

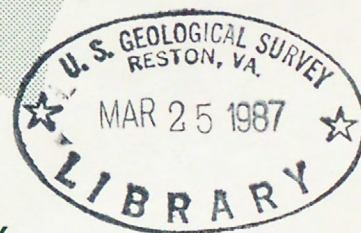
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VERIFICATION OF REGRESSION EQUATIONS FOR ESTIMATING FLOOD MAGNITUDES FOR SELECTED FREQUENCIES ON SMALL NATURAL STREAMS IN GEORGIA



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U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 86-4337



Prepared in cooperation with
STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION



Contract Research

GDOT Research Project No. **7501**

FINAL REPORT

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ESTIMATING FLOOD MAGNITUDES FOR SELECTED
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By McGlone Price and Glen W. Hess

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4337

Prepared in cooperation with the
STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION

Doraville, Georgia

1986

UNITED STATES DEPARTMENT OF INTERIOR

DONALD PAUL HODEL, Secretary

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CONVERSION FACTORS

The inch-pound units used in this report can be converted to equivalent SI (metric) units as follows:

<u>Multiply inch-pound units</u>	<u>By</u>	<u>To obtain metric units</u>
cubic foot per second (ft ³ /s)	0.2832	cubic meter per second (m ³ /s)
foot (ft)	0.3048	meter (m)
square foot (ft ²)	0.0929	square meter (m ²)
mile (mi)	1.609	kilometer
square mile (mi ²)	2.590	square kilometer (km ²)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

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ABSTRACT

In 1976 the U.S. Geological Survey, in cooperation with the Georgia Department of Transportation, began a program to monitor small natural streams in Georgia to verify the accuracy of the flood-frequency estimating equations for the five flood-frequency regions that were published in a previous study.

Data collection consisted of obtaining an additional 10 years of annual peak-flow record at 24 gaging stations and establishing and collecting annual peak-flow record at 15 additional gaging sites in areas of the State where data were unavailable. Data also were collected for an additional 10 years at four gaging stations that were converted to continuous-record gaging stations in 1976.

The flood-frequency equations were verified by comparing the observed and regression-equation estimated discharges for the 2-, 25-, and 100-year floods for the 28 gaging stations continued an additional 10 years, for the 15 gaging stations that have about 10 years of record where data were unavailable, and for all gaging stations on drainage areas of less than 50 square miles for which data were available in all five flood-frequency regions.

The rainfall-runoff-model simulated discharges from the previous study also were verified by comparisons of the observed and the rainfall-runoff-model simulated discharges for the 2-, 25-, and 100-year floods for gaging stations calibrated in the previous study.

These comparisons, based on student's t-test statistics at the 0.05 level of significance, indicate that all the flood-frequency equations computed in the previous study are valid and unbiased except for Regions 2 and 3, which indicate that the equations are slightly biased. The comparison of the discharges simulated by the rainfall-runoff model with the observed discharges for the gaging stations that have 20 years of record were unbiased, but simulated discharges for stations having 10 years of record were biased, probably because of "loss of variance" in the averaging procedures of the rainfall-runoff model and the short length of record.

The flood-frequency estimating equations computed in the previous study have been verified and are considered to be valid for natural streams in Georgia that have drainage areas of 0.1 to 20 square miles.

INTRODUCTION

A knowledge of flood characteristics is essential for (1) design of highway drainage structures, (2) planning the best use of flood-prone areas, (3) establishing flood insurance rates, and (4) many other uses by planners and engineers.

Project Background

Recognizing the need for reliable flood data and improved techniques for estimating the frequency of flooding in small streams, the U.S. Geological Survey, the Georgia Department of Transportation (GDOT), and the Federal Highway Administration, U.S. Department of Transportation, began a cooperative study in October 1963 (GDOT Research Project No. 6303) to acquire and analyze flood data for small streams (drainage areas 0.1 to 20 mi²) in Georgia. More than 100 gages were established throughout the State for the collection of storm-rainfall and flood-runoff data, as shown on plate 1.

The U.S. Geological Survey developed a rainfall-runoff model (Dawdy and others, 1972) to generate flood peaks by using available long-term rainfall data. Generally, about 10 years of rainfall-runoff data (or runoff for about 20 independent events and concurrent rainfall) were necessary to calibrate the model for the synthesis of a long flood record from long-term rainfall data. The rainfall-runoff model was used to successfully synthesize long-term flood records for 81 project stations. Station flood-frequency data and multiple regression analysis were used to develop flood-frequency estimating regression equations for five regions that have distinct flood-peak runoff characteristics. Details of that study are given in the section "Previous Studies".

The conclusions of GDOT Research Project No. 6303, published as U.S. Geological Survey Open-File Report 76-511, "Flood-Frequency Analysis for Small Natural Streams in Georgia" (Golden and Price, 1976), included the following recommendations regarding observed data:

(1) Because of operational and funding limitations, small-stream gaging stations were not located in the western Piedmont, southwest Georgia, or in the near-coastal areas. Flood data in these areas were needed to verify the use of the flood estimating equations or to provide data necessary for the development of applicable equations for these areas.

(2) Ten years of flood data are insufficient for developing reliable flood-frequency estimates of the 50- and 100-year floods. Collecting an additional 10 years of flood data at about 20 percent of the stations could provide a data base of sufficient length for verification of the synthesized rainfall-runoff records and estimating flood-frequency equations or for modification of the equations, if needed.

Purpose and Scope

As a result of the recommendations in the study by Golden and Price (1976), the present GDOT Research Project No. 7501, "Monitoring Program of Small Drainage Areas in Georgia," began in February 1976. This report describes the results of a study to:

(1) Verify the accuracy of the flood-frequency estimating equations presented by Golden and Price (1976). To accomplish this, 24 gaged sites were selected from those of the previous project (No. 6303) for the collection of an additional 10 years of record through September 1985 to provide a 20-year data base for flood-frequency comparisons. Four gages from the previous study also were converted to continuous-record stations in cooperation with the Georgia Department of Natural Resources, Geologic Survey Branch.

(2) Verify the use of flood-frequency estimating equations in areas of the State where only a small amount of flood data were available for analysis in the previous study. To accomplish this, 15 new gaging sites were established in ungaged areas as shown on plate 1. Ten years of annual peak data from 1976 through 1985 were collected and analyzed for flood-frequency comparison.

(3) Verify the rainfall-runoff-model simulated discharges by comparison with observed discharges for the 28 gaging stations with 20 years of record continued from the previous study.

Previous Studies

The flood-frequency report by Golden and Price (1976) for small natural streams draining less than 20 mi² was based on data from GDOT Research Project No. 6303. Prior to the beginning of that project in 1963, scant flood-runoff data were available for small streams (drainage areas of 0.1 to 20 mi²) in Georgia. The study provided detailed flood-runoff and concurrent storm-rainfall data for 104 sites throughout Georgia.

Because only 10 years of storm record were available at the small-stream stations, the U.S. Geological Survey's rainfall-runoff model was used for extending the flood records in time. The model was successfully calibrated for 81 stations. The standard error of estimate of the observed versus the computed peaks from these calibrations ranged from 14 to 50 percent.

Long-term rainfall records were used to synthesize a flood record of about 75 years at 81 stations where the rainfall-runoff model was successfully calibrated. More than one long-term rainfall record was used to synthesize data at each station, and the data were combined into a single record by a weighting process using, as a guide, rainfall-frequency isopluvial relations developed by the National Weather Service.

Flood data for both large and small streams in Georgia were analyzed by using the log-Pearson Type III distribution recommended by the U.S. Water Resources Council Bulletin 17 (1976). Hardison (1974) proposed the use of regional skew coefficients as opposed to the computed skew based on station data. Using Hardison's approach, a more detailed analysis of the long-term flood records in Georgia produced regional skew coefficients that differed slightly from Hardison's nationwide evaluation. The regional skew coefficients adopted for use in the study were (1) Valley and Ridge and Blue Ridge provinces, 0; (2) Piedmont province, -0.1; and (3) Coastal Plain province, -0.2.

Outliers are extreme high and low data points that depart significantly from the trend of the balance of data. The retention, modification, or deletion of these outliers will significantly affect the statistical parameters. The synthesized flood-frequency data for the 81 small-stream stations were analyzed for outliers by using the procedures in U.S. Water Resources Council Bulletin 17 (1976). Following these procedures, outlier adjustments were not required.

Flood-frequency data for large and small streams were regionalized by multiple-regression analyses, using 10 physical and climatological characteristics of the gaged basins. The large-streams data were used so that a single estimating equation could be developed that would be applicable to the range in basin size and, thus, avoid problems of estimating flood-frequency data for the transition in basin size between small and large streams. Five regions having distinct flood-peak runoff characteristics were delineated roughly by the physiographic provinces (1) Valley and Ridge, Blue Ridge, and Appalachian Plateau; (2) Piedmont, and (3) Coastal Plain, except for the, (4) Sand Hills area (a belt forming the inner margin of the Coastal Plain), and (5) the lower Ochlockonee Basin. The recommended estimating equations for all five regions for the 2-, 10-, 25-, 50-, and 100-year floods are given in table 1.

Table 1.--Summary of regression equations

[From Golden and Price, 1976]

Recurrence interval (years)	Regression equations for the indicated hydrologic region, where A = drainage area in square miles				
	1	2	3	4	5
2	169A ^{.70}	195A ^{.60}	99A ^{.58}	55A ^{.60}	120A ^{.65}
10	344A ^{.69}	446A ^{.59}	216A ^{.59}	120A ^{.60}	337A ^{.65}
25	443A ^{.69}	600A ^{.58}	280A ^{.59}	150A ^{.60}	491A ^{.65}
50	524A ^{.69}	727A ^{.58}	332A ^{.60}	180A ^{.60}	629A ^{.65}
100	610A ^{.68}	862A ^{.57}	384A ^{.61}	215A ^{.60}	785A ^{.65}

The flood-frequency study for both large and small streams in Georgia by Price (1979) also used the rainfall-runoff data from GDOT Research Project No. 6303 for small streams and the flood-frequency estimating equations were identical. That report also contains individual flood-frequency data for major streams, flood-frequency data for urban streams, and a compilation of flood data through 1974.

FLOOD-FREQUENCY ANALYSIS OF OBSERVED DATA

The observed annual peak data available for the present study are categorized as follows:

(1) Available flood data (approximately 20 years or longer) for 28 gages continued from GDOT Research Project No. 6303. Rainfall-runoff long-term record syntheses were computed for 23 of these stations.

(2) Available flood data (approximately 10 years) for 15 gaging stations established after 1976 in the western Piedmont, southwest Georgia, and the near-coastal areas where only a small amount of flood data were available for the previous study.

(3) Available flood data (approximately 10 years) for 76 stations that were discontinued at the end of the previous study. In addition, outstanding annual floods were recorded at many of these sites after the stations were discontinued.

(4) Other gaging stations operated by the U.S. Geological Survey on drainage areas of less than 50 mi² in cooperation with other agencies.

The observed data were analyzed by fitting a Pearson Type III distribution to the logarithms of the annual peak discharges following procedures outlined in U.S. Water Resources Council Bulletin 17B (1981). The Pearson Type III distribution is defined by three statistical parameters: the mean, the standard deviation, and the skew of the data array. Historical and low outliers were considered in computing the statistical parameters. The station identification number, name, drainage area, period of record, flood-frequency region, mean, standard deviation, skew, and the magnitude of floods having 2-, 25-, and 100-year recurrence intervals are given for these stations in table 2. Using the values from the observed data in table 2, the flood magnitude for any recurrence interval at these stations may be computed by using the procedures outlines in U.S. Water Resources Council Bulletin 17B (1981).

