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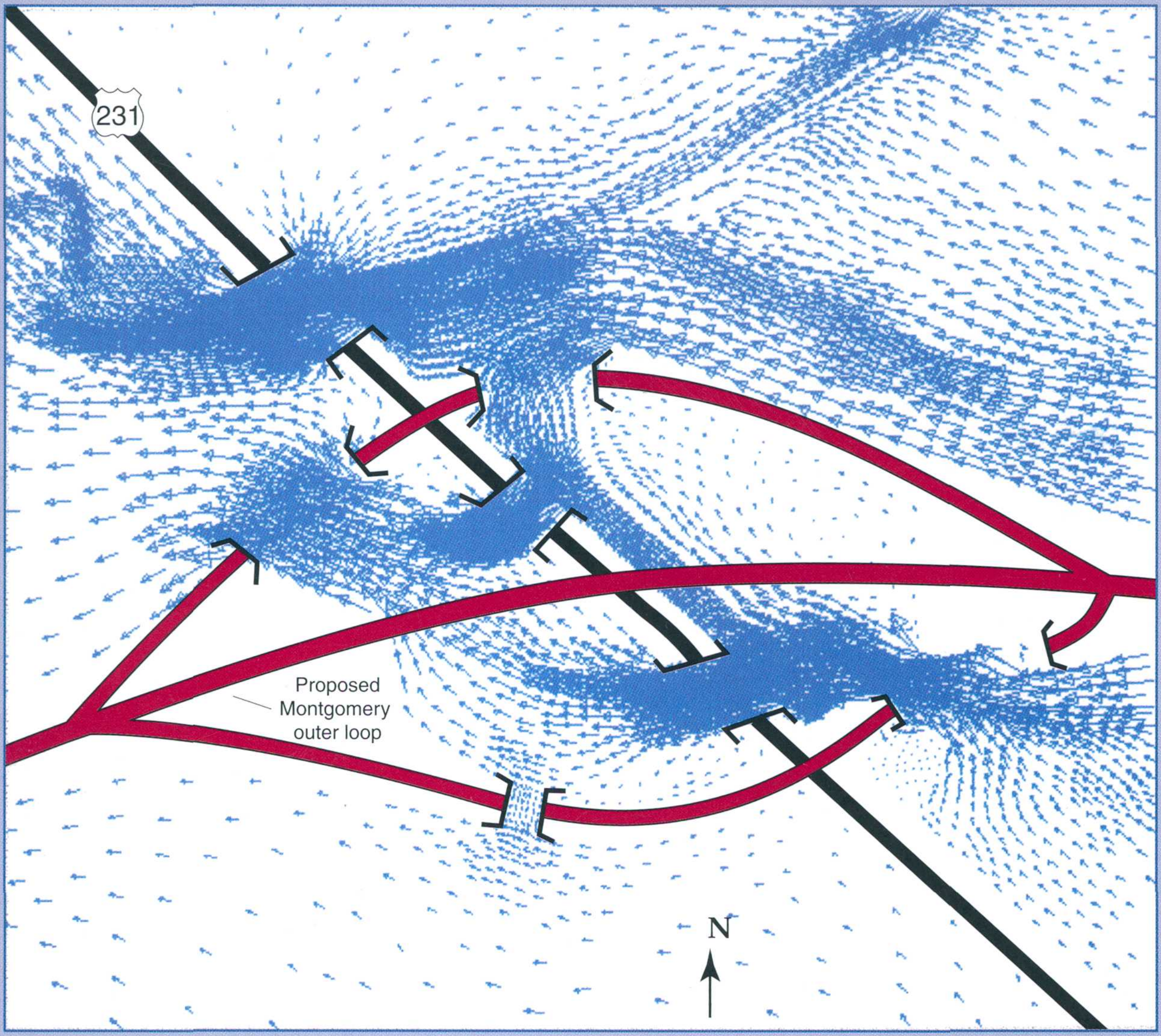
U.S. Geological Survey
Water-Resources Investigations Report 99–4040A



U.S. Department of the Interior
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Montgomery, Alabama
1999

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

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
2350 Fairlane Drive, Suite 120
Montgomery, AL 36116

Copies of this report can be purchased from:

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
feet 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

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 Sea Level Datum of 1929.

Simulations of the Effects of U.S. Highway 231 and the Proposed Montgomery Outer Loop on Flooding in the Catoma Creek and Little Catoma Creek Basins near Montgomery, Alabama

By T. S. Hedgecock

Abstract

A two-dimensional finite-element surface-water model was used to study the effects of U.S. Highway 231 and the proposed Montgomery Outer Loop on the water-surface elevations and flow distributions during flooding in the Catoma Creek and Little Catoma Creek Basins southeast of Montgomery, Montgomery County, Alabama. The effects of flooding were simulated for two scenarios—existing and proposed conditions—for the 100- and 500-year recurrence intervals. The first scenario was to model the existing bridge and highway configuration for U.S. Highway 231 and the existing ponds that lie just upstream from this crossing. The second scenario was to model the proposed bridge and highway configuration for the Montgomery Outer Loop and the Montgomery Outer Loop Interchange at U.S. Highway 231 as well as the proposed modifications to the ponds upstream.

Simulation of floodflow for Little Catoma Creek for the existing conditions at U.S. Highway 231 indicates that, for the 100-year flood, 54 percent of the flow (8,140 cubic feet per second) was conveyed by the northernmost bridge, 21 percent (3,130 cubic feet per second) by the middle bridge, and 25 percent (3,780 cubic feet per second) by the southernmost bridge. No overtopping of U.S. Highway 231 occurred. However, the levees of the catfish ponds immediately upstream from the crossing were completely overtopped. The average water-surface elevations for the 100-year flood at the upstream limits of the study reach for Catoma Creek and Little Catoma Creek were 216.9 and 218.3 feet, respectively. For the 500-year flood, the simulation indicates that 51 percent of the flow (11,200 cubic feet per second) was conveyed by the northernmost bridge, 25 percent (5,480 cubic feet per second) by the middle bridge, and 24 percent (5,120 cubic feet per second) by the southernmost bridge. The average water-surface elevations for the 500-year flood at the upstream limits of the study reach for Catoma Creek and Little Catoma Creek were 218.2 and 219.5 feet, respectively. For the 500-year flood, no overtopping of U.S. Highway 231 occurred.

Simulation of the 100-year floodflow for Little Catoma Creek for the proposed conditions indicates that, for the existing bridges on U.S. Highway 231, 54 percent of the flow (8,190 cubic feet per second) was conveyed by the northernmost bridge, 22 percent (3,350 cubic feet per second) by the middle bridge, and 24 percent (3,490 cubic feet per second) by the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining catfish ponds conveyed about 7,750 cubic feet per second (3,400 cubic feet per second for the west relief bridge and 4,350 cubic feet per second for the east relief bridge) with an average depth of flow of about 7 feet. The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 218.8 feet, which is about 0.5 foot higher than the average water-surface elevation for the existing conditions. For the 100-year flood, there

was no overtopping of either U.S. Highway 231 or the Montgomery Outer Loop. However, the levees of the proposed remaining catfish ponds were completely overtopped. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 100-year floodflow indicates that about 58 percent of the flow (14,100 cubic feet per second) was conveyed by the proposed main channel bridge and 42 percent (10,200 cubic feet per second) by the proposed relief bridge. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 216.9 feet, which is the same as the water-surface elevation for the existing conditions.

Results of model simulations for the 500-year flood for the proposed conditions indicate that there was no overtopping on either U.S. Highway 231 or the Montgomery Outer Loop. For the existing bridges on U.S. Highway 231, 52 percent of the flow (11,300 cubic feet per second) was conveyed by the northernmost bridge, 24 percent (5,290 cubic feet per second) by the middle bridge, and 24 percent (5,220 cubic feet per second) by the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining catfish ponds conveyed about 11,300 cubic feet per second (5,070 cubic feet per second for the west relief bridge and 6,230 cubic feet per second for the east relief bridge) with an average depth of flow of about 9 feet. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 500-year floodflow indicates that about 58 percent of the flow (19,700 cubic feet per second) was conveyed by the proposed main channel bridge and 42 percent (14,500 cubic feet per second) by the proposed relief bridge. The average water-surface elevations at the upstream study limits for Catoma and Little Catoma Creeks were 218.5 and 220.4 feet, respectively.

INTRODUCTION

The hydraulic performance of bridges during floods is a major concern when the opening and grade of drainage structures are designed. In the case of multiple bridge openings, it is important to know the distribution of discharge through the bridges for an efficient hydraulic design. U.S. Highway 231 crosses the Little Catoma Creek flood plain at an average angle (skew) of 45 degrees and consists of three bridge openings (fig. 1). Just upstream from the crossing are

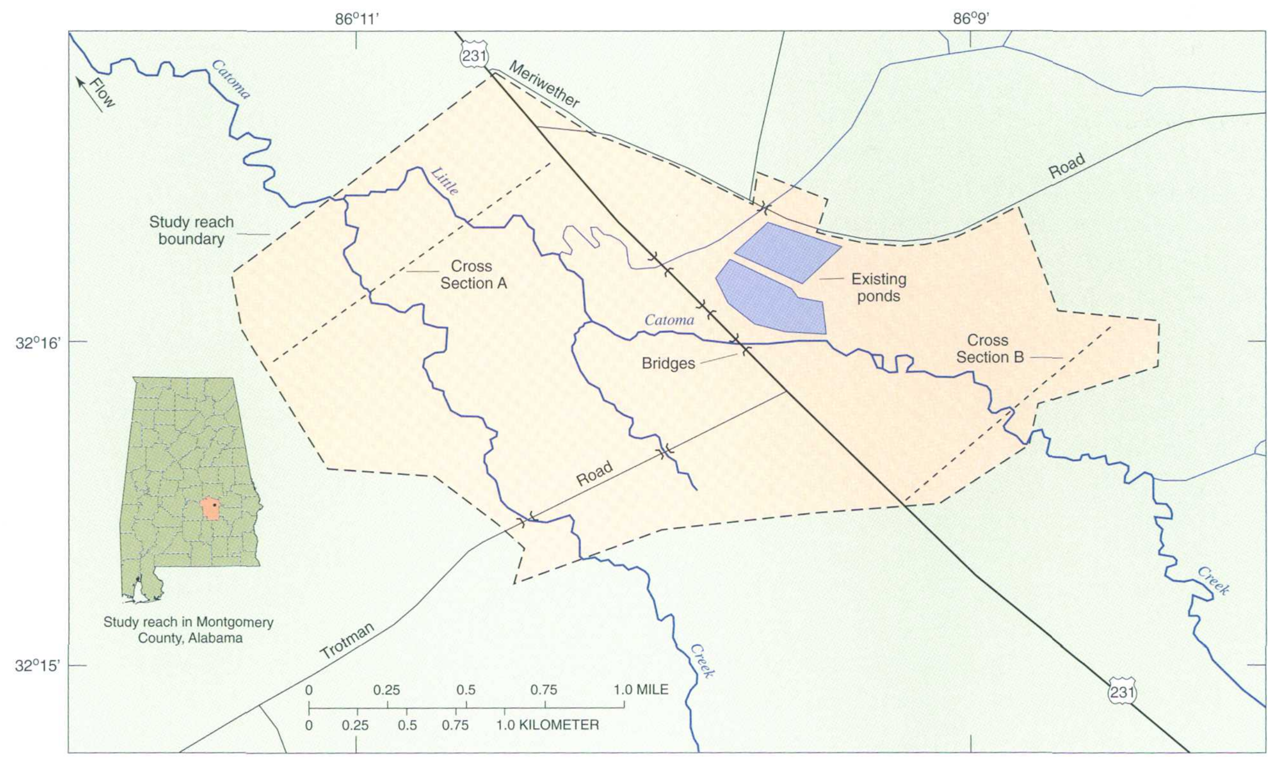


Figure 1. Catoma Creek and Little Catoma Creek study reach for existing conditions.

two groups of catfish ponds in the flood plain that affect the distribution of flow to the bridges during flooding. The proposed Montgomery Outer Loop (fig. 2) will cross U.S. Highway 231 in the vicinity of the bridges mentioned above and will encroach laterally on the Little Catoma Creek flood plain. The Alabama Department of Transportation (DOT) plans to construct an interchange between U.S. Highway 231 and the proposed Montgomery Outer Loop [Project Number DPI–035(006)]. Because of the complexity of this site and the nature of the flow, a two-dimensional flow model will best serve to determine the effects of the proposed interchange on flooding. In 1998, the U.S. Geological Survey (USGS), in cooperation with the Alabama DOT, analyzed the flood hydraulics in the Catoma Creek and Little Catoma Creek Basins. This study will serve as an aid to other States and municipalities that encounter complex flow hydraulics near bridges.

Purpose and Scope

This report presents results of the simulation of floods having 100- and 500-year recurrence intervals for existing and proposed conditions. Discharge, discharge distribution, water-surface elevation, backwater, and velocity data are given for various locations of interest throughout the study reach. Other topics discussed include the following: evaluation of hydrology, collection of survey data, development of a computational grid, selection of flow model, simulation of floodflows, and calibration and validation of the model.

Acknowledgments

The assistance of Mr. Tom Flournoy, Alabama DOT Hydraulic Engineer, and personnel of the Location Section of the Alabama DOT Design Bureau is greatly appreciated. Also, the assistance of Ms. Janice Fulford of the Office of Surface Water was very instrumental in the success of this project.

DESCRIPTION OF STUDY AREA

The study reach is located in northern Montgomery County (fig. 1) about 4 miles (mi) southeast of the Montgomery city limit. Little Catoma Creek drains about 51.4 square miles (mi^2) at U.S.

