DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION
AND THE MISSISSIPPI STATE HIGHWAY DEPARTMENT

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS, WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI

By B. E. Colson, C. O. Ming, and George J. Acrement.

Prepared in cooperation with the
DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
and the
MISSISSIPPI STATE HIGHWAY DEPARTMENT

HYDROLOGIC INVESTIGATIONS ATLAS
Published by the U.S. Geological Survey, 1979
W

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI

INTRODUCTION

New techniques for predicting water-surface profiles, needed in the design of economical, structurally sound, and environmentally compatible stream crossings, are under investigation. The investigation has accelerated with the advent of digital computers capable of analyzing large quantities of data. Among the techniques is the development of two-dimensional (2–D) digital models. Field data are essential for development and evaluation of these techniques for predicting water-surface profiles. This atlas is one of a series that provide a wide range of field data.

Since 1969 the U.S. Geological Survey has been collecting backwater data where wide, densely vegetated flood plains are crossed by highway embankments and single-opening bridges. This work was done in cooperation with the Federal Highway Administration Department of Transportation, the Alabama State Highway Department, the Louisiana Department of Transportation and Development, and the Mississippi State Highway Department. The objective of this cooperative project is to present the data in a format conducive to the development of improved models for predicting hydraulic responses of flow at highway crossings of streams in complex hydrologic and geographic settings.

Backwater data were obtained at 22 sites for 35 floods; that is, 11 sites had 1 flood each; 9 sites, 2 floods each; and 2 sites, 3 floods each. Analysis of data (Schneider and others, 1976) showed that backwater and discharge at these sites computed by methods presently in use, would be inaccurate. The floodflow data are unique in the range and detail in which information was collected and provide a base for evaluating digital models relating to open-channel flow.

The data sites (fig. 1) are listed below. This atlas shows flood data obtained on West Fork Amite River near Liberty, Miss., one of the 22 sites.

HYDROLOGIC INVESTIGATIONS ATLAS NUMBER

ALABAMA
- Buckhorn Creek near Shiloh HA–607
- Pea Creek near Louisville 608
- Poley Creek near Sanford 609
- Yellow River near Sanford 610
- Whitewater Creek near Tarentum 611

LOUISIANA
- Alexander Creek near St. Francisville HA–600
- Beaver Creek near Kentwood 601
- Comite River near Olive Branch 602
- Cypress Creek near Downsville 603
- Flagon Bayou near Libuse 604
- Little Bayou de Loutre near Truxno 605
- Tenmile Creek near Elizabeth 606

MISSISSIPPI
- Bogue Chitto near Johnston Station HA–591
- Bogue Chitto near Summit 592
- Coldwater River near Red Banks 593
- Lobutcha Creek at Zama 594
- Okatoma Creek east of Magee 595
- Okatoma Creek near Magee 596
- Tallahala Creek at Waldrup 590
- Thompson Creek near Clara 597
- West Fork Amite River near Liberty 598
- Yockanookany River near Thomastown 599

DESCRIPTION OF DATA

TYPE OF DATA

Data collected at all study sites consist of (1) depths, velocities, and discharges measured through the bridge openings, and (2) peak water-surface elevations along the highway embankment and along cross sections. A minimum of eight valley cross sections were surveyed at approximately one valley-width intervals in the vicinity of the bridge at each site. Locations of the cross sections were alined perpendicularly to the assumed direction of flow. Cross sections were extended to intersect the edge of the valley at equal water-surface elevations. Surveying procedures described in the U.S. Geological Survey Techniques of Water-Resources Investigations series (Matthai, 1967; Benson and Dalrymple, 1967) were followed.

HIGH-WATER MARKS

Water-surface elevations were determined from high-water marks identified along the cross sections and the edges of the valley after each flood. During peak discharge measurements, water-surface elevations were marked with standard surveying stakes along the upstream and downstreams sides of the highway embankment. For some floods additional high-water marks were identified in the valley adjacent to the bridge to define in detail the water surface in the approach and exit reaches.

BRIDGE GEOMETRY

Detailed bridge geometry was obtained at each site. The bridge cross section was surveyed at the most contracted section. Piers, spur dikes, wingwalls, abutment slopes, and other pertinent geometry were measured.

MANNING'S ROUGHNESS COEFFICIENT

Schneider and others (1976) used composite Manning's roughness coefficient values *n* where frequent changes in roughness occurred. In their study, composite values of *n* were verified by matching step backwater computations of the water surface with actual water-surface profiles for measured discharges. The range of *n* values used in this report is based on values used by Schneider and others (1976). Roughness varies from open fields to dense forests.

Roughness values or ranges of roughness values in different parts of the flood plain are shown on the maps. The values shown are based on water depth. The high value is the value where water depth is less than 0.6 meter and the low value applies where water depth is greater than 1.0 meter. A linear relation of roughness to water depth is assumed for water depths between 0.6 and 1.0 meter.