Table 2.--Small-stream gaging stations in Georgia

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Gages continued from Georgia Department of Transportation Research Project No. 6303										
02191280	Mill Shoal Creek near Royston	0.32	1964-85	2	2.058	0.230	-0.549	120	259	315
02191930	Buffalo Creek near Lexington	5.79	1964-85	2	2.722	.266	.047	524	1,550	2,230
02191970	Little Macks Creek near Lexington	1.77	1959-85	2	2.247	.329	-.157	180	637	941
02192300	Hog Fork Fishing Creek tributary near Tignall	.097	1959-85	2	1.647	.233	-.042	45	113	152
02200930	Spring Creek near Louisville	14.2	1965-85	4	2.393	.316	.246	240	938	1,530
02202910	Ten Mile Creek tributary at Pulaski	1.14	1965-85	3	1.960	.324	.267	88	360	599
02211459	Big Towaliga Creek near Barnesville	2.36	1969-81	2	2.520	.238	.264	323	904	1,310
02215245	Folsom Creeek tributary near Rochelle	1.44	1964-85	3	2.024	.384	-.405	112	436	633
02216610	Tillman Mill Creek near Lumber City	2.71	1966-85	3	2.356	.358	-.036	228	951	1,510
02217400	Mulberry River tributary near Winder	2.68	1965-85	2	2.619	.144	.107	414	754	926
02218450	Town Creek near Greensboro	11.9	1964-85	2	2.837	.275	.110	679	2,130	3,150
02225330	Beaver Creek near Cobbtown	9.58	1965-85	3	2.382	.231	.223	236	636	904
02225350	Reedy Creek tributary near Soperton	1.68	1965-85	3	2.050	.276	-.108	113	333	467
02226190	Little Creek near Willacoochee	6.38	1965-85	3	2.349	.345	-.106	227	870	1,330
02317710	Withlacoochee River tributary near Nashville	.86	1960-85	3	1.794	.380	-.229	64	268	411
02317775	Daniels Creek near Ashburn	1.11	1965-85	3	1.942	.282	-.483	92	243	314
02317780	Lime Sink Creek near Sycamore	.68	1965-84	3	1.928	.297	-.345	88	258	350
02317810	Arnold Creek tributary near Tifton	.47	1965-86	3	1.693	.316	-.222	51	166	238
02327350	Ochlockonee River tributary near Coolidge	1.81	1965-85	5	2.287	.324	-.079	196	700	1,050
02327550	Barnett Creek near Meigs	15.0	1965-75, 1978-85	5	2.871	.376	-.125	757	3,260	5,150
02346193	Scott Creek near Talbotton	3.36	1969-85	2	2.826	.231	-.025	671	1,690	2,280
02346210	Kimbrough Creek near Talbotton	6.62	1969-85	2	2.911	.209	-.484	846	1,740	2,100
02346217	Coleoatchee Creek near Manchester	2.82	1969-85	2	2.465	.355	-.226	301	1,140	1,700

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Gages continued from Georgia Department of Transportation Research Project No. 6303--Continued										
02381300	Fir Creek near Ellijay	1.35	1966-85	1	1.990	0.236	0.337	95	269	396
02381600	Fausett Creek near Talking Rock	9.99	1966-85	1	2.857	.332	.095	711	2,820	4,510
02384600	Pinhook Creek near Eton	4.28	1964-85	1	2.601	.189	.155	394	874	1,150
02387300	Dead Mans Branch near Resaca	.17	1965-85	1	1.862	.241	-.104	74	188	253
02388200	Storey Mill Creek near Summerville	6.02	1966-85	1	2.890	.211	.072	772	1,840	2,470
Gages established for better geographical coverage (about 1976)										
02204135	Camp Creek tributary near Stockbridge	0.28	1977-85	2	1.295	.432	-.286	21	102	162
02223349	Big Sandy Creek tributary near Irwinton	.50	1977-85	4	1.484	.151	-.245	31	54	64
02226465	Dryden Creek near Dixie Union	14.7	1978-85	3	2.531	.337	-.399	358	1,180	1,640
02227422	Crooked Creek tributary near Bristol	.42	1976-85	3	1.515	.217	-.027	33	78	104
02227990	Satilla River tributary No. 2 at Atkinson	.38	1977-85	3	1.627	.294	-.240	44	131	181
02228055	Satilla River tributary near Winokur	1.91	1980-85	3	2.002	.391	.229	97	520	948
02327860	Popple Branch near Whigham	1.71	1977-85	5	2.292	.231	.282	191	523	754
02337448	Hurricane Creek tributary near Fairplay	.33	1977-85	2	1.920	.331	.087	82	323	515
02343219	Bluff Springs Branch near Lumpkin	2.98	1977-85	3	2.231	.212	.361	165	425	604
02343267	Temple Creek near Blakely	2.78	1978-85	3	1.753	.261	-.299	58	152	200
02349330	Buck Creek tributary near Tazewell	.40	1977-85	4	1.592	.257	-.111	40	108	147
02349695	Horsehead Creek near Montezuma	.72	1977-85	3	1.994	.142	.128	98	177	218
02350685	Choctahatchee Creek tributary near Plains	.32	1977-85	3	1.712	.281	-.390	54	146	193
02411735	McClendon Creek tributary near Dallas	.88	1977-85	2	2.516	.211	.248	322	798	1,110
02411902	Mann Creek tributary near Tallapoosa	.12	1977-85	2	1.725	.219	.130	53	131	180

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Gages discontinued at end of previous study (1976) having 10 years or more of record										
02181800	Little Panther Creek near Tallulah Falls	2.47	1949, 1956-74, 1976	1	2.102	0.366	0.198	123	585	1,020
02189020	Indian Creek near Carnesville	7.63	1964-76	2	2.884	.214	.105	759	1,840	2,500
02189030	Stephens Creek tributary at Carnesville	.39	1964-76	2	2.028	.207	-.321	110	233	289
02190800	Double Branch at Bowersville	.50	1960-75	2	2.255	.268	-.209	184	506	687
02191270	Scully Shoal Creek near Danielsville	8.75	1964-75	2	2.777	.337	-.209	614	2,200	3,220
02191600	Double Branch near Danielsville	4.77	1964-76	2	2.642	.325	-.048	441	1,600	2,430
02191750	Fork Creek at Carlton	16.0	1964-75	2	2.922	.224	-.035	837	2,050	2,730
02191890	Brooks Creek near Lexington	12.3	1964-75, 1978	2	2.936	.355	-.185	884	3,410	5,160
02191910	Trouble Creek near Lexington	2.70	1959-75, 1978	2	2.164	.280	.141	145	454	663
02191960	Macks Creek near Lexington	3.45	1959-75, 1978	2	2.306	.313	.145	199	739	1,170
02192400	Anderson Mill Creek near Danburg	5.49	1964-75	2	2.726	.286	-.358	554	1,550	2,060
02192420	Anderson Mill Creek tributary near Danburg	.92	1964-75	2	2.133	.381	-.370	143	560	820
02193300	Stephens Creek near Crawfordville	6.30	1964-75	2	2.927	.231	.157	834	2,210	3,100
02193400	Harden Creek near Sharon	3.98	1964-75	2	2.684	.222	-.138	489	1,150	1,500
02193600	Rocky Creek near Washington	1.14	1964-75	2	2.555	.182	-.291	366	716	869
02201110	Nails Creek near Bartow	8.36	1965-74	3	2.462	.295	-.254	298	895	1,240
02201160	Boggy Gut Creek near Wadley	7.05	1965-74	3	2.656	.394	-.152	463	2,110	3,370
02201250	Seals Creek tributary near Midville	.99	1964-74	4	1.598	.226	-.393	41	92	114
02201830	Sculls Creek near Millen	4.38	1965-75	3	2.217	.153	-.203	167	298	355
02202810	Hughes Prong Canoochee Creek near Swainsboro	5.05	1965-75, 1980	3	2.182	.153	-.375	156	269	313
02202820	Reedy Creek near Twin City	9.36	1965-74, 1980	3	2.403	.174	.584	243	548	757
02202850	Reedy Creek near Metter	3.41	1965-74, 1980	3	2.251	.134	-.142	180	302	355

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Gages discontinued at end of previous study (1976) having 10 years or more of record--Continued										
02202950	Cypress Flat Creek near Collins	1.39	1965-74, 1980	3	2.083	0.252	0.064	120	339	480
02203150	Lotts Creek tributary near Statesboro	2.37	1965-74	3	2.121	.368	-.193	136	550	840
02208050	Alcovy River near Lawrenceville	9.97	1965-74	2	2.912	.142	.300	803	1,490	1,870
02208200	Beaverdam Creek tributary at Bold Springs	1.03	1965-75	2	2.134	.237	-.153	138	343	455
02215220	Ocmulgee River tributary near Abbeville	2.92	1965-75	3	1.854	.256	-.265	73	190	251
02215230	Cedar Creek near Pineview	7.80	1965-75	3	2.457	.328	.009	286	1,080	1,670
02215280	Ball Creek tributary near Rochelle	2.45	1960-77	3	2.305	.294	-.284	208	616	845
02217250	Buffalo Creek tributary near Jefferson	.39	1964-76	2	2.076	.228	.167	117	307	430
02217660	Little Curry Creek near Jefferson	.87	1964-76	2	2.295	.272	-.280	203	554	742
02218100	Porters Creek at Watkinsville	1.95	1964-75	2	2.497	.302	-.007	314	1,060	1,580
02223700	Indian Branch tributary near Scott	2.13	1965-75	3	2.018	.256	-.224	107	279	373
02224200	Mercer Creek near Soperton	16.1	1965-75	3	2.823	.166	.036	664	1,310	1,640
02224400	Cypress Creek near Tarrytown	6.77	1965-75	3	2.419	.258	.525	249	819	1,310
02224650	Peterson Creek at Glenwood	5.16	1965-74	3	2.375	.151	.110	236	441	547
02225180	Mulepen Creek near Adrain	13.8	1965-74	3	2.584	.279	-.225	393	1,120	1,530
02225210	Hurricane Branch near Wrightsville	3.53	1965-74, 1980	3	2.274	.228	.317	183	497	718
02225240	Crooked Creek near Kite	7.22	1965-74, 1980	3	2.139	.352	.088	136	582	954
02315650	Alapaha River tributary no. 2 near Pitts	.14	1965-75	3	1.691	.167	-.022	49	96	120
02315670	Alapaha River tributary no. 3 near Rochelle	3.95	1965-73, 1975	3	2.171	.105	.173	147	229	268
02315980	Jacks Creek near Ocilla	1.21	1960-75	3	2.010	.250	.115	101	286	410
02316220	Little Brushy Creek near Ocilla	1.65	1966-75	3	1.818	.281	-.179	67	196	272

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
<u>Gages discontinued at end of previous study (1976) having 10 years or more of record--Continued</u>										
02316260	Alapaha River tributary no. 4 near Willacoochee	4.16	1965-75	3	2.196	0.200	0.592	150	383	556
02317730	New River tributary near Nashville	.95	1960-75, 1984, 1986	3	1.929	.206	.149	84	200	270
02317760	Little River near Ashburn	8.54	1965-75	3	2.562	.252	-.123	369	980	1,330
02317765	Newell Branch near Worth	.98	1965-75	3	1.879	.309	.205	74	276	441
02317770	Newell Branch near Ashburn	6.48	1965-75	3	2.414	.190	-.447	268	519	620
02317795	Mill Creek near Tifton	6.21	1965-75, 1984, 1986	3	2.513	.372	-.248	338	1,350	2,040
02317840	Warrior Creek near Sylvester	8.24	1965-75, 1984	3	2.478	.219	.459	289	783	1,150
02317845	Warrior Creek tributary near Sylvester	1.64	1965-75	3	2.223	.200	.049	168	371	479
02317890	Little Creek near Sylvester	.39	1965-75	3	1.799	.252	-.210	64	166	222
02317905	Little Creek near Omega	4.22	1965-75, 1984, 1986	3	2.568	.265	-.381	384	987	1,280
02317910	Ty Ty Creek tributary near Crosland	2.07	1960-74, 1984, 1986	3	2.273	.236	-.248	192	462	600
02318015	Bull Creek near Norman Park	1.36	1965-75	5	2.128	.341	.036	134	537	854
02318020	Bull Creek tributary near Ellenton	.27	1960-75, 1984	5	1.874	.302	-.433	79	227	302
02327400	Sallys Branch tributary near Sale City	3.70	1966-75, 1984, 1986	5	2.596	.328	-.106	399	1,440	2,150
02350520	Abrams Creek tributary near Doles	3.77	1965-75	3	2.458	.168	.222	283	582	753
02381100	Mountaintown Creek tributary near Ellijay	2.41	1965-74, 1977, 1979	1	2.397	.256	.171	245	725	1,060
02381900	Ball Creek near Talking Rock	3.50	1965-74, 1977, 1979	1	2.596	.301	-.305	409	1,230	1,690
02382600	Sugar Creek near Chatsworth	7.30	1965-74, 1977, 1979	1	2.771	.193	-.126	596	1,260	1,600
02382800	Dry Creek at Oakman	3.06	1965-74, 1977, 1979	1	2.594	.236	.062	391	1,030	1,430
02382900	Pine Log Creek near Rydal	12.8	1964-74, 1977, 1979	1	2.807	.249	.555	608	1,930	3,050
02383000	Rock Creek near Fairmount	6.17	1952-74, 1977, 1979	1	2.623	.284	.072	417	1,340	2,000
02383200	Redbud Creek near Ranger	1.97	1964-74, 1977, 1979	1	2.518	.270	-.004	330	980	1,400

