ATLAS HA-593

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS, COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI

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

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

HYDROLOGIC INVESTIGATIONS ATLAS
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HYDROLOGIC INVESTIGATIONS
ATLAS HA-593 SHEET 1

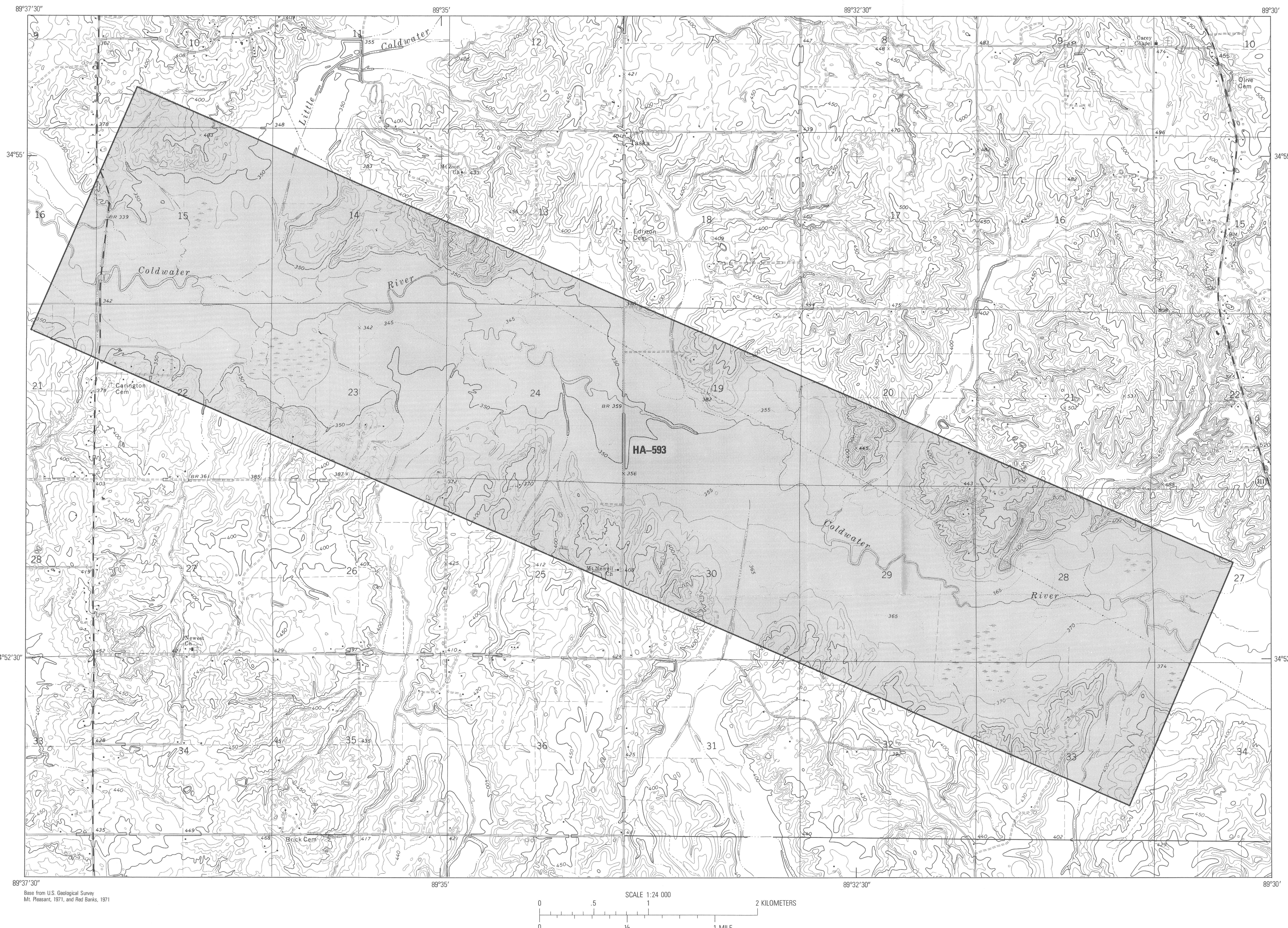

FIGURE 2—INDEX MAP OF STUDY REACH, COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS COLDWATER RIVER NEAR RED BANKS, 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 Coldwater River near Red Banks, Mississippi, 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).