PRESENTATION OF DATA

The data are presented on topographic maps enlarged from standard 1:24,000 or 1:62,500 scale U.S. Geological Survey topographic maps which comply with National Map Accuracy Standards. Accuracy limitations of the base maps are retained in the enlargements. Although positions may be scaled closely on the enlargements, they are not defined with greater accuracy than positions on the base maps.

Ground elevations are placed adjacent to solid squares. Elevations of floodmarks are indicated by numerical values adjacent to solid triangles. Floodmark elevations for separate floods are shown on separate sheets. Bridge geometry and road-embankment dimensions are shown with brief notations of pier spacing and configuration.

In addition to the data points shown on the maps, discharge measurements of selected floods, plots of cross sections, and velocity distribution diagrams are shown. Cross-section elevations are tabulated to define stream channels and flood-plain features in greater detail. Each cross section is referred to a zero station established at the extreme left edge (facing downstream) of the valley.

DATUM

All elevations presented in this report are referred to National Geodetic Vertical Datum of 1929 (NGVD).

FLOOD FREQUENCY

Flood-frequency relations are presented graphically. Techniques for deriving flood-frequency relations are those described by the U.S. Water Resources Council (1977), and by (Colson and Hudson, 1976).

INTERNATIONAL SYSTEM OF UNITS (SI)

The International System of Units (SI) is used throughout this report. All data were measured in the U.S. customary units and converted to SI units. Ground elevations which were originally determined to the nearest tenth of a foot are rounded to the nearest 0.01 meter. Water-surface elevations which were surveyed to hundredths of a foot are rounded to millimeters. The same criteria apply to all other dimensions, except contour elevations which are shown to the nearest tenth of a meter.

The following factors may be used to convert SI units to the U.S. customary units:

MULTIPLY SI UNITS	*BY*	*TO OBTAIN U.S. CUSTOMARY UNITS*
	LENGTH	
Meter (m)	3.281	Feet (ft)
	AREA	
Square meter (m^2)	10.76	Square feet (ft^2)
	VOLUME	
Cubic meter (m^3)	35.31	Cubic feet (ft^3)
	VELOCITY	
Meter per second (m/s)	3.281	Feet per second (ft/s)
	FLOW RATE	
Cubic meter per second (m^3/s)	35.31	Cubic feet per second (ft^3/s)

DATA FOR WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI

Data for West Fork Amite River near Liberty, Miss., obtained in a 5-kilometer reach crossed about midway by State Highway 567 are presented on four sheets (fig. 2). Sheet 1 contains tables showing cross-section data (table 1) and discharge data (table 2). An aerial view looking upstream in the vicinity of the bridge is shown in figure 3. Relative magnitudes of the floods are shown on the frequency curve (fig. 4).

The locations of representative ground elevations are shown on sheet 2. These are points of significant changes in cross section elevation and alinement of the axis. Plots of the cross sections are graphic presentations of the tabular data.

Bridge geometry and road embankments are shown on sheet 2 as they existed at the time of the floods. The cross section surveyed at the downstream side of the bridge is tabulated on sheet 1. The cross section shown for velocity distribution was obtained by sounding from the upstream side of the bridge during the discharge measurement.

Data for two floods on West Fork Amite River are presented. The first flood occurred December 6, 1971 (sheet 3). Ten cross sections were surveyed after this flood (sheet 2). A second flood occurred on March 25, 1973 (sheet 4).

A profile of the roadway crown was surveyed after the 1971 flood. Valley cross sections as surveyed are considered valid for both floods.

Manning's roughness coefficient values and the 1973 flood boundaries are shown on sheets 2 to 4.

FLOOD OF DECEMBER 6, 1971

Peak water-surface elevations, the measured cross section, and velocities for the flood of December 6, 1971, are shown on sheet 3. The flood crested at an elevation of 98.036 meters at the reference point located on the downstream guardrail 15 meters from the left abutment. The peak discharge was 402 cubic meters per second (m^3/s), from a stage-discharge relation developed for the site. A discharge of 391 m^3/s was measured on the recession at an elevation of 97.975 meters at the reference point (table 2). The recurrence interval of the peak discharge is approximately 100 years (Colson and Hudson, 1976). See figure 4.

FLOOD OF MARCH 25, 1973

Peak water-surface elevations for the flood of March 25, 1973, are shown on sheet 4. The average crest elevation at the downstream bridge abutments was 98.109 meters. The peak discharge was 481 m^3/s from the stage-discharge relation for the site. No discharge measurement was made during this flood. The measured cross section and velocity distribution for the measurement of April 8, 1973 are shown on sheet 4. The recurrence interval of the peak discharge is greater than 100 years (Colson and Hudson, 1976). See figure 4.

