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# Base (100-Year) Flood Elevations for Selected Sites in Marion County, Missouri

By Rodney E. Southard *and* Gary L. Wilson

## ABSTRACT

The primary requirement for community participation in the National Flood Insurance Program is the adoption and enforcement of floodplain management requirements that minimize the potential for flood damages to new construction and avoid aggravating existing flooding conditions. This report provides base flood elevations (BFE) for a 100-year recurrence flood for use in the management and regulation of 14 flood-hazard areas designated by the Federal Emergency Management Agency as approximate Zone A areas in Marion County, Missouri.

The one-dimensional surface-water flow model, HEC-RAS, was used to compute the base (100-year) flood elevations for the 14 Zone A sites. The 14 sites were located at U.S., State, or County road crossings and the base flood elevation was determined at the upstream side of each crossing. The base (100-year) flood elevations for BFE 1, 2, and 3 on the South Fork North River near Monroe City, Missouri, are 627.7, 579.2, and 545.9 feet above sea level. The base (100-year) flood elevations for BFE 4, 5, 6, and 7 on the main stem of the North River near or at Philadelphia and Palmyra, Missouri, are 560.5, 539.7, 504.2, and 494.4 feet above sea level. BFE 8 is located on Big Branch near Philadelphia, a tributary to the North River, and the base (100-year) flood elevation at this site is 530.5 feet above sea level. One site (BFE 9) is located on the South River near Monroe City, Missouri. The base (100-year) flood elevation at this site is 619.1 feet above sea level. Site BFE 10 is located on Bear Creek near Hannibal, Missouri, and the base (100-year) elevation is

565.5 feet above sea level. The four remaining sites (BFE 11, 12, 13, and 14) are located on the South Fabius River near Philadelphia and Palmyra, Missouri. The base (100-year) flood elevations for BFE 11, 12, 13, and 14 are 591.2, 578.4, 538.7, and 506.9 feet above sea level.

## INTRODUCTION

In 1968, the United States Congress passed the National Flood Insurance Act, which created the National Flood Insurance Program. Congress recognized that the success of this program requires that community participation be widespread, and that flood insurance studies be conducted to accurately assess the flood risk within each participating flood-prone community (U.S. Department of Housing and Urban Development, 1995).

The Housing and Urban Development Act of 1969 expanded participation in the National Flood Insurance Program by authorizing an Emergency Program under which insurance coverage could be provided before completion of the communities' detailed flood-insurance studies. Before these studies could be conducted for the communities, Flood Hazard Boundary Maps were prepared using either available data or approximate engineering methods. The Flood Hazard Boundary Maps identify the approximate areas within a community subject to inundation by a 100-year recurrence-interval flood. These areas are referred to as Zone A areas on the boundary maps. Zone A areas have a one percent chance of being inundated by a 100-year flood flow in any given year. The Flood Hazard Boundary Map was intended to assist communities in managing floodplain development, and insurance agents and

property owners in identifying areas where the purchase of flood insurance was advisable (U.S. Department of Housing and Urban Development, 1995).

The Flood Disaster Protection Act of 1973, which amended the 1968 National Flood Insurance Act, required that flood-prone communities be notified of their flood hazards to encourage insurance program participation. This was accomplished through publishing Flood Hazard Boundary Maps for all communities that were identified as containing flood-hazard areas. The initial Flood Hazard Boundary Maps were prepared using results from detailed flood insurance studies. As early as 1976, the Federal Emergency Management Agency (FEMA) recognized that some communities did not require a detailed flood study because few buildings existed in the floodplain, and development plans were minimal. Shortly thereafter, FEMA began designating communities with limited existing and planned development in floodplains as having approximate Zone A areas on the Flood Insurance Rate Map (U.S. Department of Housing and Urban Development, 1995). To minimize study costs, the approximate Zone A areas were to be analyzed using less-detailed methodologies than those used in detailed flood-insurance studies.

In areas designated as approximate Zone A, where base (100-year) flood elevations (BFEs) have not been provided by FEMA, communities must adopt and enforce floodplain management regulations that meet minimal National Flood Insurance Program standards (U.S. Department of Housing and Urban Development, 1995). However, in Zone A areas where base flood elevations are determined, communities are better able to manage and protect property susceptible to floods equal to or less than a 100-year flood. The U.S. Geological Survey (USGS), in cooperation with the State Emergency Management Agency, has completed a study using a one-dimensional surface-water flow-model to compute base (100-year) flood elevations for 14 approximate Zone A sites in Marion County, Missouri. The 14 selected sites were located at U.S., State, or County road crossings and the base flood elevation for a site is on the upstream side of each crossing. This report presents the results of that study.

## DESCRIPTION OF THE STUDY AREA

Marion County (fig. 1), population of about 28,000, is in the northeast part of Missouri and covers about 438 mi<sup>2</sup> (square miles). Palmyra, in east-central

Marion County, is the county seat; Hannibal is the largest town in the county. Although there is some business and industry around Hannibal, most of the county is economically dependent on farming or farm-related businesses. Farming operations mainly consist of growing row crops and raising hogs and beef cattle; some farms have dairy cattle. The floodplain of the Mississippi River is used almost exclusively for growing corn and soybeans, with some smaller acreages used for growing wheat.

Topography varies in Marion County, ranging from a nearly-level Mississippi River floodplain (east) to a prairie region of loess and glacial till (west). However, the topographic features in the county do not significantly affect the climate, which is variable during all seasons. About 60 percent of the annual precipitation [approximately 38 in. (inches)] generally occurs from April through September, and normally is adequate for growing corn, soybeans, and other grains. The average precipitation for December, January, and February is 10 to 15 percent of the annual total, as compared to 25 to 30 percent for March through May, for June through August, and for September through November (Watson, 1984).

## HYDROLOGIC AND HYDRAULIC ANALYSES

Several hydrologic or hydraulic methods can be used to estimate flood discharges for approximate Zone A areas. The HEC-1 model (U.S. Army Corps of Engineers, 1982) was developed for regulated/unregulated stream hydrology estimations and is widely used for flood elevation, discharge, and volume analyses. Thus, to estimate the base (100-year) flood discharge at site BFE 1 (regulated by Hunnewell Lake Dam), the HEC-1 model was selected. For this study, the base (100-year) flood discharges for sites BFE 2 to 14 were estimated from the 100-year regression equation (Region I) in Alexander and Wilson (1995). This regression equation for unregulated streams in rural Missouri requires computations of two specific basin parameters: drainage area and main-channel slope.

The one-dimensional surface-water flow model, HEC-RAS, developed by the U.S. Army Corps of Engineers (1997), was used in this study to compute the base (100-year) flood elevations. HEC-RAS is based on the principle of conservation of streamflow energy, which states that the energy at the upstream valley section is equal to the streamflow energy at the

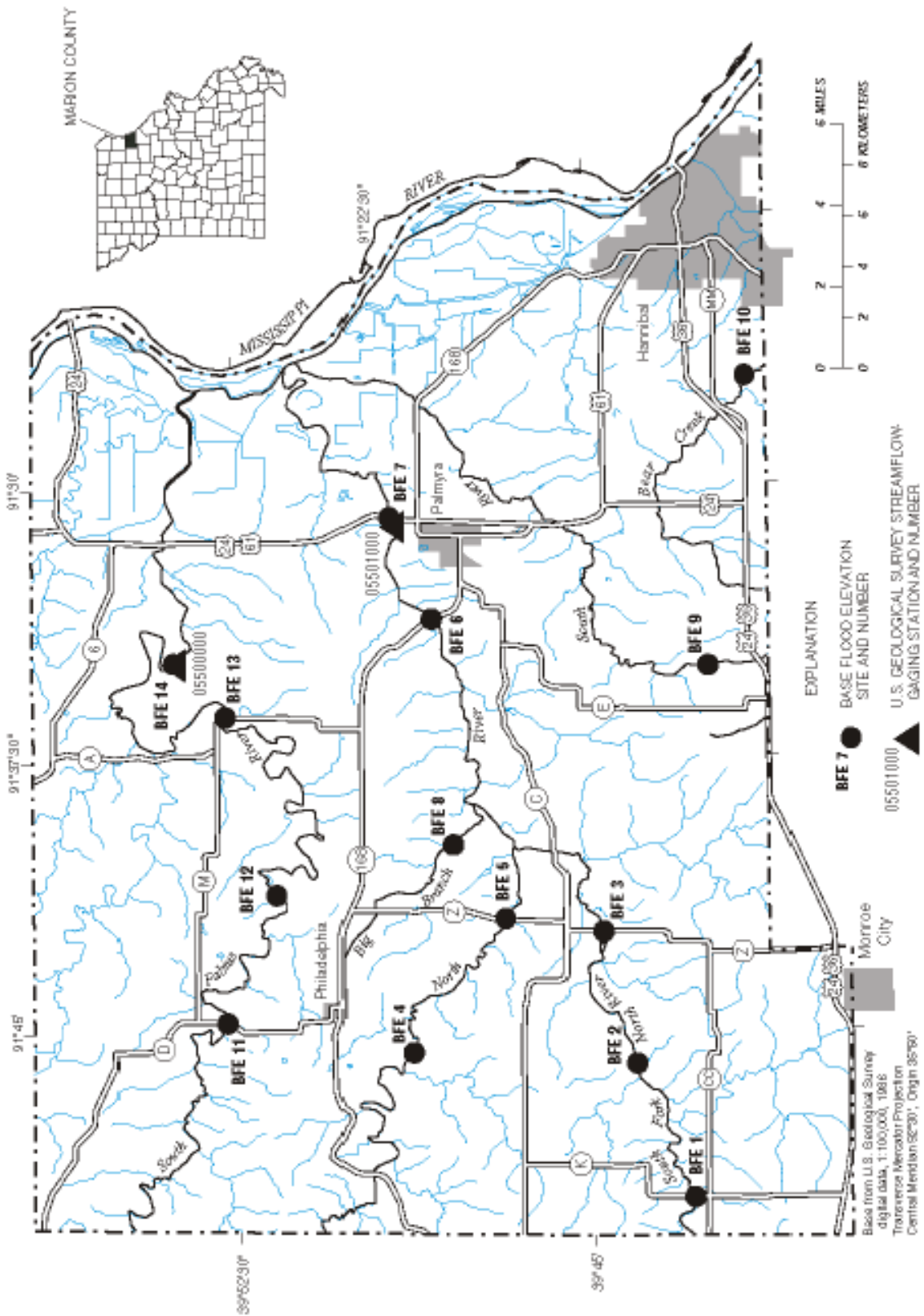


Figure 1. Location of base (100-year) flood elevation sites in Marion County, Missouri.

downstream section plus the friction and transition losses between the two sections. Starting water-surface elevations were verified by normal-depth computations at the farthest downstream valley cross section. Normal depth is the depth expected for a stream when the flow is uniform and steady (U.S. Department of Housing and Urban Development, 1995).

The hydraulic analyses for this study are based on unobstructed flow conditions. Computed base (100-year) flood elevations are valid if hydraulic structures (bridges) remain unobstructed and channel and over-bank flow conditions remain essentially unchanged. Elevations are referenced to the National Geodetic Vertical Datum of 1929, and are called “above sea level” in this report. Elevation, locations, and descriptions of the bench and reference marks are given in table 1, at the back of this report.

### Base Flood Elevation for Site BFE 1

Site BFE 1 on South Fork North River, a tributary to North River, drains 13.9 mi<sup>2</sup> and is located on State Highway K approximately 8 mi (miles) northwest of Monroe City, Missouri, in the southwest corner of Marion County (figs. 1 and 2). The BFE 1 drainage area (13.9 mi<sup>2</sup>) includes approximately 4.0 mi<sup>2</sup> of drainage (about 30 percent) into Hunnewell Lake owned by the Missouri Department of Conservation. Hunnewell Lake Dam creates 228 acres of surface area at normal pool and is used for recreation, wildlife habitat, and supplies water for fish hatchery ponds located

downstream from the dam. South Fork North River flows in an easterly direction with a channel-top width of about 60 ft (feet) and an average channel depth of 7 ft in the vicinity of the road crossing (fig. 2).

Because of the effects on peak discharges caused by Hunnewell Lake Dam, the HEC-1 model (U.S. Army Corps of Engineers, 1982) was used to compute the base (100-year) flood discharge at BFE 1. The HEC-1 model requires the estimation of several parameters: drainage area, dimensionless unit hydrograph, time of concentration, streamflow routing coefficient, and soil-infiltration rate.

To better estimate the HEC-1 model parameters, the South Fork North River BFE 1 drainage area was divided into 4 subbasins (fig. 2). The parameters for each are listed in table 2. The drainage area for each subbasin was measured from USGS 1:100,000-scale digital line graph files. Times of concentration, which are the times in hours between the centroid of rainfall excess and the peak discharge of the runoff hydrograph, were estimated from 7.5-minute topographic maps using the method described by Chow (1964). Muskingum coefficients were estimated for use in the streamflow routing equations to simulate movement of runoff through the streams and channels within the basin. Soil-infiltration rates were estimated using the Soil Conservation Service (SCS) curve number method, which relates soil loss to runoff as a function of soil cover, land-use type, and antecedent moisture conditions (Soil Conservation Service, 1972). The spillway rating used in the model was obtained from

**Table 2.** The HEC-1 model parameters with/without Hunnewell Lake Dam used to simulate peak discharge for 100-year, 1-, 2-, and 3-hour rainfall at the South Fork North River BFE 1 site near Monroe City, Missouri

[mi<sup>2</sup>, square miles; TC, time of concentration; h, hours; K, Muskingum routing-subbasin travel time; X, Muskingum routing coefficient; SCS, Soil Conservation Service; --, no data]

Subbasin number (fig. 2)	Drainage area (mi <sup>2</sup> )	TC (h)	K (h)	X	SCS curve number for 100-year, 1-, 2-, and 3-hour rainfalls
1	4.0	2.5 <sup>1</sup> , 0.4 <sup>2</sup>	1.45	0.25	90
2	4.3	3.4	1.15	.25	90
3	3.1	3.1	.50	.25	90
4	2.5	2.4	--	--	90

<sup>1</sup>Unregulated, without Hunnewell Lake Dam.

