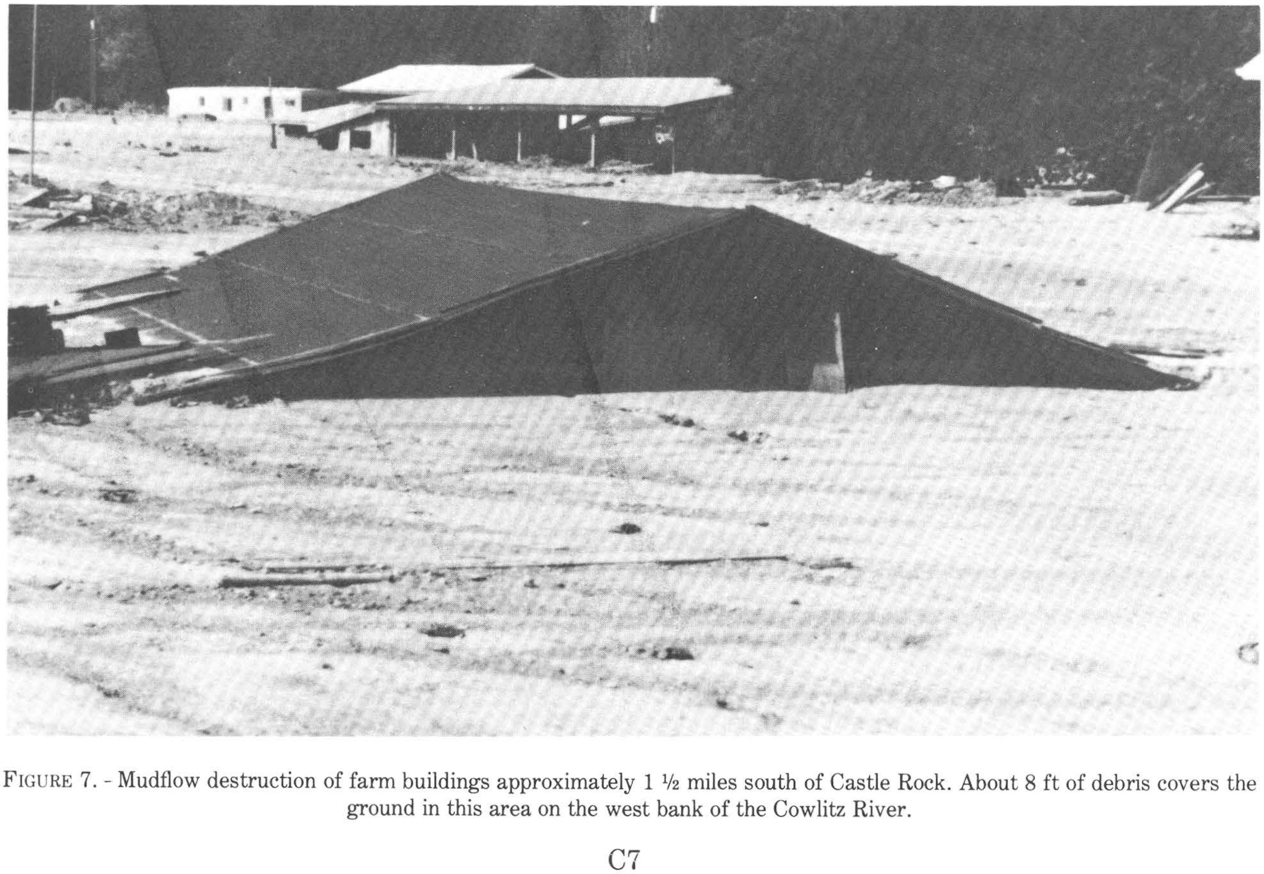

FIGURE 7. - Mudflow destruction of farm buildings approximately 1 ½ miles south of Castle Rock. About 8 ft of debris covers the ground in this area on the west bank of the Cowlitz River.

FIGURE 8. - Remains of the North Fork Toutle River bridge at Weyerhauser Logging Camp 19, Kid Valley.

FIGURE 9. - Flooding at fairgrounds across the river from Castle Rock, Washington. From 3–5 ft of sediment were deposited over the entire fairgrounds, resulting in cancellation of the annual fair. Photograph taken May 19, 1980.

confluence, but overbank deposits were not extensive. Figures 4–9 show the aftermath of overbank flow at various places along the lower Toutle and Cowlitz Rivers.

