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WATER-RESOURCES INVESTIGATIONS REPORT 84-4144

INVESTIGATION OF THE NEED FOR DISCHARGE ADJUSTMENTS FOR UNSTEADY FLOW AT SELECTED GAGING STATIONS ON STREAMS IN TENNESSEE

U.S. GEOLOGICAL SURVEY

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Braxtel L. Neely and Roy H. Bingham

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Water-Resources Investigations Report 84-4144

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Analyses and compilations used in this report are in inch-pound units of measurements. The following factors can be used to convert inch-pound units to the International System of Units (SI).

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

INVESTIGATION OF THE NEED FOR DISCHARGE ADJUSTMENTS FOR UNSTEADY FLOW AT SELECTED GAGING STATIONS ON STREAMS IN TENNESSEE

Braxtel L. Neely and Roy H. Bingham

ABSTRACT

Measured discharges made during rising or falling stages generally require adjustments to refine constant-stage rating curves (stage-discharge relations) for gaged sites. Measurements at 42 gaging stations on Tennessee streams were selected for adjustment. Two methods, generally accepted by the U.S. Geological Survey, were tested for adjusting the measurements: (1) the slope method adjusts the discharge for changing slope during the measurement and (2) the storage method adjusts for change in channel storage. The initial results of the storage method of adjustments were unsatisfactory because of uncertainty in determining channel storage at each site, and a specific trend in the results could not be defined. Consequently, the storage method of adjustment was deleted from successive analyses. Both methods are related to the rate of change in stage. Maximum adjustments in measured discharge using the slope method were less than 5 percent at 28 of the 42 stations and less than 10 percent at 39 of the 42 stations used in the analyses. The adjustments were small because most of the measurements were made during nearly stable stage. Adjustments of measurements made during stage changes of several feet per hour could be considerably larger than 10 percent.

Stage records at 10 stations showed that maximum change in stage during rises were considerably higher than the change in stage observed during the measurements. Large adjustments are usually required for a short period of time on the rising side of a hydrograph and smaller adjustments are required for a longer period of time on the falling side. Maximum adjustments in discharge using the slope method were less than 5 percent at three of the 10 stations and less than 30 percent at eight of the 10 stations used in the analyses. The mean discharge for the adjusted and unadjusted hydrographs are about the same.

INTRODUCTION

Streamflow records compiled for Tennessee streams by the U.S. Geological Survey reflect for the most part, discharges determined on the basis of steady flow principles. A constant-stage rating curve (stage-discharge relation) is applicable for steady flow because discharge is a unique function of stage. The constant-stage rating curve is defined by plotting measured discharges versus stage. Measurements should be made during periods of constant (or nearly so) stage. A constant-stage rating curve may also be applied to periods of unsteady flow (varying stage) by using average stage over short time intervals. Discharges determined by this procedure will be less than actual discharge during periods of rising stage and greater than actual discharge during falling stage. Likewise, discharge measurements during periods of rising or falling stage will plot to the right and to the left of the constant-stage rating curve, respectively. Differences between the constant-stage (steady flow) and actual (unsteady flow) discharges are frequently insignificant. A thorough analysis of several discharge measurements at a gaging station is necessary to determine the significance of the differences. When the differences are significant, additional information about the flow must be introduced so that appropriate discharge adjustments can be made.

In response to questions and suggestions related to streamflow records at gaging stations in Tennessee, a program was initiated to (1) determine if measured discharges should be adjusted to improve definition of the rating curves and (2) determine the impact of discharge adjustments on the continuous discharge records. Two methods of discharge adjustment were tested in this study. Both methods use rate of change of stage as an additional variable and account for, respectively, the effects of (1) changes in water-surface slope and (2) channel storage. Both of these methods are discussed in detail by Corbett and others (1943) and more recently by Rantz and others (1982). Also, Kennedy (1984) presents detailed examples of application of each of the methods. The purpose of this report is to summarize the two methods and describe their application to selected gaging stations in Tennessee.

Streamflow data have been collected on many streams in Tennessee as part of cooperative programs with Federal, State, and local government agencies. Rating curves for all continuous-record gaging stations operated by the U.S. Geological Survey in Tennessee were reviewed. Forty-two stations with considerable scatter of data (measured-stage discharge) about the constant-stage rating curve were selected for this study to determine if rating curve definition could be improved by adjustment of the measured discharges. Stage records at 10 stations were selected at the request of the Corps of Engineers, Nashville District, to determine the impact of discharge adjustments on the continuous flow record.

