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Simulations of Flooding on Tchoutacabouffa River at State Highways 15 and 67 at D’Iberville, Mississippi

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 01–4007

Prepared in cooperation with the

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

Cover photograph: Looking southwest near intersection of State Highways 15 and 67 on September 29, 1998 (Photograph by Trent Baldwin, USGS).

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Pearl, Mississippi
2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per second (ft/s)	0.3048	meter per second
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per second (ft^2/s)	0.0929	meter squared per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Vertical datum: All elevations in this report are in feet above sea level. In this report, “sea level” refers to the North American Vertical Datum of 1988 (NAVD of 1988).

Simulations of Flooding on Tchoutacabouffa River at State Highways 15 and 67 at D'Iberville, Mississippi

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ABSTRACT

A two-dimensional finite-element surface-water model was used to simulate the effects of the proposed State Highways 15 and 67 relocation on water-surface elevations and flow distributions for the 100-year flood on the Tchoutacabouffa River at D'Iberville, Mississippi. The Mississippi Department of Transportation plans to relocate State Highways 15 and 67 by removing a portion of the existing four-lane highway and constructing a four-lane facility upstream of the existing alignment. The proposed alignment is located on the northern floodplain and will tie into the existing highway about 1,000 feet north of the dual State Highways 15 and 67 bridges. The proposed alignment will intercept flows that cross the existing highway during large floods. Seven scenarios were simulated for the 100-year flood, including four proposed alternative configurations for drainage structures.

The model grid was developed by using surveyed floodplain cross sections and channel bathymetry data obtained by using an Acoustic Doppler Current Profiler, in combination with a global positioning system. The model was calibrated and verified by using surveyed flood profiles through the study reach and flood discharge measurements obtained at the State Highways 15 and 67 crossing. Model parameters were adjusted so that the computed water-surface profiles agreed closely with the surveyed flood profiles.

Computed water-surface differentials across the proposed alignment near the northern edge of the floodplain for the four alternatives proposed by the Mississippi Department of Transportation ranged from 1.4 to 2.6 feet. Much lower differentials were computed in the vicinity of the main-channel bridge. The computed water-surface elevation at McCully Drive, upstream of the proposed alignment, was 17.3 feet for existing conditions. Computed water-surface elevations at McCully Drive for the proposed alternatives ranged from 17.3 to 17.8 feet.

INTRODUCTION

The Mississippi Department of Transportation (MDOT) proposes to relocate State Highways 15 and 67 in the Tchoutacabouffa River floodplain near D'Iberville, Miss. (Fig.1). During lare floods, a substantial amount of flow crosses the existing alignment near the northern edge of the floodplain. The proposed relocation, on the northern floodplain upstream of the existing alignment, would force flows on the northern floodplain through the main-channel bridge, which is located at the southern edge of the flooplain. The MDOT is concerned that the proposed alignment may cause excessive backwater upstream of the site during large floods. The MDOT has proposed four alternative configurations for drainage structures. Computation of backwater for the existing conditions and the alternative proposed conditions is complicated by the State

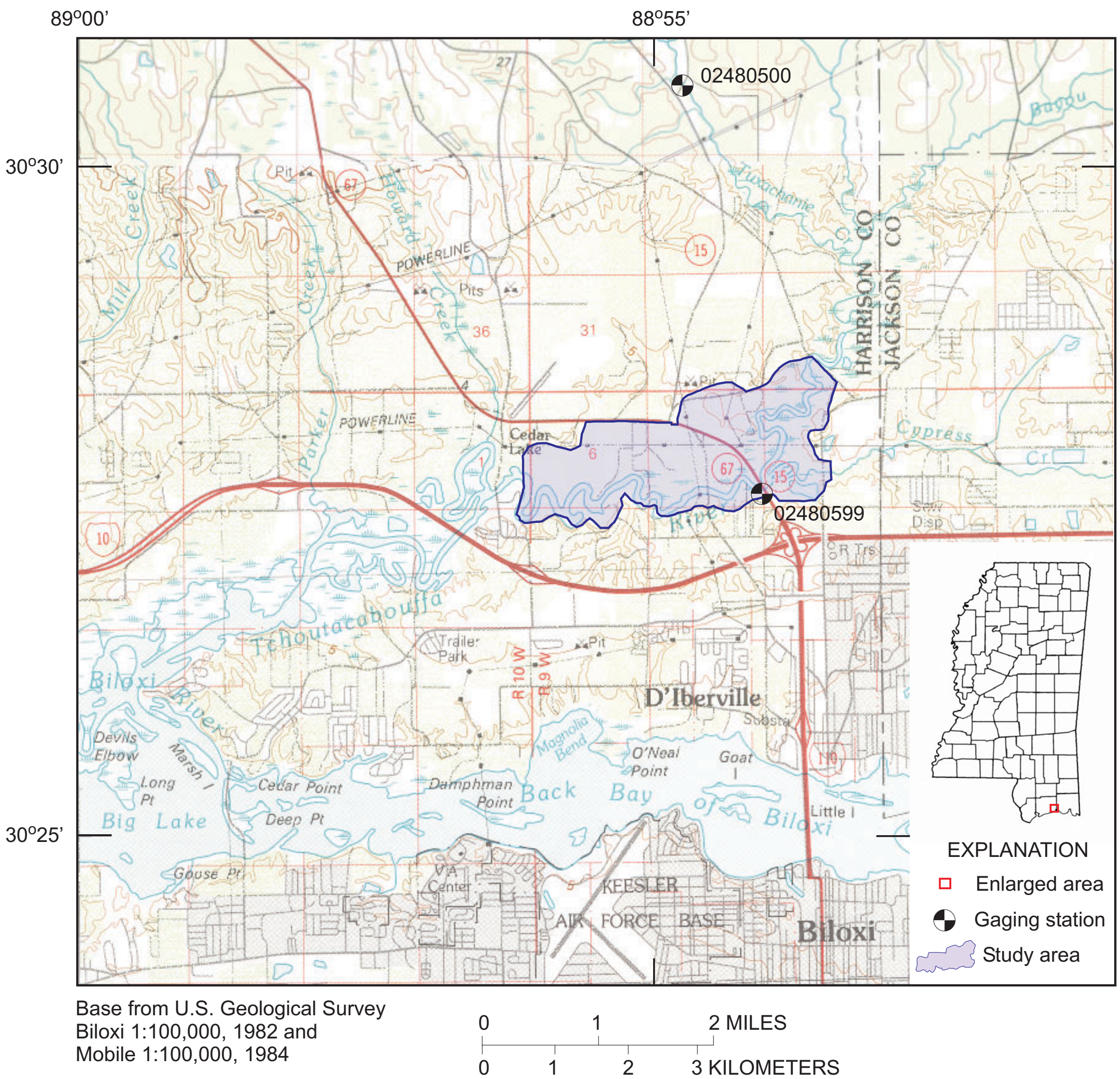

Figure 1. Lower Tchoutacabouffa River Basin and study area at D'Iberville, Mississippi.

Highway 15 and old State Highway 15 embankments located about one half mile downstream of the State Highways 15 and 67 crossing. Backwater and flow distributions can be accurately computed by using a two-dimensional flow model. In 1999, the U.S. Geological Survey (USGS), in cooperation with the MDOT, analyzed the flood hydraulics for the Tchoutacabouffa River in the vicinity of State Highways 15 and 67 near D'Iberville, Miss.

Purpose and Scope

This report presents the results of a two-dimensional flow study of the Tchoutacabouffa River at State Highways 15 and 67 near D'Iberville, Miss. Water-surface elevations and vertically-averaged horizontal velocities for the 100-year flood were simulated for former, existing, and alternative proposed conditions using a two-dimensional finite-element surface-water model. Computed water-surface elevations throughout the study reach are given for each simulation. Flow distributions are given for the existing and proposed alignments, and selected velocity data are presented. This report also discusses the collection of topographic and bathymetric data used in the study, development of the model grid, and calibration and verification of the model by using discharge measurements and flood-profile data.

Acknowledgments

The author appreciates the assistance of the MDOT engineers who provided site plans and aerial photography and the MDOT surveyors who provided more than 50,000 feet (ft) of floodplain survey. The author also acknowledges those of the USGS who collected the flood data used in this study.

DESCRIPTION OF THE STUDY AREA

The study area is located in southeastern Harrison County just north of D'Iberville, Miss. (fig. 1). The drainage area of the Tchoutacabouffa River at the State Highways 15 and 67 bridge is 217 square miles (mi^2). The study area is about 3 miles (mi) long and 1 mi wide, and is located between river miles 4.8 (south of Cedar Lake) and 10.1 (at Lamey Bridge Road). Interstate Highway 10 crosses the Tchoutacabouffa River at river mile 4.1, about 0.7 mi downstream of the downstream end of the study reach. River mileage was assigned by the USGS for use only in this report.

The Tchoutacabouffa River flows into the Biloxi River about 8.3 mi downstream of the State Highways 15 and 67 bridge. The Biloxi River flows into the Back Bay of Biloxi about 1 mi downstream of the mouth of the Tchoutacabouffa River. Water-surface elevations in the study area are affected by tides during low or moderate headwater flow conditions, but during extreme headwater flooding, tidal effects are negligible.

The average slope of the channel in the study reach is about 1.8 feet per mile (ft/mi). The Tchoutacabouffa River channel generally follows the southern edge of the floodplain and has numerous meanders and cutoffs. The floodplain is typically wooded with a few large open areas. Two 150-ft-wide power-line cuts run longitudinally and transversely across the study area. Floodplain elevations at the swampy downstream half of the study area generally range from 4 to 7 ft. The upstream half of the study area is low and swampy near the river, whereas broad knolls rise to about 16 ft along the northern edge of the floodplain.

Existing Conditions

The existing State Highways 15 and 67 alignment consists of a four-lane divided highway that crosses the Tchoutacabuffa River nearly normal to the channel and the southern floodplain (fig.2). About halfway across the floodplain, the highway begins a broad curve to the west (downstream). About 1 mi northwest of the bridge, the two-lane State Highway 15 turns to the north. The four-lane state Highway 67 continues to the west from the State Highway 15 intersection, becoming a two-lane highway within a few hundred feet of the intersection. Old State Highway 15 is a two-lane road that crosses the Tchoutacabouffa River about 0.6 mi downstream of the existing four-lane highway, and ties into State Highways 15 and 67 near station 14+640 (fig. 2). Lickskillet Road is a two-lane road that runs along the northern edge of the floodplain upstream of State Highway 15. McCully Drive is a two-lane road that intersects Lickskillet Road about 0.6 mi east of the intersection of Lickskillet Road and State Highway 15. Hickman Road is a two-lane road on the northern floodplain that intersects State Highway 67 about 0.3 mi west of the State Highway 15 intersection.

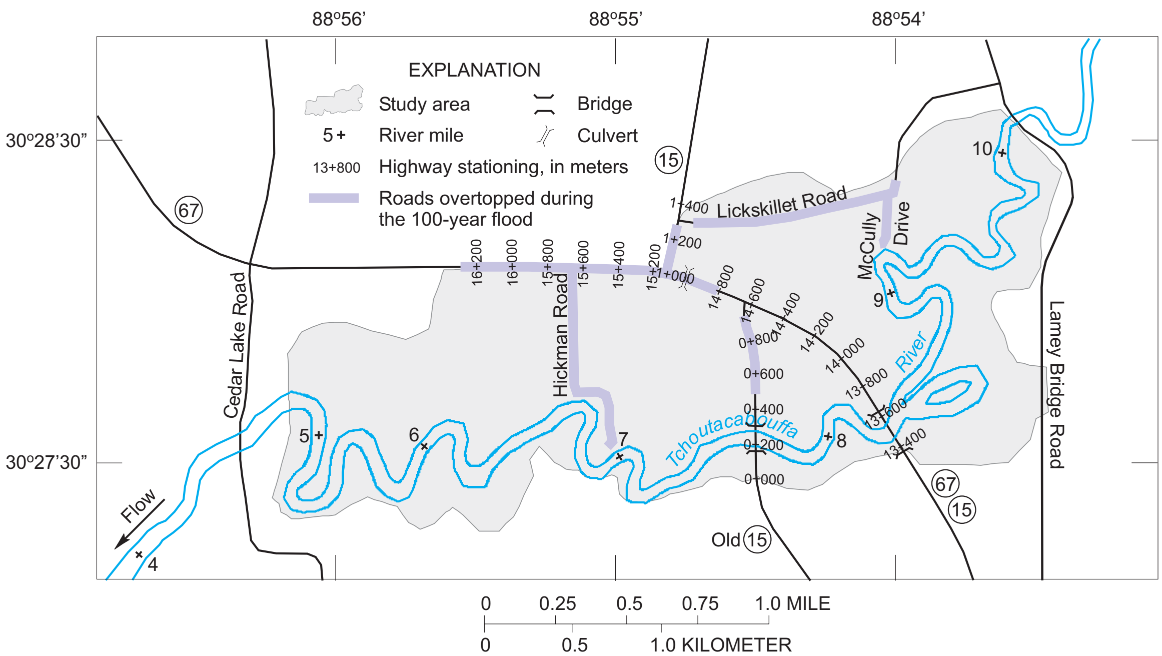

Figure 2. Existing principal roads in the study area.

