Determination of the 100-year Flood Plain on Pen Branch, Steel Creek, and their Selected Tributaries, Savannah River Site, South Carolina, 1996

By TIMOTHY H. LANIER

U.S. GEOLOGICAL SURVEY

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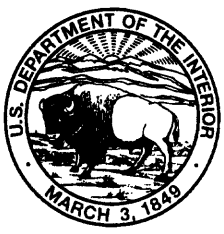

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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

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

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 -- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

ABBREVIATIONS

ERM	Elevation reference mark
NRCS	Natural Resources Conservation Service
SRS	Savannah River Site
USDOE	U.S. Department of Energy
USGS	U.S. Geological Survey
USC&GS	U.S. Coastal and Geodetic Survey
WSPRO	Water Surface Profile Computation computer model

In this report, the station number represents the distance in feet upstream from the mouth of the subject stream. For example, Station 37600 on Pen Branch is 37,600 feet upstream from the mouth of Pen Branch.

In this report, the river mile represents the distance in miles upstream from the mouth of the Savannah River. The river miles were established by the U.S. Army Corps of Engineers.

In this report, the words "right" and "left" refer to the directions that would be reported by an observer facing downstream.

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Abstract

Maps and flood profiles for the 100-year flood plain were prepared for Pen Branch, Steel Creek, and their selected tributaries at the Savannah River Site in Aiken, Allendale, and Barnwell Counties, South Carolina. The maps and profiles provide water-resource managers of the Savannah River Site with a technical basis for making flood-plain management decisions that could minimize future flood problems and provide a basis for designing and constructing drainage structures along roadways. The results are provided in tabular and graphical formats.

A hydrologic analysis was made that verified that the South Carolina upper Coastal Plain regional rural- and urban-regression equations for peak flow were applicable for the Pen Branch and Steel Creek drainage basins. The equations were verified by an analysis of the flood-frequency data collected from U.S. Geological Survey gaging station 02197342 on Fourmile Branch and by comparing predominant soil types in the Fourmile Branch, Pen Branch, and Steel Creek drainage basins.

Cross sections were surveyed throughout the basins, and other pertinent data such as flow resistance and land use were collected. The surveyed cross sections and computed 100-year recurrence-interval flows were used in a step-backwater model to compute the 100-year flood profile for Pen Branch, Steel Creek, and their selected tributaries. The profiles were used to delineate the 100-year flood plain on topographic maps.

INTRODUCTION

In 1951, the U.S. Department of Energy (USDOE), formerly the Atomic Energy Commission, created the Savannah River Site (SRS) to produce nuclear materials for national defense. The SRS is located in parts of Aiken, Allendale, and Barnwell Counties, S.C. The operation of the first nuclear production reactor, in area R, began in 1953 (fig. 1), after which four other nuclear reactors were activated in areas C, K, L, and P. Reactors in areas R and P were permanently deactivated in 1964 and 1991, respectively. The remaining reactors have been placed on stand-by since the late 1980's, except for the restart testing of K reactor in 1991. Other areas on the SRS include reactor materials (area M), separation (areas F and H), waste management (areas E, F, H, S, Y, and Z), heavy-water processing (area D), administration (areas A, B, and CS), the Savannah River Ecology Laboratory, and the Savannah Technology Center (Arnett and others, 1992).

In 1992, the U.S. Geological Survey (USGS), in cooperation with the USDOE, initiated an investigation to determine the areal extent of the inundation caused by the 100-year recurrence-interval flow (100-year flow) for the Savannah River along the SRS boundary and for the major streams and their tributaries on the SRS, with the exception of Lower Three Runs.

Purpose and Scope

This report documents the approximate boundaries of the 100-year flood plain on the SRS for Pen Branch, Steel Creek, and their selected tributaries (fig. 2). Computed 100-year flows at selected locations, and tabular and graphical profiles of the 100-year flood are presented. Descriptions and elevations of benchmarks utilized for the Pen Branch and Steel Creek Basins are listed in the appendix.

The USGS/Federal Highways Administration one dimensional step backwater computer model (WSPRO) (Shearman and others, 1986; Shearman, 1990), and the USGS A-526 culvert-flow model (Bodhaine, 1968) were used to compute water-surface profiles for each reach. Less-than-detailed methods, which require less cross-sectional definition, were used with the step-backwater and culvert flow models to compute the 100-year flood-plain boundaries. In particular, cross sections were surveyed primarily at road crossings or other easily accessible locations. Intermediate cross sections were interpolated by using the surveyed cross sections and 7.5-minute topographic maps (U.S. Geological Survey, 1963-65b). This method was requested by the USDOE, because extreme accuracy was not warranted.

Description of Study Area

The SRS occupies more than 300 mi^2 along the Georgia-South Carolina border in parts of Aiken, Allendale, and Barnwell Counties, S.C. The southwestern boundary of the SRS is formed by the Savannah River. The five major streams that drain into the Savannah River from the SRS are Upper Three Runs, Fourmile Branch, Pen Branch, Steel Creek, and Lower Three Runs (fig. 2). The SRS is located in the upper Coastal Plain physiographic province of South Carolina; the province encompasses about 20 percent of the state (fig. 1). The general topography of the upper Coastal Plain consists of rounded hills with gradual slopes; however, some areas of highly irregular terrain exist in the province, and some elevations exceed 700 ft above sea level. The highest elevation on the SRS is approximately 420 ft above sea level, near Tims Branch and the northwest boundary of SRS (fig. 2). The land-surface elevation at the boundary of the upper and lower Coastal Plains, located southeast of the SRS, is usually less than 200 ft above sea level. Upper Coastal Plain stream slopes range from 5 to 20 ft/mi, and many of the streams are bordered by swamps with wide flood plains relative to the size of the stream (Zalants, 1990).

The study area consists of Pen Branch and Steel Creek drainage basins (pl. 1). Pen Branch originates near Road F (fig. 1, pl. 1), and flows into the Savannah River south of Augusta, Ga., at river mile 141.5 (pl. 1). Pen Branch enters the Savannah River flood plain approximately 30,300 ft upstream from its confluence with the Savannah River (river mile 148.8); downstream from this point, Pen Branch becomes braided and is undefinable during high-flow conditions. Because of the effect of backwater from the Savannah River, the downstream study limit of the 100-year flood-plain and profile computations begins upstream from where Pen Branch enters the Savannah River flood plain (fig. 1). The total drainage area of Pen Branch before it enters the Savannah River Swamp is 22.2 mi^2.

There are two upstream study limits. The upstream study limit of Pen Branch is Road C (fig. 1, pl. 1); this point was selected because there is no industrialization or road crossings in the drainage area upstream of Road C. An unnamed tributary flows into Pen Branch at Station 75150. The upstream study limit of this tributary is Road 6 (fig. 1, pl. 1). This point was selected because there are no road crossings upstream from this point and the drainage area upstream of Road 6 is less than 1.0 mi^2.

Steel Creek originates near Road F (fig. 1, pl. 1), and flows into the Savannah River south of Augusta, Ga., at river mile 141.5 (pl. 1). Steel Creek enters the Savannah River flood plain approximately 8,200 ft upstream from its confluence with the Savannah River (river mile 143.4); downstream from this point, Steel Creek becomes braided and is undefinable during high-flow conditions. Because of the effect of backwater from the Savannah River, the downstream study limit of the 100-year flood-plain and profile computations begins upstream from where Steel Creek enters the Savannah River flood plain (fig. 1). The total drainage area of Steel Creek before it enters the Savannah River Swamp is 35.1 mi^2.

There are three upstream study limits. The upstream study limit of Steel Creek is the toe of L lake dam (fig. 1, pl. 1). Meyers Branch, a tributary to Steel Creek, flows into Steel Creek at Station 22700. The upstream study limit of Meyers Branch is Old Dunbarton Road (pl. 1). An unnamed tributary to Meyers Branch flows into Meyers Branch at Station 21800.

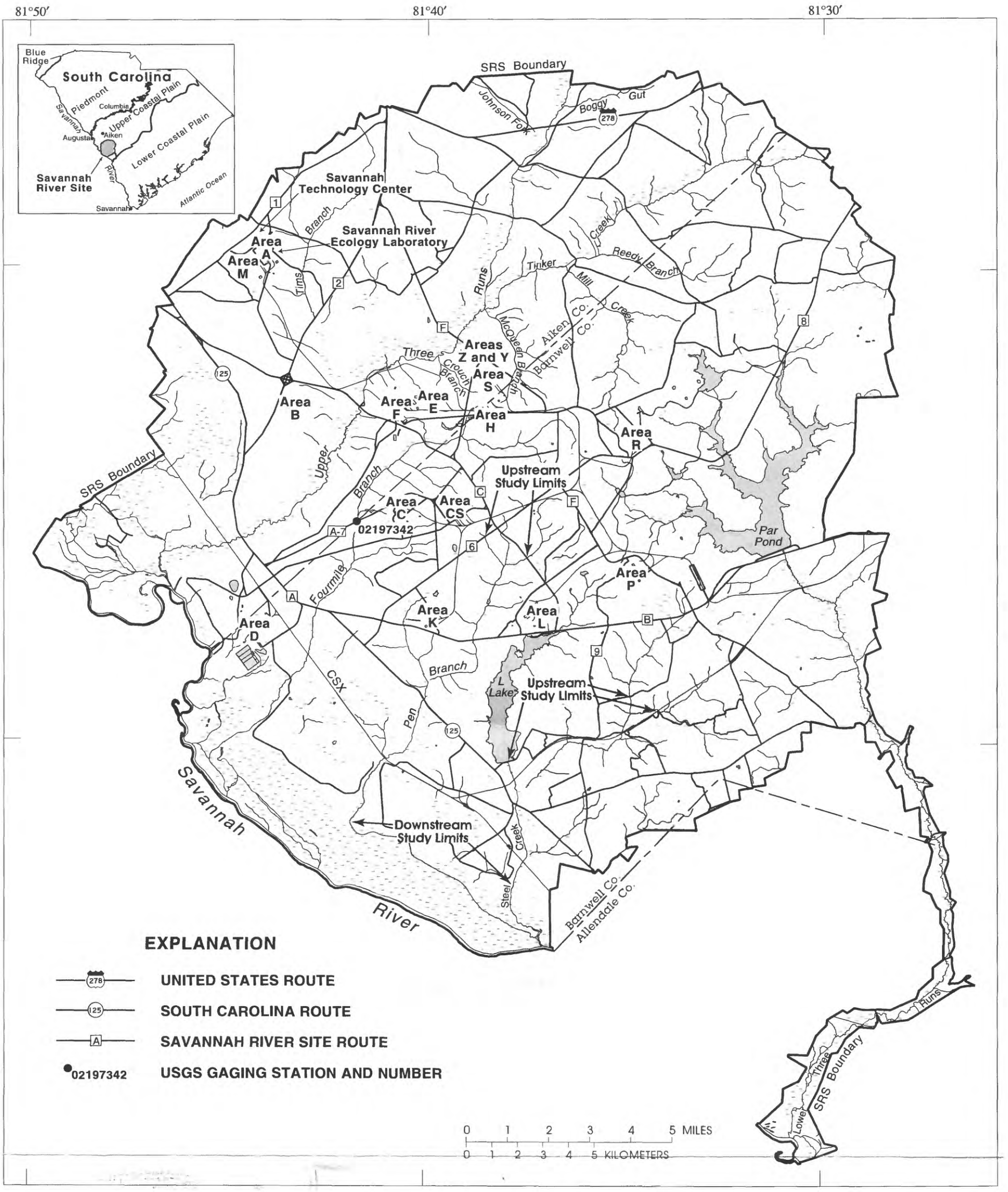

Figure 1. The Savannah River Site with site areas and streams in Aiken, Allendale, and Barnwell Counties, S.C.