<sup>2</sup>Regulated, with Hunnewell Lake Dam.

the Application for Registration Permit, Hunnewell Lake, Shelby County, Missouri (Missouri Department of Conservation, written commun., 1989).

To determine which 100-year rainfall parameter [1-, 2-, or 3-hour duration (Huff and Angel, 1992)] would be the best input for the HEC-1 model, the model was calibrated first without Hunnewell Lake Dam using the regression equation 100-year peak discharge of 6,190 ft<sup>3</sup>/s as the target discharge (Alexander and Wilson, 1995). The 100-year, 3-hour rainfall (4.50 in.) yielded the closest result and was therefore used as the rainfall parameter in the HEC-1 model with Hunnewell Lake Dam in place. The regulated HEC-1 model simulation computed a base (100-year) flood discharge of 5,160 ft<sup>3</sup>/s (tables 3 and 4).

The base (100-year) flood elevation for site BFE 1 determined from HEC-RAS analyses is 627.7 feet above sea level (table 4). Six cross sections were used in the analyses, including two valley and channel cross sections (5 and 6) obtained by field (transit-stadia) surveys at or near BFE 1 (fig. 2) and aligned perpendicular to the assumed direction of flow. Also, 7.5-minute topographic maps were used to supplement the field survey cross-section data (1–4) where needed. During the field survey, a main-channel cross section of South Fork North River was defined from the downstream side of the State Highway K bridge. Pertinent bridge and embankment geometry details for the piers, wingwalls, abutment/embankment slopes, and road profile were obtained from field survey. Manning’s roughness coefficients used in the HEC-RAS analyses were determined from field observations (Arcement and

Schneider, 1989) and ranged from 0.045 to 0.055 for the main channel and from 0.075 to 0.100 for the floodplain. The starting water-surface elevation was determined by normal-depth computations and from HEC-RAS convergence analyses.

### Base Flood Elevation for Site BFE 2

Site BFE 2 on South Fork North River, a tributary to North River, is located about 2.1 mi north of State Highway CC on County Road 231, and approximately 9 mi north of Monroe City, near the southwest corner of Marion County (figs. 1 and 3). South Fork North River flows in an easterly direction at site BFE 2 and has a channel-top width of about 120 ft and an average channel depth of 10 ft in the vicinity of the road crossing. The 59.0-mi<sup>2</sup> drainage basin upstream from site 2 predominantly is farmland (rural). Using the Alexander and Wilson (1995) 100-year recurrence-interval regression equation gives a base (100-year) flood discharge of 13,400 ft<sup>3</sup>/s for site BFE 2 (table 4).

The base (100-year) flood elevation for site BFE 2 is 579.2 feet above sea level (table 4). Six cross sections were used in the HEC-RAS analyses to determine BFE 2, including three valley and channel cross sections (4–6) obtained by field (transit-stadia) survey at or near BFE 2 (fig. 3). During the field survey, a main-channel cross section of South Fork North River was defined from the downstream side of County Road 231 bridge. Also, pertinent bridge and embankment geometry of piers, wingwalls, abutment/embankment slopes,

**Table 3.** Peak discharges with/without Hunnewell Lake Dam, simulated by HEC-1 model, for 100-year, 1-, 2-, and 3-hour rainfall at the South Fork North River BFE 1 site near Monroe City, Missouri

[in., inch; ft<sup>3</sup>/s, cubic feet per second; --, not determined]

	Simulated peak discharge (ft <sup>3</sup> /s)		
	100-year, 1-hour (3.50 in. rainfall)	100-year, 2-hour (4.20 in. rainfall)	100-year, 3-hour (4.50 in. rainfall)
Unregulated, without Hunnewell Lake Dam	4,650	5,810	6,190
Regulated, with Hunnewell Lake Dam	--	--	5,160

**Table 4.** Summary of base (100-year) flood discharges and elevations for selected sites in Marion County, Missouri[mi<sup>2</sup>, square mile; ft/mi, foot per mile; ft<sup>3</sup>/s, cubic foot per second; ft, foot]

Map no. (fig. 1)	Stream and location	Drainage area (A) (mi <sup>2</sup> )	Main-channel slope (S) (ft/mi)	Base (100-year) flood discharge <sup>1</sup> (ft <sup>3</sup> /s)	Base (100-year) flood elevation <sup>2</sup> (ft)
BFE 1	South Fork North River at State Highway K near Monroe City, Mo.	13.9	23.1	5,160 <sup>3</sup>	627.7
BFE 2	South Fork North River at County Road 231 near Monroe City, Mo.	59.0	14.2	13,400	579.2
BFE 3	South Fork North River at State Highway Z near Monroe City, Mo.	75.3	12.0	14,900	545.9
BFE 4	North River at County Road 195 near Philadelphia, Mo.	187	5.43	20,500	560.5
BFE 5	North River at State Highway Z near Philadelphia, Mo.	199	5.24	21,000	539.7
BFE 6	North River at State Highway 168 near Palmyra, Mo.	348	5.18	30,200	504.2
BFE 7	North River at U.S. Highway 24–61 at Palmyra, Mo.	359	5.15	31,200	494.4
BFE 8	Big Branch at County Road 230 near Philadelphia, Mo.	18.3	29.6	8,080	530.5
BFE 9	South River at County Road 272 near Monroe City, Mo.	10.4	17.5	4,650	619.1
BFE 10	Bear Creek at County Road 418 near Hannibal, Mo.	21.8	16.0	7,320	565.5
BFE 11	South Fabius River at State Highway D near Philadelphia, Mo.	363	3.96	28,300	591.2
BFE 12	South Fabius River at County Road 159 near Philadelphia, Mo.	379	3.92	28,900	578.4
BFE 13	South Fabius River at State Highway A near Palmyra, Mo.	394	3.40	28,300	538.7
BFE 14	South Fabius River at County Road 315 near Palmyra, Mo.	605	3.13	36,200	506.9

<sup>1</sup>Alexander and Wilson (1995), Q100=376(A)0.652 (S)0.346, Region I.<sup>2</sup>Above seal level.<sup>3</sup>From HEC-1 analysis at site BFE1.



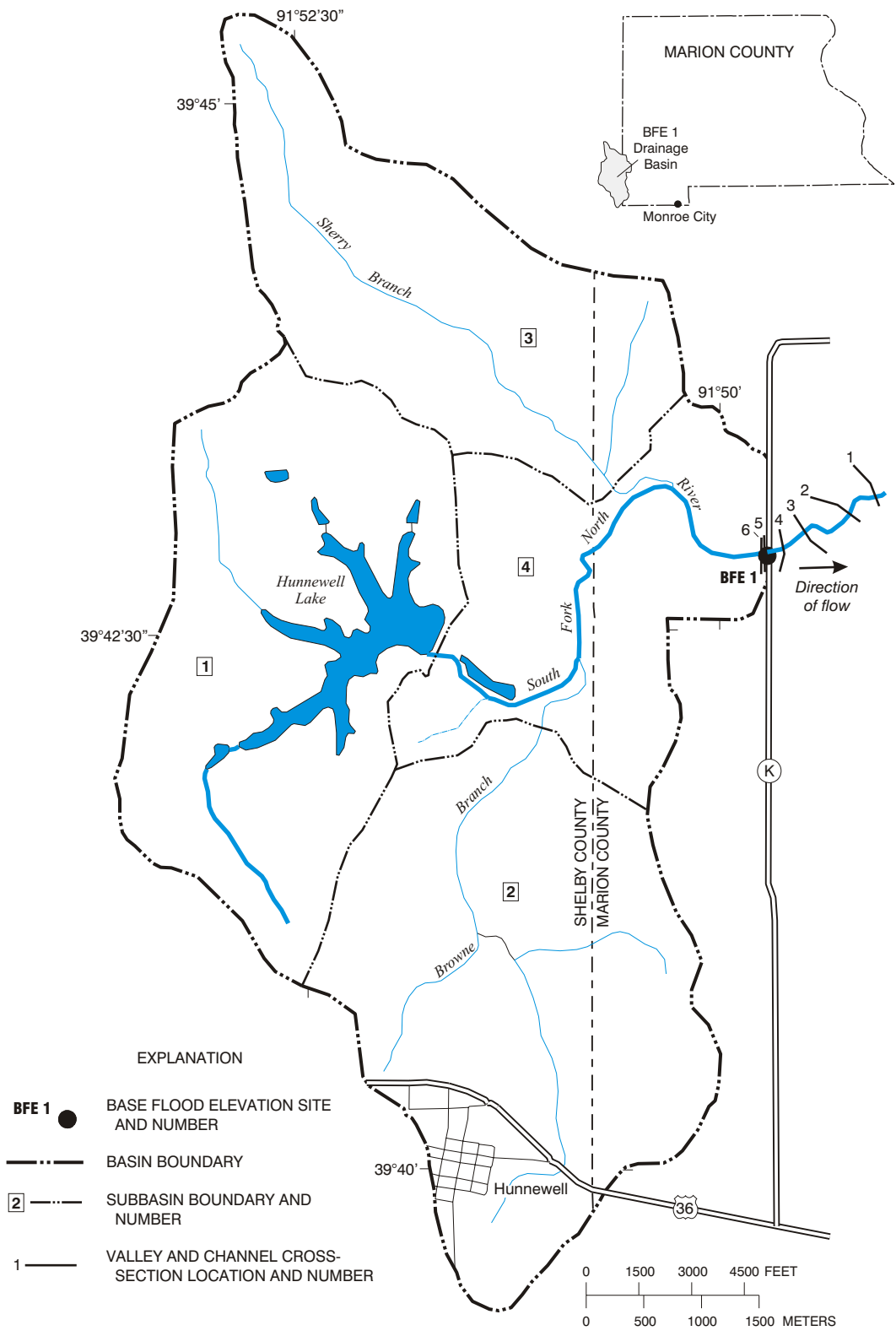
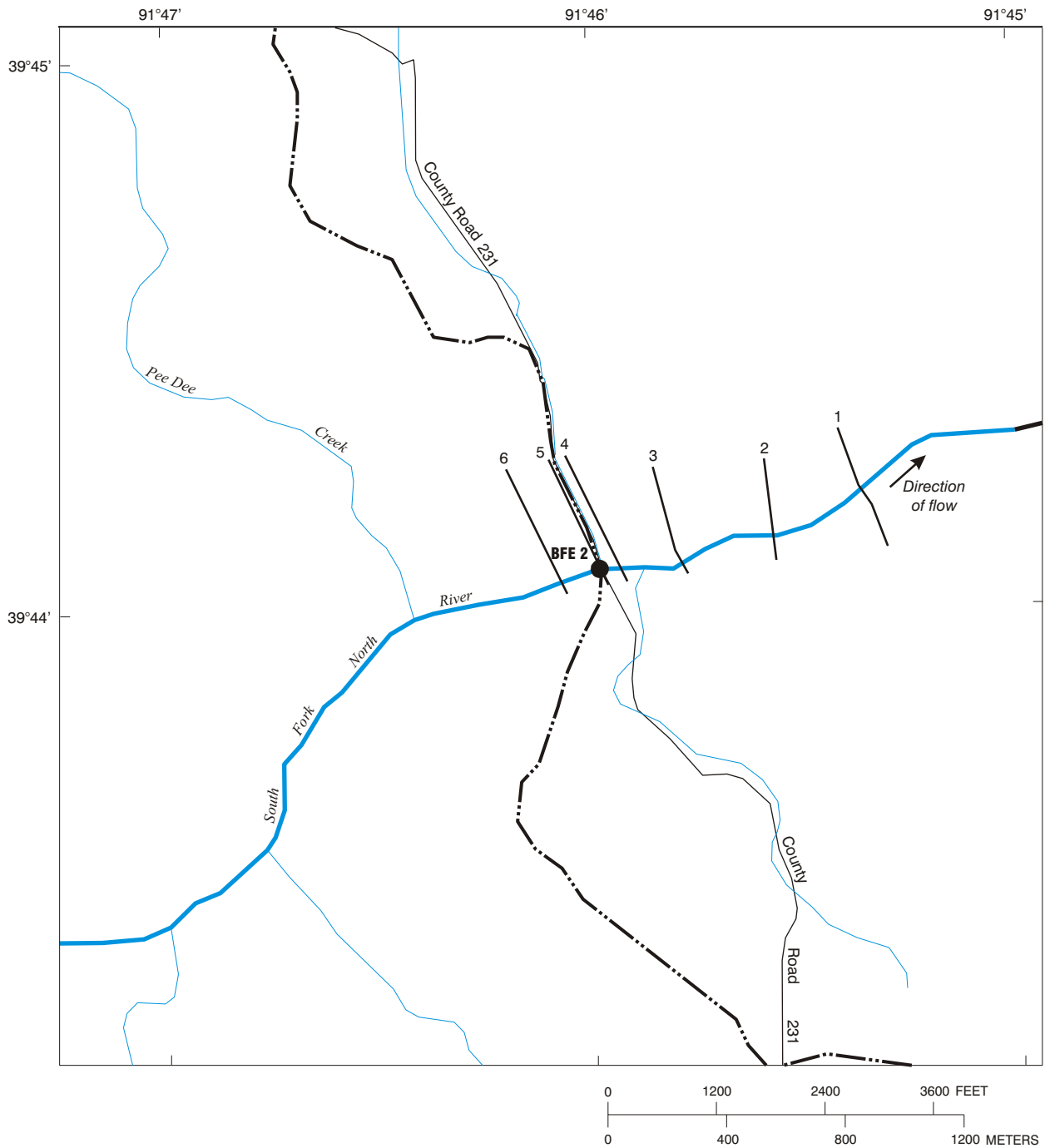


Figure 2. South Fork North River base (100-year) flood elevation site (BFE 1) near Monroe City, Missouri.