The primary waterway opening along the State Highways 15 and 67 alignment consists of 872-ft-long dual bridges (fig.3). A 9-ft-wide by 3-ft-high (9 x 3) box culvert is located on State Highways 15 and 67 near station 15+000. Prior to 1998, a 393-ft-long bridge (Coursey Bridge) on old State Highway 15 crossed the channel. The MDOT State Aid Division replaced the bridge with a 420-to-long bridge in 1998. Low chords for the bridges on State Highways 15 and 67 and old State Highway 15 are above the elevation of the 100-year flood.

During large floods, State Highway 67 is overtopped for nearly a mile in the vicinity of Hickman Road (fig. 2). About half of the floodwater approaching the State Highways 15 and 67 intersection flows over State Highways 15 and 67 southward to the downstream floodplain. The remainder flows over State Highway 15 westward, becoming nearly stagnant north of State Highway 67, and then flowing southward across a broad stretch of that road. During large floods, the differential between water surfaces upstream and downstream of the State Highways 15 and 67 alignment, east of the State Highway 15 intersection, will likely approach 2 ft. Downstream of the State Highways 15 and 67 main-channel bridge a small portion of the flow expands toward the northwest onto the floodplain and crosses several hundred feet of old state Highway 15. The Lickskillet Road, McCully Drive, and Hickman Road grades are about equal to surrounding ground elevations and have no substantial effect on floodflows.

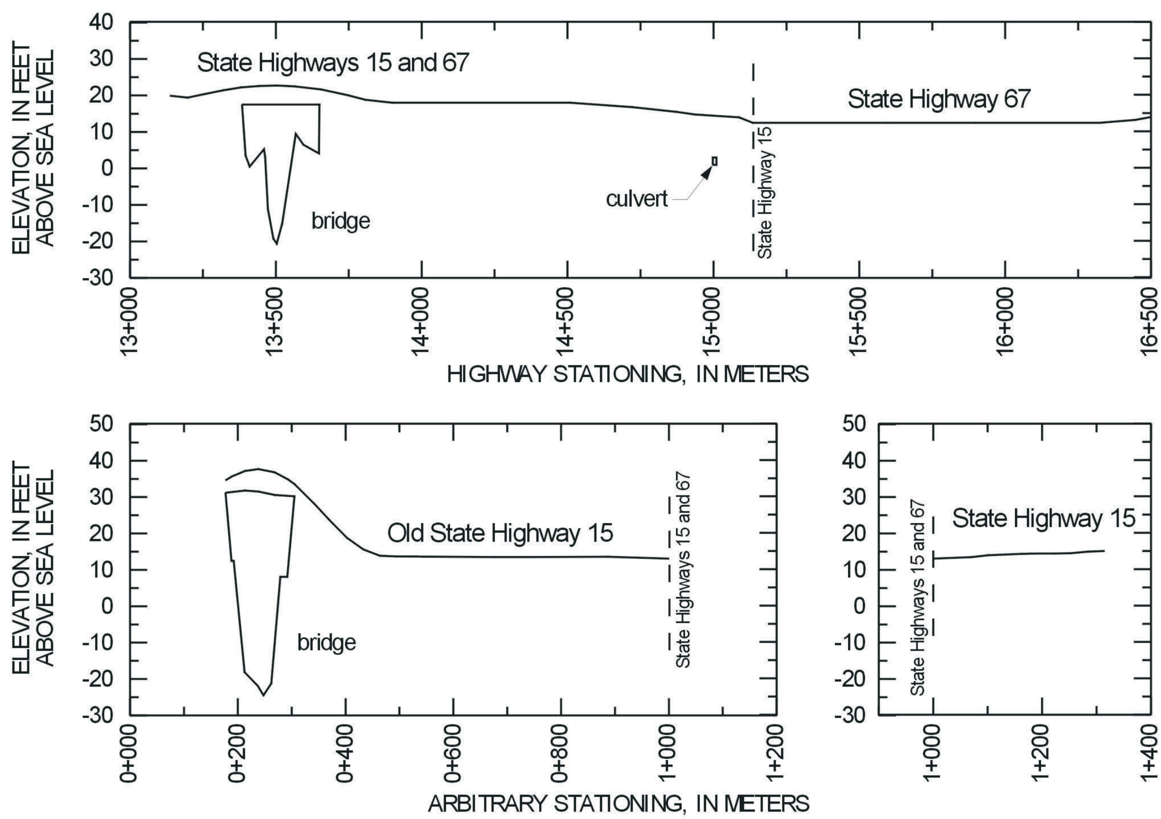

Figure 3. Existing roadway profiles and waterway openings.

Proposed Conditions

The MDOT plans to relocate State Highways 15 and 67 by removing a portion of the existing four-lane highway embankment and constructing a four-lane facility upstream of the existing alignment (fig. 4). The proposed alignment is located on the northern floodplain and will tie into the existing highway about 1,000 ft north of the dual State Highways 15 and 67 bridges. The existing main-channel bridges are not scheduled to be replaced at this time. Part of Lickskillet Road will be removed and an at-grade interchange will be constructed to connect Lickskillet Road and existing State ighway 67 to the new highway. Center-line elevations for the proposed State Highways 15 and 67 alignment range from 19 to 23 ft (fig. 5), and floodflows likely will not overtop the proposed roadway. East of the proposed alignment, floodflows likely will overtop Lickskillet Road where grades are generally 15 to 17 ft. The MDOT has proposed four alternative configurations for drainage structures on the proposed relocations of State highways 15 and 67 and Lickskillet Road.

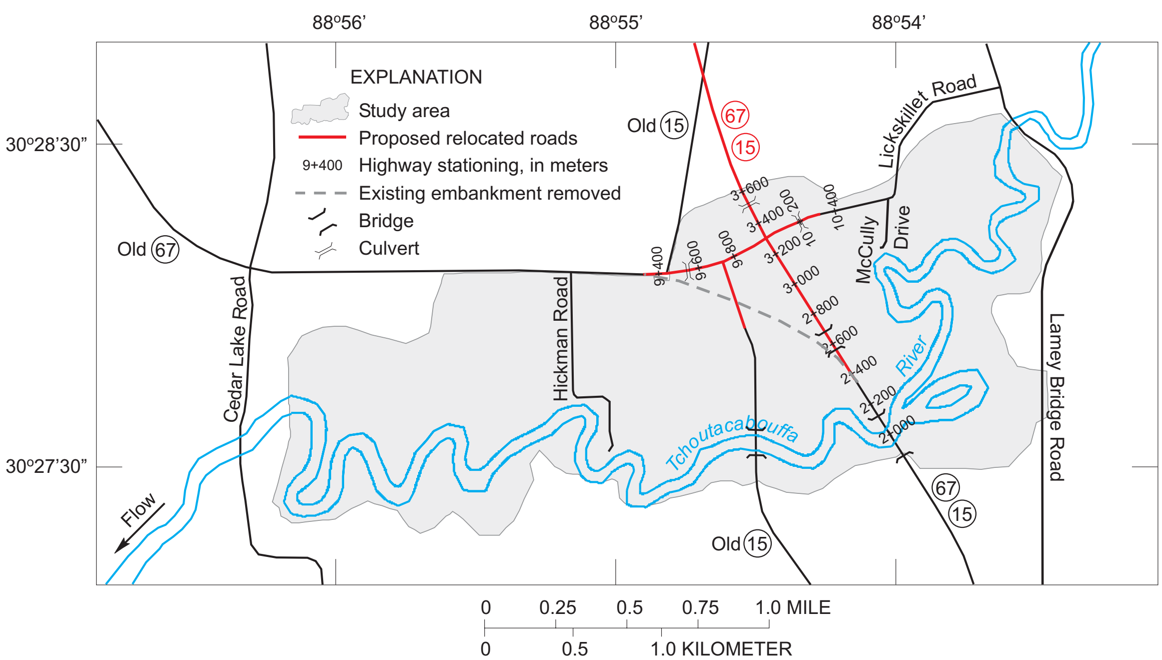

Figure 4. Proposed principal roads in the study area.

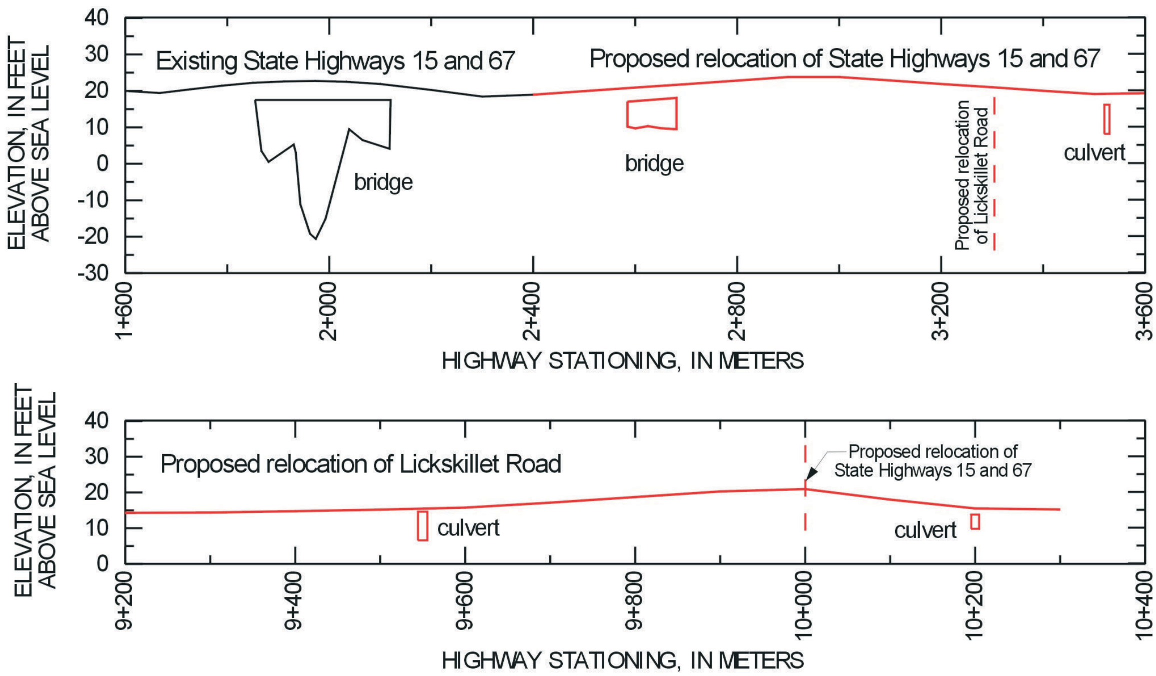

Figure 5. Proposed roadway profiles and waterway openings.

Plans provided by the MDOT for proposed alternative A indicate the placement of a pair of 53-in-diameter pipes at station 3+525 on the new alignment north of the proposed Lickskillet Road interchange and a pair of 6 x 4 ft pipe arches at station 9+550 on the proposed relocation of Lickskillet Road just upstream (east) of the existing State Highway 15 intersection (fig. 5). Plans indicate the placement of a 2.4 x 1.5 ft pipe arch at station 10+200 on the relocated Lickskillet Road east of the proposed alignment, but this pipe will carry only a fraction of the floodflows that cross Lickskillet Road to the north and approach the 53-in-diameter pipes.

Proposed alternative B includes construction of a 315-ft-long relief bridge to be located near station 2+633 north of the main-channel bridges (fig.4). Pipe dimensions are the same as for alternative A.

Proposed alternative C includes the 315-ft-long relief bridge, but uses a series of lare box culverts in place of the pipes which are called for in alternatives A and B. Alternative C uses a triple 10 x 4 ft box culvert at station 10+200 on Lickskillet Road east of the proposed alignment (in addition to road overflow for this segment of Lickskillet Road), a triple 10 x 8 ft box culvert at station 3+525 on the new alignment north of Lickskillet Road, and a triple 12 x 8 ft box culvert at station 9+550 on the proposed Lickskillet Road just upstream of the existing State Highway 15 intersection.