EFFECT OF MUDFLOWS ON FLOOD ELEVATIONS

Hydraulic characteristics of the lower Toutle and Cowlitz Rivers were analyzed to compute flood stages on both rivers before and after the mudflows. The water-surface elevations were computed with the aid of the U.S. Geological Survey's step-backwater computer program (Shearman, 1976).

Cross-sectional data for the backwater analyses were obtained from several sources. Step-backwater analyses for the rivers before the mudflows were based on data provided by U.S. Army Corps of Engineers (written commun., 1980), Tudor Engineering Company (written commun.,

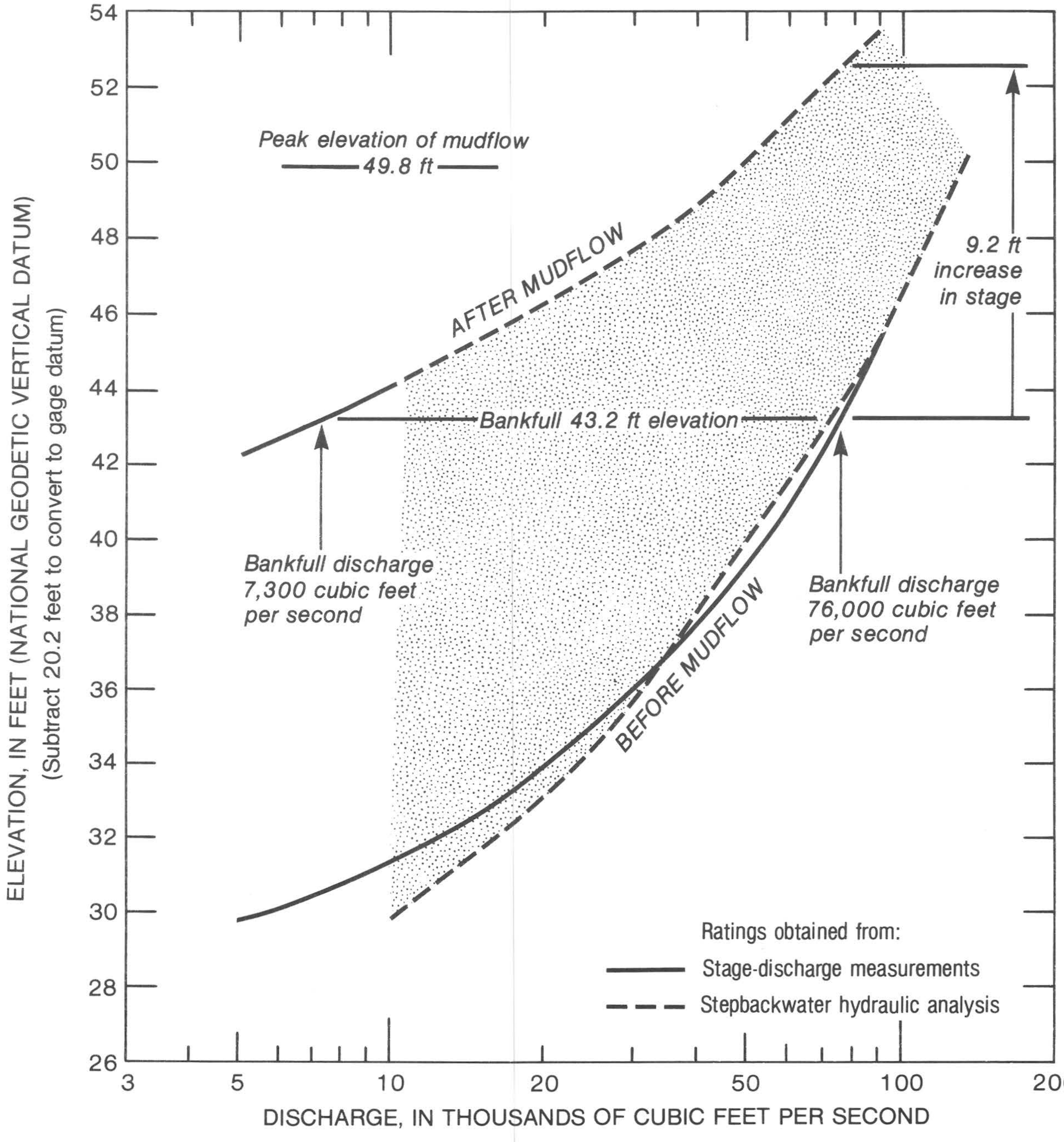

FIGURE 10. - Relation between river stage and discharge prior to and after the mudflows of May 18, 1980, Cowlitz River at Castle Rock, Washington.