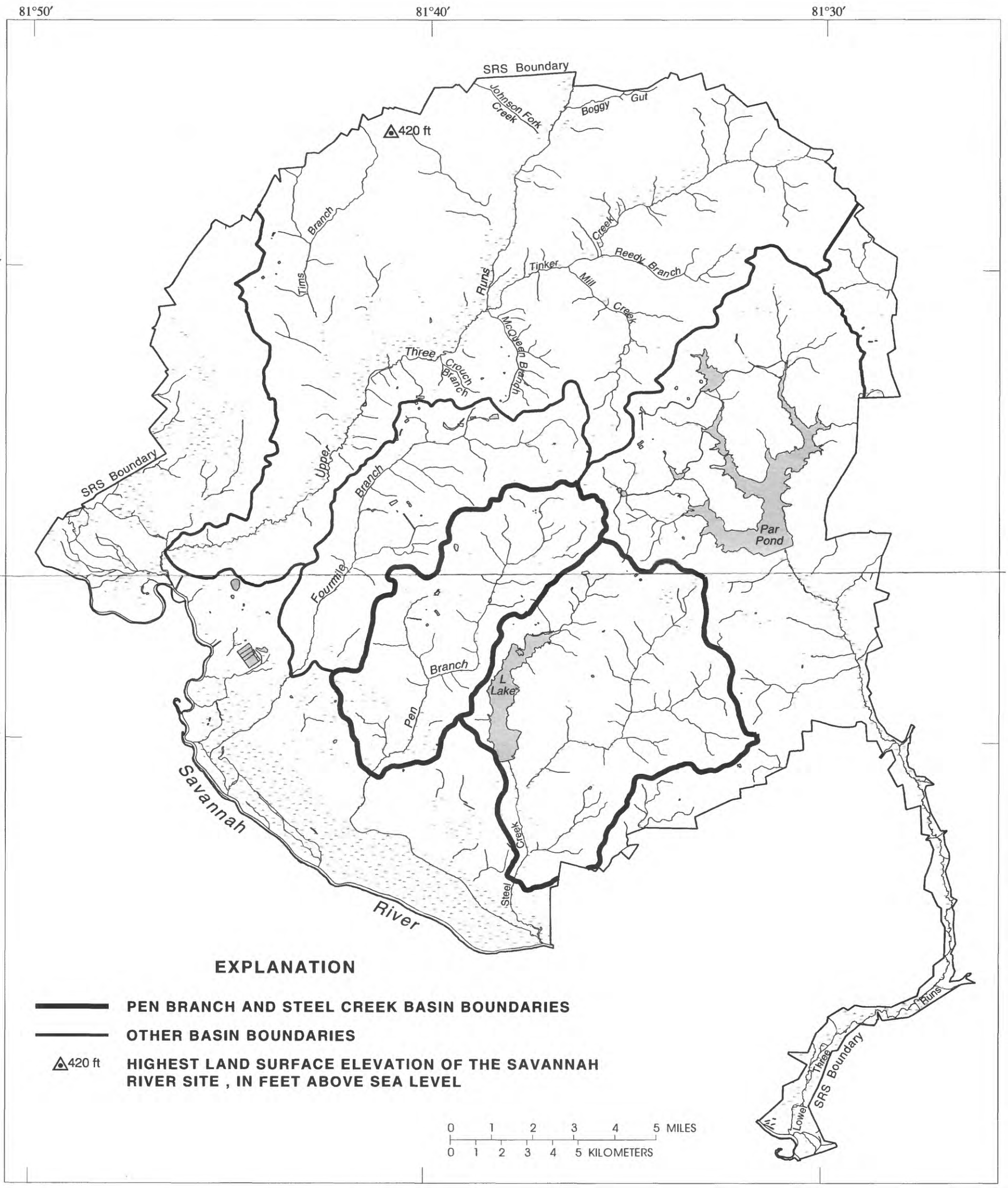

Figure 2. Boundaries, drainage basins, and stream locations at the Savannah River Site, S.C.

The upstream study limit of the unnamed tributary is the CSX railway crossing (pl. 1).

The entire Pen Branch drainage basin and all but 0.4 mi^2 of the Steel Creek drainage basin lie within the SRS (fig. 2). Both basins contain significant industrialization within areas CS, K, L, and P (fig. 1).

Acknowledgment

The author is grateful to Mr. Lee Davis, USDOE, for his logistical and administrative support of this project.

HYDROLOGIC AND HYDRAULIC DATA COLLECTION

Hydrologic data, which include drainage area, soil type, impervious area, and peak-flow records at USGS gaging stations, were used to estimate the 100-year flows for Pen Branch, Steel Creek, and their selected tributaries. The drainage areas for the basins were delineated using 7.5-minute series topographic maps at selected locations along each reach (U.S. Geological Survey, 1963-65b). These locations were selected based on major tributary confluences, changes in drainage-area shape, and changes of imperviousness within the drainage basins. Soil types were determined from the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) soil reports of Aiken and Barnwell Counties and the Savannah River Plant Area (Rogers, 1977, 1985, 1990). Industrialized areas in the drainage basins were determined from aerial photographs, 7.5-minute series topographic maps (U.S. Geological Survey, 1963-65b), the SRS Atlas (Savannah River Site, 1994), and field inspections. Only urbanization in and around the industrial areas of the basins, which include areas CS, K, L, and P, were considered. Paved roads outside of these areas were not included. Percentage-imperviousness data associated with urbanized areas were obtained from Cronshey and others (1986). Peak-flow data were obtained from USGS gaging station 02197342, Fourmile Branch at Road A-7 (fig. 1). These peak-flow data were used to verify the methods of regionalization of selected recurrence-interval flows described by Guimaraes and Bohman (1992) and Bohman (1992).

Cross sections for the step-backwater analysis were taken upstream and (or) downstream from bridge and culvert crossings, along road grades at these crossings, and at selected locations along the streams, such as natural or man-made expansions or contractions and powerline right-of-ways. In addition, elevation data and structural geometry for all bridges and culverts were determined by field surveys. synthesized cross sections were developed by using surveyed cross-sectional data and 7.5-minute series topographic maps (U.S. Geological Survey, 1963-65b).

Cross-section elevations were referenced to sea level. In areas where no elevation reference marks (ERM) were located, a global positioning system was used to establish temporary ERM. Standard surveying levels were used to reference the temporary ERM to more permanent structures. ERM's are described in the Appendix.

Manning's roughness coefficients used in the hydraulic computations were estimated for the channels and flood plains using engineering judgement. Coefficient estimates were based on field notes, photographs, and methods documented by Arcement and Schneider (1984, 1989) and Barnes (1967).

FLOOD FREQUENCY

The regional rural- and urban-regression equations developed by Guimaraes and Bohman (1992) and Bohman (1992) were used to compute the 100-year flows for Pen Branch, Steel Creek, and their selected tributaries. The soil types in these two drainage basins resemble those normally occurring in upper Coastal Plain drainage basins. These upper Coastal Plain soil types also are found in the Fourmile Branch Basin (fig. 2). Therefore, 100-year flows were computed using the log-Pearson method and 23 years of peak-flow data from gaging station 02197342, Fourmile Branch at Road A-7 (fig. 1), and were compared to the 100-year flows computed using the regional rural- and urban-regression equations. This comparison showed that the regional rural- and urban-regression equations reasonably describe the 100-year flows of Fourmile Branch. Because the soil types are similar, the equations are applicable to the Pen Branch and Steel Creek drainage basins.

Using the peak-flow data of the gaging station 02197342, a 100-year flow of 1,080 ft^3/s was computed using the log-Pearson method. However, the 100-year flow computed with the regional rural-regression equation at the gaging station using a drainage area of 12.5 mi^2 was 661 ft^3/s. This large difference in computed flows is probably the result of the 5.0-percent impervi-

ousness of the basin. Whereas, the lower limit of imperviousness used to develop the regional urban-regression equations presented by Bohman (1992) is 10 percent. Therefore, a relation of impervious area to flow was established for the drainage area of gaging station 02197342: zero-percent imperviousness in the rural flows and 10- to 50-percent imperviousness in the urban flows (fig. 3). The relation and an impervious area of 5.0 percent were used to obtain a 100-year flow of 1,170 ft^3/s. This flow was adjusted using methods described in Guimaraes and Bohman (1992) for determining flood frequency at or near a gaged site on the same stream. A 100-year flow of 1,110 ft^3/s was obtained, compared to 1,080 ft^3/s computed by the log-Pearson method. The flows are well within the 95-percent confidence limits of both methods. Therefore, the regional rural- and urban-regression equations were used to compute the 100-year flows on the Pen Branch and Steel Creek drainage basins.

The equations are as follows:

For rural upper Coastal Plain watersheds (Guimaraes and Bohman, 1992);

$$RQ_{100} = 116\,(A)^{0.690}, \quad (1)$$

and for urban watersheds (Bohman, 1992);

$$UQ_{100} = 10.4(A)^{0.506}(TIA)^{0.932}(RQ_{100})^{0.280}, \quad (2)$$

where

RQ_{100} is the 100-year recurrence-interval flow for rural drainage basins, in cubic feet per second;

A is the drainage area, in square miles;

UQ_{100} is the 100-year recurrence-interval flow for urban drainage basins, in cubic feet per second; and

TIA is the total impervious area, in percent of total drainage area.

Equation 1 requires that the drainage areas be greater than 4.4 mi^2 and less than 1,720 mi^2. In this study, the relation was extended downward to .53 mi^2, because no other regional regression equation specific to South Carolina was available. This extrapolation seems acceptable, because the logarithmic regional relation is linear (Guimaraes and Bohman, 1992). In addition, the relations for other physiographic provinces are generally linear throughout the range of data and, therefore, the relation for the upper Coastal Plain could be extrapolated below a drainage area of 4.4 mi^2.

Equation 2 requires that the impervious area be greater than 10 percent, and the drainage area be greater than 0.18 mi^2 and less than 41.0 mi^2. The subbasins of Pen Branch and Steel Creek meet the drainage-area requirement for urbanized basins; however, the impervious area of the subbasins is typically less than 10 percent. Therefore, the previously described method to adjust flows for urbanization at gaging station 02197342 was used to compute flows for the subbasins, which had an imperviousness of less than 10 percent.

The damping effect of L Lake on the magnitude of the 100-year flows for Steel Creek was not considered because it would have required pond-routing computations, which are outside the scope of this study. Therefore, in the case of the 100-year flood, the computed profiles could represent the probable maximum elevation to be expected.

The 100-year flow was computed at 13 locations on Pen Branch, one location on an unnamed tributary to Pen Branch, five locations on Steel Creek, five locations on Meyers Branch, and one location on an unnamed tributary to Meyers Branch. The results of the hydrologic analyses are presented in table 1.