Proposed alternative D includes construction of a 157-ft-long relief bridge located near station 2+657 north of the main-channel bridges. Alternative D also uses the same series of box culverts specified for alternative C.

Hydrology

The USGS has operated a crest-stage gage (station no. 02480599) on Tchoutacabouffa River at the State Highways 15 and 67 crossing since 1997. The USGS operated a continuous-record gage on Tuxachanie Creek (station no. 02480500, fig. 1) from 1952 to 1972 and a crest-stage gage since 1972. Tuxachanie Creek flows into the Tchoutacabouffa River about 3.2 mi upstream of the State Highways 15 and 67 crossing. The gage on Tuxachanie Creek is located about 2.5 mi upstream of the mouth of Tuxachanie Creek. The drainage area upstream of station no. 02480500 is about 43 percent of the drainage area at the State Highways 15 and 67 crossing. Both of these gages are operated and maintained by the USGS in cooperation with the MDOT.

Extreme floods occurred in the Tchoutacabouffa River Basin in 1995 and 1998. Flood marks were recovered throughout the study area after the floods of May 10, 1995, and September 29, 1998 (table 1). Flood marks were recovered just east of the State Highways 15 and 67 intersection after the September 1998 flood. The average elevations of these flood marks were 16.5 and 14.5 ft, upstream and downstream of State Highways 15 and 67.

Table 1. Peak flood elevations on Tchoutacabouffa River for the floods of May 10, 1995, and September 29, 1998

[ft, feet; --, no data]

Location	River mile	Peak Elevation May 10, 1995 (ft)	Peak Elevation September 29, 1998 (ft)
Interstate Highway 10	4.1	8.7	9.7
Cedar Lake Road	4.6	--	10.6
Hickman Road	6.7	12.1	14.2
State Highways 15 and 67	8.3	14.6	16.6
McCully Drive	9.2	16.3	18.0
Lamey Bridge Road	10.1	18.0	19.6

Flood marks near the southern edge of the floodplain were at elevations of 16.6 ft upstream and downstream of the highway, indicating no substantial difference in water-surface elevation through the main-channel bridge. Two discharge measurements (table 2) were obtained at the State Highways 15 and 67 crossing on September 29, 1998, when water flowed over the road in the vicinity of the State Highway 15 intersection. The road overflow discharges shown in table 2 were measured between station 14+830 (fig. 2) on State Highways 15 and 67 and station 1+250 on State Highway 15. The peak discharges corresponding to the floods of May 1995 and September 1998 were estimated to be 34,500 ft^3/s and 48,000 ft^3/s, respectively.

Table 2. Measured discharges for Tchoutacabouffa River at the State Highways 15 and 67 crossing

[ft, feet; ft^3/s, cubic feet per second]

Date	Main-channel bridge Elevation (ft)	Main-channel bridge Discharge (ft^3/s)	Road overflow discharge (ft^3/s)	Total discharge (ft^3/s)
9/29/98	16.16	38,100	5,300	43,400
9/29/98	15.24	35,200	2,300	37,500

Flood frequencies for the Tchoutacabouffa River near D'Iberville, Miss., were estimated based on a comparison of observed discharges at the State Highways 15 and 67 crossing with those recorded at station no. 02480500 on Tuxachanie Creek. Station flood-frequency discharges for the 50- to 500-year floods at station no. 02480500 were 18 to 55 percent greater, respectively, than regional estimates given by Landers and Wilson (1991). Therefore, flood-frequency discharges at the State Highways 15 and 67 crossing were assumed to similarly exceed the regional estimates. The 100-year flood discharge is about 42,200 ft^3/s, which is about 28 percent greater than the regional 100-year flood estimate. If the regional estimate based on techniques presented by Landers and Wilson (1991) had been used, then the 100-year flood would have been exceeded in both 1995 and 1998, which seems unreasonable based on gage data on Tuxachanie Creek. The flood of May 10, 1995, is estimated to have been about a 50-year flood at the State Highways 15 and 67 crossing, and the flood of September 29, 1998, is estimated to have been about a 100- to 200-year flood, based on recurrence intervals corresponding to the peak discharges recorded at the gage on Tuxachanie Creek.

The U.S. Army Corps of Engineers (COE), Mobile District, operates a tidal gage at the entrance to Back Bay of Biloxi. Storm tides have been recorded at Back Bay of Biloxi since 1882 by the COE and others. The highest recorded storm tide was 15.5 ft (during Hurricane Camille on August 18, 1969), which had a recurrence interval of about 170 years according to Wilson and Hudson (1969). A peak storm tide of 12.6 ft was also surveyed at the Tchoutacabouffa River at old State Highway 15. Analysis of tidal records collected at the gage since 1969 suggests that the storm tide caused by Hurricane Camille had a recurrence interval of about 300 years. The effect of storm tides on headwater floods in the study area was not simulated.

Cypress Creek flows into the Tchoutacabouffa River just upstream of the State Highways 15 and 67 crossing. The drainage area of Cypress Creek is about 8.4 mi^2, which is less than 4 percent of the total drainage area at the crossing. Because of the large difference in drainage area sizes, the response time of Cypress Creek is much less than that of the Tchoutacabouffa River; therefore, flows from Cypress Creek into the study area generally do not affect Tchoutacabouffa River peaks.

DESCRIPTION OF THE MODEL

The two-dimensional Finite-Element Surface-Water Modeling System (FESWMS) (Froehlich, 1989) was used to analyze flooding in the study area. A two-dimensional flow model was used because of the complex nature of flows in the vicinity of the State Highways 15 and 67 crossing. FESWMS routes flow through a model grid, which represents the topography of the study area, and uses the finite-element method to solve the system of equations that govern two-dimensional flow in a horizontal plane. Various hydraulic parameters are assigned to the model to reflect conditions in the study area.

Three non-linear partial differential equations (Lee and Froehlich, 1989) are needed to define two-dimensional flow in a horizontal (X, Y) plane. Two of these are equations of motion in the X and Y directions. The third equation is the continuity equation, which ensures conservation of mass. The model grid is divided into a number of triangular and quadrilateral elements that are defined by node points at the corners and at the midpoints of the sides. The three differential equations are applied to each of the nodes. The Galerkin method (Lee and Froehlich, 1989) is used to solve these equations over the entire grid. An iterative solution procedure is then applied to minimize the residuals of the solved differential equations. FESWMS computes depth-averaged velocities in the X and Y directions by integrating the three differential equations though the vertical water column.

Data Requirements

An accurate description of the topography in the study area is required to effectively model floodflows. The MDOT provided data from 16 cross-sectional and longitudinal profiles (fig. 6). Additional ground-elevation data were obtained from as-built plans furnished by the MDOT. Floodplain edges were determined from a 7.5-minute USGS topographic map. The channel banks were defined using a geo-rectified aerial photograph of the study area. Channel bathymetry was determined from data obtained by the USGS using an Acoustic Doppler Current Profiler, in combination with a global positioning system (fig. 6). Road grade and bridge data were provided by the MDOT.

Whereas a two-dimensional flow study could be performed using surveyed topographic data alone, use of hydrologic data greatly increases the reliability of the model. The aforementioned measured flows and flood profiles were used to make the model more realistically reflect the actual flood hydraulics through the reach.

Finite-Element Grid

A finite-element grid was used to represent the topography of the study area. A grid with larger elements is less accurate than one with smaller elements. Mass conservation errors occur when the computed flow entering an element is not equal to the computed flow leaving the element. Smaller elements are required for greater accuracy in areas

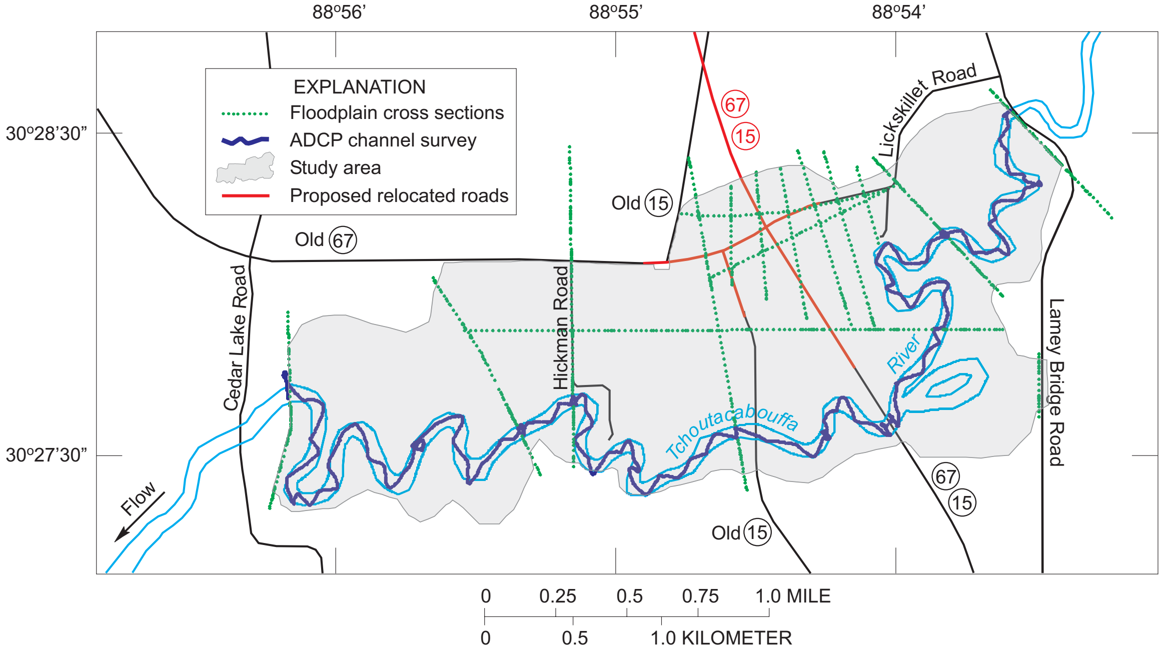

Figure 6. Topographic and bathymetric data obtained in the study area.

where flow direction or depth changes rapidly. The finite-element grid was created by using the Surface-Water Modeling System (SMS) (Brigham Young University, 1999). Portions of the grid were refined with smaller elements to reduce mass conservation errors. The channel banks and roadways were incorporated into the grid by importing the geo-rectified aerial photograph into SMS. The grid used to model existing conditions (figs. 7 and 8) has 2,118 elements and 5,699 nodes. The grids for former and various proposed conditions required more elements and nodes.

Open- or closed-boundary conditions are applied to each node on the perimeter of the grid (fig.7). Open-boundary conditions include a specified water-surface elevation at the downstream end of the grid and specified discharges entering the grid at selected locations. Based on flood profiles, the water-surface elevation at the downstream end of the grid was estimated to be 10.5 ft for the 100-year flood. The 100-year flood discharge (42,400 ft^3/s) was assigned to the upstream boundary and distributed across the section based on conveyance. For all scenarios except "natural conditions," no elements were defined for the area north of State Highway 67 and west of State Highway 15. The discharge crossing State Highway 15 north of the State Highways 15 and 67 intersection was computed by using weir-flow equations and assigned to re-enter the grid through an open boundary along State Highway 67 west of the intersection (fig. 7). The flow was distributed evenly across the open boundary because State Highway 67 is fairly flat west of State Highway 15. Slip conditions (velocity greater than zero at and parallel to the boundary) were applied to closed boundaries such that momentum would be conserved in a direction tangent to the boundary and no flow crosses the boundary. Weir and culvert nodes permit flow across closed boundaries.