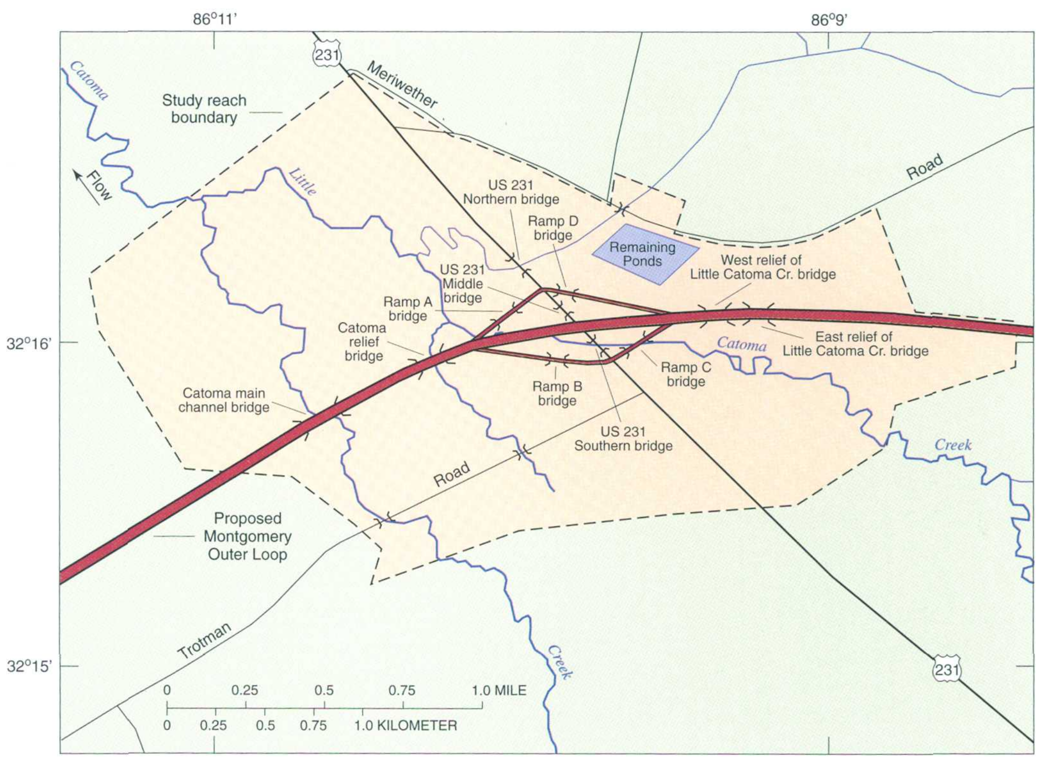


Figure 2. Catoma Creek and Little Catoma Creek study reach for proposed conditions.

Highway 231. About 1 mi downstream from U.S. Highway 231, Little Catoma Creek flows into Catoma Creek. The combined drainage area at the confluence is about 154 mi^2. The USGS has operated a gaging station on Catoma Creek (gaging station 02421000) since 1952. The gage is located about 9 mi downstream from the study reach at U.S. Highway 331.

The study reach includes a 1.3-mi reach and a 1.0-mi reach of the Catoma Creek and Little Catoma Creek Basins, respectively (fig. 1). The basins range in width from about 0.7 mi for Little Catoma Creek to a little more than 1 mi for Catoma Creek. The study reach extends from about 1.1 mi downstream from the proposed interchange to about 0.9 mi upstream from the U.S. Highway 231 crossing of Little Catoma Creek. The total area of the study reach is about 2 mi^2. Little Catoma Creek flows in a northwesterly direction into Catoma Creek about 1 mi downstream from the proposed interchange. An unnamed tributary to Little Catoma Creek flows southwest from the Meriwether Road area into Little Catoma Creek just downstream from U.S. Highway 231.

The average slope of the basins in the study reach is about 3 feet per mile (ft/mi). The Catoma Creek Basin is characterized as flat, swampy, and heavily wooded with dense vegetation throughout. The basin consists of numerous small braided meandering channels, many of which contain small beaver dams that make the channels ineffective for conveying flow. The Little Catoma Creek Basin also is characterized as flat and swampy with some moderately wooded areas and some open areas with little vegetation. Just downstream from U.S. Highway 231, near the northern boundary of the study reach, a section of the flood plain is open and is currently being used for row cropping. Upstream from U.S. Highway 231 on the right overbank, two groups of catfish ponds are located in the flood plain. A few wooded areas and very little overbank vegetation are present in the vicinity of these ponds. Little Catoma Creek also is classified as a small meandering stream that has a significant degree of beaver activity, especially downstream from the southernmost bridge on U.S. Highway 231.

Existing Conditions

U.S. Highway 231 is a four-lane divided highway that crosses the Little Catoma Creek flood plain at an average angle (skew) of 45 degrees (fig. 1). There are three bridge openings in U.S. Highway 231, each having spillthrough-type abutments, sloping embankments, and no wingwalls. The bridge lengths are 326 ft for the northernmost bridge, 180 ft for the middle bridge, and 248 ft for the southernmost bridge. Just upstream from U.S. Highway 231 are several catfish ponds in the flood plain that affect the distribution of flow to the bridges during flooding. The heights of the levees impounding these ponds range from 4 to 6 ft above the flood plain.

Meriwether Road is a two-lane secondary road that is located near the northeastern boundary of the study reach (fig. 1). Meriwether Road extends roughly parallel to the Little Catoma Creek flood plain and intersects U.S. Highway 231 near the northern boundary of the study reach.

Trotman Road is a two-lane secondary road that intersects U.S. Highway 231 about 1,500 ft upstream from the southern boundary of the study reach (fig. 1). Trotman Road extends from its intersection with U.S. Highway 231 toward the southwest and crosses the Catoma Creek flood plain at an average angle (skew) of less than 10 degrees. There are presently two bridge openings in Trotman Road, each having vertical-type abutments, sloping embankments, and 45-degree wingwalls. The bridge lengths are 374 ft for the westernmost (main channel) bridge and 305 ft for the easternmost (relief) bridge.

Proposed Conditions

The Alabama DOT plans to construct the Montgomery Outer Loop from Interstate 85 (I-85) southward to U.S. Highway 231. From U.S. Highway 231, the Montgomery Outer Loop will extend westward, intersecting U.S. Highway 331, Interstate 65 (I-65), and U.S. Highway 31, eventually connecting with U.S. Highway 80 (fig. 3). The Montgomery Outer Loop will be a multi-lane divided highway that will serve as a bypass around the city of Montgomery. The Montgomery Outer Loop will intersect U.S. Highway 231 in the vicinity of the bridges over Little Catoma Creek (fig. 2). At this intersection, the Alabama DOT plans to construct a diamond interchange (fig. 2) that will consist of four bridges for the ramps and one bridge for the mainline crossing. Upstream from U.S. Highway 231, the Montgomery Outer Loop will very nearly parallel Little Catoma Creek. The Alabama DOT plans to construct two relief bridges on the mainline just upstream from the proposed remaining ponds. Both of these bridges will be about 260 ft long

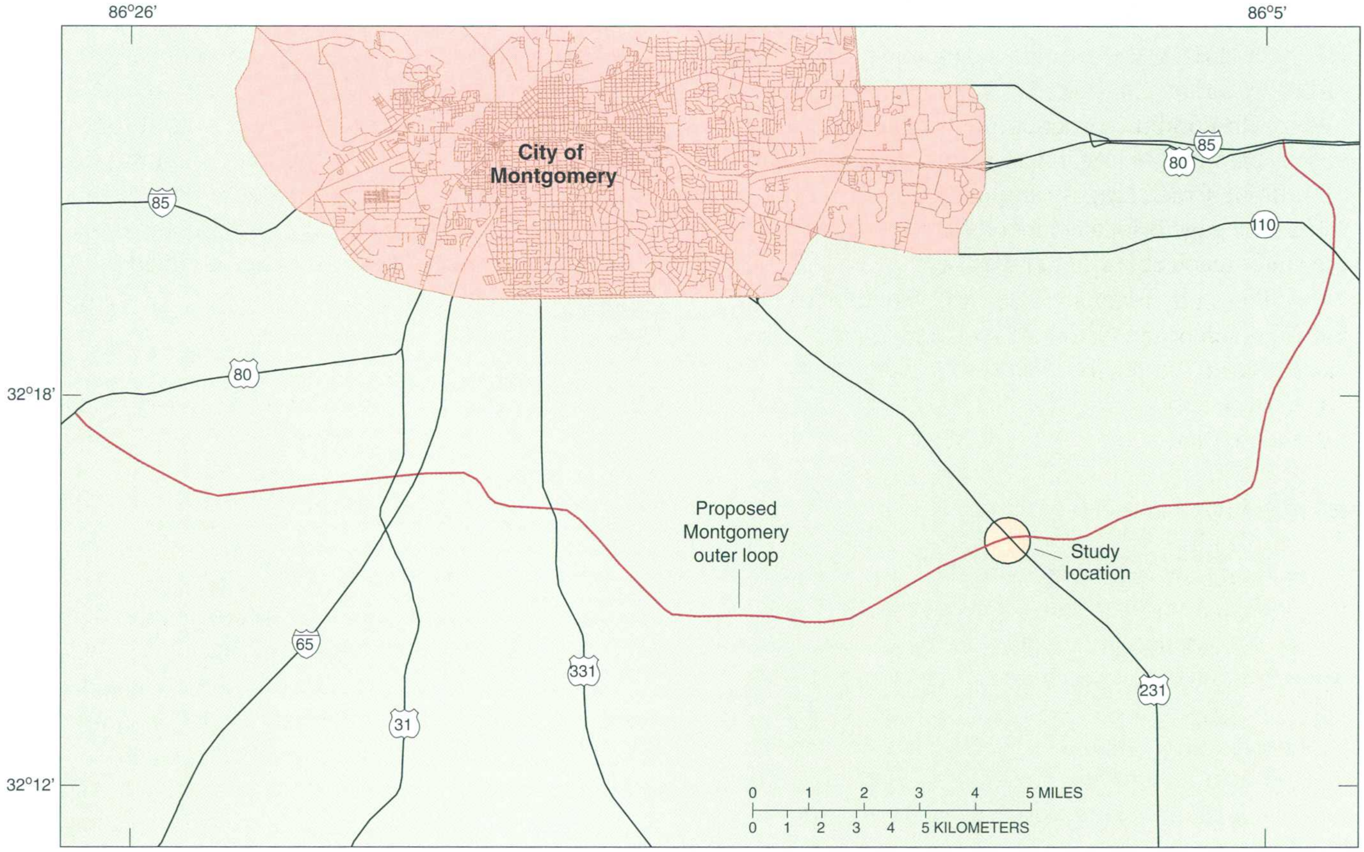


Figure 3. Proposed Montgomery Outer Loop.

and will permit flow from Little Catoma Creek to be conveyed to the north side of the Montgomery Outer Loop. Downstream from U.S. Highway 231, the Montgomery Outer Loop will cross the Catoma Creek flood plain at an average angle (skew) of less than 10 degrees. The Montgomery Outer Loop will cross Catoma Creek about 2,000 ft downstream from Trotman Road, and will consist of two bridge openings. The more westward (main channel) bridge will be about 500 ft long and the more eastward (relief) bridge about 320 ft long. All proposed bridges will have spillthrough-type abutments, sloping embankments, and no wingwalls.

Hydrology

Flood frequencies in the Catoma Creek and Little Catoma Creek Basins were estimated by using techniques outlined in "Magnitude and Frequency of Floods in Alabama" (Atkins, 1996). Flood-peak discharges for floods having 100- and 500-year recurrence intervals were estimated for combined flooding on Catoma Creek and Little Catoma Creek. Discharges were estimated for Little Catoma Creek at U.S. Highway 231 (51.4 mi^2) and Catoma Creek at Trotman Road (100 mi^2) by using USGS regression equations for hydrologic area 3. The discharges computed for each site were added together to get the total discharge at the downstream limit of the study reach. Since a worst-case scenario simulation for flood stages was desired, discharges for simultaneous peaks were used. The 100- and 500-year flood discharges at the downstream limit are 38,200 and 54,200 cubic feet per second (ft^3/s), respectively. For U.S. Highway 231, the discharges for Little Catoma Creek were estimated to be about 14,900 ft^3/s (100-year) and 20,900 ft^3/s (500-year). For Trotman Road and the Montgomery Outer Loop, the discharges for Catoma Creek were estimated to be about 23,300 ft^3/s (100-year), and 33,300 ft^3/s (500-year). For comparison, the discharges used in the current Federal Emergency Management Agency (FEMA) flood study (effective date of January 2, 1992) at the confluence of Catoma and Little Catoma Creeks were 35,300 ft^3/s for the 100-year flood and 53,200 ft^3/s for the 500-year flood.

Discharges for the unnamed tributary to Little Catoma Creek at Meriwether Road were estimated by using the ratio of its drainage area to the drainage area of Little Catoma Creek at U.S. Highway 231. This ratio was multiplied by the total discharges computed for U.S. Highway 231 to get the partial discharges for the tributary. The discharges for the unnamed tributary to Little Catoma Creek at Meriwether Road were estimated to be about 1,900 ft^3/s (100-year) and 2,700 ft^3/s (500-year). Because of the large magnitudes of the floods simulated in this study, sustained peak discharges are probable. Therefore, steady-flow conditions were simulated.