MODEL SELECTION AND DEVELOPMENT

Water-surface elevations for the 100-year flows were computed by using WSPRO (Shearman and others, 1986; Shearman, 1990), A-526 (Bodhaine, 1968), or where flow is affected by backwater from the Savannah River, data from Lanier (1996) were used. The WSPRO model can compute backwater caused by bridges without subdividing the reach, however, the reach must be subdivided at culverts and a separate culvert-flow computation must be made to determine the backwater caused by the culvert. The culvert backwater was calculated by using the A-526 culvert-flow model. The computed water-surface elevation at the approach to the culvert was used as the initial water-surface elevation for the WSPRO analysis of the next upstream reach.

The downstream limits of the Pen Branch and Steel Creek study areas were located at their respective confluences with the Savannah River. Because the

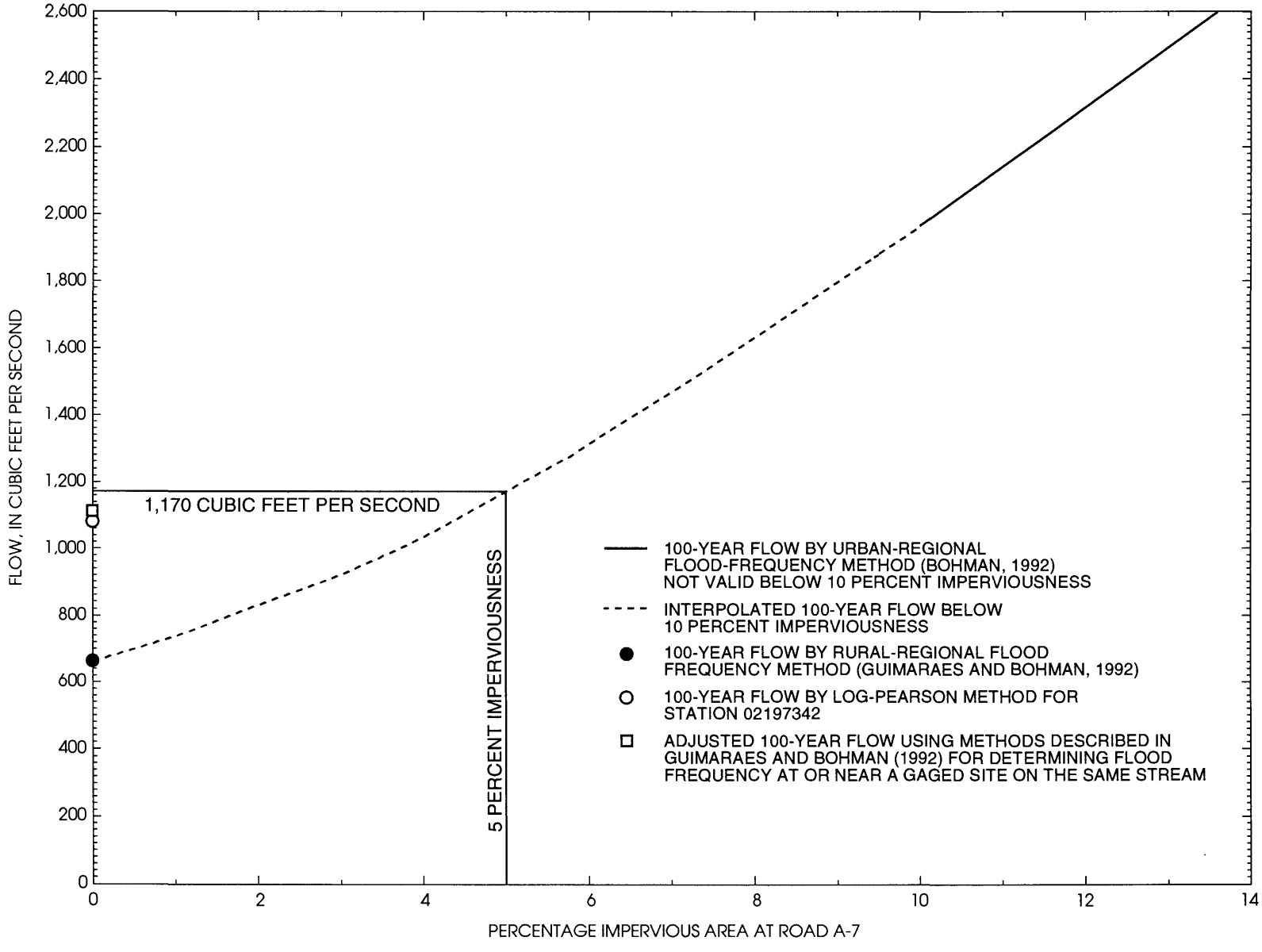

Figure 3. Relation of percentage impervious area and 100-year recurrence-interval flow for Station 02197342, Fourmile Branch at Road A-7, Savannah River Site, S.C.

Table 1. Summary of the 100-year recurrence-interval flows for Pen Branch, Steel Creek, and their selected tributaries, Savannah River Site, S.C.

[mi^2, square miles; ft^3/s, cubic feet per second; ft, feet; --, cross section not surveyed; # ,impervious area less than 1 percent]

Location (pl. 1)	Drainage area (mi^2)	Percentage impervious area	One-hundred-year flow (ft^3/s)	Cross-section name
Pen Branch				
Station 38100; 1,950 ft downstream from Road A-13.2	21.5	2	1,150	--
Station 40050; Road A-13.2	21.2	2	1,150	BR30
Station 41100; 159 ft upstream from the CSX railway bridge crossing Pen Branch	18.0	2.4	1,080	--
Station 51444; Road A	16.4	2.6	1,040	BR75
Station 54000; 2,556 ft upstream from Road A	11.1	1.7	710	--
Station 57200; 5,756 ft upstream from Road A	10.2	1.8	675	--
Station 64635; Road B	9.23	2.0	620	BR130
Station 69300; 300 ft upstream from Road 6-4.2	7.89	1.9	570	--
Station 72525; 3,955 ft downstream from Road C-6	6.92	2.0	520	--
Station 75000; 1,480 ft downstream from Road C-6	5.96	2.4	500	--
Station 75650; 830 ft downstream from Road C-6	4.26	#	315	--
Station 78600; Road C (Main Branch)	2.10	#	190	RDCM
Station 78600; Road C (Tributary)	1.68	#	170	RDCT
Unnamed Tributary to Pen Branch (Confluence at Station 75100 of Pen Branch)				
Station 4625; Road 6	.53	27	550	SEC290
Steel Creek				
Station 8800; 5,110 ft downstream from CSX railway bridge	35.1	#	1,350	--
Station 11088; 2,822 ft downstream from CSX railway bridge	34.4	#	1,330	SEC10

Table 1. Summary of the 100-year recurrence-interval flows for Pen Branch, Steel Creek, and their selected tributaries, Savannah River Site, S.C. (Continued)

[mi^2, square miles; ft^3/s, cubic feet per second; ft, feet; --, cross section not surveyed; # ,impervious area less than 1 percent]

Location (pl. 1)	Drainage area (mi^2)	Percentage impervious area	One-hundred-year flow (ft^3/s)	Cross-section name
Station 15550; 1,640 ft upstream from CSX railway bridge	29.9	#	1,210	--
Station 21859; Road A	28.9	#	1,180	BR50
Station 23575; 1,716 ft upstream from Road A	9.24	1.0	540	--
Meyers Branch				
Station 400; 400 ft upstream from confluence with-Pen Branch	19.5	#	900	--
Station 5750; 13,150 ft downstream from CSX railway crossing	17.9	#	850	--
Station 10200; 8,700 ft downstream from CSX railway crossing	14.8	#	740	--
Station 18900; CSX railway crossing	11.9	#	640	RR115
Station 22150; 3,250 ft upstream from CSX railway crossing	6.36	#	420	--
Unnamed tributary to Meyers Branch (Confluence at Station 21800 of Meyers Branch)				
Station 200; 200 ft upstream from confluence with Meyers Branch	4.95	#	350	--

drainage area of the Savannah River is much larger than the drainage areas in this study, it is assumed that at the time of the 100-year flood, the flow in the study areas would have peaked and receded before peak flow occurred on the Savannah River. Similarly, the drainage areas of Pen Branch and Steel Creek are much larger than the drainage areas of their respective tributaries, therefore, it is assumed that at the time of the 100-year flood, the flow in the tributaries would have peaked and receded before peak flow occurred on Pen Branch and Steel Creek.

The elevation of the 100-year flood on the Savannah River at the mouth of Pen Branch is 103.0 ft, which intersects the channel of Pen Branch at Station 42391. Therefore, due to the backwater of the Savannah River, the initial Pen Branch water-surface elevation was computed by slope-conveyance at cross section SEC10, which is located 37,950 ft upstream from the confluence of Pen Branch and the Savannah River (fig. 1, pl. 1).

The elevation of the 100-year flood on the Savannah River at the mouth of Steel Creek is 98.0 ft, which intersects the channel of Steel Creek at Station 19220. Due to the backwater of the Savannah River, the initial Steel Creek water-surface elevation was computed by slope-conveyance methods at cross section RD09, which is located 11,088 ft upstream from the

confluence of Steel Creek and the Savannah River (fig. 1, pl. 1).

A convergence test was completed to verify the starting elevation of Pen Branch, Steel Creek, and their respective tributaries. This was done by starting the WSPRO model at a cross section downstream from the initial cross section, and varying the starting water-surface elevation at this downstream point by plus and minus 2.0 ft. If, for each scenario, the computed water-surface-elevation at the actual starting cross section does not change, convergence is reached and therefore the computed water-surface elevation will be used as the starting water-surface elevation in the actual 100-year flood model.

DETERMINATION OF THE 100-YEAR FLOOD PLAIN AND PROFILE

The step-backwater model WSPRO (Shearman, 1990) was utilized to compute a profile for Pen Branch, Steel Creek, and their selected tributaries. The computed profiles were used to determine the 100-year flood plain on each reach. Data (Lanier,1996) were used to delineate the 100-year flood plain where flow is affected by backwater from the Savannah River.

Pen Branch

Pen Branch was analyzed from its confluence with the Savannah River to Road C (pl. 1). Station 0 is located at the confluence of Pen Branch and Savannah River. The 78,648-ft long study segment consists of 36-surveyed and 76-synthesized cross sections. Within the study area, three highway bridges, one railway bridge, four culvert crossings, and six breached dams or old road beds cross Pen Branch. The highway bridges are located on Roads A-13.2, A, and B at Stations 40050, 51444, and 64635, respectively (pl. 1). The CSX railway bridge crosses Pen Branch at Station 40941 (pl. 1). The culverts are located at Roads B-3, 6-4.2, C-6, and C at Stations 56586, 69000, 76480, and 78600, respectively (pl. 1). The breached dams/road beds are located at Stations 41515, 48747, 62900, 67838, 69712, and 72375 (pl. 1). Road 6-4.23 is located at Station 69712 but does not cross Pen Branch. In the area of Pen Branch affected by backwater from the Savannah River, the 100-year flood plain widths range from 475 ft at Station 38800 to 1,600 ft at Station 35000 (pl. 1). Upstream from this area, the 100-year flood- plain widths range from 140 ft at Station 78000 to 750 ft at Station 41200 (pl. 1). Backwater caused by the road and railway bridges ranges from less than 1.0 ft at Road B to 1.6 ft at Road A-13.2. In addition, Roads B-3, 6-4.2, and C-6 are overtopped by depths of 0.7 ft, 0.2 ft, and 0.6 ft, respectively. Graphical and tabular profiles of Pen Branch are shown in figures 4 through 6 and listed in table 2, respectively. The areal extent of the inundation caused by the 100-year flood on Pen Branch is shown in plate 1.

