SIMULATIONS OF FLOODFLOWS IN THE MAGBY CREEK FLOOD PLAIN NEAR OLD MILL ROAD AT COLUMBUS, MISSISSIPPI

By Paul C. Floyd

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.01894	meter per kilometer
foot per second (ft/s)	0.3408	meter per second
foot to the one-sixth power ($ft^{1/6}$)	0.8204	meter to the one-sixth power
mile (mi)	1.609	kilometer
square foot per second (ft^2/s)	0.0929	square meter per second
square mile (mi^2)	2.590	square kilometer

Sea level: All elevations presented in this report are in feet above sea level. "Sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

SIMULATIONS OF FLOODFLOWS IN THE MAGBY CREEK FLOOD PLAIN NEAR OLD MILL ROAD AT COLUMBUS, MISSISSIPPI

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ABSTRACT

A two-dimensional finite-element surface-water model was used to study the effects of the newly constructed U.S. Highway 82 and six newly constructed pond levees on the water-surface elevations and flow distributions in the Magby Creek flood plain east of Columbus, Lowndes County, Mississippi. Different flow scenarios within the Magby Creek flood plain were simulated using various conditions for the two floods of 1990 and the 50- and 100-year floods. These various conditions include (1) the conditions for the two floods of 1990, (2) previous conditions (without the U.S. Highway 82 embankments and pond levees in place), (3) existing conditions, and (4) existing conditions with a hypothetical floodflow diversion levee at the U.S. Highway 82 bridge.

Simulations of floodflows for the two similar floods, which occurred in 1990 after construction of the highway and pond levees, indicate that the peak discharge through the U.S. Highway 82 bridge opening was about 600 cubic feet per second, about 140 percent more than the discharge would have been without the pond levees in place. Simulations of existing conditions with the U.S. Highway 82 embankments and Magby Creek distributary bridge in place indicate that about 360 and 410 cubic feet per second would pass through the highway bridge opening to flow in the Magby Creek distributary flood plain during the peak discharges of the 50- and 100-year floods, respectively. Other simulations of the 1990 floods indicate that about 600 cubic feet per second would have flowed in the distributary flood plain before construction of the highway, and about 800 and 960 cubic feet per second flowed in the distributary flood plain during the 50- and 100-year floods, respectively. Simulations depicting the hypothetical floodflow diversion levee which would extend into the Magby Creek flood plain from the highway bridge opening indicate that about 950 cubic feet per second would have been diverted into the Magby

Creek distributary flood plain during the 1990 floods, and about 1,500 and 1,650 cubic feet per second would be diverted into the distributary flood plain during the 50- and 100-year floods, respectively.

Simulations without the pond levees indicate that discharges in the Magby Creek distributary flood plain decreased by an average of about 57 percent when the U.S. Highway 82 embankments and bridge were constructed. Flows in the Magby Creek flood plain approaching Lehmberg Road increased by about 10 percent. Simulations with a hypothetical floodflow diversion levee connecting the west spur dike of the highway bridge to the east levee of pond 2 indicate that discharges in the Magby Creek distributary flood plain would increase by about 300 percent above present conditions with the highway in place. The total flows in the Magby Creek flood plain approaching Lehmberg Road would decrease by about 19 percent. Simulations indicate that the hypothetical diversion levee would increase flows in the Magby Creek distributary flood plain by an average of about 73 percent above the pre-U.S. Highway 82 conditions and decrease the pre-U.S. Highway 82 flows in the Magby Creek flood plain approaching Lehmberg Road by about 11 percent.

INTRODUCTION

During construction of the relocated U.S. Highway 82 near Columbus, Miss. (fig. 1), two separate rainfall events occurred resulting in flooded residences and businesses along Lehmberg Road in the Magby Creek Basin east of Columbus on February 17, 1990, and December 23, 1990. Local residents were concerned that the magnitude of the flooding appeared greater for a given rainfall and intensity with the newly constructed highway in place than before it was constructed. Several meetings concerning the frequency and magnitude of the flooding along Lehmberg Road were held among residents and local, State, and Federal officials. In 1992, the U.S. Geological Survey (USGS), in cooperation with the Mississippi Department of Transportation (MDOT), analyzed the flood hydraulics in the Magby Creek Basin.

Purpose and Scope

This report discusses the results of a study in which a two-dimensional finite-element surface-water model was used to (1) determine the effects of the newly constructed U.S. Highway 82 and the newly constructed pond levees on water-surface elevations and the flows in the Magby Creek flood plain that approach Lehmberg Road, and (2) determine the effects of a hypothetical floodflow diversion levee on water-surface elevations and the flows in the Magby Creek flood plain that approach Lehmberg Road. The report also discusses the selection of an appropriate model as well as the general theory and requirements of the selected model and the calibration strategy involved in the modeling process.

Acknowledgments

The assistance of Mr. Paul Swindoll, MDOT District Engineer, and personnel of the MDOT Starkville project office in expeditiously surveying the study area is gratefully acknowledged. The cooperation of Mr. Robert C. Ferguson in allowing passage on his land is also appreciated.

DESCRIPTION OF STUDY AREA

The study area is a 2.3-mi reach of the Magby Creek Basin east of Columbus, in Lowndes County, Mississippi (fig. 1). The width of the basin ranges from 0.3 to 0.6 mi. Magby Creek flows in a westerly direction into Luxapallila Creek about 1.2 mi downstream of the study area. The average slope of the Magby Creek Basin located within the study area is about 11 ft/mi. The north boundary of the study area is near and roughly parallel to State Highway 50, and the south boundary is the north embankment of U.S. Highway 82. Near the upstream (eastern) end of the study area, a distributary to Magby Creek was constructed to divert floodflows from the Magby Creek Basin into the Vernon Branch Basin to lessen the magnitude of floods occurring at Lehmberg Road. Local residents state that the distributary channel was dug about 70

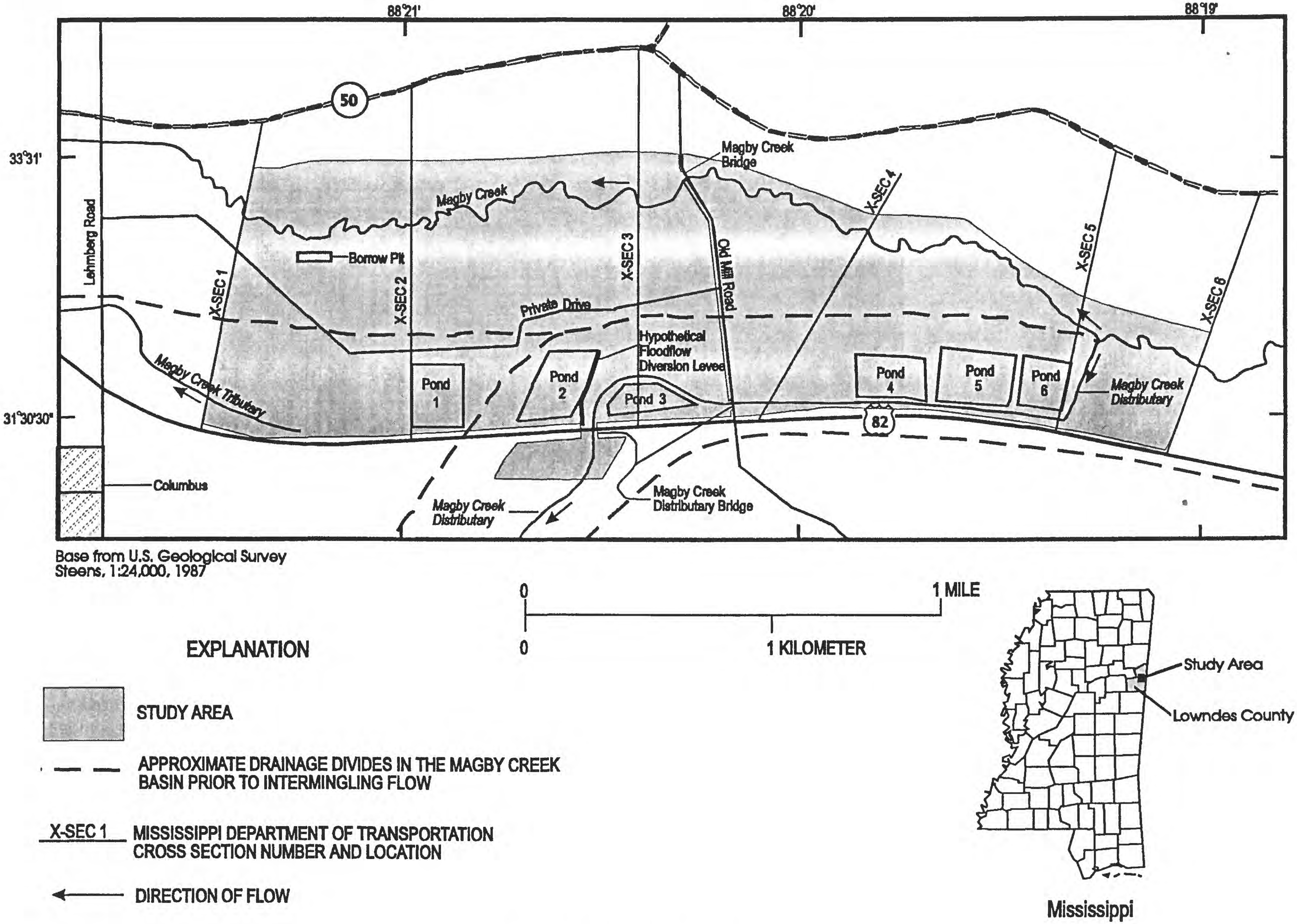


Figure 1. – Location of study area.

years ago. The distributary diverts flows from Magby Creek south to U.S. Highway 82 and then west parallel to the north highway embankment.

A shallow flood plain begins for the distributary where it leaves Magby Creek. The distributary flood plain is contained within the Magby Creek flood plain, but flows do not intermingle until about a 5-year flood occurs. A 5-year flood has a 20 percent chance of being equaled or exceeded in any given year.

Anthropogenic Features

The study area includes anthropogenic (manmade) features which affect the flood hydraulics in the Magby Creek flood plain. Old Mill Road crosses the flood plain from north to south near the middle of the study reach. There are two bridge openings in Old Mill Road (fig. 1). One bridge is for Magby Creek near the north edge of the flood plain, and the other is for the distributary near the south edge of the flood plain. Both bridges have vertical abutments and wingwalls and are, therefore, classified as type IV bridge openings (Shearman and others, 1986). The Magby Creek bridge is 140 ft long, and the bridge for the distributary is 80 ft long. The embankment for Old Mill Road is about 3 ft higher than the surrounding flood plain. According to local residents, Old Mill Road was overtopped by floodflows in March 1970 and April 1979. However, Old Mill Road was not overtopped during the two floods of 1990.

Lehmberg Road crosses the Magby Creek flood plain about 1,600 ft downstream of the west end of the study area and was overtopped during the 1970, 1979, and the February and December 1990 floods. The area is moderately populated, and several business establishments are located along its premises.

A private drive connects Old Mill Road and Lehmberg Road. The drive is near the approximate drainage divide between Magby Creek and its distributary (fig. 1). The private drive is not elevated above the natural flood plain and has no significant effect upon directions of floodflows.

A borrow pit was recently dug on private land near the downstream end of the study area (fig. 1). Local residents expressed concern about the pit possibly diverting floodflows away from Magby Creek toward populated areas. USGS personnel examined the borrow pit and the surrounding area and noted that no soil deposits (spoil banks) were located in the vicinity which would divert floodflows. Therefore, during extreme flood conditions, the pit would have insignificant effect on flow patterns.

During construction of the new U.S. Highway 82, six ponds were built on private land along the highway's north embankment. The ponds range in size from about 7 to 15 acres, and the heights of the levees surrounding the ponds are about 1 to 2 ft. Three of the ponds were built west of Old Mill Road near the U.S. Highway 82 Magby Creek distributary bridge. The ponds are referred to from west to east as pond 1 to pond 6 (fig. 1).

From Old Mill Road, the Magby Creek distributary flows west around the north side of pond 3 and then south to exit the study area through the 200-ft bridge opening in U.S. Highway 82. The pond owner removed the levees from around pond 3 during the winter of 1991-92. The distributary continues south into Vernon Branch about 1.3 mi downstream of the highway.

Hydrology

Flood frequencies in the Magby Creek Basin were estimated using techniques outlined in the USGS report by Landers and Wilson (1991). The combined drainage area of Magby Creek and Magby Creek distributary at Old Mill Road is 42.1 mi^2. The length of Magby Creek upstream of Old Mill Road is about 18 mi, and the average slope between 10 and 85 percent of the length is about 8.4 ft/mi. Based on the regressions presented by Landers and Wilson (1991), a flood-frequency curve (fig. 2) was developed for Magby Creek at Old Mill Road. The 50- and 100-year flood discharges are about 8,030 and 9,130 ft^3/s, respectively.

High-water marks were recovered in the study area after the floods of February and December 1990 at the two bridges on Old Mill Road and at the U.S. Highway 82 bridge. However, it was not possible to recover the required amount of high-water data at the bridge sites to perform indirect discharge measurements. The marks indicated that the two floods were similar. The peak discharges for the floods were not measured, but were estimated to be about 2,800 ft^3/s from a statistical comparison of recorded peak discharges with drainage areas at nearby gaging stations (areal study technique). The areal study technique is discussed in the USGS report by Rantz and others (1982). From figure 2, both 1990 floods were about 3-year events.

DESCRIPTION OF SELECTED MODEL

All floodflows are three-dimensional where the flow direction at any given point within the system is a resultant of its three component velocity vectors in the X, Y, and Z directions. Three-dimensional analyses of floodflows are complex and time consuming and may result in excessive project costs. However, most floodflows are dominated by velocities in the horizontal plane and can be acceptably simulated in one or two dimensions.

The complexity of the analyses of floodflows varies with the physical and hydrologic characteristics of the area to be studied. For example, if a study area were a straight reach of flood plain with no constrictions, bridges, or obstructions, the velocity vectors would be in one direction (dimension). Floodflows could then be simulated with a one-dimensional step-backwater model. Flows become more difficult to simulate as they pass around obstructions and through bridges, and in many cases, accurate simulations of such flows cannot be obtained with a one-dimensional model.