MODELING APPROACH

Floodflow simulations for the study were based on a two-dimensional finite-element surface-water model. First, a computational grid representing the flow system for the existing conditions was constructed with an automated grid generator and survey data supplied by the Alabama DOT. This grid was then used as input into the two-dimensional finite-element flow model, and simulations were performed for the 100- and 500-year floodflows. This process was repeated for the proposed conditions.

Model Description

The Finite Element Surface-Water Modeling System for Two-Dimensional Flow in a Horizontal Plane (FESWMS-2DH) (Froehlich, 1989) was selected as an appropriate model for simulating the two-dimensional flows within the study reach. The model uses the Galerkin finite-element method to solve three partial-differential equations representing conservation of mass and momentum (Lee and Froehlich, 1989). A depth-averaged velocity is computed at each computational point (node) in the model domain. The model area is divided into triangular sections (elements) of variable size, which are better for fitting the model to physical features. Input data requirements can be separated into three major categories:

1. **Geographical information.** Land-surface elevations for each element, and dimensions and locations of each element (as defined by the computational grid).
2. **Flow parameters.** Resistance coefficients for each element, possibly as a variable function of depth or velocity.
3. **Boundary conditions.** Water level or no-flow conditions at the edges of the model; also any net inflows and outflows to each cell. Boundary conditions are set up to execute the model.

The theory of the model is beyond the scope of this report; however, a detailed explanation of the theory is provided in the research report by Lee and Froehlich (1989).

Model Implementation

There are several steps involved in the application of a two-dimensional finite-element flow model. First, a finite-element grid representing the flow system must be constructed and tested for its integrity. Once a stable grid has been constructed, boundary conditions, such as water-surface elevation and discharge, must be determined to execute the model. Finally, several model parameters and options must be considered before it can be determined which will produce the best results for floodflow simulations.

Computational Grid

The use of a finite-element model requires that the study reach be divided into elements that form a grid. In the case of a triangular grid, nodes are located at the corners and mid-sides of the elements and are assigned coordinates and elevations. A finite-element grid should be carefully designed so that mass is conserved within the system. The finite-element grid needs to be more refined (smaller elements) in areas where changes in velocity or bathymetry are substantial than in areas where changes are gradual. The software package TRIGRID was used to construct the computational grids representing the flow system in this study. TRIGRID is an automated grid generator that uses vertex triangulation methods in which vertices (nodes) are distributed through the model domain and then connected appropriately by a triangulation algorithm.The finite-element grid used for modeling the existing conditions consists of 7,363 elements and 15,107 nodes (fig. 4); the grid for the proposed

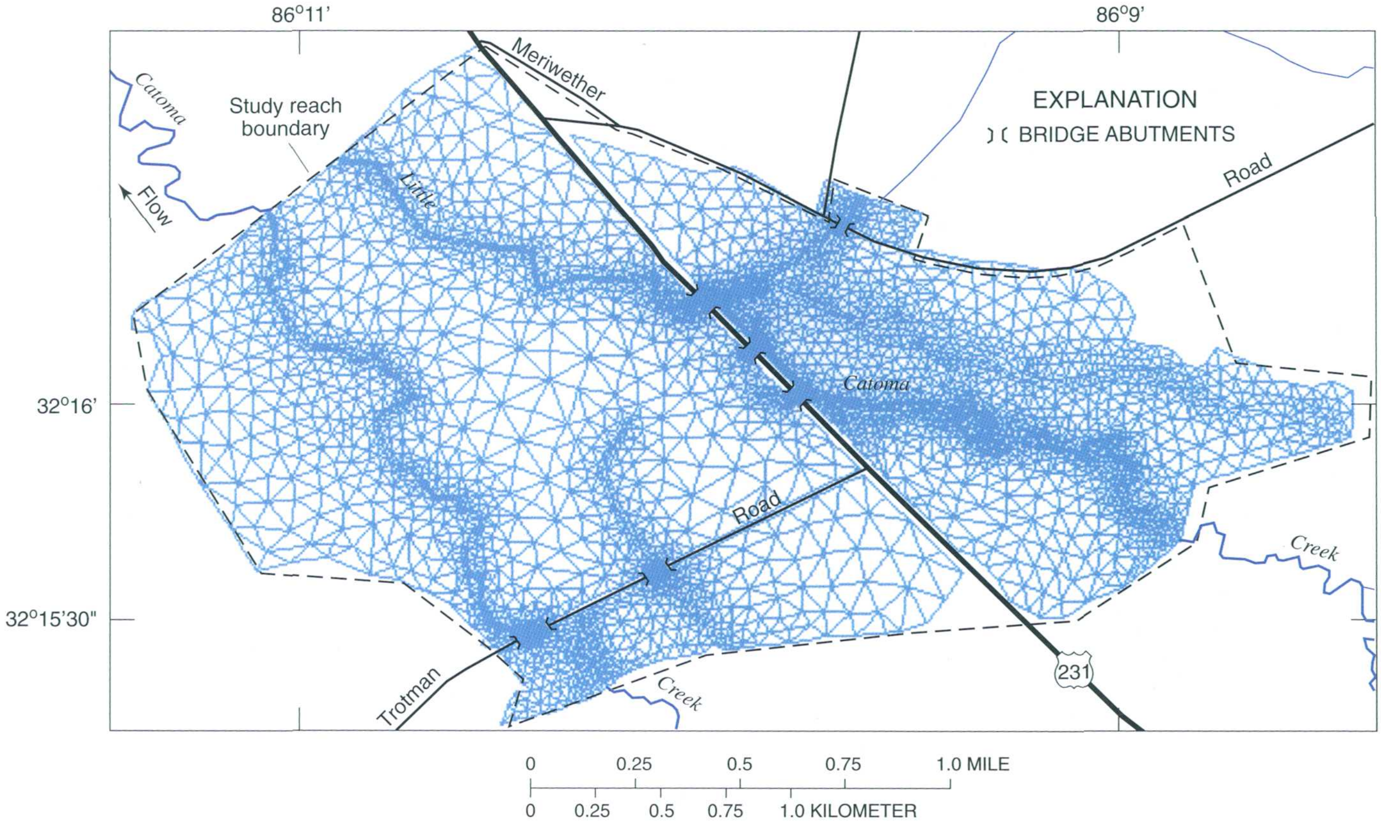


Figure 4. Finite-element grid used in flow simulations for existing conditions.

conditions has 7,610 elements and 15,790 nodes (fig. 5).

Boundary Conditions

Boundary conditions are established around the perimeter of a finite-element network; they are identified as either closed or open. Closed boundaries represent obstructions, such as shorelines, embankments, and levees, that do not allow flows to pass through. The locations of the closed boundaries representing the shorelines in this study were estimated using water-surface profiles determined from WSPRO [a one-dimensional step-backwater model used for computing water-surface profiles (Shearman, 1990)]. For the simulations in this study, all solid boundaries were set up for tangential slip condition, which forces all flow adjacent to the solid boundaries to flow parallel to the boundaries. Flows also were allowed to pass over solid boundaries to simulate weir flows over embankments.

Open boundaries represent boundaries that allow flows to enter or leave the finite-element network. In this study, open boundaries are located at the upstream and downstream ends of the Catoma Creek and Little Catoma Creek segments of the study reach, as well as at the upstream end of the unnamed tributary to Little Catoma Creek. The open boundary conditions at the upstream boundaries are the discharges for the different flows being simulated. The open boundary conditions for the downstream end of the study reach are normal water-surface elevations estimated from slope-conveyance computations. The downstream boundary conditions computed using WSPRO are 211.0 and 212.8 ft for the 100- and 500-year floods, respectively. Step-backwater analyses indicate that water-surface profiles for the 100- and 500-year floods computed with different downstream starting elevations

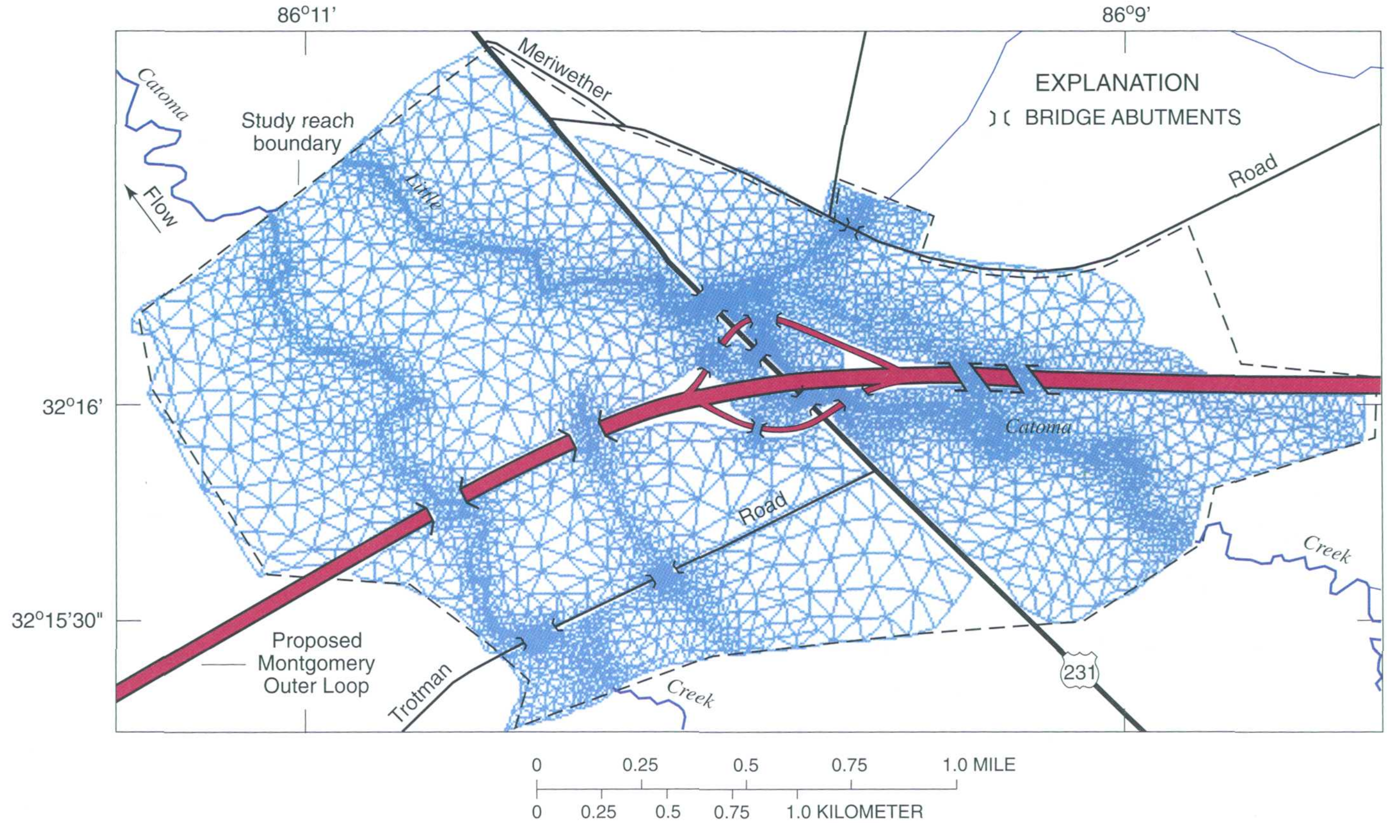


Figure 5. Finite-element grid used in flow simulations for proposed conditions.

converged to within 0.1 ft at the downstream end of the study reach. Therefore, any error in the boundary conditions at the downstream end of the study reach does not affect the solution at the bridges upstream. Additionally, results of step-backwater computations for the 50-year flood discharge of 31,800 ft^3/s yielded a water-surface elevation of 213.2 ft at the downstream side of the northernmost bridge on U.S. Highway 231. This compares closely to the 213.0-ft highwater mark elevation at that bridge for the February 1961 flood (C.O. Ming, written commun., 1981). At the Catoma Creek gage downstream, the February 1961 discharge was estimated to be 48,600 ft^3/s (Atkins, 1996), very close to the 50-year flood discharge (47,700 ft^3/s).

Model Parameters

Several modeling parameters and options were considered and varied throughout the modeling process to ensure that the best simulation of floodflows was achieved. Manning's roughness coefficient (fig. 6) and base kinematic eddy viscosity were the two primary model parameters that were varied throughout the modeling. Default values for all other modeling parameters were used for floodflow simulations. These parameters included the following: water density, air density, dimensionless turbulence coefficient, discharge coefficient for weir flow, relaxation factor, depth tolerance, and coefficients used to compute the momentum correction coefficient. Additionally, a low-order numerical integration technique was performed for each simulation. Wind effects were ignored and a constant density was assumed (assumed flow was well mixed vertically). Any unsteady effects of the floodflow were ignored. Some of the modeling options that were considered were (1) steady-state versus time-dependent solution, (2) elements being "turned on" and "off" during a run versus elements being left "on" (Froehlich, 1989), and (3) varying the number of iterations to be performed to reach a converged solution.