SUMMARY

Floodflow data that will provide a base for evaluating digital models relating to open-channel flow were obtained at 22 sites on streams in Alabama, Louisiana, and Mississippi. Thirty-five floods were measured. Analysis of the data indicated methods currently in use would be inaccurate where densely vegetated flood plains are crossed by highway embankments and single-opening bridges. This atlas presents flood information at the site on West Fork Amite River near Liberty, Miss. Water depths, velocities, and discharges through bridge openings on West Fork Amite River near Liberty, Miss. for floods of December 6, 1971, and March 25, 1973, are shown, together with peak water-surface elevations along embankments and along cross sections. Manning's roughness coefficient values in different parts of the flood plain are shown on maps, and flood-frequency relations are shown on a graph.

ADDITIONAL INFORMATION

Other information pertaining to floods in Alabama, Louisiana, and Mississippi may be obtained at the offices of the U.S. Geological Survey listed below:

U.S. Geological Survey
Room 202, Oil and Gas Board Building (P. O. Box V)
University, Alabama 35486

U.S. Geological Survey
6554 Florida Boulevard (P. O. Box 66492)
Baton Rouge, Louisiana 70896

U.S. Geological Survey
430 Bounds Street
Jackson, Mississippi 39206

SELECTED REFERENCES

Barnes, H. H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geol. Survey Water Supply Paper 1849, 213 p.

Benson, M. A., and Dalrymple, T., 1967, General field and office procedures for indirect discharge measurements: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, Chap. A1, 30 p.

Bradley, J. N., 1970, Hydraulics of bridge waterways: Federal Highway Admin., Hydraulic Design Ser. No. 1, 111 p.

Colson, B. E., and Hudson, J. W., 1976, Flood frequency of Mississippi streams: Mississippi State Highway Dept., 34 p.

Hains, C. F., 1973, Floods in Alabama, magnitude and frequency: Alabama Highway Dept., 37 p.

Hedman, E. R., 1964, Effects of spur dikes on flow through constrictions: Am. Soc. Civil Engineers Proc., Jour. Hydraulics Div., v. 91, no. HY4, July 1965, p. 155–165.

Matthai, H. F., 1967, Measurement of peak discharge at width contractions by indirect methods: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A4, 44 p.

Neely, B. L., Jr., 1976, Floods in Louisiana, magnitude and frequency, 3d ed.: Louisiana Dept. Highways, 340 p.

Schneider, V. R., Board, J. W., Colson, B. E., Lee, F. N., and Druffel, L., 1976, Computation of backwater and discharge at width constrictions of heavily vegetated flood plains: U.S. Geol. Survey Water-Resources Inv. 76–129, 64 p.

U.S. Water Resources Council, 1977, Guidelines for determining flood flow frequency: Washington, D.C., U.S. Water Resources Council Bull. 17A, 163 p.