1980), and Towill, Inc. (written commun., 1980). Step-backwater analyses for the rivers after the mudflows were based on detailed surveys of the channels and flood plains by the U.S. Geological Survey and the U.S. Army Corps of Engineers on June 19, 1980, and on two channel surveys by the U.S. Geological Survey between May 19 and June 18, 1980. The computed profiles and inundation limits for postmudflow conditions were based upon the assumptions that the stream channels and flood plains would remain in a static and stable condition during the passage of the flood wave, and that the flowing fluid would exhibit the same sort of friction and viscosity characteristics as normal floodwater.

Prior to the eruption and subsequent mudflows, flood stage on the Cowlitz River at the Castle Rock gage was 43.2 ft (fig. 10) with a corresponding flow of 76,000 cubic feet per second (National Weather Service, oral commun., 1980). Floodstage at the U.S. Geological Survey gage at Castle Rock after the mudflows remained about the same as before, but the capacity of the channel to convey water was reduced to less than one-tenth (7,300 cubic feet per second) of the pre-eruption level. A flow of 76,000 cubic feet per second occurring after the mudflows would produce a stage 9.2 ft higher at the Castle Rock gaging station (fig. 10), and a stage 9.0 ft higher at the cross section 1,400 ft downstream (fig. 3). In the vicinity of Castle Rock,