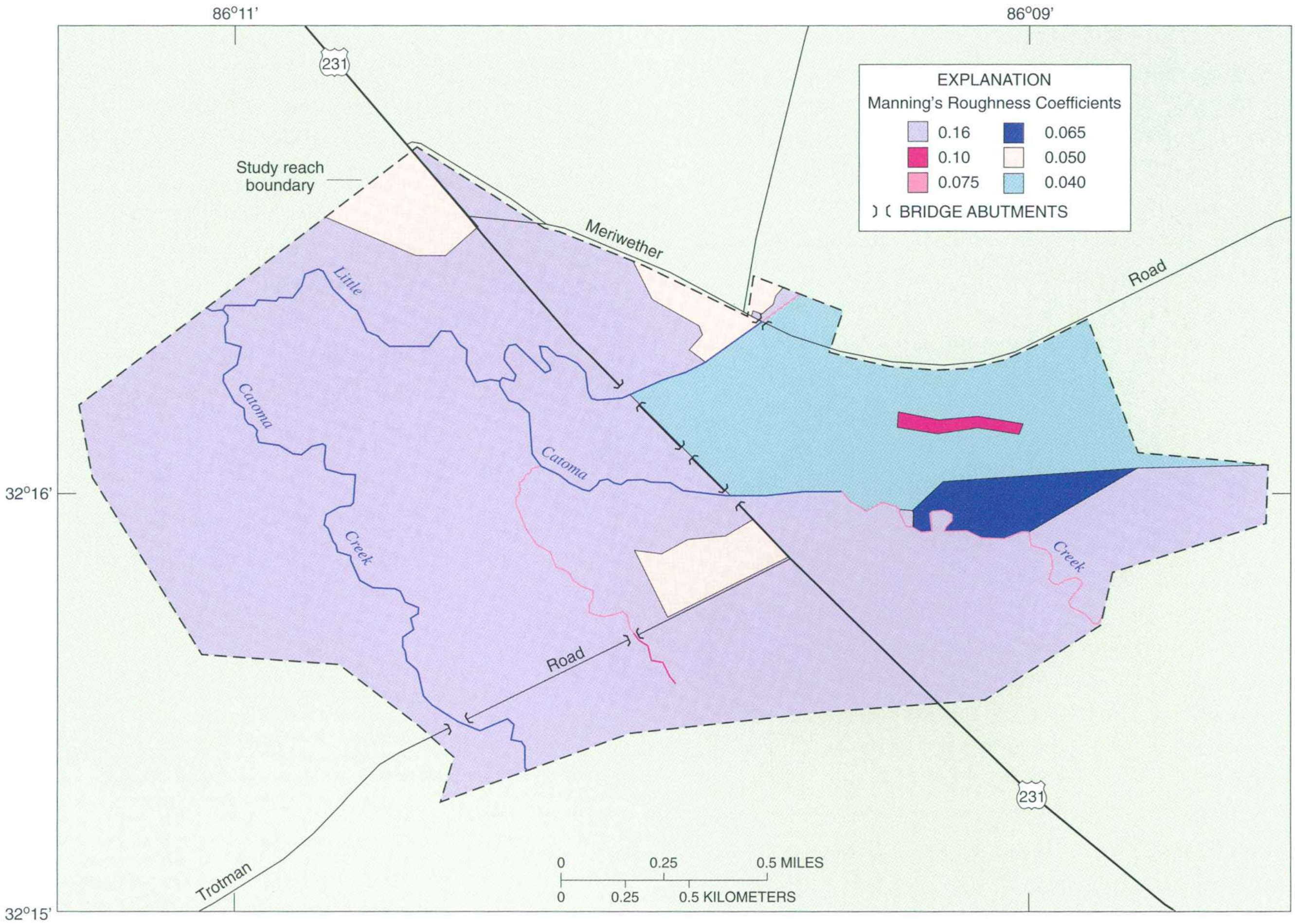


Figure 6. Manning's roughness coefficients used in Catoma Creek and Little Catoma Creek study reach.

Model Calibration and Validation

Calibration is the process of adjusting model input parameters so that model results closely compare to actual measured data. Because no historical hydraulic data exist for the site and no significant hydraulic event occurred during the study, there were no proper data available to calibrate the FESWMS model. Grid configuration, the selection of Manning's roughness coefficients, and the selection of depth-averaged eddy viscosities were based on engineering judgment and experience. The proper technique for validating a calibrated model is to simulate a separate hydraulic event for which the discharge and water-surface elevations are known independent of the original event. If no model parameters are adjusted to reach a solution comparable to the recorded data for the independent event, the model is commonly considered well calibrated for a limited range of discharges. Since there was no recorded event to simulate, it was not possible to validate the model.

Sensitivity Analysis

The sensitivity of model results to changes in model parameters was observed. Manning's roughness coefficients and base kinematic eddy viscosity (eq. 4–19, Froehlich, 1989) were adjusted from the original values used in the initial convergence of the model. Changes in Manning's roughness coefficients had minimal effects on the model results (about 0.1 ft). Changes in base kinematic eddy viscosity, however, had somewhat significant effects on the solution. For each floodflow simulation, a beginning base kinematic eddy viscosity of 250 feet squared per second (ft^2/s) was used. Once a converged solution was reached for the targeted boundary conditions, the base kinematic eddy viscosity was lowered in a series of steps to a value of 10 ft^2/s. It was observed that, for base eddy viscosities between 250 and 30 ft^2/s, there were significant changes in the solution (about 0.5 ft) at the upstream boundaries. However, for base eddy viscosities between 30 and 10 ft^2/s, there were no significant changes in the solution (less that 0.1 ft) at the upstream boundaries.

SIMULATION OF FLOODFLOWS

Floodflows for the 100- and 500-year floods were simulated for the existing and proposed conditions. The 100- and 500-year flood discharges were simulated because hydraulic structures are designed by the Alabama DOT to meet Federal, State, and local guidelines. These guidelines require the design of a hydraulic structure to adequately pass the 100-year flood such that backwater is not excessively increased. Additionally, these guidelines require that theoretical scour be computed for the proposed hydraulic structures for the 100- and 500-year floods. A worst-case scenario simulation for flood stage was performed for the 100- and 500-year floods. In these worst-case scenarios, discharges for simultaneous peaks on Catoma and Little Catoma Creeks were used, and the ponds upstream from U.S. Highway 231 were assumed to remain in place during the floods.

100-Year Flood

Floodflows were simulated depicting the Catoma Creek and Little Catoma Creek 100-year flood for the existing and proposed conditions. The estimated 100-year flood discharge is 38,200 ft^3/s at the confluence and has a 1 percent chance of being equaled or exceeded in any given year. During the 100-year flood, floodwaters would submerge the entire widths of the Catoma Creek and Little Catoma Creek flood plains. The average depth computed for a series of nodes along cross section A (fig. 1) in the Catoma Creek flood plain was about 7 ft; the average depth computed for a series of nodes along cross section B (fig. 1) in the Little Catoma Creek flood plain was about 5 ft. During this flood event, the levees of the ponds upstream from U.S. Highway 231 would be submerged by an average depth of about 1.0 ft. Trotman and Meriwether Roads would be completely submerged, whereas U.S. Highway 231 and the proposed Montgomery Outer Loop would not be overtopped during floodflows.

Existing Conditions

The 100-year floodflow was simulated with the present land and highway configuration in place. This simulation included the present embankments and bridge geometries for U.S. Highway 231, Trotman Road, and Meriwether Road. The existing catfish ponds upstream from U.S. Highway 231 also were included in the simulation. Simulation of the 100-year flood for Little Catoma Creek at U.S. Highway 231 indicates that 54 percent (8,140 ft^3/s) of the flow was conveyed by the northernmost bridge, 21 percent (3,130 ft^3/s) by the middle bridge, and 25 percent (3,780 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges were 4.7 feet per second (ft/s) for the northernmost bridge, 3.1 ft/s for the middle bridge, and 3.7 ft/s for the southernmost bridge. Results indicate that no overtopping of U.S. Highway 231 occurred. However, the levees of the catfish ponds upstream were completely overtopped. The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 218.3 ft. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 216.9 ft. A plot of computed water-surface elevations for the 100-year flood for the existing conditions is shown in figure 7. A plot of corresponding velocity contours is shown in figure 8, and a plot of computed velocity vectors in the vicinity of U.S. Highway 231 is shown in figure 9.

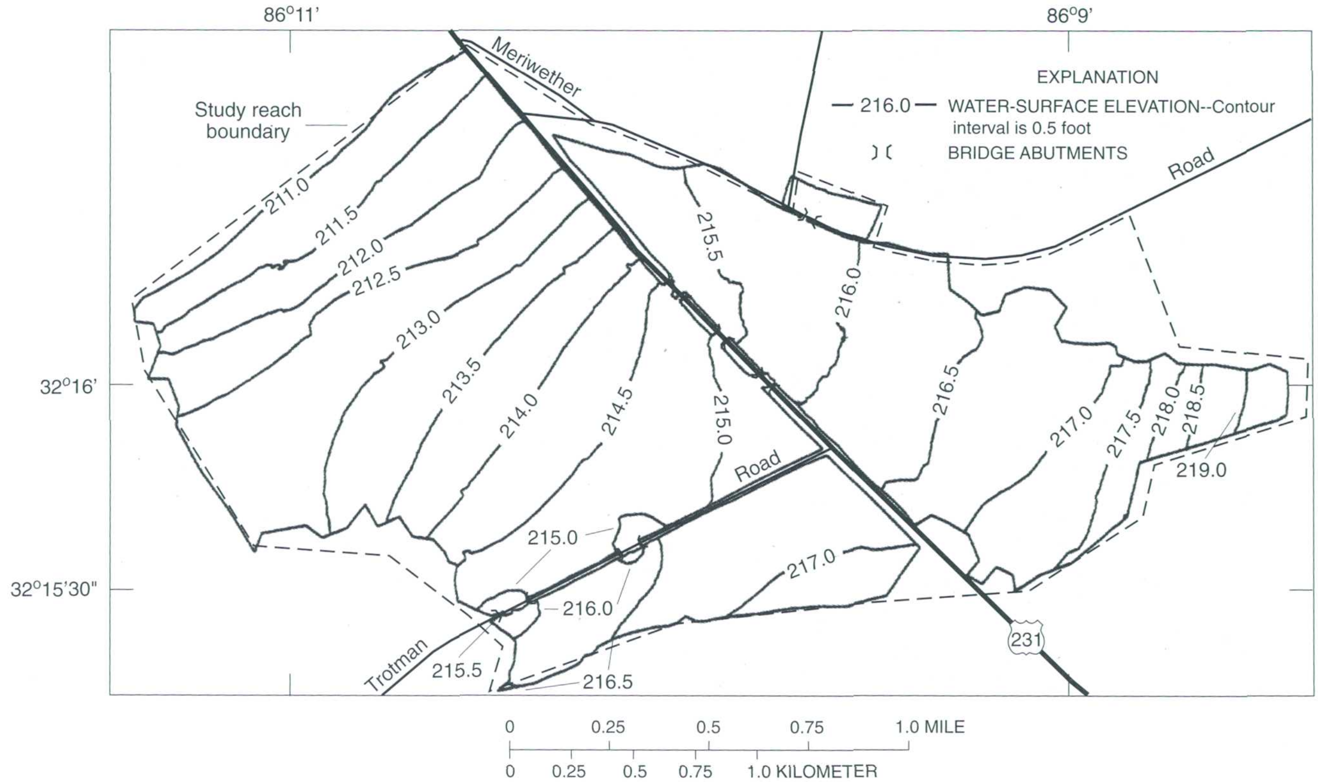


Figure 7. Computed water-surface elevations for 100-year flood for existing conditions.