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
<u>Gages discontinued at end of previous study (1976) having 10 years or more of record--Continued</u>										
02383220	Redbud Creek tributary near Ranger	0.56	1965-73, 1977, 1979	1	1.998	0.304	0.571	93	385	676
02385700	Rock Creek near Chatsworth	3.46	1965-74, 1979	1	2.454	.163	.274	280	567	734
02387100	Polecat Creek near Spring Place	1.22	1964-74, 1977, 1979	1	2.434	.185	.505	262	615	857
02387200	Beamer Creek near Spring Place	1.29	1964-74, 1977, 1979	1	2.525	.162	.287	321	652	844
02387560	Oothkalooga Creek tributary at Adairsville	3.56	1965-74, 1977, 1979	1	2.542	.208	.681	330	894	1,340
02387700	Rocky Creek at Curryville	9.41	1965-74, 1977, 1979	1	2.954	.204	.521	865	2,210	3,200
02387800	Bailey Creek near Villanow	3.82	1965-74, 1977, 1979	1	2.730	.330	.309	517	2,190	3,730
02388400	Dozier Creek near Shannon	3.00	1965-74, 1977, 1979	1	2.595	.261	.101	390	1,150	1,660
02397750	Duck Creek above LaFayette	6.34	1965-74, 1977	1	2.908	.170	.359	790	1,680	2,230
03566660	Sugar Creek near Ringgold	4.44	1965-74	1	2.727	.156	.693	512	1,080	1,470
03566687	Little Chickamauga Creek tributary near Ringgold	3.36	1965-74	1	2.528	.203	.667	320	843	1,250
<u>Other gages on drainage areas of less than 50 square miles operated by U.S. Geological Survey</u>										
02182000	Panther Creek near Toccoa	32.5	1927-76, 1978	1	3.350	0.380	-0.049	2,250	10,200	16,600
02188500	Beaverdam Creek at Dewy Rose	35.8	1852, 1908, 1928, 1943-77	2	3.150	.265	.175	1,390	4,260	6,320
02189050	North Fork Broad River above Toccoa	3.66	1959-66, 1969	2	2.514	.324	-.194	334	1,150	1,660
02189600	Bear Creek near Mize	3.62	1957-69	2	2.602	.310	.071	396	1,420	2,180
02190100	Toms Creek near Eastanollee	3.79	1957-69	2	2.673	.221	.281	460	1,200	1,710
02190200	Toms Creek tributary near Avalon	1.20	1955-65, 1967-69	2	2.523	.243	-.319	343	832	1,070
02196820	Butler Creek at Fort Gordon	7.50	1969-84	4	2.512	.132	-.426	332	527	598
02197190	McBean Creek near McBean	41.4	1963-85	4	2.466	.094	.458	288	442	521

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Other gages on drainage areas of less than 50 square miles operated by U.S. Geological Survey--Continued										
02197600	Brushy Creek near Wrens	28.0	1959-84	4	2.604	0.227	0.091	399	1,020	1,400
02201800	Richardson Creek near Millen	43.0	1963-83	3	2.802	.301	.061	630	2,170	3,290
02202300	Mill Creek near Statesboro	39.0	1963-74	3	2.828	.168	-.426	692	1,250	1,470
02203559	Peacock Creek near McIntosh	33.0	1967-77	3	2.598	.278	-.204	405	1,160	1,600
02205000	Wildcat Creek near Lawrenceville	1.59	1954-84	2	2.271	.310	.001	187	653	985
02205500	Pew Creek near Lawrenceville	2.23	1954-63	2	2.459	.329	-.351	301	985	1,380
02206000	Shetley Creek near Norcross	.98	1954-63, 1973	2	2.212	.363	.196	159	745	1,290
02207000	Garner Creek near Snellville	5.54	1954-63, 1983	2	2.744	.306	.036	552	1,920	2,910
02213050	Walnut Creek near Gray	29.0	1962-84	2	3.483	.288	-.273	3,130	9,100	12,400
02213400	Little Tobesofkee Creek near Forsyth	16.8	1951-61	2	3.028	.439	.021	1,060	6,290	11,400
02217000	Allen Creek near Talmo	17.3	1952-74, 1976	2	3.110	.290	.114	1,270	4,260	6,450
02217450	Mulberry River tributary no. 2 near Jefferson	.72	1965-74, 1976	2	2.300	.135	.326	196	356	444
02219300	Mile Branch near Madison	.95	1964-72	2	2.533	.143	-.300	347	586	682
02220550	Whitten Creek near Sparta	15.0	1961-85	2	3.151	.191	.012	1,410	3,060	3,950
02221000	Murder Creek near Monticello	24.0	1952-76	2	3.100	.263	-.211	1,290	3,470	4,680
02223300	Big Sandy Creek near Jeffersonville	31.0	1959-71	4	2.537	.316	.015	344	1,230	1,880
02224800	Oconee River tributary no. 2 near Glenwood	1.38	1965-74	3	1.861	.268	-.064	73	211	297
02226030	Doctors Creek near Ludowici	33.0	1966-85	3	2.645	.194	.134	438	985	1,300
02226700	Whitehead Creek near Denton	28.0	1953, 1957-63	3	2.834	.241	-.424	710	1,650	2,080
02227430	Little Satilla Creek near Odum	49.0	1929, 1949-78, 1984	3	2.873	.441	-.522	815	3,640	5,350
02317820	Arnold Creek near Tifton	4.88	1965-73	3	2.295	.248	-.154	200	519	697

Table 2.--Small-stream gaging stations in Georgia--Continued

Station No.	Station name	Drainage area (mi ²)	Period of record (years)	Flood-frequency region (fig. 1)	Station statistical data			Flood magnitude (ft ³ /s)		
					Mean (log)	Standard deviation (log)	Skew of logarithms	2-year	25-year	100-year
Other gages on drainage areas of less than 50 square miles operated by U.S. Geological Survey--Continued										
02317900	Ty Ty Creek at Ty Ty	47.0	1948, 1951-78, 1984, 1986	3	2.914	0.272	-0.212	840	2,350	3,200
02327900	Wolf Creek near Whigham	19.0	1948, 1951-77	5	3.050	.305	-.045	1,130	3,790	5,610
02337400	Dog River near Douglasville	43.0	1951-77, 1982	2	3.500	.299	-.302	3,280	9,820	13,500
02337500	Snake Creek near Whitesburg	37.0	1955-84	2	3.541	.146	.411	3,400	6,550	8,400
02341600	Juniper Creek near Geneva	47.4	1963-85	4	2.885	.209	.231	753	1,850	2,550
02344300	Camp Creek near Fayetteville	17.2	1961-73	2	3.029	.158	.142	1,060	2,050	2,580
02349900	Turkey Creek near Byromville	45.0	1951-84	3	3.013	.358	-.217	1,060	4,090	6,130
02351800	Muckaloochee Creek near Smithville	47.0	1943, 1948, 1950, 1952-78	3	2.828	.353	-.054	678	2,750	4,310
02356100	Spring Creek near Arlington	49.0	1951-65, 1970-80	3	3.091	.348	-.166	1,260	4,790	7,230
02382000	Scarecorn Creek at Hinton	21.3	1940-42, 1960-74, 1979	1	3.037	.180	.076	1,080	2,280	2,930
02385500	Mill Creek at Dalton	40.1	1945-59	1	3.400	.155	.120	2,490	4,760	5,940
02387570	Oothkalooa Creek at Adairsville	21.7	1964-74, 1977, 1979	1	3.061	.203	.649	1,090	2,870	4,240
02388000	West Armuchee Creek near Subligna	36.4	1951, 1961-81	1	3.559	.243	.224	3,550	10,100	14,600
02388300	Heath Creek near Rome	14.7	1969-85	1	2.900	.197	.005	794	1,760	2,290
02389300	Shoal Creek near Dawsonville	21.7	1959-74, 1977, 1982	1	3.303	.232	-.268	2,060	4,850	6,240
02394400	Pumpkinvine Creek below Dallas	42.8	1951-77, 1982, 1984	1	3.362	.254	-.101	2,330	6,280	8,600
02394950	Hills Creek near Taylorsville	25.0	1960-74, 1977, 1979, 1982	1	3.201	.307	.020	1,580	5,500	8,310
02411800	Little River near Buchanan	20.2	1960-84	2	3.223	.236	-.056	1,680	4,280	5,780
03545000	Hiwassee River near Presley	45.5	1942-84	1	3.322	.220	.123	2,080	5,190	7,120
03566685	Little Chickamauga Creek near Ringgold	35.5	1964-75	1	3.256	.269	.118	1,780	5,450	8,010

COMPARISONS OF FLOOD-FREQUENCY DATA

The following comparisons of flood-frequency data were made to determine if there are significant differences between the flood frequency of observed discharges based on data through 1985 and (a) those discharges obtained from the estimating equations for the five flood-frequency regions (1976), and (b) those discharges computed for the 1976 study from the long-term synthesis of annual peaks using the U.S. Geological Survey rainfall-runoff model.

(1) Comparison of regression-equation estimated discharges (1976) with observed discharges through 1985 for the 28 small-stream gaging sites continued from GDOT Research Project No. 6303 that have at least 20 years of observed annual-peak record.

(2) Comparison of regression-equation estimated discharges (1976) with observed discharges through 1985 for the 15 small-stream gaging sites that have about 10 years of annual-peak record since 1976 and that were installed for better geographical coverage in areas where only a small amount of flood data were available in the previous study.

(3) Comparison of rainfall-runoff-model simulated discharges computed for the 1976 study with observed discharges through 1985 for 23 sites having about 20 years of annual-peak record continued from GDOT Research Project No. 6303.

(4) Comparison of rainfall-runoff-model simulated discharges computed for the 1976 study with observed discharge for 81 sites through 1974 for which 10 years of annual-peak record were available for calibration of the rainfall-runoff model in the previous study.

(5-9) Comparison of regression-equation estimated discharges obtained from the five regional flood-frequency estimating equations (1976) with the observed discharges through 1985 for all gaging sites in each region having drainage areas of less than 50 mi².

STATISTICAL ANALYSIS METHODS USED FOR FLOOD-FREQUENCY COMPARISONS

The statistical analyses and computations were done by using "Statistical Analysis System" (SAS)¹ (SAS Institute, Inc., 1982). All statistical analyses were performed by transforming the discharge data to logarithmic units and computing the logarithmic residual, x , of the estimated discharge minus the observed discharge. The average residual, \bar{x} , and the standard deviation of the differences, s , were computed for the 2-, 25-, and 100-year floods. The root mean squared difference or error, RMS, was computed as

$$\text{RMS} = \sqrt{\bar{x}^2 + s^2} \quad (1)$$

¹The use of the trade name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

The root mean square error is considered to be an approximation of the standard error of estimate (Sauer, 1985) and was used for a comparison with the standard error of estimate of the regression (SER) of the estimating equations. The final log values of \bar{x} , s , and RMS of the residuals were converted to percentages. The results of the different analyses comparing the RMS and standard error of estimate of the flood-frequency estimating equations for each of the comparisons and supplemental comparisons are shown in table 3.

Each series of logarithmic differences, x , for the 2-, 25-, and 100-year floods were analyzed by using the student's t-test at the 0.05 level of significance to determine if their mean, \bar{x} , was significantly different from zero. An \bar{x} significantly different from zero would indicate a possible bias in the flood-frequency estimating techniques.

Additionally, the comparison of x 's and the logarithms of the respective observed discharges for the 2-, 25-, and 100-year flood-frequency discharges were analyzed. An attempt was made to fit a straight line of the form $\bar{x} = a + bLQ$, where "b" is the slope of the line, "LQ" is the logarithm of the observed discharge value, and "a" is a constant through the plotting points using a least squares regression. A line significantly different from $\bar{x} = 0$ indicates a possible systematic error, or bias, in techniques for estimating discharges. The bias of the resulting line fits were evaluated at the 0.05 level of significance on the basis of the student's t-test statistics for both "b", the slope of the line, and "a", the constant. An example of this plot for comparison 1 is shown in figure 1. The equation in figure 1 from the log linear regression was

$$\log \bar{x} = 0.365 - 0.122 \log \text{observed discharge.} \quad (2)$$

The mean of the residuals in figure 1 was 0.0024 logarithmic units. The student's t-test indicated that the mean, \bar{x} , was not significantly different from zero and therefore was unbiased. The t-test indicated that the constant 0.365 and slope 0.122 of the regression equation tested independently were not significantly different from zero.

The results of the bias computations of the residuals for each of the comparisons are shown in table 4.

