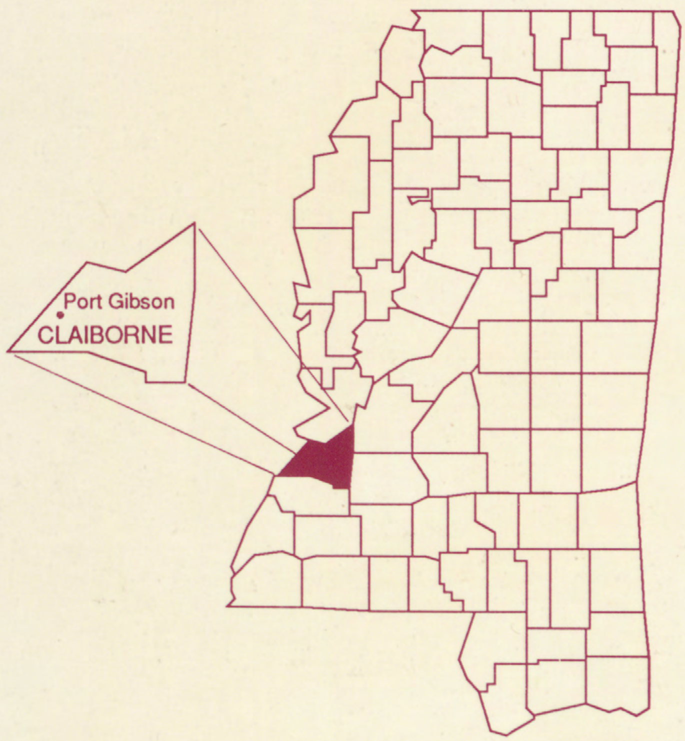
CHANNEL AND BANK STABILITY OF BAKERS CREEK AT STATE HIGHWAY 547 NEAR PORT GIBSON, CLAIBORNE COUNTY, MISSISSIPPI



U.S. GEOLOGICAL SURVEY
Open-File Report 92-636

Prepared in cooperation with the

MISSISSIPPI STATE HIGHWAY DEPARTMENT

CHANNEL AND BANK STABILITY OF BAKERS CREEK AT STATE HIGHWAY 547 NEAR PORT GIBSON, CLAIBORNE COUNTY, MISSISSIPPI

By D. Phil Turnipseed and W. Trent Baldwin

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Jackson, Mississippi
1992

DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
pounds per square foot (lb/ft^2)	47.88	newtons per square meter
pounds per cubic foot (lb/ft^3)	157.09	newtons per cubic meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
inch (in.)	0.0254	meter

Mississippi State Highway Department Datum: In this report, elevations are referenced to Mississippi State Highway Department Datum (MSHDD)--a site-specific datum. At this site, elevations referenced to MSHDD are to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929 and referred to in this report as sea level.

DEFINITION OF TERMS

Selected terms used in this report are defined below.

Angle of internal friction -angle of the plane of contact of soil particles with the horizontal at the point of sliding (shearing); angle whose tangent is the coefficient of friction between the soil particles (Cernica, 1982).

Channel-bed aggradation - filling in of the channel because streamflows are not sufficient to transport the material delivered from upstream channel-bed degradation (Simon and Hupp, 1986a).

Channel-bed degradation -headward erosion of the channel bed usually caused by increases in downstream channel gradient and cross-sectional area by man (Simon and Hupp, 1986a).

Cohesion -attraction of adsorbed water and soil particles that produce a body, which holds together but deforms plastically at varying water contents (Sowers, 1979).

Dry bulk-unit weight -ratio of the weight of the soil solids to the volume of the soil sample (Das, 1984).

Factor of safety -ratio of the resisting force (shear strength of the soil) to the driving force (weight of the soil). If the resisting force is less than the driving force, the factor of safety is less than 1.0, and therefore, failure occurs (Huang, 1983).

Failure-block width -the measured width of the failure block or the distance between affected stems of woody plants growing in bank material that has failed and fallen down slope and the existing top-bank edge (Hupp, 1987).

Iowa Borehole Shear Test -direct measure of shear strength of fine- to medium-grained soils in situ (from inside a borehole) (Handy, 1981).

Knickpoint -an abrupt change in channel-bed elevation along a reach of channel relative to the upstream or downstream direction.

Moisture content -ratio of the weight of the water present to the weight of the soil solids (Das, 1984).

Planar failure -landslide along a surface of rupture whereby the mass progresses down and out along a more or less planar or gently undulatory surface and has little rotational movement or backward tilting characteristics (Huang, 1983).

Rotational failure -landslide along a surface of rupture that is concave upward. The exposed cracks are concentric in plan and concave toward the direction of movement (Huang, 1983).

Shear strength -capacity of a soil to resist shear; in terms of effective stress, it can be given by the equation:

$$s' = c' + \sigma' \tan \phi'$$

where:

σ' is effective normal stress on plane of shear

c' is effective cohesion or apparent cohesion of the soil; and

ϕ' is effective angle of internal friction.

(Das, 1984).

Slough-line angle -angle attained by projecting the slope of failed blocks of soil mass (which represents a temporary angle of stability) to its intersection with the top of channel bank (flood-plain level). It is used to determine short-term (10-20 years) bank widening (Simon and Hupp, 1986b).

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ABSTRACT

The channel bed of Bakers Creek at the State Highway 547 crossing near Port Gibson, Claiborne County, Mississippi, has been relatively stable since 1961 except for about 2 feet of aggradation, which occurred between 1989 and 1992, probably because of floods in 1990 and 1991. Some changes have occurred in the channel width, however. Botanical evidence indicates that several bank failures in the vicinity of the crossing occurred during extreme floods in the spring of 1974.

Rates of channel gradation and widening--as determined from channel descriptions and botanical and geomorphological evidence along the banks--were used in conjunction with soil properties to estimate probable future channel changes in the next 10 to 20 years. If changes in channel-bed elevations in the past 30 years are representative of gradation patterns in the near future, then no significant channel degradation in the next 10 to 20 years is expected at the highway crossing. However, projections indicate bankfull channel width could increase as much as 8 feet upstream and 15 feet downstream of the highway crossing in the next 10 to 20 years. These projections are based on the assumption that no channel or watershed modifications and no unusually large and destructive flooding will occur before the year 2010.