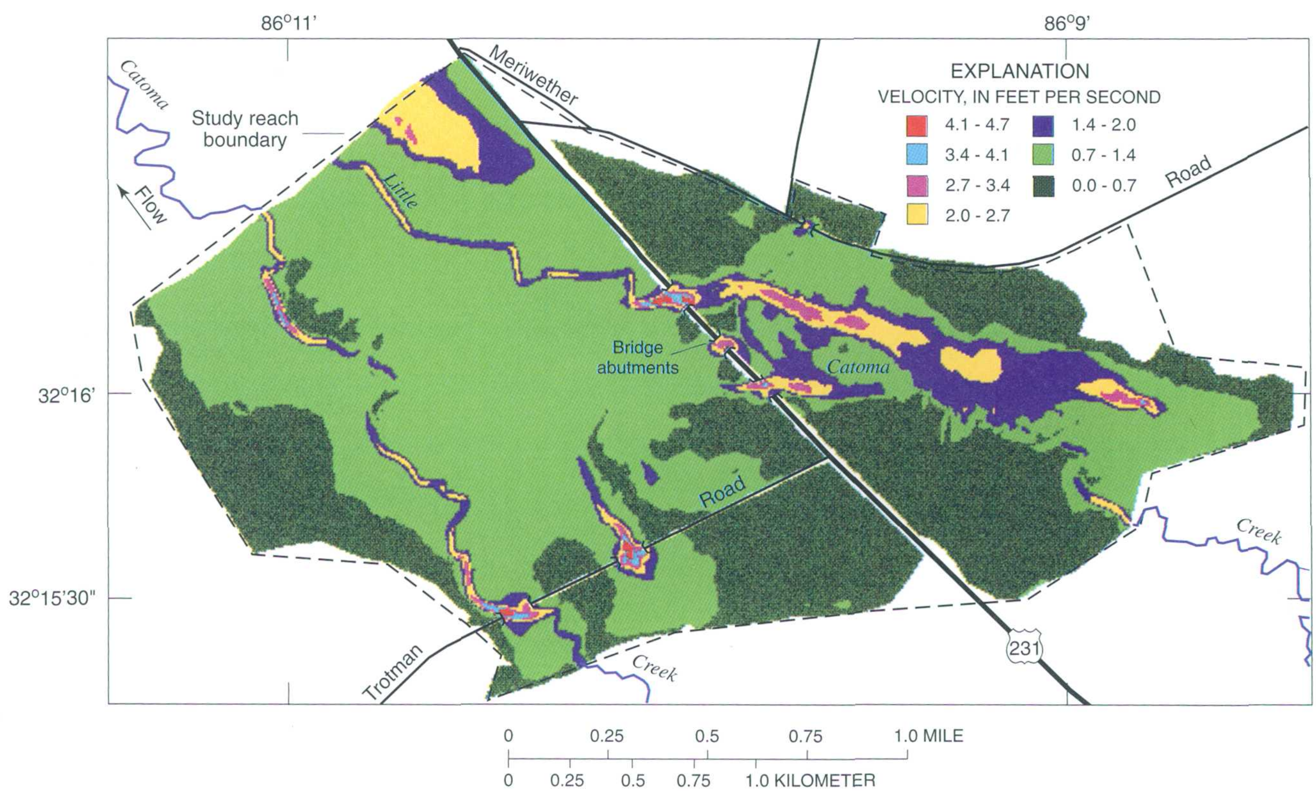
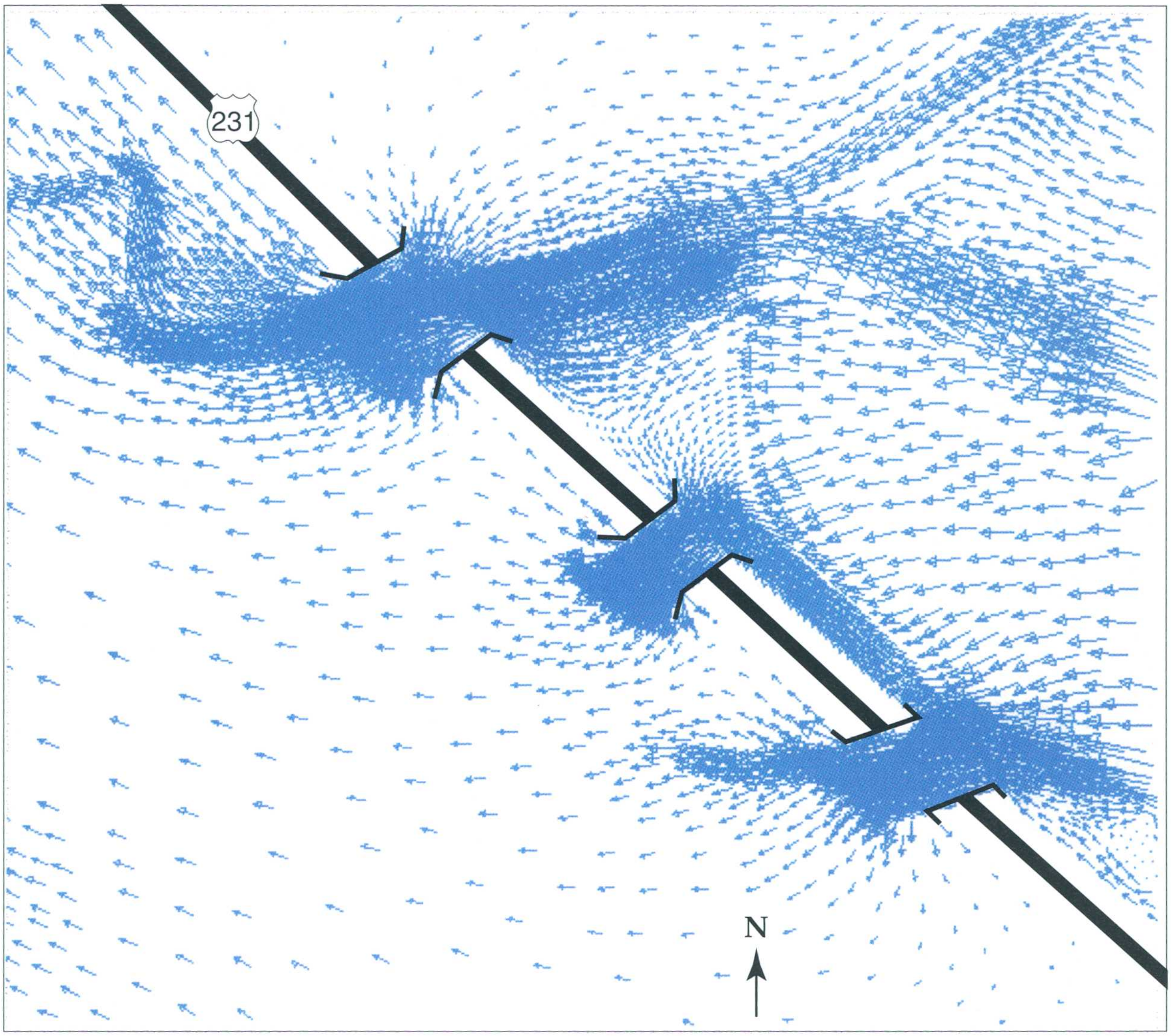


Figure 8. Computed velocity contours for 100-year flood for existing conditions.



EXPLANATION

VECTOR--Length is 1 foot per second. Greater vector length represents greater relative velocity. Head points in direction of flow.

) (BRIDGE ABUTMENTS

Figure 9. Computed velocity vectors for 100-year flood in the vicinity of U.S. Highway 231.

Proposed Conditions

Simulation of the 100-year floodflow for Little Catoma Creek for the proposed conditions indicates that, for the existing bridges on U.S. Highway 231, 54 percent of the flow (8,190 ft^3/s) was conveyed by the northernmost bridge, 22 percent (3,350 ft^3/s) by the middle bridge, and 24 percent (3,490 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges on U.S. Highway 231 were 4.7 ft/s for the northernmost bridge, 3.1 ft/s for the middle bridge, and 2.8 ft/s for the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining group of catfish ponds conveyed about 7,750 ft^3/s (3,400 ft^3/s in the west relief bridge and 4,350 ft^3/s in the east relief bridge) with an average depth of flow of about 7 ft. The maximum point velocities predicted for these bridges were 3.6 and 5.1 ft/s for the west and east relief bridges, respectively. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 100-year floodflow indicates that about 58 percent of the flow (14,100 ft^3/s) was conveyed by the proposed main channel bridge and 42 percent (10,200 ft^3/s) by the proposed Catoma Creek relief bridge (fig. 2). The maximum point velocities predicted for these bridges were 5.1 and 3.9 ft/s for the main channel and relief bridges, respectively. The maximum point velocities computed for the proposed interchange ramp bridges (fig. 2) were 3.3, 0.4, 4.7, and 2.2 ft/s for ramps A, B, C, and D, respectively.

The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 218.8 ft, which is about 0.5 ft higher than the water-surface elevation for the existing conditions. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 216.9 ft, which is the same as the water-surface elevation for the existing conditions. For the 100-year flood, there was no overtopping of either U.S. Highway 231 or the Montgomery Outer Loop. However, the levees of the proposed remaining catfish ponds were completely overtopped. For each bridge mentioned above, average downstream and approach water-surface elevations were estimated by taking the average of the water-surface elevations at a group of nodes on a line at the location of interest. Approach elevations were selected from nodes about one bridge length upstream from each bridge. Backwater was estimated by comparing the average approach elevations to those computed for the same location for the existing conditions. Head was computed by subtracting the average downstream elevation from the average approach elevation. For Catoma Creek, the average water-surface elevation one bridge length (500 ft) upstream from the Montgomery Outer Loop was computed to be about 0.8 ft higher than that for the existing conditions. A complete tabulation of the hydraulic data for the 100-year flood for the bridges mentioned above is presented in table 1. Hydraulic data for the proposed interchange ramp bridges are presented in table 2. A plot of computed water-surface elevations for the 100-year flood for the proposed conditions is shown in figure 10. A plot of corresponding velocity contours is shown in figure 11. Plots of computed velocity vectors in the vicinity of the bridges cited above are shown in figures 12–14.

Table 1. Hydraulic data for Catoma and Little Catoma Creeks for simulated floodflows having a 100-year recurrence interval

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

Bridge description (fig. 2)	Downstream water-surface elevation (ft)	Discharge (ft^3/s)	Percent flow	Approach water-surface elevation (ft)	Head (ft)	Maximum point velocity (ft/s)
Little Catoma Creek at U.S. Highway 231 (existing conditions)						
North bridge	214.62	8,140	54	215.52	0.9	4.7
Middle bridge	215.03	3,130	21	215.56	.6	3.1
South bridge	215.18	3,780	25	215.75	.6	3.7
Little Catoma Creek at U.S. Highway 231 (proposed conditions)						
North bridge	215.02	8,190	54	215.78	.8	4.7
Middle bridge	215.50	3,350	22	215.77	.3	3.1
South bridge	215.59	3,490	24	215.76	.2	2.8
Bridge description (fig. 2)	**Downstream water-surface elevation (ft)**	**Discharge (ft^3/s)**	**Percent flow**	**Approach water-surface elevation (ft)**	**Backwater (ft)**	**Maximum point velocity (ft/s)**
Catoma Creek at proposed Montgomery Outer Loop						
Main bridge	213.56	14,100	58	214.90	.8	5.1
Relief bridge	214.22	10,200	42	215.14	.7	3.9
Little Catoma Creek relief bridges at proposed Montgomery Outer Loop						
West bridge	216.27	3,400	27	216.65	.1	3.6
East bridge	216.51	4,350	34	217.04	.3	5.1

Table 2. Hydraulic data for the proposed interchange ramp bridges for simulated floodflows having a 100-year recurrence interval

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

Bridge description (fig. 2)	Downstream water-surface elevation (ft)	Discharge (ft^3/s)	Approach water-surface elevation (ft)	Average depth (ft)	Maximum point velocity (ft/s)
Ramp A................	215.27	6,940	215.46	7.8	3.3
Ramp B................	215.60	102	215.62	6.4	.4
Ramp C................	215.90	5,030	216.22	7.8	4.7
Ramp D	215.78	1,620	215.80	7.3	2.2

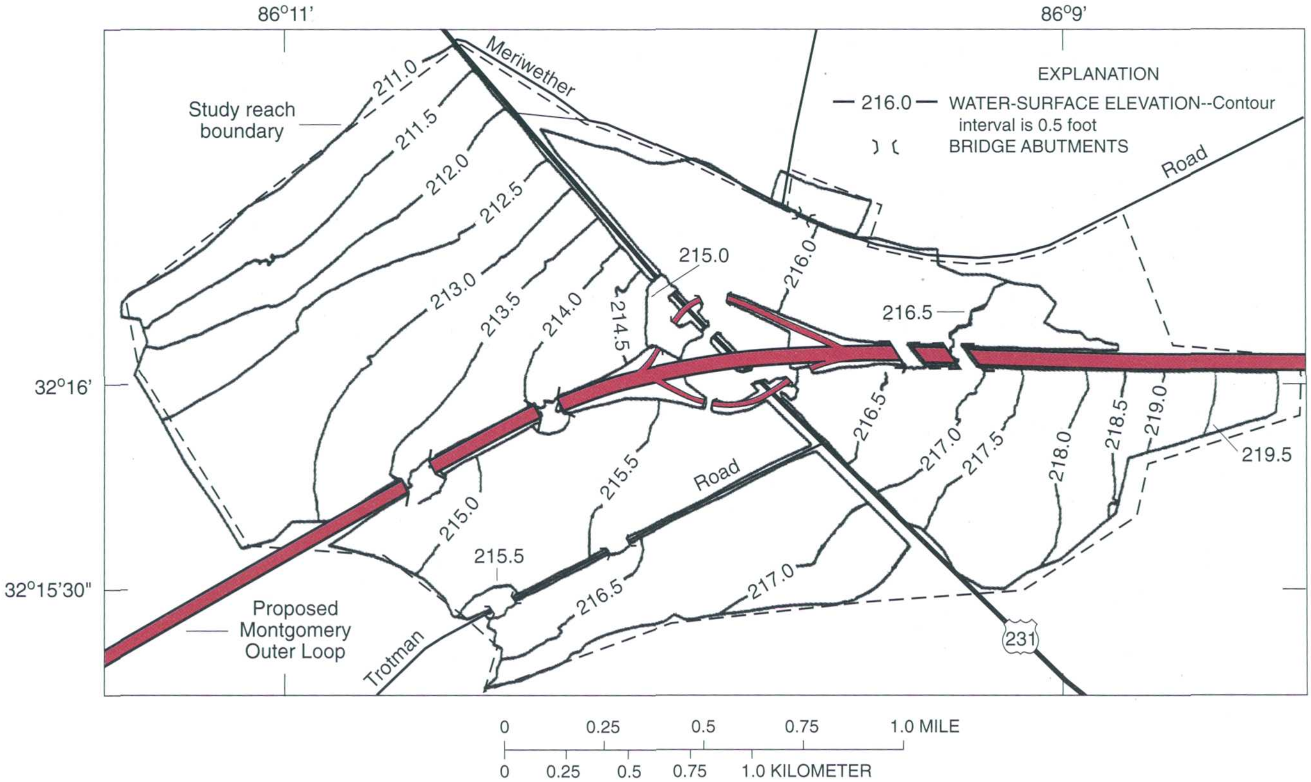


Figure 10. Computed water-surface elevations for 100-year flood for proposed conditions.