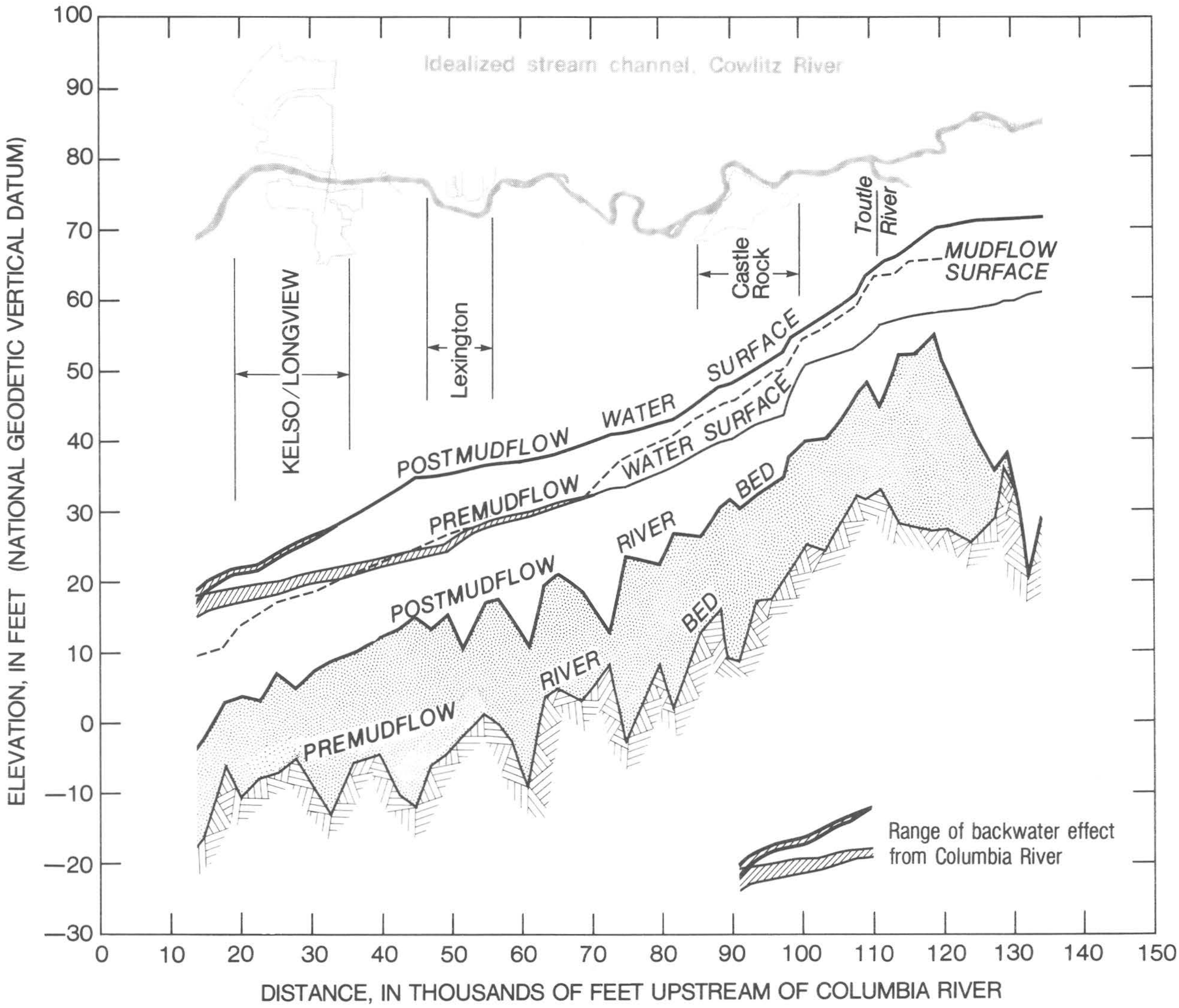

FIGURE 11. - *A*. Channel bottom and water surface elevation of the lower Cowlitz River prior to and after the mudflows of May 18, 1980. Pre- and post-eruption water surfaces are based upon flows of 76,000 cubic feet per second below and 38,000 cubic feet per second above the Toutle River.

a postmudflow discharge of 76,000 cubic feet per second would be contained by the levee on the east bank but would inundate the valley to the west. Figure 1 shows the area that would be inundated by a flood of 76,000 cubic feet per second under post-eruption conditions.

Increases in stage along both the lower Toutle and lower Cowlitz Rivers as a result of mudflow deposits are shown in figure 11. These stage profiles were computed for a flow of 76,000 cubic feet per second in the Cowlitz River, and for proportional flows of 38,000 cubic feet per second in the Toutle River, and in the Cowlitz River above the Toutle River. The post-eruption increases in the stage profiles in figure 11 are based on channel conditions during June 1980, and do not reflect subsequent channel changes that have resulted from fill, scour, dredging, or alteration of levees.

Elevations of mudflows along the lower Toutle and Cowlitz Rivers, as determined from mudlines, are also shown in figure 11. The peak elevation of the North Fork mudflow at the Castle Rock gage was 49.8 ft (fig. 10). For comparison, table 1 gives the stages and discharges for recorded floods which have exceeded 76,000 cubic feet per second at this gage. (Compiled from: U.S. Geological Survey, 1958, 1963, 1971–79).

PRESENT AND PLANNED FLOOD-ALLEVIATION MEASURES

Postmudflow profiles for selected flows were computed for the lower Cowlitz River and transmitted to the Federal Emergency Management Agency (FEMA) on May 26, 1980. Subsequently, FEMA formally requested the U.S.