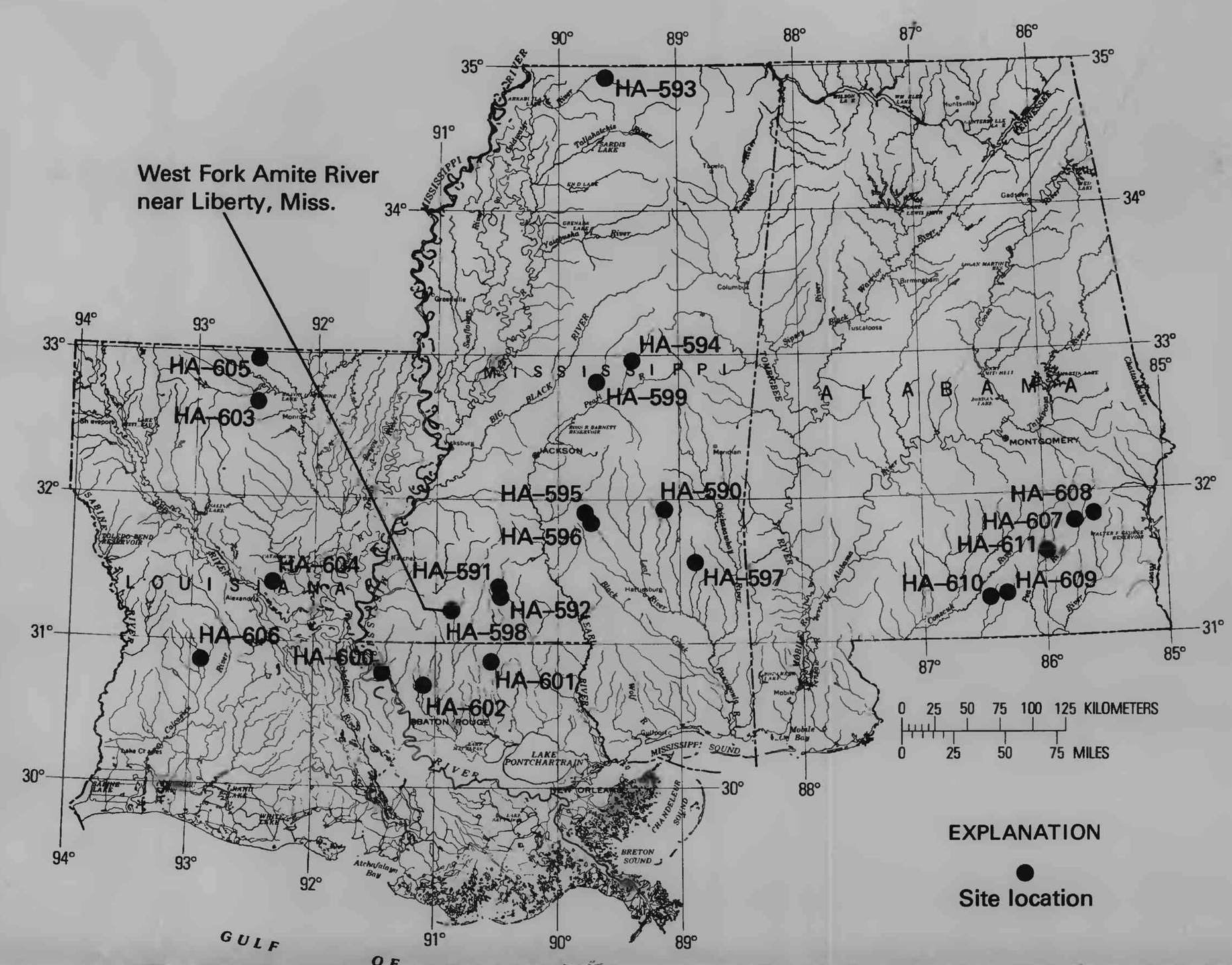

FIGURE 1.—INDEX MAP OF STUDY SITES IN THE BRIDGE BACKWATER INVESTIGATION PROJECT, ALABAMA, LOUISIANA, AND MISSISSIPPI.