Because of the multiple bridge openings and shallow flow depths around pond levees, the existing flow patterns within the study area could not be adequately

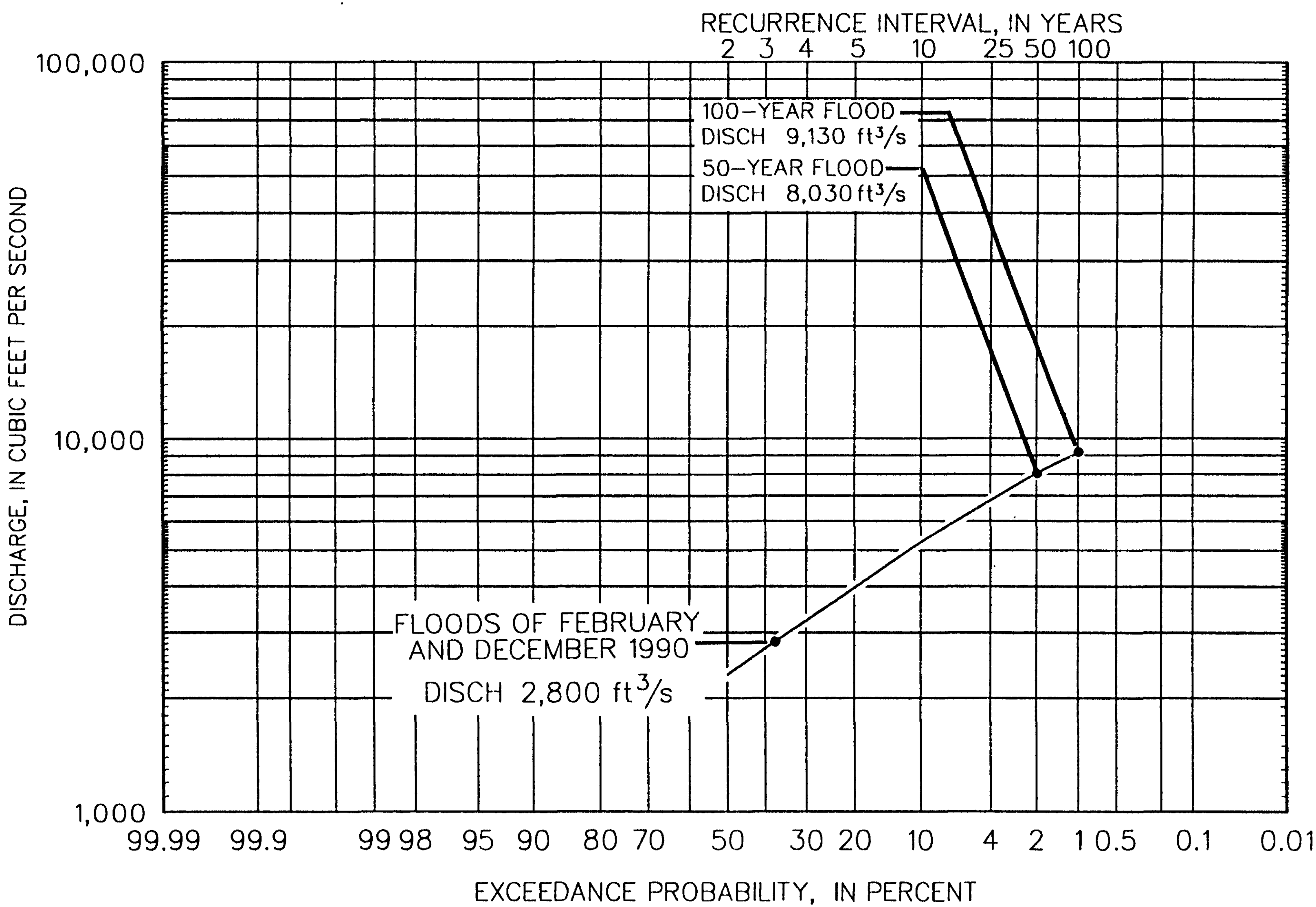


Figure 2. -- Magnitude and frequency of annual floods, Magby Creek at Old Mill Road at Columbus, Mississippi.

simulated with a one-dimensional model. The Finite Element Surface-Water Modeling System for 2-Dimensional Flow in the Horizontal Plane (FESWMS-2DH) (Froehlich, 1989) was selected as an appropriate model for simulating the two-dimensional flows within the study area.

General Theory of the Model

FESWMS-2DH is a vertically (or depth) averaged model used to simulate two-dimensional flows in the horizontal plane and consists of the three following programs:

(1) DINMOD (pre-processing program for data input, plotting, and checking),
(2) FLOMOD (flow modeling program), and
(3) ANOMOD (post-processing program for analyzing and plotting FLOMOD output).

The model uses the Galerkin finite-element method to solve three partial-differential equations representing conservation of mass and momentum (Lee and Froehlich, 1989). When using a finite-element model, the study area is divided into triangular and quadrangular elements that form a grid. Nodes are located at the corners and mid-sides of the elements and are assigned coordinates and elevations. The finite-element grid used in this study has 1,780 elements and 8,047 nodes (fig. 3).

Because the system of flow equations is nonlinear, a Newton iterative method of approaching a solution is used (Gilbert and Froehlich, 1987). 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).

Data Requirements of the Model

A finite-element network should be carefully designed so that mass is conserved within the system. The finite-element grid needs to be more refined in areas where changes in velocity or bathymetry are substantial than in areas where changes are gradual.

Topographic Data

Topography is a major factor in the design of the finite-element grid. In this study, six flood plain cross sections (fig. 1) were surveyed by personnel of the Starkville project office of the MDOT during the winter of 1991-92 and the resultant data were utilized for the grid development. The MDOT also provided survey data locating the pond levees in relation to U.S. Highway 82. Topographic data from USGS topographic maps were used to supplement the MDOT survey data. Roadway embankment elevations (for weir flow computations) and bridge openings were surveyed by USGS personnel in March 1992 to complete the topographic data requirements of the model.

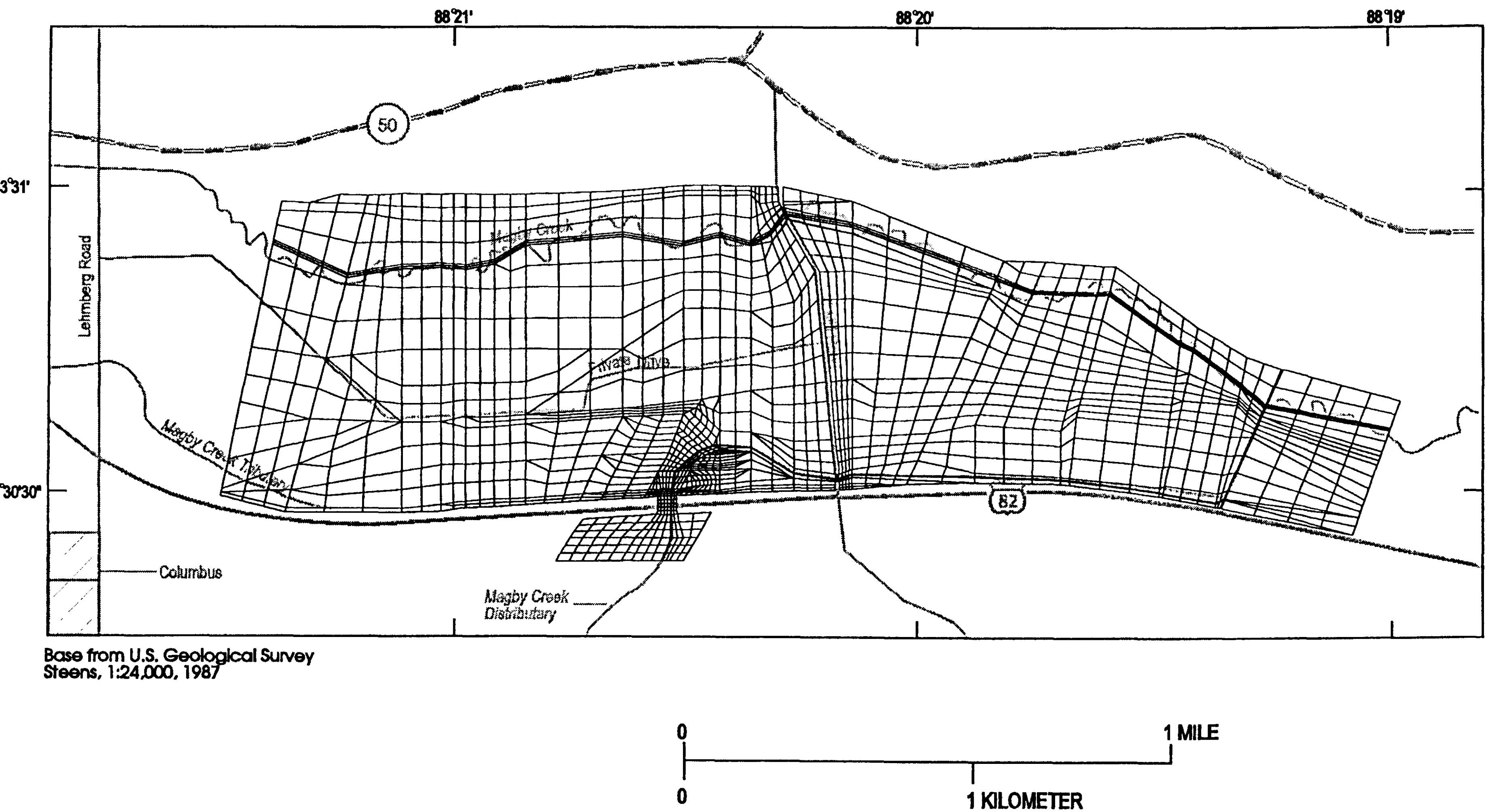


Figure 3. – Finite-element grid used in flow simulations.

Hydraulic Data

Hydraulic data used by the model are discharges, flood elevations, and roughness coefficients. Discharge data are discharges which correspond to the floods being simulated. When using the FESWMS model, the discharges may vary with time; but for many applications, simulations of steady-flow conditions will give adequate results. Because of the large magnitudes of the floods simulated in this study, sustained peak discharges are probable. Therefore, steady-flow conditions were simulated.

Flood elevations corresponding to the flows being modeled can be determined from field surveys, surface-water gaging stations, or visual observations. The elevation data are used by the model as boundary conditions or they can be used to verify model calibration.

In the FESWMS finite-element grid, each element has a roughness value assigned for flow calculations. Roughness coefficients (Manning's "n") were determined during field observations in October 1991 and were estimated to represent winter and early spring conditions when vegetation is sparse and flooding is most likely to occur (fig. 4).

Boundary Conditions

Boundary conditions are established around the perimeter of a finite-element network and are represented by either closed or open boundaries. Boundary conditions are usually determined from measurements, observations, or surveys of hydraulic data.

Closed boundaries do not allow flows to pass through and are used to represent shorelines, obstructions, levees, and embankments. Boundaries representing shorelines should be located near the edges of the areas of flow so that the flow depths are always positive. Negative flow depths result in erroneous computations. 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 are set up for tangential slip conditions. The tangential slip conditions force all flows adjacent to the solid boundaries to flow parallel to the boundaries. Flows can also be allowed to pass over solid boundaries to simulate weir flows over embankments.

Open boundaries are established where flows enter or leave the finite-element system. In this study, open boundaries are located at the upstream and downstream ends of the study area and the section south of the U.S. Highway 82 bridge where the Magby Creek distributary flows leave the study area to approach Vernon Branch. The boundary conditions at the upstream end of the study area are the discharges for the different flows being simulated. The boundary conditions at the downstream end of the study area are normal water-surface elevations estimated from slope-conveyance computations.

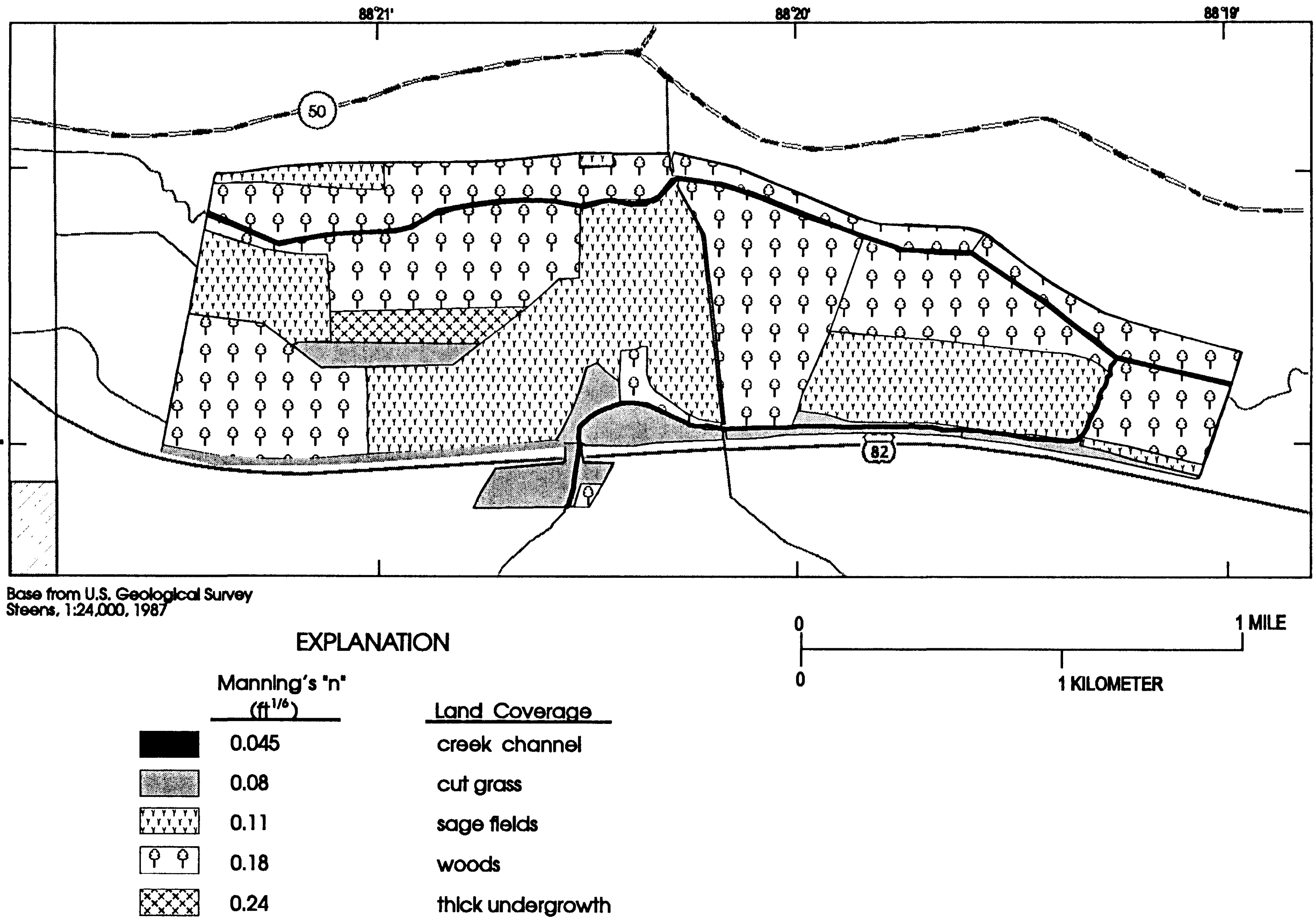


Figure 4. -- Map of study area showing land coverages and selected roughness coefficients.