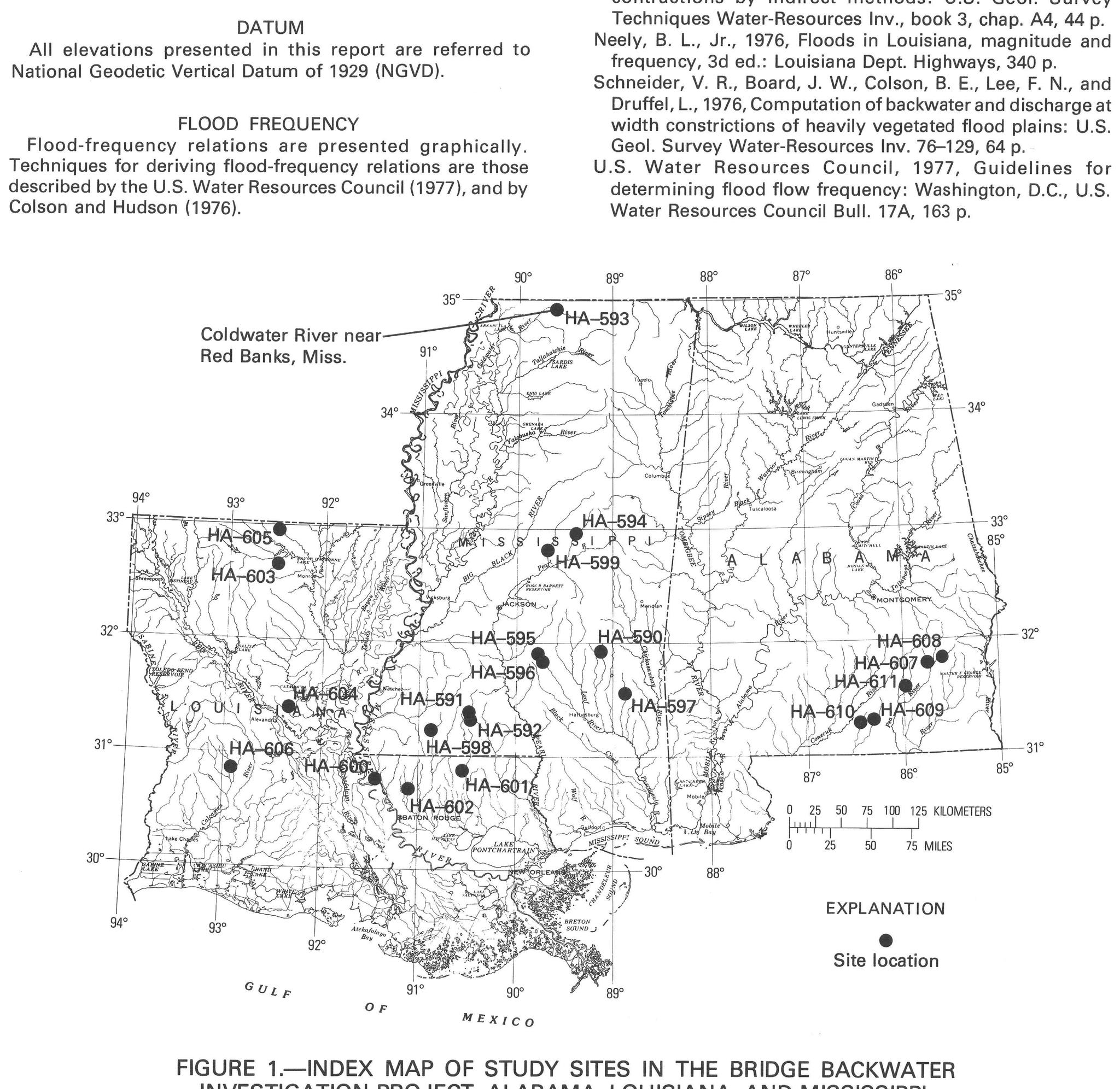

FIGURE 1.—INDEX MAP OF STUDY SITES IN THE BRIDGE BACKWATER INVESTIGATION PROJECT, ALABAMA, LOUISIANA, AND MISSISSIPPI.