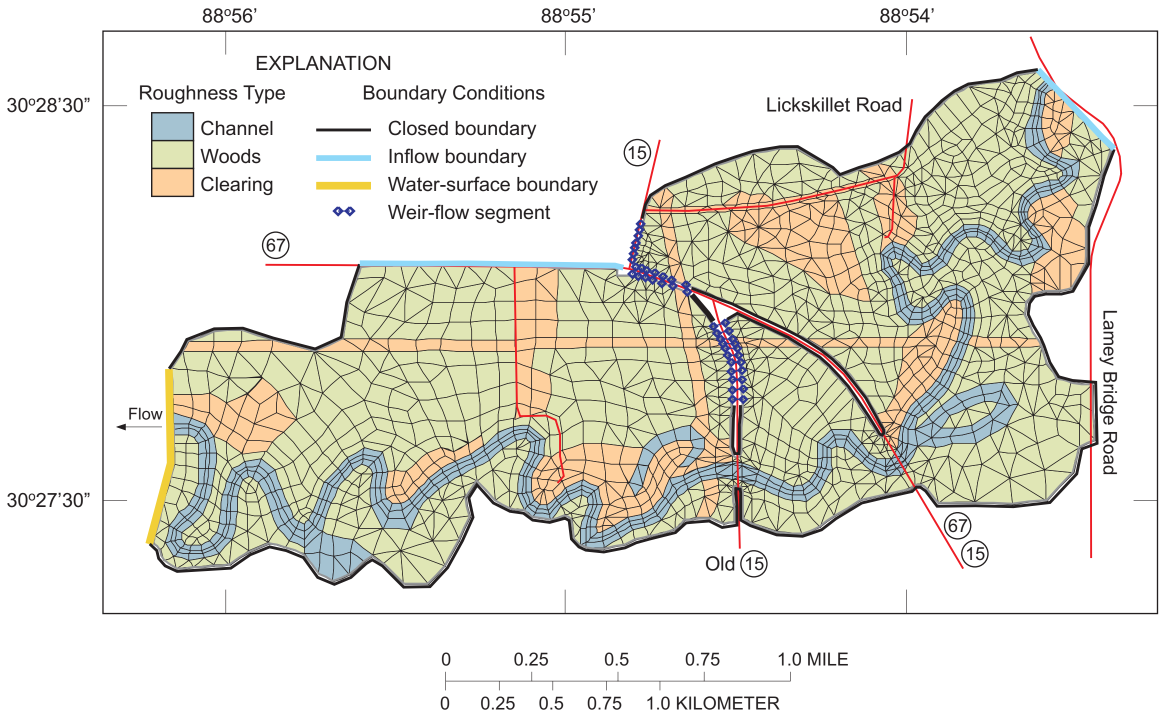

Figure 7. Finite-element grid for existing conditions with roughness types shaded.

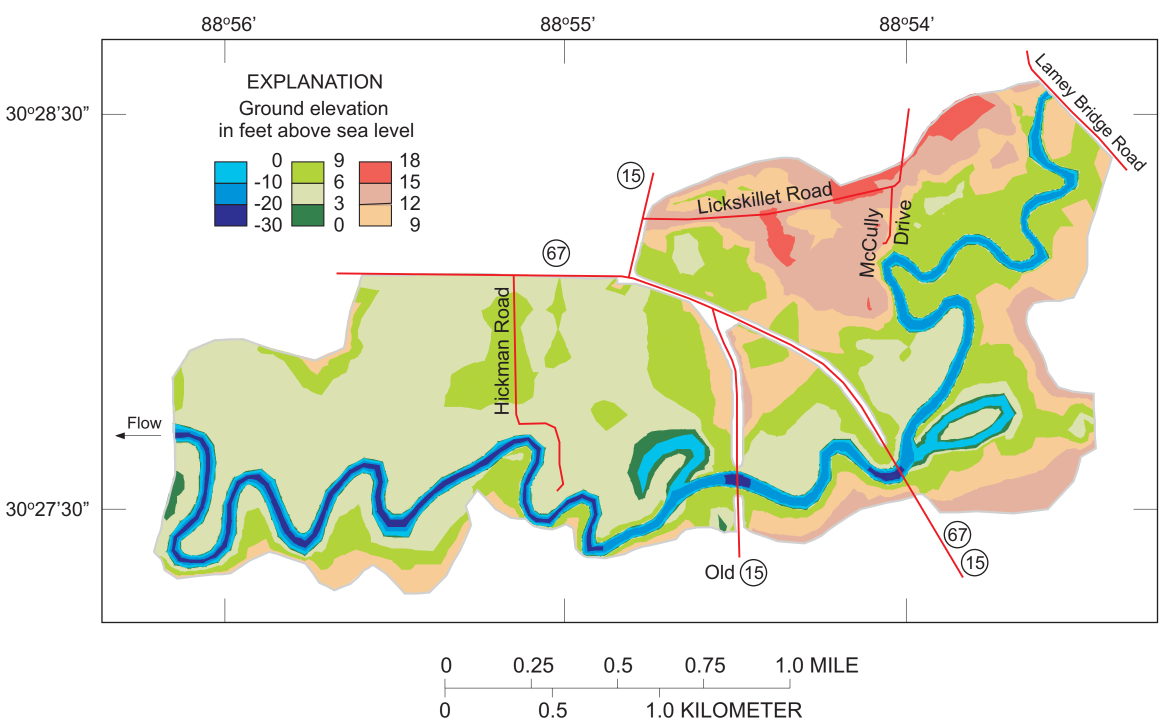

Figure 8. Grid topography for existing conditions.

Model Parameters

FESWMS allows the user to assign various hydraulic parameters to the model. Parameters not assigned by the user are given appropriate default values. Roughness coefficients (Manning's "n") were assigned to elements based on aerial photography. Initial roughness coefficients were selected by personnel of the USGS (Arcement and Schneider, 1989). A kinematic eddy viscosity of 10 feet squared per second (ft^2/s) was selected as a target value for each simulation; a value of about 100 ft^2/s was used to ensure convergence during the first few runs of each simulation (Froehlich, 1989). A weir-flow coefficient of 0.53 was used for all road overflow segments. Entrance-loss coefficients for culverts were chosen based on the culvert type and flow control. The option to automatically turn off dry elements was used. Default values were used for other parameters in FESWMS. All simulations were run assuming steady-state flow conditions.

MODEL CALIBRATION AND TESTING

Calibration is the process of adjusting the model parameters until the model results adequately reflect observed conditions. Parameters obtained from the calibration simulation are valid only for the conditions (water-surface elevations and discharge) for which they were determined. Verification is made by simulating a separate set of measured boundary conditions with the model parameters obtained in the calibration process. If the model results agree closely with the independent set of measured conditions, the model is verified. Whereas the eddy viscosity was adjusted iteratively to aid in convergence of the model, the roughness coefficient was adjusted so that the computed water-surface profiles through the study reach closely agreed with the surveyed flood profiles. The model was calibrated to the flood of September 1998 and verified by simulating the flood of May 1995 (table 1). Parameters governing road overflow were adjusted to accurately model measured road overflow for the discharge measurements made on September 29, 1998 (table 2). Because much of the measured weir flow occurred across a super-elevated roadway curve, an effective weir-crest elevation was computed for each weir segment so that the computed discharge for each segment approximately equaled the measured discharge for that segment. The 100-year flood discharge (42,200 ft^3/s) is bounded by the floods of May 1995 and September 1998.

The model was calibrated for existing conditions (fig. 2) by simulating the flood of September 1998 (48,000 ft^3/s). Based on the surveyed flood profile (table 1), a water-surface elevation of 11.0 ft was assigned to the downstream end of the grid. Elements were classified as woods, clearing, or channel for assignment of roughness coefficients (fig. 7). By using roughness coefficients of 0.15, 0.06, and 0.034 for woods, clearing, and channel elements, respectively, computed water-surface elevations agreed closely with surveyed flood-mark elevations (table 3, fig. 9). The surveyed and computed water-surface elevations in the vicinity of the State Highways 15 and 67 intersection represent conditions along the northern edge of the floodplain; therefore, flood marks at the State Highways 15 and 67 bridge are not shown in figure 9. The calibrated roughness coefficients are slightly lower than those that would be predicted by a one-dimensional

Table 3. Observed and computed flood elevations on Tchoutacabouffa River for the flood of September 29, 1998

[ft, feet; DS, downstream; US, upstream; SR, State Highway]

Location	Observed flood mark elevation (ft)	Computed water-surface elevation (ft)	Computed minus observed (ft)
Hickman Road	14.2	14.3	+0.1
DS side SR 15 and 67 intersection	14.7	14.7	+0.0
US side SR 15 and 67 intersection	16.4	16.6	+0.2
State Highways 15 and 67 bridge	16.6	16.5	-0.1
McCully Drive	18.0	18.0	+0.0
Lamey Bridge Road	19.6	19.9	+0.3

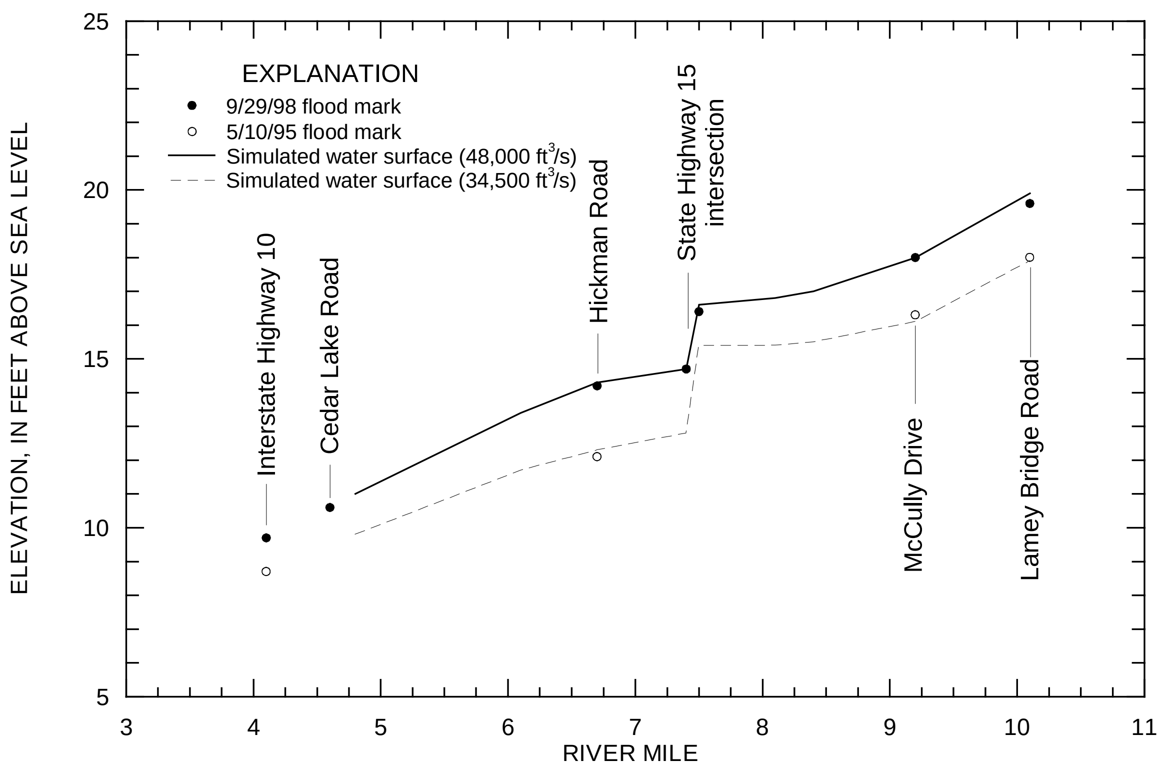

Figure 9. Surveyed and computed flood profiles.

flow model, largely because of the longer flow path of the two-dimensional model. Computed road overflow was 7,310 ft^3/s for the flood of September 1998.

A sensitivity analysis was performed to determine the effects of changing the Manning's roughness coefficients or the kinematic eddy viscosity (figs. 10 and 11, respectively). All roughness coefficients were varied concurrently from 80 to 120 percent of the calibrated values. The computed water-surface elevations at several locations were compared to corresponding water-surface elevations from the calibration simulation. Figure 10 shows the changes in computed water-surface elevations that resulted from changing the roughness coefficients. Water-surface elevations at Lamey Bridge Road at the upstream end of the study area were the most sensitive to changes in the roughness coefficients. A 10 percent change in all roughness coefficients resulted in a 0.4 ft change in the computed water-surface elevation at Lamey Bridge Road. Water-surface elevations at the upstream side of the State Highways 15 and 67 embankment and near the northern edge of the floodplain were least sensitive to changes in the roughness coefficients because the highway embankment controls these water-surface elevations. The kinematic eddy viscosity was varied from 2 to 100 ft^2/s; a value of 10 ft^2/s was used in the calibration simulation. Again, the computed water-surface elevations at several locations were compared to corresponding water-surface elevations from the calibration simulation. Figure 11 shows the changes in computed water-surface elevations that resulted from changing the kinematic eddy viscosity. For a kinematic eddy viscosity of 100 ft^2/s, computed water-surface elevations were typically 0.5 ft higher than those corresponding to a kinematic eddy viscosity of 10 ft^2/s. However, for all kinematic eddy viscosities less than 40 ft^2/s, the average change in computed water-surface elevations was less than 0.2 ft (fig. 11).

The model was verified by simulating the flood of May 1995 (34,500 ft^3/s). Based on the surveyed flood profile, a water-surface elevation of 9.8 ft was assigned to the downstream end of the grid. Computed water-surface elevations agreed closely with surveyed flood-mark elevations (table 4, fig. 9). Computed road overflow was 1,020 ft^3/s for the flood of May 1995.

