FLOODFLOW CHARACTERISTICS AT PROPOSED BRIDGE SITE FOR STATE HIGHWAY 99, KANSAS RIVER AT WAMEGO, KANSAS

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CONVERSION FACTORS

For those readers interested in metric units, the inch-pound units used in this report can be converted to the International System of Units (SI) using the following factors:

Multiply inch-pound unit	By	To obtain SI unit
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
cubic foot per second (ft^3/s)	28.32	liter per second
foot per second	0.3048	meter per second

Sea level: In this report "sea level" refers to the 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 of 1929."

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ABSTRACT

The Kansas Department of Transportation has proposed replacing a bridge over the Kansas River on State Highway 99, at Wamego, Kansas. This report evaluates the ability of the main channel along with the existing agricultural levee to contain the flow of the Kansas River, the effect of overflow structures under the highway south of the bridge, and the effect of an island upstream from the proposed bridge.

The design of the proposed new bridge is adequate for passage of a 100-year flood of 155,000 cubic feet per second; however, the existing levee along the right bank of the river upstream of the proposed bridge will not confine the flow to the main channel because parts of the levee have been broken or removed.

The present overflow structures would allow a discharge of 26,000 cubic feet per second to occur in the bypass reach with a maximum depth of flow over the highway of 1.3 feet. If the structures were removed but the highway grade maintained, the discharge would increase to about 30,000 cubic feet per second with a depth of flow over the highway of 1.5 feet. If the overflow structures were removed and the elevated sections of the highway grade leveled, the discharge would increase to about 31,500 cubic feet per second, with a maximum depth of flow over the highway of 1.3 feet. The velocity of flow through four 30-inch-diameter concrete culverts located at overflow-structure sites would be 8.6 feet per second. Foreseeable changes in the island upstream from the proposed bridge would not interfere with the flow capacity of the new bridge.

INTRODUCTION

The Kansas Department of Transportation has proposed replacing a bridge over the Kansas River on State Highway 99, at Wamego, Kansas. As part of the ongoing cooperative program with the Department, the U.S. Geological Survey conducted a hydraulic analysis for the proposed Wamego bridge.

The specific objectives of the analysis described in this report were to evaluate, using a peak discharge with an average recurrence interval of 100 years, (1) the ability of the main channel along with the agricultural levee to contain the flow of the Kansas River, (2) the effect of removing two overflow structures under the highway south of the main-channel bridge, (3) the effect of an island located upstream from the proposed bridge, and (4) flow velocities for culverts at overflow-structure sites. Objectives 1-3 included the need for information on the flows and water-surface elevations at the proposed bridge.

DESCRIPTION OF SITE

The existing bridge, built in 1929, is a seven-span Marsh Arch type structure with 128-foot spans and a roadway width of 20 feet. Located under the highway south of the bridge are two overflow structures that are reinforced-concrete deck girders with 27.5-foot spans; the northernmost overflow structure has six spans and a length of 165 feet, and the southernmost structure has eight spans and a length of 220 feet (fig. 1). Located along the right bank of the main channel is an agricultural levee that extends about 1 mile downstream and about 2 miles upstream from the bridge. The levee was built sometime prior to 1951. Just upstream from the bridge is an island that is about 800-feet long and 100-feet wide. According to local residents, prior to the 1951 flood the island was about 20 acres in size and contained a cabin and well.

AVAILABLE DATA

A streamflow-gaging station, Kansas River at Wamego, Kansas (station number 06887500), is located on the downstream side of the present bridge (fig. 1). This station has been in operation since 1919.

A discharge of 155,000 ft^3/s for a flood having an average recurrence interval of 100 years was used by the Kansas Department of Transportation for design of the new bridge opening and was used for the hydraulic analysis in this report. This discharge value is based on a flood-frequency analysis of 71 annual peak discharges at the Wamego gaging station from 1914 to 1984. The analysis was done by the Kansas Department of Transportation (R.S. Chambers, Kansas Department of Transportation, written commun., 1986). The peak discharge of 155,000 ft^3/s is within 3 percent of the estimated 100-year peak discharge of 160,000 ft^3/s, which was determined by the U.S. Army Corps of Engineers (Kansas City District), and has been used in previous flood studies along the Kansas River (U.S. Army Corps of Engineers, 1969).