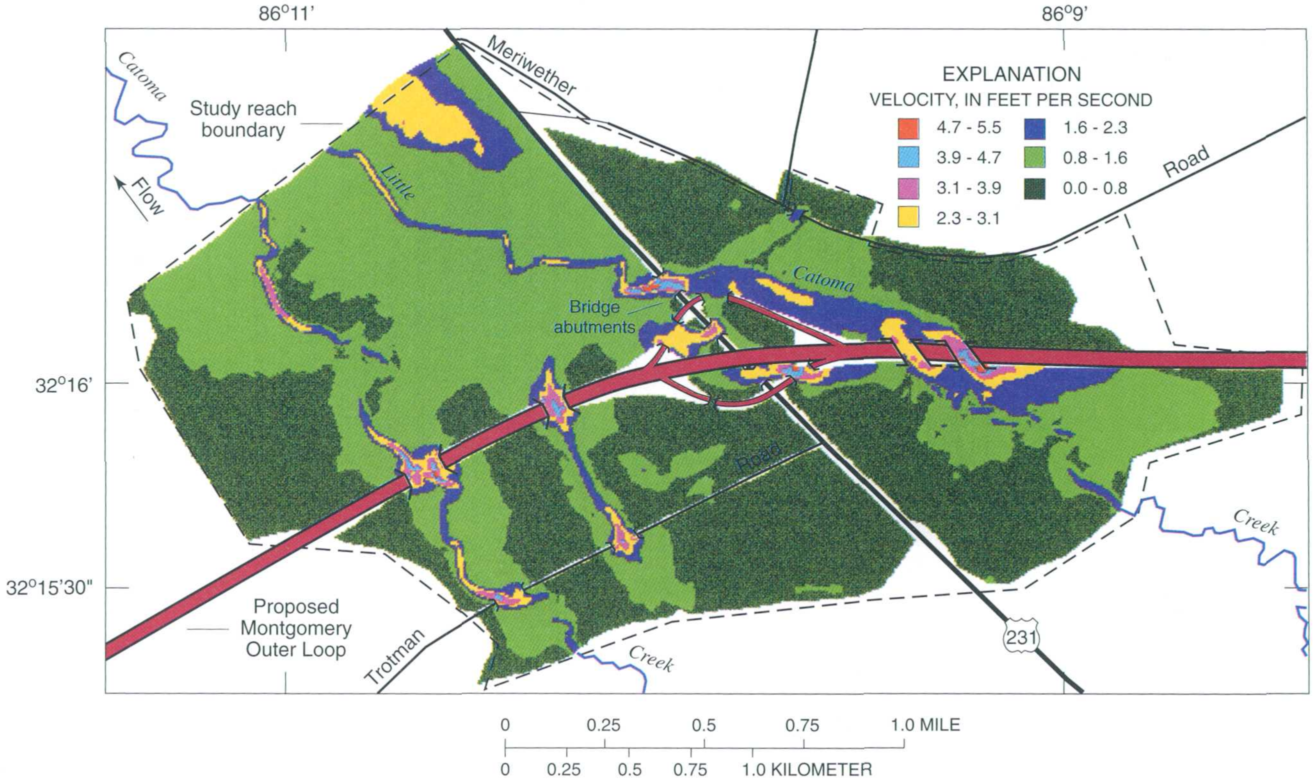
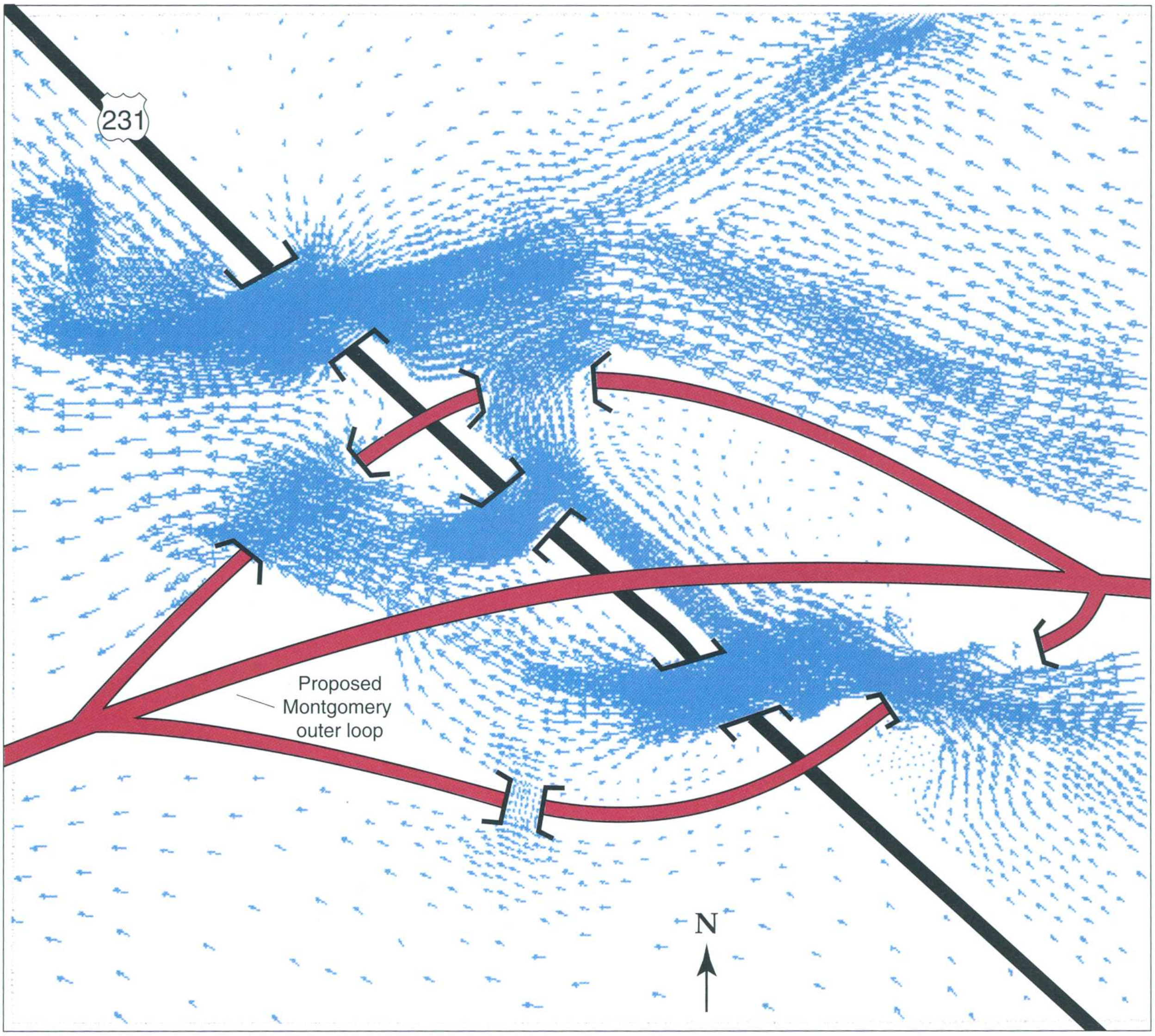


Figure 11. Computed velocity contours for 100-year flood for proposed conditions.

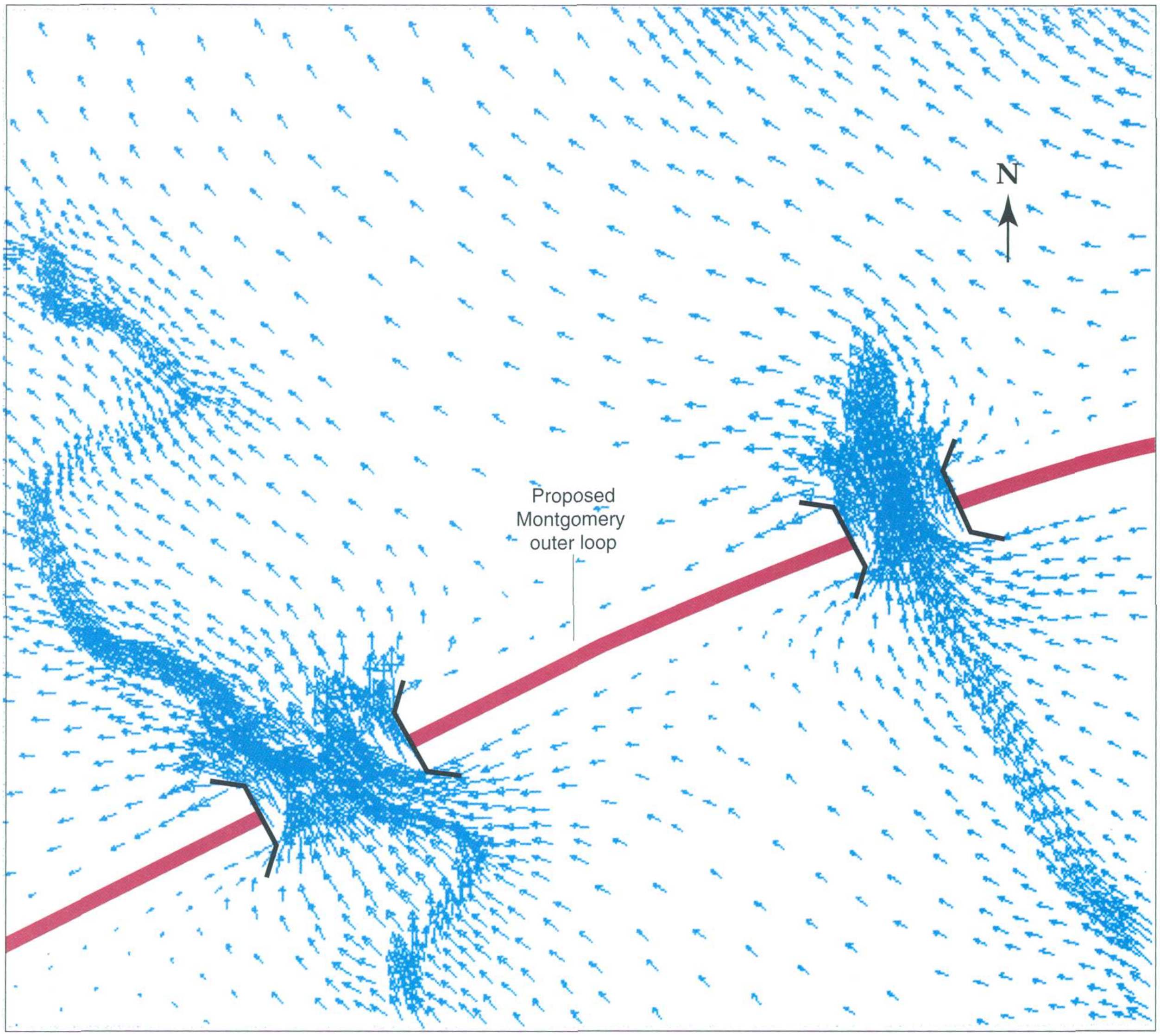


EXPLANATION

VECTOR--Length is 1 foot per second. Greater vector length represents greater relative velocity. Head points in direction of flow.

) (BRIDGE ABUTMENTS

Figure 12. Computed velocity vectors for 100-year flood in the vicinity of the proposed interchange.

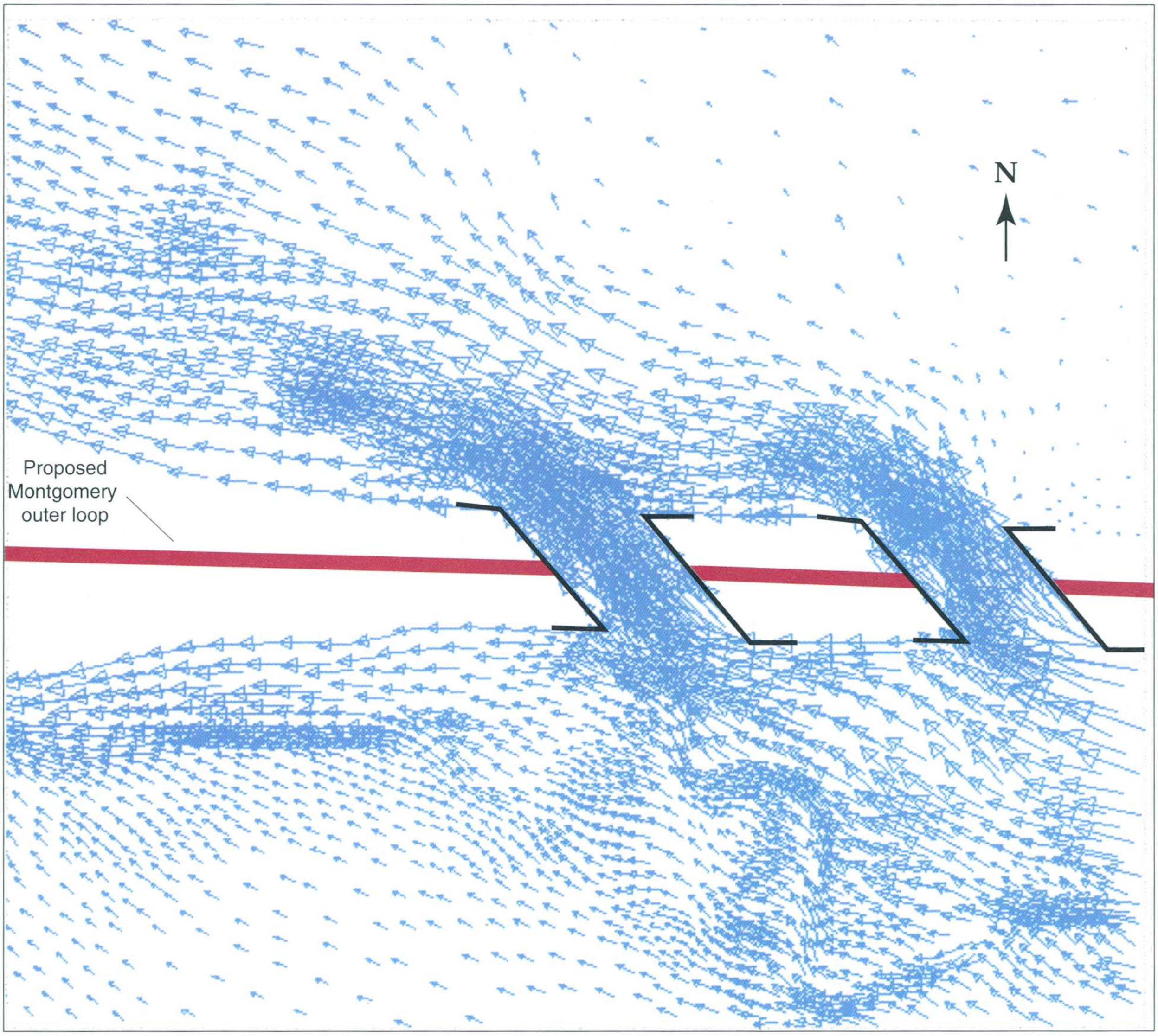


EXPLANATION

VECTOR--Length is 1 foot per second. Greater vector length represents greater relative velocity. Head points in direction of flow.