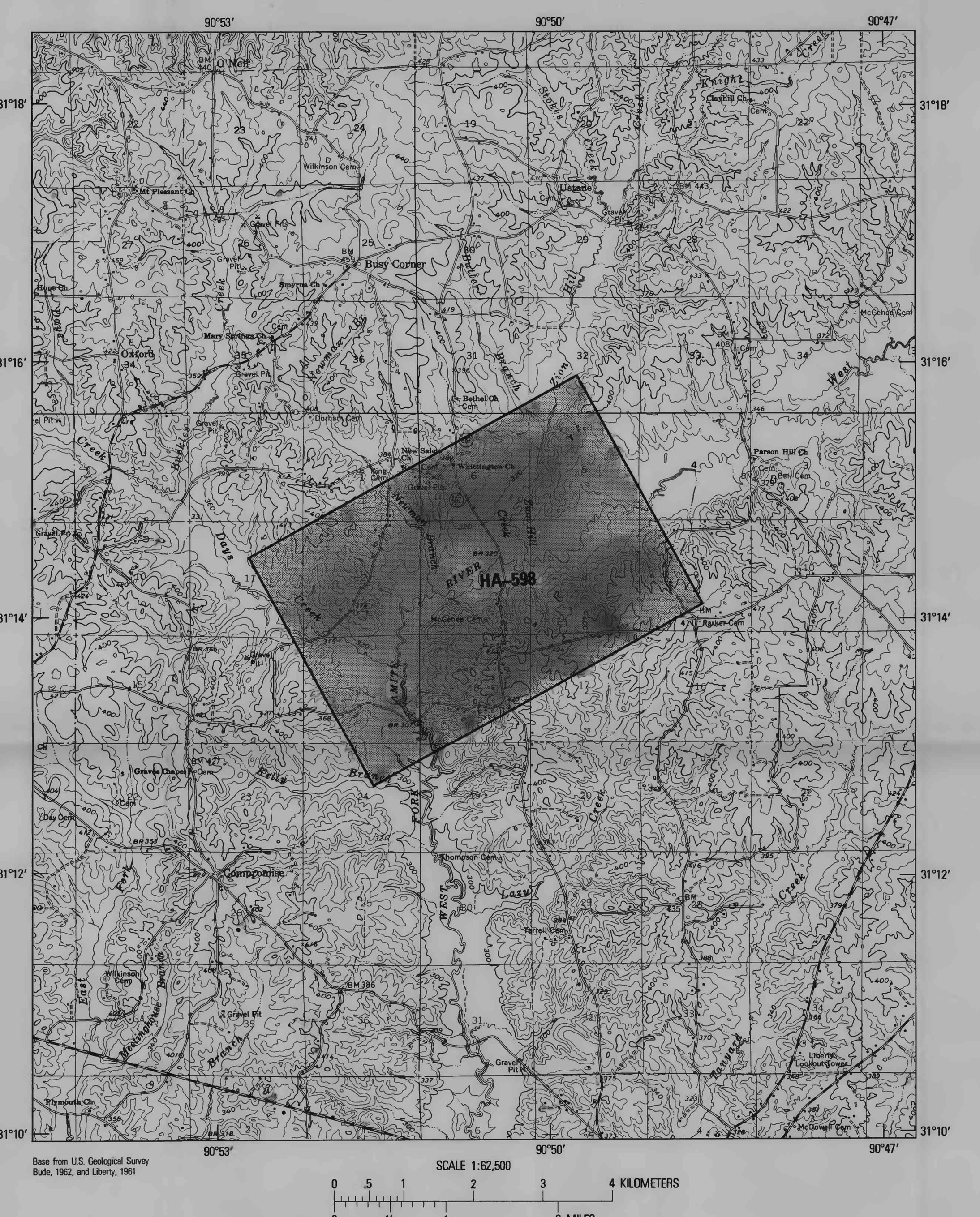

FIGURE 2—INDEX MAP OF STUDY REACH, WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI

FIGURE 3—AERIAL VIEW LOOKING UPSTREAM AT BRIDGE ON STATE HIGHWAY 567 NEAR LIBERTY, MISSISSIPPI

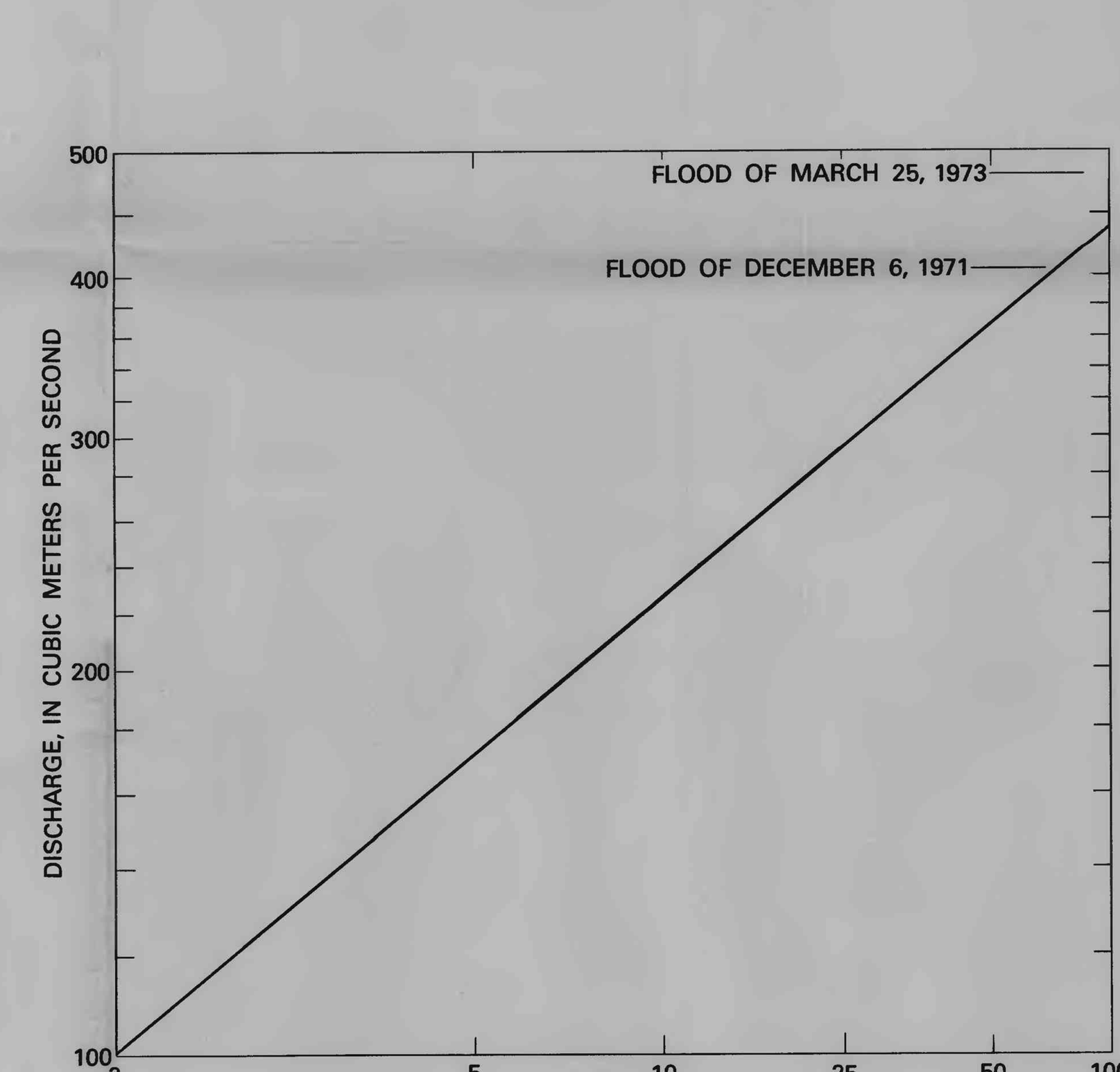

FIGURE 4—FREQUENCY OF FLOODS, WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI

TABLE 1.—VALLEY CROSS-SECTION DATA FOR WEST FORK AMITE RIVER NEAR LIBERTY, MISSISSIPPI.