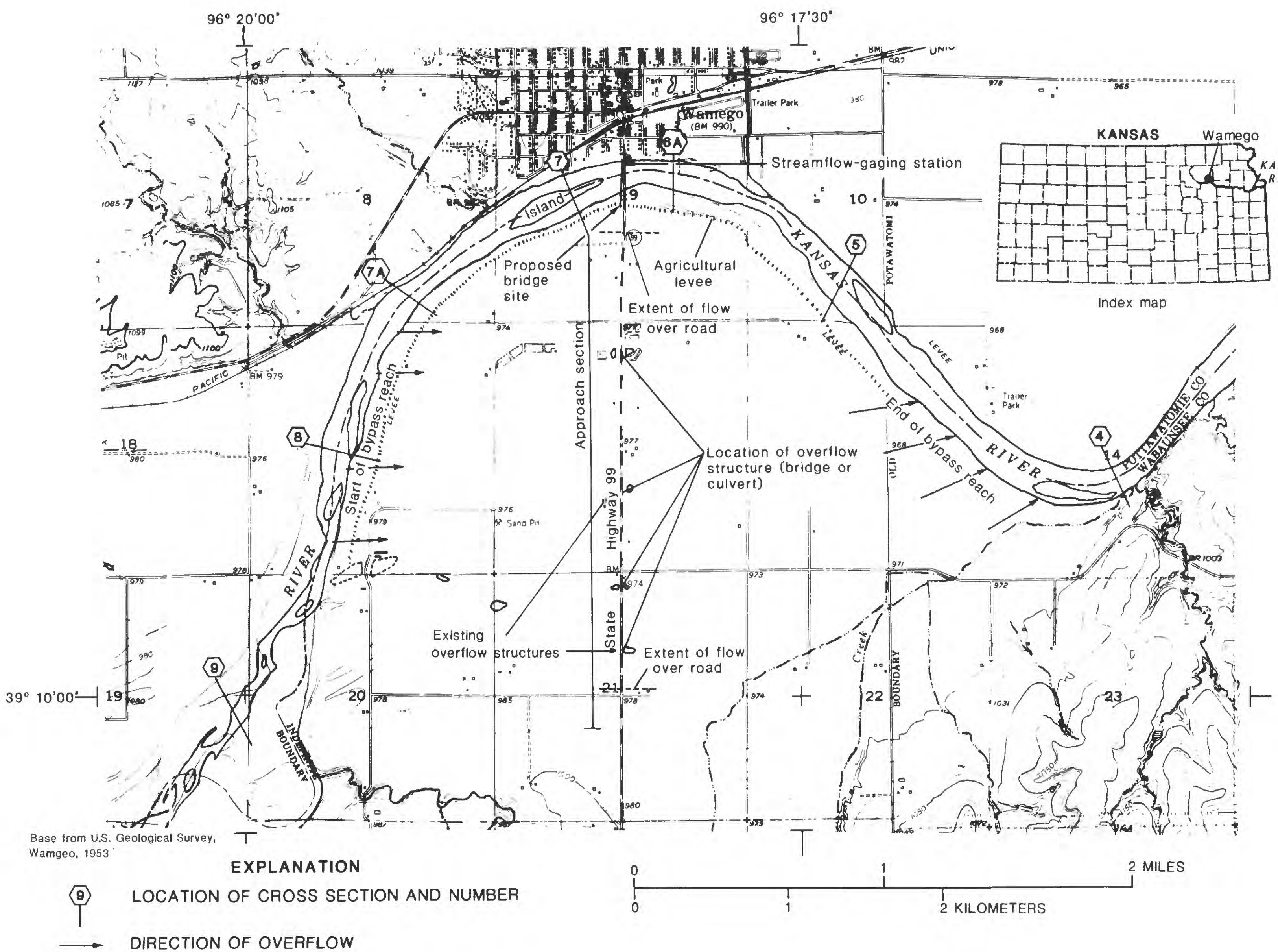


Figure 1.--Location of proposed bridge, main channel of Kansas River, agricultural levee, overflow structures, and bypass reach.

Data for cross-section and flood-plain definitions were obtained from a flood-insurance study for the city of Wamego (U.S. Department of Housing and Urban Development, 1980) and a flood-insurance study for Riley County (U.S. Department of Housing and Urban Development, 1981). Additional cross-section definition and levee elevations were obtained from aerial photographs (Kucera and Associates, Inc., 1976, scale 1:4,800).

Construction plans for the new bridge, present overflow structures, and the State Highway 99 road elevations were obtained from the Kansas Department of Transportation. The proposed new bridge is a continuous-composite welded-steel-plate girder structure with a 40-foot roadway and 6-foot-wide piers.

The profile of the top of the levee upstream from the bridge (based on 1976 aerial photography) indicates that some low spots exist. An onsite inspection was conducted on September 17, 1986, by representatives of the Kansas Department of Transportation and the U.S. Geological Survey. Inspection indicated that additional sections of the levee had been removed and that farming operations were being carried to the river's edge. Due to the present condition of the levee, overbank flow would occur along the right bank (bypass reach) at a discharge of about 105,000 ft^3/s. The overbank flow would bypass the proposed bridge and flow through the overflow structures located along State Highway 99 south of the bridge. However, the levee at the proposed bridge site is intact and would provide the main channel with sufficient capacity to carry the design discharge of 155,000 ft^3/s.

HYDRAULIC ANALYSIS

Analytical Approach

Water-surface elevations were computed using the step-backwater computer program of the U.S. Geological Survey (Shearman and others, 1986). Starting elevations were determined by the slope-conveyance method (Rantz and others, 1982). Cross sections 1-4, located downstream from the proposed bridge (fig. 2), were used to insure that the water-surface profile converges to a normal water-surface elevation prior to computing additional profiles for any proposed changes. The computation of additional elevations reflected differences caused by the proposed bridge and other flow conditions being considered in the hydraulic analysis.

Separate water-surface elevations were computed for the main-channel and the bypass reach based on apportioned discharges because of different reach lengths and varying effects of backwater in the respective reaches. The computed water-surface elevations differ according to four different design options tested for in the bypass reach. Various hydraulic conditions at the overflow structures also can affect the amount of discharge that can be conveyed in the bypass reach and in the main channel.

The procedure for proportioning streamflow discharge between the main channel and the bypass reach was to start at the downstream cross section after the bypass flow reenters the main channel (cross section 4, fig. 1).

Separate elevations then were computed in an upstream direction to a cross section immediately upstream (cross section 9) from the point where the overbank flow can enter into the bypass reach. The discharges were adjusted until the computed water-surface elevations in the main channel and the bypass reach were balanced at the cross section located upstream from the point of overbank flow (Davidian, 1984).