EXPLANATION

- BFE 2** ● BASE FLOOD ELEVATION SITE AND NUMBER
- · — · — BASIN BOUNDARY
- 1 — VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

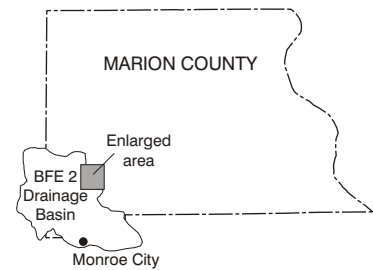


Figure 3. South Fork North River base (100-year) flood elevation site (BFE 2) near Monroe City, Missouri.

and road profile were obtained from the field survey. Topographic maps (7.5-minute) were used to supplement the field survey cross-section data (1–3) where needed. Manning’s roughness coefficients used in the HEC-RAS analyses were determined from field observations (Arcement and Schneider, 1989) and ranged from 0.042 to 0.052 for the main channel and from 0.070 to 0.150 for the floodplain. The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### **Base Flood Elevation for Site BFE 3**

Site BFE 3 on South Fork North River, a tributary to North River, is located on State Highway Z about 6 mi north of U.S. Highway 24–36 and approximately 7 mi north of Monroe City, in the southwest part of Marion County (figs. 1 and 4). South Fork North River flows in an easterly direction at or near site BFE 3, with State Highway Z structures causing little or no constriction to flow across the floodplain. South Fork North River has a channel-top width of about 130 ft and an average channel depth of 14 ft in the vicinity of the road crossing. Upstream from site 3, the majority of the 75.3-mi<sup>2</sup> drainage area is farmland (rural). The 100-year recurrence-interval computed from the regression equation (Alexander and Wilson, 1995) for rural basins gives a base (100-year) flood discharge of 14,900 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 3 is 545.9 feet above sea level (table 4). Six cross sections were used in the HEC-RAS analyses, including three valley cross sections (4–6) obtained by field (transit-stadia) survey at or near BFE 3 (fig. 4) and aligned perpendicular to the assumed direction of flow. During the field survey, a South Fork North River main-channel cross section was defined from the downstream side of State Highway Z bridge. Bridge-geometry information for the site included details for the piers, wing-walls, abutment/embankment slopes, and road profile from the field survey. However, the subsequent analysis suggested that the bridge section was not acting as a contracted opening at the 100-year discharge; therefore, the State Highway Z bridge and road section were analyzed as a composite valley section. Manning’s roughness coefficients used in the HEC-RAS analyses were determined from field observations (Arcement and Schneider, 1989) and ranged from 0.042 to 0.055 for the main channel and from 0.060 to 0.150 for the

floodplain. The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

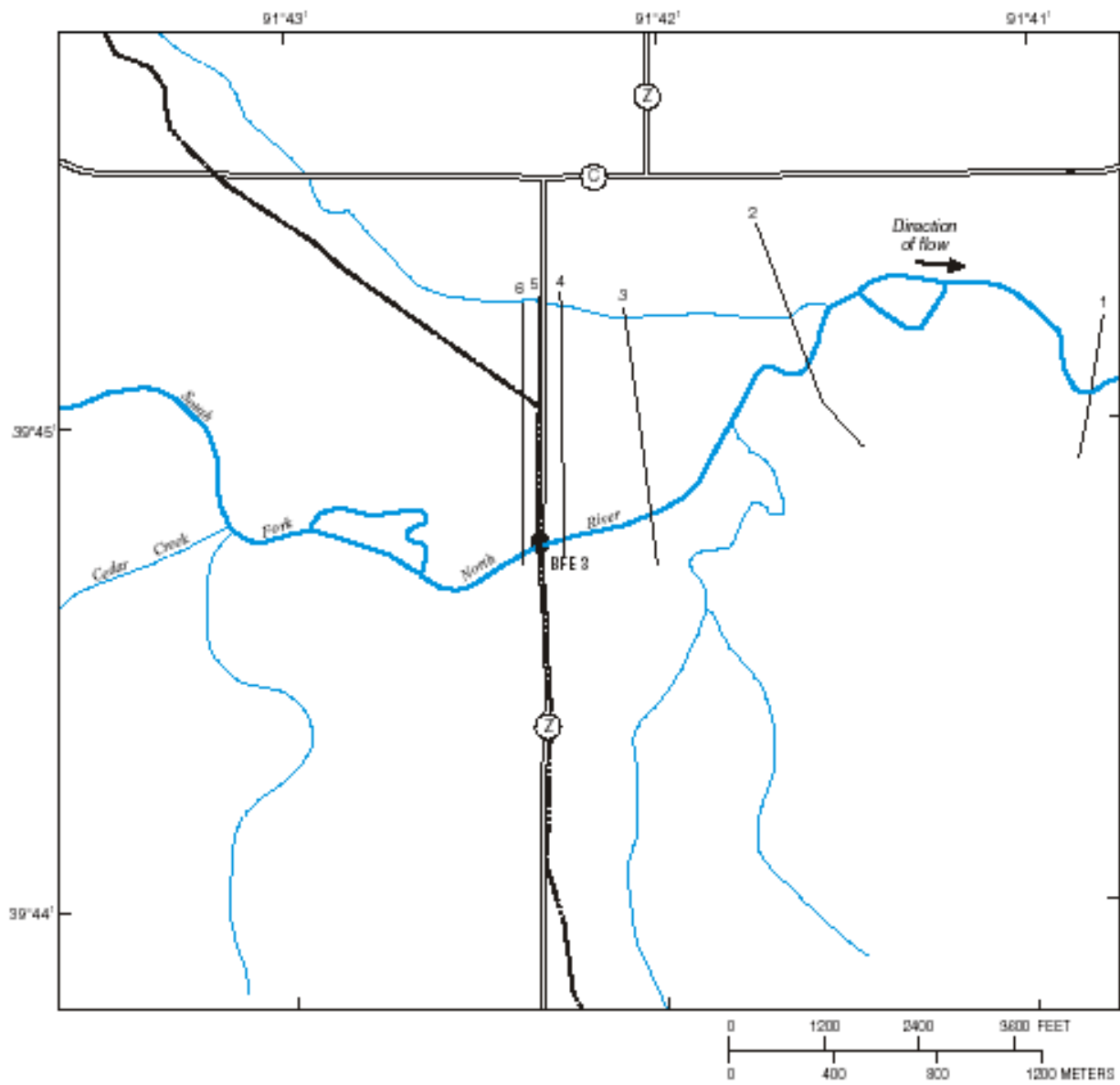
### **Base Flood Elevation for Site BFE 4**

Site BFE 4 on the North River, a tributary to the Mississippi River, is located about 2.0 mi south of State Highway 168 along County Road 195 and approximately 3 mi south of Philadelphia, near the west-central part of Marion County (figs. 1 and 5). North River flows in an easterly direction at site 4, with County Road 195 structures causing little or no constriction to the flow across the floodplain. In the vicinity of the road crossing, North River has a channel-top width of about 160 ft, and an average depth of about 13 ft. The 187-mi<sup>2</sup> drainage basin upstream from site 4 predominantly is farmland (rural). The 100-year recurrence-interval computed from the regression equation from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 20,500 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 4 is 560.5 feet above sea level (table 4). Three valley and channel cross sections (4–6) were obtained by field (transit-stadia) surveys at or near the BFE 4 location (fig. 5); also, 7.5-minute topographic maps were used to estimate three valley cross sections (1–3) downstream from site 4. During the field survey, a North River main-channel cross section was defined from the downstream side of County Road 195 bridge. However, the County Road 195 bridge and road section were analyzed as a composite valley section. Manning’s roughness coefficients used in the analyses were determined from field observations (Arcement and Schneider, 1989). Coefficients ranged from 0.045 to 0.055 for the main channel and from 0.060 to 0.200 for the floodplain. The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### **Base Flood Elevation for Site BFE 5**

Site BFE 5 on North River, a tributary to the Mississippi River, is located on State Highway Z about 3.9 mi south of State Highway 168 and approximately 6 mi southeast of Philadelphia, near the central part of Marion County (figs. 1 and 6). The North River main channel meanders downstream from the Highway Z bridge, then flows east a short distance before its confluence

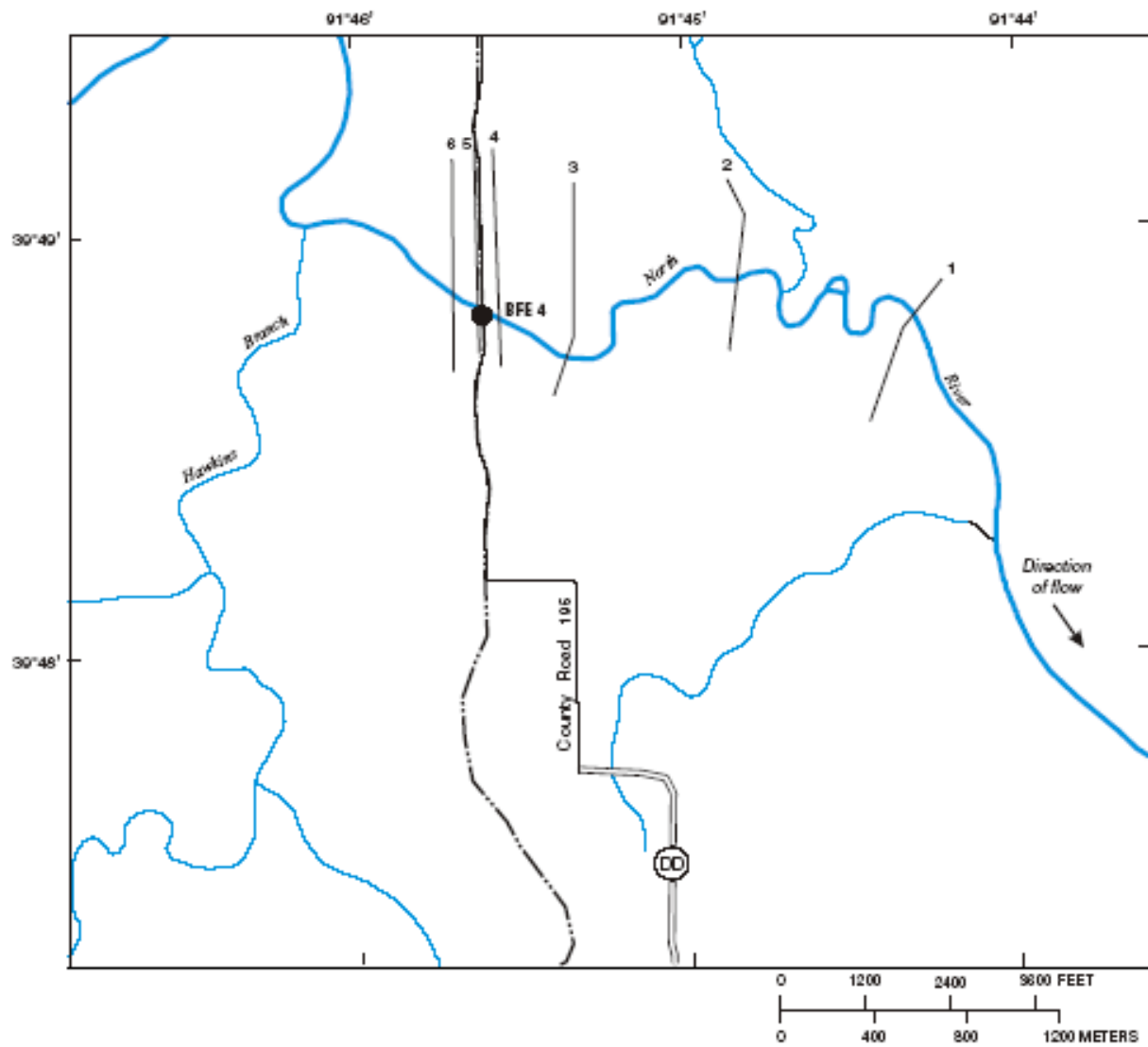


EXPLANATION

- BFE 3 ● BASE FLOOD ELEVATION SITE AND NUMBER
- BASIN BOUNDARY
- 1 — VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER



Figure 4. South Fork North River base (100-year) flood elevation site (BFE 3) near Monroe City, Missouri.