DATA ANALYSES

The stage-discharge relation for steady flow at a section in an open channel is constant if the channel is stable and if the water-surface slope for a given stage remains the same. For conditions other than steady flow, the water-surface slope and channel storage should be considered in evaluating the stage-discharge relations. The principal reason for adjustments in the measured discharge (if changing slope or storage is a factor) is to correct these measurements to steady flow conditions to define the constant-stage rating curve. A factor curve is developed in conjunction with the rating curve to be used to adjust constant-stage (steady flow) discharges to actual (unsteady flow) discharges.

Slope and storage analyses were used to adjust measured discharges for 42 gaging stations on selected streams in Tennessee (fig. 1). Slope analyses were used to adjust computed discharges from stage records at 10 of these stations.

Slope Method

Variable slopes affecting streamflow are generally caused by backwater, changes in discharge, or a combination of the two. The slope method in this study is commonly referred to as the Boyer method and can be used to adjust streamflow that is affected by changes in the water-surface slope. For any given stage, discharge is related to the square root of the slope as indicated in the following equation.

$$Q_m/Q_c = \sqrt{\frac{S_c + 1/U\ dh/dt}{S_c}} = \sqrt{\frac{\text{Slope during measurement}}{\text{Slope for constant discharge}}} \qquad (1)$$

where

Q_m = measured discharge, in cubic feet per second,
Q_c = constant discharge in cubic feet per second from rating curve,
S_c = water-surface slope in feet/foot for constant discharge and stage,
U = velocity of the flood wave, in feet per second.
dh/dt = rate of change in stage, in feet per hour, and
$1/U\ dh/dt$ = change in slope of water surface, in feet per foot per second.

Dividing through by S_c, equation (1) is further reduced to:

$$Q_m/Q_c = \sqrt{1 + ((1/US_c)\ (dh/dt))}. \qquad (2)$$

Based on information from Corbett and others (1943), it appears that the velocity of the flood wave, U, is between 1.3 and 1.7 times larger than the corresponding mean velocity, V_m, for uniform channels and that the most probable value is 1.3. Therefore, for practical application in this study, it is assumed that the channel is uniform and the flood wave velocity, U, is approximately 1.3 times the mean velocity, V_m. The mean velocity was determined from all discharge measurements below bankfull stage. The mean velocities from discharge measurements above bankfull stage for stations with bridge and road fill constrictions were higher than the velocities would be without the constrictions. The higher velocities result from flow acceleration caused by the bridge and road fill constrictions. A graphical relation between stage and U was estimated by plotting stage versus U(1.3 V_m) for all values below bankfull stage. The graphs were extended to estimate velocities for measurements above bankfull stage. Extension of the graph for Duck River above Hurricane Mills (03603000) is illustrated in figure 2.

Water-surface slope is assumed to parallel the general slope of the streambed when discharge and stage are constant. Based on that assumption, the water-surface slope, S_c, was estimated from topographic maps.