Unnamed Tributary to Pen Branch

The unnamed tributary to Pen Branch was analyzed from its confluence with Pen Branch to Road 6 (pl. 1). Station 0 is located at the confluence of the unnamed tributary and Pen Branch. The 5,000-ft long study segment consists of 3-surveyed and 27-synthesized cross sections. Within the study area, there is one culvert crossing. The culvert is located at Road 6, at Station 4625 (pl. 1). The 100-year flood-plain widths range from 30 ft at Station 4000 to 400 ft at Station 4950 (pl. 1). Road 6 is not overtopped. Graphical and tabular profiles of the unnamed tributary to Pen Branch are shown in figure 7 and listed in table 3, respectively. The areal extent of the inundation caused by the 100-year flood on the unnamed tributary to Pen Branch is shown in plate 1.

Steel Creek

Steel Creek was analyzed from its confluence with the Savannah River to the toe of the L Lake dam (pl. 1). Station 0 is located at the confluence of Steel Creek and Savannah River. The 27,200-ft long study segment consists of 12-surveyed and 28-synthesized cross sections. Within the study area, there is one highway bridge, two railway bridges, and four breached dams or old road beds that cross Steel Creek. The highway bridge is located at Road A at Station 21859 (pl. 1). Two CSX railway bridges cross Steel Creek at Stations 13910 and 25243, respectively (pl. 1). The breached dams/road beds are located at Stations 11050, 11125, 20425, and 22300 (pl. 1). In the area of Steel Creek affected by backwater from the Savannah River, the 100-year flood-plain widths range from 750 ft at Station 11550 to 1,050 ft at Station 10000 (pl. 1). Upstream from this area, the 100-year flood- plain widths range from 325 ft at Station 26500 to 1,000 ft at

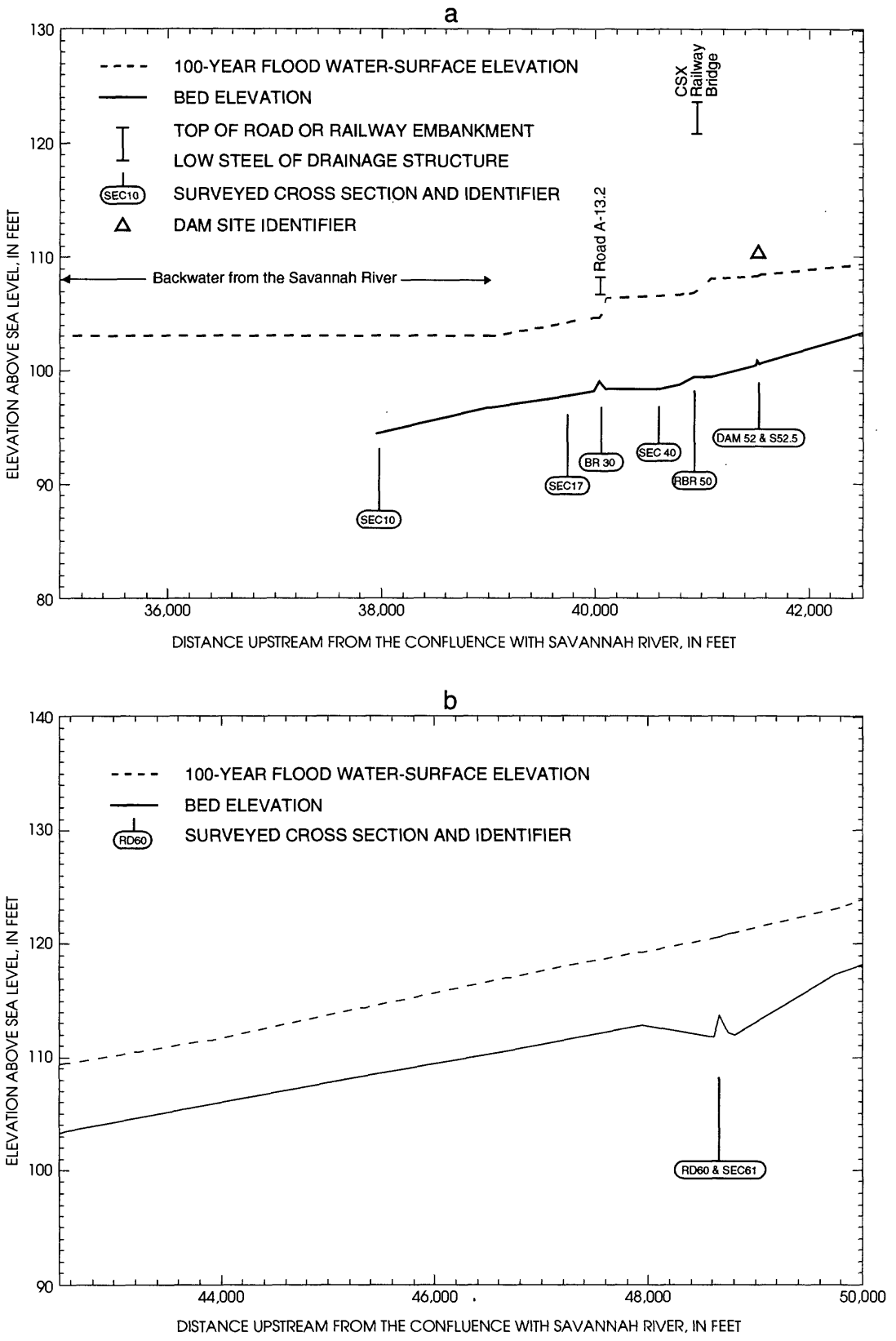

Figure 4. Flood profile of Pen Branch from (a) Station 35000 to Station 42500 and (b) Station 42500 to Station 50000, Savannah River Site, S.C.

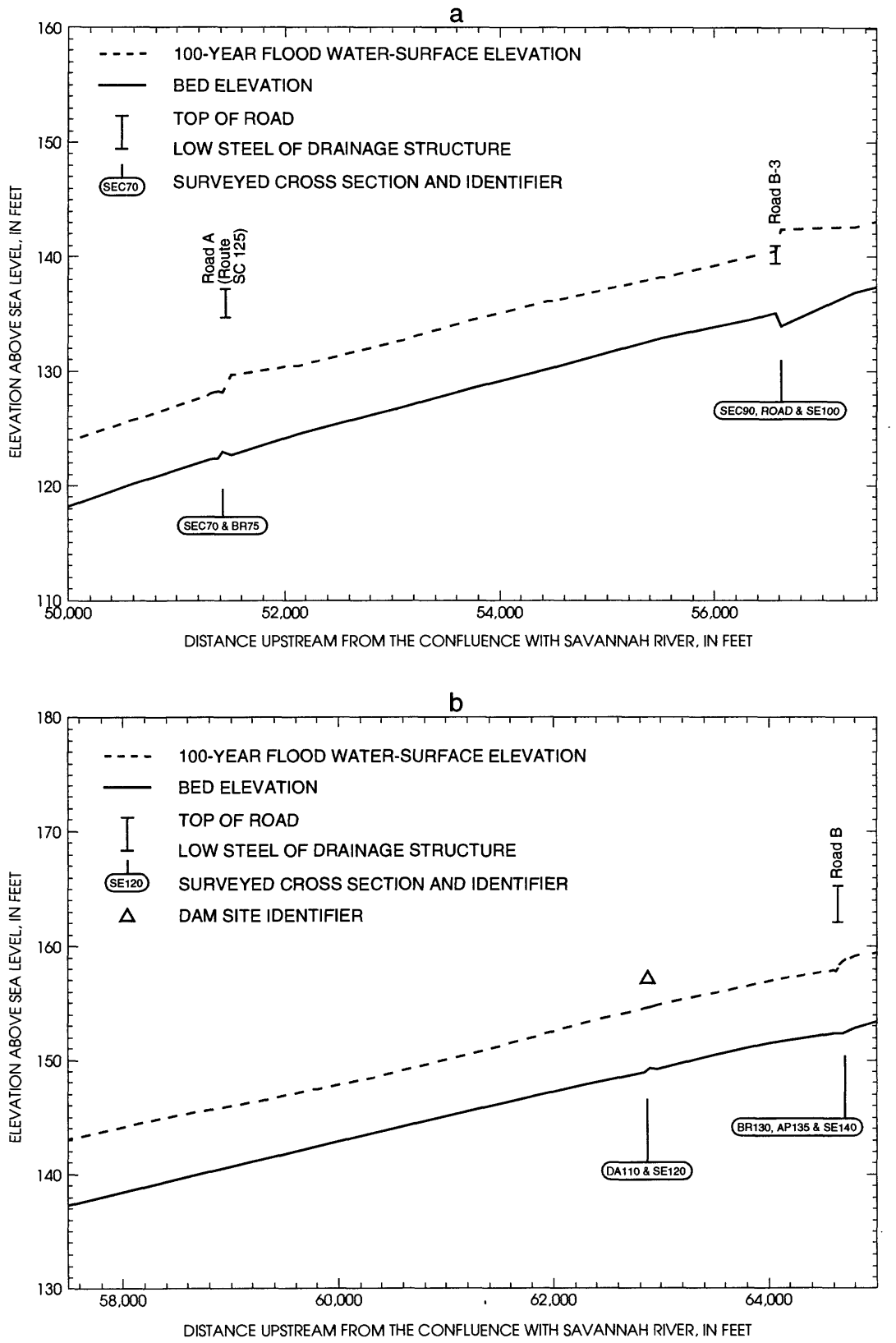

Figure 5. Flood profile of Pen Branch from (a) Station 50000 to Station 57500 and (b) Station 57500 to Station 65000, Savannah River Site, S.C.