- EXPLANATION
- BFE 4** ● BASE FLOOD ELEVATION SITE AND NUMBER
  - BASIN BOUNDARY
  - 1 — VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

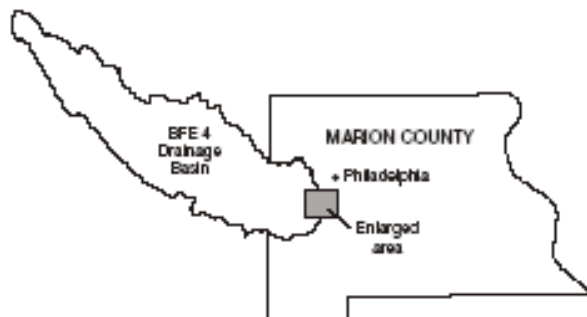


Figure 5. North River base (100-year) flood elevation site (BFE4) near Philadelphia, Missouri.

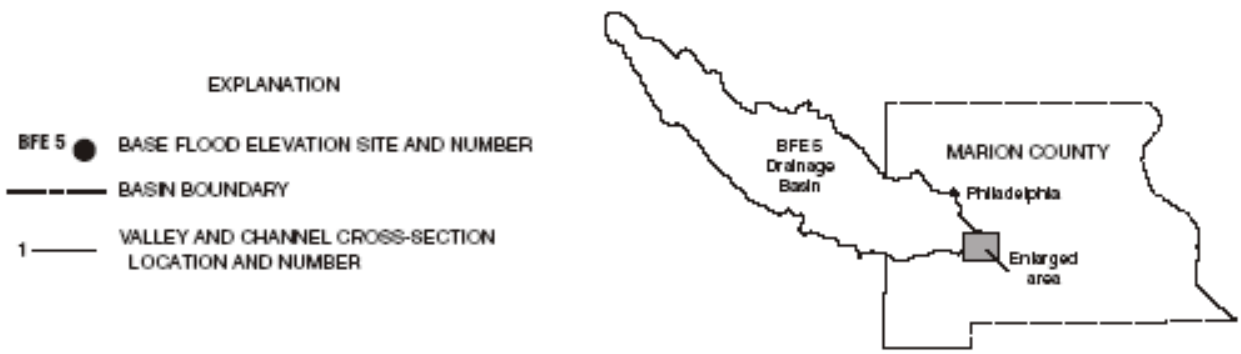
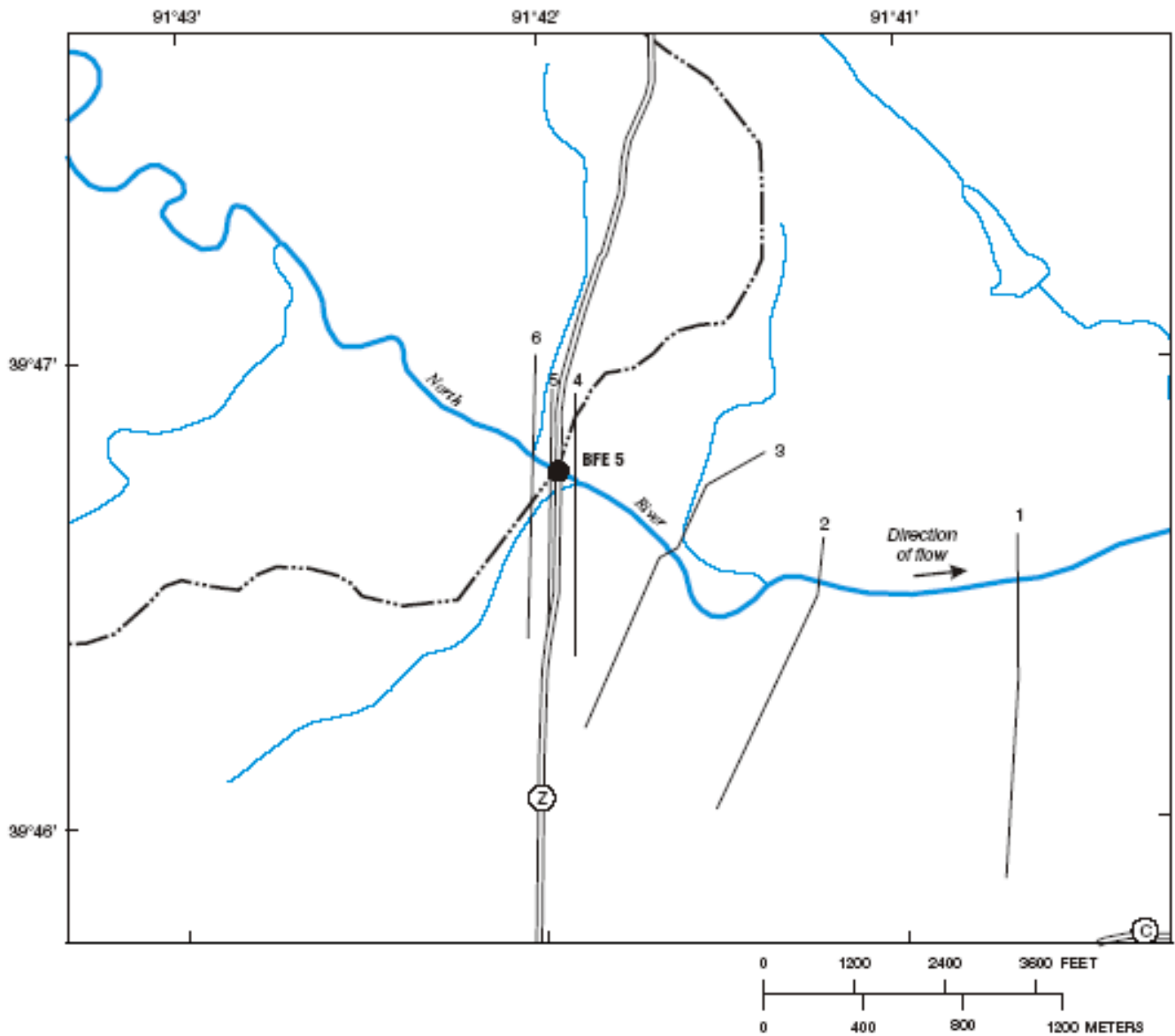


Figure 6. North River base (100-year) flood elevation site (BFE 5) near Philadelphia, Missouri.

with the South Fork North River. In the vicinity of the road crossing, North River has a channel-top width of about 150 ft, and an average depth of about 12 ft. The 199-mi<sup>2</sup> drainage basin upstream from site 5 predominantly is rural; the 100-year recurrence-interval computed from the regression equation from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 21,000 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 5 is 539.7 feet above sea level (table 4). Six cross sections were used in the HEC-RAS computations, including three valley and channel cross sections (4–6) obtained by field (transit-stadia) survey at or near the BFE 5 site (fig. 6); also, 7.5-minute topographic maps were used to estimate three cross sections (1–3) downstream from site 5. The geometry of the North River main-channel cross section was defined along the downstream side of State Highway Z bridge. Bridge and embankment geometry data of the piers, wingwalls, abutment/embankment slopes, road profile, and other hydraulic features were measured during the field survey. Manning's roughness coefficients used in the analyses were determined from field observations (Arcement and Schneider, 1989). Coefficients ranged from 0.042 to 0.054 for the main channel and from 0.100 to 0.150 for the floodplain. The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### Base Flood Elevation for Site BFE 6

Site BFE 6 on North River, a tributary to the Mississippi River, is located on State Highway 168 approximately 2 mi west of Palmyra, near the central part of Marion County (figs. 1 and 7). North River has a channel-top width of about 145 ft, and an average depth of about 14 ft in the vicinity of the road crossing. The 348-mi<sup>2</sup> drainage area upstream from site 6 predominantly is rural; the 100-year recurrence-interval computed from the regression equation from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 30,200 ft<sup>3</sup>/s (table 4).

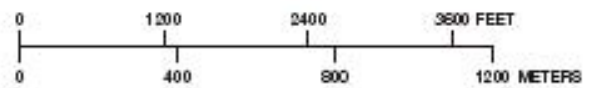
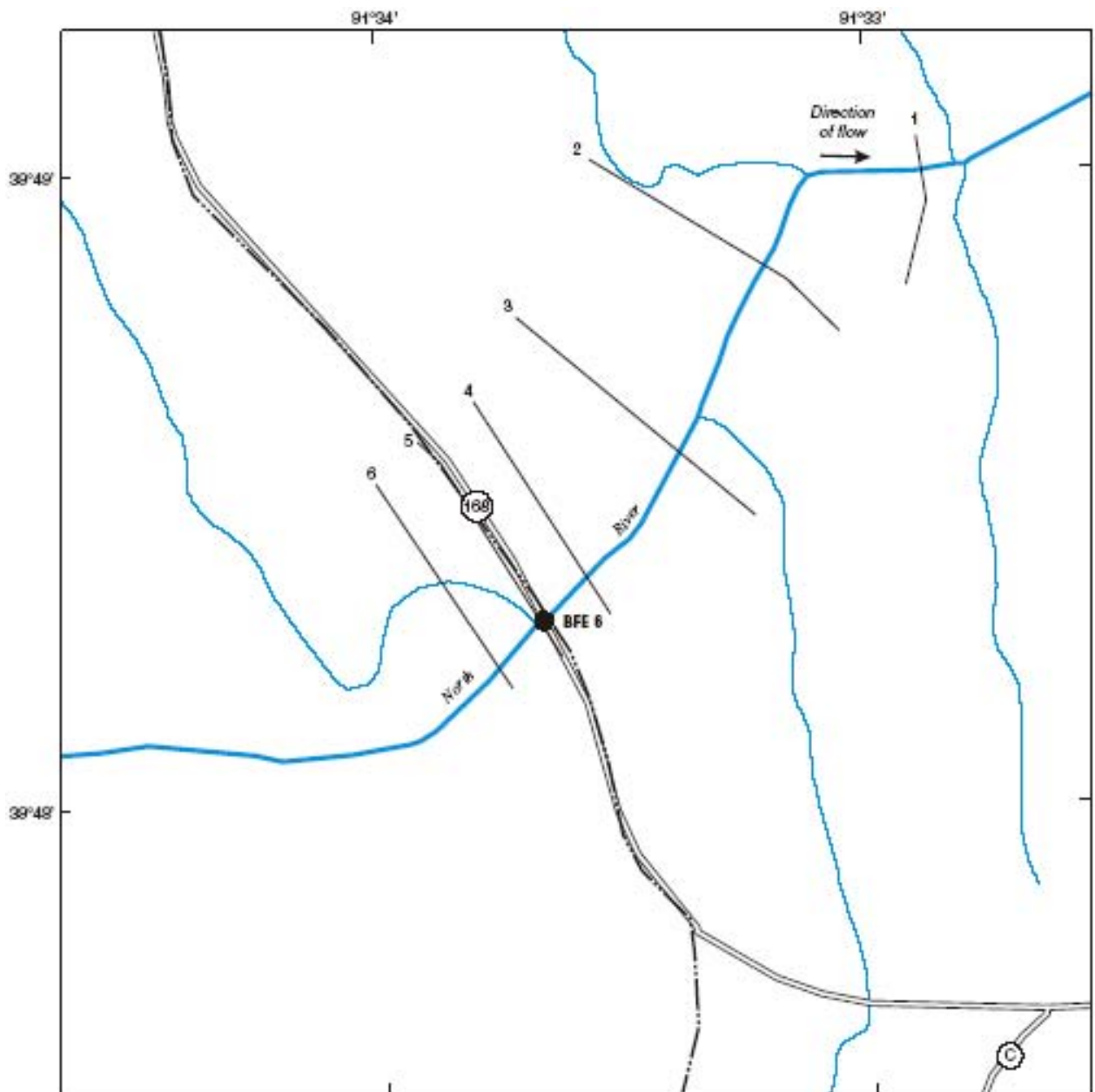
The base (100-year) flood elevation for site BFE 6 is 504.2 feet above sea level (table 4). Three valley and channel cross sections (4–6) were obtained by field (transit-stadia) survey at or near BFE 6 (fig. 7); also, 7.5-minute topographic maps were used to estimate three valley cross sections (1–3) downstream from site 6. During the field survey, a main-channel cross section

of North River was taken along the downstream side of the State Highway 168 bridge. The Highway 168 bridge and embankment geometry details for the piers, wingwalls, abutment/embankment slopes, road profile, and other hydraulic features were measured during the field survey. Manning's roughness coefficients used in the analysis were determined from field observations (Arcement and Schneider, 1989). Coefficients ranged from 0.042 to 0.050 for the main channel and from 0.100 to 0.150 for the floodplain. The starting water-surface elevation was determined by normal-depth computation and from the HEC-RAS convergence analyses.