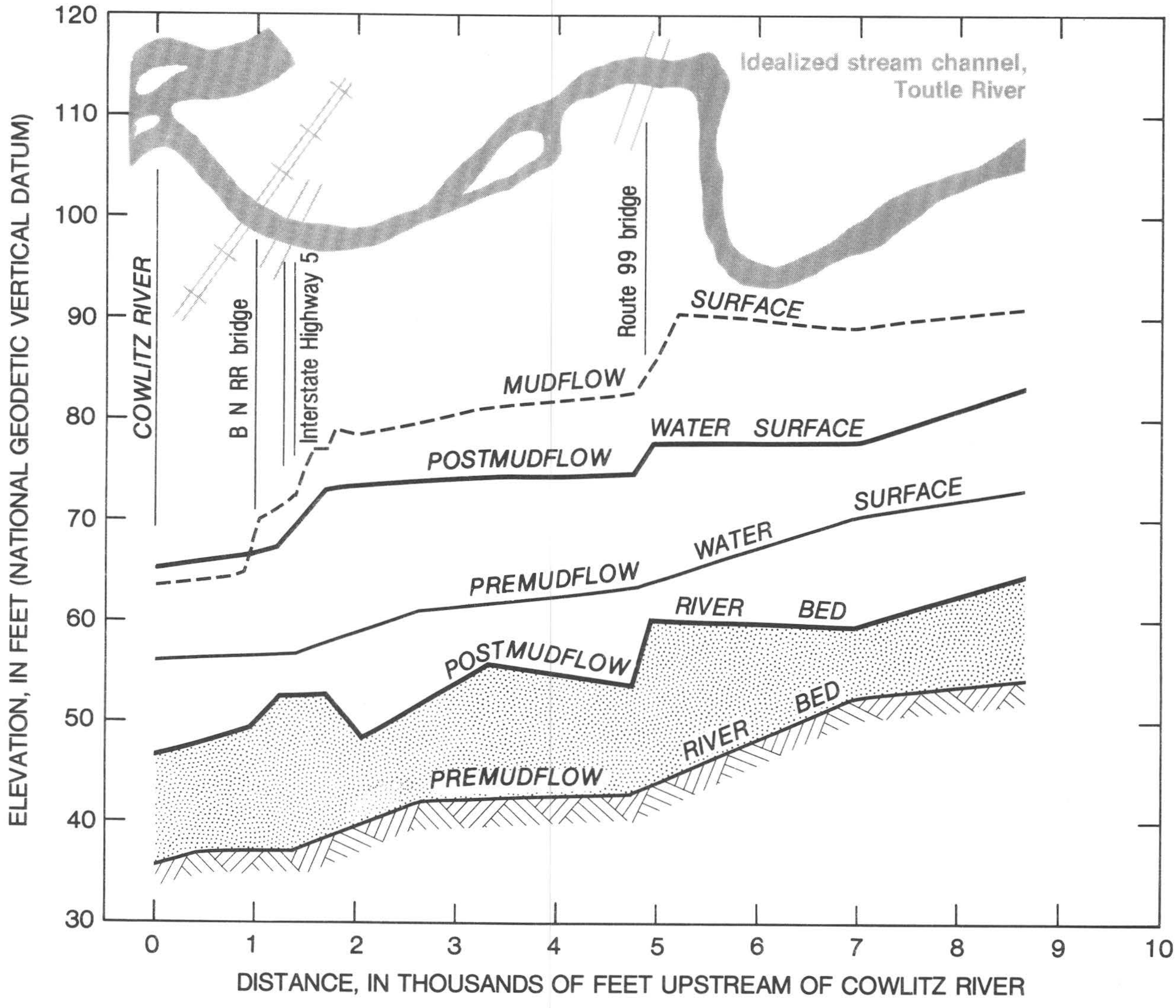

FIGURE 11. - *B*. Channel bottom and surface elevation of the lower Toutle River prior to and after the mudflows of May 18, 1980. Pre- and post-eruption water surfaces are based upon a flow of 38,000 cubic feet per second.

TABLE 1. - *Peak discharges exceeding 76,000 cubic feet per second and corresponding river stages of Cowlitz River at Castle Rock, Washington, during 1927-78*

Date of peak	Discharge (cubic feet per second)	River stage (feet)[c]
Dec. 23, 1933	139,000	51.8
Dec. 4, 1975	[a]86,700	44.73
Dec. 2, 1977	[a]86,400	44.68
Dec. 13, 1946	85,100	44.60
Dec. 23, 1964	[b]83,900	44.61
Jan. 20, 1972	[a]81,600	44.00

[a]Flow regulated by Mayfield Reservoir and Riffe Lake. Total usable capacity, 1,318,800 acre-feet.
[b]Flow regulated by Mayfield Reservoir. Usable capacity, 21,380 acre-feet.
[c]Subtract 20.2 feet to convert to gage datum.

Geological Survey to conduct continuing detailed field surveys for defining the extent of the hazards.

Several agencies made extensive efforts to reduce the flood hazard before the flood season began. The flood season is generally in December. Physical steps include dredging of channels and the construction of levees and sediment-retention structures. Nonstructural steps include redesigned operating plans for Cowlitz River reservoirs, hydrologic surveillance, flood-warning systems, and evacuation plans.

DREDGING

The Corps of Engineers began dredging operations in the lower Cowlitz River on June 10, 1980 (see fig. 12). By June 19, 1980, 120,000 cubic yards of sediment had been removed from the lower end of the river, but no effect was noted on the stage-discharge relation at the Castle Rock gage. As of September 30, about 18 million cubic yards of sediment had been removed, and dredging was continuing at the rate of about 1/3 million cubic yards per day. By November 1, 1980, the Corps of Engineers planned to have removed enough sediment from the Cowlitz River channel to increase its bankfull (flood stage) capacity to 50,000 cubic feet per second - 26,000 cubic feet per second less than the bankfull capacity prior to the mudflows.