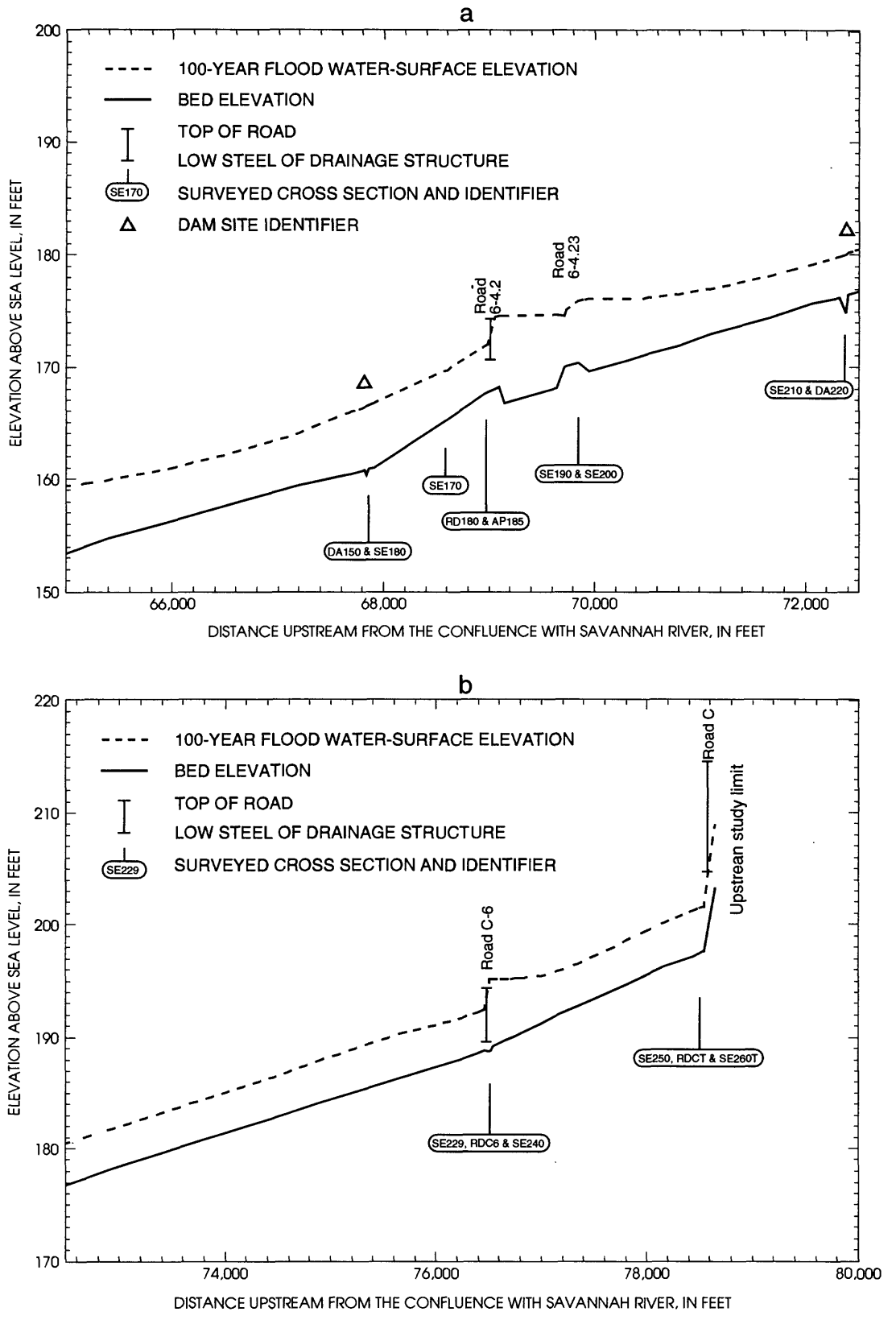

Figure 6. Flood profile of Pen Branch from (a) Station 65000 to Station 72500 and (b) Station 72500 to Station 78648, Savannah River Site, S.C.

Table 2. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Pen Branch, Savannah River Site, S.C.

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
SEC10	37950	2,100 ft downstream from Road A-13.2	surveyed	1,150	590	[2]103.0
SEC17	39770	280 ft downstream from Road A-13.2	surveyed	1,150	663	104.31
EX20	39994	56 ft downstream from Road A-13.2	synthesized	1,150	662	104.64
BR30	40050	Road A-13.2	surveyed	1,150	41	[3]104.63
APP31	40106	56 ft upstream from Road A-13.2	synthesized	1,150	704	106.39
SEC40	40609	559 ft upstream from Road A-13.2	surveyed	1,150	760	106.58
EX45	40796	145 ft downstream from CSX railway bridge	synthesized	1,150	748	106.69
RBR50	40941	CSX railway bridge	surveyed	1,150	62	[3]106.85
APP51	41086	145 ft upstream from CSX railway bridge	synthesized	1,150	776	108.08
S51.5	41500	15 ft downstream from breached dam	synthesized	1,080	618	108.32
DAM52	41515	Breached dam 574 ft upstream from CSX railway bridge	surveyed	1,080	67	108.26
S52.5	41530	15 ft upstream from breached dam	surveyed	1,080	619	108.44
S59.5	48616	2,828 ft downstream from Road A	synthesized	1,040	427	120.48
RD60	48672	2,772 ft downstream from Road A	surveyed	1,040	226	120.61
SEC61	48747	2,697 ft downstream from Road A	surveyed	1,040	424	120.85

Table 2. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Pen Branch, Savannah River Site, S.C. (Continued)

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
SEC62	48808	2,636 ft downstream from Road A	synthesized	1,040	507	120.98
SEC70	51315	129 ft downstream from Road A	surveyed	1,040	364	128.01
EX70	51382	62 ft downstream from Road A	synthesized	1,040	367	128.26
BR75	51444	Road A	surveyed	1,040	38	[3]128.16
APP81	51505	61 ft upstream from Road A	synthesized	1,040	396	129.65
SEC90	56328	258 ft downstream from Road B-3	surveyed	675	372	140.07
EXPI1	56558	28 ft downstream from Road B-3	synthesized	675	369	140.48
ROAD	56586	Road B-3	surveyed	675	258	[4]141.79
SE100	56611	25 ft upstream from Road B-3	surveyed	675	430	142.42
SY110	62850	50 ft downstream from breached dam	synthesized	620	221	154.56
DA110	62900	Breached dam 6,314 ft upstream from Road B-3	surveyed	620	108	154.65
SE120	62964	64 ft upstream from breached dam	surveyed	620	220	154.80
EX129	64600	35 ft downstream from Road B	synthesized	620	223	157.90
BR130	64635	Road B	surveyed	620	21	[3]157.80
AP135	64683	48 ft upstream from Road B	surveyed	620	63	158.66
SE140	64794	159 ft upstream from Road B	surveyed	620	296	159.16

Table 2. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Pen Branch, Savannah River Site, S.C. (Continued)

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
S150H	67820	18 ft downstream from breached dam	synthesized	570	265	166.31
DA150	67838	Breached dam 1,162 ft downstream from Road 6-4.2	surveyed	570	100	166.41
SE160	67911	73 ft upstream from breached dam	surveyed	570	269	166.70
SE170	68606	394 ft downstream from Road 6-4.2	surveyed	570	480	169.72
RD180	69000	Road 6-4.2	surveyed	570	117	[4]174.48
AP185	69057	57 ft upstream from Road 6-4.2	surveyed	570	459	174.51
SE190	69712	Road 6-4.23	surveyed	570	194	[5]174.57
SE200	69945	233 ft upstream from Road 6-4.23	surveyed	570	437	176.07
SE210	72312	63 ft downstream from breached dam	surveyed	520	322	179.86
DA220	72375	4,105 ft downstream from Road C-6	surveyed	520	87	180.03
SY221	72400	25 ft upstream from breached dam	synthesized	520	326	180.25
SE229	76394	86 ft downstream from Road C-6	surveyed	315	183	192.17
RDC6	76480	Road C-6	surveyed	315	105	[4]195.00
AP240	76509	29 ft upstream from Road C-6	synthesized	315	329	195.10
SE240	76520	40 ft upstream from Road C-6	surveyed	315	322	195.10
SE250	78445	155 ft downstream from Road C	surveyed	315	235	201.23

Table 2. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Pen Branch, Savannah River Site, S.C. (Continued)

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
RDCT[6]	78600	Road C (Tributary)	surveyed	170	15	[3]208.87
SE260T[6]	78645	45 ft upstream Road C (Tributary)	surveyed	170	217	208.87
RDCM	78600	Road C (Main)	surveyed	190	18	[3]202.92
SE260M	78648	48 ft upstream Road C (Main)	surveyed	190	140	202.92

[1]All surveyed cross sections are shown in plate 1; synthesized cross sections are not shown in plate 1.
[2]Backwater from the Savannah River.
[3]Road or railway is not overtopped.
[4]Road is overtopped.
[5]Road does not cross Pen Branch.
[6]Shown on profile plot.

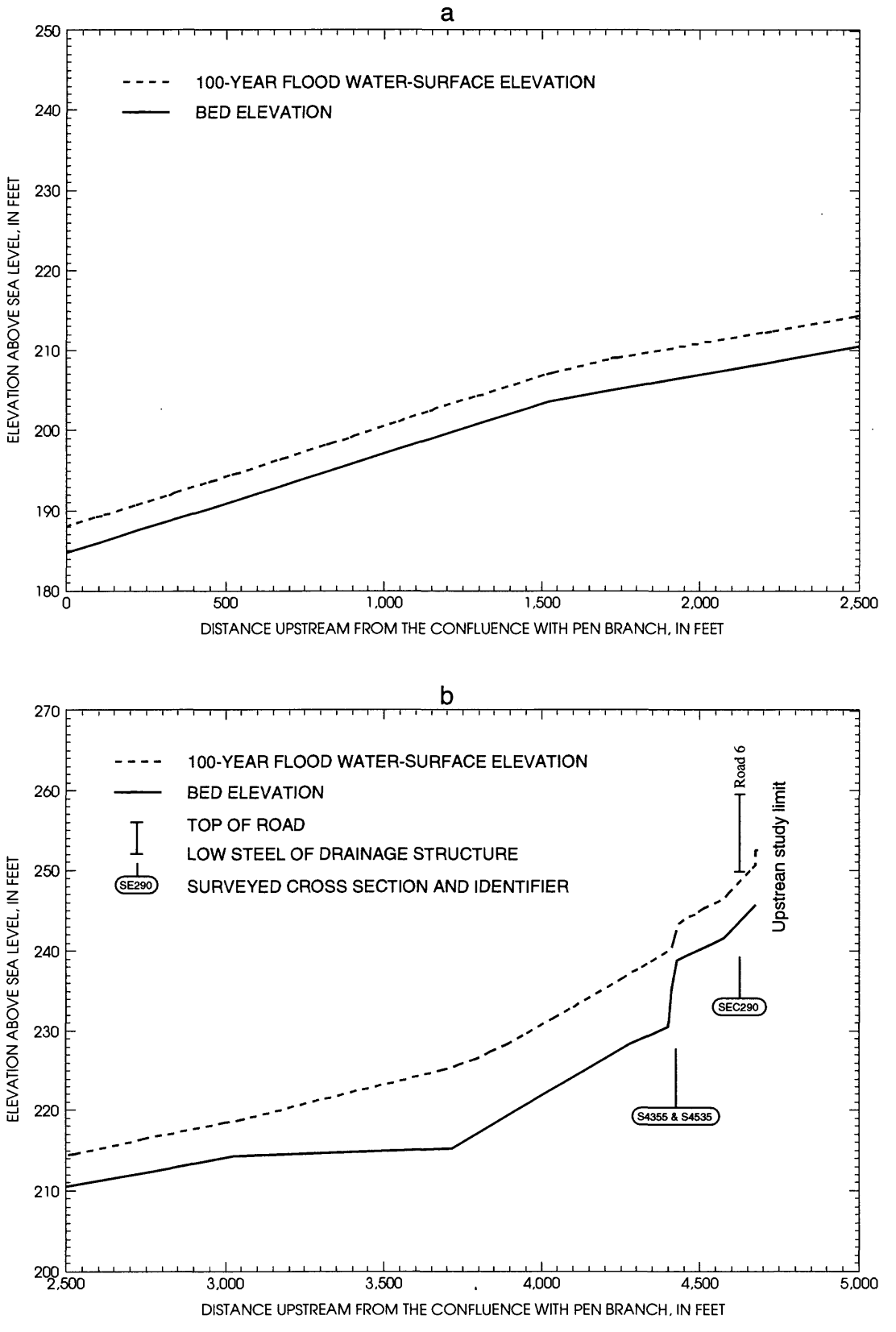

Figure 7. Flood profile of unnamed tributary to Pen Branch from (a) Station 0 to Station 2500 and (b) Station 2500 to Station 4685, Savannah River Site, S.C.