INTRODUCTION

The Mississippi State Highway Department (MSHD) reconstructed the State Highway 547 crossing of Bakers Creek near Port Gibson, Claiborne County, Miss. (fig. 1), in 1979. The banks of the creek in the vicinity of the crossing have sloughed in recent years. As part of a cooperative program between the U.S. Geological Survey (USGS) and the MSHD to study the potential for gradation and widening of streams at highway crossings, the USGS conducted a study of channel-bed and bank stability for Bakers Creek at the State Highway 547 crossing.

Purpose and Scope

This report describes the existing channel and bank conditions and presents the results of a study to determine the potential for near-future (through the year 2010) gradation and widening of Bakers Creek at the State Highway 547 crossing near Port Gibson, Miss. Past and present channel and bank conditions were determined on the basis of measured channel-bed elevations, bank failures, and ages and types of trees on the channel banks. Dry bulk-unit weights and shear-strength properties of bank material were used to evaluate the potential for bank failures. Channel-gradation patterns were estimated on the basis of the assumption that past changes in channel-bed elevations are representative of probable future gradation patterns. Channel widening was estimated by using existing channel geometry, botanical evidence, and the bank-stability analyses. This report is the seventh in a series of channel and bank stability reports for selected stream crossings in Mississippi.

General Description of Bakers Creek

Bakers Creek is a naturally meandering stream located in the Loessial Bluff, East Gulf Coastal Plain physiographic region (Thornbury, 1965). The drainage area of Bakers Creek at State Highway 547 is about 34.8 mi^2 and the length of the channel upstream of the site is about 13.5 mi. The average channel slope in the vicinity of the crossing is about 7 ft/mi. A small tributary is crossed by State Highway 547 about 0.2 mi west of the main-channel bridge. The tributary flows into Bakers Creek about 0.2 mi downstream of the Bakers Creek crossing. Approximately 0.5 mi downstream from the State Highway 547 crossing, Bakers Creek flows into Little Bayou Pierre. Bakers Creek at the State Highway 547 crossing is affected by backwater during flooding on Little Bayou Pierre; backwater could cause aggradation of the channel bed at the site. No knickpoints on the channel bed of Bakers Creek were observed in the field. The channel bed of Bakers Creek in the vicinity of State Highway 547 is incised into a layer of gray sand, which is overlain, in places, by a layer of silty sand and gravel and is subject to scour and fill during large floods. The State Highway 547 crossing has been the site of large debris piles during floods in the recent past, according to personnel of the USGS and the MSHD. These debris piles have contributed to significant scour and bridge failure. The meandering nature of the creek causes undercutting of the lower banks in the vicinity of the bridge.

During the construction of the State Highway 547 bridge in 1978-79, a temporary detour bridge was placed downstream to reroute traffic. In January 1979, that bridge failed during a large flood which resulted from excessive rainfall on January 19-20, 1979. A total of 7.10 in. of rainfall was reported at Port Gibson for the 24-hour period ending at 7:00 a.m. on Jan. 20, 1979. The resulting flood on Bakers Creek, which was estimated to have had maximum velocities greater than 5 ft/s according to MSHD personnel, piled debris (large trees) against the temporary bridge. The temporary bridge probably failed because the bridge pilings were undermined by local and contraction scour caused primarily by the debris.