Step-backwater analyses (in the upstream direction) indicated that water-surface profiles for the 50- and 100-year flood discharges computed with different downstream starting elevations converged about 2,500 ft upstream of the downstream end of the study area. The U.S. Highway 82 bridge is about 5,000 ft upstream of the downstream end of the study area. Therefore, any error in the boundary conditions at the downstream end of the study area do not affect the flows near the U.S. Highway 82 bridge. The downstream boundary conditions computed from the slope-conveyance computations are 189.8, 191.6, and 191.9 ft for the floods of 1990 and the 50- and 100-year floods, respectively. The changes in discharges approaching Lehmberg Road caused by the simulation of different flood plain scenarios for a given total discharge changed the downstream elevations by only about 0.2 ft. Because the maximum error of 0.2 ft at the downstream boundary near Lehmberg Road was minimal, the downstream boundary conditions were not changed for each flow condition for the flood discharge being simulated. A separate convergence study showed that profiles converged by 1,000 ft upstream of the downstream boundary with a 0.2 ft starting error. Therefore, the slight errors in downstream starting water-surface elevations introduced by the varying discharges approaching Lehmberg Road for an individual flood do not affect the solutions near the U.S. Highway 82 bridge.

The boundary conditions representing the Magby Creek distributary are water-surface elevations and were based on average flow depths. The flood plain flow depths near the U.S. Highway 82 bridge were fairly uniform and the flow depths were assumed to be similar at the boundary representing the Magby Creek distributary. Computed elevations under the highway bridge using the 1990 flood discharges agreed within 0.1 ft of the recorded high-water elevations under the bridge. This close agreement between simulated and recorded elevations at the highway bridge indicates that the assumption of uniform flow depths at the open boundary representing the Magby Creek distributary was appropriate.

Calibration Strategy

The calibration strategies involved in this study are based on interpretive applications of basic hydraulic principles. Hydraulic data for proper calibration of the FESWMS model are limited due to the non-occurrence of a hydraulic event (flood) during the study. However, a limited number of high-water marks were recovered after the floods of February and December 1990. The discharges for both of these floods were estimated (using the areal study technique) to be about 2,800 ft^3/s. The areal study technique of estimating peak flood discharges can be in error as much as plus or minus 25 percent.

Parameters for model calibration were estimated based on engineering judgment because of the lack of data. After the calibrated model converged upon a solution, no parameters were adjusted. The parameters representing the depth-averaged eddy viscosities were set to 100 ft^2/s for the 1990 flood discharges and 400 ft^2/s for the 50- and 100-year discharges. Previous studies indicated that because of the lack of information for the proper values of the eddy viscosity parameters, the relatively high values stated above are adequate and any adjustment to the viscosity parameter has minimal affects upon the final solution after the model converges (Gilbert and Froehlich, 1987). With limited high-water marks and an estimated discharge, the model could not be calibrated as well as desired; however, the simulated elevations did adequately correspond with the surveyed high-water elevations which indicates that the finite-element grid, the selected roughness coefficients (fig. 4), the selected model parameters, and the estimated discharge were reasonable.

The finite-element grid used in the simulations of the 1990 floods was also used for simulations of the 50- and 100-year floods. The 50- and 100-year flood discharges are used for the design of hydraulic structures, but there are no calibration data for these floods. The results of the simulations for the 50- and 100-year floods should be judged accordingly.

A convergence study was performed in which the original finite-element grid used for flow simulations (fig. 3) was refined by a factor of about 4. Each quadrangular element was subdivided into four similar elements, each triangular element was divided into three similar elements, and the 1990 floods with all ponds in place were simulated. The 1990 flood simulations utilized 3,872 elements and 18,030 nodes with the refined grid. On an average, the simulated discharges flowing around the pond levees using the refined grid agreed within 3.5 percent with the results obtained when using the original grid. When using the refined grid, the computed water-surface elevations agreed within 0.1 ft of the water-surface elevations computed using the original grid. The maximum difference in water-surface elevations when comparing the results obtained from using the two grids is about 0.3 ft and occurs in two areas upstream of Old Mill Road. Because the results obtained when using the refined grid agreed closely with those obtained when using the original grid, it was concluded that the original grid was adequate for flow simulations in this study.

Model Validation

The proper technique of validating a calibrated model is to simulate a separate hydraulic event for which the discharge and 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.

Because the two floods of 1990 were similar, it was not possible to validate the calibrated model. However, it was assumed that the model was calibrated as well as possible because (1) of the close agreement between surveyed and simulated elevations as stated above, and (2) simulations of the 1990 floodflows indicated the correct locations of damage to the pond levees by overtopping.

SIMULATION OF FLOODFLOWS

Eleven floodflows were simulated and categorized according to discharges as the 1990 floods, the 50-year flood, or the 100-year flood. In each category, flows were simulated with and without the U.S. Highway 82 embankments in place and with a floodflow diversion levee connecting the west spur dike of the 200- ft bridge opening on the highway to the east levee of pond 2. The floodflow diversion levee was simulated using the 50- and 100-year flood discharges to study its effect upon the flows approaching Lehmberg Road. Various simulations of the two 1990 floods were also run depicting past and present conditions so the effect of the flood plain encroachments could be studied in detail.

The 50- and 100-year flood discharges were simulated because hydraulic structures are designed by the MDOT to meet specific guidelines set by the Federal Highway Administration (FHWA). These guidelines generally require the design of a hydraulic structure to adequately pass the 50-year flood and to pass the 100-year flood with an increase in backwater elevation (usually one bridge length upstream) no greater than 1.0 ft.

Floods of February and December 1990

From the areal study technique, the peak discharges for the floods of 1990 were estimated to be about 2,800 ft^3/s. The recurrence interval for this discharge is about 3 years, which means a similar flood has a 33 percent chance of being equaled or exceeded in any given year.

During the floods of 1990, the U.S. Highway 82 embankments were in place. The six ponds located on private land near the north embankment of U.S. Highway 82 were also in existence during this time and some pond levees were slightly damaged by the flows.

The 1990 floods were not severe enough to inundate the entire Magby Creek flood plain. It appears that the flows were maintained near the main channel of Magby Creek until they were separated at the Magby Creek distributary. Eyewitnesses state that at Old Mill Road, the Magby Creek channel was flowing full and the Magby Creek distributary was out of its banks. Conveyance computations indicate that at the point of flow separation at the distributary when Magby Creek is flowing full, the Magby Creek channel is capable of conveying 1,400 ft^3/s. The remaining 1,400 ft^3/s flowed downstream in the Magby Creek distributary flood plain.

Because the Magby Creek flood plain was not inundated during the 1990 floods, there was no intermingling flow between the Magby Creek and the Magby Creek distributary flood plains. Therefore, the elements representing the Magby Creek channel and flood plain were deactivated (turned off) and only flows in the Magby Creek distributary flood plain were simulated (1,400 ft^3/s). The following simulations represent the flow conditions for the floods of 1990 within the Magby Creek distributary flood plain with alterations depicting observed, present, and possible scenarios. In the following sections, the percentage of the total flood discharge of 2,800 ft^3/s is stated in parenthesis following the computed discharge.

Flows for 1990 Conditions

Floodflows were simulated depicting the floods of February and December 1990. Flow simulations of the 1990 floods indicate that about 400 ft^3/s (14 percent) flowed south of pond 4, pond 5, and pond 6 at the U.S. Highway 82 embankment in the riprap channel constructed by the MDOT near the upstream end of the study area. Simulations indicate that about 600 ft^3/s (21 percent) flowed through the Magby Creek distributary bridge at U.S. Highway 82. The remaining 800 ft^3/s (29 percent) flowed in the south one-half of the Magby Creek flood plain toward Lehmberg Road (fig. 5).

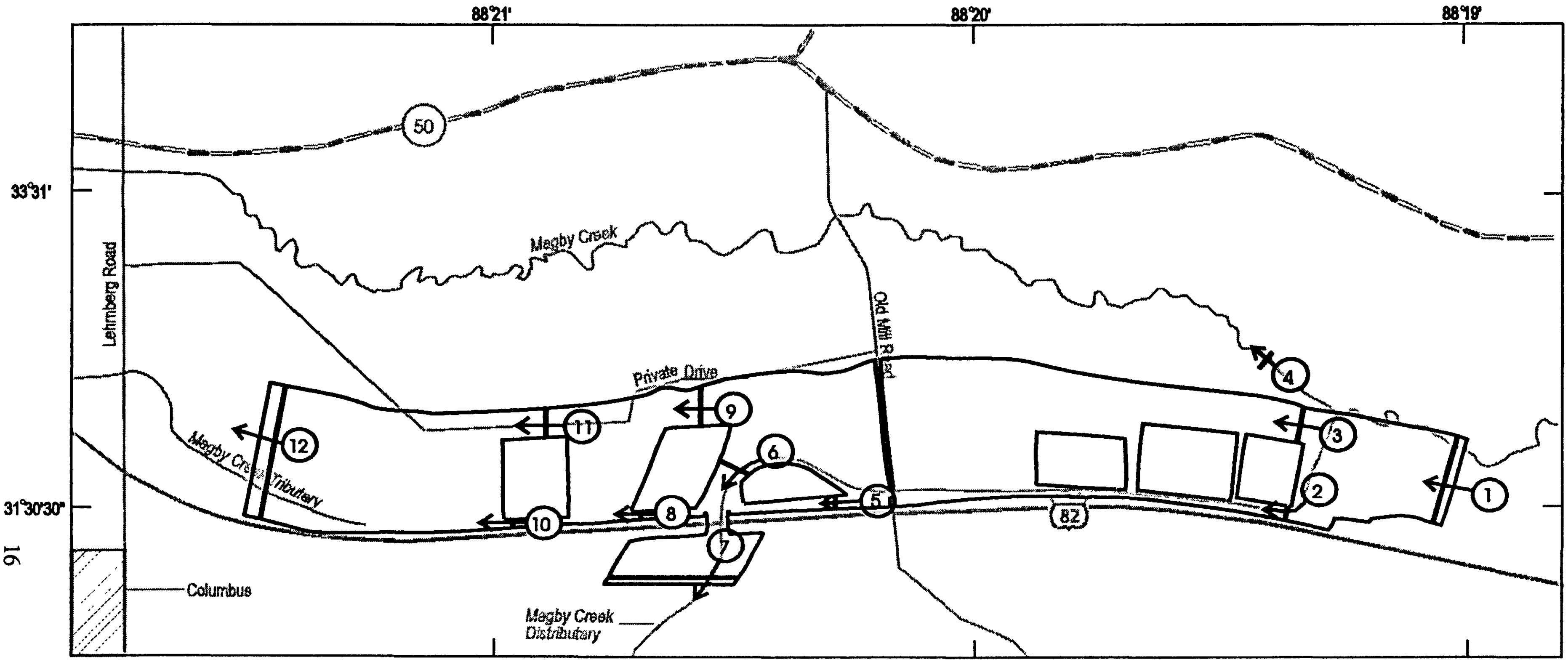
High-water marks were surveyed at the Magby Creek distributary bridge at Old Mill Road and were 201.5 and 201.1 ft at the upstream and downstream sides, respectively. The average elevation of high-water marks under the U.S. Highway 82 bridge was 197.6 ft. The elevations determined from the simulations of the 1990 floods were 202.0 and 201.6 ft at the upstream and downstream sides of the Old Mill Road bridge, respectively. The simulated elevation at the downstream side of the U.S. Highway 82 bridge was 197.7 ft. Water-surface elevations for the 1990 floods were plotted for analyses and comparison with other flow scenarios (fig. 6).

Velocity vectors in the vicinity of the U.S. Highway 82 bridge were also plotted so computed flow directions for the 1990 floods could be visually observed (fig. 7). Simulations indicate that the flows separated and flowed around the pond 3 levees. During the 1990 floods, the flows north of pond 3 [about 1,050 ft^3/s (38 percent)] separated with about 540 ft^3/s (19 percent) flowing north of pond 2 and about 510 ft^3/s (18 percent) flowing between pond 2 and pond 3. Simulations indicate the flows passing between the west spur dike of the highway bridge and the southeast corner of pond 2 were about 260 ft^3/s (9 percent).

Flows with Pond 3 Removed

To study the full effect of pond 3 during the two floods of 1990, flows were simulated with the pond 3 levees removed. The pond owner removed the levees from around pond 3 after the floods of 1990. Therefore, if no changes are made within the flood plain or the highway bridge opening, the flows simulated without pond 3 would occur during a flood similar to those of 1990. Simulation of flows without the pond 3 levees was accomplished by activating (turning on) the elements representing pond 3, and therefore, allowing flows to pass through them.

Removal of the levees surrounding pond 3 had no effect on elevations and flow distributions upstream of Old Mill Road when simulating the floods of 1990. Therefore, the control for the 1990 floodflows in the study area upstream of Old Mill Road was the Magby Creek distributary bridge at Old Mill Road.



Base from U.S. Geological Survey
Steens, 1:24,000, 1987

EXPLANATION

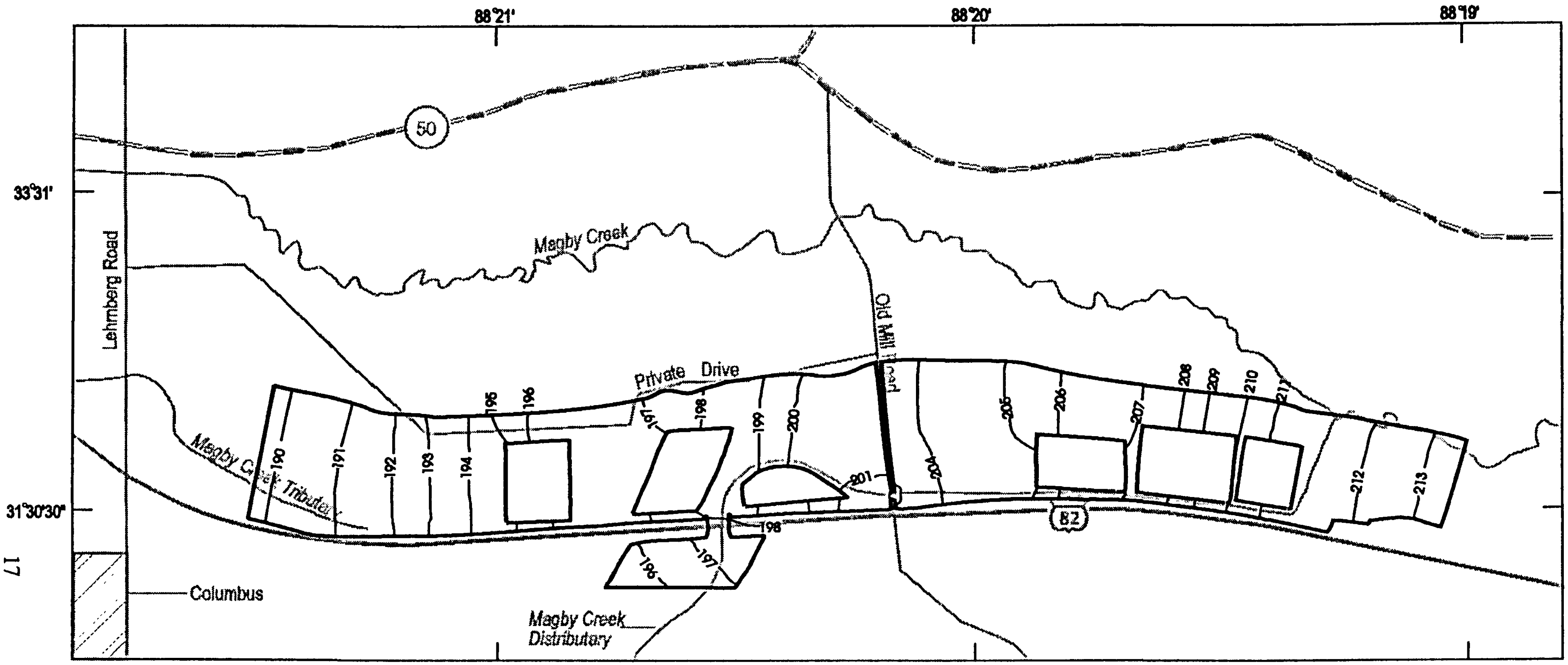
12 FLOW SECTION AND DIRECTION

0 — 1 MILE

0 — 1 KILOMETER

FLOW SECTION NUMBER	DISCHARGE, IN CUBIC FEET PER SECOND
1	1,400
2	400
3	1,000
4	1,400
5	350
6	510
7	600
8	260
9	540
10	200
11	600
12	800

Figure 5. -- Computed flow distributions for the two floods of 1990.