Table 3. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of unnamed tributary to Pen Branch, Savannah River Site, S.C.

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
S900	900	3,725 ft downstream from Road 6	synthesized	550	222	199.19
S2210	2210	2,415 ft downstream from Road 6	synthesized	550	221	212.29
S4355	4355	270 ft downstream from Road 6	surveyed	550	17	238.96
S4535	4535	90 ft downstream from Road 6	surveyed	550	177	245.68
SEC290	4625	Road 6	surveyed	550	10	[2]252.68
SY300	4685	60 ft upstream from Road 6	synthesized	550	339	252.68

[1]All surveyed cross sections are shown in plate 1; synthesized cross sections are not shown in plate 1.
[2]Road is not overtopped.

Station 17700 (pl. 1). Backwater caused by the road and railway bridges ranges from less than 1.0 ft at Road A to 1.1 ft at the downstream CSX railway bridge. Graphical and tabular profiles of Steel Creek are shown in figures 8 and 9 and listed in table 4, respectively. The areal extent of the inundation caused by the 100-year flood on Steel Creek is shown in plate 1.

Meyers Branch

Meyers Branch was analyzed from its confluence with Steel Creek to Old Dunbarton Road (pl. 1). Station 0 is located at the confluence of Meyers Branch and Steel Creek. The 26,000-ft long study segment consists of 9-surveyed and 44-synthesized cross sections. Within the study area, there are two culvert crossings, one highway bridge, and one breached dam crossing Steel Creek. The culverts are located at the CSX Railway and Old Dunbarton Road at Stations 18900 and 24075, respectively (pl. 1). The highway bridge is located on Road 9 at Station 11962 (pl. 1). The breached dam/road bed is located at Station 19254 (pl. 1). The 100-year flood-plain widths range from 90 ft at Station 18850 to 950 ft at Station 4900 (pl. 1). Backwater caused by the Road 9 bridge is 0.6 ft. In addition, Old Dunbarton Road is overtopped by a depth of 1.0 ft. Graphical and tabular profiles of Meyers Branch are shown in figures 10 and 11 and listed in table 5, respectively. The areal extent of the inundation caused by the 100-year flood on Meyers Branch is shown in plate 1.

Unnamed Tributary to Meyers Branch

The unnamed tributary to Meyers Branch was analyzed from its confluence with Meyers Branch to the breached dam 442 ft upstream of the CSX railway crossing (pl. 1). Station 0 is located at the confluence of the unnamed tributary and Meyers Branch. The 4,500-ft long study segment consists of 4-surveyed and 11-synthesized cross sections. Within the study area, there is one culvert crossing and one breached dam that cross the unnamed tributary. The culvert is located at the CSX railway crossing at Station 3810 (pl. 1). The breached dam is located at Station 4252 (pl. 1). The 100-year flood-plain widths range from 130 ft at Station 3600 to 400 ft at Station 100 (pl. 1). Graphical and tabular profiles of the unnamed tributary are shown in figure 11 and listed in table 6, respectively. The areal extent of the inundation caused by the 100-year flood on the unnamed tributary to Meyers Branch is shown in plate 1.

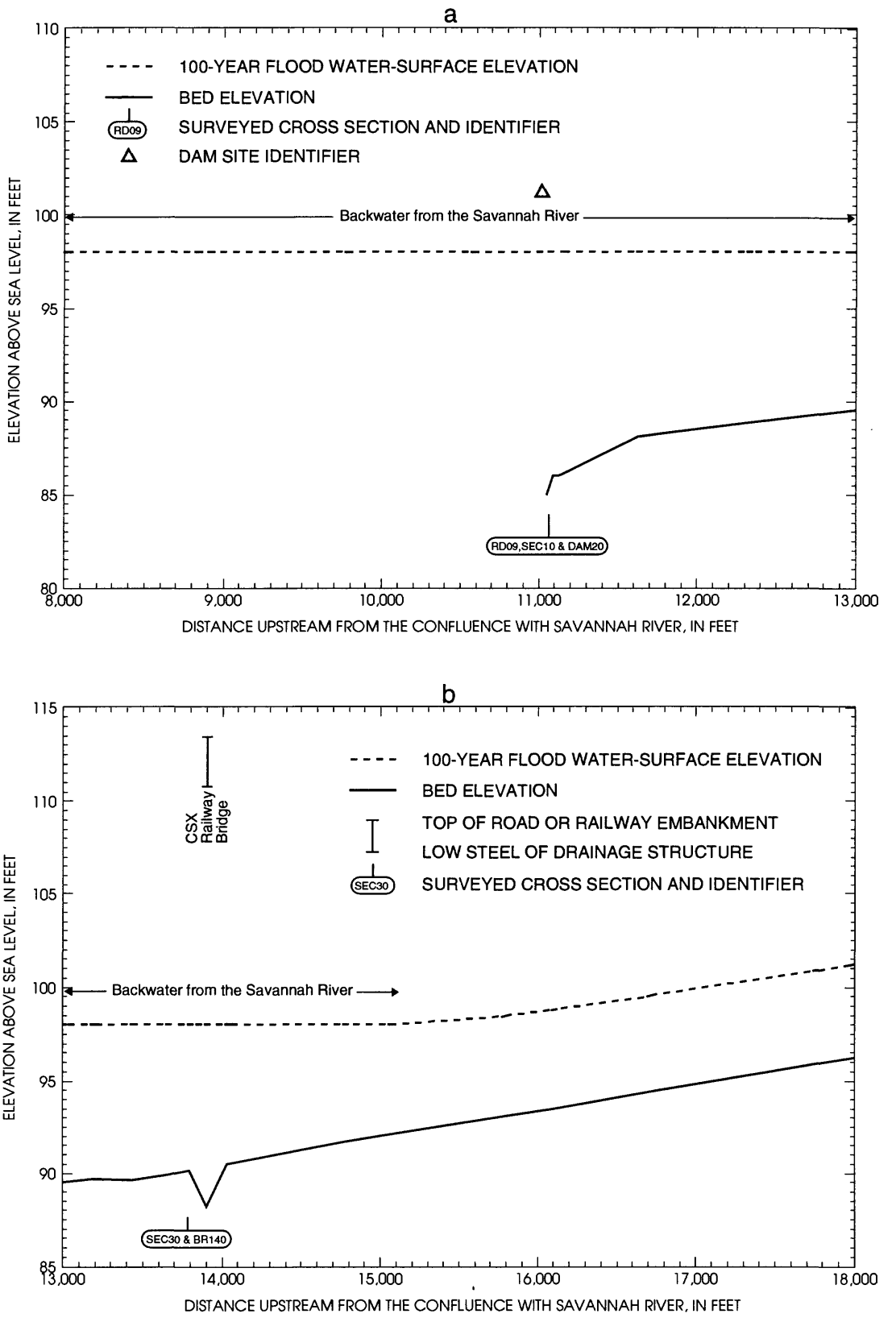

Figure 8. Flood profile of Steel Creek from (a) Station 8000 to Station 13000 and (b) Station 13000 to Station 18000, Savannah River Site, S.C.

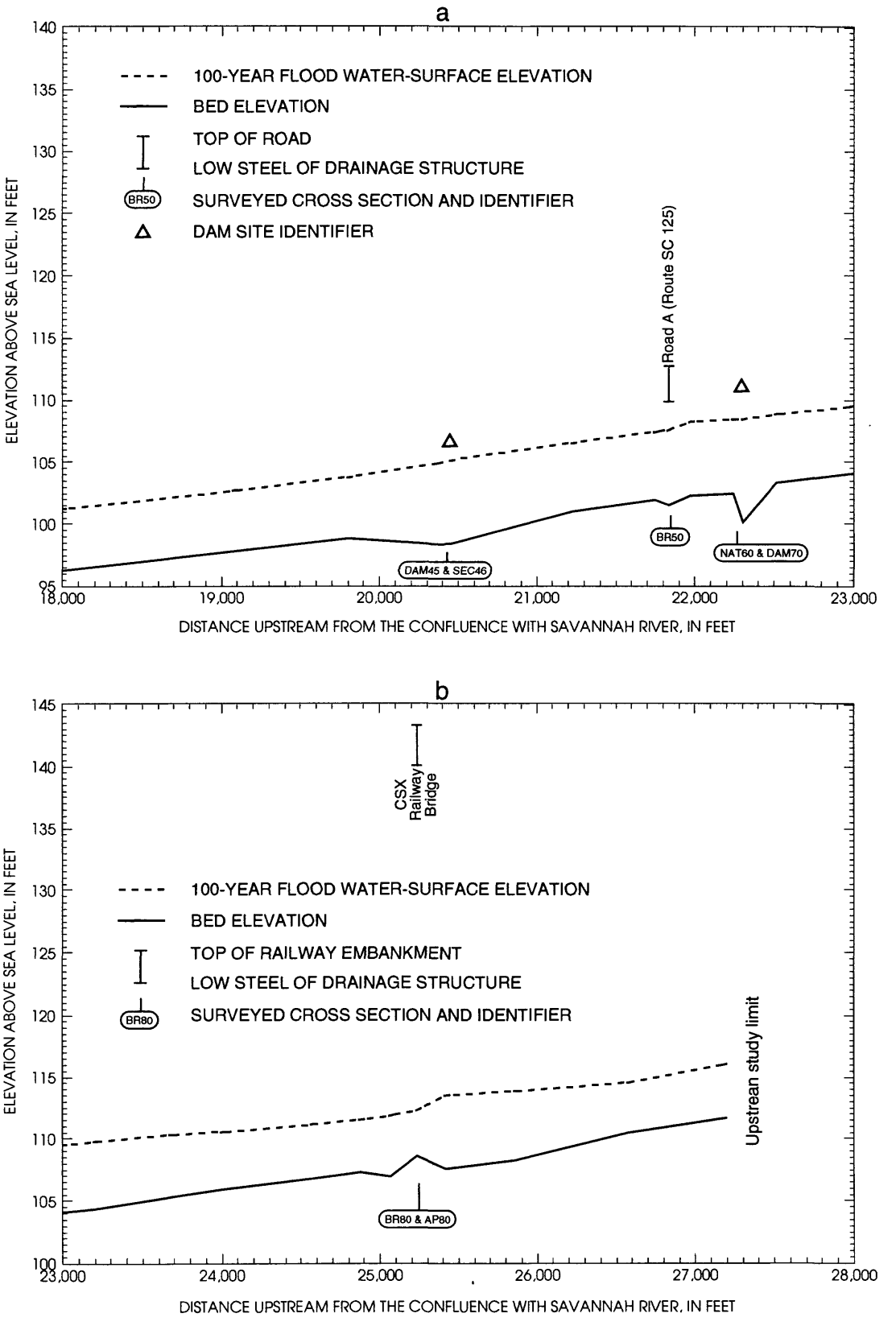

Figure 9. Flood profile of Steel Creek from (a) Station 18000 to Station 23000 and (b) Station 23000 to Station 27300, Savannah River Site, S.C.

Table 4. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Steel Creek, Savannah River Site, S.C.