Table 3.--Comparison of residuals between regression-equation estimated (1976) and observed discharges through 1985 for the 2-, 25-, and 100-year floods

Comparison	Number of stations (n)	Recurrence interval (R.I.)	Mean residual (\bar{x})	Standard deviation (s)	Root mean squared (RMS)	Reported study error (SER) (percent)
		log units (percent)				
1	28	2	0.0237/+6	0.1235/+29	0.1258/+29	28
	28	25	.0069/+2	.1228/+29	.1230/+29	30
	28	100	.0024/+1	.1412/+33	.1412/+33	35
1A	25	2	.0096/+2	.1040/+24	.1044/+24	28
	25	25	-.0024/-1	.0888/+20	.0888/+20	30
	25	100	-.0041/-1	.1121/+26	.1122/+26	35
2	15	2	.1002/+26	.2256/+54	.2468/+60	28
	15	25	.1207/+32	.1984/+47	.2322/+56	30
	15	100	.1256/+34	.2149/+52	.2489/+60	35
2A	12	2	.0098/+2	.1166/+27	.1170/+27	28
	12	25	.0417/+10	.1197/+28	.1268/+30	30
	12	100	.0485/+12	.1555/+37	.1629/+38	35
3	23	2	.0338/+8	.0789/+18	.0858/+20	--
	23	25	.0023/+1	.1140/+27	.1140/+27	--
	23	100	-.0090/-2	.1373/+32	.1376/+32	--
4	81	2	.0440/+11	.0858/+20	.0954/+22	--
	81	25	.0217/+5	.1341/+31	.1358/+32	--
	81	100	.0058/+1	.1699/+40	.1700/+40	--
4A	70	2	.0401/+10	.0796/+18	.0891/+21	--
	70	25	.0185/+4	.0938/+22	.0956/+22	--
	70	100	.0029/+1	.1187/+28	.1187/+28	--
4B	23	2	.0629/+16	.0788/+18	.1008/+23	--
	23	25	.0093/+2	.1230/+29	.1234/+29	--
	23	100	-.0164/-4	.1680/+40	.1688/+40	--
5 (Region 1)	34	2	.0262/+6	.1436/+34	.1460/+34	29
	34	25	-.0084/-2	.1507/+35	.1509/+35	28
	34	100	-.0306/-7	.1609/+38	.1642/+39	31
5A	30	2	.0307/+7	.1306/+31	.1342/+31	29
	30	25	.0100/+2	.1158/+27	.1162/+27	28
	30	100	-.0091/-2	.1165/+27	.1168/+27	31
6 (Region 2)	53	2	-.0062/-1	.1773/+42	.1774/+42	34
	53	25	.0199/+5	.1478/+34	.1472/+34	31
	53	100	.0242/+6	.1586/+37	.1604/+38	34
6A	44	2	-.0286/-6	.1323/+32	.1354/+32	34
	44	25	.0048/+1	.0873/+20	.0874/+20	31
	44	100	.0113/+3	.0992/+23	.0998/+23	34
6B	13	2	.0213/+5	.1370/+32	.1386/+32	34
	13	25	.0255/+6	.0985/+23	.1017/+24	31
	13	100	.0355/+9	.1115/+26	.1170/+27	34
7 (Region 3)	64	2	.0610/+15	.1457/+34	.1580/+42	33
	64	25	.0766/+19	.1830/+47	.1984/+47	40
	64	100	.0810/+21	.2107/+50	.2257/+54	46
7A	53	2	.0495/+12	.1203/+28	.1301/+30	33
	53	25	.0447/+11	.1328/+31	.1401/+33	40
	53	100	.0440/+11	.1502/+36	.1604/+38	46
7B	16	2	.0462/+11	.0871/+20	.0986/+23	33
	16	25	-.0263/-6	.1080/+25	.1112/+26	40
	16	100	-.0418/-9	.1136/+26	.1210/+28	46
8 (Region 4)	9	2	.0128/+3	.1526/+36	.1531/+36	20
	9	25	.0763/+19	.2063/+49	.2200/+53	25
	9	100	.1101/+29	.2440/+59	.2676/+66	35
8A	8	2	-.0169/-4	.1324/+31	.1335/+31	20
	8	25	.0233/+6	.1404/+33	.1423/+33	25
	8	100	.0506/+12	.1777/+42	.1848/+44	35
9 (Region 5)	7	2	-.0826/-17	.0813/+19	.1159/+27	25
	7	25	-.0086/-2	.0760/+18	.0765/+18	27
	7	100	.0228/+5	.0802/+19	.0834/+19	30

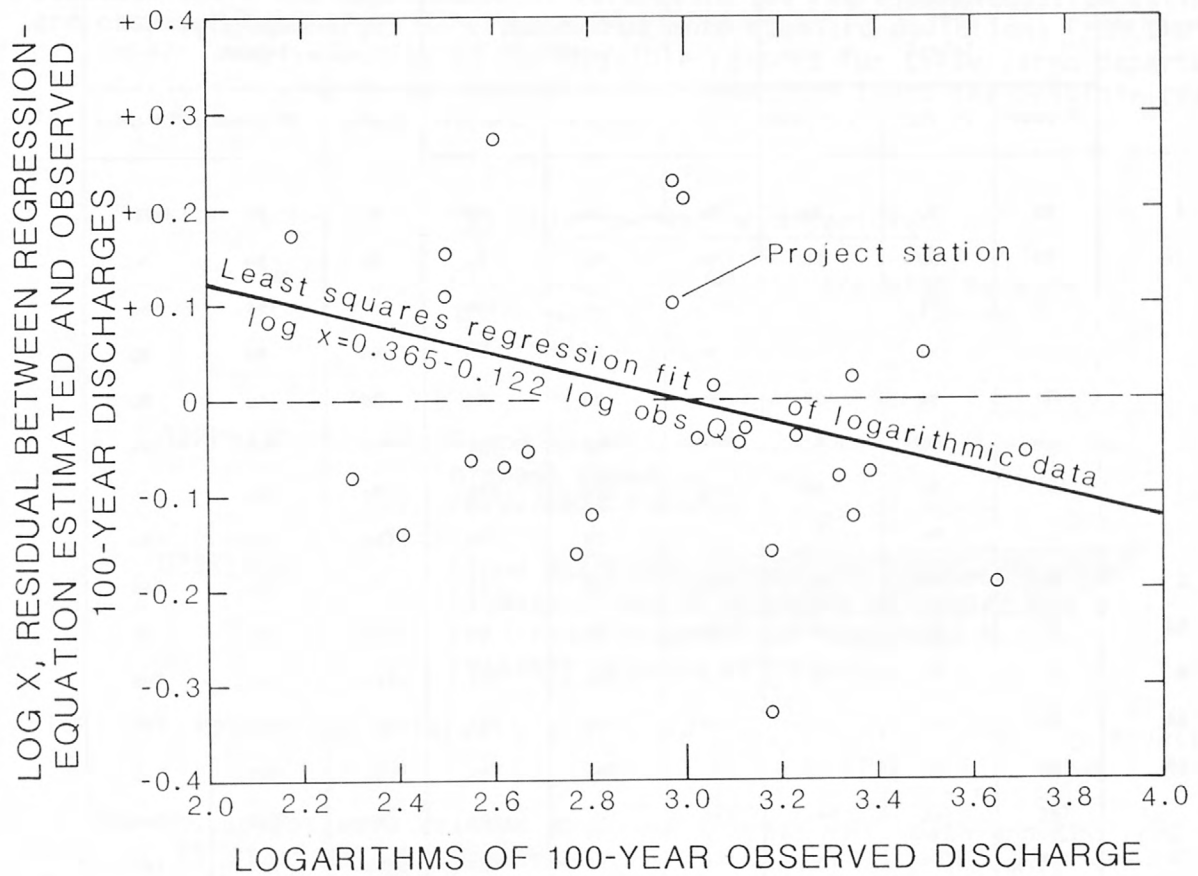


Figure 1.—Comparison of logarithms of residuals between regression-equation estimated and observed discharges and logarithms of observed discharge for 100-year flood for comparison 1.

Table 4.--Bias of observed discharge comparisons of flood-frequency data based on student's t-test statistics at 0.05 level of significance

Comparison	Average mean residual (\bar{x}), t-test			Linear regression test of logarithmic data					
				Constant (a), t-test			Slope (b), t-test		
	2-year	25-year	100-year	2-year	25-year	100-year	2-year	25-year	100-year
1	No	No	No	No	No	No	No	No	No
1A	No	No	No	No	No	No	No	No	No
2	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	No	No	No	No	No	No	No	No	No
3	No	No	No	No	No	No	No	No	No
4	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes
4B	Yes	No	No	Yes	No	No	Yes	No	No
5	No	No	No	No	Yes	Yes	No	Yes	Yes
5A	No	No	No	No	No	No	No	No	No
6	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
6A	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
6B	No	No	No	No	Yes	Yes	No	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	No	No	No	No	No	No	No	No	No
8A	No	No	No	No	No	Yes	No	No	Yes
9	Yes	No	No	No	No	No	No	No	No

RESULTS OF NINE COMPARISONS

Comparison 1

The mean regression-equation estimated discharge for comparison 1 was about 3 percent (average mean error of 2-, 25-, and 100-year recurrence intervals) higher than the mean observed discharge for the 28 stations having 20 years of record continued from the previous project. The t-test indicates that the comparison 1 regression-equation estimated discharges were unbiased. Stations where the logarithmic difference in the regression-equation estimated and observed discharges were about 2 or more standard deviations from the mean difference were investigated for possible reasons for these large departures. The stations having large departures in comparison 1 and the possible reasons for the departures are:

<u>Station number</u>	<u>Possible reason for departure</u>
02216610	Flood magnitude values are high because there were two floods with recurrence intervals of 100 years in 19 years of record.
02225330	Flood magnitude values are low because the highest flood in 20 years of record had a recurrence interval of less than 5 years.
02381300	Flood magnitude values are low because the highest flood in 18 years of record had a recurrence interval of less than 5 years, possibly because of storage.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 1 data and the remaining data for 25 stations were analyzed as comparison 1A. The only significant change was that the mean difference and standard deviation of the differences were reduced. As indicated in table 3, the RMS errors are slightly lower than the average of the standard error of estimate for the 5 regression estimating equations given in the previous study. The comparison of the regression-equation estimated and observed discharges for the 2-, 25-, and 100-year floods are shown in figure 2.

Comparison 2

The mean regression-equation estimated discharge for comparison 2 was about 30 percent higher than the mean observed discharge for the 15 stations having about 10 years of record established after the previous study for better geographical coverage. The t-test indicates that comparison 2 is biased for the 25- and 100-year floods. The stations having large departures in comparison 2 and possible reasons for the departures are:

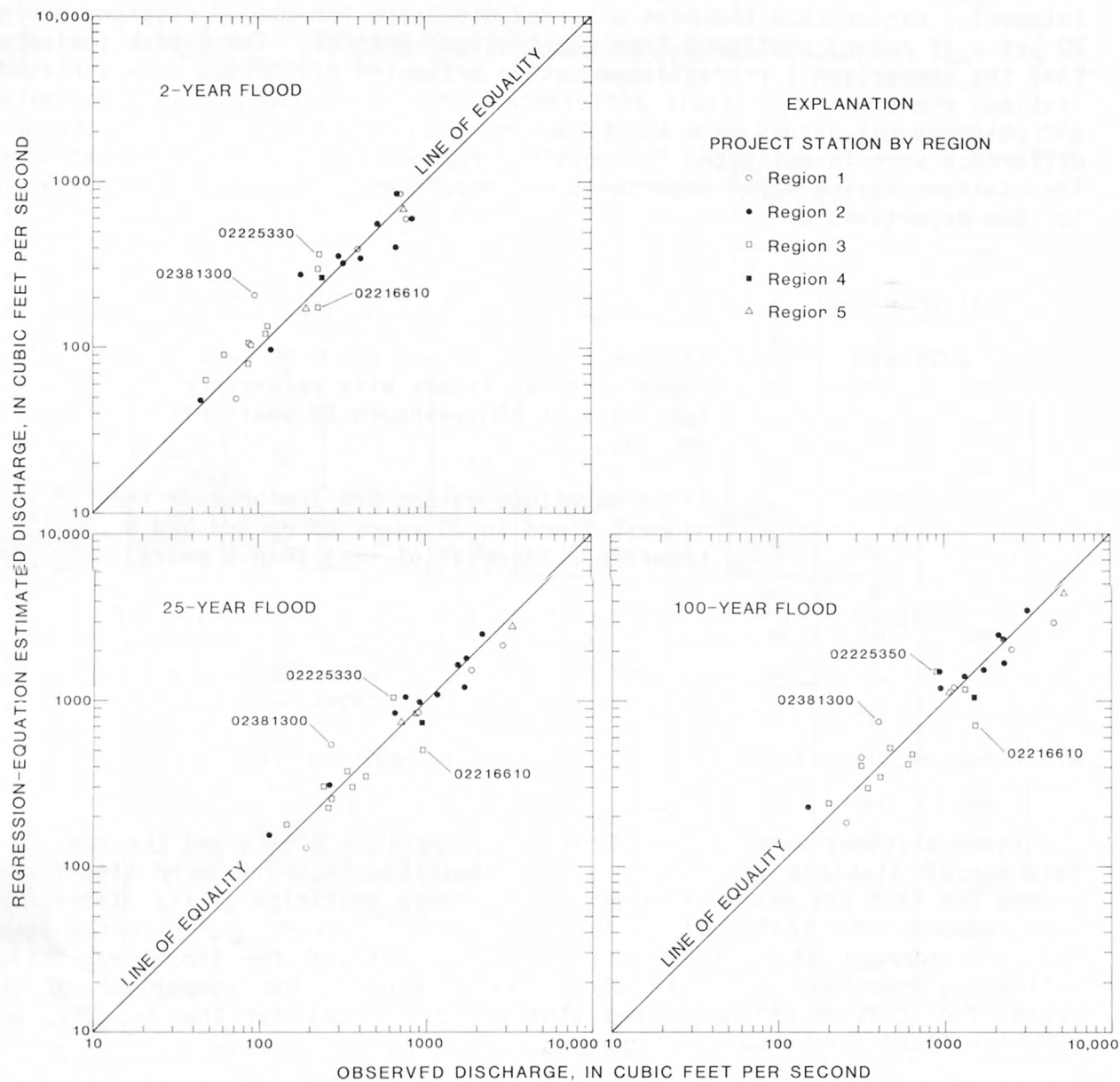


Figure 2.—Comparison of regression-equation estimated and observed discharges for 2-, 25-, and 100-year floods for small-stream gaging stations continued from Georgia Department of Transportation Research Project No. 6303.