Base from U.S. Geological Survey
Steens, 1:24,000, 1987

EXPLANATION

——— 194 ——— COMPUTED WATER-SURFACE ELEVATIONS - - Shows simulated peak water-surface elevations during the 1990 floods. Contour interval is 1.0 foot. Datum is sea level

Figure 6. - - Computed water-surface elevations, 1990 floods.

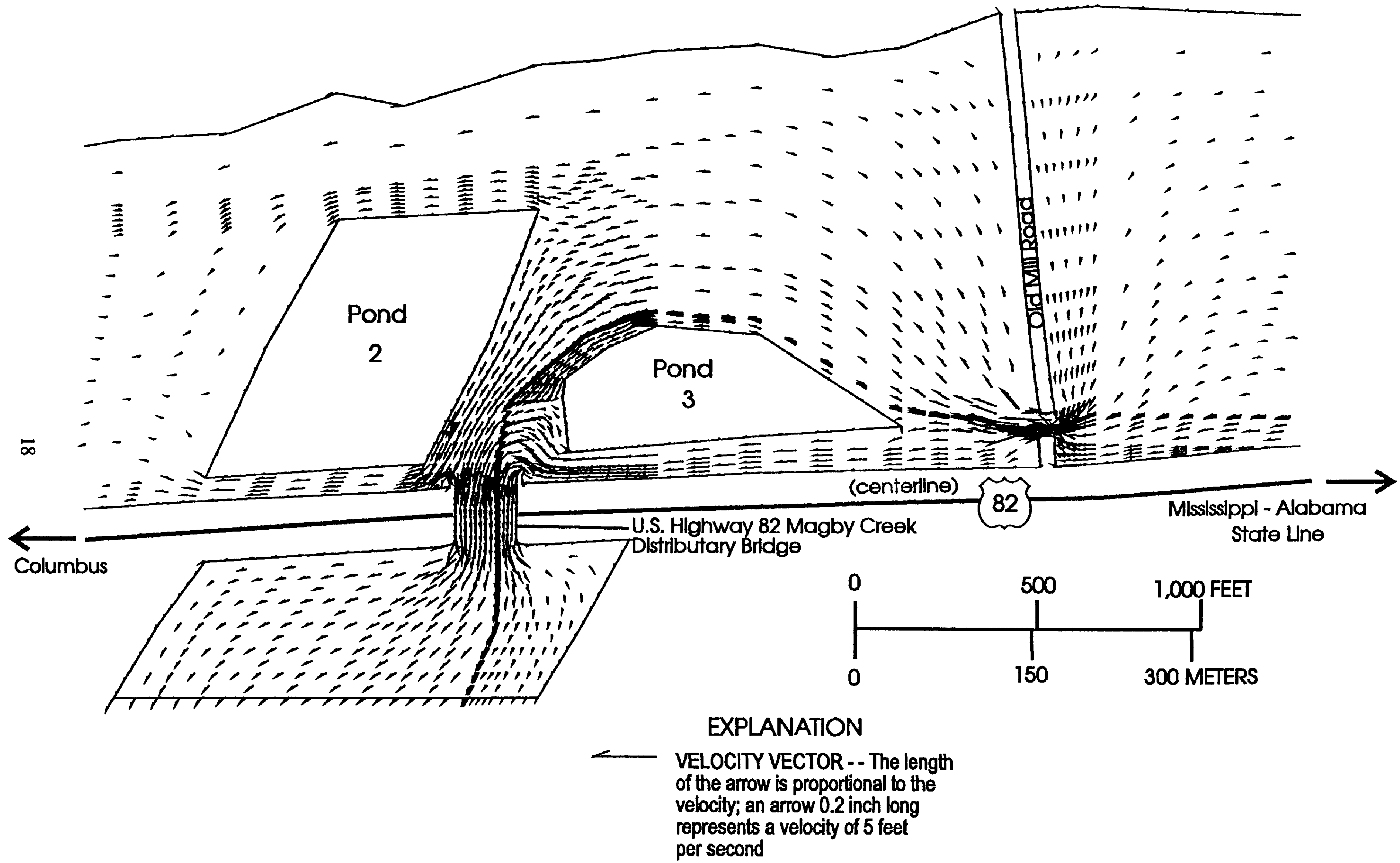


Figure 7. - - Computed velocity vectors for the two floods of 1990 near the U.S. Highway 82 bridge.

With flows not confined near the highway embankment upstream of the U.S. Highway 82 bridge by the pond 3 levees, the simulated velocities were not as large for the flows that were prone to bypass the bridge. The simulations indicate about an 8 percent increase in discharge (50 ft^3/s) would be conveyed through the bridge without the pond 3 levees in place for a total of 650 ft^3/s (23 percent). About 300 ft^3/s (11 percent) would flow between the west spur dike and the southeast corner of pond 2 and about 450 ft^3/s (16 percent) would flow around the north side of pond 2. A total discharge of about 750 ft^3/s would continue in the south one-half of the Magby Creek flood plain to approach Lehmberg Road, about 6 percent less than with the pond 3 levees in place. Water-surface elevations representing flow conditions without the pond 3 levees are plotted in figure 8.

Flows with All Ponds Removed

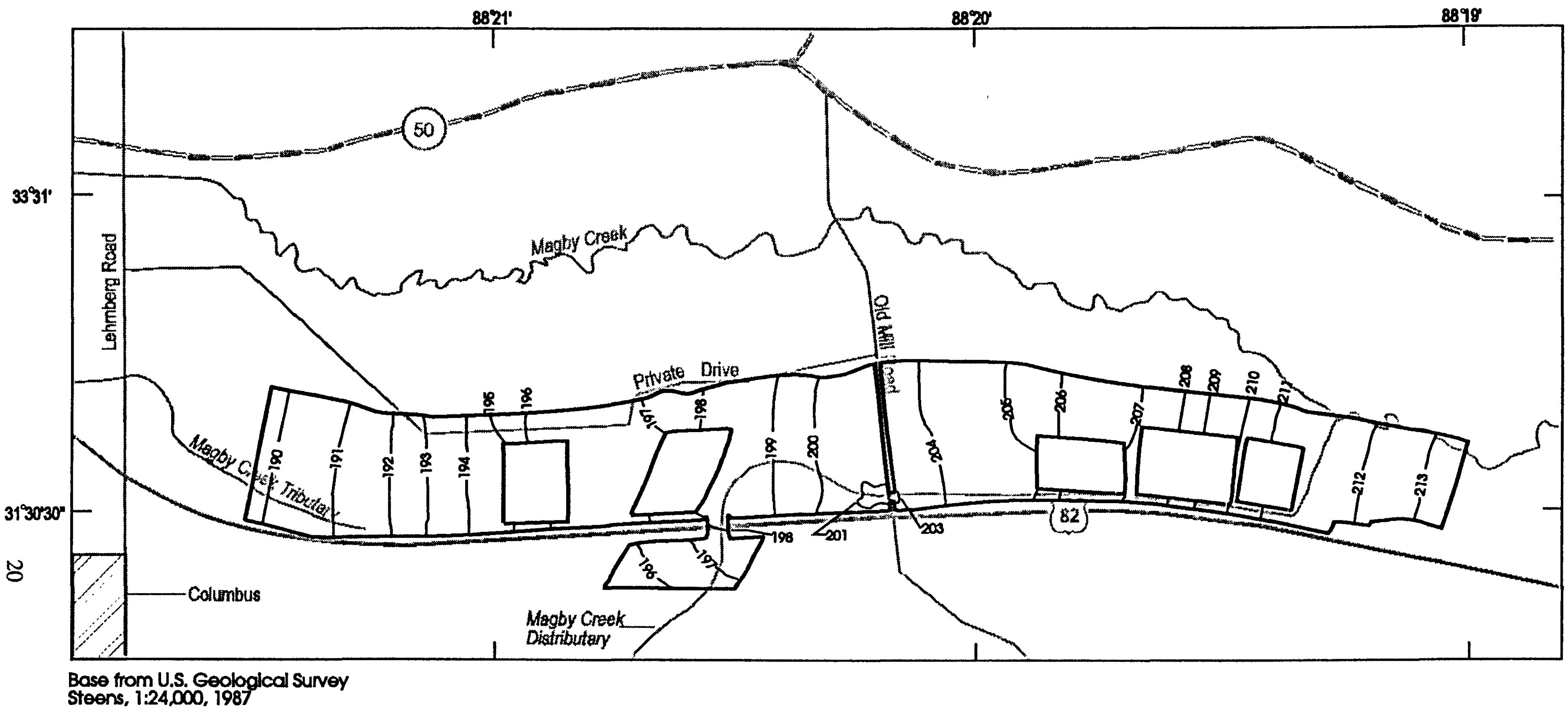
Simulations using the 1990 flood discharges were run with all pond levees removed so that their effect on flow patterns in the Magby Creek distributary flood plain during the 1990 floods could be studied. As in the previous simulation, the elements representing the ponds were activated so that flows could pass through.

Flow simulations indicate that about 250 ft^3/s (9 percent) would pass through the U.S. Highway 82 bridge and about 1,150 ft^3/s (41 percent) would flow down the south one-half of the Magby Creek flood plain toward Lehmberg Road. Therefore, flows through the highway bridge during the 1990 floods were about 140 percent larger [(600 ft^3/s minus 250 ft^3/s)/250 ft^3/s] than what they would have been if the pond levees were not in existence. Water-surface elevations representing flow conditions with all ponds removed are shown in figure 9.

Flows with All Ponds and U.S. Highway 82 Removed

Flows prior to the construction of U.S. Highway 82 and the pond levees were simulated for the 1990 flood discharges (2,800 ft^3/s) so that a complete comparison could be made of the different flow scenarios. The elements in the finite-element grid representing the U.S. Highway embankments and the pond levees were activated to allow flows to pass through.

Results of the simulations indicated that about 600 ft^3/s (21 percent) flowed down the Magby Creek distributary flood plain before the U.S. Highway 82 and pond levees were constructed. The remaining 800 ft^3/s (29 percent) would have flowed toward Lehmberg Road in the south one-half of the Magby Creek flood plain. Water-surface elevations representing the 1990 flood discharges before the construction of U.S. Highway 82 and the pond levees were plotted (fig. 10).



Base from U.S. Geological Survey
Steens, 1:24,000, 1987

0 — 1 MILE

0 — 1 KILOMETER

EXPLANATION

——194—— COMPUTED WATER-SURFACE ELEVATIONS - - Shows simulated peak water-surface elevations. Contour interval is 1.0 foot. Datum is sea level

Figure 8. - - Computed water-surface elevations for the 1990 floods with pond 3 levees removed.

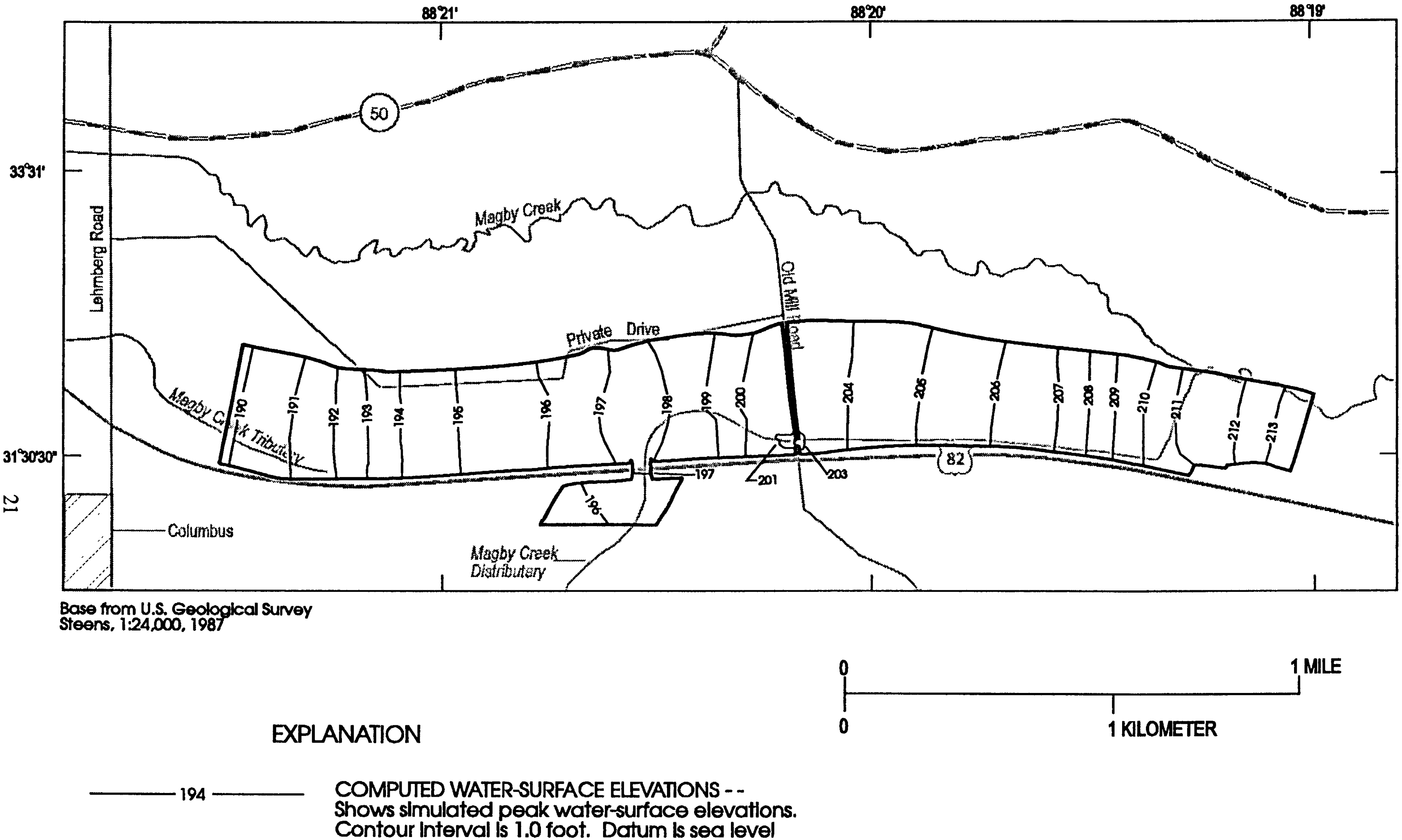


Figure 9. - - Computed water-surface elevations for the 1990 floods with all pond levees removed.