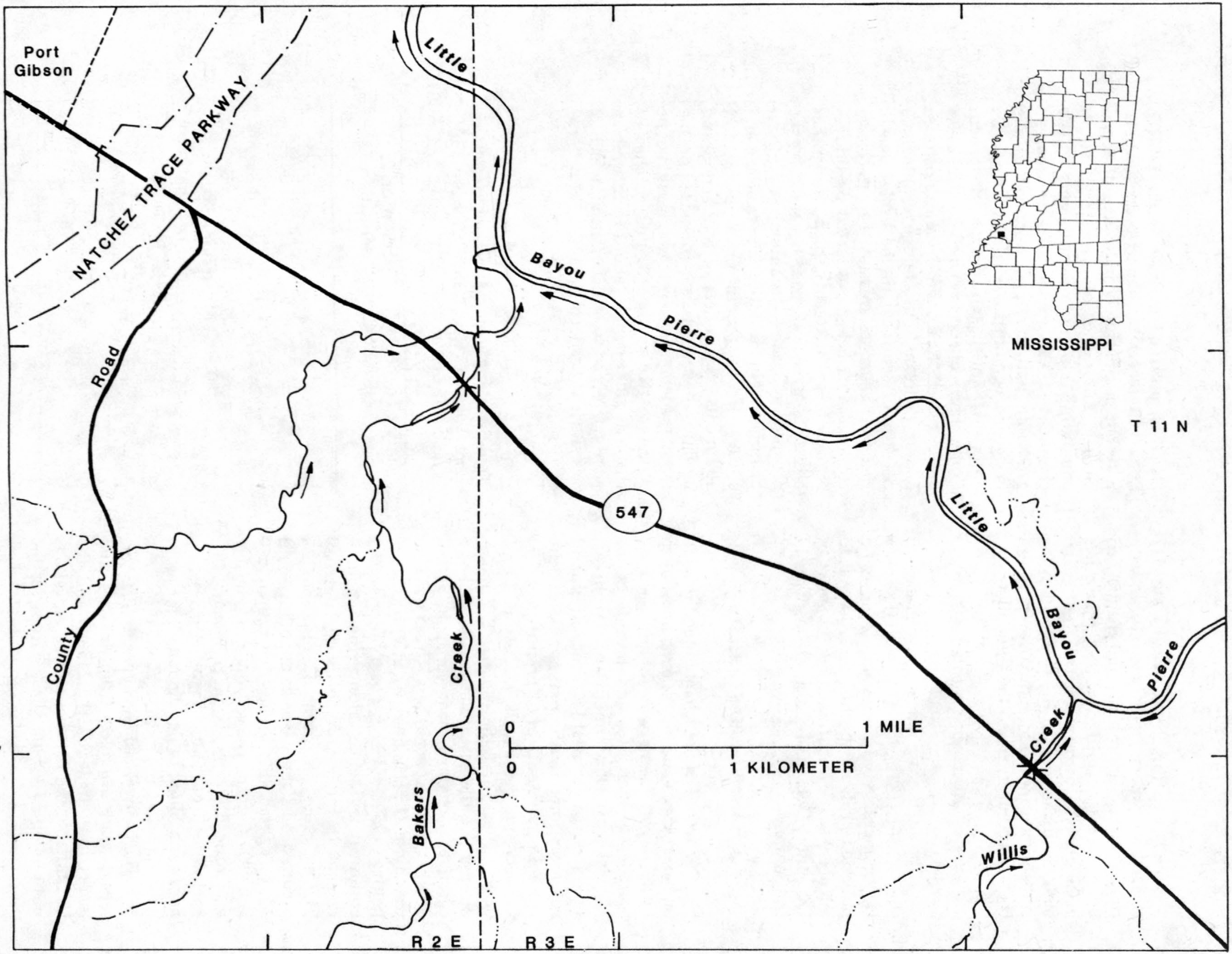

Figure 1.--Location of Bakers Creek at State Highway 547 near Port Gibson.

The existing State Highway 547 crossing of Bakers Creek is reinforced with riprap on the channel banks and channel bed underneath the bridge. Sheet piling has been placed upstream on the right (east) bank to further protect the bridge from the cutbank of a meander, and more riprap has been placed upstream of the sheet piling.

Acknowledgments

The authors are indebted to members of the Mississippi State Highway Department, Hydraulics Division, who provided bridge-inspection records, and to members of the Department's Soil Mechanics Laboratory, who assisted in the analyses of soil samples.

CHANNEL-BED STABILITY

No record of any channel modification on Bakers Creek and only one modification to Little Bayou Pierre was found based on searches of map files and records at the Mississippi Department of Archives, searches of available literature, and conversations with personnel of the U.S. Department of Agriculture, Soil Conservation Service, the U.S. Army, Corps of Engineers; and the MSHD. The modification to Little Bayou Pierre consisted of a cutoff of a channel meander about 5.6 mi downstream from Bakers Creek, in the vicinity of U.S. Highway 61 at Port Gibson, before 1950. Field observations and botanical evidence along the channel reaches in the vicinity of State Highway 547 indicated no recent degradation has occurred on Bakers Creek, although about 2 ft of aggradation occurred between 1989 and 1992 (fig. 2). The aggradation probably was caused by floods in 1990 and 1991. Backwater from Little Bayou Pierre could have contributed to this aggradation.

The channel-bed elevations used in this report were obtained from surveys and inspections made by the MSHD and the USGS (table 1). All channel-bed elevations were obtained by the USGS except for the elevation obtained in 1979 by the MSHD. Some differences in channel-bed elevations may not be absolutely indicative of actual change, but rather of error involved in comparing survey measurements. The channel-bed elevations used to analyze gradation patterns were obtained at the bridge; no significant evidence of contraction and (or) local scour was observed. Contraction scour occurs when flow velocities are increased for a short distance upstream and downstream from a bridge resulting in a net loss of sediment in the bridge reach. Increased velocities are caused by the cross-sectional area being contracted by bridge-approach embankments, piers, and other obstructions. Local scour is caused by the erosion of the streambed by local disturbances in the flow, such as vortices and eddies in the vicinity of piers and abutments. The effect of contraction and local scour would be superimposed on the recent gradation and, therefore, would not be representative of the selected reaches of channels studied. Elevations in this report were referenced to MSHD Datum, which at this site is to sea level datum.

Table 1.--*Measured channel-bed elevations for Bakers Creek at State Highway 547 near Port Gibson, 1961-92*

Year	Channel-bed elevation (feet)	Source of information
1961	80.8	U.S. Geological Survey
1977	80.3	U.S. Geological Survey
1979	80.5	Mississippi State Highway Department bridge plans
1989	79.9	U.S. Geological Survey
1992	82.0	U.S. Geological Survey