Table 4. Observed and computed flood elevations on Tchoutacabouffa River for the flood of May 10, 1995

[ft, feet]

Location	Observed flood mark elevation (ft)	Computed water-surface elevation (ft)	Computed minus observed (ft)
Hickman Road	12.1	12.3	+0.2
State Highways 15 and 67 bridge	14.6	14.6	+0.0
McCully Drive	16.3	16.1	-0.2
Lamey Bridge Road	18.0	17.9	-0.1

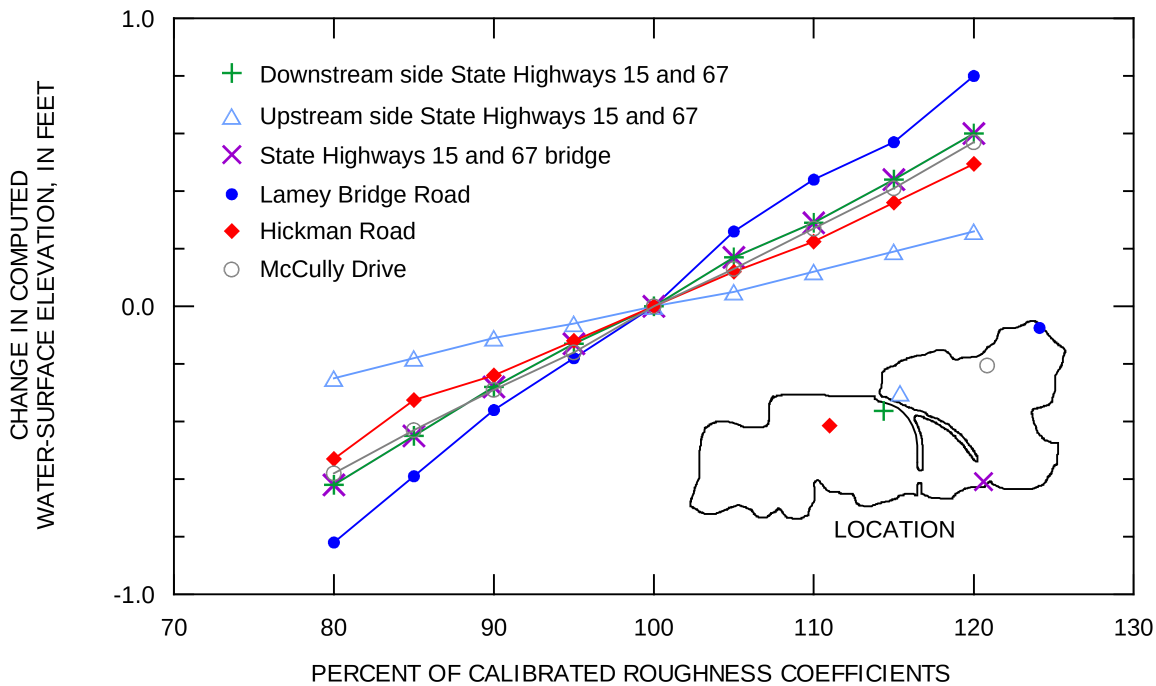

Figure 10. Sensitivity of roughness coefficients.

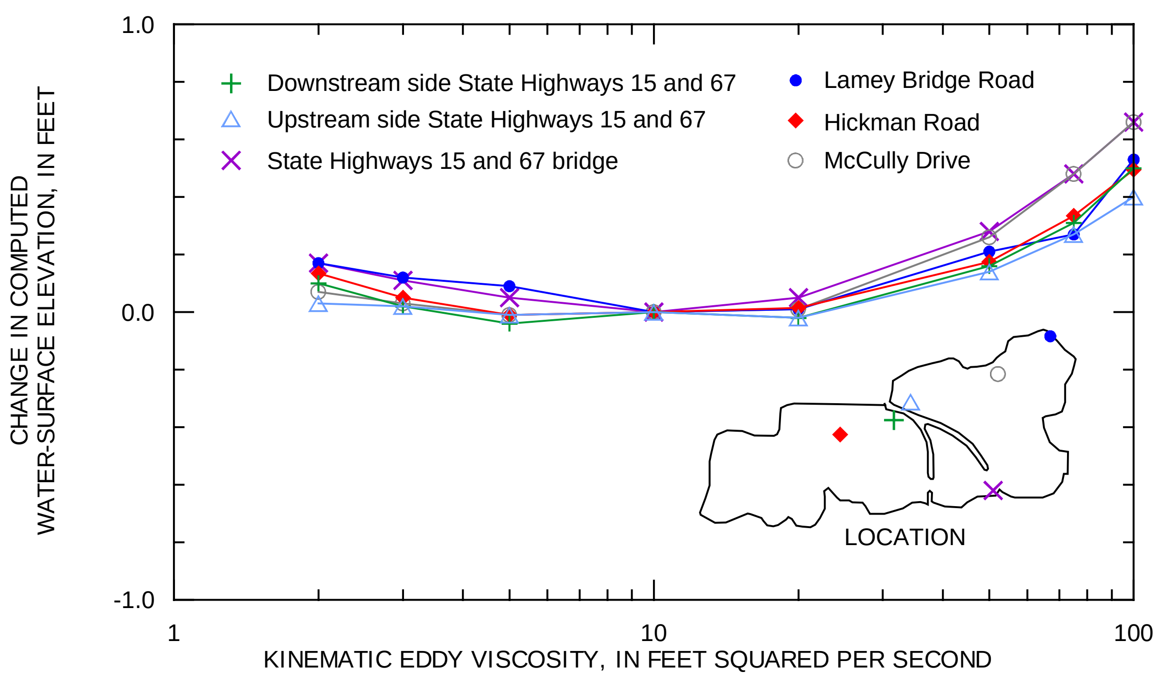

Figure 11. Sensitivity of kinematic eddy viscosity.

SIMULATIONS OF THE 100-YEAR FLOOD

The model was calibrated for existing conditions, and the grids used for all other simulations are modified forms of the grid (fig. 7) used for existing conditions. Grid modifications and the results of each simulation of the 100-year flood are presented below.

Mass conservation was verified for each simulation. Flux lines were used to compute the total discharge passing various sections in the grid. The maximum computed discharge differed from the modeled inflow by only about 3 percent. The average difference was about 2 percent.

Natural Conditions

To model natural conditions in the study area, all highway embankments, weirs, and culverts were removed from the model. Natural floodplain elevations were substituted in place of existing highway embankment elevations. Elements were added north of State Highway 67 and west of State Highway 15, where water ponds upstream of State Highway 67 under existing conditions. Several dry elements along the boundary of the grid were deleted because no backwater occurs without the highway embankments. Also, the broad knoll south of Lickskillet Road was dry, forming an island 500 ft wide and more than 1,000 ft long. About 16,000 ft^3/s flowed in the channel near the location of the existing State Highways 15 and 67 bridge. Computed water-surface elevations for the 100-year flood at the locations of the existing State Highways 15 and 67 bridge and McCully Drive were 15.4 and 16.6 ft, respectively.

Old State Highway 15 Only

To simulate conditions prior to 1976 in the study area, the State Highways 15 and 67 embankment east of the intersection with old State Highway 15 was removed. Results of the simulation indicate 36,100 ft^3/s (86 percent of the total) flowed through the old State Highway 15 bridge and 5,900 ft^3/s (14 percent), including 400 ft^3/s north of the existing State Highways 15 and 67 intersection, flowed over the road north of the bridge. About 200 ft^3/s flowed through the 9 x 3 ft box culvert near the existing State Highways 15 and 67 intersection. About 1.5 ft of water-surface differential occurred across the old State Highway 15 embankment near the northern edge of the floodplain. Computed water-surface elevations for the 100-year flood at the existing State Highways 15 and 67 bridge and McCully Drive were 15.8 and 16.9 ft, respectively.

Existing Conditions

Results of the 100-year flood simulation for existing conditions (figs. 12 and 13) indicate that about 4,430 ft^3/s (10 percent of the total) flowed over the road north and east of the State Highways 15 and 67 intersection. The 9 x 3 ft box culvert east of the intersection conveyed about 270 ft^3/s. Water depths of 1 to 4 ft were computed along

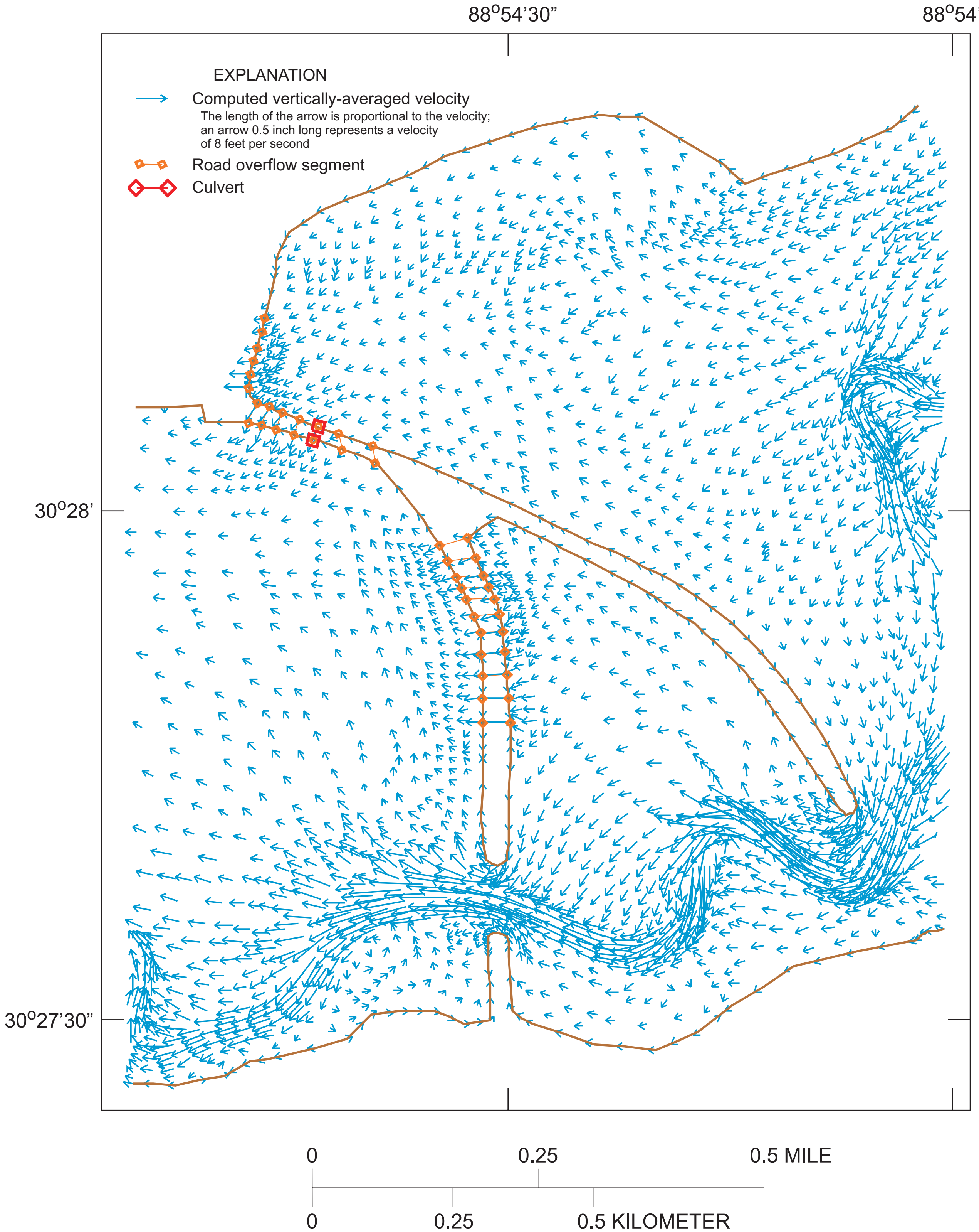

Figure 12. Computed velocity vectors for the 100-year flood for existing conditions.