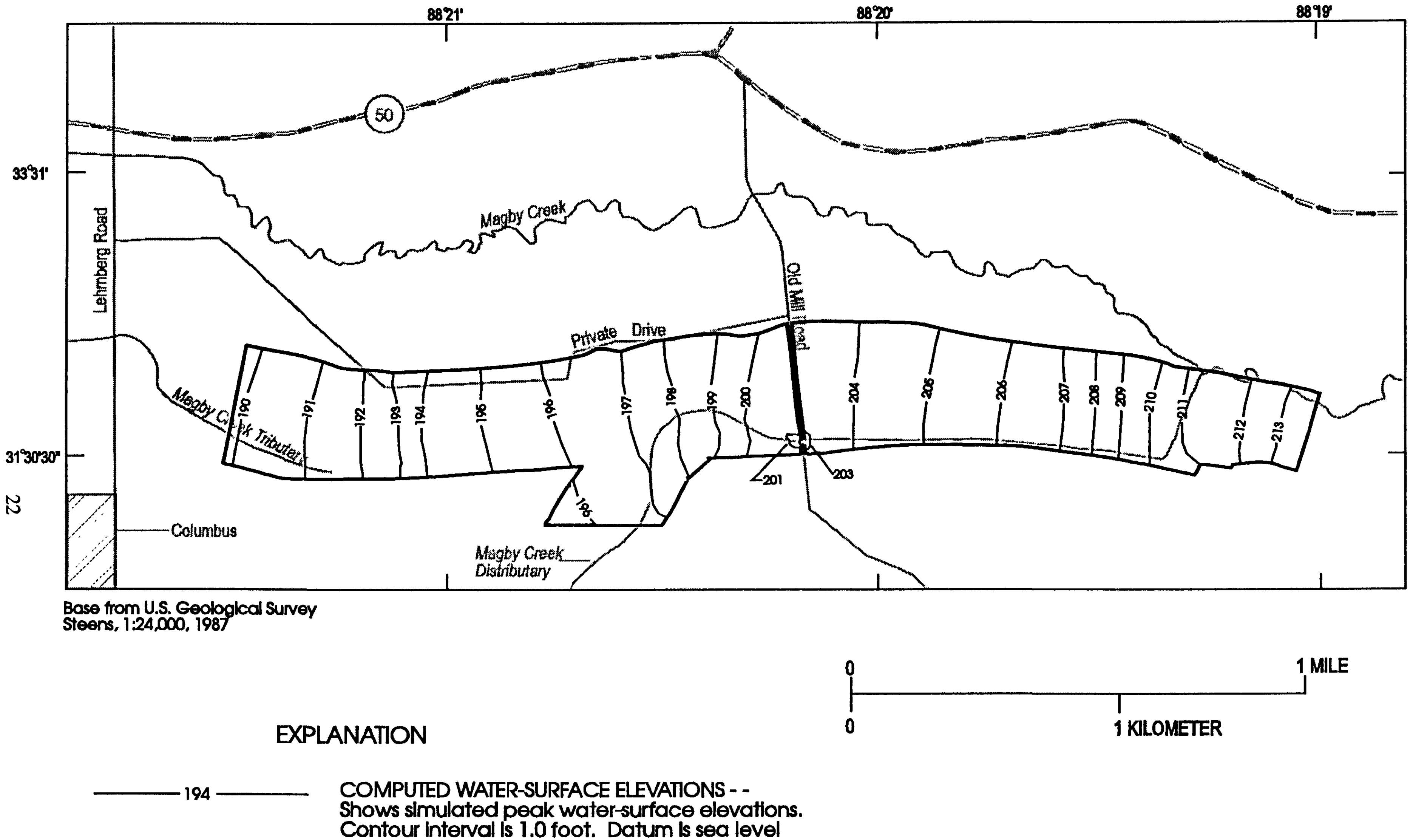


Figure 10. - - Computed water-surface elevations for the 1990 floods with U.S. Highway 82 embankments removed.

Flows with Diversion Levee Connecting West Spur Dike and Pond 2

The 1990 flood discharges with a hypothetical floodflow diversion levee connecting the west spur dike on the U.S. Highway 82 bridge to the east levee of pond 2 were not simulated. Sufficient data were provided by previous simulations to estimate flow distributions.

Output from previous simulations (flows with the pond 3 levees removed) indicate that during a flood similar to the 1990 floods and assuming that the pond 3 levees are not rebuilt, about 300 ft^3/s would flow between the west spur dike of the highway bridge and the southeast corner of pond 2 and about 650 ft^3/s would flow through the highway bridge. If a levee were constructed connecting the west spur dike to the east levee of pond 2, the 300 ft^3/s would then flow through the bridge for a total of 950 ft^3/s (34 percent). Therefore, about 450 ft^3/s (16 percent) would flow around the north levee of pond 2 toward Lehmberg Road in the south part of the Magby Creek flood plain. Because no flows were simulated for the 1990 floods with the hypothetical levee in place, a plot of the water-surface elevations was not obtained.

50-Year Flood

Floodflows were simulated depicting the Magby Creek 50-year flood. The estimated 50-year flood discharge is 8,030 ft^3/s (fig. 2) and has a 2 percent chance of being equaled or exceeded in any given year. The 50-year flood was selected for flow analyses because it is the primary flood that the MDOT uses in the design of hydraulic structures.

During the 50-year flood, floodwaters would submerge the entire width of the Magby Creek flood plain with an average depth of about 2.4 ft. Because the heights of the pond levees are about 1 to 2 ft, it is assumed that they would be destroyed during a 50-year flood. Therefore, the levees of pond 1 to pond 6 were removed for these simulations.

Flows with U.S. Highway 82 in Place

The 50-year floodflows were simulated with the U.S. Highway 82 embankments in place. Simulations indicate that the 50-year floodflows would overtop Old Mill Road by about 1.0 ft. The average computed water-surface elevations at the upstream and downstream sides of Old Mill Road at the weir section are 204.3 and 202.3 ft, respectively; thus, a differential of about 2.0 ft is expected. The computed submergence factor for the weir flow conditions at Old Mill Road during the 50-year flood is 1.0 (non-submergence).

The discharge across Old Mill Road during a 50-year flood was simulated with 17 weir sections representing roadway embankment elevations and widths. The total length of the weir (perpendicular to the floodflows) is about 1,770 ft. Simulations indicate that the discharge across Old Mill Road during the 50-year flood would be about 5,350 ft^3/s (67 percent). Because of submergence, flows through the bridges at Old Mill Road were simulated as pressure flows. The simulated discharges through the bridges were computed from an average of flow checks at five sections in each opening. Flow checks are discharges computed by the FESWMS model across a line of element sides defined by a list of nodes. The flow-check lines spanned the width of the bridge openings and were composed of the element sides within the openings. The simulated discharges at Old Mill Road through the Magby Creek bridge and the Magby Creek distributary bridge were 1,850 ft^3/s (23 percent) and 830 ft^3/s (10 percent), respectively.

The simulations indicate that about 360 ft^3/s (4 percent) of the 8,030 ft^3/s would pass through the U.S. Highway 82 bridge. The remaining 7,670 ft^3/s (96 percent) would flow downstream toward Lehmberg Road. Water-surface elevations representing the 50-year flood were plotted (fig. 11).

Flows with U.S. Highway 82 Removed

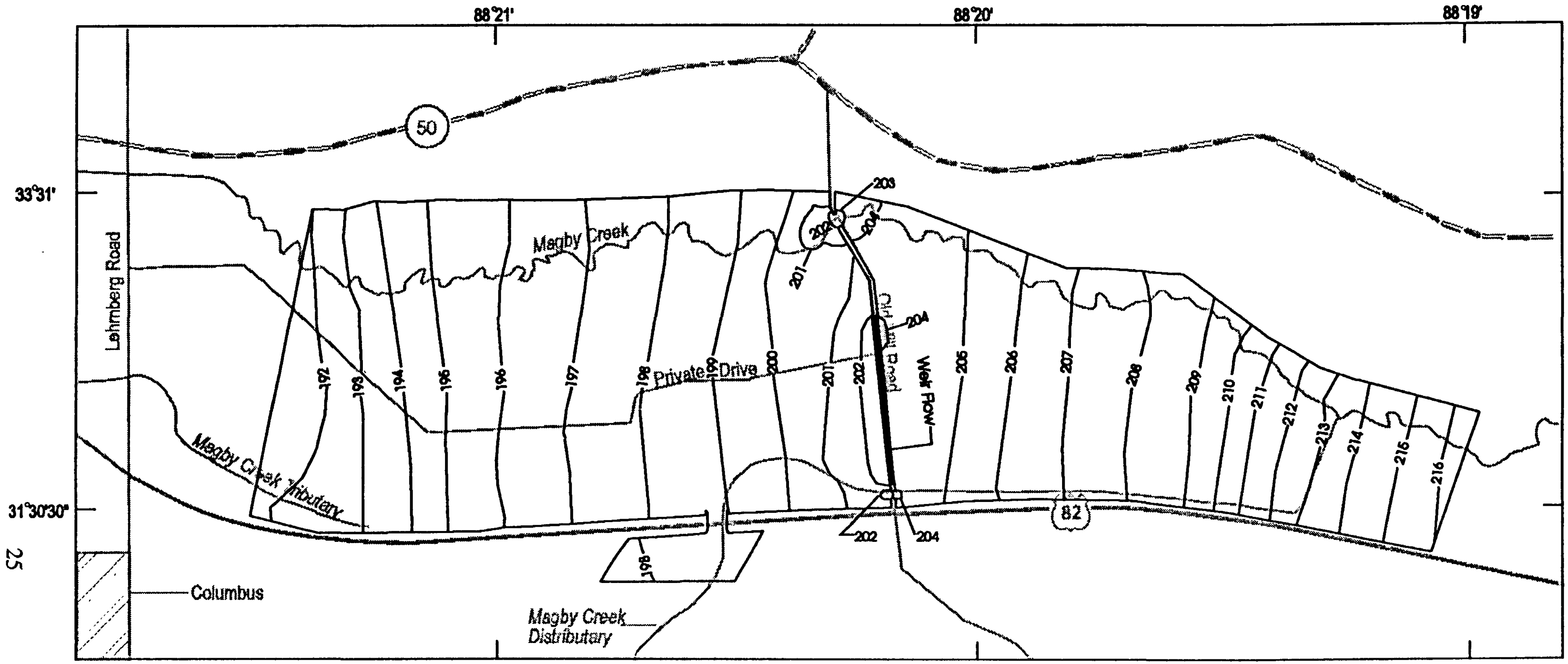
The 50-year flood was also simulated without the U.S. Highway 82 embankments in place. The flow distributions and elevations at and above Old Mill Road were the same as those in the simulation with the highway embankments in place. Therefore, flows upstream of Old Mill Road are controlled by the combined weir and bridge flows at Old Mill Road and are not affected by the construction of the U.S. Highway 82 embankments.

The simulations indicate that about 800 ft^3/s (10 percent) of the 8,030 ft^3/s would flow down the Magby Creek distributary flood plain to exit the system whereas the remaining 7,230 ft^3/s (90 percent) would flow down the Magby Creek flood plain toward Lehmberg Road. Water-surface elevations representing a 50-year flood with the highway embankments removed are shown in figure 12.

Flows with Diversion Levee Connecting West Spur Dike and Pond 2

The 50-year flood was simulated with a hypothetical floodflow diversion levee connecting the west spur dike on the U.S. Highway 82 bridge to the east levee of pond 2. For flow simulations, it was assumed that the diversion levee and the east levee of pond 2 were high enough to avoid overtopping by floodflows. The east levee of pond 2 extends about 1,000 ft into the Magby Creek flood plain from the west spur dike.