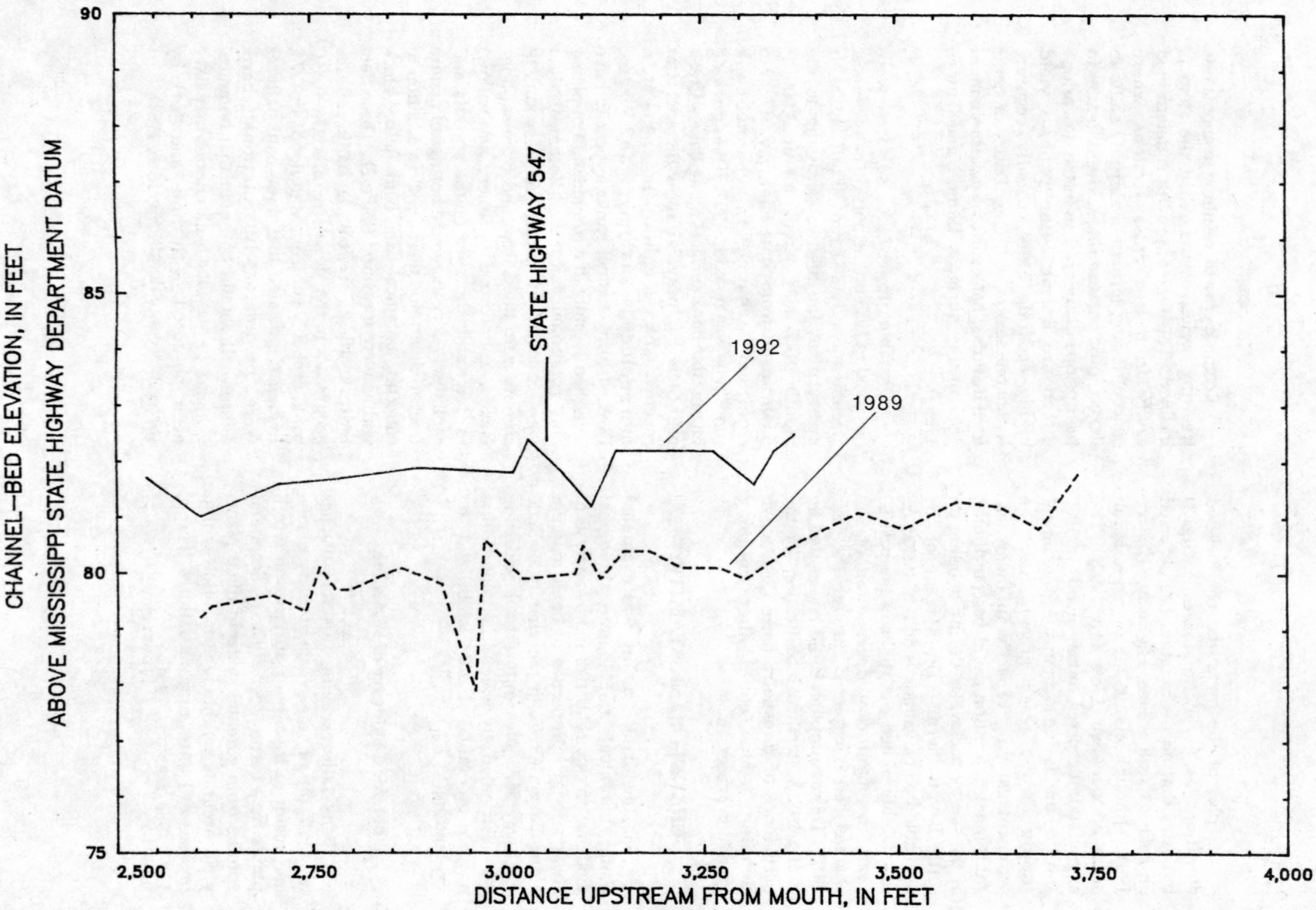

Figure 2.--Channel-bed profiles in 1989 and 1992 for Bakers Creek in the vicinity of State Highway 547 near Port Gibson.

A plot of the measured channel-bed elevations as a function of time (fig. 3) indicates that no degradation has occurred on Bakers Creek at State Highway 547 since 1961, although about 2 ft of aggradation occurred between 1989 and 1992. The aggradation occurred during floods in 1990 and 1991 and is due to an upstream sediment supply to the reach greater than the sediment carrying capacity in the reach. Additional deposition could be contributed at the site by backwater during flooding on Little Bayou Pierre. The average of the available bed elevations is 80.7 ft. Based on the stability of bed elevations in the past 30 years, no significant degradation of the channel bed is expected through the year 2010. This assumption could be negated by channel or watershed modifications or the occurrence of unusually large destructive flooding, which could alter on-going gradation processes.

CHANNEL-BANK STABILITY

Channel-bank stability was evaluated using botanical and geomorphological evidence on channel banks and by analysis of shear strength properties of bank material along Bakers Creek in the vicinity of State Highway 547. Near-future bank widening was estimated by extending slough-line angles on failed banks stabilized by vegetation.

Botanical Evidence of Widening

Bank failures along unstable reaches may kill, tilt, or scar existing woody plants, and result in fresh bank surfaces on which plants may become established. Scars and sprouts from parental stems of tilted plants yield accurate (within 1 year, often within one season) dates of bank failures (Hupp, 1987, 1988, Sigafoos, 1964).

Eccentric growth, resulting in anomalous tree-ring series, occurs when the stem is inclined. This type of growth is determined easily from tree cross sections where concentric-ring formation abruptly shifts to the eccentric because ring width is greater in the upslope direction than in the downslope direction. Eccentric-ring patterns yield highly accurate dates, usually accurate within one season, of tilting. Dating of stems from disturbed bank surfaces yields minimum ages of the surfaces (Simon and Hupp, 1986b).

Unstable upper-bank surfaces were observed in 1989 on the outside bank of most stream meanders from about 1,000 ft upstream of the highway crossing to the mouth of Bakers Creek about 3,000 ft downstream from State Highway 547. No significant change in channel-bank conditions was noted in 1992. Trees growing on unstable bank surfaces along Bakers Creek near State Highway 547 show the effects of recent bank sloughing in their stem morphology, anatomy, and ages. Downstream, channel banks appear to have sloughed recently in a combination of planar and rotational failures. Botanical data were collected by taking cross sections of sprouts from tilted trees and from saplings (such as cottonwood, sycamore, and willow) to determine the ages of the sprouts and saplings, and by increment borings of mature trees to determine their ages. In addition to collecting botanical data, bank failure-block widths were measured (table 2). These data indicate 10- to 12-ft-wide bank failures occurred on the downstream right (east) bank, probably subsequent to floods in 1974. Evidence indicated that these bank failures were predominately rotational bank failures. It should be noted that botanical evidence of previous bank failures may have been obscured with time and (or) by succeeding large floods (Sigafoos, 1964).

Table 2.--*Botanical and geomorphological data collected in 1989 on Bakers Creek in the vicinity of State Highway 547 near Port Gibson*

Distance from bridge (feet)		Failure-block width (feet)		Description of data collection
upstream	downstream	left (west) bank	right (east) bank	
300	--	6-8	--	Dated 15-year-old tilt sprout on willow.
--	100	--	10-12	Cored 45-50-year-old sycamore, showing compression about 15-17 years ago; also dated 16-year-old sycamore tilt sprout.
--	400	--	--	Noted undercutting at toe of right bank.
--	600	--	--	Cored several cottonwoods on right (east) bank, average age equal to 15 years
--	800	--	--	Cored 17-19-year-old willow that had tilted.
--	1,100	6-8	--	Noted recent failure of 14-inch elm (diameter measured about 4 feet from ground level).