### Base Flood Elevation for Site BFE 7

Site BFE 7 on North River, a tributary to the Mississippi River, is located on U.S. Highway 24–61 about 1 mi north of Palmyra, in the east-central part of Marion County (figs. 1 and 8). In the vicinity of the road crossing, North River has an average channel-top width of 170 ft, and an average channel depth of 15 ft. The 359-mi<sup>2</sup> drainage basin upstream from site 7 predominantly is rural; the 100-year recurrence interval computed from the regression equation from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 31,200 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 7 is 494.4 feet above sea level (table 4). Six cross sections were used in the HEC-RAS analyses, including three valley and channel cross sections (4–6) obtained by field (transit-stadia) survey at the BFE 7 location (fig. 8); these cross sections were surveyed perpendicular to the assumed direction of flow. Also, 7.5-minute topographic maps were used to estimate three valley cross sections (1–3) downstream from U.S. Highway 24–61. The geometry of the existing North River main-channel cross section was taken along the upstream side of the south-bound lane of U.S. Highway 24–61 bridge. All pertinent bridge and embankment geometry details for the piers, wingwalls, abutment/embankment slopes, and road profile were measured during the field survey. Manning's roughness coefficients used in the analyses were determined from field observations of the stream and floodplain (Arcement and Schneider, 1989). Coefficients ranged from 0.040 to 0.050 for the main channel and from 0.100 to 0.150 for the floodplain. A USGS streamflow-gaging station (05501000) is located approximately 1,000 ft upstream from the BFE 7 site (fig. 8). During the gaging-station period of



EXPLANATION

- BFE 6** ● BASE FLOOD ELEVATION SITE AND NUMBER
- BASIN BOUNDARY
- 1— VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

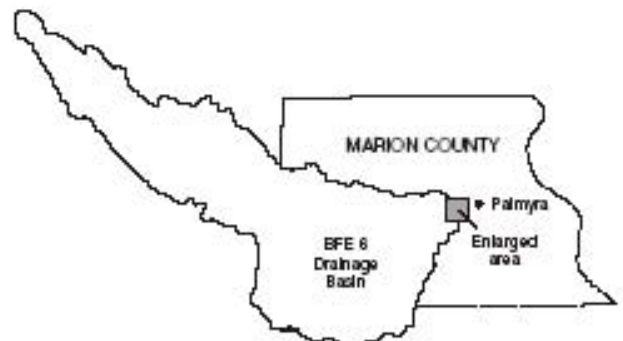
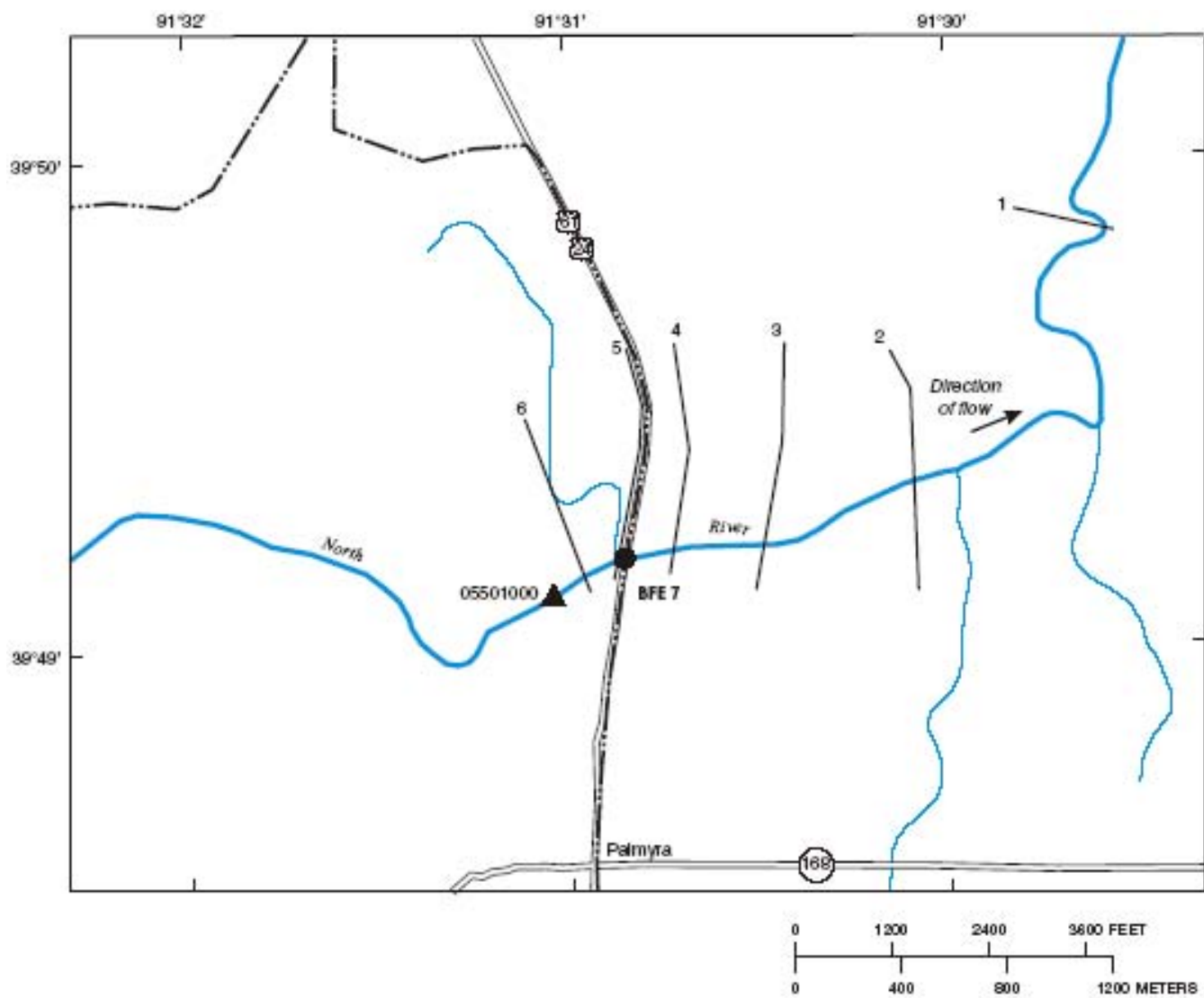


Figure 7. North River base (100-year) flood elevation site (BFE 6) near Palmyra, Missouri.





- EXPLANATION**
- BFE 7** ● BASE FLOOD ELEVATION SITE AND NUMBER
  - 05501000** ▲ U.S. GEOLOGICAL SURVEY STREAMFLOW GAGING STATION AND NUMBER
  - BASIN BOUNDARY
  - 1** --- VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

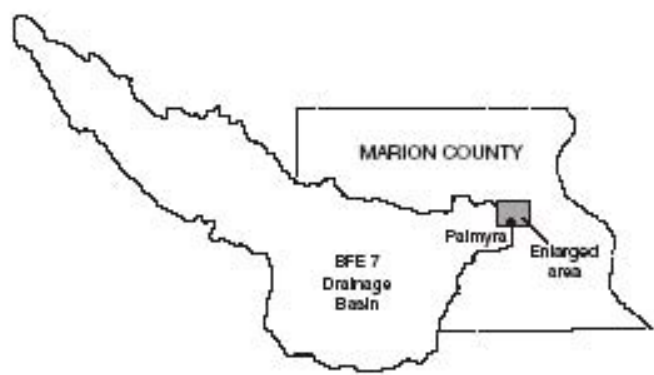


Figure 8. North River base (100-year) flood elevation site (BFE 7) near Palmyra, Missouri.

record, 1935 to 1998, a few occurrences of Mississippi River backwater have been recorded at site 7. For this study, the 1993 (backwater) flood-peak elevation of 494.17 feet above sea level and a discharge of 28,600 ft<sup>3</sup>/s were used to determine the starting water-surface elevation for the HEC-RAS analysis.

### Base Flood Elevation for Site BFE 8

Site BFE 8 on Big Branch, a tributary to North River, is located about 1.8 mi east of State Highway Z along County Road 230 and approximately 7 mi south-east of Philadelphia, in the central part of Marion County (figs. 1 and 9). County Road 230 (bridge or other structures) causes minimal or no constriction to flow across the floodplain. In the vicinity of the road crossing, Big Branch has an average channel-top width of 70 ft, and an average channel depth of 7 ft. The 18.3-mi<sup>2</sup> drainage area upstream from site 8 predominantly is rural; the 100-year recurrence interval computed from the regression equation from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 8,080 ft<sup>3</sup>/s for site BFE 8 (table 4).

The base (100-year) flood elevation for site BFE 8 is 530.5 feet above sea level (table 4). Five cross sections (3–7) were obtained by field (transit-stadia) survey at or near the site (fig. 9); also, two valley cross sections estimated from 7.5-minute topographic maps (1 and 2) were used to extend the study reach downstream from site 8. During the field survey, a Big Branch main-channel cross section was defined from the downstream side of County Road 230 bridge. However, the County Road 230 bridge and road section were analyzed as a composite valley section. Manning's roughness coefficients ranged from 0.042 to 0.048 for the main channel and from 0.060 to 0.150 for the floodplain (Arcement and Schneider, 1989). The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### Base Flood Elevation for Site BFE 9

Site BFE 9 on South River, a tributary to the Mississippi River, is located about 1 mi east of State Highway E along County Road 272 and approximately 10 mi northeast of Monroe City, in south-central Marion County (figs. 1 and 10). In the vicinity of the road crossing, South River has an average channel-top width of 35 ft, and an average channel depth of 8 ft. The 10.4-

mi<sup>2</sup> drainage basin upstream from site 9 is a mixture of woods and pasture (rural). The 100-year recurrence interval computed from the regression equation for rural basins from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 4,650 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 9 is 619.1 feet above sea level (table 4). Seven cross sections (fig. 10) were used in the HEC-RAS analyses, with 7.5-minute topographic maps used to estimate four valley cross sections (1–4) downstream from site 9. Three valley and channel cross sections (5–7) were obtained by field (transit-stadia) survey; these cross sections were surveyed perpendicular to the assumed direction of flow. During the field survey, main-channel cross sections for South River and tributary (West) were defined along the downstream side of County Road 272. Pertinent bridge and embankment geometry details for the piers, wingwalls, abutment/embankment slopes, and road profile were obtained from the field survey. Manning's roughness coefficients ranged from 0.050 to 0.052 for the main channel and from 0.125 to 0.250 for the floodplain (Arcement and Schneider, 1989). The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### Base Flood Elevation for Site BFE 10

Site BFE 10 on Bear Creek, a tributary to the Mississippi River, is located about 1.5 mi east of the junction of State Highway MM and U.S. Highway 36 on County Road 418 and approximately 3 mi west of Hannibal, near the southeast corner of Marion County (figs. 1 and 11). Bear Creek has a channel-top width of about 80 ft and an average channel depth of 6 ft in the vicinity of the road crossing. The 21.8-mi<sup>2</sup> drainage area upstream from site 8 predominantly is rural; the 100-year recurrence-interval computed from the regression equation for rural basins from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 7,320 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 10 is 565.5 feet above sea level (table 4). Three valley and channel cross sections (5–7) were obtained by field (transit-stadia) survey at or near the BFE 10 location (fig. 11). Also, 7.5-minute topographic maps were used to estimate four valley cross sections (1–4) and to supplement the field surveyed data where needed. During the field survey, a main-channel cross section of Bear

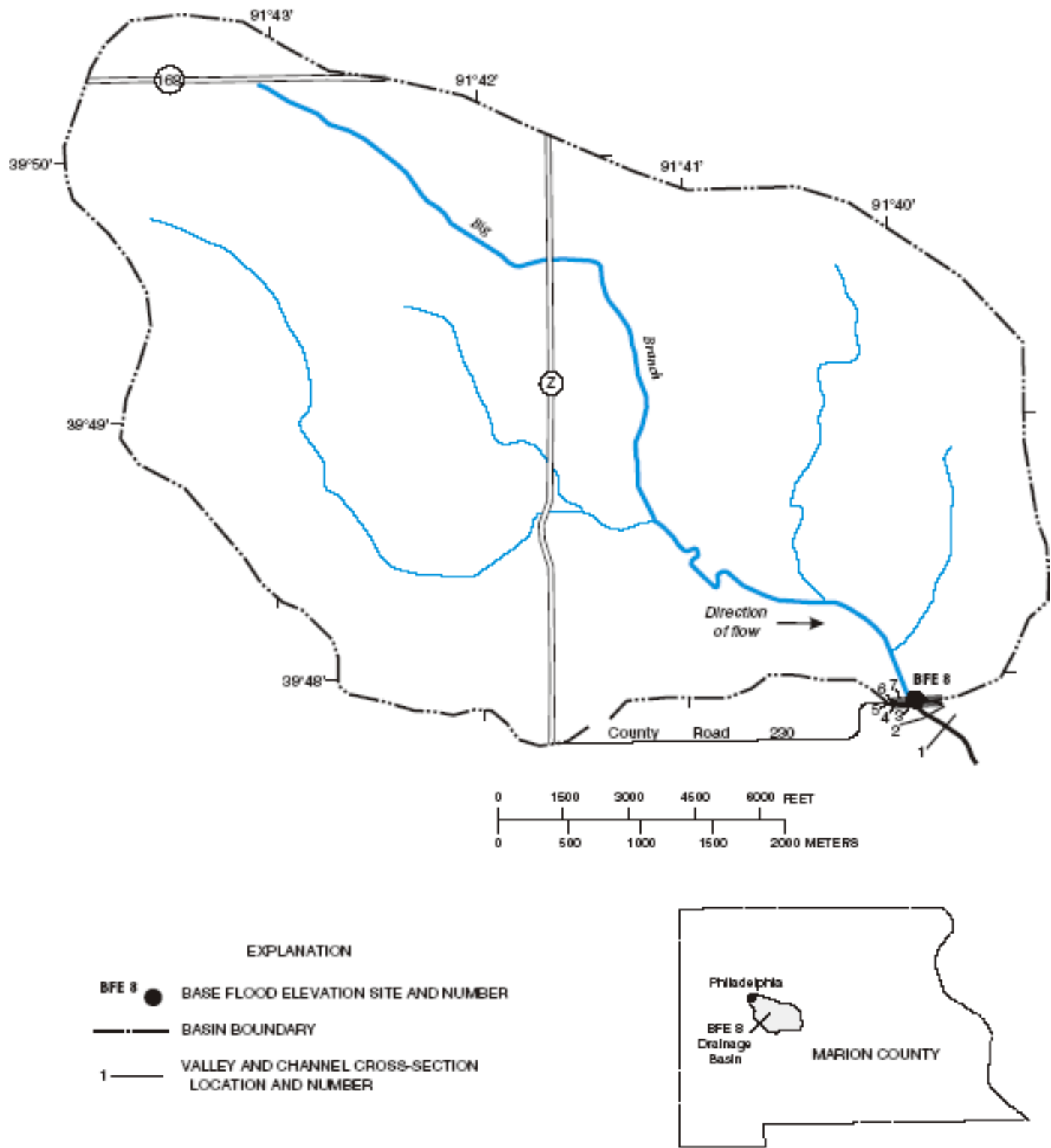


Figure 9. Big Branch base (100-year) flood elevation site (BFE 8) near Philadelphia, Missouri.