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
RD09	11050	Breached road; 2,860 ft downstream from CSX railway bridge	surveyed	1,330	860	[2]98.0
SEC10	11088	37 ft downstream from breached dam	surveyed	1,330	790	[2]98.0
DAM20	11125	Breached dam; 2,785 ft downstream from CSX railway bridge	surveyed	1,330	790	[2]98.0
SYN21	11145	20 ft upstream from breached dam	synthesized	1,330	790	[2]98.0
SEC30	13770	140 ft downstream from CSX railway bridge	surveyed	1,330	933	[2]98.0
BRI40	13910	CSX railway bridge	surveyed	1,330	65	[2,3]98.0
APP40	14029	119 ft upstream from CSX railway bridge	synthesized	1,330	879	[2]98.0
SYN46	20400	25 ft downstream from a breached dam	synthesized	1,180	739	104.94
DAM45	20425	Breached dam; 1,434 ft downstream from Road A	surveyed	1,180	361	104.98
SEC46	20450	25 ft upstream from a breached dam	surveyed	1,180	743	105.13
EX50	21748	111 ft downstream from Road A	synthesized	1,180	745	107.41
BR50	21859	Bridge at Road A (Route S.C. 125)	surveyed	1,180	76	[3]107.56
AP50	21970	111 ft upstream from Road A	synthesized	1,180	665	108.22
NAT60	22240	381 ft upstream from Road A	surveyed	1,180	688	108.44
DAM70	22300	Breached dam; 441 ft from Road A	surveyed	1,180	84	108.45

Table 4. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Steel Creek, Savannah River Site, S.C. (Continued)

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
EX80	25069	174 ft downstream from CSX railway bridge	synthesized	540	320	111.86
BR80	25243	CSX railway bridge	surveyed	540	50	[3]112.28
AP80	25417	174 ft upstream from CSX railway bridge	surveyed	540	272	113.49
S80C	27200	1,957 ft upstream from CSX railway bridge	synthesized	540	422	116.06

[1]All surveyed cross sections are shown in plate 1; synthesized cross sections are not shown in plate 1.
[2]Backwater from the Savannah River.
[3]Road or railway not overtopped.

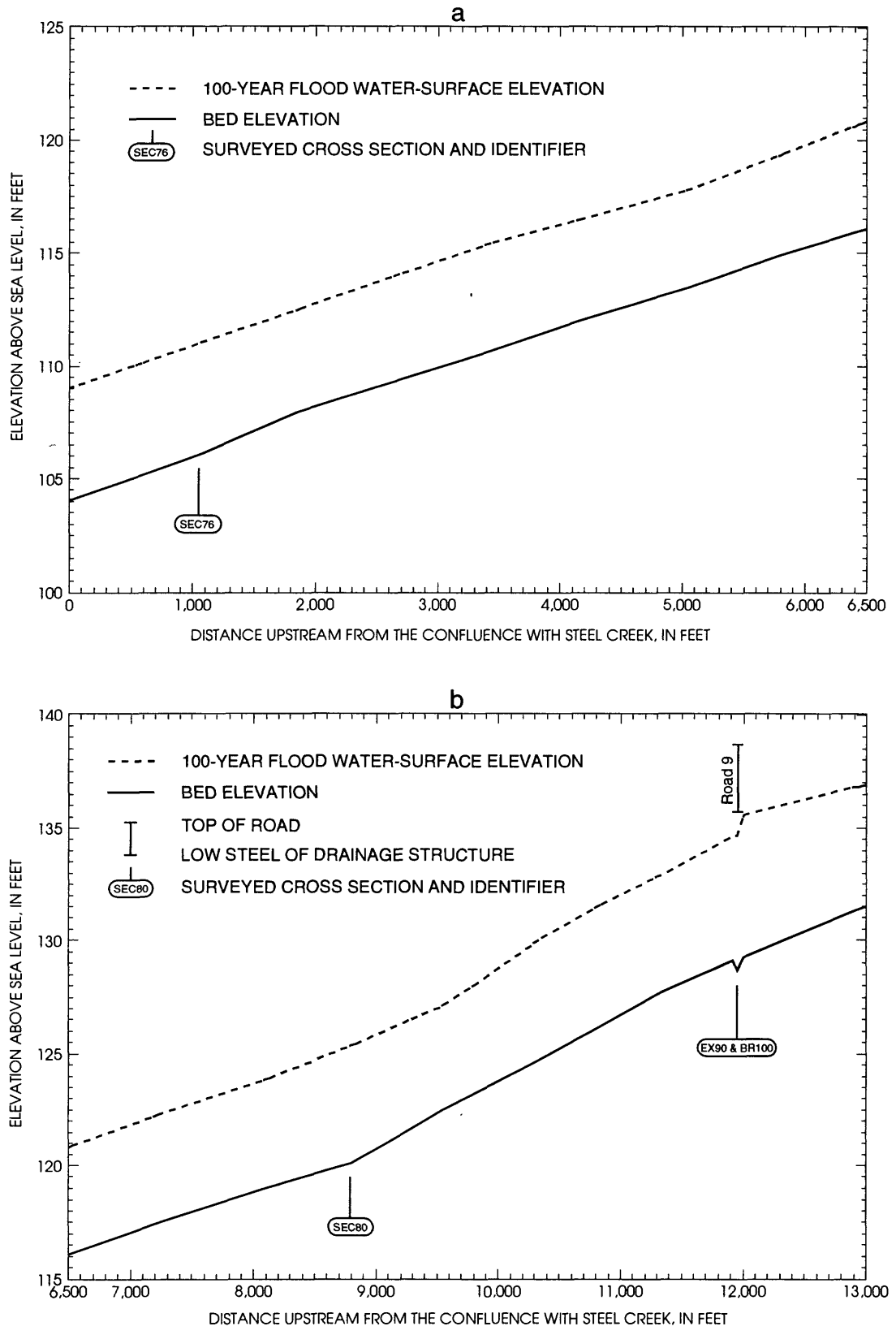

Figure 10. Flood profile of Meyers Branch from (a) Station 0 to Station 6500 and (b) Station 6500 to Station 13000, Savannah River Site, S.C.

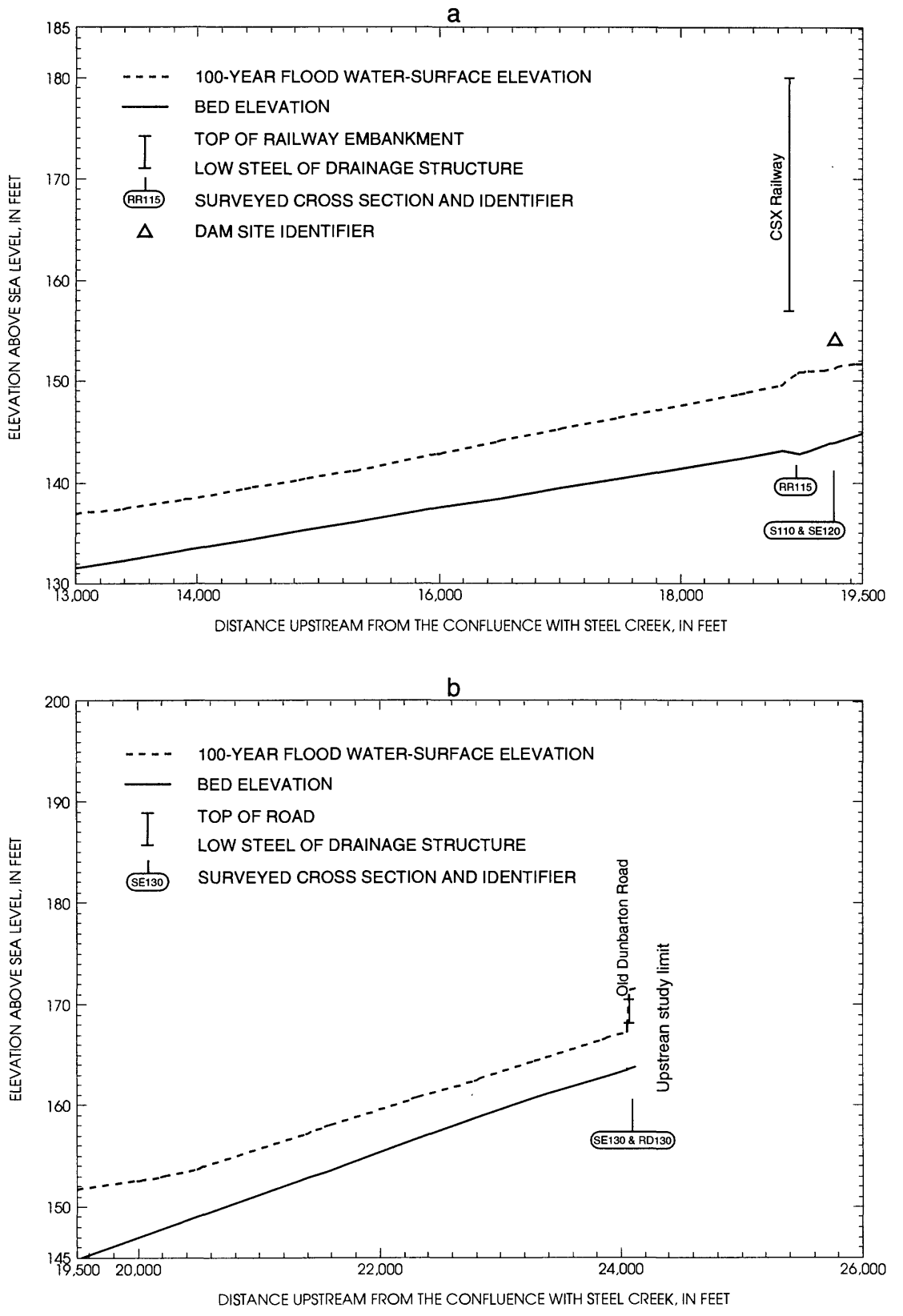

Figure 11. Flood profile of Meyers Branch from (a) Station 13000 to Station 19500 and (b) Station 19500 to Station 24120, Savannah River Site, S.C.

Table 5. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of Meyers Branch, Savannah River Site, S.C.

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
SEC76	1075	10,887 ft downstream from Road 9	surveyed	900	608	111.07
SEC80	8800	3,162 ft downstream from Road 9	surveyed	850	517	125.36
EX90	11920	42 ft downstream from Road 9	surveyed	740	315	134.65
BR100	11962	Bridge at Road 9	surveyed	740	31	[2]134.68
AP100	12004	42 ft upstream from Road 9	synthesized	740	346	135.59
EX110	18836	64 ft downstream from CSX railway	synthesized	640	209	149.59
RR115	18900	CSX railway culvert	surveyed	640	16	150.83
S105	18984	84 ft upstream from CSX railway	synthesized	640	247	150.83
S110	19254	Breached dam; 354 ft upstream from CSX railway	surveyed	640	35	151.05
SE120	19284	30 ft upstream from breached dam	surveyed	640	229	151.35
SE130	23860	215 ft downstream from Old Dunbarton Road	surveyed	420	331	166.58
RD130	24075	Old Dunbarton Road	surveyed	420	161	[3]171.40
AP130	24120	45 ft upstream from Old Dunbarton Road	synthesized	420	475	171.58

[1]All surveyed cross sections are shown in plate 1; synthesized cross sections are not shown in plate 1.
[2]Road or railway is not overtopped.
[3]Road is overtopped.