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 COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI

Data for Coldwater River near Red Banks, Miss., obtained in a 7-kilometer reach crossed about midway by a Marshall County road are presented on three 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. Stationing along cross sections was projected along straight lines perpendicular to the flow. 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 sections shown for velocity distribution were obtained by sounding from the upstream side of the bridge during the discharge measurements.

Data for two floods on Coldwater River are presented. The first flood occurred December 30, 1969 (sheet 3). Ten cross sections were surveyed after this flood (sheet 2). A second flood occurred on February 22, 1971 (sheet 3).

After the 1971 flood, cross section 6 was surveyed to better define the geometry of the approach to the bridge. Valley cross sections as surveyed are considered valid for both floods.

Manning's roughness coefficient values and the 1971 flood boundaries are shown on sheets 2 and 3.

FLOOD OF DECEMBER 30, 1969

Peak water-surface elevations, the measured cross section, and velocities for the flood of December 30, 1969, are shown on sheet 3. The flood crested at an elevation of 107.375 meters at the reference point located on the downstream guardrail 98 meters from the left abutment. The peak discharge was 99.1 cubic meters per second (m^3/s), from a stage-discharge relation developed for the site. A discharge of 77.3 m^3/s was measured on the recession at an elevation of 107.296 meters at the reference point (table 2). The recurrence interval of the peak discharge is less than 2 years (Colson and Hudson, 1976). See figure 4.

FLOOD OF FEBRUARY 22, 1971

Peak water-surface elevations for the flood of February 22, 1971, are shown on sheet 4. The crest elevation at the reference point was 107.594 meters. The peak discharge was 139 m^3/s from the stage-discharge relation for the site. A discharge of 125 m^3/s was measured on the recession at an elevation of 107.527 meters at the reference point (table 2). The measured cross section and velocity distribution for the measurement of February 22, 1971 are shown on sheet 3. The recurrence interval of the peak discharge is less than 2 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 Coldwater River near Red Banks, Miss. Water depths, velocities, and discharges through bridge openings on Coldwater River near Red Banks, Miss., for floods of December 30, 1969, and February 22, 1971, 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 graphs.

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 3—AERIAL VIEW LOOKING UPSTREAM IN VICINITY OF BRIDGE ON MARSHALL COUNTY ROAD, COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI

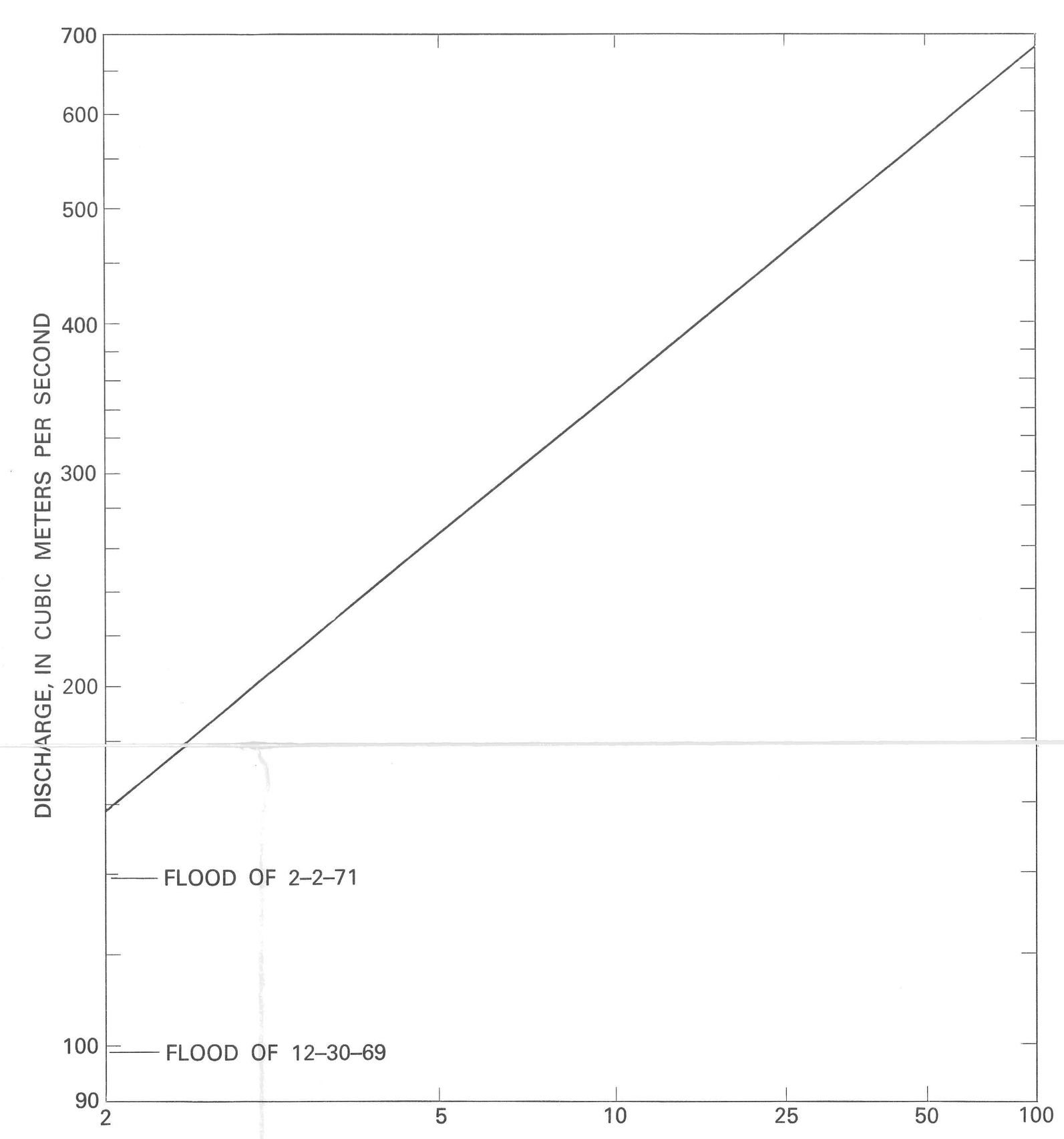

FIGURE 4—FREQUENCY OF FLOODS, COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI

TABLE 1—VALLEY CROSS SECTION DATA FOR COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI. ZERO STATION IS AT THE LEFT EDGE OF THE VALLEY (FACING DOWNSTREAM)

CROSS SECTION 1

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	103.91
23	103.64
53	103.56
79	103.55
110	103.15
163	102.88
186	102.68
201	102.75
224	102.47
247	102.27
268	101.98
288	101.75
305	101.67
326	101.58
384	101.45
411	101.31
451	101.43
465	102.02
494	101.82
518	101.61
524	100.97
525	100.28
528	100.03
529	99.80
532	99.90
533	100.12
535	100.35
538	100.67
541	101.09
543	101.29
544	101.78
551	101.60
557	101.69
567	101.72
580	101.86
594	101.46
622	101.30
634	101.12
671	101.27
671	99.92
673	100.20
677	101.35
701	101.20
725	100.96
748	100.98
762	101.23
785	101.30
823	101.03
841	101.13
872	101.01
917	100.03
919	99.88
922	99.98
924	100.13
927	100.32
929	100.71
929	100.98
942	101.00
949	100.84
953	101.04
962	100.86
971	100.95
986	100.79
997	100.68
1004	100.59
1009	100.49
1015	100.25
1017	99.79
1023	99.89
1029	100.10
1035	99.55
1038	100.07
1067	101.20
1093	102.04
1119	103.00