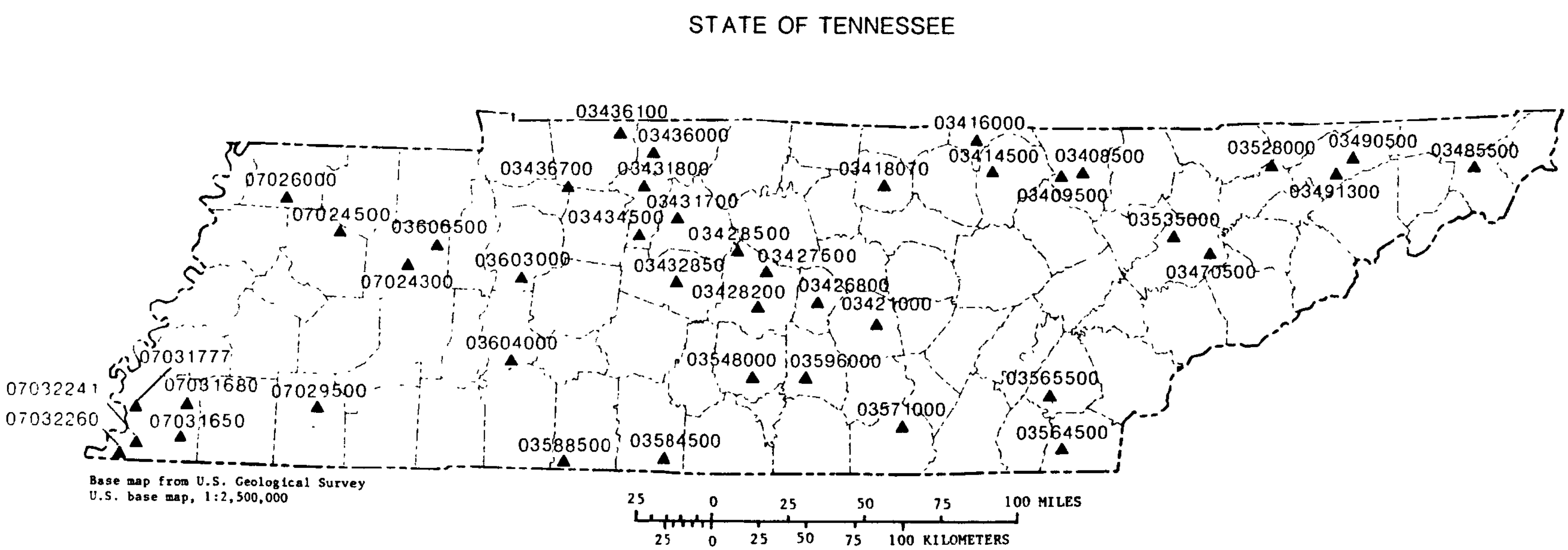

Figure 1.--Location and station number of gaging stations for which measured discharges were adjusted for changing stage and channel storage.

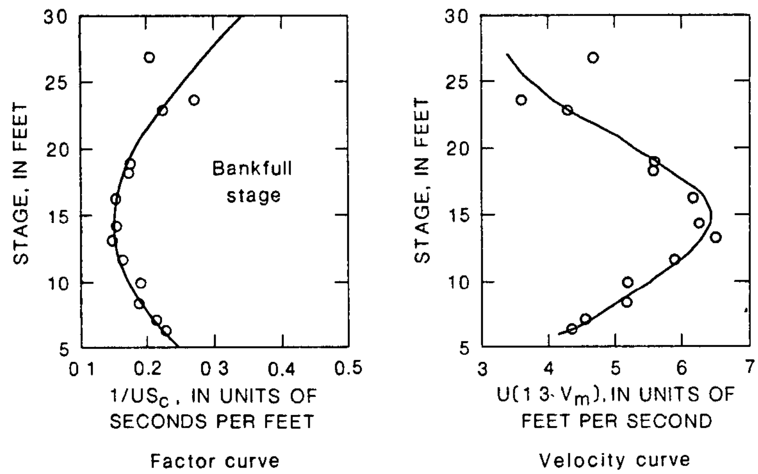

Figure 2.--Relations between stage and velocity, and stage versus factor ($1/US_c$) (Duck River above Hurricane Mills 03603000).

Values of U and S_c, as described above, were used to compute $1/US_c$. A factor curve was developed by plotting $1/US_c$ for each measurement versus stage and a curve drawn to average the points (fig. 2). The $1/US_c$ value was determined from this factor curve for each discharge measurement, and then the measurement was adjusted by solving for the relation between the constant-stage discharge, Q_c, and the measured discharge, Q_m, as expressed by equation (2). The adjusted discharge was then plotted against stage to redefine and improve the constant-stage rating curve. The minimum and maximum discharge measurements, and the mean of all measurements for each station used in the analyses, and adjustments of measurements taken during the maximum change in stage are given in table 1. The maximum adjustments resulted in less than 5 percent difference in discharge at 28 of the stations, and 5 percent or more at 14 of the stations.

A value of $1/US_c$ was also computed for each measurement by using equation (2); values of other terms in the equation were known. An attempt was made to plot the values of $1/US_c$ against stage and average the points with a smooth curve. At all stations except one, a smooth curve could not be drawn because of too much scatter in the plotted points. Many of the values were either negative, which indicates that adjustments of the measured discharges were in the wrong direction, or the magnitude of the values differed by large amounts and a specific trend in plotted points could not be defined.

Table 1.--Summary of measured discharges used in the analyses and resulting adjustments of the measurements taken during maximum change in stage