Main Channel

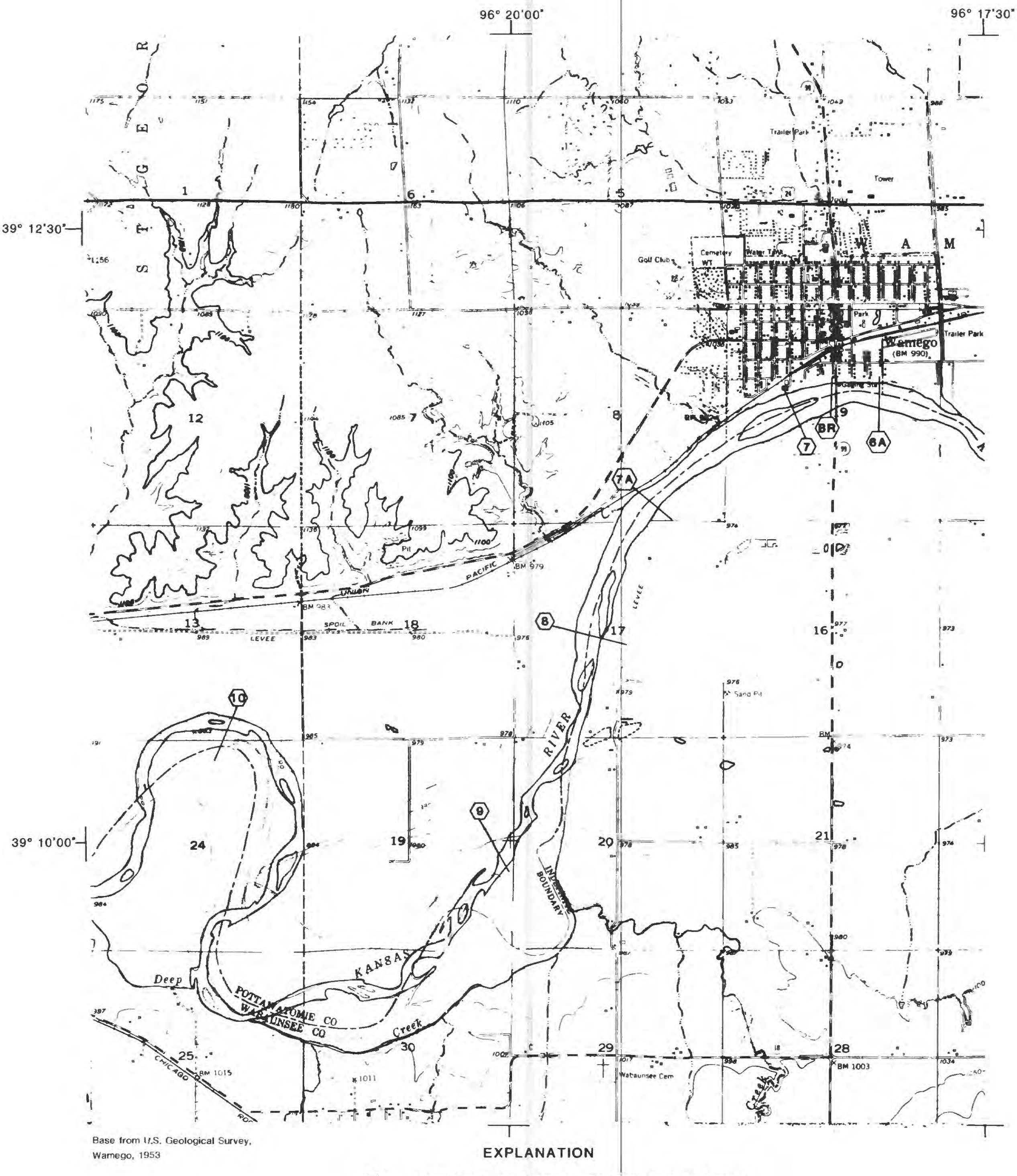
Since the proposed bridge would span the main channel from a bluff in Wamego to the top of the agricultural levee, it presents no constriction to streamflow. However, the water-surface elevation in the main channel upstream from the bridge increases by 0.12 foot due to the backwater from the bridge piers. The water-surface elevation at the bridge would be 977.19 feet. Figure 3 shows the water-surface elevation along the main channel, assuming that all flow (100-year design discharge) is contained by the levee along the right bank.

Figure 4 shows the elevation of the levee top, as determined from aerial photography taken in 1976. The levee had already been broken in places for access roads used in farming operations. Since additional sections are now missing, the levee definitely cannot contain the flow in the main channel. Included in figure 4 are water-surface elevations for the 100-year, 50-year, and start of flow in bypass reach discharges. These water-surface elevations indicate the ineffectiveness of the levee to contain high flows in the main channel.

Overflow Structures

The bypass reach along the right bank was analyzed for the effect of four design options presented by the Kansas Department of Transportation that reflect different hydraulic conditions at the overflow structures. The first option considered the overflow structures and elevated road grade as they presently exist (1987). The second option considered removal of the overflow structures and the elevated road grade remaining as it presently exists. The third option considered removal of the overflow structures and lowering of the elevated road grade so as to present a level road grade without any rises. The fourth option considered four 30-inch concrete culverts to be placed under the road for drainage purposes, with the road elevated to prevent flow over the road; analysis of this design option was limited to the determination of the exit velocity from the culverts.

Under existing conditions (first option), the average water-surface elevation of 978.58 feet at the roadway was computed for a discharge of 26,000 ft^3/s in the bypass reach. The computation showed a maximum depth of flow over the road of 1.3 feet (fig. 5). The discharge in the main channel was 129,000 ft^3/s. The water-surface elevation at the proposed new bridge was 976.41 feet, which is 0.78 foot lower than that computed when all of the flow was contained in the main channel.