Table 3.--*Dry bulk-unit weight and shear-strength properties of bank material as determined from borehole tests on the right (east) bank of Bakers Creek about 75 feet downstream from State Highway 547 near Port Gibson*

[ft, feet; lb/ft^3, pounds per cubic foot; lb/ft^2, pounds per square foot]

General soil description	Bore hole depth (ft)	Dry bulk-unit weight (lb/ft^3)	Cohesion (lb/ft^2)	Angle of internal friction (degrees)
Dark brown, silty clay	0 - 1.0	86	274	30.0
Brown silty clay	1.0 - 3.0	93	338	19.3
Brown clay	3.0 - 8.5	97	300	21.6
Gray sand	8.5 - 14.5	104	[a]0	[a]39.2

[a] Mississippi State Highway Department (1978)

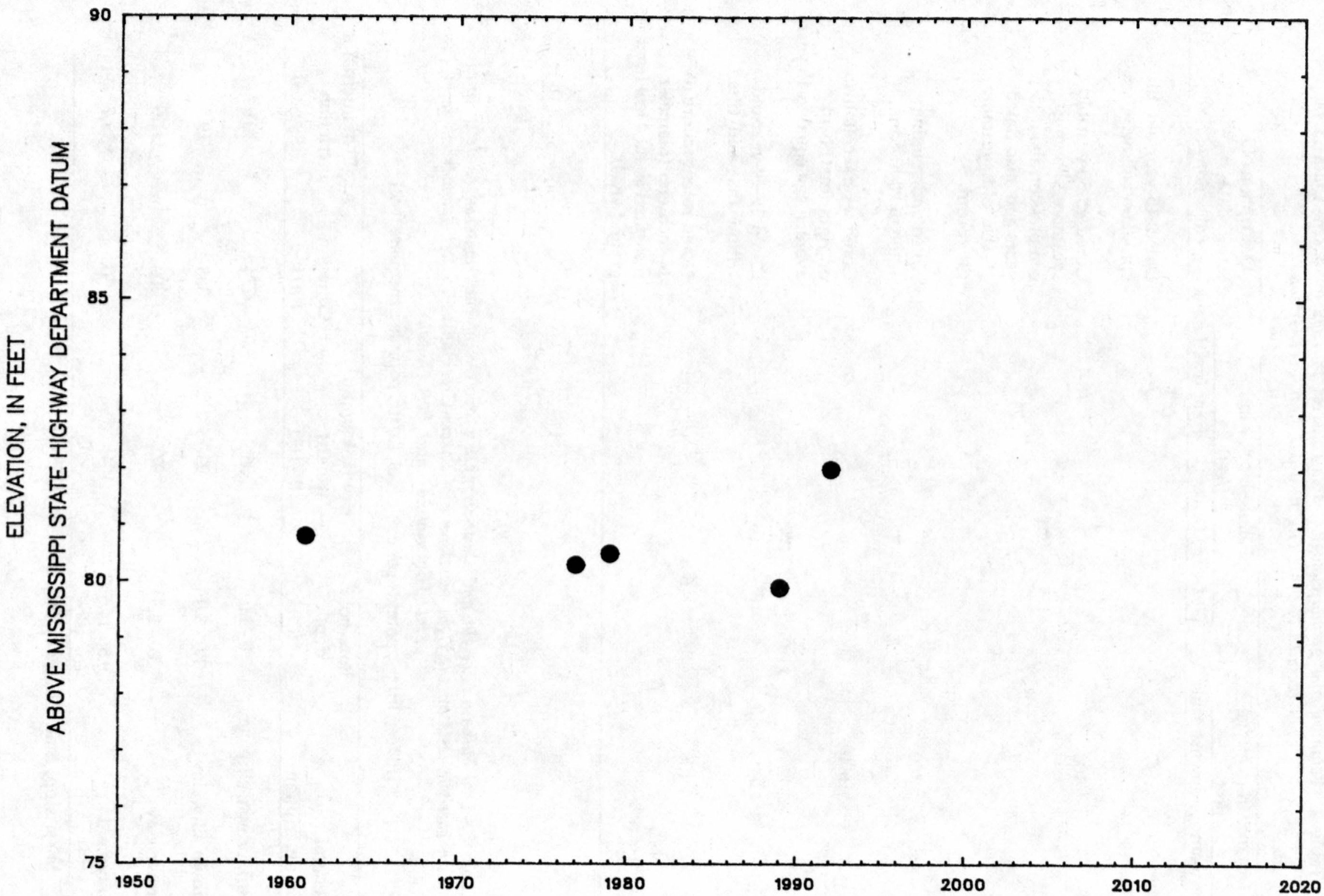

Figure 3.---Measured channel -bed elevations for Bakers Creek at State Highway 547 near Port Gibson,1961-92.

Stability Analyses

Shear-strength properties of the channel banks were determined on the right (east) bank of Bakers Creek about 75 ft downstream from State Highway 547 with the Iowa Borehole Shear Tester[1] (BST), (Handy and Fox, 1967) and were used in combination with surveyed channel geometry to assess channel stability at the site. Dry bulk-unit weight and shear-strength properties of bank material obtained at the site are listed in table 3. The average moisture content of the soils when tested was about 20 percent.

Shear-strength data obtained using the BST have compared reasonably well with the results of triaxial shear-strength tests (Thorne and others, 1981). BST results for individual soil strata were used in stability analyses.

The factor of safety used in describing channel-bank stability is the ratio of the resisting force (shear-strength of the bank material) to the driving force (weight of the bank material). Therefore, if the resisting force is equal to the driving force, then the factor of safety is 1.0. Theoretically, when the factor of safety is less than 1.0, failure occurs, and when it is greater than 1.0, failure does not occur. These analyses are based on the assumption that all the forces are considered. A factor of safety of at least 1.5 usually is used in design.

Factors of safety for rotational bank failures for selected percentages of bank saturation were determined by bank-stability analyses using shear-strength properties and dry bulk-unit weights of the bank material at channel cross sections located 300 ft upstream and 75 ft downstream from the State Highway 547 crossing. An iterative search to determine the minimum factor of safety for each selected percentage of bank saturation was done using the computer program REAME (Rotational Equilibrium Analysis of Multilayered Embankments) developed by Huang (1983).

The critical-failure surfaces with the respective factors of safety for selected bank-saturation conditions are shown in figures 4 and 5. Factors of safety ranged from 0.6 on the right (east) bank of the cross section located about 75 ft downstream of the State Highway 547 crossing to 1.8 on the right (east) bank of this cross section at all levels of saturation tested, indicating that the banks of the creek in the vicinity of State Highway 547 are fairly unstable (fig. 5). The upstream right (east) bank becomes susceptible to failure (factor of safety less than 1.5) when the channel bank is more than 50 percent saturated and fails when the channel bank is 100 percent saturated (fig. 4). The upstream left (west) bank appears stable, with a factor of safety greater than 1.5 even at 100-percent bank-saturation conditions. Failure-block widths on the upstream right (east) bank measured about 7 ft near a cross section located about 200 ft upstream of the sheet piling and riprap bank protection in place upstream of the State Highway 547 bridge. A failure-block width of about 5 ft was computed for the right (east) bank of the cross section located 75 ft downstream from the bridge (fig. 5). Smaller failure blocks occur near the toes of both banks of the downstream cross section. These failures may be due to the non-cohesive nature of the gray sand that forms the channel bed and lower banks in the vicinity of the highway crossing in combination with the natural meandering nature of the stream. Field observations in 1989 and 1992 confirm undercutting on the lower banks, especially at meander bends.