CROSS SECTION 2

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	105.64
61	104.39
118	104.27
173	103.72
242	103.36
302	103.45
349	103.24
422	102.87
459	102.84
510	102.78
539	102.57
574	102.32
586	102.35
618	102.26
633	102.47
655	102.35
684	102.20
727	102.29
739	102.05
741	101.44

CROSS SECTION 2 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
743	102.26
770	102.05
793	101.96
810	101.86
813	101.86
817	101.80
819	101.28
823	100.00
840	100.71
844	101.83
847	101.99
858	102.08
871	102.17
889	102.23
896	102.08
897	101.41
907	101.38
912	102.11
931	102.17
947	102.14
961	102.20
981	102.20
1003	102.05
1019	102.41
1037	102.57
1051	102.63
1072	102.53
1084	102.78
1088	102.05
1089	102.81
1095	102.78
1114	102.60
1137	102.60
1155	102.57
1190	102.60
1196	102.63
1214	102.72
1236	102.84
1264	102.84
1307	103.02
1339	103.05
1526	103.88
1585	104.55

CROSS SECTION 3

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	105.70
32	105.19
66	104.67
140	104.55
169	104.61
222	104.42
291	104.33
355	104.15
367	104.12
380	104.06
401	104.00
451	103.75
497	103.63
572	103.57
591	103.39
614	103.42
634	103.30
668	103.42
692	103.45
746	103.36
760	103.39
830	103.72
857	103.63
893	103.24
904	103.63
920	103.54
932	103.51
938	103.17
946	103.54
958	103.27
984	103.11
999	102.93
1014	102.93
1046	103.08
1052	102.63
1064	103.11
1088	103.05
1089	102.47
1093	102.50
1094	103.14
1100	102.75
1112	103.11
1113	102.69
1119	102.78
1127	102.93
1131	102.47
1137	101.99
1138	103.33
1155	103.33
1169	103.69
1187	103.88
1238	103.97
1282	104.30
1341	107.29

CROSS SECTION 4

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	107.23
47	106.83
73	106.71
117	106.71
172	106.22
228	105.89
281	105.70
329	105.58
364	105.52
394	105.28
419	105.09
429	105.06
459	104.85
472	104.85
509	104.64
534	104.73
537	104.45
541	104.36
544	104.76
566	104.52
576	104.64
590	104.55
610	104.58
615	104.39
637	104.64
662	104.61
670	104.58
697	104.61
728	104.45
745	104.55
750	104.39
765	104.39
797	104.39
816	104.45
836	104.45
853	104.45
857	104.33
874	104.45
904	104.42
933	104.36
958	104.52
982	104.64
986	104.33
987	103.21
1000	103.78
1001	104.24
1033	104.18
1062	104.42
1075	104.49
1091	104.27
1093	103.54
1099	103.63
1101	104.12
1112	104.42
1127	106.04
1143	107.59

CROSS SECTION 5

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	108.51
49	107.32
82	106.53
159	106.25
262	106.04
272	106.07
282	106.01
302	106.07
321	106.10
332	105.95
360	105.98
378	106.13
398	106.31
402	104.91
421	104.88
424	106.28
429	106.07
444	106.10
462	105.83
473	106.07
488	105.98
514	105.83
517	105.70
519	106.04
541	105.95
554	105.92
563	105.92
569	105.61
571	106.01
590	106.04
610	106.04
629	106.16
643	105.89
697	105.98
735	106.01
777	106.01
821	106.16
866	106.25

CROSS SECTION 5 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
901	106.50
958	106.92
1005	107.26
1052	107.62
1094	107.69
1159	108.30

BRIDGE SECTION

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	107.90
0	106.59
12	106.47
28	106.47
42	106.56
55	106.56
62	106.62
73	106.74
77	106.28
85	106.50
88	104.64
91	104.30
95	105.09
98	105.13
100	106.65
103	106.16
108	104.67
113	104.18
119	103.94
121	104.09
123	104.49
125	106.50
134	106.19
150	106.50
152	107.90