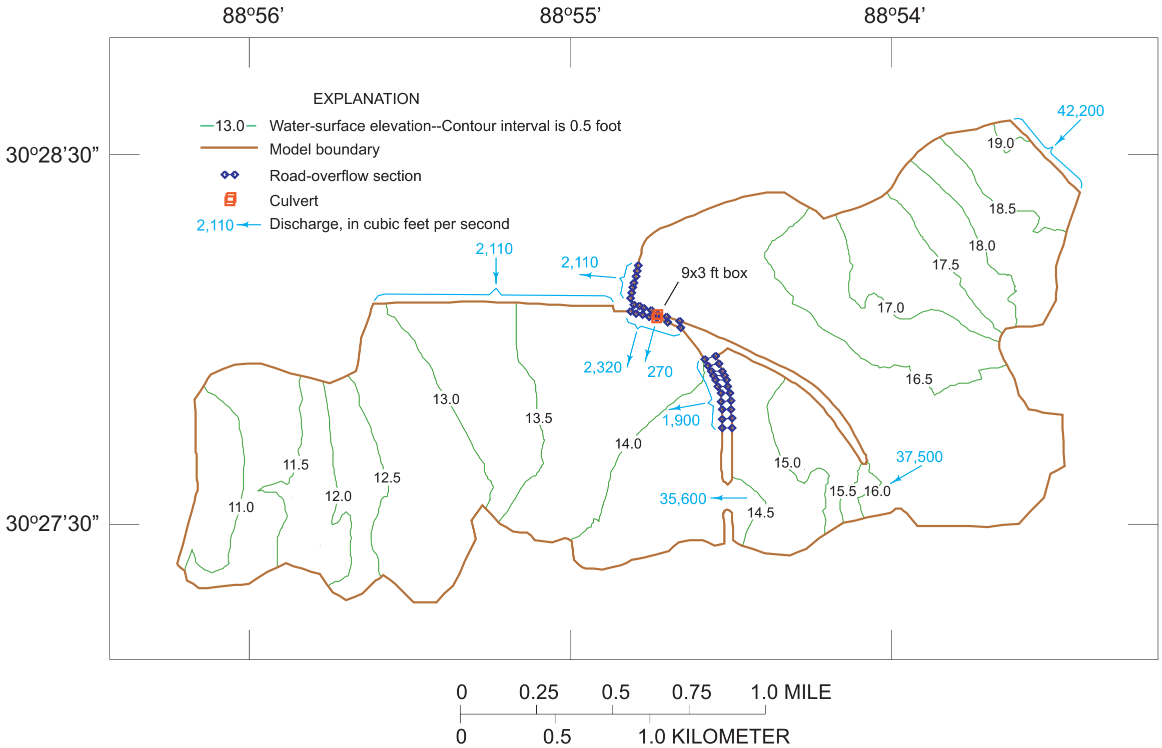

Figure 13. Computed water-surface elevations and discharges for the 100-year flood for existing conditions.

Lickskillet Road. Flows crossing Lickskillet Road were modeled by using 2-dimensional elements (rather than weir segments) because much of the road elevation is about equal to surrounding ground elevations. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively. About 2.2 ft of water-surface differential occurred across the State Highways 15 and 67 embankment near the northern edge of the floodplain.

Mississippi Department of Transportation Proposed Alternative A

To model proposed alternative A, grid elements were removed along the proposed alignment and elements were inserted where portions of the existing embankment would be removed. The pair of 53-in-diameter pipes on the new alignment and the pair of 6 x 4 ft pipe arches on the proposed relocation of Lickskillet road were modeled in FESWMS by using type 4 (submerged inlet and outlet) flow conditions (Bodhaine, 1968). Results of the 100-year flood simulation for proposed alternative A (fig. 14) indicate that about 200 ft^3/s flowed through the pair of 53-in-diameter pipes north of Lickskillet Road. The mean velocity computed for the pair of 53-in-diameter pipes was 6.5 feet per second (ft/s). The 2.4 x 1.5 ft pipe arch on the proposed relocation of Lickskillet Road was not modeled. Water flowed northward across Lickskillet Road at a depth of 2 ft. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.2 and 17.8 ft, respectively.

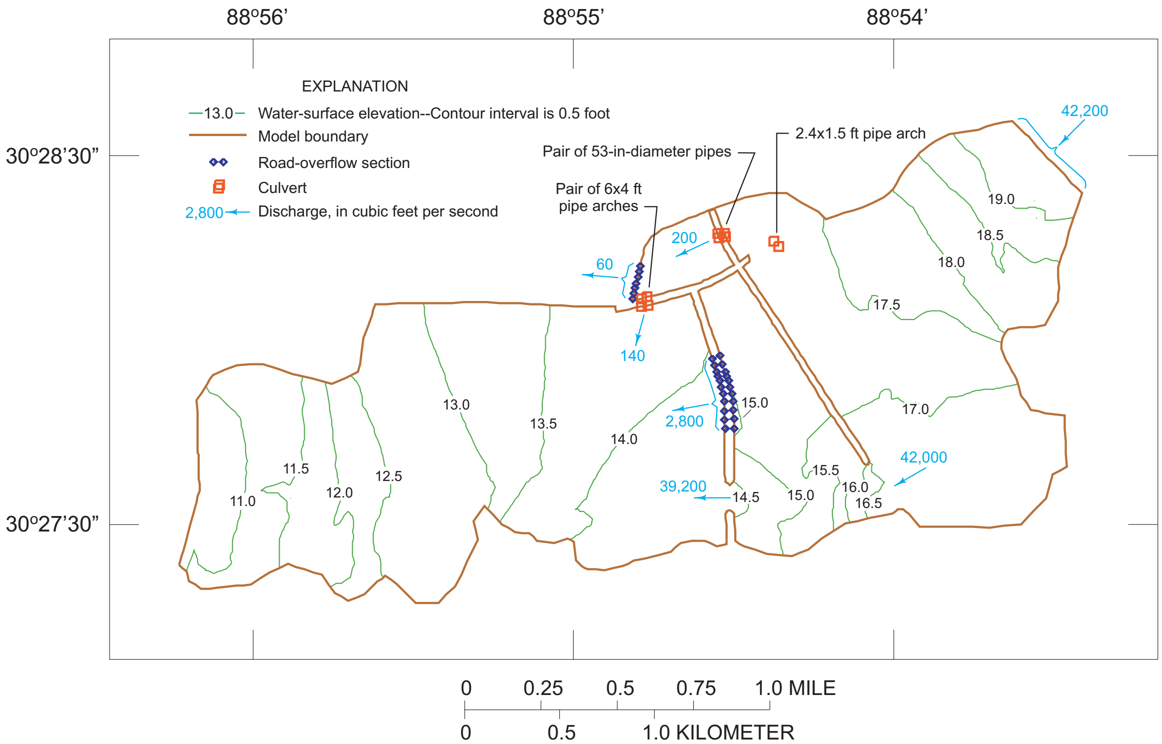

Figure 14. Computed water-surface elevations and discharges for the 100-year flood for proposed alternative A.

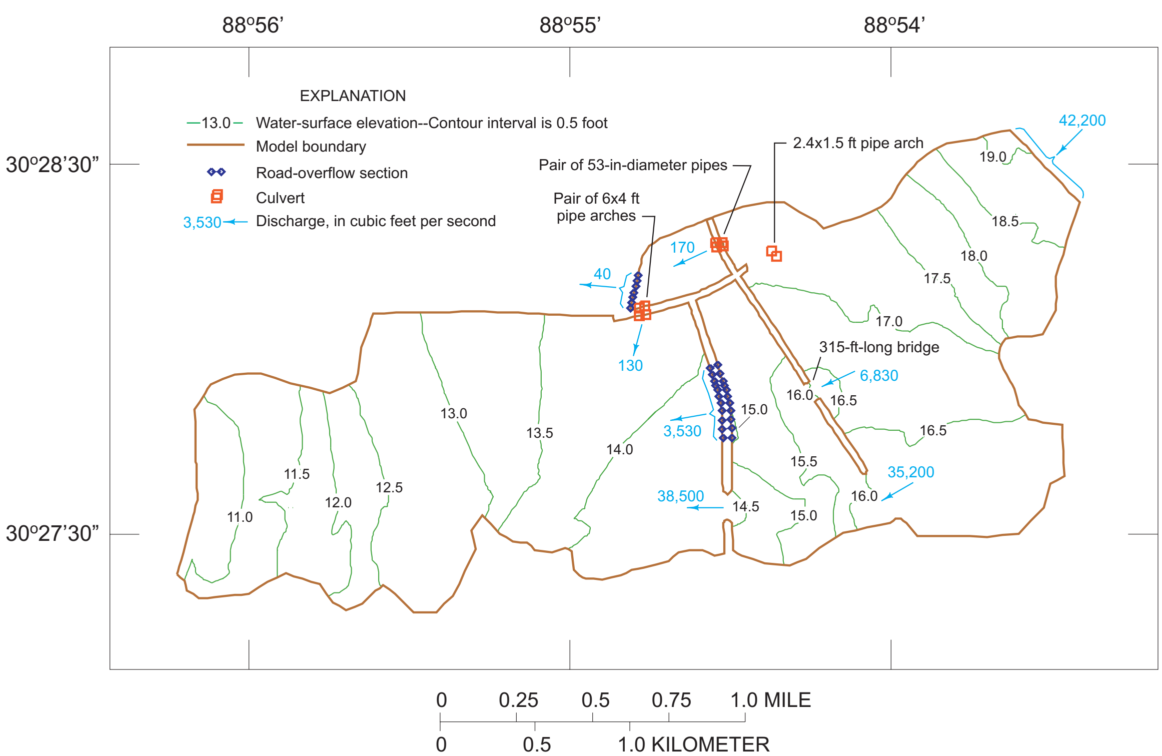

Figure 15. Computed water-surface elevations and discharges for the 100-year flood for proposed alternative B.

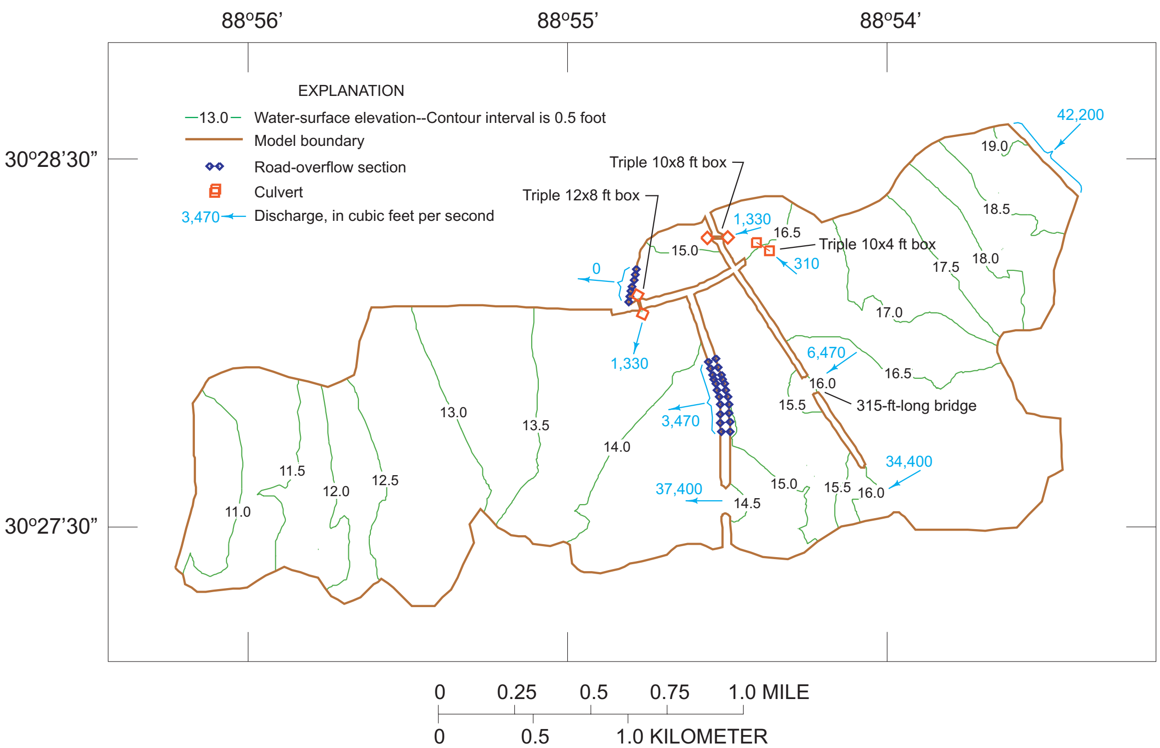

Figure 16. Computed water-surface elevations and discharges for the 100-year flood for proposed alternative C.