<u>Station number</u>	<u>Possible reason for departure</u>
02204135	Flood magnitude values are low because the highest flood in 9 years of record had a recurrence interval of less than 2 years, possibly because of storage.
02343267	Flood magnitude values are low because the highest flood in 8 years of record had a recurrence interval of less than 2 years.
02411735	Flood magnitude values are high because one flood with a recurrence interval of 100 years and two floods with recurrence intervals of 20 years occurred in 9 years of record.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 2 data and the remaining data for 12 stations were analyzed as comparison 2A. The mean difference between the regression-equation estimated and observed discharges was reduced from about 30 percent to 10 percent. The RMS values were about the same as the average of the standard error of estimate for the five regression equations. The t-test indicates that comparison 2A is unbiased. The comparisons of the regression-equation estimated and observed discharges for the 2-, 25-, and 100-year floods are shown in figure 3.

Comparison 3

The mean rainfall-runoff-model simulated discharge for comparison 3 for the 2-year flood was 8 percent greater than the mean observed discharge and was 2 percent less for the 100-year flood. The t-test indicates that comparison 3 is unbiased. The comparison of the rainfall-runoff-model simulated discharges and the observed discharges for the 2-, 25-, and 100-year floods are shown in figure 4.

Comparison 4

Mean rainfall-runoff-model simulated discharge for comparison 4 for the 2-year flood was 11 percent greater than the mean observed discharge but was only 1 percent greater for the 100-year flood. The t-test indicates that the average mean residual is biased for the 2-year flood, and unbiased for the 25- and 100-year floods. The t-test indicates that the slope and intercept are biased for the 2-, 25-, and 100-year floods. The stations in comparison 4 having large departures and possible reasons for the departures are:

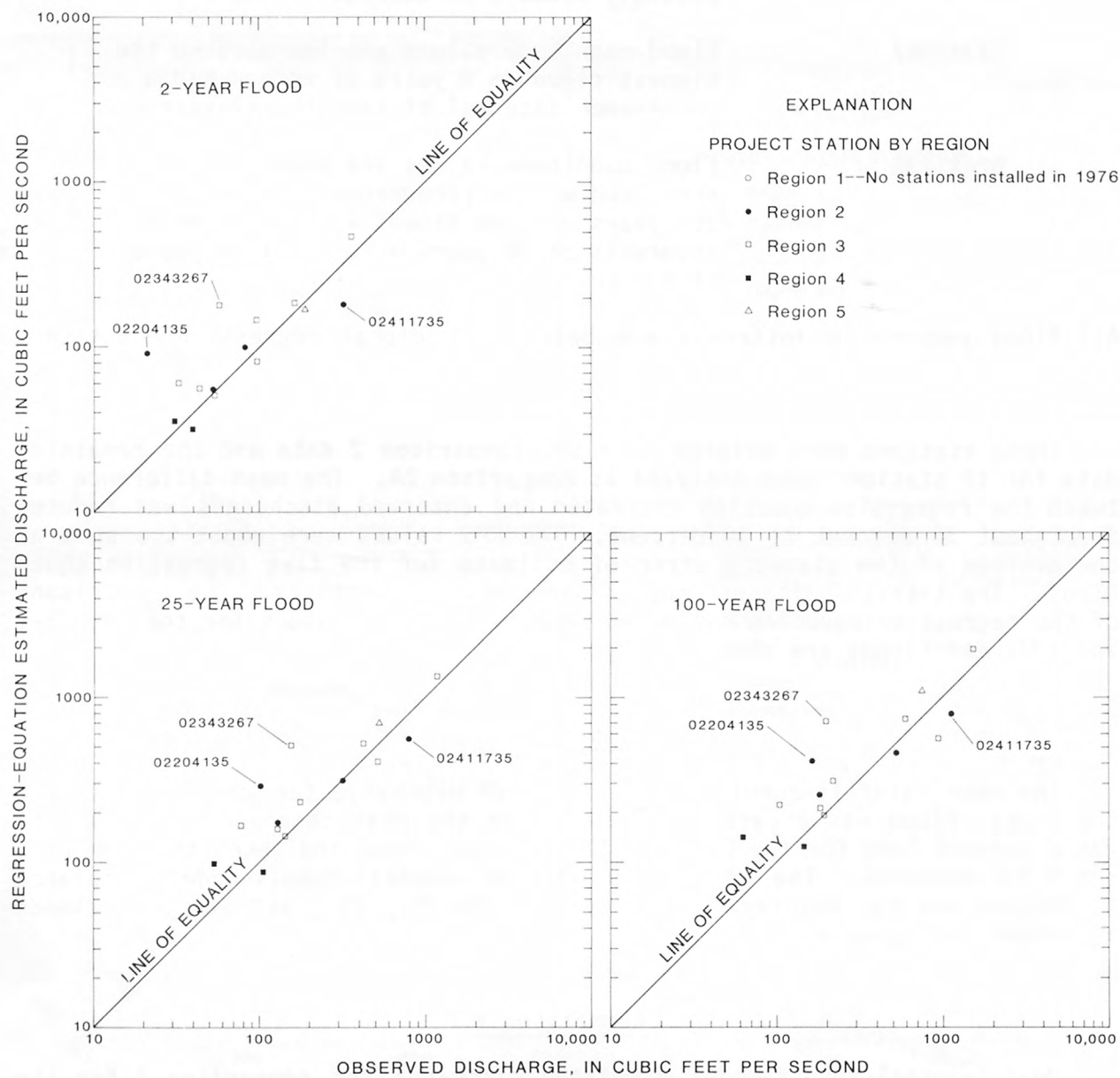


Figure 3.—Comparison of regression-equation estimated and observed discharges for 2-, 25-, and 100-year floods for small-stream gaging stations installed about 1976.

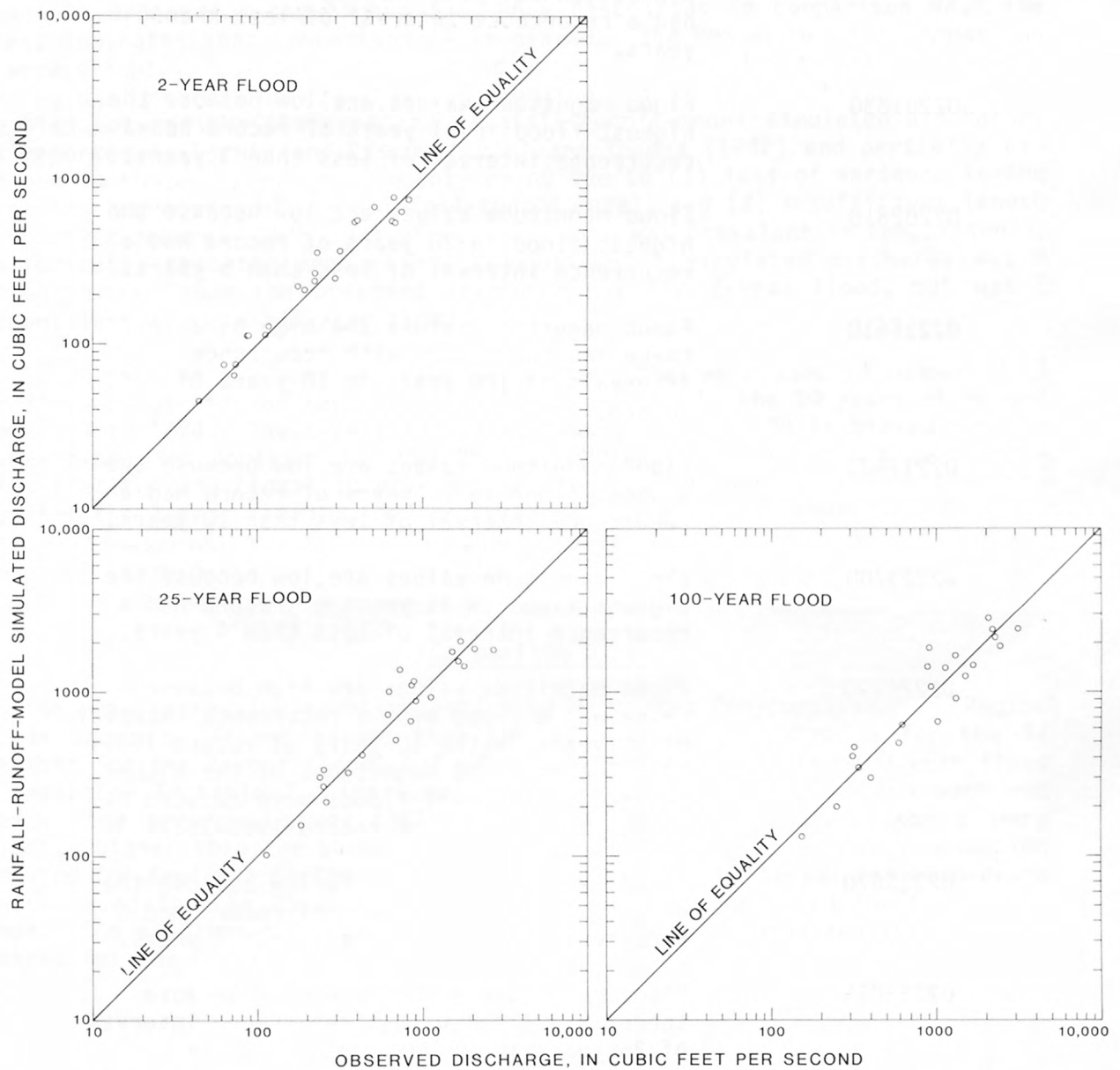


Figure 4.—Comparison of rainfall-runoff-model simulated and observed discharges for 2-, 25-, and 100-year floods for 23 calibrated small-stream gaging stations continued from Georgia Department of Transportation Research Project No. 6303.

<u>Station number</u>	<u>Possible reason for departure</u>
02191910	Flood magnitude values are low because the highest annual peak in 20 years of record had a recurrence interval of less than 5 years.
02201830	Flood magnitude values are low because the highest flood in 11 years of record had a recurrence interval of less than 3 years.
02202810	Flood magnitude values are low because the highest flood in 20 years of record had a recurrence interval of less than 5 years.
02216610	Flood magnitude values are high because there are two floods with recurrence intervals of 100 years in 10 years of record.
02217400	Flood magnitude values are low because the highest flood in 20 years of record had a recurrence interval of less than 10 years.
02223700	Flood magnitude values are low because the highest flood in 11 years of record had a recurrence interval of less than 4 years.
02226190	Flood magnitude values are high because there was a flood with a recurrence interval of 50 years in the 10 years of record 1965-74. The computed magnitudes of the higher recurrence-interval floods were reduced by using the 20 years of record 1965-85.
02315670	Flood magnitude values are low because the highest flood in 11 years of record had a recurrence interval of less than 2 years.
02318015	Flood magnitude values are high because there is a flood with a recurrence interval of 25 years in 11 years of record.
02327400	Flood magnitude values are high because there are floods with recurrence intervals of 25- and 50-years in 20 years of record.
02387800	Flood magnitude values are high because there are two floods with recurrence intervals of 100-years and one flood with a recurrence interval of 50 years in 35 years of record.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 4 data and the remaining data for 70 stations were analyzed as comparison 4A. The mean difference between the rainfall-runoff-model simulated discharges and observed discharge was about the same for comparisons 4 and 4A. The RMS errors were reduced about 10 percent for the higher frequency discharges in comparison 4A. The t-test indicates that comparison 4A is biased. The RMS errors for comparison 4A were slightly less than the standard error of regression for the average of the regional regression equations, though the comparison was slightly biased. The bias between the observed and rainfall-runoff-model simulated discharges was reported by Lichty and Liscum (1978) and Thomas (1982) and partially explained in those reports as probably being due to (1) loss of variance in the averaging procedures of the rainfall-runoff model, and (2) insufficient length of observed record. This loss of variance also was prevalent in comparison 3, and indicates that the mean rainfall-runoff-model simulated discharge was 8 percent higher than the observed discharge for the 2-year flood, but was 2 percent less for the 100-year flood.