Base from U.S. Geological Survey, Wamego, 1953

EXPLANATION

(9) LOCATION OF CROSS SECTION AND NUMBER

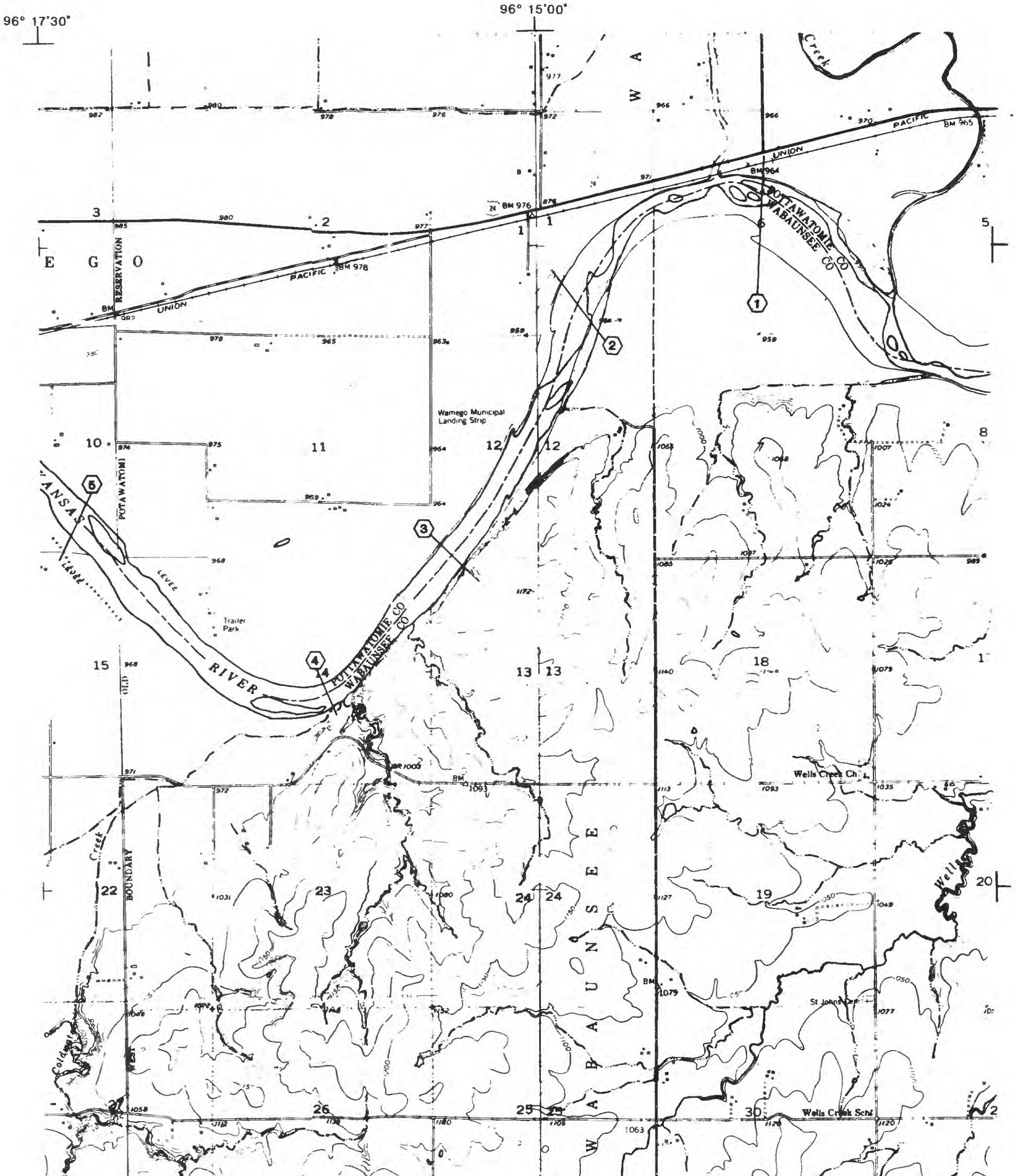


Figure 2.--Location of cross sections along main channel.

For the second option, the overflow structures were removed, and an overflow discharge of 30,000 ft^3/s was used. The maximum flow depth over the road was 1.5 feet at a water-surface elevation of 978.79 feet, and the maximum velocity was 5.6 feet per second (fig. 6). The discharge in the main channel for this option was 125,000 ft^3/s, and the water-surface elevation at the new bridge was 976.30 feet.

If the overflow structures were removed and the road grade reduced (third option), the maximum depth of flow over the road would be 1.3 feet at a water-surface elevation of 978.62 feet and a maximum velocity of 5.2 feet per second (fig. 7). Overflow discharge for this option would be 31,500 ft^3/s. Discharge in the main channel would be 123,500 ft^3/s, and the water-surface elevation at the new bridge would be 976.26 feet.