Simulations indicate that flow distributions and water-surface elevations upstream of Old Mill Road would remain unchanged by the construction of the floodflow diversion levee. However, the diversion levee would divert more floodflows from the Magby Creek flood plain through the U.S. Highway 82 bridge. With the diversion levee in place, about 1,500 ft^3/s (19 percent) would flow through the U.S. Highway 82 bridge and about 6,530 ft^3/s (81 percent) would flow down the Magby Creek flood plain



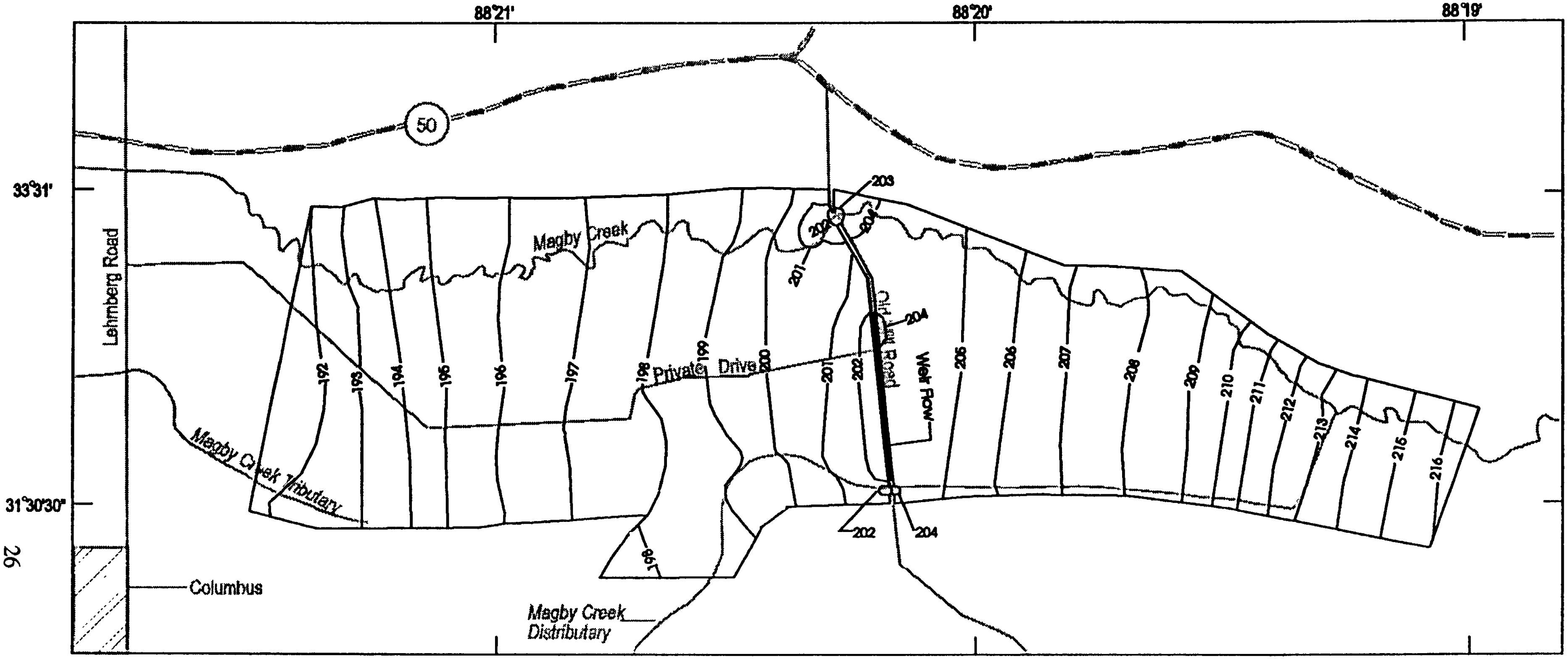
Base from U.S. Geological Survey
Steens, 1:24,000, 1987

0 — 1 MILE
0 — 1 KILOMETER

EXPLANATION

——— 194 ——— COMPUTED WATER-SURFACE ELEVATIONS - -
Shows simulated peak water-surface elevations.
Contour Interval is 1.0 foot. Datum is sea level

Figure 11. - - Computed water-surface elevations for a 50-year flood.



Base from U.S. Geological Survey
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EXPLANATION

——— 194 ——— COMPUTED WATER-SURFACE ELEVATIONS - - Shows simulated peak water-surface elevations. Contour interval is 1.0 foot. Datum is sea level

Figure 12. - - Computed water-surface elevations for a 50-year flood with U.S. Highway 82 embankments removed.

toward Lehmberg Road. Water-surface elevations representing a 50-year flood with a hypothetical floodflow diversion levee connecting the west spur dike to pond 2 were plotted (fig. 13) for visual inspection of simulated flows.

100-Year Flood

The Magby Creek 100-year flood was also simulated. The estimated 100-year flood discharge is 9,130 ft^3/s (fig. 2) and has a 1 percent chance of being equaled or exceeded in any given year. The 100-year flood was selected for flow analyses because the FHWA requires hydraulic structures to allow the flood to pass and meet specified backwater limitations.

During the 100-year flood, floodwaters would submerge the entire width of the Magby Creek flood plain with an average depth of about 2.7 ft. Because the heights of the pond levees are about 1 to 2 ft, it is assumed that they would be destroyed during a 100-year flood. Therefore, the levees of pond 1 to pond 6 were removed for these simulations.

Flows with U.S. Highway 82 in Place

The 100-year flood was simulated with the U.S. Highway 82 embankments in place. Simulations indicate that the 100-year flood would overtop Old Mill Road by about 1.1 ft. The average computed water-surface elevations at the upstream and downstream sides of Old Mill Road at the weir section are 204.4 and 202.5 ft, respectively; thus, a differential of about 1.9 ft is expected. The computed submergence factor for the weir flow conditions at Old Mill Road during the 100-year flood is 1.0 (non-submergence).

The discharge across Old Mill Road during a 100-year flood was simulated with 17 weir sections representing roadway embankment elevations and widths. The total length of the weir (perpendicular to the floodflows) is about 1,770 ft. Simulations indicate that the discharge across Old Mill Road during the 100-year flood would be about 6,270 ft^3/s (69 percent). Because of submergence, flows through the bridges at Old Mill Road were simulated as pressure flows. The simulated discharges through the bridges were computed from an average of flow checks at five sections in each opening. The flow-check lines spanned the width of the bridge openings and were composed of the element sides within the openings. The simulated discharges at Old Mill Road through the Magby Creek bridge and the Magby Creek distributary bridge were 2,000 ft^3/s (22 percent) and 860 ft^3/s (9 percent), respectively.

The simulations indicate that about 410 ft^3/s (4 percent) of the 9,130 ft^3/s would pass through the U.S. Highway 82 bridge. The remaining 8,720 ft^3/s would flow down the Magby Creek flood plain toward Lehmberg Road. Water-surface elevations representing a 100-year flood with the relocated U.S. Highway 82 in place were plotted (fig. 14).

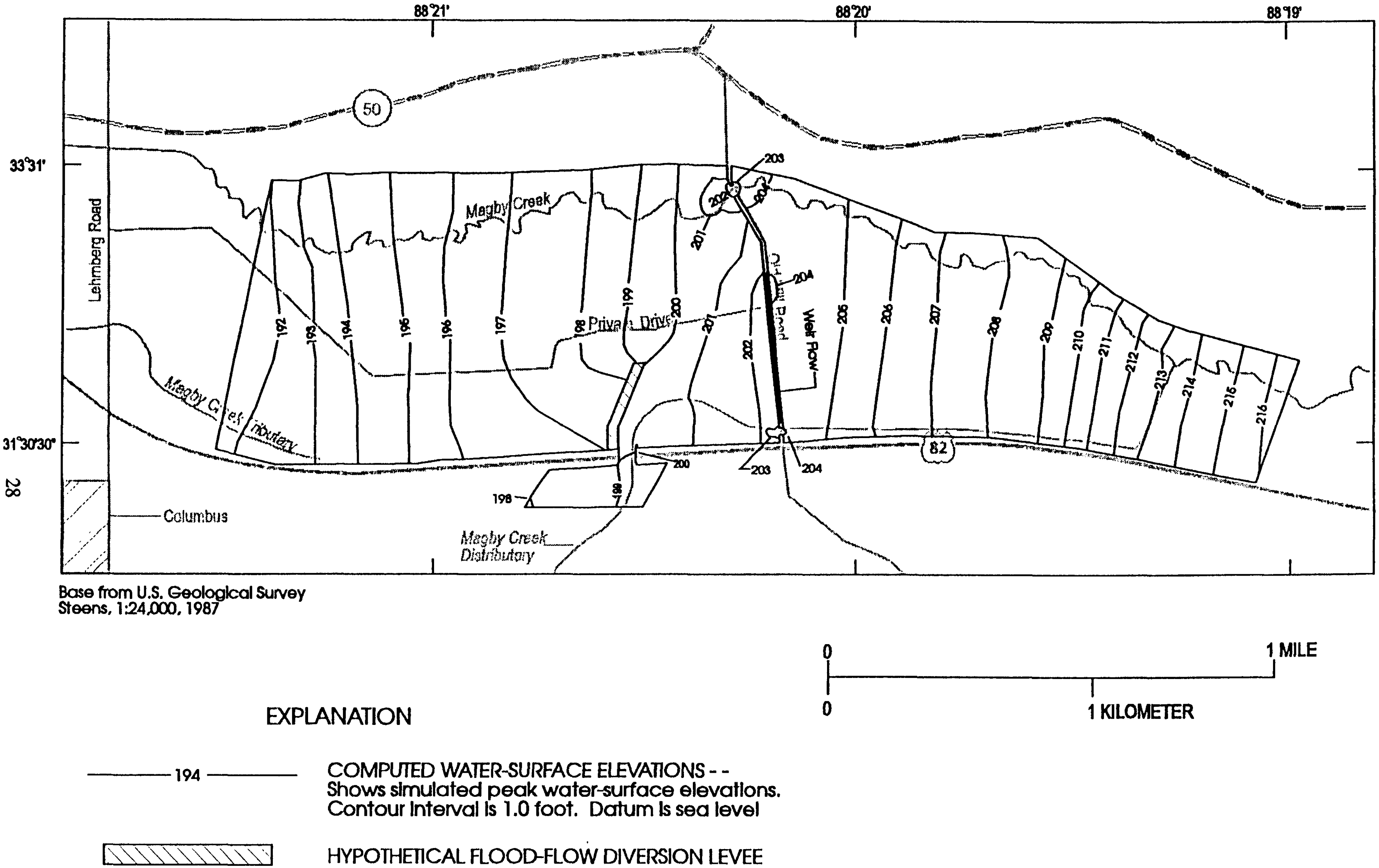
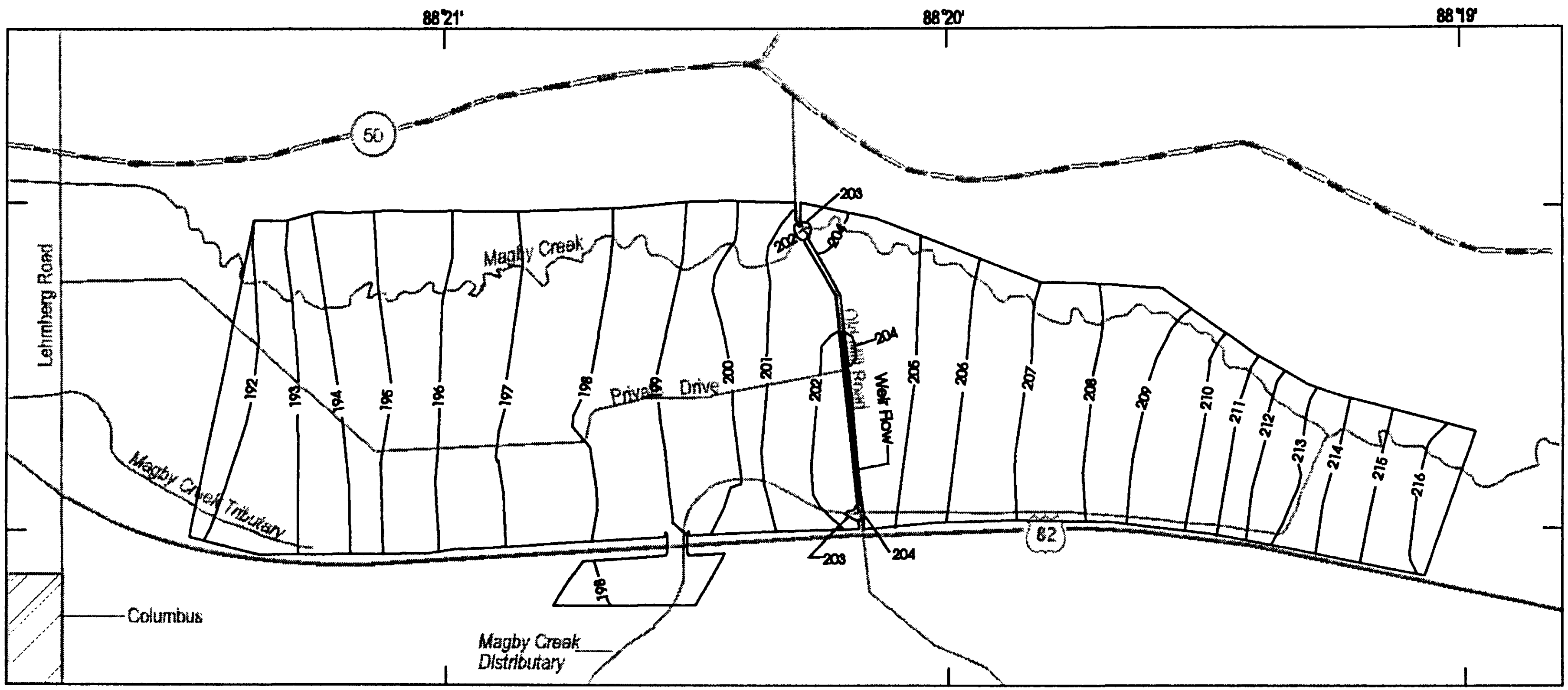
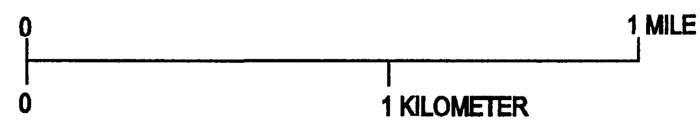


Figure 13. - - Computed water-surface elevations for a 50-year flood with a levee connecting west spur dike to pond 2.



Base from U.S. Geological Survey
Steens, 1:24,000, 1987



EXPLANATION

——— 194 ——— COMPUTED WATER-SURFACE ELEVATIONS - -
Shows simulated peak water-surface elevations.
Contour interval is 1.0 foot. Datum is sea level

Figure 14. - - Computed water-surface elevations for a 100-year flood.

Flows with U.S. Highway 82 Removed

The 100-year flood was also simulated without the U.S. Highway 82 embankments in place. As with the 50-year flood, water-surface elevations and flow distributions at and upstream of Old Mill Road were not affected by the removal of the highway embankments. Therefore, the 100-year floodflows upstream of Old Mill Road were not affected by the construction of the U.S. Highway 82 embankments.

The simulations indicate that about 960 ft^3/s (11 percent) of the 9,130 ft^3/s would flow in the Magby Creek distributary flood plain to exit and the remaining 8,170 ft^3/s (89 percent) would flow in the Magby Creek flood plain toward Lehmberg Road. Water-surface elevations representing a 100-year flood with the highway embankments removed were plotted (fig. 15).