Comparison 4B analyzed the same 23 stations that were used in comparison 3 for 22 years of station record (1964-85) by using only the 10 years of record from 1964 to 1974. The t-test indicates that comparison 4B is biased for the 2-year flood and unbiased for the 25- and 100-year floods. The t-test indicates that the additional 10 years of record used in comparison 3 removed the bias for the 2-year flood. The comparison of the rainfall-runoff-model simulated and observed discharges for the 81 stations used in comparison 4 are shown in figure 5.

Comparison 5

The mean regression-equation estimated discharge for comparison 5 (Region 1) was about 6 percent higher than the mean observed discharge for the 34 stations for the 2-year flood, but was 7 percent lower for the 100-year flood as indicated in table 3. There were 10 stations in Region 1 which were not used in the previous study (1976). The RMS errors for comparison 5 were slightly higher than the standard error of estimate of the regression equation computed for Region 1 in the previous study (1976). The t-test for comparison 5 was biased for the 25- and 100-year flood, but was unbiased for the 2-year flood. The stations in comparison 5 having large departures and the possible reasons for the departures are:

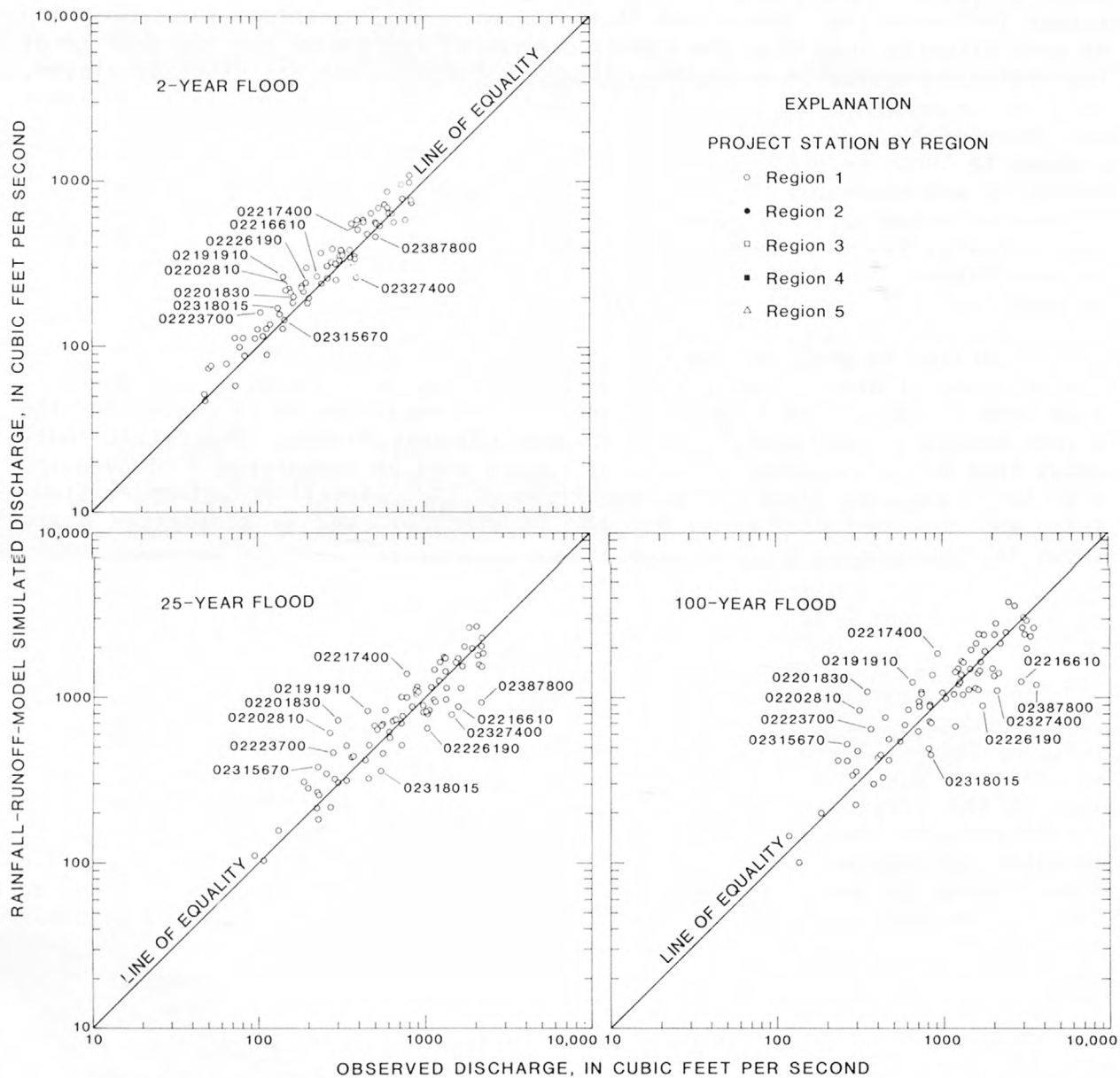


Figure 5.—Comparison of rainfall-runoff-model simulated and observed discharges through 1974 for 2-, 25-, and 100-year floods for 81 small-stream gaging stations calibrated for Georgia Department of Transportation Research Project No. 6303.

<u>Station number</u>	<u>Possible reason for departure</u>
02381300	Explained in comparison 1.
02387800	Explained in comparison 4.
02182000	Flood magnitude values are high because there were five floods with recurrence intervals of 100 years in 60 years of record.
02388000	Flood magnitude values are high because there were five floods with recurrence intervals higher than 50 years in 21 years of record.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 5 data and the remaining data were analyzed as comparison 5A. The mean difference between the regression-equation estimated and observed discharges was about the same for comparison 5A as comparison 5, but the RMS error was reduced about 10 percent for the 25- and 100-year floods. The t-test indicates that comparison 5A is unbiased. The comparison of the regression equations from the previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 1 are shown in figure 6.

Regressions for the 2-, 25-, and 100-year flood discharges versus drainage area were made for the observed data through 1985 at the 30 stations used in comparison 5A. These regressions indicate the following percentage differences between the 1985 regressions of the observed data and the estimating equations (1976) for Region 1.

Drainage area (mi ²)	Percent difference		
	2-year flood	25-year flood	100-year flood
0.1	+17	+21	+29
1	+2	+7	+12
5	-7	-1	+1
10	-12	-5	-3
20	-14	-8	-8

These differences indicate that the observed discharge generally is within 12 percent of the discharge based on the 1976 estimating equations for drainage areas from 1 to 20 mi². The differences for drainage areas of less than 1 mi² are greater than 17 percent for 0.1 mi², but less than the standard error of estimate for Region 1.

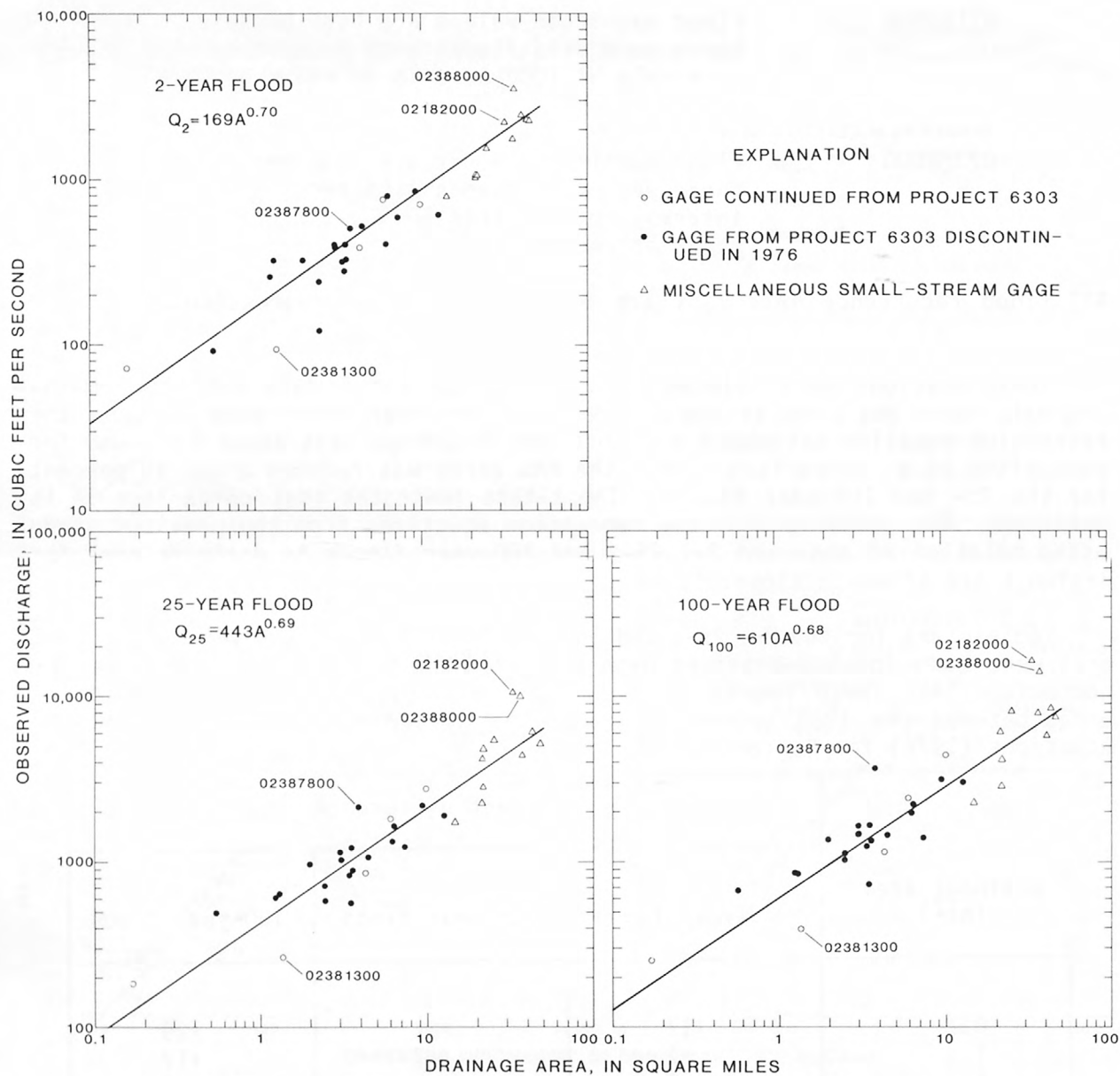


Figure 6.—Comparison of regression equations from previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 1.

Comparison 6

The mean regression-equation estimated discharge for comparison 6 (Region 2) was about 1 percent less than the mean observed discharge for the 53 stations for the 2-year flood but was 6 percent higher for the 100-year flood as indicated in table 3. There were 19 stations in Region 2 which were not used in the previous study (1976). The RMS errors for comparison 6 were slightly higher than the standard error of estimate for the regression equation computed for Region 2 in the previous study. The t-test for the average mean residual indicates that comparison 6 is unbiased. The t-test for the linear regression test indicates that the comparison is biased. The stations in comparison 6 having large departures and the possible reasons for the departures are:

<u>Station number</u>	<u>Possible reason for departure</u>
02189030	Flood magnitude values are low because there is a flood with less than a 5-year recurrence interval in 13 years of record. There also is a storage pond upstream.
02191910	Explained in comparison 4.
02191960	Flood magnitude values are low because there was only one flood with a recurrence interval greater than 5 years in 37 years of record.
02204135	Explained in comparison 2.
02208050	Flood magnitude values are low because there is only about a 5-year recurrence-interval flood in 10 years of record.
02208200	Flood magnitude values are low because there is less than a 4-year recurrence interval flood in 11 years of record.
02213050	Flood magnitude values are high because there are three floods with recurrence intervals of 100 years in 37 years of record.
02213400	Flood magnitude values are high because there are three floods with recurrence intervals of 25 years in 11 years of record.
02337400	Flood magnitude values are high because there are three floods with recurrence intervals of 100 years in 35 years of record.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 6 data and the remaining data analyzed as comparison 6A. The mean difference between the regression-equation estimated and observed discharges was about the same for comparisons 6 and 6A. The RMS errors were reduced about 12 percent in comparison 6A. The RMS errors of comparison 6A were more than 10 percent less than the standard error of estimate for the Region 2 regression equation. The t-test statistics for comparison 6A for the slope and intercept were reduced from comparison 6 and were only slightly biased. Because comparison 4 indicated that bias might be due to the short period of observed record, the 13 stations in comparison 6A having 20 years or more of data were analyzed as comparison 6B. The mean difference between the regression-equation estimated and observed discharges increased about 5 percent for comparison 6B from 6A. The RMS errors for comparison 6B and 6A were about the same. The t-test for average mean residual remained unbiased. The t-test for the linear regression test indicates that the 2-year flood is unbiased whereas the 25- and 100-year floods are biased.