CROSS SECTION 6

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	108.57
17	107.59
29	107.29
53	107.02
63	107.05
67	107.44
87	107.99
90	107.29
97	107.26
139	107.11
156	107.11
158	106.77
161	107.11
187	107.17
212	107.17
240	107.11
248	107.20
281	107.14
312	107.05
342	107.05
370	107.20
401	107.08
431	107.08
474	107.05
498	106.95
525	106.80
532	105.89
538	106.86
551	106.80
561	106.07
573	106.68
580	105.95
584	106.86
607	106.89
619	106.50
623	105.67
629	106.95
641	107.02
647	105.34
653	105.55
655	107.08
657	107.08
675	106.92
702	107.05
714	107.11
716	106.50
717	107.11
725	107.17
758	107.23
789	107.47
820	107.69
850	107.69
850	107.90
872	107.93
900	108.11
933	108.08
943	107.90
972	107.87
1017	108.05
1058	108.23
1070	109.73

CROSS SECTION 7

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	110.00
35	109.03
101	108.69
178	108.42
256	108.20
286	108.11
311	107.99
361	107.96
393	107.81
421	107.78
450	107.66
465	107.69
491	107.62
521	107.75
535	107.78
568	107.59
572	106.86
578	107.81
592	107.66
619	107.53
639	107.29
653	107.32
674	107.32
705	107.47
715	107.35
717	106.98
730	107.26
744	107.41
752	107.47
769	107.29
789	107.47
796	106.86
807	107.05
808	107.26
814	107.11
823	107.05
824	106.68
824	106.74
825	107.17
831	107.47
834	107.11
839	106.98
843	107.59
873	107.50
882	107.38
904	107.75
928	107.81
942	108.02
944	107.14
959	106.86
961	107.84
964	107.75
974	108.05
987	109.12
994	109.91
1001	110.28
1008	111.16
1014	111.68

CROSS SECTION 8

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	111.68
53	111.47
122	111.37
241	110.67
317	110.37
404	110.25
471	109.85
506	109.70
557	109.64
564	109.48
565	109.30
569	109.76
587	109.64
597	109.48
612	109.42
630	109.36
635	109.18
640	109.48
656	109.09
678	109.18
699	109.12
700	109.21
706	108.97
712	109.21
738	109.36
744	109.42
760	109.61
773	109.73
782	109.79
802	107.62
810	107.93
812	109.27
815	109.85
827	109.91
838	109.33
859	109.67
887	109.64
910	109.64

CROSS SECTION 8 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
919	109.45
942	109.79
949	109.76
969	109.82
1017	110.28
1041	110.55
1065	110.79
1091	111.01
1121	111.16
1172	111.47
1212	111.80

CROSS SECTION 9

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	112.78
30	112.53
100	112.14
137	111.80
194	111.22
209	111.10
233	110.92
256	110.76
316	110.76
372	110.55
423	110.46
445	110.37
459	110.25
504	110.49
531	110.64
547	110.58
548	109.85
549	109.55
550	109.73
551	110.76
585	110.61
602	110.67
669	110.83
698	110.86
720	110.79
752	110.83
779	110.64
781	109.76
784	109.48
786	109.36
788	109.24
789	108.97
790	109.18
791	110.49
797	110.64
803	110.83
820	111.22
832	111.95
845	112.20
853	112.78

CROSS SECTION 10

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	118.08
23	117.23
43	115.95
111	115.37
151	115.12
204	114.82
274	114.51
343	114.15
419	113.81
472	112.93
504	113.26
524	113.42
529	113.45
557	113.05
569	113.14
574	113.20
611	113.32
623	113.23
628	113.36
629	112.23
638	112.17
638	112.41
638	113.11
646	113.36
668	112.96
685	113.02
696	112.65
700	113.02
707	113.45
716	112.87
727	112.56
735	112.81
750	112.84
771	113.08
784	113.11
812	113.51
841	113.96
879	114.39
903	114.30
929	114.60
963	114.82
1051	115.70
1117	115.79
1203	116.95