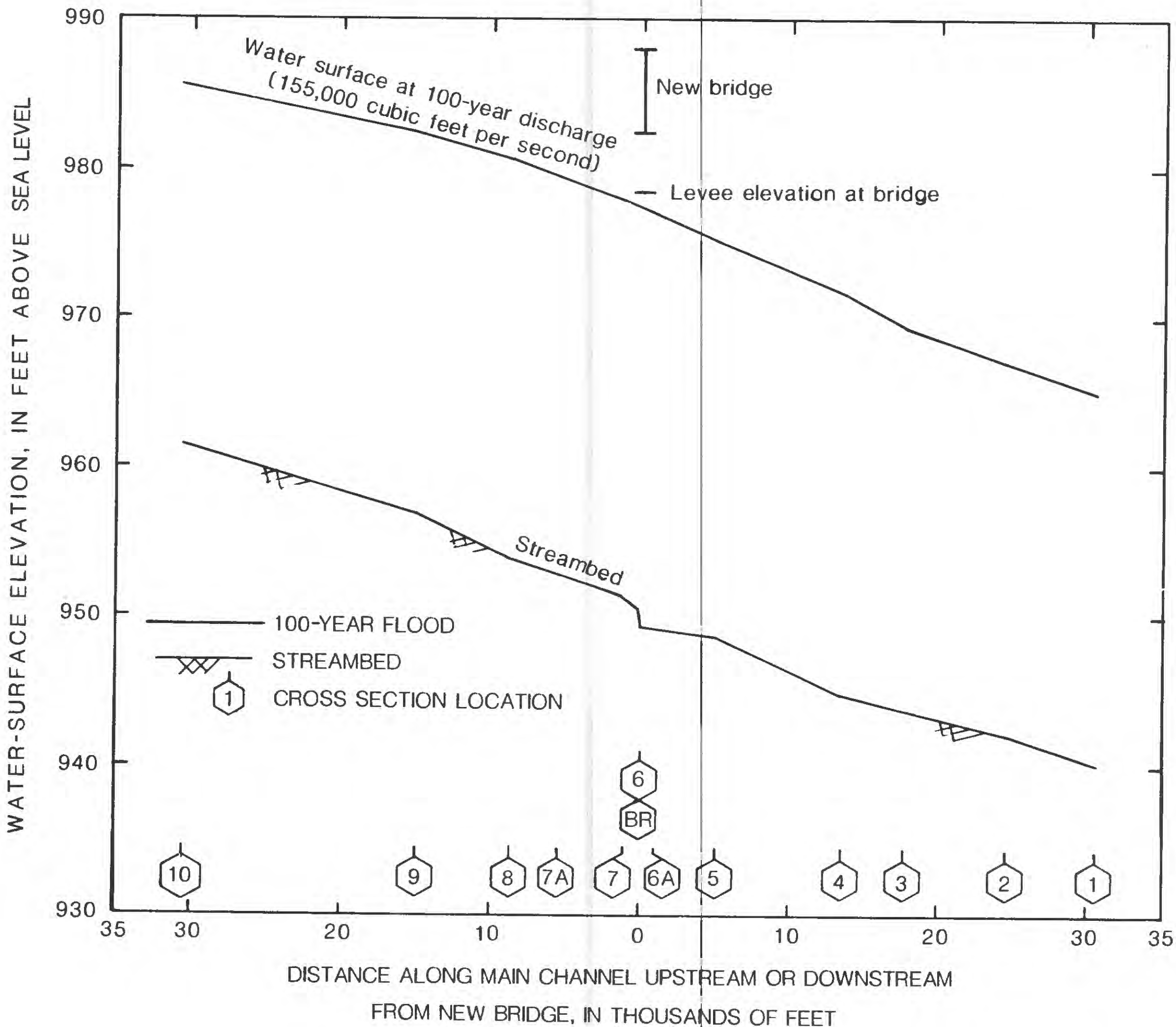


Figure 3.--Water-surface elevation for main channel, assuming all flow is contained in main channel.

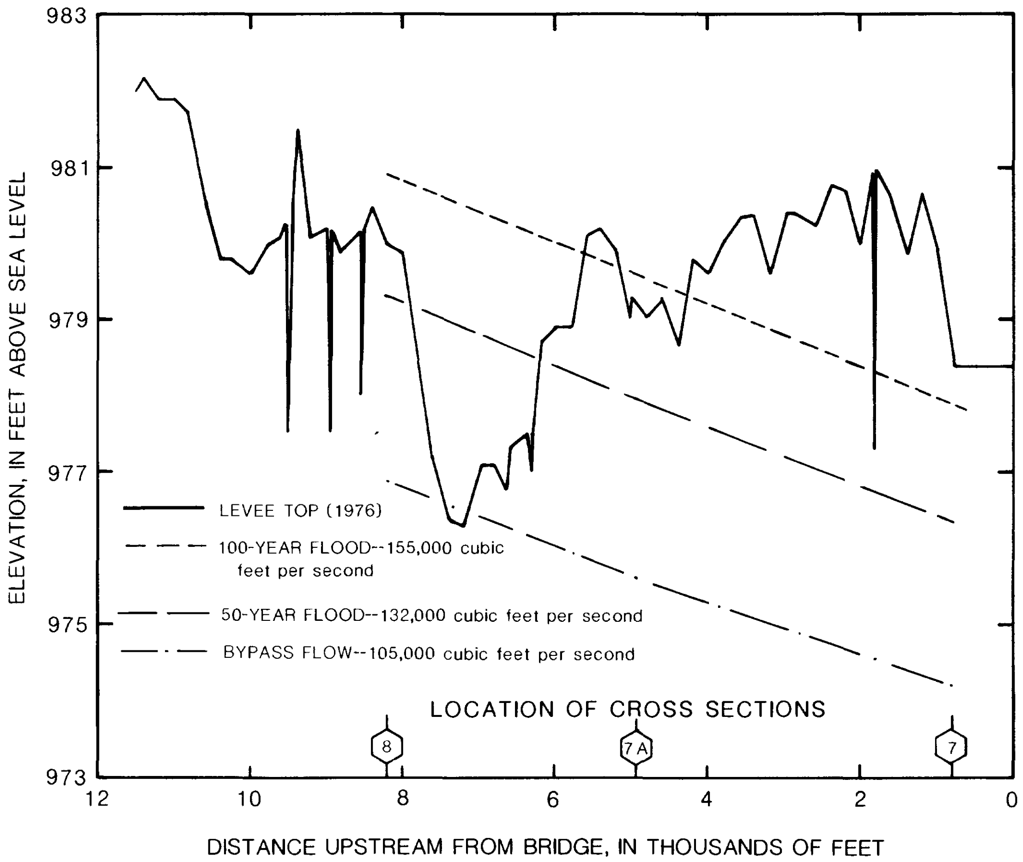


Figure 4.--Elevations for top of levee and water surface upstream from bridge, assuming all flow is contained in main channel.