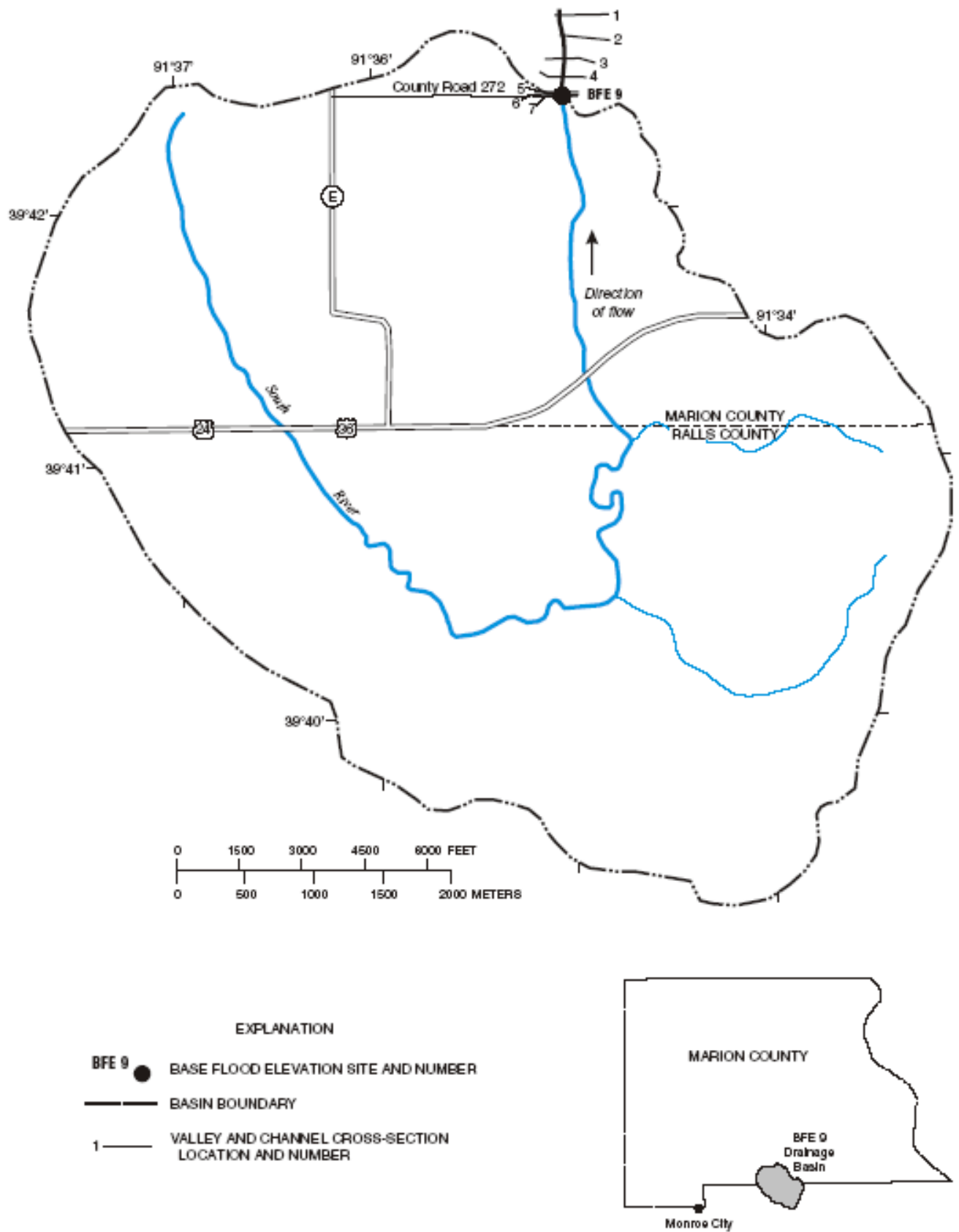
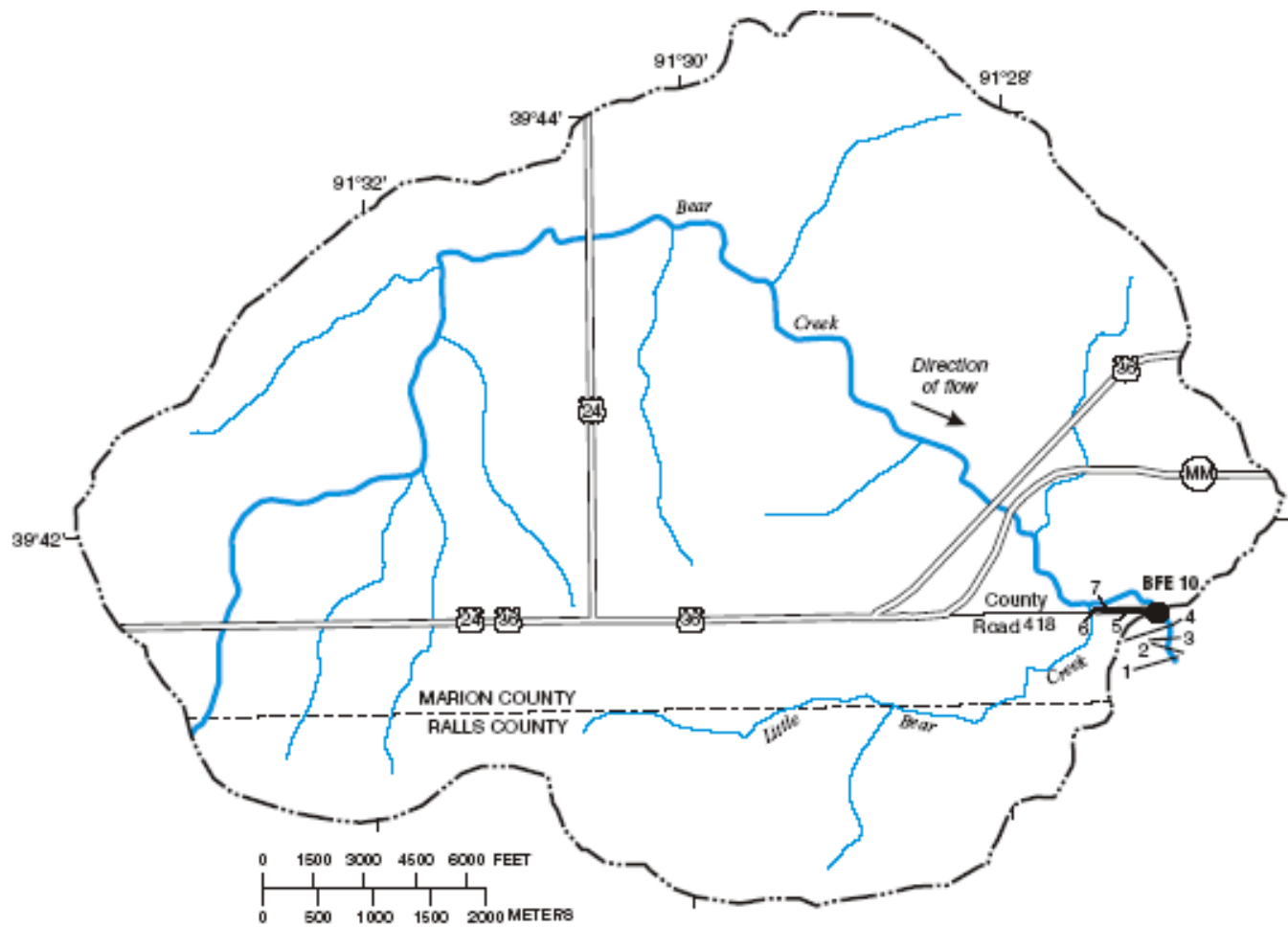


Figure 10. South River base (100-year) flood elevation site (BFE 9) near Monroe City, Missouri.



EXPLANATION

- BFE 10 ● BASE FLOOD ELEVATION SITE AND NUMBER
- BASIN BOUNDARY
- 1 --- VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

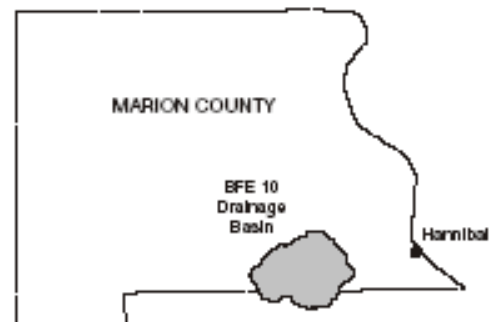


Figure 11. Bear Creek base (100-year) flood elevation site (BFE 10) near Hannibal, Missouri.

Creek was defined along the downstream side of the County Road 418 bridge. In this study, the effect of the railroad bridge and embankment (approximately 1,000 ft downstream) was considered in the HEC-RAS analyses. Pertinent County Road 418 bridge and railroad bridge geometry data for the piers, wingwalls, and abutment/embankment slopes were obtained during the field survey. Manning's roughness coefficients ranged from 0.042 to 0.047 for the main channel and from 0.100 to 0.150 for the floodplain (Arcement and Schneider, 1989).

### **Base Flood Elevation for Site BFE 11**

Site BFE 11 on the South Fabius River, a tributary to the Fabius River, is located on State Highway D approximately 2.8 mi north of Philadelphia, in the northwest part of Marion County (figs. 1 and 12). The South Fabius River has an average channel-top width of 140 ft and an average channel depth of 14 ft in the vicinity of the road crossing. The 363-mi<sup>2</sup> drainage area upstream from site 11 predominantly is rural; the 100-year recurrence-interval computed from the regression equation for a rural basin from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 28,300 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 11 is 591.2 feet above sea level (table 4). Three valley and channel cross sections (4–6) were obtained by field (transit-stadia) survey at or near the BFE 11 location (fig. 12), with 7.5-minute topographic maps used to estimate three valley sections (1–3) downstream from site 11. During the field survey, a main-channel cross section of the South Fabius River was defined along the downstream side of the State Highway D bridge. Pertinent bridge and embankment geometry data for the piers, wingwalls, abutment/embankment slopes, and road profile were measured during the field survey. Manning's roughness coefficients used in the analyses were determined from field observations of the stream and floodplain (Arcement and Schneider, 1989). Coefficients ranged from 0.040 to 0.052 for the main channel and from 0.100 to 0.150 for the floodplain. The starting water-surface elevation was determined by normal-depth computation and from HEC-RAS convergence analyses.

### **Base Flood Elevation for Site BFE 12**

Site BFE 12 on the South Fabius River, a tributary to the Fabius River, is located 2.5 mi north of State Highway 168 along County Road 159 and approximately 4.5 mi northeast of Philadelphia, in Marion County (figs. 1 and 13). The County Road 159 structures cause little or no constriction of flow across the floodplain. The South Fabius River has an average channel-top width of 120 ft and an average channel depth of 14 ft in the vicinity of the road crossing. The 379-mi<sup>2</sup> drainage area upstream from site 12 predominantly is rural; the 100-year recurrence-interval computed from the regression equation for a rural basin from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 28,900 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 12 is 578.4 feet above sea level (table 4). Three valley and channel cross sections (5–7) were obtained by field (transit-stadia) survey at or near the BFE 12 location (fig. 13) and were aligned perpendicular to the assumed direction of flow. Also, 7.5-minute topographic maps were used to estimate four valley cross sections (1–4) downstream from site 12. During the field survey, a main-channel cross section of the South Fabius River was defined along the downstream side of County Road 159 bridge. Bridge and embankment geometry of the piers, wingwalls, abutment/embankment slopes, road profile, and other hydraulic features were obtained during the field survey. However, the County Road 159 bridge and road embankment were analyzed as a composite valley section. Manning's roughness coefficients ranged from 0.040 to 0.050 for the main channel and from 0.080 to 0.250 for the floodplain (Arcement and Schneider, 1989). The starting water-surface elevation for the HEC-RAS analyses was determined by normal-depth computation.