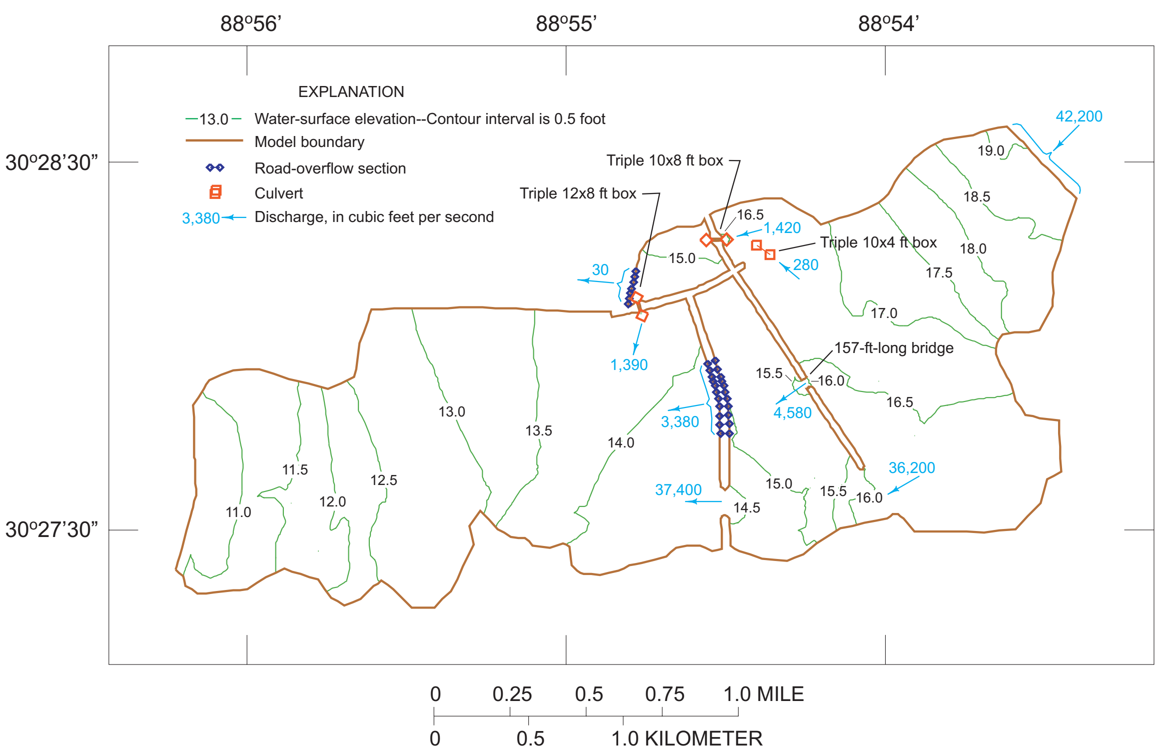

Figure 17. Computed water-surface elevations and discharges for the 100-year flood for proposed alternative D.

Mississippi Department of Transportation Proposed Alternative B

In addition to grid modifications used in proposed alternative A, elements were added to model the 315-ft-long relief bridge for proposed alternative B. Results of the 100-year flood simulation for proposed alternative B (fig. 15) indicate that about 6,830 ft^3/s (16 percent of the total) flowed through the proposed 315-ft-long relief bridge and about 170 ft^3/s flowed through the pair of 53-in-diameter pipes north of Lickskillet Road. The mean velocity computed for flow through the relief bridge was 3.1 ft/s. The mean velocity for flow through the pair of 53-in-diameter pipes was 5.5 ft/s. The 2.4 x 1.5 ft pipe arch on the proposed relocation of Lickskillet Road was not modeled. Water flowed northward across Lickskillet Road at a depth of 1.5 ft. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.0 and 17.4 ft, respectively.

Mississippi Department of Transportation Proposed Alternative C

Alternative C includes elements for the proposed relief bridge, but large box culverts are specified in place of the pipes and pipe arches used in alternatives A and B. Type 3 (tranquil) flow occurred at the proposed triple 12 x 8 ft and triple 10 x 8 ft box culverts (Bodhaine, 1968). Therefore, these culverts were modeled by using two-dimensional elements because culvert computations in FESWMS do not include type 3 flow. Results of the 100-year flood simulation for proposed alternative C (fig. 16) indicate that about 6,470 ft^3/s (15 percent of the total) flowed through the proposed 315-ft-long relief bridge and about 1,330 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 ft culvert north of Lickskillet Road. About 310 ft^3/s flowed through the proposed triple 10 x 4 ft culvert on Lickskillet Road and about 1,020 ft^3/s crossed Lickskillet Road east of the proposed relocation with a depth of about 1 ft. The mean velocity computed for flow through the relief bridge was 2.9 ft/s. The mean velocity for flow through the triple 10 x 8 ft culvert was 6.5 ft/s. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively.

Mississippi Department of Transportation Proposed Alternative D

Alternative D includes a 157-ft-long relief bridge, half as long as the relief bridge specified for alternatives B and C; alternative D uses the same triple box culverts as those in alternative C. Results of the 100-year flood simulation for proposed alternative D (figs. 17 and 18) indicate that about 4,580 ft^3/s (11 percent of the total) flowed through the proposed 157-ft-long relief bridge and about 1,420 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 ft culvert north of Lickskillet Road. About 280 ft^3/s flowed through the proposed triple 10 x 4 ft culvert on Lickskillet Road and about 1,140 ft^3/s crossed Lickskillet Road east of the proposed relocation with a depth of about 1.2 ft. The mean velocity computed for flow through the relief bridge was 4.1 ft/s. The mean velocity for flow through the triple 10 x 8 ft box culvert was 6.5 ft/s. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively.

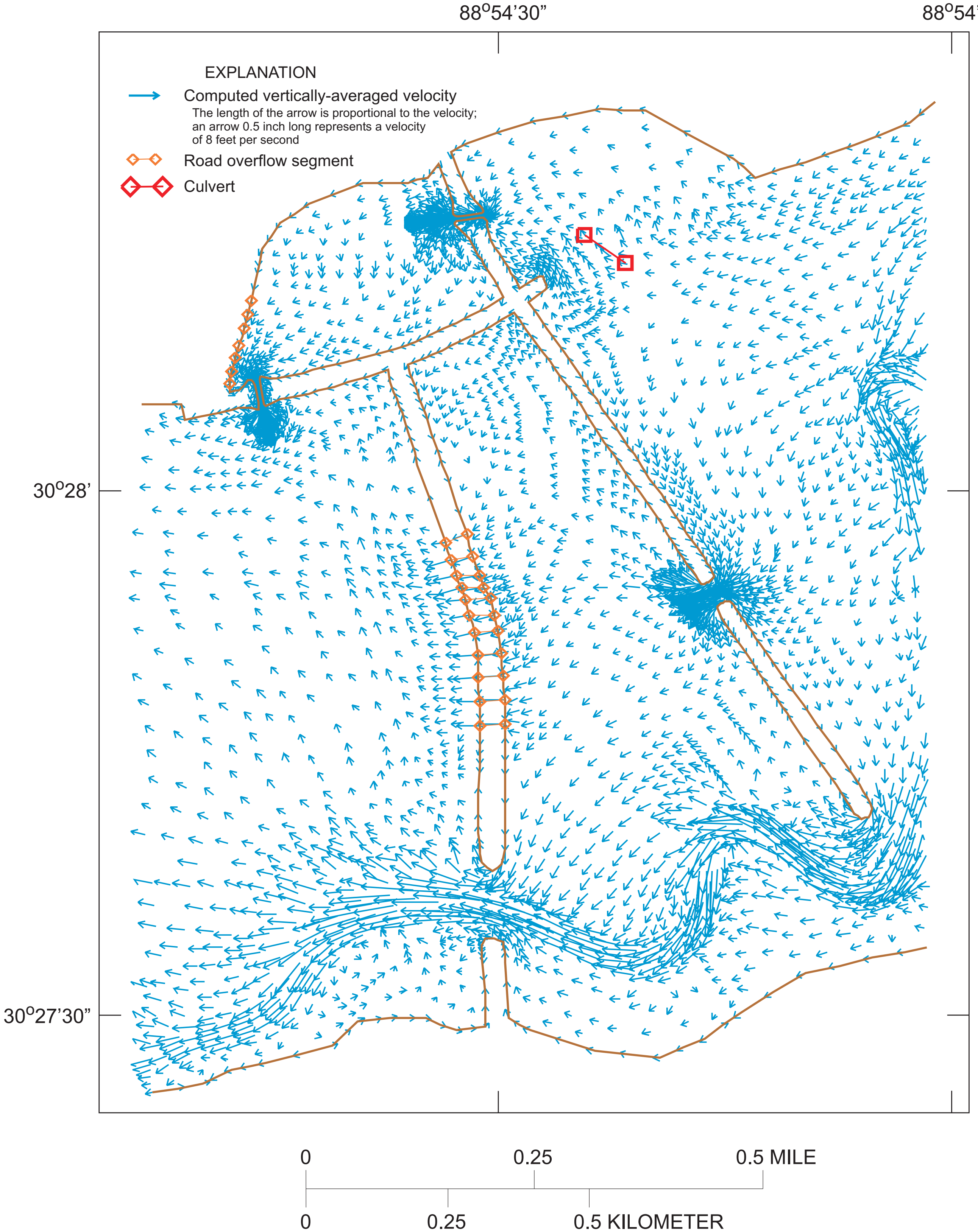

Figure 18. Computed velocity vectors for the 100-year flood for proposed alternative D.

COMPARISON OF ALTERNATIVES

Computed 100-year flood profiles along the southern and northern edges of the floodplain for the former, existing, and proposed conditions in the study area are shown in figures 19 and 20, respectively, and are summarized in table 5. Substantial lateral variations in computed water-surface elevations can be seen on figures 13-17. For the existing conditions, there was about 0.7 ft of backwater (above natural conditions) at a point 500 ft upstream of the State Highways 15 and 67 bridge (table 5, fig. 19), and there was about 1.5 ft of backwater (above natural conditions) near the northern edge of the floodplain at the upstream side of the proposed alignment (fig. 20). Water-surface elevations upstream of State Highways 15 and 67 for proposed alternative A ranged from 0.5 ft to more than 1 ft higher than those for existing conditions. For proposed

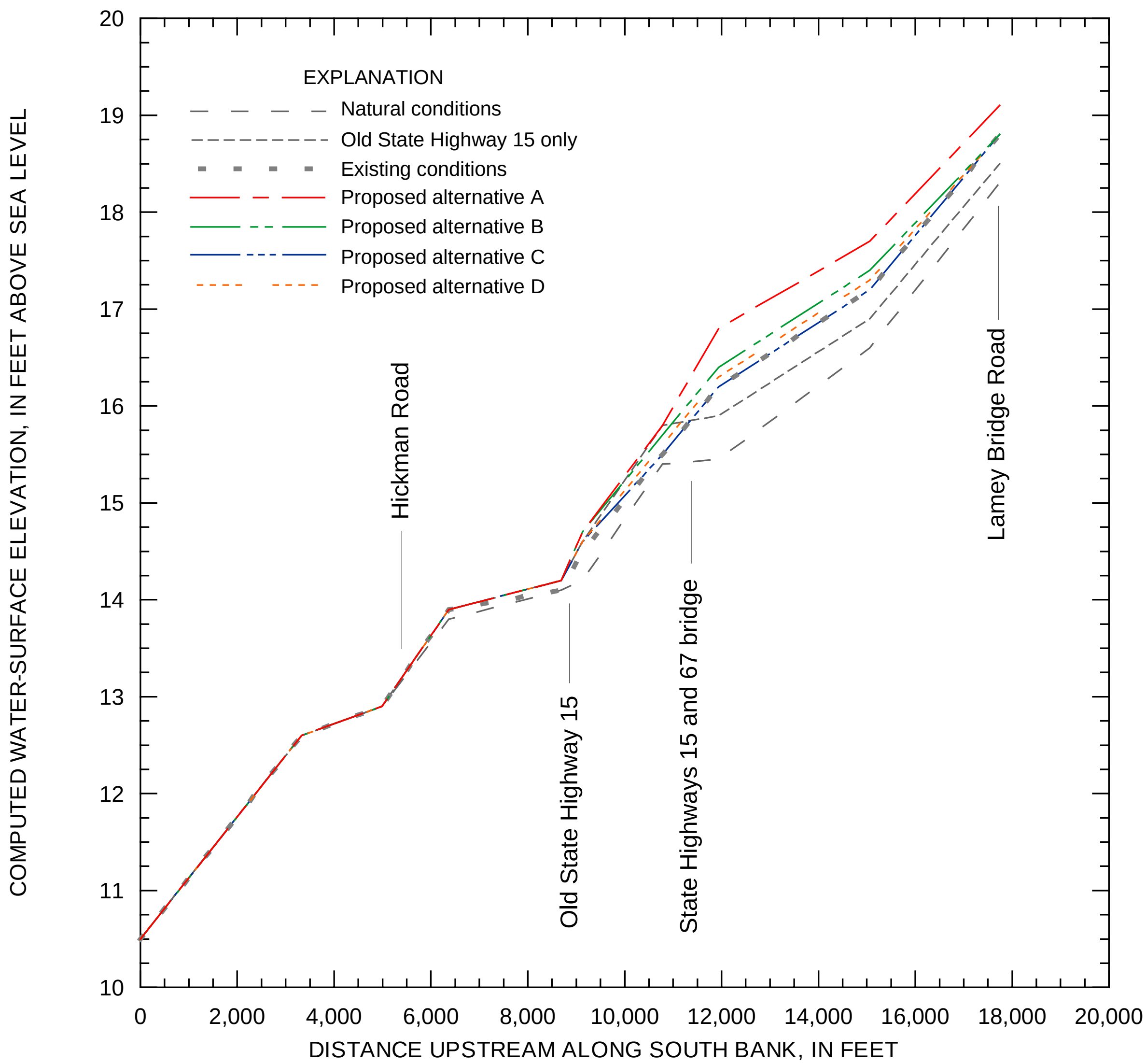

Figure 19. Computed 100-year flood profiles along the southern edge of the floodplain.