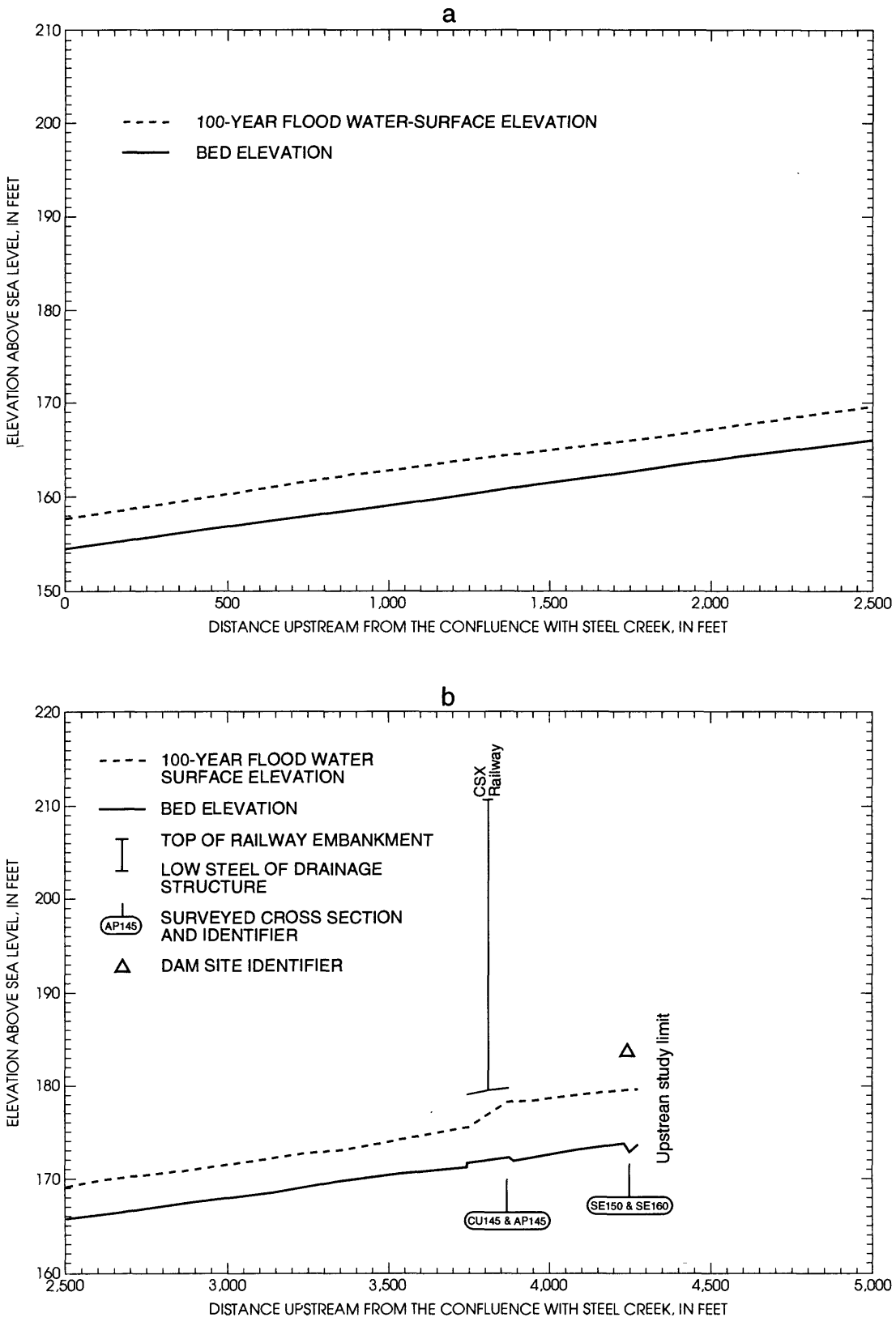

Figure 12. Flood profile of unnamed tributary to Meyers Branch from (a) Station 0 to Station 2500 and (b) Station 2500 to Station 4280, Savannah River Site, S.C.

Table 6. Cross-section name, Station, location, type, and 100-year flow, flood-plain width, and water-surface elevation for selected cross sections of unnamed tributary to Meyers Branch, Savannah River Site, S.C.

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

Cross-section name	Cross-section Station	Cross-section location	Type of cross section[1]	100-year flow (ft^3/s)	100-year flood-plain width (ft)	100-year water-surface elevation (ft above sea level)
S150A	300	3,510 ft downstream from CSX Railway crossing	synthesized	350	312	159.05
S150E	2970	840 ft downstream from CSX Railway crossing	synthesized	350	263	171.25
DSCUL	3743	67 ft downstream from CSX Railway crossing	synthesized	350	281	175.24
CU145	3810	CSX railway crossing	surveyed	350	6	[2]177.92
AP145	3885	75 ft upstream from CSX railway	surveyed	350	24	177.92
SE150	4237	427 ft upstream from CSX railway crossing	surveyed	350	313	179.29
SE160	4252	Breached dam, 442 ft upstream from CSX railway crossing	surveyed	350	70	179.26
SY150	4280	28 ft upstream from breached dam	synthesized	350	312	179.40

[1]All surveyed cross sections are shown in plate 1; synthesized cross sections are not shown in plate 1.
[2]Railway is not overtopped.

SUMMARY

In 1951, the U.S. Department of Energy, formerly the Atomic Energy Commission, created the Savannah River Site to produce nuclear materials for national defense. The Savannah River Site is located in parts of Aiken, Allendale, and Barnwell Counties, S.C. In 1992, the U.S. Geological Survey, U.S. Department of the Interior, in cooperation with the U.S. Department of Energy, initiated an investigation to determine the areal and vertical extent of inundation caused by the 100-year recurrence-interval flood for the Savannah River along the Savannah River Site southwestern boundary, and for the major streams and their tributaries on the Savannah River Site, with the exception of Lower Three Runs.

Hydrologic and hydraulic data were collected for the Pen Branch and Steel Creek drainage basins. The hydrologic data includes drainage area, soil type, impervious area, and peak-flow records at USGS gaging stations. The hydraulic data includes surveyed cross sections taken upstream and (or) downstream from bridge and culvert crossings, along paved road grades at these crossings, and at selected locations along the streams, such as natural or man-made expansions or contractions and powerline right-of-ways. In additions, elevation data and structural geometry for all bridges and culverts were determined by field surveys. Manning's roughness coefficients were estimated for the channels and flood plains using engineering judgement.

A flood-frequency analysis was made to estimate the 100-year recurrence-interval flow for the Pen Branch and Steel Creek drainage basins. This analysis showed that the U.S. Geological Survey regional rural- and urban-regression equations for South Carolina reasonably describe the 100-year flows for Pen Branch, Steel Creek, and their tributaries.

The computed 100-year flows and surveyed cross sections were used in a step-backwater model to compute the 100-year flood plain for Pen Branch, Steel Creek, and their selected tributaries. In areas affected by backwater from the Savannah River data from a previously published report will be used to determine the 100-year profile. The profiles computed by the step-backwater model or the previously published report were used to delineate the 100-year flood plain on topographic maps.

This report includes maps of the flood plain and profiles of the 100-year flood on Pen Branch, Steel Creek, and their selected tributaries. The results also are provided in tabular format. This report provides water-resource managers with a technical basis for making flood-plain management decisions that could minimize future flood problems and provide a basis for designing and constructing drainage structures along roadways.

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APPENDIX--Description of elevation reference marks

APPENDIX-- Description of Elevation Reference Marks

[ft, feet; USGS, U.S. Geological Survey; mi, mile; USC&GS, U.S. Coastal and Geodetic Survey]
(In this report, the words "right" and "left" refer to directions that would be reported by an observer facing downstream.)

Elevation reference mark	Description	Elevation above sea level (ft)
PB2	Chiseled square in the upstream right abutment curb of Road A-13.2 bridge crossing Pen Branch. Established by the USGS.	108.15
PB4	Chiseled square on the upstream right abutment headwall of Road A bridge crossing Pen Branch. Established by the the USGS.	137.18
PB130	Chiseled square on the downstream left headwall of the Road B bridge crossing Pen Branch. Established by the USGS.	164.93
SC50	Chiseled square on the downstream right headwall of the Road A bridge crossing Steel Creek. Established by the USGS.	112.93
MB100	Chiseled square on the downstream right headwall of the Road 9 bridge crossing Meyers Branch. Established by the USGS.	136.81
MB110	Chiseled square on the upstream left headwall of the CSX railway culvert crossing Meyers Branch. Established by the USGS.	159.25
A101	Brass tablet located 0.45 mi northeast along the CSX railway from the railroad station at Robbins, 0.9 mi west of the Road A overpass over the track, at the graded road crossing, in the Y-fork of a spur track leading to the southwest and connects with the main track to the southeast, 28 ft south of the south rail of the main track, 92 ft northwest of the northwest rail of the spur track, 2 ft west of the metal witness post. Established by the USC&GS.	124.70
C101	Brass tablet located 1.55 mi northwest along CSX railroad from Robbins Station, at a graded road crossing, 94 ft northeast of northeast rail at the centerline of crossing, 36 ft northwest of the centerline of the road, 2 ft southeast of metal witness post. Established by the USC&GS.	129.25
F101	Brass tablet located 4 mi northeast along CSX railway from Robbins Station, 0.1 mi east of milepost K 426, at the crossing of Road 9, 27 ft south of the south rail, 89 ft southeast of center line of the crossing, 1.5 ft east of witness post. Established by the USC&GS.	172.47

APPENDIX-- Description of Elevation Reference Marks (Continued)

[ft, feet; USGS, U.S. Geological Survey; mi, mile; USC&GS, U.S. Coastal and Geodetic Survey]
(In this report, the words "right" and "left" refer to directions that would be reported by an observer facing downstream.)

Elevation reference mark	Description	Elevation above sea level (ft)
H101	Brass tablet located 4.75 mi northwest along CSX railway from Robbins Station, at the crossing of Road A-13 and CSX Railway, 24 ft northeast of the northeast rail, 27 ft southwest of the center line of the road, 69 ft north of the center of the crossing, and 1 ft southeast of a metal witness post. Established by the USC&GS.	150.193
K103	Brass tablet located 6.1 mi northeast along Road 3 from CSX railroad crossing, at the junction of Road C and Road 3 in the Y formed by these roads, 24 ft southwest of the center line of the southwest lane of Road C, 69 ft south of the centerline of Road 3 at the junction of this road with the south leg of road 3, 1.5 ft north of metal witness post. Established by the USC&GS.	312.77
R102	Brass tablet located 3.15 mi southwest of the junction of Road C and Road 3, about 0.4 mi northeast of four 6-ft diameter concrete pipes over Fourmile Branch, at the junction of the woods road leading north, 59 ft north of the center line of Road 3, 37 ft west of the center line of the woods road, 2 ft east of the metal witness post, 1.5 ft below the level of the highway. Established by the USC&GS.	200.154
U102	Brass tablet located at the junction of Roads C and 5, set in the junction Y of Road 5, 80.5 ft southwest of the centerline of the southwest two of four lanes of Road C north, 77 ft southeast of the center line of Road 5, 71 ft northwest of the centerline of the southeast leg of the junction. Established by the USC&GS.	301.213
Y100	Brass tablet located 1.55 mi northeast along CSX railroad from Robbins Station, 0.2 miles northeast of Road A overpass over the track, northwest end of southwest abutment to a 125 ft concrete bridge crossing Steel Creek. Established by the USC&GS.	143.55