### **Base Flood Elevation for Site BFE 13**

Site BFE 13 on the South Fabius River, a tributary to the Fabius River, is located on State Highway A about 3.4 mi north of State Highway 168 and approximately 9 mi northwest of the town of Palmyra, Missouri, in the north-central part of Marion County (figs. 1 and 14). The South Fabius River flows in an easterly direction at and near site 13; however, about 1,500 ft downstream the channel bends sharply to the left (north). The South Fabius River has an average channel-top width of 115 ft and an average channel depth of

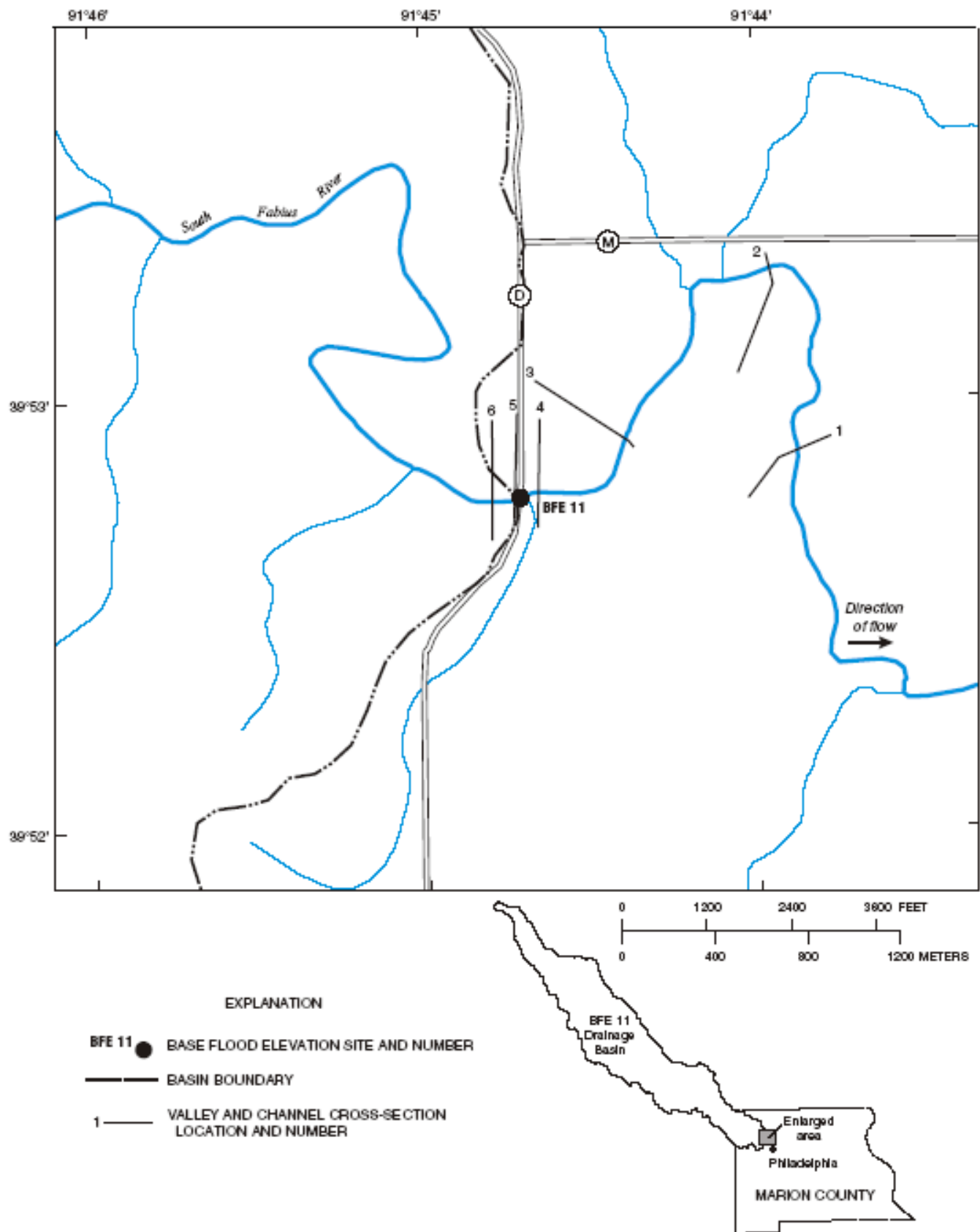
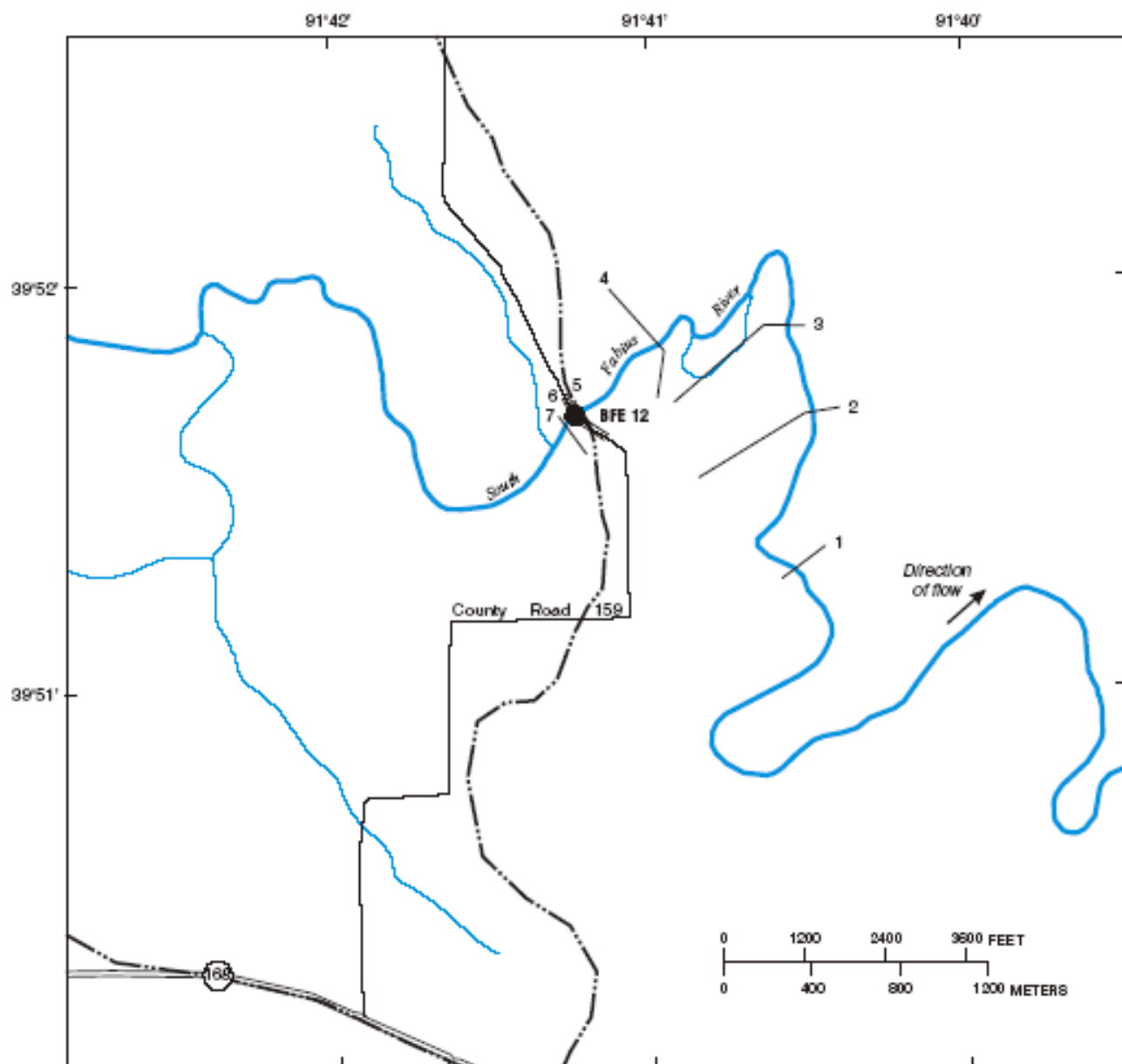


Figure 12. South Fabius River base (100-year) flood elevation site (BFE 11) near Philadelphia, Missouri.



- EXPLANATION
- BFE 12** ● BASE FLOOD ELEVATION SITE AND NUMBER
  - BASIN BOUNDARY
  - 1—— VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

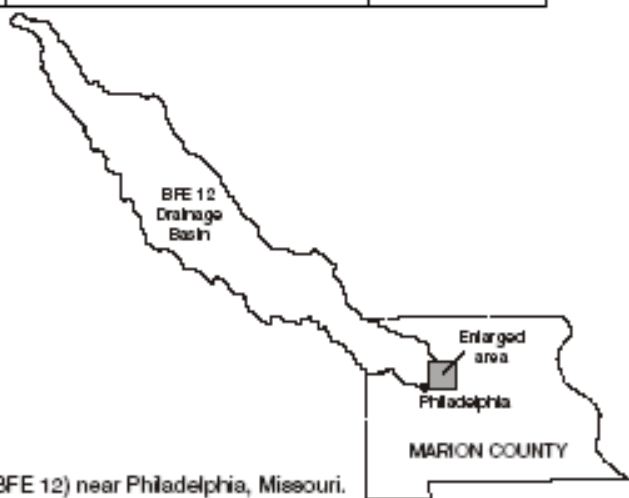


Figure 13. South Fabius River base (100-year) flood elevation site (BFE 12) near Philadelphia, Missouri.



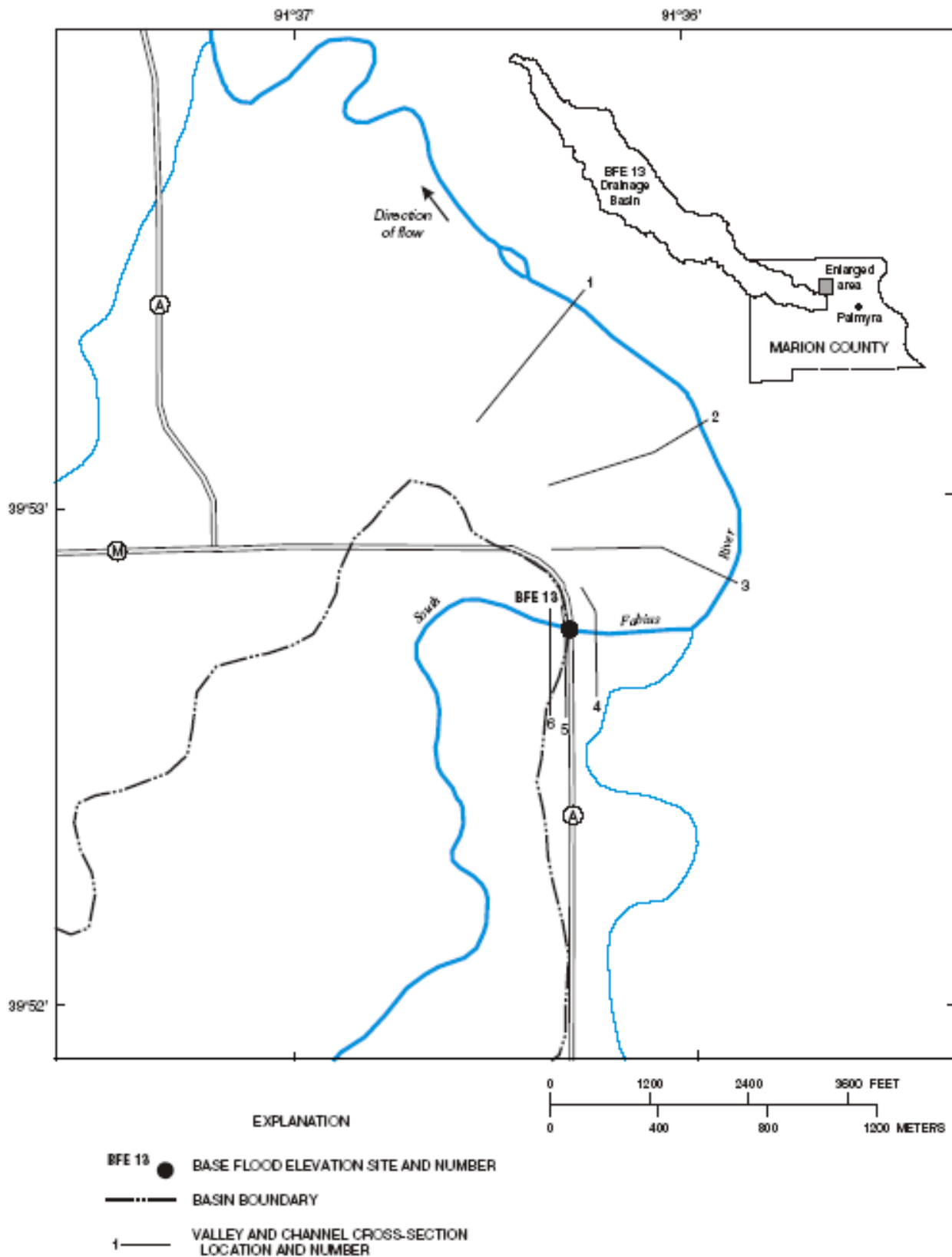


Figure 14. South Fabius River base (100-year) flood elevation site (BFE 13) near Palmyra, Missouri.

12 ft in the vicinity of the road crossing. The 394-mi<sup>2</sup> drainage area upstream from site 13 predominantly is rural; the 100-year recurrence-interval computed from the regression equation for a rural basin from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 28,300 ft<sup>3</sup>/s (table 4).

The base (100-year) flood elevation for site BFE 13 is 538.7 feet above sea level (table 4). Three valley and channel cross sections (4–6) were obtained by field (transit-stadia) survey in the vicinity of State Highway A bridge (fig. 14); these cross sections were surveyed perpendicular to the assumed direction of flow. Also, 7.5-minute topographic maps were used to estimate three valley sections (1–3) downstream from site 13. The geometry of the South Fabius River main-channel cross section was defined along the downstream side of State Highway A bridge. Bridge and embankment geometry of the piers, wingwalls, abutment/embankment slopes, road profile, and other hydraulic features were measured during the field survey. Manning's roughness coefficients ranged from 0.040 to 0.045 for the main channel and from 0.075 to 0.150 for the floodplain (Arcement and Schneider, 1989). The starting water-surface elevation for the HEC-RAS analyses was determined by normal-depth computation.