LEVEES

Before the mudflows, the levees constructed along the Cowlitz River afforded protection from floods of magnitude up to 138,000 cubic feet per second for the cities of Castle Rock, Kelso, and Longview (Federal Insurance Administration, 1979a, 1979b, 1979c). The North Fork mudflow came within inches of the top, but was contained by the east bank levee built to protect the city of Castle Rock (fig. 9). In contrast, the mudflow overtopped the west bank of the river in the vicinity of the Castle Rock Bridge where no levee exists (fig. 9), and farther downstream, topped the west side levee illustrated in figure 3. The degree of flood protection afforded by the levees after the mudflows is unknown. Within 2 weeks after the mudflows, the levee protecting Castle Rock was raised 2–4 ft to protect against an estimated 100-year flood under premudflow conditions (fig. 3). In September 1980, plans were formulated to raise the levee an additional 5 ft. The adequacy of levees under postmudflow conditions will depend on the progress of dredging, and the amount of additional material deposited by future flows, especially the high flows of the coming autumn and winter.

SEDIMENT-RETENTION STRUCTURES

On June 8–9, 1980, the Corps of Engineers let contracts for construction of sediment-retention structures on both the North and South Forks by November 1, 1980. The structure on the North Fork is being constructed 20.7 miles upstream from the mouth, with a spillway capacity of 8,300 cubic feet per second and a sediment-storage capacity of 2,400 acre feet. As of September 30, the structure was about 90 percent completed. The structure on the South Fork Toutle River has been constructed 7.0 miles upstream from the mouth, with a spillway capacity of 10,000 cubic feet per second and a sediment-storage capacity of 210 acre-feet.

The potential effectiveness of these structures for preventing or slowing the downstream movement of sediment is unknown. Even if the retention reservoirs are effective, some sediment will be carried through the structures and additional sediment will be scoured from the downstream channels and flood plains. Sediment deposition will definitely continue in the lower Toutle and Cowlitz Rivers.

FLOOD CONTINGENCY PLANS

Following the mudflows, local, county, and Federal agencies formulated plans for the surveillance of the lower Toutle and Cowlitz Rivers and for the dissemination of flood warnings.

EVACUATION

At a July 8–9, 1980, conference at Washington State University entitled "The Aftermath of Mount St. Helens," the Corps of Engineers assessed the need for possibly evacuating people along the lower Cowlitz River. It was noted that evacuation might be required prior to autumn and winter high flows even after the combined program of dredging, raising levees, and installation of sediment-retention structures. As reported by the Tacoma News Tribune on July 10, 1980, the Governor of Washington suggested that entire towns located along the Cowlitz River may need to be relocated to ensure the safety of the residents and their property. No action was taken on this suggestion as of September 1980. The time required for major, orderly relocation of towns rules out accomplishment of this action before the onset of the high river flows anticipated during the autumn and winter. Evacuation, therefore, is the only feasible course of action if flooding becomes imminent. Timely evacuation will require continued surveillance of rainfall, snow in storage, and river stage and discharge.

CONTINUED SURVEILLANCE AND FLOOD WARNING

Within 6 days after the eruption, the U.S. Geological Survey installed a river-stage station on the North Fork Toutle River at Kid Valley, and stages were being transmitted via satellite to the National Weather Service River Forecast Center in Portland, Oregon; the U.S. Forest Service in Vancouver, Washington; the Cowlitz County Sheriff's Office; and the Washington District Office, U.S. Geological Survey. Additionally, one stage station was installed on the North Fork Toutle River upstream from Kid Valley and two on the