Widening Analyses

Estimates of near-future (10 to 20 years) channel-bank widening can be obtained by projecting the streambank slough-line angle on a plotted cross section (Simon and Hupp, 1986a). Extension of this slough-line angle

[1]The use of trade or product names in this report is for identification purposes only, and does not constitute endorsement by the U.S. Geological Survey.

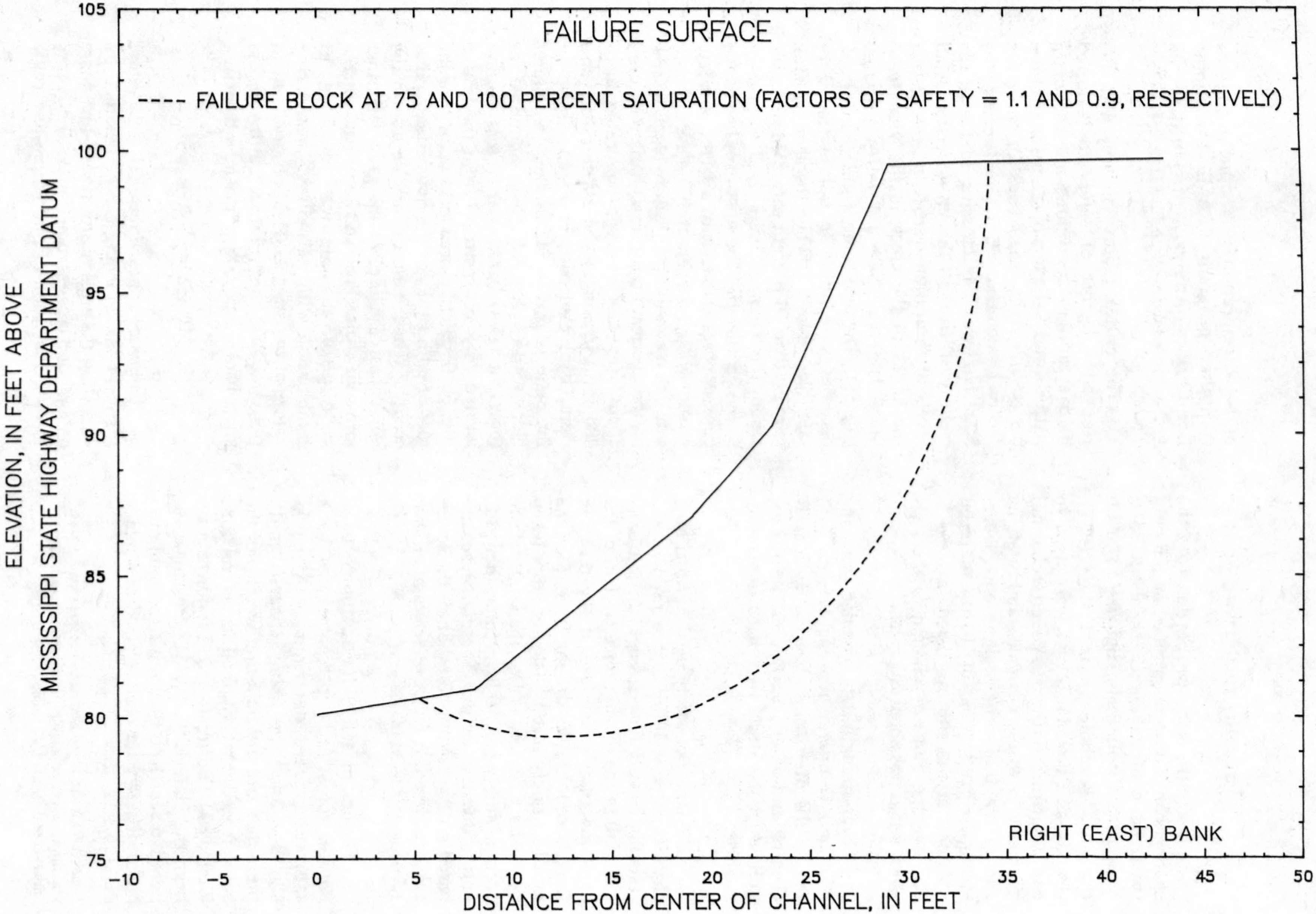

Figure 4.--Bank profile showing critical failure surfaces for the right (east) bank of Bakers Creek, 300 feet upstream from State Highway 547 near Port Gibson, 1989.