alternative A there was about 2.7 ft of backwater above natural conditions (or 1.2 ft above existing conditions) near the northern edge of the floodplain at the upstream side of the proposed alignment. Upstream water-surface elevations for proposed alternative B ranged from 0.2 ft higher at the southern edge of the floodplain to 0.7 ft higher at the northern edge of the floodplain, compared to those for existing conditions. Upstream water-surface elevations for proposed alternative C were nearly equal to those for existing conditions. Upstream water-surface elevations for proposed alternative D were generally 0.1 to 0.3 ft higher than those for existing conditions. Computed water-surface differentials across the proposed alignment near the northern edge of the floodplain for the proposed alternatives A, B, C, and D were 2.6, 2.1, 1.4, and 1.5 ft, respectively (fig. 20). Much lower differentials were computed in the vicinity of the main-channel bridge (fig. 19).

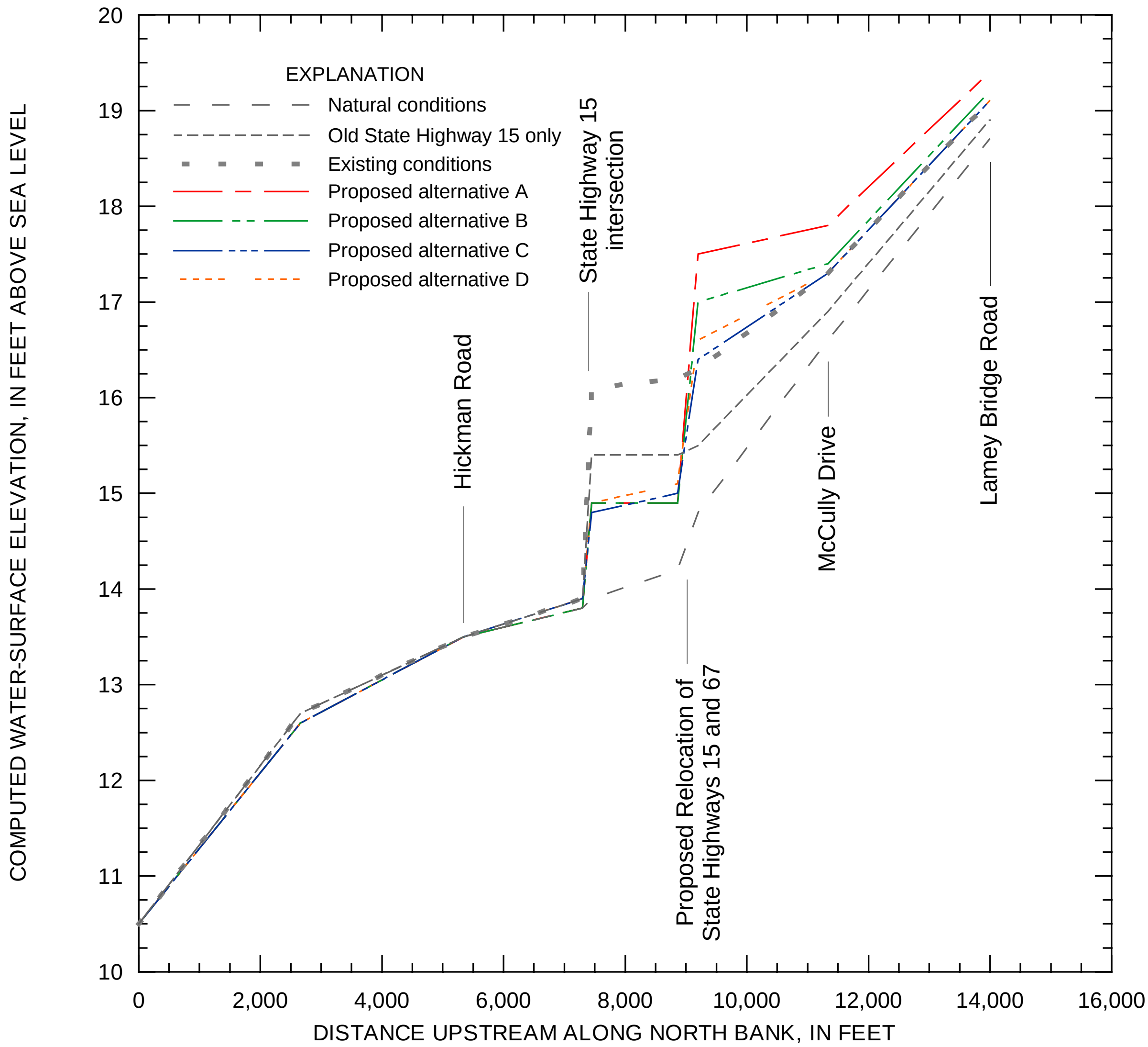

Figure 20. Computed 100-year flood profiles along the northern edge of the floodplain.

Table 5. Summary of computed 100-year flood profiles

[ft, feet; DS, downstream; US, upstream; SR, State Highway]

Simulation	Southern edge of floodplain: Location	Southern edge of floodplain: Water-surface elevation (ft)	Northern edge of floodplain: Location	Northern edge of floodplain: Water-surface elevation (ft)
Natural conditions			DS side of SR 15 and 67 intersection	13.8
	DS side of Old SR 15	14.1	US side of SR 15 and 67 intersection	13.9
	US side of Old SR 15	14.2	DS of proposed SR 15 and 67 relocation	14.2
	SR 15 and 67 bridge	15.4	US of proposed SR 15 and 67 relocation	14.8
	500 ft US of SR 15 and 67 bridge	15.5	McCully Drive	16.6
	Lamey Bridge Road	18.3	Lamey Bridge Road	18.7
Old SR 15 only			DS side of SR 15 and 67 intersection	13.9
	DS side of Old SR 15	14.2	US side of SR 15 and 67 intersection	15.4
	US side of Old SR 15	14.6	DS of proposed SR 15 and 67 relocation	15.4
	SR 15 and 67 bridge	15.8	US of proposed SR 15 and 67 relocation	15.5
	500 ft US of SR 15 and 67 bridge	15.9	McCully Drive	16.9
	Lamey Bridge Road	18.5	Lamey Bridge Road	18.9
Existing conditions			DS side of SR 15 and 67 intersection	13.9
	DS side of Old SR 15	14.1	US side of SR 15 and 67 intersection	16.1
	US side of Old SR 15	14.5	DS of proposed SR 15 and 67 relocation	16.2
	SR 15 and 67 bridge	15.9	US of proposed SR 15 and 67 relocation	16.3
	500 ft US of SR 15 and 67 bridge	16.2	McCully Drive	17.3
	Lamey Bridge Road	18.8	Lamey Bridge Road	19.1
Proposed alternative A			DS side of SR 15 and 67 intersection	13.8
	DS side of Old SR 15	14.2	US side of SR 15 and 67 intersection	14.9
	US side of Old SR 15	14.7	DS of proposed SR 15 and 67 relocation	14.9
	SR 15 and 67 bridge	16.2	US of proposed SR 15 and 67 relocation	17.5
	500 ft US of SR 15 and 67 bridge	16.8	McCully Drive	17.8
	Lamey Bridge Road	19.1	Lamey Bridge Road	19.4
Proposed alternative B			DS side of SR 15 and 67 intersection	13.8
	DS side of Old SR 15	14.2	US side of SR 15 and 67 intersection	14.9
	US side of Old SR 15	14.7	DS of proposed SR 15 and 67 relocation	14.9
	SR 15 and 67 bridge	16.0	US of proposed SR 15 and 67 relocation	17.0
	500 ft US of SR 15 and 67 bridge	16.4	McCully Drive	17.4
	Lamey Bridge Road	18.8	Lamey Bridge Road	19.2
Proposed alternative C			DS side of SR 15 and 67 intersection	13.9
	DS side of Old SR 15	14.2	US side of SR 15 and 67 intersection	14.8
	US side of Old SR 15	14.6	DS of proposed SR 15 and 67 relocation	15.0
	SR 15 and 67 bridge	15.9	US of proposed SR 15 and 67 relocation	16.4
	500 ft US of SR 15 and 67 bridge	16.2	McCully Drive	17.3
	Lamey Bridge Road	18.8	Lamey Bridge Road	19.1
Proposed alternative D			DS side of SR 15 and 67 intersection	13.9
	DS side of Old SR 15	14.2	US side of SR 15 and 67 intersection	14.9
	US side of Old SR 15	14.6	DS of proposed SR 15 and 67 relocation	15.1
	SR 15 and 67 bridge	15.9	US of proposed SR 15 and 67 relocation	16.6
	500 ft US of SR 15 and 67 bridge	16.3	McCully Drive	17.3
	Lamey Bridge Road	18.8	Lamey Bridge Road	19.1

SUMMARY AND CONCLUSIONS

The two-dimensional finite-element surface-water modeling system, FESWMS, was used to study the effects of the proposed State Highway 67 relocation on water-surface elevations and flow distributions for the 100-year flood on the Tchoutacabouffa River near D'Iberville, Miss. Seven scenarios were modeled for the 100-year flood including: (1) natural conditions (no roadway embankments in the study area), (2) old State Highway 15 only (with the existing State Highways 15 and 67 embankment removed), (3) existing conditions, (4) proposed alternative A (new alignment with no relief bridge), (5) proposed alternative B (new alignment with 315-ft-long relief bridge), (6) proposed alternative C (new alignment with 315-ft-long relief bridge and large box culverts), and (7) proposed alternative D (new alignment with 157-ft-long relief bridge and large box culverts).

The model was calibrated and verified for existing conditions by using two discharge measurements obtained at the State Highways 15 and 67 crossing and two flood profiles through the study reach. Calibrated roughness coefficients corresponding to woods, clearing, and channel elements were 0.15, 0.06, and 0.034, respectively.

For natural conditions, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.4 and 16.6 ft, respectively. With only old Highway 15 in place, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.8 and 16.9 ft, respectively. For existing conditions, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively.

For proposed alternative A, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.2 and 17.8 ft, respectively. About 200 ft^3/s flowed through the double 53-in-diameter pipes north of Lickskillet Road.

For proposed alternative B, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.0 and 17.4 ft, respectively. About 6,830 ft^3/s (16 percent of the total) flowed through the proposed relief bridge, and about 170 ft^3/s flowed through the double 53-in-diameter pipes north of Lickskillet Road.

For proposed alternative C, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively. About 6,470 ft^3/s (15 percent of the total) flowed through the proposed relief bridge, and about 1,330 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 ft box culvert north of Lickskillet Road. About 310 ft^3/s flowed through the proposed triple 10 x 4 ft box culvert on Lickskillet Road, and about 1,020 ft^3/s crossed Lickskillet Road east of the proposed relocation.

For proposed alternative D, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively. About 4,580 ft^3/s (11 percent of the total) flowed through the proposed relief bridge, and about 1,420 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 ft culvert north of Lickskillet Road. About 280 ft^3/s flowed through the proposed triple 10 x 4 ft culvert on Lickskillet Road, and about 1,140 ft^3/s crossed Lickskillet Road east of the proposed relocation.

Substantial lateral variations in computed water-surface elevations were noted upstream of State Highways 15 and 67. Computed water-surface differentials across the proposed alignment near the northern edge of the floodplain for the proposed alternatives A, B, C, and D were 2.6, 2.1, 1.4, and 1.5 ft, respectively. Much lower differentials were computed in the vicinity of the main-channel bridge.

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