In the fourth option, four 30-inch-diameter concrete culverts, 120-feet long, were placed under the roadway south of the proposed bridge, assuming that there was no flow over the road. A calculation was made (using an option of the step-backward program) to determine the velocity at the culvert exits (Shearman and others, 1986). The levee at the downstream side of the bridge separates the flow in the main channel from the flow in the bypass reach. Therefore, the water-surface elevation at the culvert exits reflects the eddy effect of ponded water backing up in the bypass reach and is equal to the water-surface elevation at the downstream terminus of the levee (estimated by water-surface elevation at cross section 5). The water-surface elevations at the culvert exits, 975.10 feet, and at the approach section, 977.91 feet, were obtained from the profile computed when all the flow was contained in the main channel. The elevation of the culvert inverts was presumed to be 960.0 feet. The computed discharge of 42.25 ft^3/s through each culvert resulted in exit velocities of 8.6 feet per second.

Island

The island shown in figure 1 does not have an effect on backwater at the proposed bridge since it is upstream of the bridge. In order to investigate the effect of an increase in size of the island due to sedimentation, a computation was made for an island double the present width and height. The computed water-surface elevation was about 0.2 foot higher than the normal water-surface elevation for the 100-year discharge of 155,000 ft^3/s upstream from the island (fig. 8). Another computation was made using an island that extended downstream through the bridge opening. The computed water-surface elevation was about 0.4 foot higher than the normal water-surface elevation. Any increase in the size of the island seems unlikely because of the reduced supply of sediment in the river following completion of upstream reservoirs.

SUMMARY

The design of the proposed new bridge is adequate for passage of the discharge having a 100-year recurrence interval of 155,000 ft^3/s due to the physical location of spanning the main channel from the levee on the south bank to the bluff at the city of Wamego on the north bank.

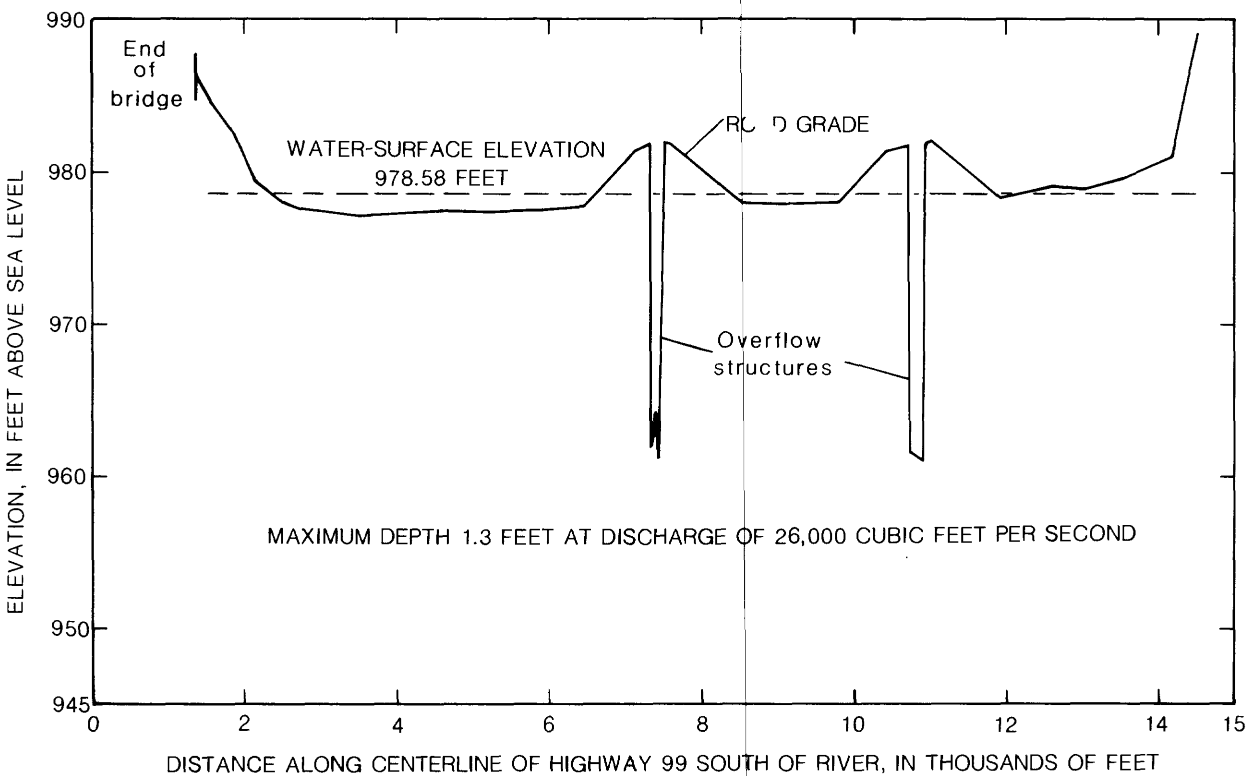


Figure 5.--Cross section for overflow with present structures.