TABLE 2—DISCHARGE MEASUREMENTS DECEMBER 30, 1969, AND FEBRUARY 22, 1971, COLDWATER RIVER NEAR RED BANKS, MISSISSIPPI. ZERO STATION IS AT THE EDGE OF THE LEFT ABUTMENT (FACING DOWNSTREAM)

DISCHARGE MEASUREMENT OF DECEMBER 30, 1969. (WATER-SURFACE ELEVATION=107.295 METERS) TOTAL DISCHARGE=77.3 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
0.3	0.30	0	0.0	0.0
2.1	0.98	0	0.0	0.0
2.7	0.98	16	0.6	0.156
5.8	1.04	16	0.6	1.451
8.8	1.07	19	0.6	1.128
14.9	0.85	31	0.6	0.378
21.0	0.88	19	0.6	0.607
27.1	0.85	25	0.6	0.491
33.2	0.67	28	0.6	0.390
39.3	0.61	31	0.5	0.576
45.4	0.61	33	0.5	0.174
51.5	0.64	36	0.6	0.658
57.6	0.76	38	0.6	0.594
63.7	0.79	38	0.6	0.341
69.8	0.76	41	0.6	0.457
75.9	0.91	41	0.6	0.457
82.0	1.07	31	0.6	0.341
88.1	1.52	8	0.2	0.552
			0.8	0.225
91.1	3.14	21	0.2	0.558
			0.8	0.600
95.1	2.74	25	0.6	1.006
97.2	2.68	41	0.2	0.643
			0.8	0.783
103.3	1.04	36	0.6	0.149
109.4	1.43	19	0.6	0.576
115.5	1.13	8	0.6	0.341
121.6	0.79	8	0.6	0.457
127.7	0.88	0	0.6	0.269
133.8	1.22	0	0.6	0.317
139.9	0.76	0	0.6	0.634
145.4	1.01	11	0.6	0.634
148.4	0.94	16	0.6	1.189
151.5	0.91	31	0.6	0.802
151.8	0.91	0	0.6	0.802

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

DISCHARGE MEASUREMENT OF FEBRUARY 22, 1971. (WATER-SURFACE ELEVATION=107.527 METERS) TOTAL DISCHARGE=125 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
0.3	1.07	180	0.6	0.207
2.7	1.13	0	0.6	0.415
7.3	1.34	23	0.6	1.725
10.4	1.34	25	0.6	1.052
14.9	1.16	25	0.6	0.896
21.0	1.10	23	0.6	0.613
27.1	1.07	19	0.6	0.732
33.2	0.98	23	0.6	0.521
39.3	0.91	23	0.6	0.732
45.4	0.79	25	0.6	0.732
51.5	0.94	31	0.6	0.783
57.6	1.07	36	0.6	0.674
63.7	1.10	41	0.6	0.433
69.8	1.04	41	0.6	0.613
75.9	1.13	41	0.6	0.451
82.0	1.31	31	0.6	0.472
88.1	1.77	0	0.2	0.552
			0.8	0.335
91.1	3.54	23	0.2	0.463
			0.8	0.378
94.2	3.11	23	0.2	1.244
			0.8	0.896
97.2	2.93	25	0.2	0.957
			0.8	0.957
100.3	2.41	36	0.2	0.643
			0.8	0.765
103.3	1.22	36	0.6	0.497
109.4	1.55	25	0.2	0.802
			0.8	0.424
115.5	1.40	8	0.6	0.649
121.6	0.98	8	0.6	0.674
127.7	1.04	11	0.6	0.512
133.8	1.07	11	0.6	0.347
139.9	1.10	0	0.6	0.838
143.0	2.19	0	0.2	0.747
			0.8	0.732
146.0	1.19	16	0.6	0.689
150.6	0.98	25	0.6	1.817
152.1	0.91	0	0.0	0.0

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

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