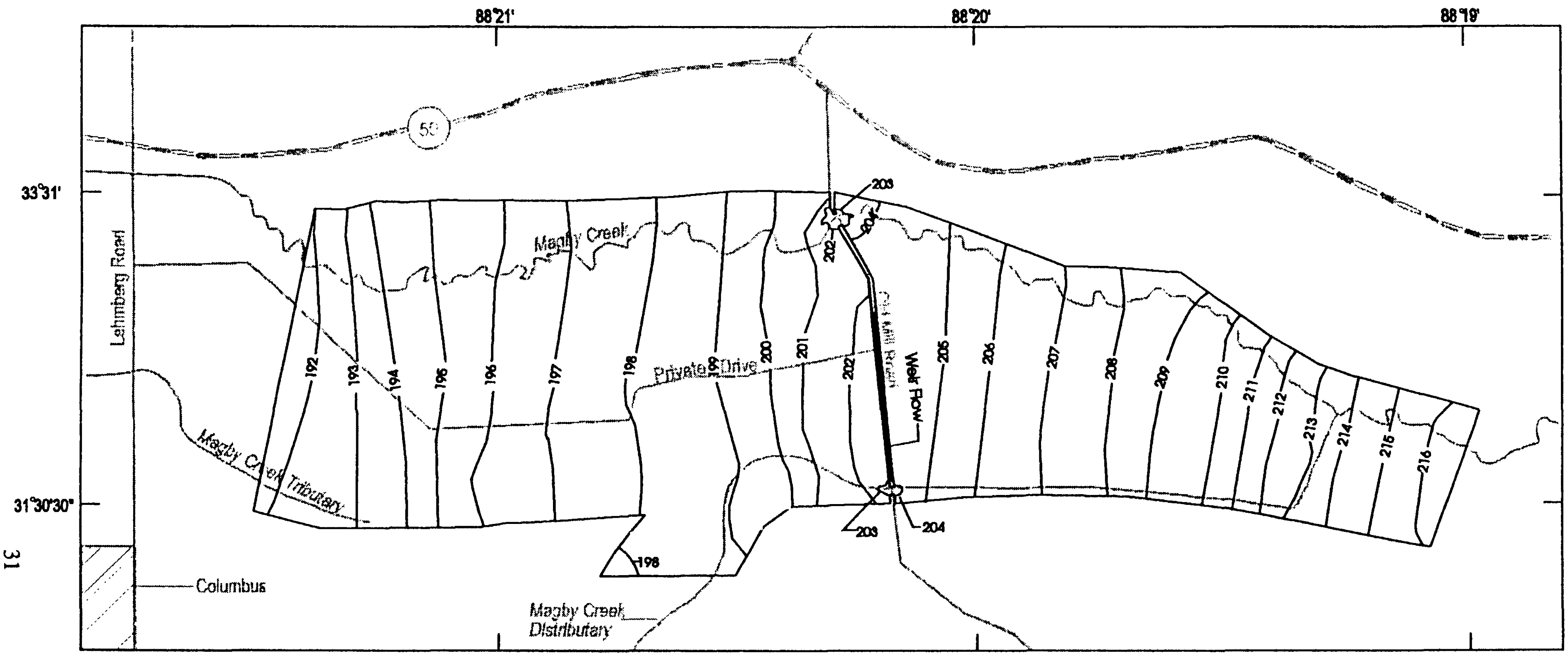
The computed lines of equal backwater and drawdown for the 100-year flood are shown in figure 16. In this study, backwater is defined as an increase in natural water-surface elevations due to a constriction or obstruction of flows. The natural water-surface elevations are those before construction of U.S. Highway 82. Drawdown is a decrease in natural water-surface elevations due to increased velocities or decreased discharges from flow diversions.

Flows with Diversion Levee Connecting West Spur Dike and Pond 2

The 100-year flood was simulated with a hypothetical floodflow diversion levee in place connecting the west spur dike on the U.S. Highway 82 bridge to the east levee of pond 2. For flow simulations, it was assumed that the connecting diversion levee and the east levee of pond 2 were high enough to avoid overtopping by floodflows.

Simulations indicate that the flows upstream of Old Mill Road would remain unchanged by the construction of the floodflow diversion levee. However, the diversion levee would divert more floodflows from the Magby Creek flood plain through the U.S. Highway 82 bridge to leave the system. With the diversion levee in place, about 1,650 ft^3/s (18 percent) of the 9,130 ft^3/s would flow through the U.S. Highway 82 Magby Creek distributary bridge and about 7,480 ft^3/s (82 percent) would flow down the Magby Creek flood plain toward Lehmberg Road. Water-surface elevations representing a 100-year flood with a hypothetical floodflow diversion levee connecting the west spur dike to pond 2 were plotted (fig. 17) for visual inspection of simulated flows. The computed lines of equal backwater and drawdown for the 100-year flood with the diversion levee in place are shown in figure 18.

The computed discharges in the Magby Creek distributary flood plain were plotted versus total basin flow (fig. 19). Three scenarios are plotted: (1) flows with U.S. Highway 82 embankments in place, (2) flows without U.S. Highway 82 embankments in place, and (3) flows with U.S. Highway 82 embankments in place with a hypothetical floodflow diversion levee connecting the west spur dike to pond 2. The computed



Base from U.S. Geological Survey
Steens, 1:24,000, 1987

0 — 1 MILE

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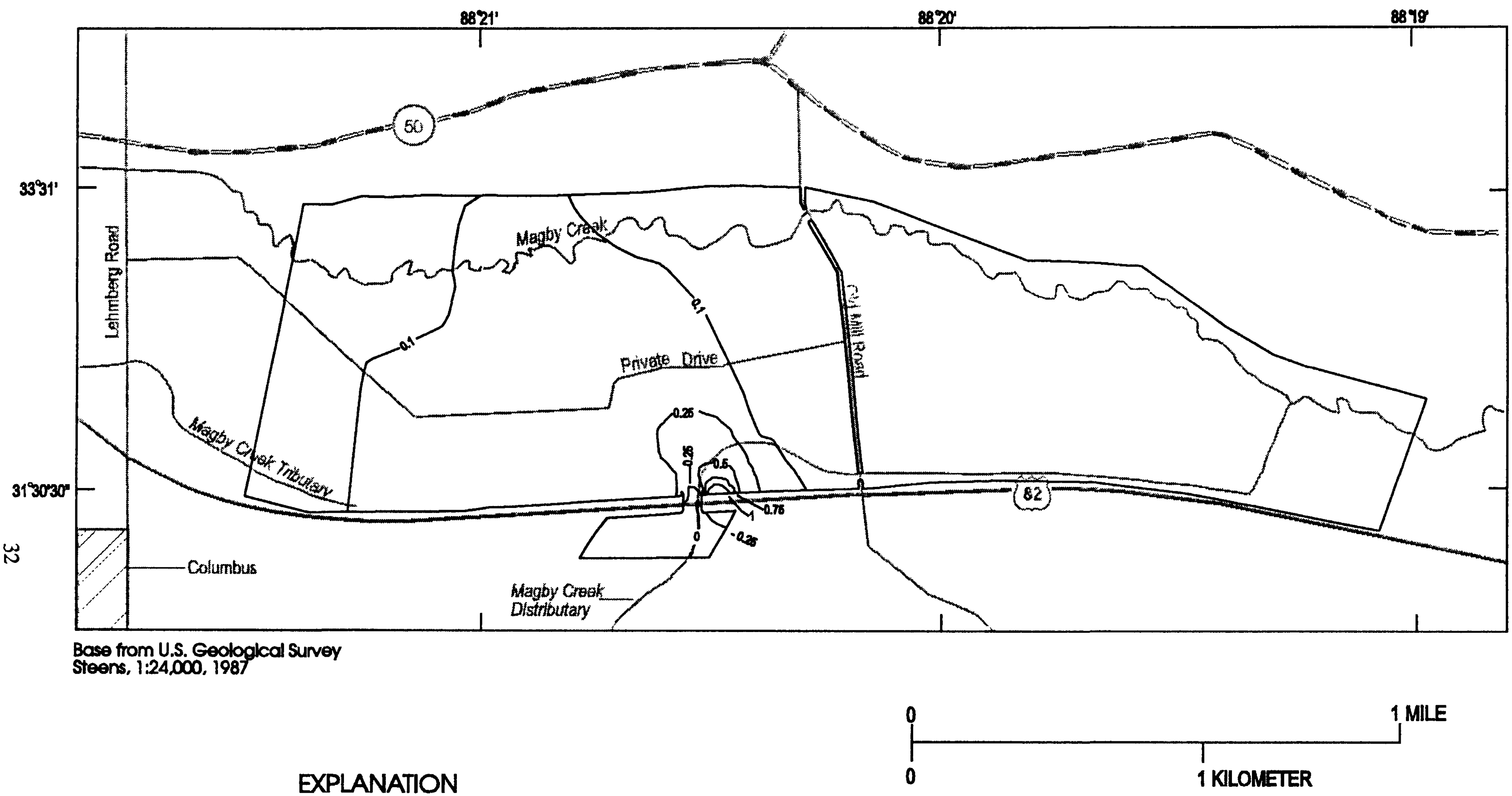
EXPLANATION

——— 194 ——— COMPUTED WATER-SURFACE ELEVATIONS - - Shows simulated peak water-surface elevations. Contour interval is 1.0 foot. Datum is sea level

Figure 15. - - Computed water-surface elevations for a 100-year flood with U.S. Highway 82 embankments removed.



Base from U.S. Geological Survey
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EXPLANATION

——— 0.1 ——— COMPUTED LINE OF EQUAL BACKWATER OR DRAWDOWN - - Contour Interval, in feet, is varied; a negative value denotes drawdown

Figure 16. - - Computed line of equal backwater or drawdown for a 100-year flood.

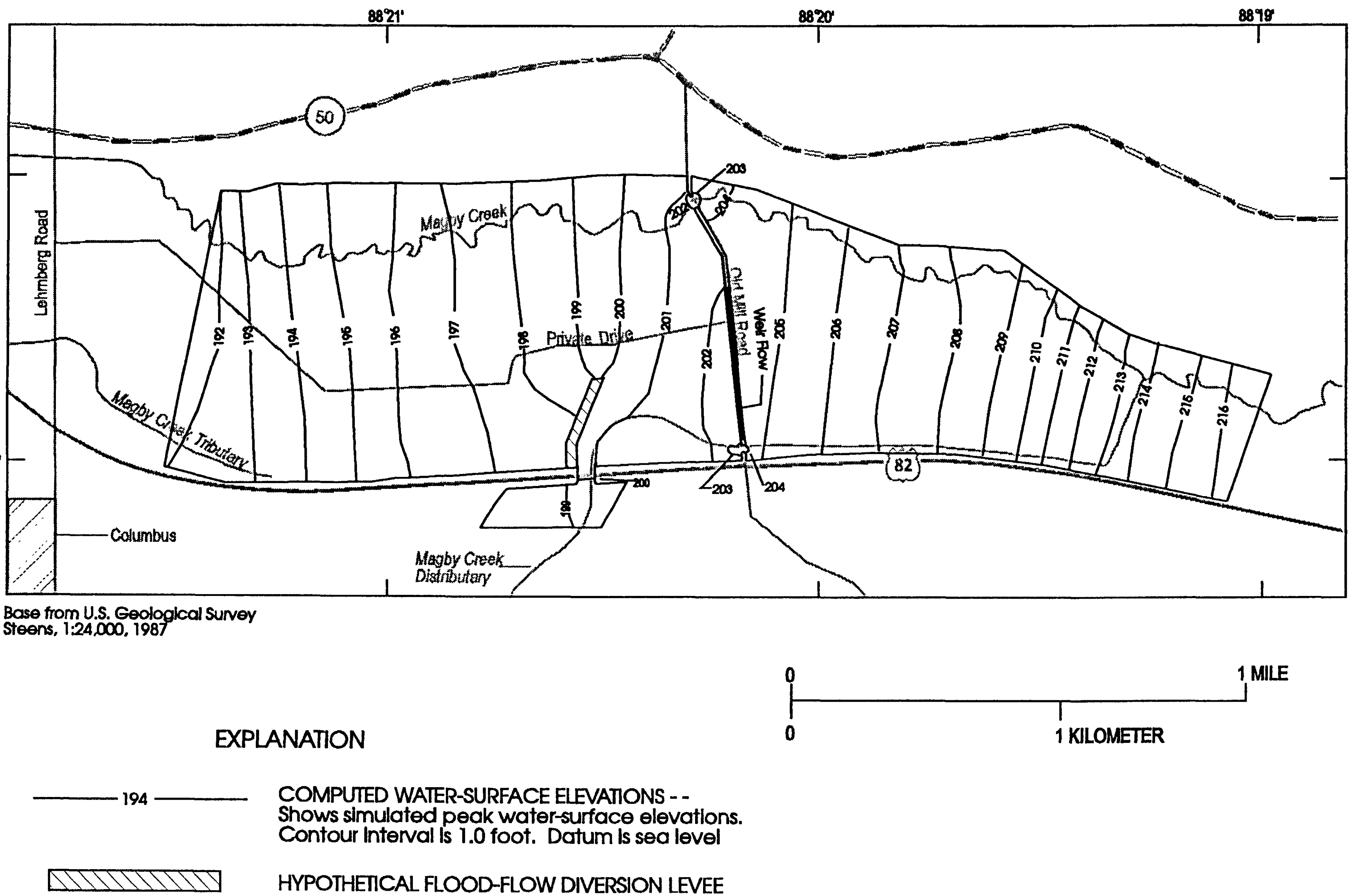

Figure 17. - - Computed water-surface elevations for a 100-year flood with a levee connecting west spur dike to pond 2.

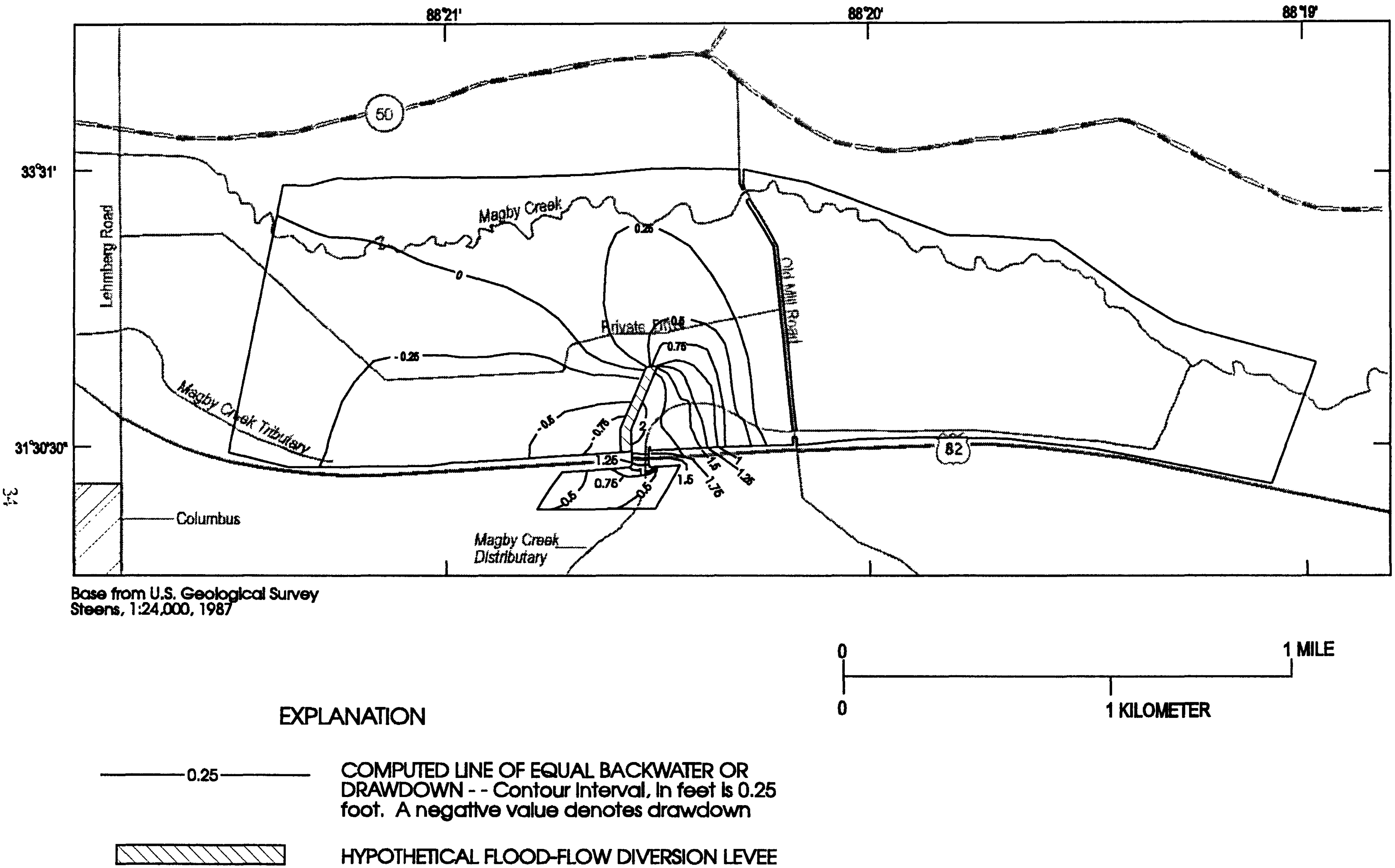

Figure 18. - - Computed line of equal backwater or drawdown for a 100-year flood with a levee connecting west spur dike and pond 2.