CROSS SECTION 1

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	95.77
18	95.10
40	94.31
58	93.91
76	93.73
94	93.48
118	93.27
141	93.30
144	92.38
145	89.49
154	89.92
158	90.65
161	93.15
187	93.42
218	93.39
235	93.60
244	93.70
250	93.94
272	93.42
292	93.39
311	93.42
334	93.66
342	93.63
387	93.18
419	93.54
439	93.73
444	93.18
445	90.46
449	90.59
454	93.06
462	93.57
486	93.66
497	93.63
560	93.70
574	93.33
575	92.45
581	92.26
585	93.91
595	93.91
616	93.60
637	93.48
672	93.57
690	93.76
717	94.18
746	94.58
760	94.91
822	96.26

CROSS SECTION 2

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	96.44
21	95.37
48	94.88
58	94.88
76	95.10
91	95.10
119	95.22
152	94.91
175	94.98
192	95.01
227	95.07
251	94.91
279	94.95
316	94.49
322	94.40
326	92.08
327	91.38
333	91.38
334	92.05
335	92.35
340	95.01
353	95.10
380	94.91
415	94.37
446	94.43
467	94.61
471	94.31
474	92.14
477	92.45
479	93.73
493	94.34
518	94.64
536	94.43
564	94.21
616	94.37
640	95.10
650	95.49
683	96.13
699	96.53

CROSS SECTION 3

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	97.66
30	96.96
58	96.32
101	95.28
126	95.68
143	95.74
174	95.43
187	95.34
193	93.63
194	92.84
204	92.72
205	93.63
207	95.92
252	95.74
283	95.62
301	95.40
316	95.28
360	95.52
408	95.37
416	95.19
427	94.91
435	95.40
442	95.43
449	94.61
451	94.61
454	94.46
458	94.67
462	95.19
489	95.62
536	95.65
547	95.68
558	95.55
573	95.28
590	95.34
594	94.40
595	94.12
600	93.82
601	95.19
625	95.40
632	95.40
690	96.38
696	96.65
720	97.60

CROSS SECTION 4

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	99.06
15	97.44
27	96.71
39	96.01
53	95.89
58	96.01
63	95.19
67	96.13
84	96.01
134	95.98
189	96.26
220	96.07
262	96.32
297	96.38
322	96.35
326	96.35
332	94.00
333	92.99
340	92.84
346	94.00
351	95.74
368	95.89
377	95.92
388	96.19
420	96.29
450	95.89
466	95.95
491	96.29
528	96.41
556	96.56
571	96.44
573	95.46
574	94.24
579	95.43
583	95.71
600	95.89
620	96.10
646	96.16
681	95.77
683	95.37
733	95.98
765	95.95
792	95.86
796	95.92
817	95.68
839	95.98
858	96.56
875	97.02
890	97.84

CROSS SECTION 5

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	98.36
15	98.05
68	97.05
94	96.53
128	96.19
158	96.13
184	96.47
198	95.83
212	95.83
215	96.26
243	96.35
263	96.62
267	96.32
268	94.91
271	94.12
277	94.79
283	93.76
284	93.09
293	92.90
295	93.76
299	96.10
309	96.26
335	96.38
342	96.68
350	96.41
377	96.56
380	94.49
382	93.24

CROSS SECTION 5 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
396	94.49
400	96.32
417	96.44
427	96.59
455	96.32
469	96.19
475	95.25
481	95.89
496	96.10
514	96.74
536	97.23
576	97.90
606	98.15
616	97.84
641	96.99
668	96.07
682	95.74
685	95.43
691	95.40
693	95.83
746	96.13
756	96.01
779	96.10
809	96.10
852	95.95
856	95.77
856	96.10
870	95.92
898	96.04
917	96.19
952	96.53
985	97.05
1006	97.47
1022	98.12