For all three comparisons of Region 2 data, the t-tests for the differences between the regression-equation estimated and observed discharges for comparisons 6A and 6B are less than the estimated standard error of estimate for the Region 2 regression equations. Although linear regression tests for the 25- and 100-year floods indicate that comparisons 6A and 6B are biased, the t-test statistics are only slightly biased, so for practical significance, the regression equation for Region 2 is valid. The comparison of the regression equations from the previous study using relation of observed 2-, 25-, and 100-year floods to the drainage area for Region 2 are shown in figure 7.

Regressions for the 2-, 25-, and 100-year flood discharge versus drainage area were made for observed data through 1985 at the 44 stations used in comparison 6A. These regressions indicate the following percentage differences in the 1985 regression of observed data and the estimating equations for Region 2 (1976).

Drainage area (mi ²)	Percent difference		
	2-year flood	25-year flood	100-year flood
0.1	+5	-8	-12
1	+7	-2	-5
5	+8	+2	+1
10	+9	+4	+4
20	+9	+6	+6

These differences indicate that the observed discharge generally is within 9 percent of the discharge from the 1976 estimating equations for drainage areas of 0.1 to 20 mi² in Region 2.

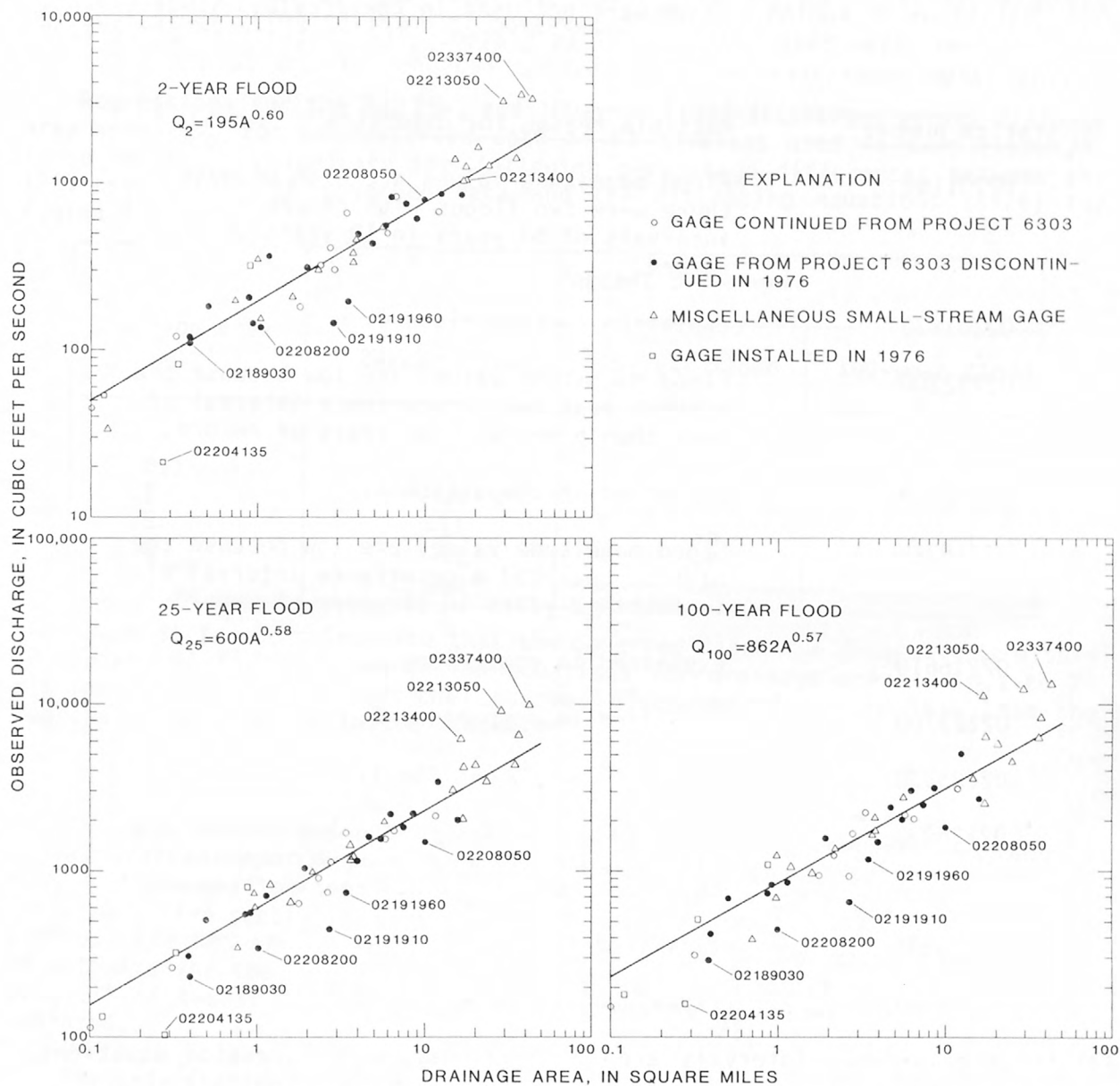


Figure 7.—Comparison of regression equations from previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 2.

Comparison 7

The mean regression-equation estimated discharge for comparison 7 (Region 3) was 15 percent higher than the mean observed discharge from the 64 stations for the 2-year flood and 21 percent higher for the 100-year flood. There were 12 stations in Region 3 which were not used in the previous study (1976). The t-test indicates that comparison 7 is biased. The stations in comparison 7 having large departures and the possible reasons for the departures are:

<u>Station number</u>	<u>Possible reason for departure</u>
02201160	Flood magnitude values are high because there were two floods with recurrence intervals of 50 years in 10 years of record.
02201830	Explained in comparison 4.
02202300	Flood magnitude values are low because the highest peak had a recurrence interval of less than 5 years in 10 years of record.
02202810	Explained in comparison 4.
02215220	Flood magnitude values are low because the highest peak had a recurrence interval of less than 2 years in 11 years of record.
02216610	Explained in comparison 1.
02223700	Explained in comparison 4.
02225330	Explained in comparison 1.
02226030	Flood magnitude values are low because the highest peak had a recurrence interval of less than 10 years in 25 years of record.
02315670	Explained in comparison 4.
02343267	Explained in comparison 2.

All flood recurrence intervals are based on regional regression equations.

These stations were deleted from the comparison 7 data and the remaining data analyzed as comparison 7A. The mean difference between the regression-equation estimated and observed discharges was reduced about 10 percent in comparison 7A. The average RMS errors for comparison 7A were about 8 percent lower than those for comparison 7. The t-test indicates that only the linear regression test for the 25-year flood is biased.

The RMS errors for comparisons 7 and 7A are less than the estimated standard error of estimate for the Region 3 regression equations. Although the slope and intercept of comparison 7A indicate bias, the t-test statistic is only slightly biased, so for practical significance, the regression equation for Region 3 is valid. The comparison of the regression equations from the previous study using relation of observed 2-, 25-, and 100-year floods to the drainage area for Region 3 are shown in figure 8.

Regressions for the 2-, 25-, and 100-year flood discharges versus drainage area were made for the observed data at 53 stations used in comparison 7A. These regressions indicate the following percentage differences between the 1985 regressions of observed data and the estimating equations (1976) for Region 3.

Drainage area (mi ²)	Percent difference		
	2-year flood	25-year flood	100-year flood
0.1	-7	-17	-11
1	-9	-12	-10
5	-11	-9	-9
10	-11	-8	-9
20	-12	-6	-9

These differences indicate that the observed discharge generally is within 10 percent of the 1985 regression equations for drainage areas of 0.1 to 20 mi² for Region 3, although the observed discharge always is less than the regression-equation estimated discharge.

Comparison 8

The mean regression-equation estimated discharge for comparison 8 (Region 4) was greater than the mean observed discharge for the 9 stations in Region 4 by 3, 19, and 24 percent for the 2-, 25-, and 100-year floods, respectively. There were five stations in Region 4 which were not used in the previous study (1976). The RMS errors for comparison 8 were higher than the standard error of estimate for the regression equation computed for Region 4 in the previous study. The t-test indicates that the regression equations for Region 4 are unbiased.

The only station having a large departure in Region 4 was station 02197190 which has appreciable storage from ponds and swamps. The flood-magnitude values for the station were low because only one 2-year flood occurred in 21 years of record. This station was deleted from comparison 8 and the remaining data were analyzed as comparison 8A. The mean difference between the regression-equation estimated and observed discharges was reduced about 10 percent in comparison 8A from comparison 8. The RMS errors for the 25- and 100-year floods were reduced about 20 percent and were only slightly higher than the standard error of estimate for the regression equations for Region 4. The t-test indicates that comparison 8A is unbiased except for the 100-year flood which is slightly biased.

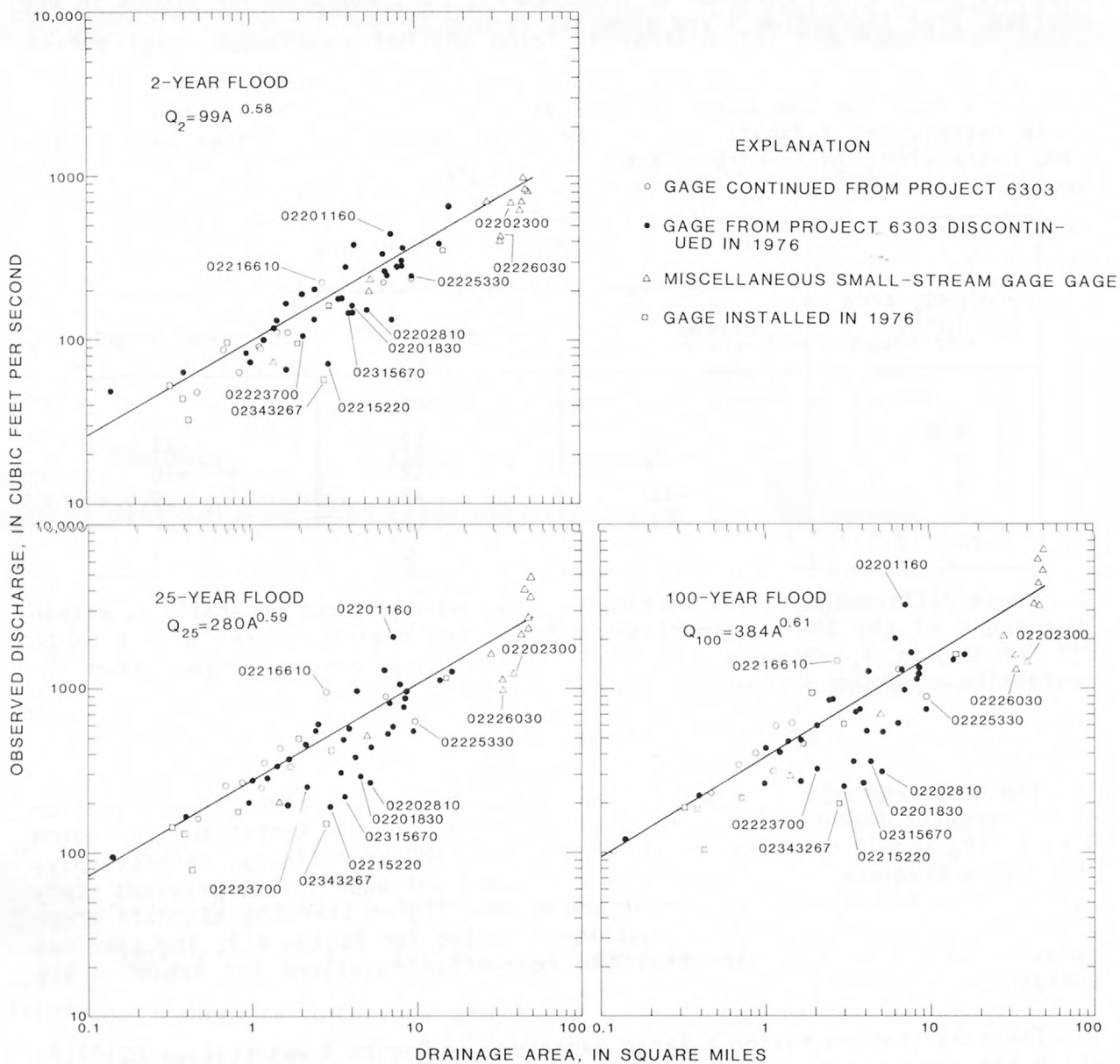


Figure 8.—Comparison of regression equations from previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 3.