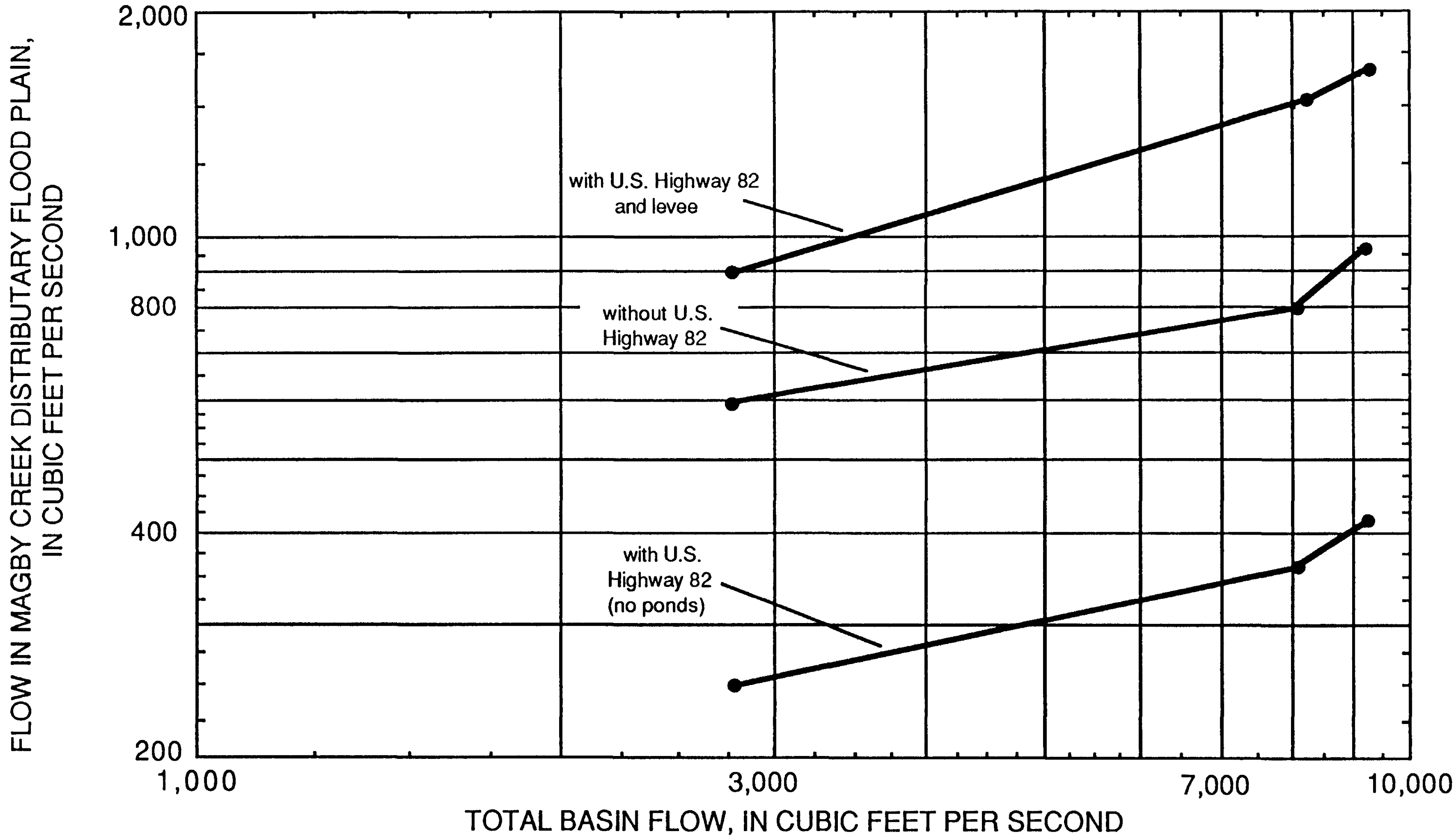

Figure 19. -- Computed discharges in the Magby Creek distributary flood plain for the simulated flows.

discharges in the Magby Creek flood plain approaching Lehmberg Road were also plotted versus total basin flow (fig. 20). The three scenarios plotted are the same as in figure 19. The effects of the pond levees are not graphically represented in figures 19 and 20 because of the numerous unknown variables involved due to the sudden changes in flows in the Magby Creek distributary and Magby Creek flood plains when the pond levees fail. Therefore, the following information is based on the results of the simulations depicting flows without the pond levees.

Simulations indicate that discharges in the Magby Creek distributary flood plain decreased by an average of about 57 percent when the U.S. Highway 82 embankments and bridge were constructed. Flows were diverted away from the Magby Creek distributary flood plain and the discharges in the Magby Creek flood plain approaching Lehmberg Road increased by about 10 percent. Floodflows simulated with a hypothetical diversion levee connecting the west spur dike of the highway bridge to the east levee of pond 2 indicate that discharges in the Magby Creek distributary flood plain would increase by about 300 percent above present conditions with the highway in place. Flows in the Magby Creek flood plain presently approaching Lehmberg Road would decrease by about 19 percent. Simulations indicate that the hypothetical diversion levee would increase flows in the Magby Creek distributary flood plain by an average of about 73 percent above the pre-U.S. Highway 82 conditions and decrease the pre-U.S. Highway 82 flows in the Magby Creek flood plain approaching Lehmberg Road by about 11 percent.

SUMMARY AND CONCLUSIONS

A two-dimensional finite-element surface-water model was used to study the effects of newly constructed U.S. Highway 82 and six newly constructed pond levees on the water-surface elevations and flow distributions in the Magby Creek flood plain east of Columbus, Lowndes County, Mississippi. Different flow scenarios within the Magby Creek flood plain were simulated using various conditions for the two floods of 1990 and the 50- and 100-year floods. These various conditions include: (1) the conditions for the two floods of 1990, (2) previous conditions (without the U.S. Highway 82 embankments and pond levees in place), (3) existing conditions, and (4) existing conditions with a hypothetical floodflow diversion levee at the U.S. Highway 82 bridge.

Flood discharges of 2,800 ft^3/s were simulated because floods of similar magnitude occurred in February and December 1990. Pond 3 was in existence at the time of the 1990 floods and simulations of floodflows indicate that the pond 3 levees diverted about 50 ft^3/s from the U.S. Highway 82 bridge opening. The simulated discharge through the highway bridge during the two 1990 floods was 600 ft^3/s. Simulations indicate that about 650 ft^3/s would have flowed through the highway bridge if the pond 3 levees were removed. However, if all pond levees were removed, about 250 ft^3/s would have passed through the U.S. Highway 82 bridge. Therefore, flows through the highway bridge were about 140 percent larger than what they would have been if the pond levees were not in existence. Further simulations of the 1990 floods indicated that about

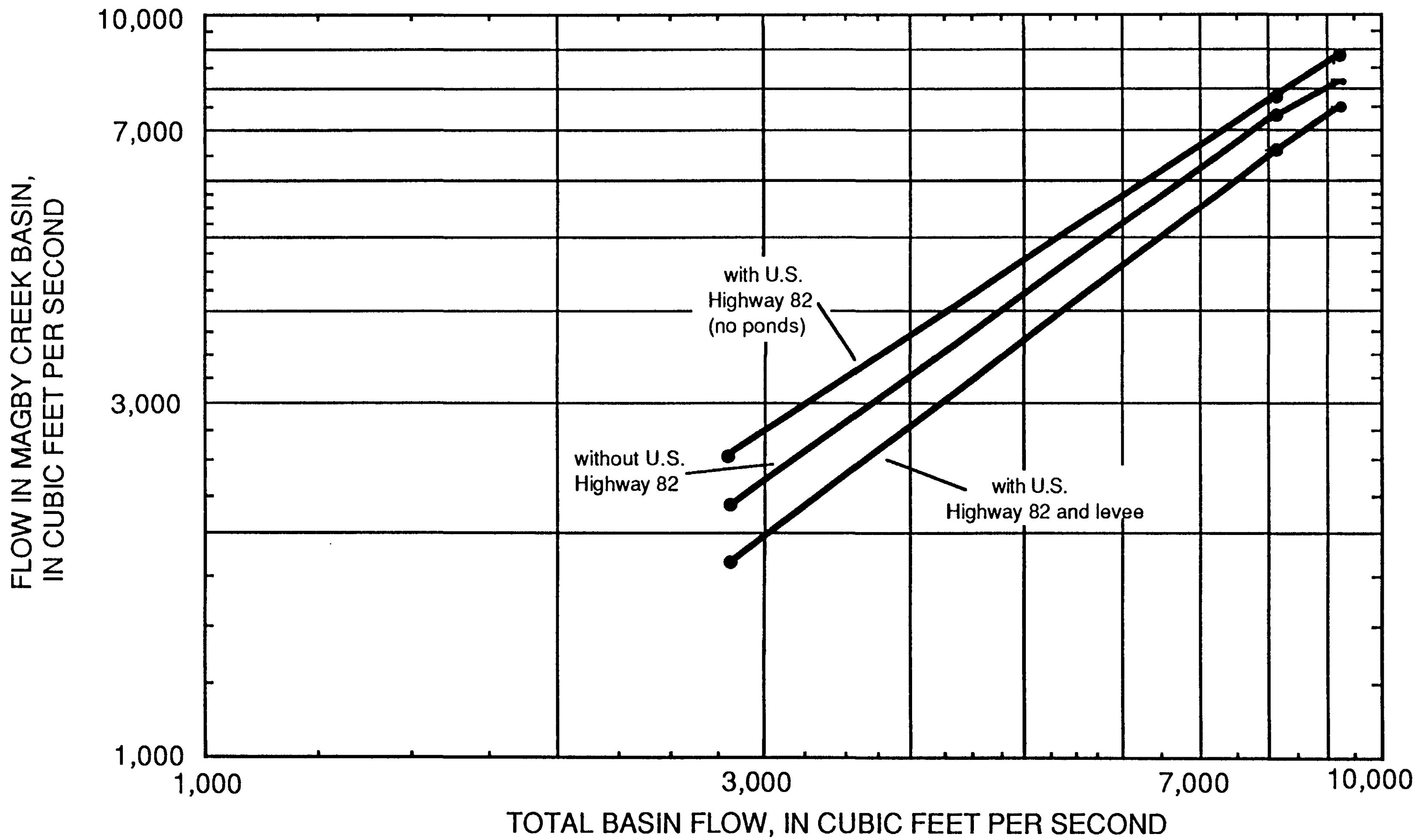

Figure 20. -- Computed discharges in the Magby Creek flood plain for the simulated flows.

600 ft^3/s would have flowed down the Magby Creek distributary flood plain before construction of the highway.

Examination of flow distributions for the 1990 floods without the pond 3 levees in place indicate that about 300 ft^3/s would pass between the southeast corner of pond 2 and the west spur dike of the highway to progress along the highway embankment. If a floodflow diversion levee were in place connecting the west spur dike to the east levee of pond 2, the 300 ft^3/s would be diverted and a total of 950 ft^3/s would pass through the highway bridge during a flood similar to the floods of 1990.

The 50-year flood (8,030 ft^3/s) was analyzed because it is the flood for which a hydraulic structure located on a U.S. highway is designed. Flows were analyzed for conditions with and without the U.S. Highway 82 embankments in place and also with a hypothetical floodflow diversion levee connecting the west spur dike of the highway to the east levee of pond 2. Simulations indicated that the highway had no effect on flows upstream of Old Mill Road. The simulated discharges in the Magby Creek distributary flood plain were about 360 ft^3/s with the highway embankments in place and about 800 ft^3/s with the embankments removed. The simulated discharge in the Magby Creek distributary flood plain with a hypothetical floodflow diversion levee connecting the west spur dike of the highway bridge to the east levee of pond 2 was about 1,500 ft^3/s.

The 100-year flood (9,130 ft^3/s) was also analyzed because the FHWA established backwater limitations based upon the 100-year flood discharge. Flows were analyzed for conditions with and without the U.S. Highway 82 embankments in place and also with a hypothetical floodflow diversion levee in place. Simulations indicate that the highway had no effect on flows upstream of Old Mill Road. Simulations indicate that the discharges flowing in the Magby Creek distributary flood plain would be about 410 ft^3/s with the highway embankments in place and about 960 ft^3/s with the highway embankments removed. The simulated discharge in the Magby Creek distributary flood plain with a hypothetical floodflow diversion levee connecting the west spur dike of the highway bridge to the east levee of pond 2 was about 1,650 ft^3/s.

Simulations without the pond levees indicate that discharges in the Magby Creek distributary flood plain decreased by an average of about 57 percent when the U.S. Highway 82 embankments and bridge were constructed. Flows in the Magby Creek flood plain approaching Lehmberg Road increased by about 10 percent. Simulations with a hypothetical floodflow diversion levee connecting the west spur dike of the highway bridge to the east levee of pond 2 indicate that discharges in the Magby Creek distributary flood plain would increase by about 300 percent above present conditions with the highway in place. The total flows in the Magby Creek flood plain approaching Lehmberg Road would decrease by about 19 percent. Simulations indicate that the hypothetical diversion levee would increase flows in the Magby Creek distributary flood plain by an average of about 73 percent above the pre-U.S. Highway 82 conditions and decrease the pre-U.S. Highway 82 flows in the Magby Creek flood plain approaching Lehmberg Road by about 11 percent.

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