CROSS SECTION 6

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	99.33
13	98.51
24	97.54
42	96.47
49	96.32
62	95.77
76	95.46
97	96.56
110	96.35
115	96.01
119	96.16
127	95.86
135	94.85
136	95.86
141	96.56
146	96.68
157	96.62
164	96.38
176	96.83
181	96.16
187	95.43
189	93.82
194	94.58
195	94.91
196	96.41
198	96.38
202	95.59
207	94.18
209	95.04
209	93.88
231	94.06
233	95.89
235	96.59
244	96.71
258	96.50
272	96.56
283	96.16
293	95.95
303	95.52
326	95.98
330	96.68
349	96.71
374	95.95
383	95.46
394	93.27
399	94.40
400	96.44
414	96.56
431	95.37
445	96.32
458	96.99
487	96.68
525	96.71
568	96.99
586	96.96
609	96.80
640	97.08
684	97.26
735	97.66
785	98.85
807	98.91
822	98.45
849	97.14
864	96.71
872	96.16
884	96.62
898	96.56
925	96.71
940	96.56
953	96.62
980	96.77
1000	96.83
1015	96.90
1031	96.83
1038	95.37
1040	96.77
1052	97.14
1103	97.20
1120	97.14
1134	97.41
1159	97.72
1166	98.15
1180	98.69
1199	99.40
1211	100.10

CROSS SECTION 7

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	98.85
9	98.33
15	98.21
19	97.51
22	96.80
43	96.04
45	95.92
46	96.93
60	97.51
76	97.08
93	96.26
105	96.74
111	96.65
123	96.26
131	96.16
148	96.71
162	96.93
165	96.68
169	93.18
174	93.45
175	94.12
185	96.29
200	96.87
212	97.02
226	96.90
232	95.80
238	93.88
249	93.88
253	96.04
258	96.29
276	96.62
292	96.59
313	96.77
345	96.80
348	96.38
351	93.70
372	94.27
374	96.29
438	96.56
454	97.02
470	97.02
485	96.99
510	96.90
524	96.80
539	96.83
564	96.83
574	96.80
599	96.90
619	96.99
630	96.96
657	97.11
679	97.14
700	97.11
722	97.35
732	97.47
755	97.60
775	97.66
798	97.32
828	96.80
848	96.96
868	96.87
907	96.99
927	96.90
960	97.08
996	97.29
1015	97.14
1037	97.23
1058	97.11
1086	97.32
1128	97.47
1143	97.11
1144	96.56
1150	96.29
1152	97.17
1166	97.63
1181	98.39
1194	99.00
1202	99.58
1212	99.67

CROSS SECTION 8

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	100.28
15	98.97
23	97.78
26	96.77
29	98.66
32	96.74
51	97.05
66	97.26
92	96.38
127	96.96
158	96.90
166	95.86
170	94.06
189	93.82
190	96.16
199	97.66

CROSS SECTION 8 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
222	97.23
232	97.23
243	96.74
247	95.22
255	97.05
273	97.05
275	96.90
276	94.79
279	94.85
280	95.55
291	96.32
342	97.08
367	97.23
408	97.35
470	97.32
477	97.02
482	95.86
484	96.29
495	97.05
529	97.57
544	97.32
573	97.75
605	97.38
607	97.23
613	96.53
639	96.32
653	96.99
673	97.35
696	98.57
701	99.36

CROSS SECTION 9

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	100.89
7	100.16
17	99.30
50	98.69
91	98.02
122	97.57
160	97.11
163	96.38
168	96.29
170	96.32
177	97.26
212	97.90
215	96.87
216	94.27
226	94.91
228	97.17
232	97.60
255	97.78
293	97.75
317	97.66
372	97.51
397	97.35
400	96.65
402	96.87
406	96.68
415	97.38
434	97.47
514	97.57
525	96.41
539	96.50
540	97.41
565	97.44
570	96.90
571	96.38
574	97.02
580	97.32
594	97.47
623	97.57
634	97.02
664	97.20
684	97.29
723	98.18
737	98.33

CROSS SECTION 9 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
764	98.30
786	98.48
797	99.27
803	100.10

CROSS SECTION 10

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	102.11
13	101.74
45	100.83
65	100.28
110	99.79
135	99.12
156	98.82
158	99.43
186	98.94
210	98.66
223	98.82
228	97.26
249	98.82
263	98.21
273	96.44
276	95.83
283	95.52
284	96.44
285	97.54
290	98.60
333	98.48
348	97.93
400	98.57
436	98.85
458	98.79
489	98.36
505	98.60
512	97.87
514	97.54
516	97.87
519	98.63
538	98.48
561	98.63
576	98.72
600	98.05
613	97.69
621	97.99
637	97.41
646	97.96
653	97.96
658	97.35
666	98.08
674	97.75
683	97.08
691	99.40
704	100.58

BRIDGE SECTION 1

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	98.42
2	97.57
6	96.32
12	96.13
18	95.83
24	95.83
30	95.95
37	95.34
43	93.24
49	91.78
55	91.56
61	91.74
67	92.51
73	95.16
79	96.44
83	96.77
83	98.42

TABLE 2.—DISCHARGE MEASUREMENTS DECEMBER 6, 1971, AND APRIL 8, 1973, WEST FORK AMITE RIVER AT STATE HIGHWAY 567 NEAR LIBERTY, MISS. ZERO STATION IS AT THE EDGE OF THE LEFT ABUTMENT (FACING DOWNSTREAM).