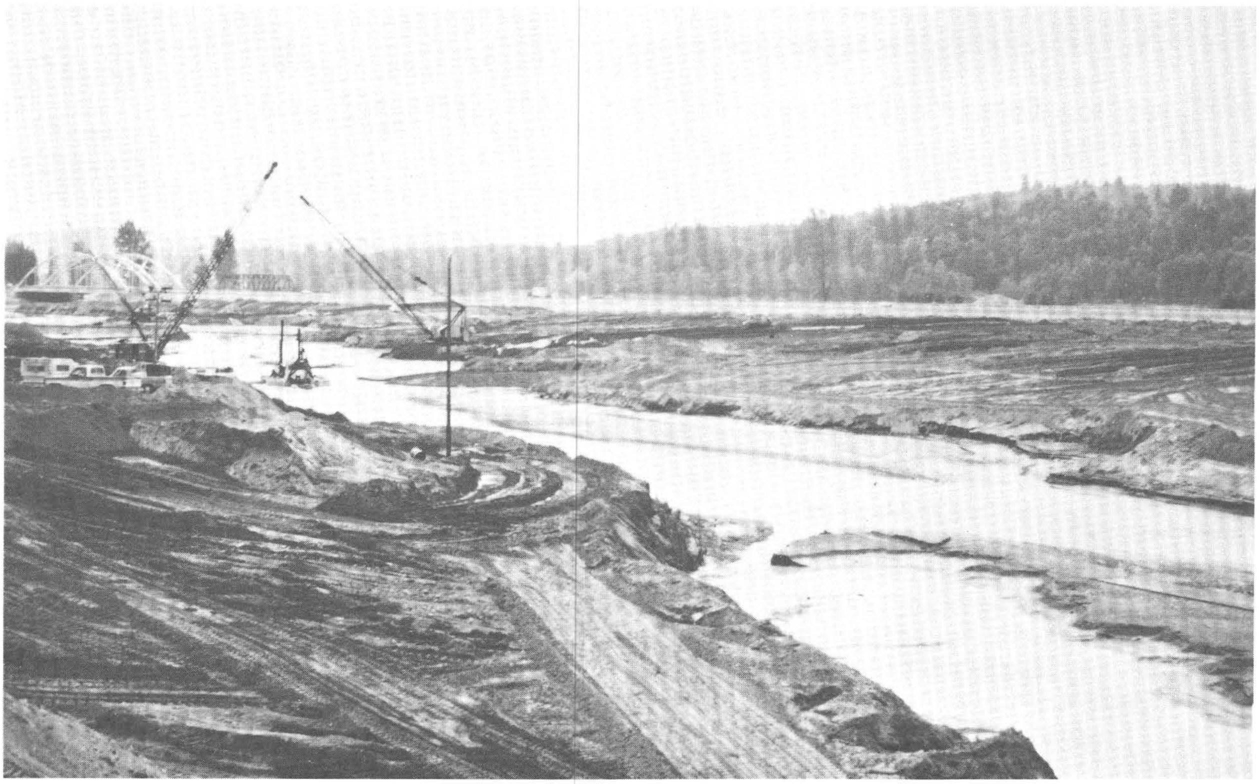

FIGURE 12. - Dredging operations on the Toutle River just upstream from its confluence with the Cowlitz River. Photograph taken September 11, 1980.

South Fork Toutle River, all constructed to transmit stages via satellite. River stages are also being telemetered by radio from gages on the Cowlitz River at Castle Rock and the Toutle River at the Highway 99 crossing near the mouth, and will soon be telemetered from a gage on the Toutle River near the town of Toutle Lake. The location of the river surveillance sites are shown in figure 13. When flooding appears possible, stage data will be transmitted every 5 minutes from each gage, thereby providing at least several hours of warning to residents on the Cowlitz River.

The U.S. Geological Survey is periodically resurveying the lower Toutle and Cowlitz Rivers and reanalyzing the river hydraulics. Water profiles are being prepared after each resurvey, and inundation maps are updated as needed. This effort not only provides continued monitoring of the flood hazards, but also documents the effects of dredging and the movement of sediment.

ACKNOWLEDGMENTS

Appreciation is expressed to the U.S. Army Corps of Engineers, Portland District; Tudor Engineering Company, Seattle, Washington; and Towill, Inc., San Francisco, California, who furnished cross-sectional data, aerial photographs, and other useful information.

REFERENCES CITED

Crandell, D. R., and Mullineaux, D. R., 1978, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383–C, p. C–1 to C–26.

Cummans, John, 1981, Mudflows resulting from the May 18, 1980, eruption of Mount St. Helens, Washington: U.S. Geological Survey Circular 850–B, 16 p.

Federal Insurance Administration, 1979a, Flood insurance study, city of Castle Rock, Cowlitz County, Washington, U.S. Department of Housing & Urban Development Federal Emergency Management Agency No. 530277, 15 p.

———1979b, Flood insurance study, city of Kelso, Cowlitz County, Washington: U.S. Department of Housing & Urban Development, 20 p.

———1979c, Flood insurance study, city of Longview, Cowlitz County, Washington: U.S. Department of Housing & Urban Development, 19 p.

Shearman, J. O., 1976, Computer applications for step-backwater and floodway analyses, User's manual: U.S. Geological Survey Open-File Report 76–499, 103 p.

U.S. Geological Survey, 1958, 1963, 1971, 1972, Surface water supply of the United States, Part 14, Pacific Slope Basins in Oregon and Lower Columbia River basin, U.S. Geological Survey Water-Supply Papers 1318, 1738, 1935, 2135.