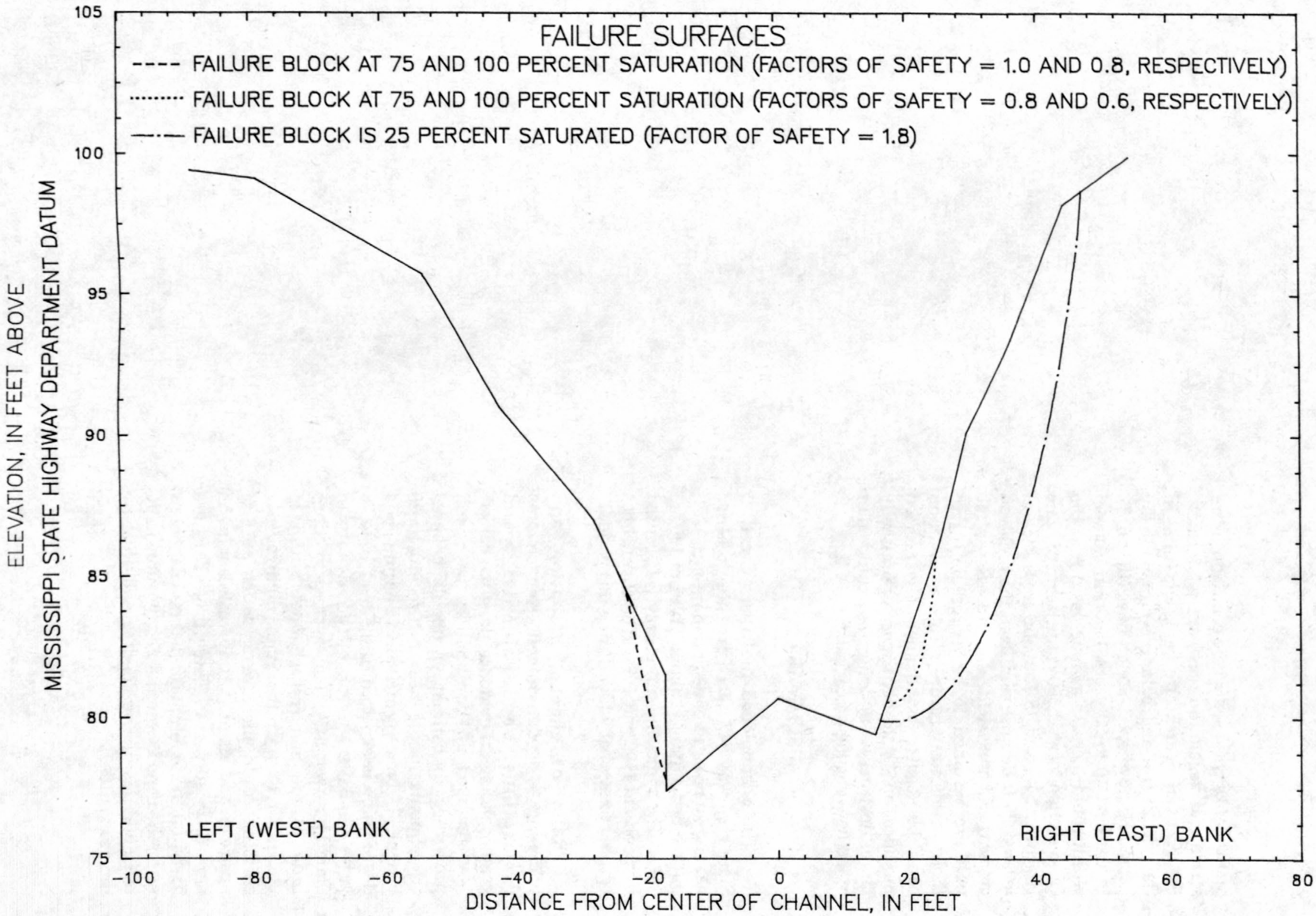

Figure 5.—Cross section showing critical failure surfaces for channel banks on Bakers Creek, 75 feet downstream from State Highway 547 near Port Gibson, 1989.

on the banks was used where conditions were stable and vegetation was well established. Estimates of near-future bank widening in the vicinity of the bridge were made by extending developed slough lines (figs. 6, 7). In the next 10 to 20 years, bankfull channel width could increase as much as 8 ft at the cross section located 300 ft upstream of State Highway 547, and 15 ft at the cross section located 75 ft downstream from the highway crossing. Channel-widening processes in the past are assumed to be representative of those in the near future. This assumption could be negated by channel or watershed modifications or the occurrence of unusually large, destructive flooding that could alter on-going widening processes.

SUMMARY

The channel bed of Bakers Creek at State Highway 547 near Port Gibson, Miss., has shown no signs of degradation since 1961, but the bed aggraded about 2 ft from 1989 to 1992. The aggradation probably was caused by floods in 1990 and 1991. The channel has become somewhat wider during this period.

Rates of channel gradation and widening -- as determined from channel descriptions, and botanical and geomorphological evidence along the banks -- were used in conjunction with soil properties to estimate probable channel adjustments in the near future (10 to 20 years). No significant channel-bed degradation is expected in the next 10 to 20 years on Bakers Creek in the vicinity of State Highway 547. However, projections indicate the bankfull channel width of Bakers Creek near the State Highway 547 crossing could increase as much as 8 ft upstream and about 15 ft downstream in the next 10 to 20 years. These projections are based on the assumption that no channel or watershed modifications and no unusually large and destructive flooding will occur by the year 2010.