DISCHARGE MEASUREMENT OF DECEMBER 6, 1971 (WATER-SURFACE ELEVATION=97.975 METERS) TOTAL DISCHARGE=391 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
2.4	0.0	0	0.0	0.0
6.1	1.28	0	0.6	0.512
9.1	1.45	0	0.6	0.664
12.2	3.11	0	0.2	0.887
			0.8	0.658
15.2	4.83	0	0.2	0.829
			0.8	1.180
18.3	5.67	0	0.2	0.948
			0.6	1.573
			0.8	1.987
21.3	6.22	0	0.2	1.289
			0.8	2.204
22.9	6.46	0	0.2	1.951
			0.8	1.878
24.4	6.52	0	0.2	2.204
			0.8	1.914
25.9	6.64	0	0.2	2.356
			0.8	2.414
27.4	6.71	0	0.2	2.548
			0.8	1.987
29.0	6.71	0	0.2	2.533
			0.8	1.951
30.5	6.89	0	0.2	2.252
			0.6	2.356
			0.8	2.030
32.0	6.64	0	0.2	2.030
			0.8	2.414
33.5	6.95	0	0.2	1.323
			0.6	2.168
			0.8	2.112
35.1	6.64	0	0.2	1.131
			0.8	1.652
36.6	6.71	0	0.2	0.969
			0.6	1.573
			0.8	1.262
38.1	6.22	0	0.2	0.829
			0.8	1.612
39.6	6.04	8	0.2	0.774
			0.8	1.506
41.1	5.12	8	0.2	0.811
			0.8	0.668
42.7	3.29	0	0.2	0.869
			0.8	0.634
44.2	3.23	0	0.2	0.887
			0.8	0.381
45.7	2.93	0	0.2	0.948
			0.8	0.232
48.8	1.95	0	0.2	1.289
			0.8	0.695
51.8	1.95	8	0.2	1.353
			0.8	0.887
54.9	1.95	0	0.2	1.353
			0.8	0.994
57.9	2.07	8	0.2	1.914
			0.8	1.262
61.0	2.01	11	0.2	2.204
			0.8	1.539
64.0	1.95	14	0.2	2.304
			0.8	1.539
67.1	1.83	14	0.2	1.844
			0.8	1.692
70.1	1.77	11	0.2	0.850
			0.8	0.850
73.2	1.40	36	0.6	0.218
76.2	1.52	0	0.6	0.0
79.2	1.34	180	0.6	0.168
83.5	0.0	0	0.0	0.0

[1]Observation depth is the ratio of the velocity—observation depth to the total depth at the station.

DISCHARGE MEASUREMENT OF APRIL 8, 1973. (WATER-SURFACE ELEVATION=96.934 METERS) TOTAL DISCHARGE=58.9 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
7.6	0.0	0	0.0	0.0
12.2	3.35	180	0.2	0.122
			0.8	0.079
15.2	4.39	41	0.2	0.116
			0.8	0.082
18.3	4.57	16	0.2	0.140
			0.8	0.146
21.3	4.94	0	0.2	0.168
			0.8	0.448
22.9	5.18	0	0.2	0.283
			0.8	0.469
24.4	5.55	0	0.2	0.344
			0.8	0.494
25.9	5.67	0	0.2	0.625
			0.8	0.561
27.4	5.85	0	0.2	0.683
			0.8	0.655
29.0	5.97	11	0.2	0.744
			0.8	0.597
30.5	6.04	19	0.2	0.796
			0.8	0.561
32.0	6.04	14	0.2	0.728
			0.8	0.503
33.5	6.04	8	0.2	0.683
			0.8	0.494
35.1	5.79	0	0.2	0.671
			0.8	0.366
36.6	5.55	0	0.2	0.469
			0.8	0.402
38.1	5.12	0	0.2	0.302
			0.8	0.482
39.6	5.00	31	0.2	0.152
			0.8	0.149
41.1	4.57	36	0.2	0.137
			0.8	0.122
42.7	3.84	31	0.2	0.146
			0.8	0.079
44.2	1.52	36	0.2	0.146
			0.8	0.116
45.7	1.52	180	0.2	0.082
			0.8	0.0
48.8	0.49	180	0.0	0.070
51.8	0.61	180	0.0	0.043
54.9	0.61	0	0.0	0.0
57.9	0.67	0	0.0	0.0
61.0	0.67	0	0.0	0.0
64.0	0.67	0	0.0	0.037
67.1	0.61	0	0.0	0.037
70.1	0.49	0	0.0	0.0
73.2	0.24	0	0.0	0.0
76.2	0.30	0	0.0	0.0
79.6	0.0	0	0.0	0.0

[1]Observation depth is the ratio of the velocity—observation depth to the total depth at the station.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1979—W79343

For sale by Branch of Distribution, U.S. Geological Survey 1200 South Eads Street, Arlington, VA 22202 and Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225