) (BRIDGE ABUTMENTS

Figure 13. Computed velocity vectors for 100-year flood in the vicinity of the proposed Montgomery Outer Loop crossing of Catoma Creek.



EXPLANATION

VECTOR--Length is 1 foot per second. Greater vector length represents greater relative velocity. Head points in direction of flow.

) (BRIDGE ABUTMENTS

Figure 14. Computed velocity vectors for 100-year flood in the vicinity of the proposed Little Catoma Creek relief bridges.

500-Year Flood

Floodflows were simulated depicting the Catoma Creek and Little Catoma Creek 500-year flood for the existing and proposed conditions. The estimated 500-year flood discharge is 54,200 ft^3/s at the confluence and has a 0.2 percent chance of being equaled or exceeded in any given year. During the 500-year flood, floodwaters would submerge the entire widths of the Catoma Creek and Little Catoma Creek flood plains. The average depth computed for a series of nodes along cross section A (fig. 1) in the Catoma Creek flood plain was about 9 ft; the average depth computed for a series of nodes along cross section B (fig. 1) in the Little Catoma Creek flood plain was about 7 ft. During this flood event, the levees of the ponds upstream from U.S.

Highway 231 would be submerged by an average depth of about 3 ft. Trotman and Meriwether Roads would be completely submerged, whereas U.S. Highway 231 and the proposed Montgomery Outer Loop would not be overtopped during floodflows.

Existing Conditions

The 500-year floodflow was simulated with the present land and highway configuration in place. This simulation included the present embankments and bridge geometries for U.S. Highway 231, Trotman Road, and Meriwether Road. The existing group of catfish ponds upstream from U.S. Highway 231 also were included in the simulation. Simulation of the 500-year flood for Little Catoma Creek at U.S. Highway 231 indicates that 51 percent (11,200 ft^3/s) of the flow was conveyed by the northernmost bridge, 25 percent (5,480 ft^3/s) by the middle bridge, and 24 percent (5,120 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges were 5.5 ft/s for the northernmost bridge, 5.3 ft/s for the middle bridge, and 4.3 ft/s for the southernmost bridge. Results indicate that no overtopping of U.S. Highway 231 occurred. The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 219.5 ft. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 218.2 ft. A plot of computed water-surface elevations for the 500-year flood for the existing conditions is shown in figure 15, and a plot of corresponding velocity contours is shown in figure 16.

Proposed Conditions

Simulation of the 500-year floodflow for Little Catoma Creek for the proposed conditions indicates that, for the existing bridges on U.S. Highway 231, 52 percent of the flow (11,300 ft^3/s) was conveyed by the northernmost bridge, 24 percent (5,290 ft^3/s) by the middle bridge, and 24 percent (5,220 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges on U.S. Highway 231 were 5.3 ft/s for the northernmost bridge, 4.3 ft/s for the middle bridge, and 3.8 ft/s for the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining group of catfish ponds conveyed about 11,300 ft^3/s (5,070 ft^3/s in the west relief bridge and 6,230 ft^3/s in the east relief bridge) with an average depth of flow of about 9 ft. The maximum point velocities predicted for these bridges were 3.6 and 5.1 ft/s for the west and east relief bridges, respectively. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 500-year floodflow indicates that about 58 percent of the flow (19,700 ft^3/s) was conveyed by the proposed main channel bridge and 42 percent (14,500 ft^3/s) by the proposed Catoma Creek relief bridge (fig. 2). The maximum point velocities predicted for these bridges were 5.8 and 4.7 ft/s for the main channel and relief bridges, respectively. The maximum point velocities computed for the proposed interchange ramp bridges (fig. 2) were 3.9, 1.1, 5.0, and 2.5 ft/s for ramps A, B, C, and D, respectively.

The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 220.4 ft, which is about 0.9 ft higher than the water-surface elevation for the existing conditions. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 218.5 ft, which is about 0.3 ft higher than the water-surface elevation for the existing conditions. For the 500-year flood, there was no overtopping of either U.S. Highway 231 or the Montgomery Outer Loop. However, the levees of the proposed remaining catfish ponds were completely overtopped. For each bridge mentioned above, average downstream and approach water-surface elevations, head, and backwater were estimated using the procedures described earlier. A complete tabulation of the hydraulic data for the 500-year flood for the bridges mentioned above is presented in table 3. Hydraulic data for the proposed interchange ramp bridges are presented in table 4. A plot of computed water-surface elevations for the 500-year flood for the proposed conditions is shown in figure 17, and a plot of corresponding velocity contours is shown in figure 18.

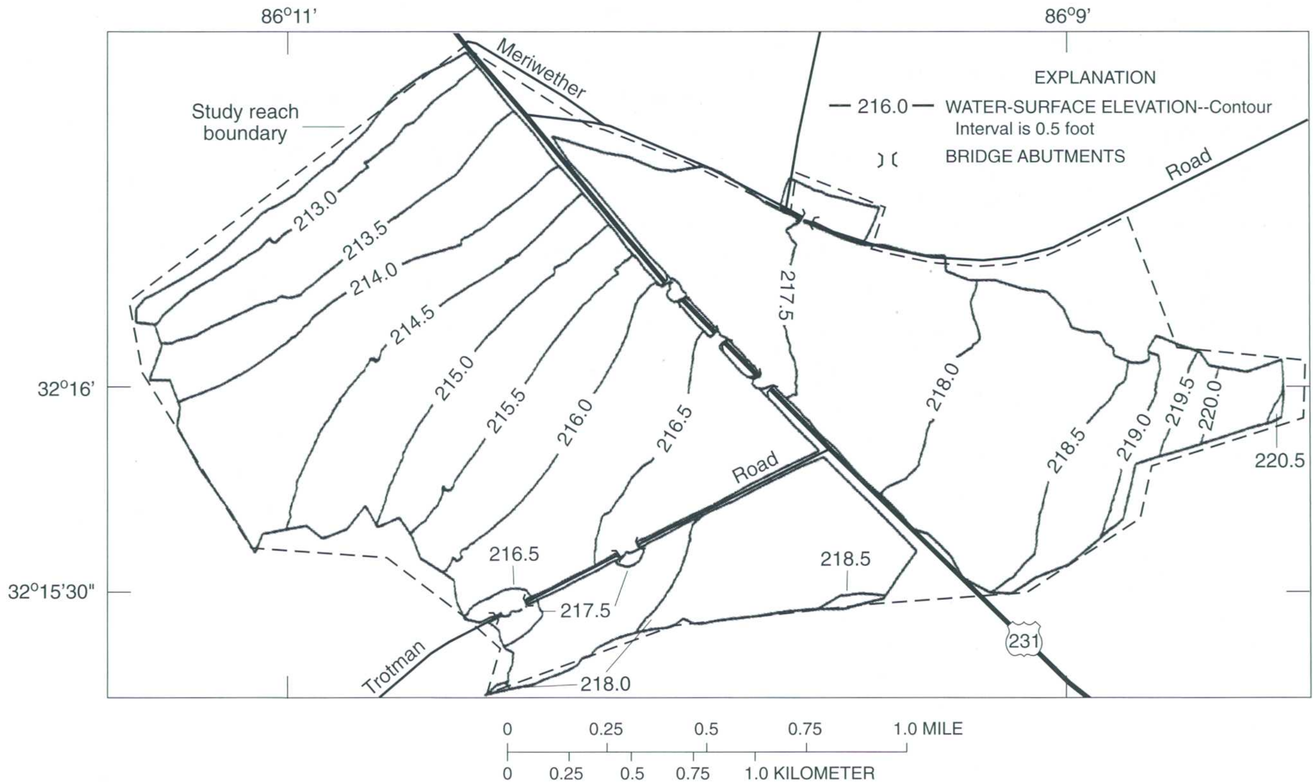


Figure 15. Computed water-surface elevations for 500-year flood for existing conditions.

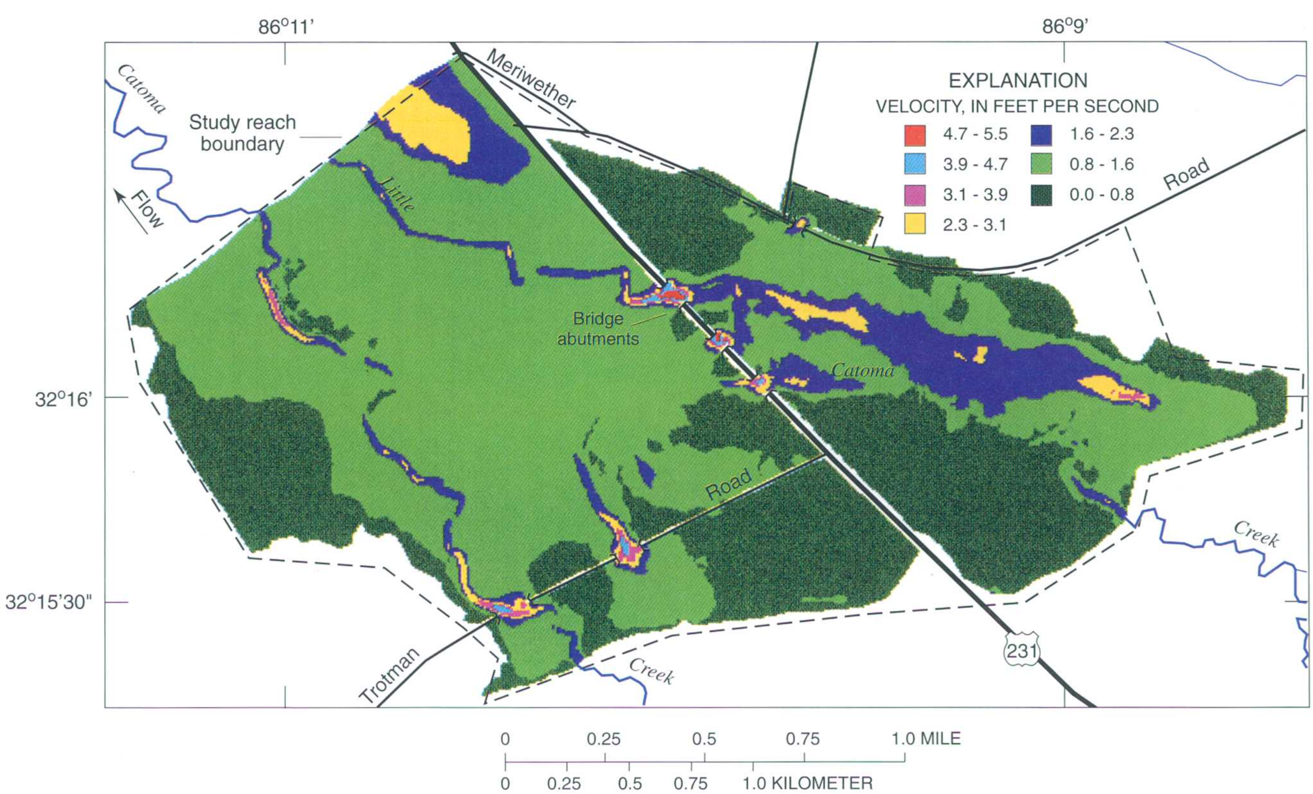


Figure 16. Computed velocity contours for 500-year flood for existing conditions.