———1972-75, Water resources data for Washington, Part 1, Surface-water records: Tacoma, Washington, 1971–74.

———1976-79, Water resources data for Washington, 1975–1978: Tacoma, Washington, report nos. WA75–1, WA76–1, WA77–1, WA78–1.

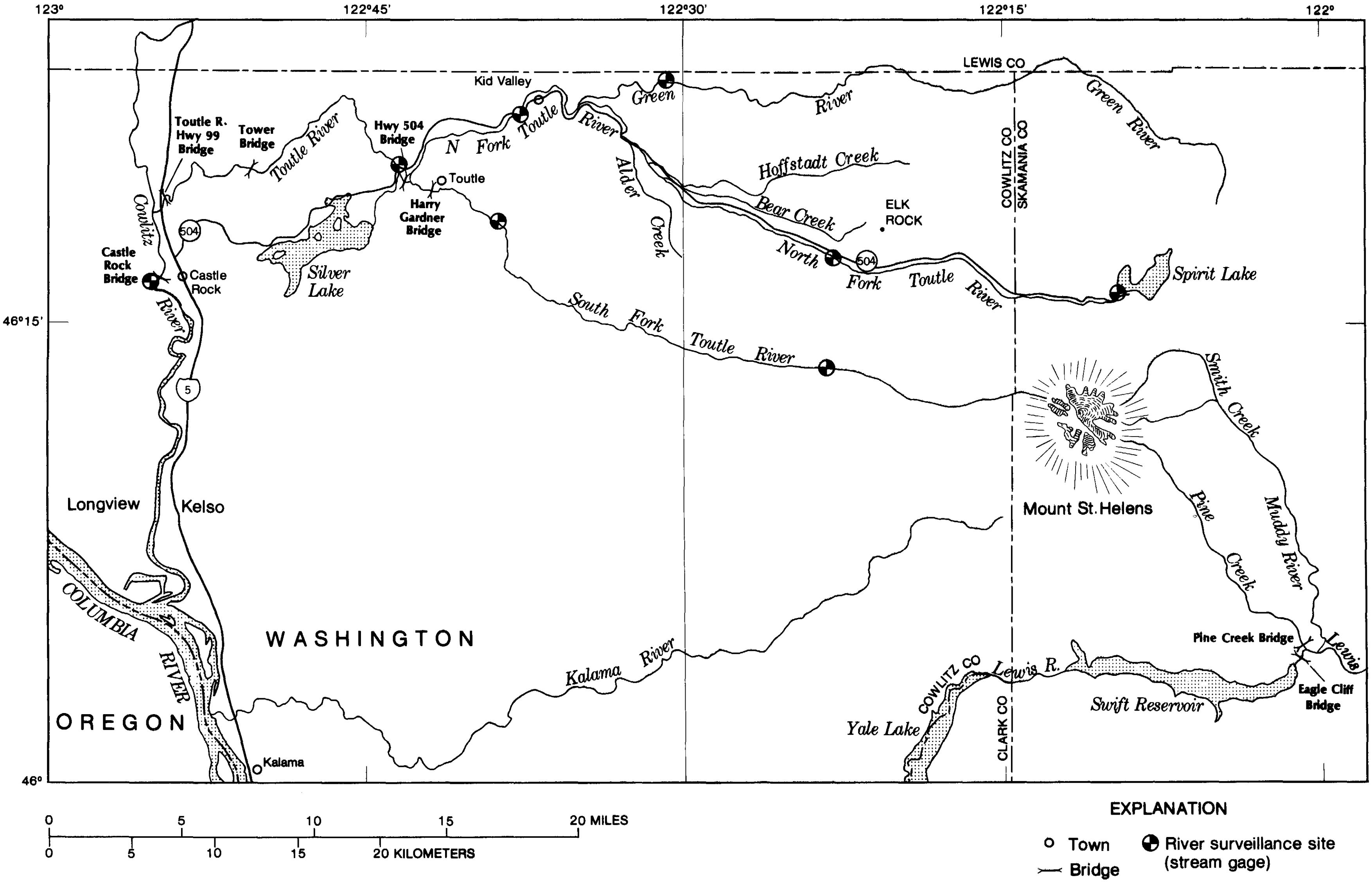

FIGURE 13. - Map showing location of river surveillance sites in the lower Toutle and Cowlitz River systems.