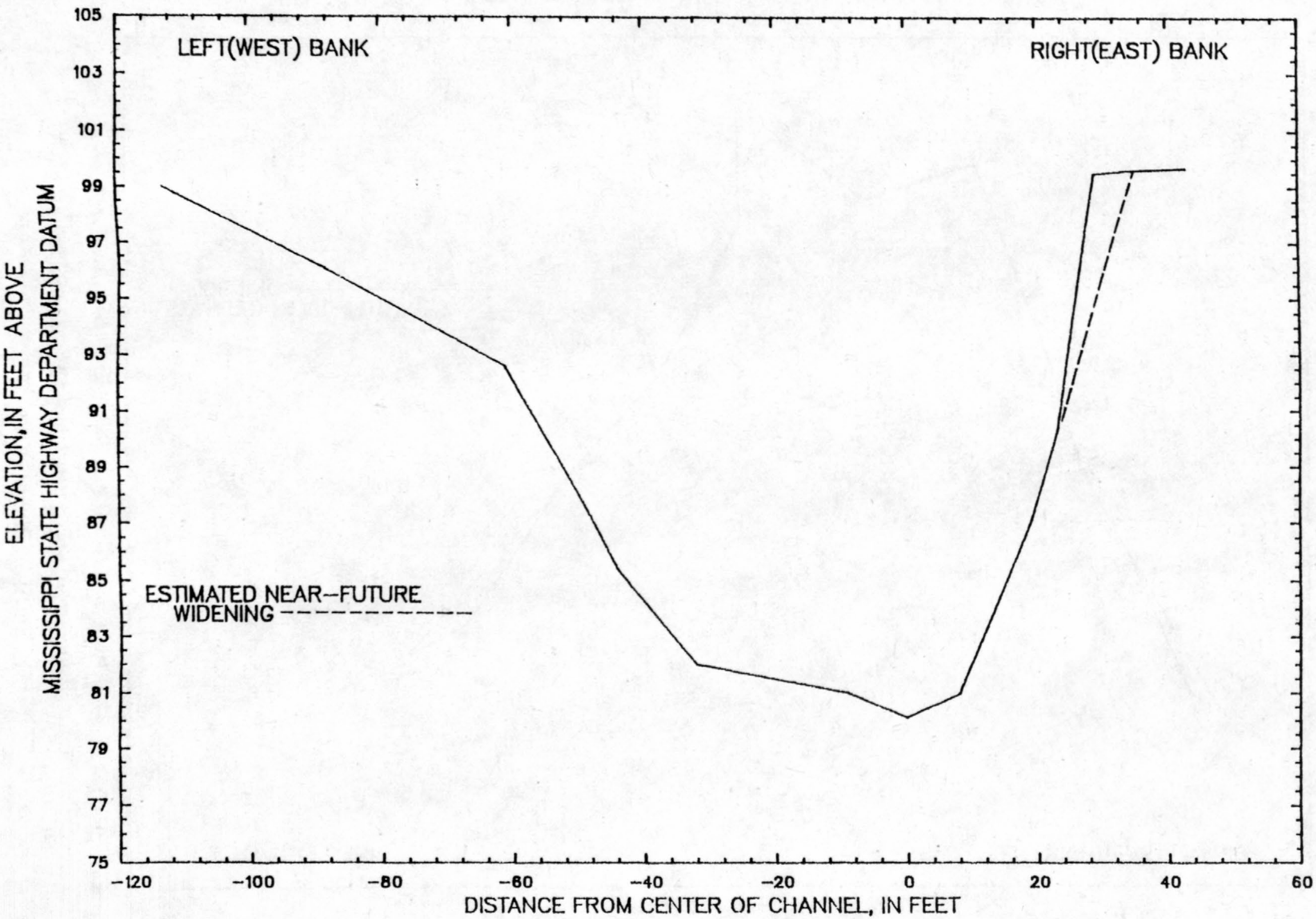

Figure 6.--Channel cross section showing estimate of near-future widening for Bakers Creek, 300 feet upstream from State Highway 547 near Port Gibson, 1989.

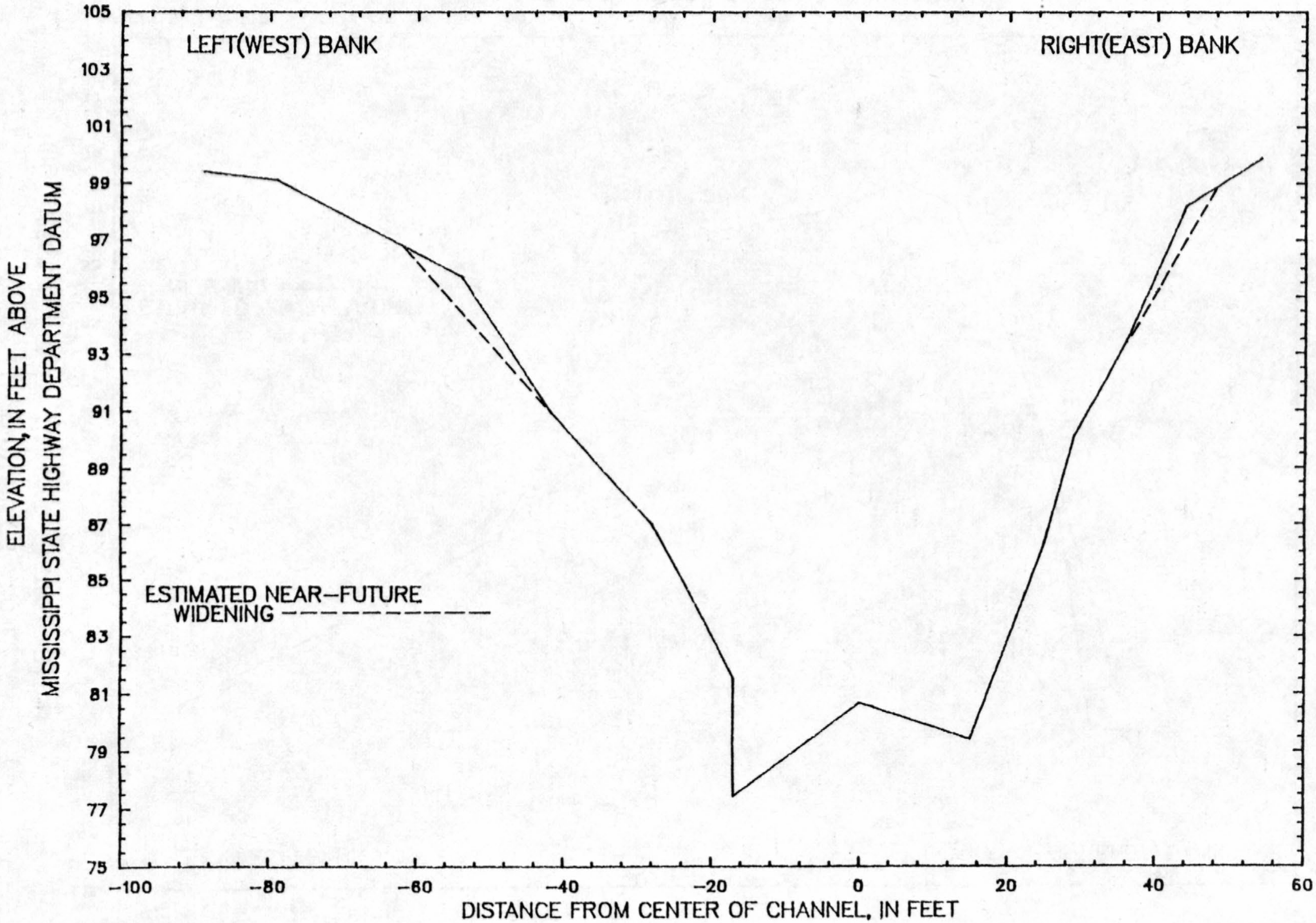

Figure 7.--Channel cross section showing estimates of near-future widening for Bakers Creek, 75 feet downstream from State Highway 547 near Port Gibson, 1989.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—775-177