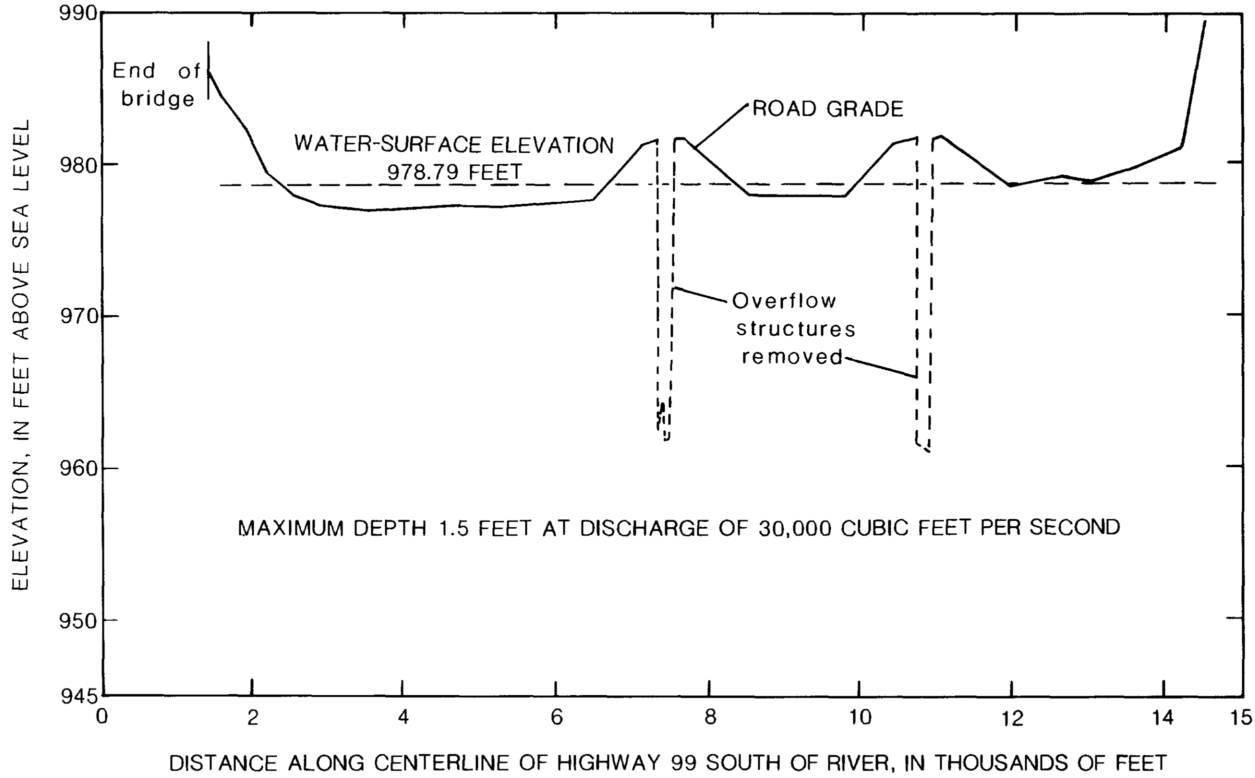


Figure 6.--Cross section for overflow with structures removed.

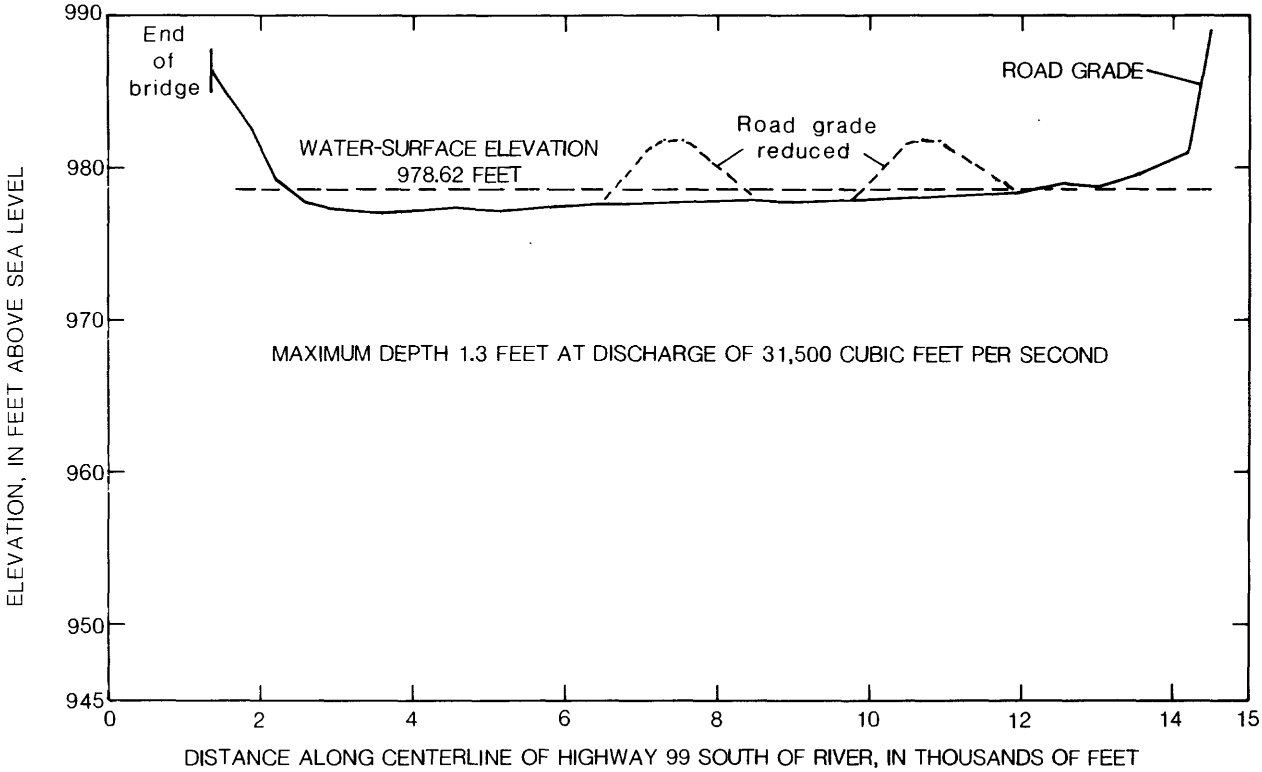


Figure 7.--Cross section for overflow with structures removed and road grade reduced.