No regressions of the observed data through 1985 versus drainage area were made for Region 4 because of the small number of stations. The comparison of the regression equations from the previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 4 are shown in figure 9.

Comparison 9

The mean regression-equation estimated discharge for comparison 9 (Region 5) varied from 17 percent less for the 2-year flood to 5 percent more for the 100-year flood from the mean observed discharge for the 7 stations in Region 5. There was one station in Region 5 that was not used in the previous study (1976). Two other stations that the previous study included in Region 3 were considered to be in Region 5 for this comparison because they are close to the region boundary and the recorded flood data are more indicative of Region 5. These stations (023218025 and 02318020) are shown on plate 1. The t-test indicates that for comparison 9, only the average mean residual for the 2-year flood is biased. No regressions of the observed data through 1985 versus drainage area were made for Region 5 because of the small number of stations. The comparison of the regression equations from the previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 5 are shown in figure 10.

SUMMARY

In 1976 the U.S. Geological Survey, in cooperation with the Georgia Department of Transportation, began a program to monitor small natural streams in Georgia. The purpose of the monitoring program was to verify the accuracy of the flood-frequency estimating equations for the five flood-frequency regions published in U.S. Geological Survey Open-File Report 76-511, "Flood-Frequency Analysis for Small Natural Streams in Georgia" (Golden and Price, 1976).

The data collection for the present study consisted of obtaining 10 years of additional annual peak-flow record at 24 selected crest-stage gaging stations and at four continuous-recording gages where 10 years of data were available. This provided a data base of 20 years of record for verification of the synthesized rainfall-runoff model records and flood-frequency estimating equations of the 1976 report. In addition, 15 gaging stations were established in areas of the State where only a small amount of data were available for the previous study and about 10 years of annual peak data were collected to verify the use of the estimating equations in these areas.

The estimating flood-frequency equations have been evaluated by making the following comparisons of observed, regression-equation estimated, and rainfall-runoff-model simulated discharges for the 2-, 25-, and 100-year floods:

- (1) Comparison of regression-equation estimated discharges with observed discharges for the 28 stations that have at least 20 years of annual peak record and that were continued from the previous project.

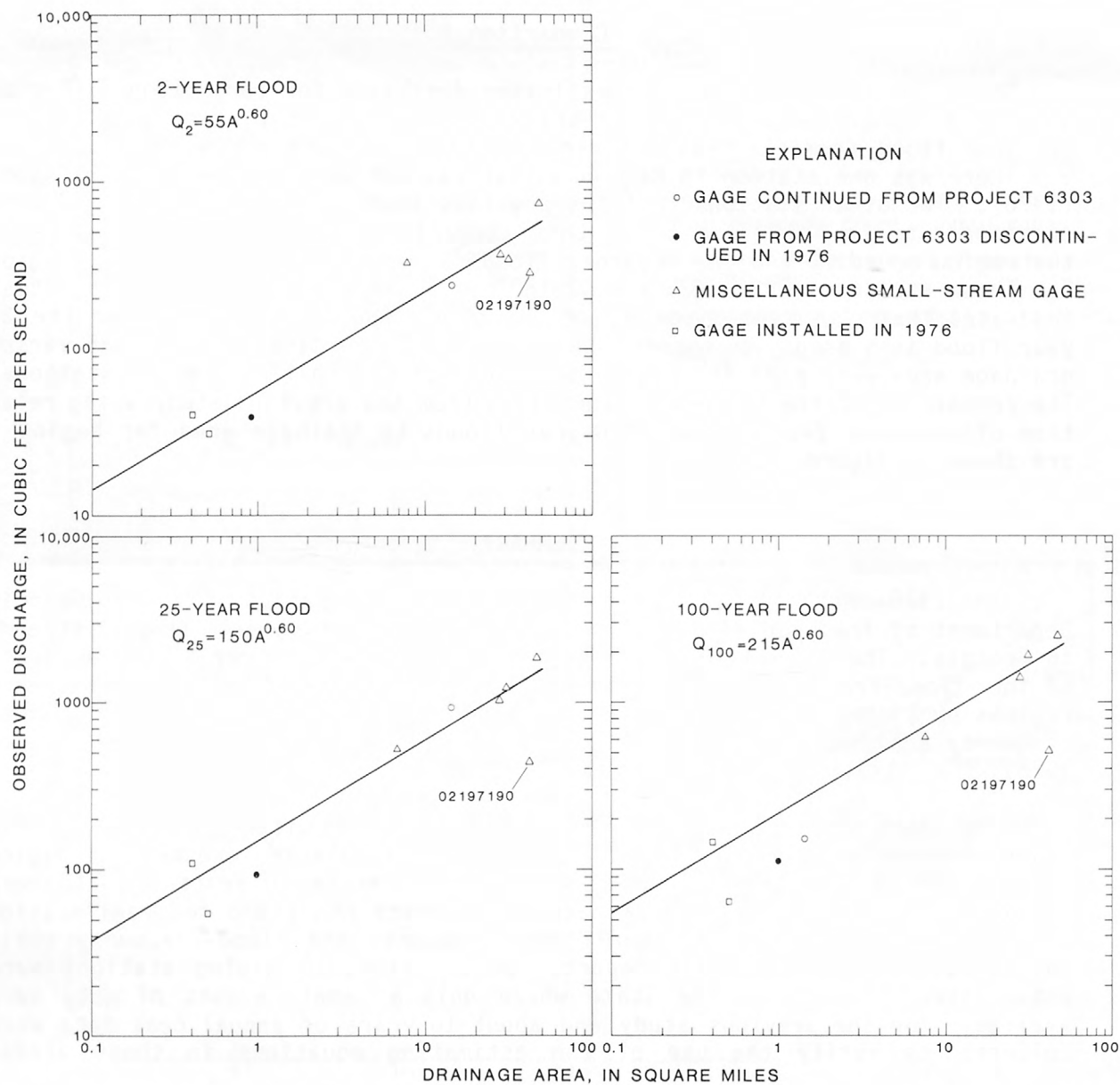


Figure 9.—Comparison of regression equations from previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 4.

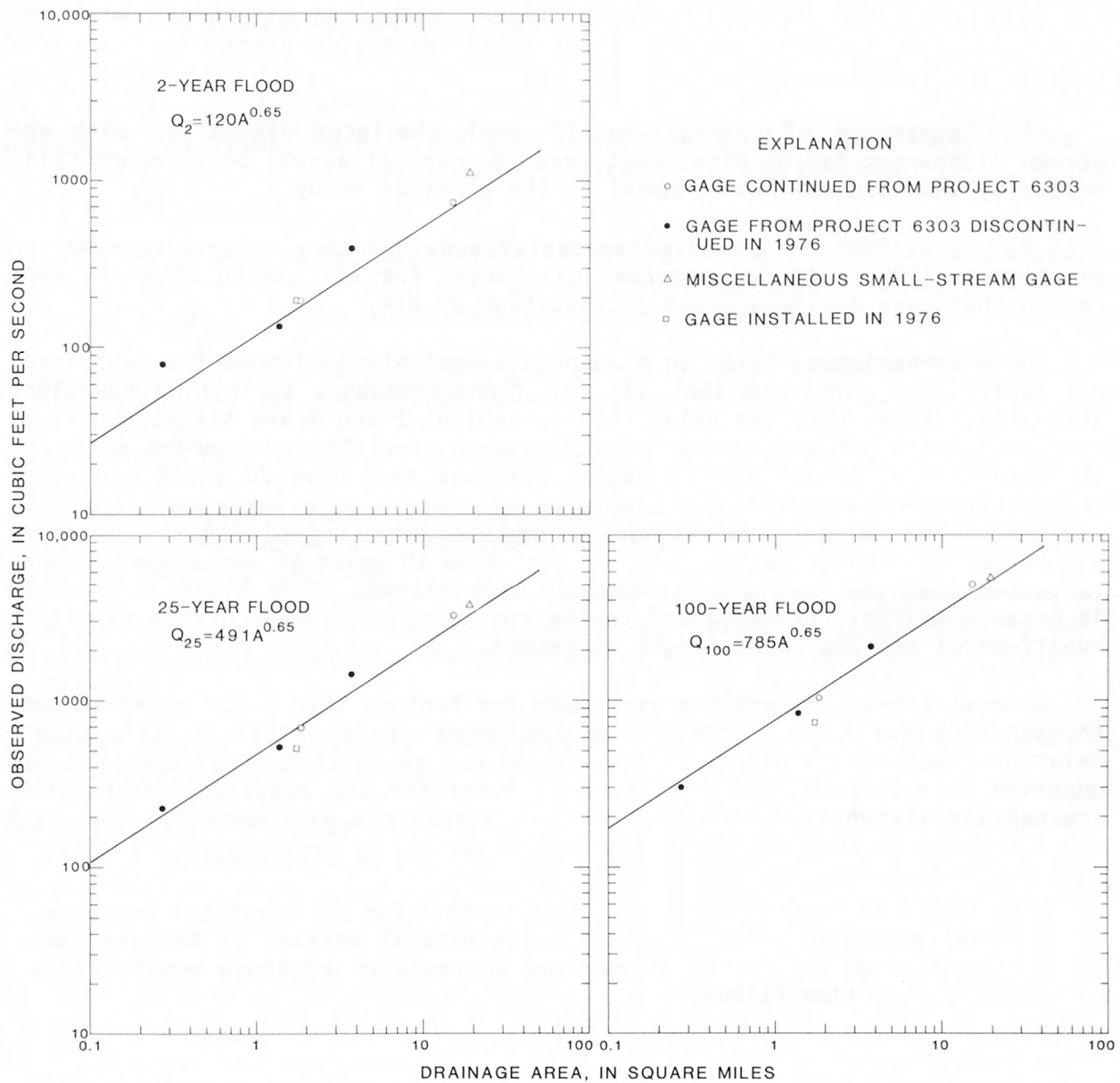


Figure 10.—Comparison of regression equations from previous study using relation of observed 2-, 25-, and 100-year floods to drainage area for Region 5.

(2) Comparison of regression-equation estimated discharges with observed discharges for the 15 gaging sites that have approximately 10 years of annual peak record since 1976 and that were installed for better geographical coverage.

(3) Comparison of rainfall-runoff-model simulated discharges with observed discharges at 23 sites that have approximately 20 years of annual peak record continued from the previous study.

(4) Comparison of rainfall-runoff-model simulated discharges with observed discharges for 81 sites that have 10 years of annual peak record calibrated by the rainfall-runoff model in the previous study.

(5-9) Comparison of the five regional flood-frequency estimating-equation discharges (1976) with the observed discharges for all gaging sites in each region that have drainage areas of less than 50 mi².

These comparisons, based on student's t-test statistics at the 0.05 level of significance, indicate that all the flood-frequency estimating equations are valid, except that the relations for Regions 2 and 3 are slightly biased. The comparisons of the rainfall-runoff-model simulated discharges with the observed discharges for the 23 gaging stations that have 20 years of annual peak record indicate that the simulated discharges were unbiased. The comparison of the rainfall-runoff-model simulated discharges with the observed discharges for the 81 gaging stations that have 10 years of annual peak record indicated that the simulated discharges were biased. This biasness probably is because of "loss of variance" in the averaging procedures of the rainfall-runoff model and the short length of record.

General linear regressions were made for Regions 1 to 3 for observed data through 1985 for gaging stations on drainages of less than 50 mi². These relations indicated that the difference in the regression equations that use observed data through 1985 and those computed for the previous study (1976) are not significantly different. No new regressions were made for Regions 4 and 5 because of the small number of stations.

The results of these comparisons indicate that for all practical purposes, the original equations (1976) are valid for natural streams in Georgia that have drainage areas of 0.1 to 20 mi² and no revision of those equations is warranted at this time (1986).

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