### Base Flood Elevation for Site BFE 14

Site BFE 14 on the South Fabius River, a tributary to the Fabius River, is located about 3 mi south of State Highway 6 along County Road 315 and approximately 13 mi northwest of the town of Palmyra, Missouri, in the north-central part of Marion County (figs. 1 and 15). The County Road 315 structures cause little or no constriction across the floodplain. The South Fabius River has an average channel-top width of 165 ft and an average channel depth of 13 ft in the vicinity of the road crossing. The 100-year recurrence-interval regression equation for this rural basin (605 mi<sup>2</sup>) from Alexander and Wilson (1995) gives a base (100-year) flood discharge of 36,200 ft<sup>3</sup>/s for site BFE 14 (table 4).

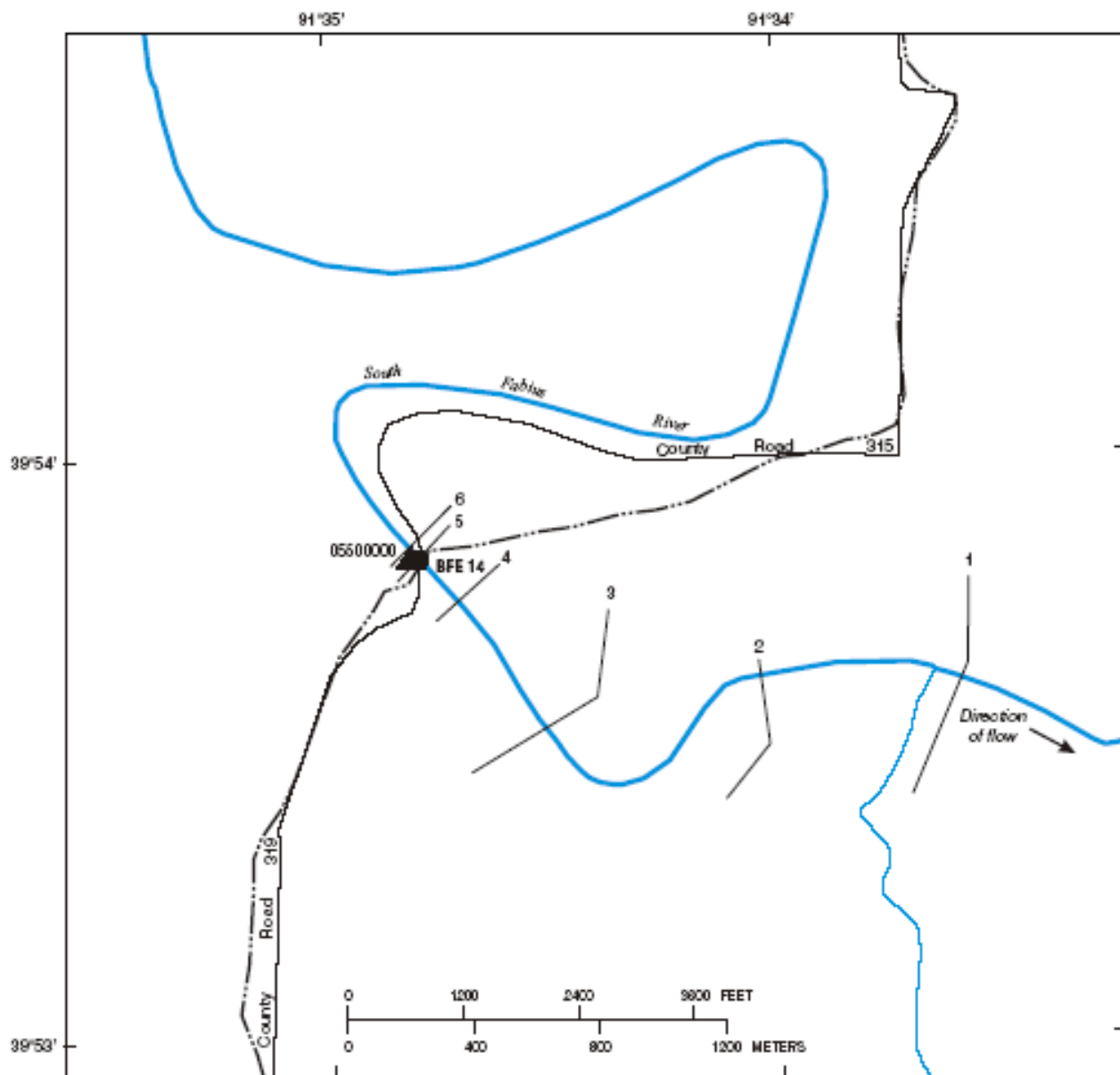
The base (100-year) flood elevation for site BFE 14 is 506.9 feet above sea level (table 4). Three valley and channel cross sections (4–6) were obtained by field (transit-stadia) survey in the vicinity of County Road 315 bridge (fig. 15), and these cross sections were surveyed perpendicular to the assumed direction of flow. Also, 7.5-minute topographic maps were used to estimate three valley sections (1–3) downstream from site 14. The geometry of the existing South Fabius River

main-channel was defined along the downstream side of County Road 315 bridge. Bridge and embankment geometry of the piers, wingwalls, abutment/embankment slopes, road profile, and other hydraulic features were measured or obtained during the field survey. Since County Road 315 embankment causes no constriction of flow across the floodplain, bridge and embankment geometry data were used as a composite cross section in the analyses. A USGS streamflow-gaging station (05500000) is located at the BFE 14 site (fig. 15). Manning's roughness coefficients ranged from 0.040 to 0.046 for the main channel and from 0.100 to 0.150 for the floodplain (Arcement and Schneider, 1989).

## SUMMARY

The primary requirement for community participation in the National Flood Insurance Program is the adoption and enforcement of floodplain management requirements. The purpose of the requirements is to minimize the potential for flood damages to existing and proposed development in flood-hazard areas. The U.S. Geological Survey, in cooperation with the State Emergency Management Agency, has completed a study using a one-dimensional surface-water flow model to compute base (100-year) flood elevations for selected sites in Missouri. This report provides base (100-year) flood elevations for 14 flood-hazard areas designated by the Federal Emergency Management Agency as approximate Zone A areas in Marion County, Missouri.

The one-dimensional surface-water flow model, HEC-RAS, was used to compute the base flood elevations for the 14 sites. The 14 sites were all located at U.S., State, or County road crossings and the base flood elevation was determined along the upstream side of each crossing. Eight of the 14 sites are in the North River Basin near or at the communities of Monroe City (BFE 1, 2, and 3), Philadelphia (BFE 4, 5, and 8), and Palmyra (BFE 6 and 7), Missouri. Sites BFE 1, 2, and 3 are located on South Fork North River at State Highway K, County Road 231, and State Highway Z. The base (100-year) water-surface elevations for BFE 1, 2, and 3 are 627.7, 579.2, and 545.9 feet above sea level. Sites BFE 4, 5, 6, and 7 are located on the main stem of the North River at County Road 195, State Highways Z and 168, and U.S. Highway 24-61. The base (100-year) water-surface elevations for BFE 4, 5, 6, and 7 at the upstream side of each road crossing are 560.5, 539.7,



EXPLANATION

- BFE 14 ● BASE FLOOD ELEVATION SITE AND NUMBER
- 05500000 ▲ U.S. GEOLOGICAL SURVEY STREAMFLOW GAGING STATION AND NUMBER
- BASIN BOUNDARY
- 1 — VALLEY AND CHANNEL CROSS-SECTION LOCATION AND NUMBER

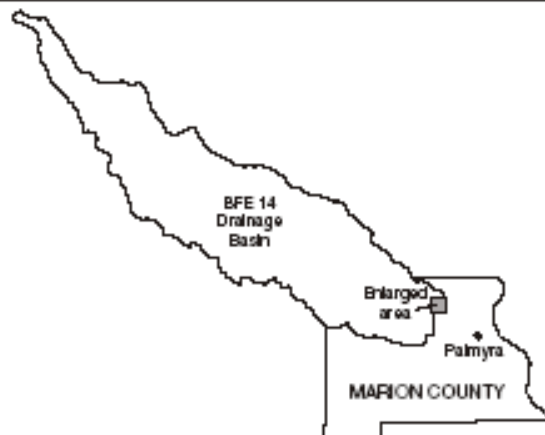


Figure 15. South Fabius River base (100-year) flood elevation site (BFE 14) near Palmyra, Missouri.

504.2, and 494.4 feet above sea level. Site BFE 8 is located on Big Branch, a tributary to the North River at County Road 230. The base (100-year) water-surface elevation for BFE 8 is 530.5 feet above sea level.

Two sites are located on tributaries to the Mississippi River near the communities of Monroe City (BFE 9) and Hannibal (BFE 10), Missouri. Site BFE 9 is located on the South River at County Road 272. The base (100-year) water-surface elevation for BFE 9 is 619.1 feet above sea level. Site BFE 10 is located on Bear Creek at County Road 418. The base (100-year) water-surface elevation for BFE 10 is 565.5 feet above sea level.

Four sites are in the South Fabius River Basin near the communities of Philadelphia (BFE 11 and 12) and Palmyra (BFE 13 and 14), Missouri. Sites BFE 11, 12, 13, and 14 are all located on the main stem of the South Fabius River at State Highway D, County Road 159, State Highway A, and County Road 315. The base (100-year) water-surface elevations for BFE 11, 12, 13, and 14 are 591.2, 578.4, 538.7, and 506.9 feet above sea level.

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## SUPPLEMENTAL DATA

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**Table 1.** Bench and reference mark elevations and locations for selected sites in Marion County, Missouri [ft. feet]

Bench or reference mark number	Bench or reference mark elevation <sup>a</sup> (ft)	Description of location
RM 1–BFE 1	632.29	Cut square on top of southeast concrete curb of State Highway K bridge over South Fork North River near Monroe City.
RM 2–BFE 1	632.29	Cut plus (+) on top of northeast concrete curb of State Highway K bridge over South Fork North River near Monroe City.
RM 1–BFE 2	585.31	Cut square on northeast corner of concrete bridge deck of County Road 231 over South Fork North River near Monroe City.
RM 2–BFE 2	585.26	Cut square on southwest corner of concrete bridge deck of County Road 231 over South Fork North River near Monroe City.
RM 1–BFE 3	553.40	Cut square on top of northwest concrete curb of State Highway Z bridge over South Fork North River near Monroe City.
RM 2–BFE 3	559.30	Cut square on top of southwest concrete wingwall of State Highway Z bridge over South Fork North River near Monroe City.
RM 1–BFE 4	566.21	Cut square on top of northeast concrete handrail of County Road 195 bridge over North River near Philadelphia.
RM 1–BFE 5	546.11	Cut square on top of southeast concrete wingwall of State Highway Z bridge over North River near Philadelphia.
RM 2–BFE 5	546.08	Top of bolt in northeast concrete wingwall of State Highway Z bridge over North River near Philadelphia.
RM 1–BFE 6	505.75	Cut square on top of southwest concrete abutment of State Highway 168 over North River near Palmyra.
RM 3–BFE 7	504.09	Cut square on top of southwest concrete handrail on southbound U.S. Highway 61 bridge over North River near Palmyra.
RM 1–BFE 8	531.08	Top of rivet on west end of steel culvert, southwest of County Road 230 bridge over Big Branch near Philadelphia.
RM 2–BFE 8	533.18	Cut square on top of south concrete headwall of County Road 230 bridge over Big Branch near Philadelphia.
RM 3–BFE 8	533.04	Cut square on top of north concrete headwall of County Road 230 bridge over Big Branch near Philadelphia.
RM 1–BFE 9	617.43	Cut square on south concrete headwall of County Road 230 culvert on South River near Monroe City.
RM 2–BFE 9	619.92	Cut square on south edge of concrete deck of County Road 272 bridge over tributary to South River near Monroe City.

**Table 1.** Bench and reference mark elevations and locations for selected sites in Marion County, Missouri—Continued

Bench or reference mark number	Bench or reference mark elevation <sup>a</sup> (ft)	Description of location
RM 1–BFE 10	570.26	Cut square on northeast corner of concrete bridge deck, at third handrail post from east end of County Road 418 bridge over Bear Creek near Hannibal.
RM 2–BFE 10	570.28	Cut square on southwest corner of concrete bridge deck of County Road 418 bridge over Bear Creek near Hannibal.
RM 1–BFE 11	596.21	Cut square on top of southeast concrete wingwall of State Highway D bridge over South Fabius River near Philadelphia.
RM 1–BFE 12	579.18	Cut square on top of concrete curb at southeast corner of County Road 159 bridge over South Fabius River near Philadelphia.
RM 2–BFE 12	579.18	Cut square on top of concrete curb at northeast corner of County Road 159 bridge over South Fabius River near Philadelphia.
BM 1–BFE 13	589.75	Standard tablet stamped “TT 21 C 1947” about 0.25 mile northwest of bridge over South Fabius River, on crown of ridge, in concrete post. Latitude 39°52'49”, Longitude 91°36'28”.
RM 1–BFE 13	542.15	Top northeast corner of northeast concrete wingwall of State Highway A bridge over South Fabius River near Palmyra.
BM 3–BFE 14	501.36	Top of bolt spike set in center of southwest concrete wingwall of County Road 315 bridge over South Fabius River near Palmyra.

<sup>a</sup>Above sea level