The levee along the right bank of the Kansas River will not contain high flows in the main channel because parts of the levee upstream from the bridge have been broken or removed for farming operations. Overbank flow will occur at a discharge of about 105,000 ft^3/s.

The present overflow structures underneath the roadway south of the proposed bridge would allow a discharge of about 26,000 ft^3/s to occur in the bypass reach at a maximum depth of 1.3 feet over the road. The water-surface elevation at the new bridge would be 976.41 feet.

If the overflow structures were removed but the road grade maintained at the present elevation, the amount of discharge in the bypass reach would increase to about 30,000 ft^3/s. The maximum depth of flow over the road would be about 1.5 feet. The water-surface elevation would be 976.30 feet at the new bridge.

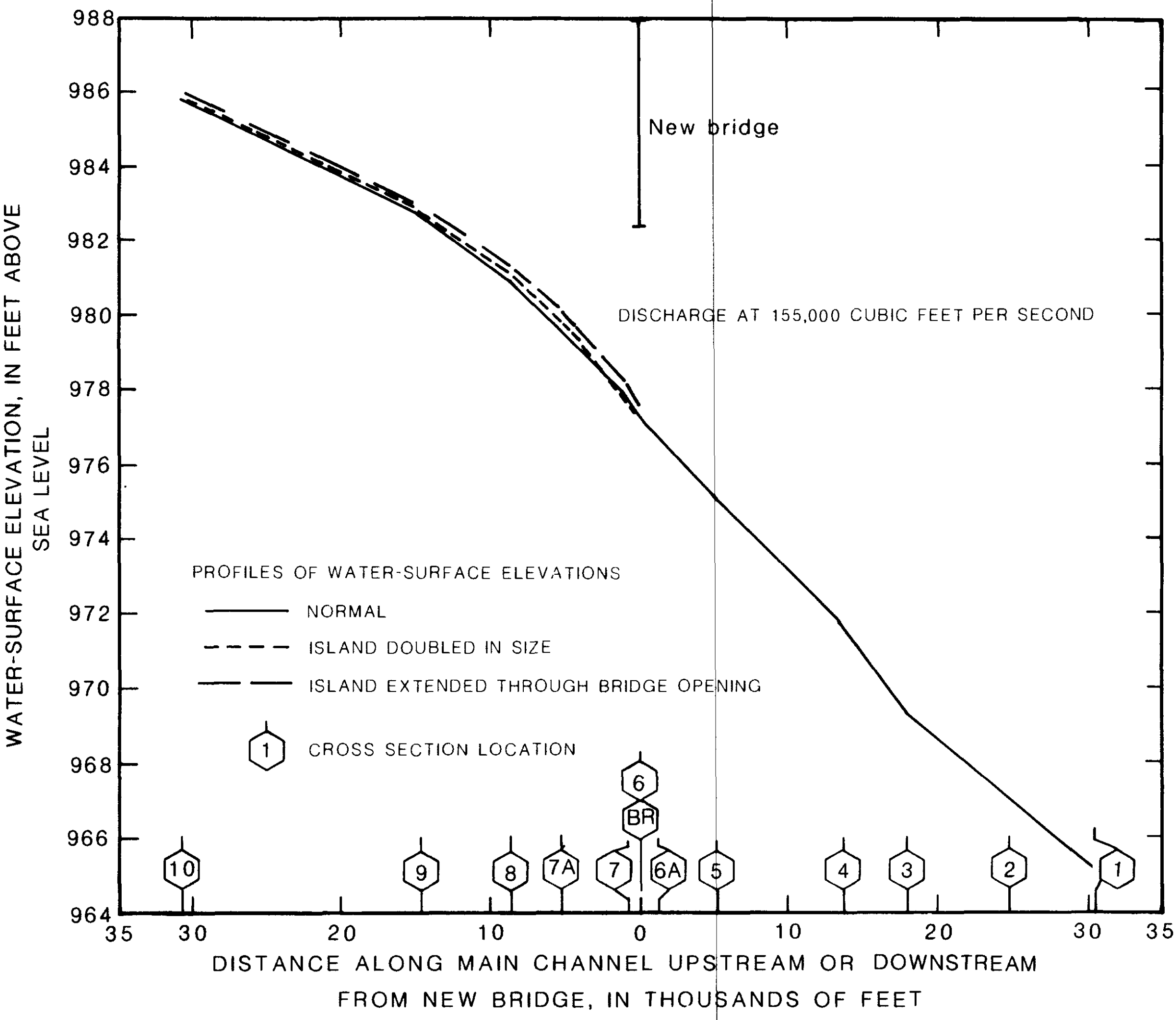


Figure 8.--Water-surface elevations for effect of upstream island, assuming all flow is contained in main channel.

If the overflow structures were removed and the elevated sections of road grade leveled, discharge in the bypass reach would increase to about 31,500 ft^3/s. The maximum depth of flow over the road would decrease to about 1.3 feet. The water-surface elevation at the new bridge would decrease to 976.26 feet.

The velocity of flow at the exit of four 30-inch-diameter concrete culverts was computed to be 8.6 feet per second, assuming there was no flow over the top of the road.

The presence of the island upstream from the proposed bridge does not interfere with the flow capacity of the new bridge, and any growth of the island due to deposition of sediment seems unlikely.

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