Table 3. Hydraulic data for Catoma and Little Catoma Creeks for simulated floodflows having a 500-year recurrence interval

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

Bridge description (fig. 2)	Downstream water-surface elevation (ft)	Discharge (ft^3/s)	Percent flow	Approach water-surface elevation (ft)	Head (ft)	Maximum point velocity (ft/s)
Little Catoma Creek at U.S. Highway 231 (existing conditions)						
North bridge.........	216.26	11,200	51	217.31	1.0	5.5
Middle bridge	216.62	5,480	25	217.34	.7	5.3
South bridge.........	216.88	5,120	24	217.48	.6	4.3
Little Catoma Creek at U.S. Highway 231 (proposed conditions)						
North bridge.........	216.82	11,300	52	217.82	1.0	5.3
Middle bridge	217.34	5,290	24	217.80	.5	4.3
South bridge.........	217.46	5,220	24	217.73	.3	3.8

Bridge description (fig. 2)	Downstream water-surface elevation (ft)	Discharge (ft^3/s)	Percent flow	Approach water-surface elevation (ft)	Backwater (ft)	Maximum point velocity (ft/s)
Catoma Creek at proposed Montgomery Outer Loop						
Main bridge..........	215.20	19,700	58	216.74	.8	5.8
Relief bridge	215.90	14,500	42	217.08	1.0	4.7
Little Catoma Creek relief bridges at proposed Montgomery Outer Loop						
West bridge	218.16	5,070	28	218.54	.6	3.6
East bridge	218.23	6,230	35	218.80	.7	5.1

Table 4. Hydraulic data for the proposed interchange ramp bridges for simulated floodflows having a 500-year recurrence interval

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

Bridge description (fig. 2)	Downstream water-surface elevation (ft)	Discharge (ft^3/s)	Approach water-surface elevation (ft)	Average depth (ft)	Maximum point velocity (ft/s)
Ramp A	216.92	11,200	217.26	9.6	3.9
Ramp B	217.49	640	217.58	8.5	1.1
Ramp C	217.90	6,750	218.25	9.1	5.0
Ramp D	217.80	2,960	217.85	9.4	2.5

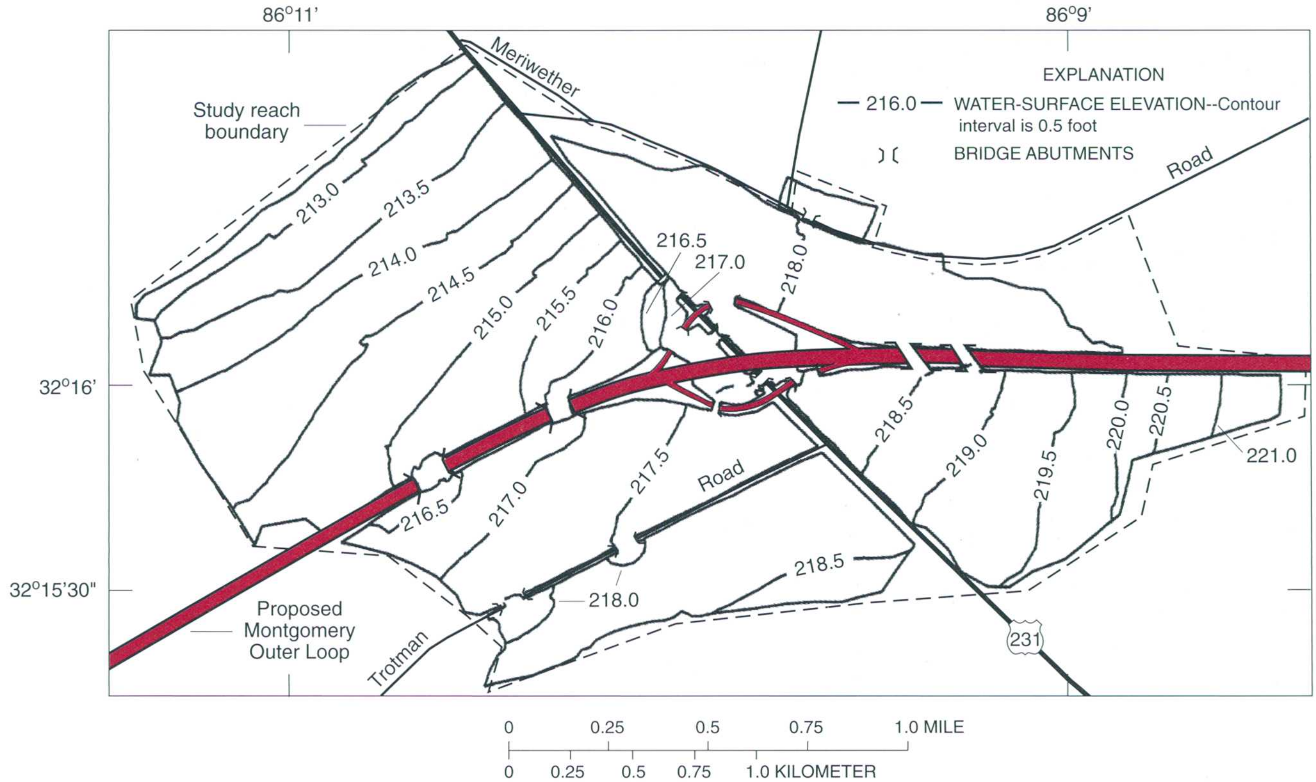


Figure 17. Computed water-surface elevations for 500-year flood for proposed conditions.

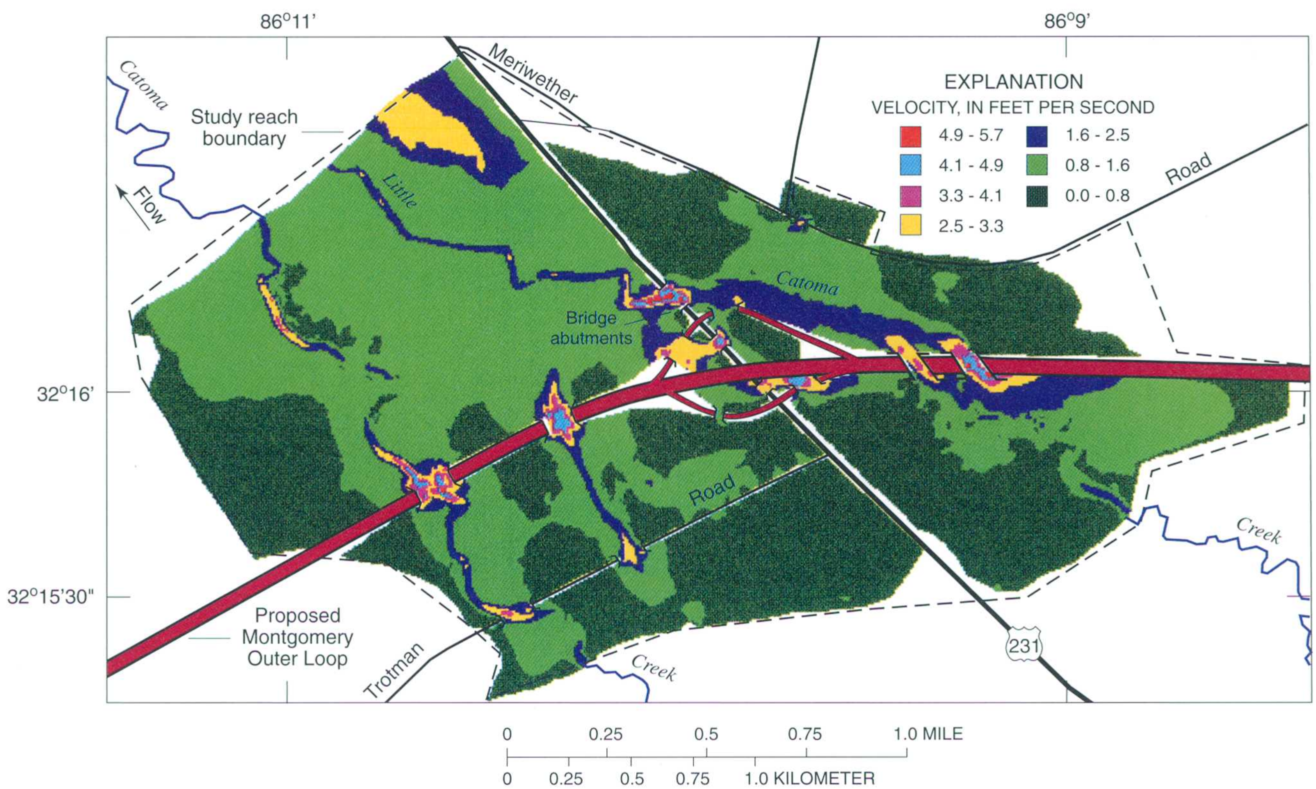


Figure 18. Computed velocity contours for 500-year flood for proposed conditions.

SUMMARY AND CONCLUSIONS

A two-dimensional finite-element surface-water model was used to study the effects of U.S. Highway 231 and the proposed Montgomery Outer Loop on the water-surface elevations and flow distributions during flooding in the Catoma Creek and Little Catoma Creek Basins southeast of Montgomery, Montgomery County, Alabama. The effects of flooding were simulated for two scenarios—existing and proposed conditions—for the 100- and 500-year recurrence intervals. The first scenario was to model the existing bridge and highway configuration for U.S. Highway 231 and the existing ponds that lie just upstream from this crossing. The second scenario was to model the proposed bridge and highway configuration for the Montgomery Outer Loop and the Montgomery Outer Loop Interchange at U.S. Highway 231 as well as the proposed modifications to the ponds upstream.

Simulation of floodflow for Little Catoma Creek for the existing conditions at U.S. Highway 231 indicates that, for the 100-year flood, 54 percent of the flow (8,140 ft^3/s) was conveyed by the northernmost bridge, 21 percent (3,130 ft^3/s) by the middle bridge, and 25 percent (3,780 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges were 4.7 ft/s for the northernmost bridge, 3.1 ft/s for the middle bridge, and 3.7 ft/s for the southernmost bridge. No overtopping of U.S. Highway 231 occurred. However, the levees of the catfish ponds immediately upstream from the crossing were completely overtopped. The average water-surface elevations for the 100-year flood at the upstream limits of the study reach for Catoma Creek and Little Catoma Creek were 216.9 and 218.3 ft, respectively. For the 500-year flood, the simulation indicates that 51 percent of the flow (11,200 ft^3/s) was conveyed by the northernmost bridge, 25 percent (5,480ft^3/s) by the middle bridge, and 24 percent (5,120 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges were 5.5 ft/s for the northernmost bridge, 5.3 ft/s for the middle bridge, and 4.3 ft/s for the southernmost bridge. The average water-surface elevations for the 500-year flood at the upstream limits of the study reach for Catoma Creek and Little Catoma Creek were 218.2 and 219.5 ft, respectively. For the 500-year flood, no overtopping of U.S. Highway 231 occurred.

Simulation of the 100-year floodflow for Little Catoma Creek for the proposed conditions indicates that, for the existing bridges on U.S. Highway 231, 54 percent of the flow (8,190 ft^3/s) was conveyed by the northernmost bridge, 22 percent (3,350 ft^3/s) by the middle bridge, and 24 percent (3,490 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges on U.S. Highway 231 were 4.7 ft/s for the northernmost bridge, 3.1 ft/s for the middle bridge, and 2.8 ft/s for the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining catfish ponds conveyed about 7,750 ft^3/s (3,400 ft^3/s in the west relief bridge and 4,350 ft^3/s in the east relief bridge) with an average depth of flow of about 7 ft. The maximum point velocities predicted for these bridges were 3.6 and 5.1 ft/s for the west and east relief bridges, respectively. The average water-surface elevation at the upstream limit of the study reach for Little Catoma Creek was 218.8 ft, which is about 0.5 ft higher than the average water-surface elevation for the existing conditions. For the 100-year flood, there was no overtopping of either U.S. Highway 231 or the proposed Montgomery Outer Loop. However, the levees of the proposed remaining catfish ponds were completely overtopped. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 100-year floodflow indicates that about 58 percent of the flow (14,100 ft^3/s) was conveyed by the proposed main channel bridge, whereas 42 percent (10,200 ft^3/s) was conveyed by the proposed Catoma Creek relief bridge. The maximum point velocities predicted for these bridges were 5.1 and 3.9 ft/s for the main channel and relief bridges, respectively. The average water-surface elevation about one bridge length (500 ft) upstream from the Montgomery Outer Loop was computed to be about 0.8 ft higher than that for the existing conditions. The average water-surface elevation at the upstream limit of the study reach for Catoma Creek was 216.9 ft, which is the same as the water-surface elevation for the existing conditions.

Results of the model simulation for the 500-year flood for the proposed conditions indicate that there was no overtopping on either U.S. Highway 231 or the Montgomery Outer Loop. The floodflow simulation indicates that, for the existing bridges on U.S. Highway 231, 52 percent of the flow (11,300 ft^3/s) was conveyed by the northernmost bridge, 24 percent (5,290 ft^3/s) by the middle bridge, and 24 percent (5,220 ft^3/s) by the southernmost bridge. The maximum point velocities predicted for the bridges on U.S. Highway 231 were 5.3 ft/s for the northernmost bridge, 4.3 ft/s for the middle bridge, and 3.8 ft/s for the southernmost bridge. The two proposed relief bridges on the Montgomery Outer Loop upstream from the proposed remaining catfish ponds conveyed about 11,300 ft^3/s (5,070 ft^3/s in the west relief bridge and 6,230 ft^3/s in the east relief bridge) with an average depth of flow of about 9 ft. The maximum point velocities predicted for these bridges were 3.6 and 5.1 ft/s for the west and east relief bridges, respectively. For the Montgomery Outer Loop crossing of Catoma Creek, simulation of the 500-year flood-flow indicates that about 58 percent of the flow (19,700 ft^3/s) was conveyed by the proposed main channel bridge, whereas 42 percent (14,500 ft^3/s) was conveyed by the proposed relief bridge. The maximum point velocities predicted for these bridges were 5.8 and 4.7 ft/s for the main channel and relief bridges, respectively. The average water-surface elevations at the upstream study limits for Catoma and Little Catoma Creeks were 218.5 and 220.4 ft, respectively.

Results of the model simulation for the 100-year flood in the vicinity of the interchange ramp bridges indicate that the maximum point velocities computed for the bridges were 3.3, 0.4, 4.7, and 2.2 ft/s for ramps A, B, C, and D, respectively. For the 500-year flood, the simulation indicates that the maximum point velocities computed for the bridges were 3.9, 1.1, 5.0, and 2.5 ft/s for ramps A, B, C, and D, respectively.

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