Gaging stations		No. of measurements	Measured discharge used in analyses, in ft^3/s			Rate of change in stage feet/hour		Measured discharge, during maximum change in stage, in ft^3/s	Adjusted discharge for maximum change in stage	
No.	Name		Minimum	Mean	Maximum	Minimum change	Maximum change		$\frac{Qm}{\sqrt{1+1/US_c \frac{dh}{dt}}}$	Percent difference from measured
03408500	New River at New River	33	3,490	10,400	26,900	0.05	-2.03	26,900	30,090	11.9
03409500	Clear Fork near Robbins	57	1,000	3,980	34,000	0	- .37	9,670	9687	.2
03414500	East Fork Obey River near Jamestown	29	1,070	4,700	26,100	0	1.06	6,530	6,335	-3.0
03416000	Wolf River near Byrdtown	33	564	1,840	7,230	.01	.67	1,630	1,617	- .8
03418070	Roaring River above Gainesboro	12	579	4,470	15,600	.01	-1.28	9,380	9,723	3.7
03421000	Collins River near McMinnville	58	1,050	5,040	42,500	0	- .73	24,100	24,710	2.5
03426800	East Fork Stones River at Woodbury	18	618	1,720	3,140	.10	1.36	1,180	1,151	-2.5
03427500	East Fork Stones River near Lascassas	13	4,500	13,800	28,500	.11	-1.51	8,890	9,337	5.0
03428200	West Fork Stones River at Murfreesboro	7	2,240	12,600	26,600	.07	.87	4,770	4,653	-2.5
03428500	West Fork Stones River near Smyrna	6	6,480	10,300	13,200	.12	.86	13,200	13,054	-1.1
03431700	Richland Creek at Nashville	20	222	1,260	5,630	0	-6.52	2,150	2,444	13.7
03431800	Sycamore Creek near Ashland City	17	1,090	3,780	14,100	.05	- .67	5,220	5,280	1.1
03432350	Harpeth River at Franklin	10	2,600	7,420	20,000	0	- .90	3,130	3,425	9.4
03434500	Harpeth River near Kingston Springs	27	2,200	7,620	30,200	0	- .61	12,900	13,212	2.4
03436000	Sulphur Fork Red River near Adams	28	2,000	5,660	35,100	.15	-1.75	7,870	8,619	9.5
03436100	Red River at Port Royal	32	3,000	13,200	59,600	.02	- .69	9,620	10,321	7.3
03436700	Yellow Creek near Shiloh	18	1,230	3,380	9,620	.01	.94	6,000	5,871	-2.2
03470500	French Broad River near Knoxville	34	10,100	15,900	35,800	0	.27	10,100	10,100	0
03485500	Doe River at Elizabethton	48	319	1,040	7,010	0	.67	766	763	- .4
03490500	Holston River at Surgoinsville	51	8,360	23,200	57,700	0	- .61	39,000	39,942	2.4
03491300	Beech Creek at Kepler	44	60	266	1,280	0	1.10	310	302	-2.3
03528000	Clinch River above Tazewell	50	3,020	12,000	48,500	0	- .40	25,300	25,540	.9
03535000	Bullrun Creek near Halls Crossroads	59	330	1,440	5,950	0	.41	508	495	-2.6
03564500	Ocoee River at Parksville	28	2,920	4,880	13,900	0	-1.71	3,870	3,870	0
03565500	Oostanaula Creek near Sanford	19	629	1,430	4,070	0	.25	1,570	1,565	- .3
03571000	Sequatchie River near Whitwell	33	1,020	2,620	18,200	.01	.46	3,190	3,011	-5.6
03584500	Elk River near Prospect	34	3,000	7,110	25,600	.01	- .55	16,000	17,430	8.9
03588500	Shoal Creek at Iron City	21	2,980	11,600	50,500	.02	- .56	15,700	15,840	.9
03596000	Duck River below Manchester	23	1,000	3,430	11,400	.02	- .84	6,480	6,568	1.4
03598000	Duck River at Shelbyville	26	2,900	9,990	34,300	.01	- .69	13,000	13,460	3.5
03603000	Duck River above Hurricane Mills	32	6,070	18,600	79,900	0	- .30	17,600	18,020	2.4
03604000	Buffalo River near Flat Woods	42	1,030	6,840	46,300	0	- .69	7,270	8,064	10.9
03606500	Big Sandy River at Bruceton	38	414	1,550	8,020	0	.54	415	393	-5.3
07024300	Beaver Creek at Huntingdon	28	309	1,210	8,340	0	- .31	335	348	3.9
07024500	South Fork Obion River at Greenfield	22	152	1,710	19,200	0	.45	522	490	-6.1
07026000	Obion River at Obion	49	5020	9,880	44,900	0	.32	7,400	6,986	-5.6
07029500	Hatchie River at Bolivar	30	2,190	8,120	33,500	0	- .11	20,300	21,040	3.6
07031650	Wolf River at Germantown	40	1,080	5,550	32,300	0	- .48	15,200	15,610	2.7
07031680	Fletcher Creek near Cordova	18	46	176	550	- .15	-5.65	95	104	9.5
07031777	Lick Creek at Memphis	15	40	215	1,180	0	-2.92	507	521	2.8
07032241	Black Bayou at Memphis	7	47	84	162	- .53	5.80	130	124	-4.6
07032260	Cypress Creek at Memphis	3	566	781	1,100	1.93	6.36	1,100	1,027	-6.6

In attempting to draw a curve, more weight was given to plotted points that had larger dh/dt values. Cypress Creek at Memphis (07032260) was the only station where the constant-stage curve could definitely be improved by the adjustments.

Measured discharges used in these analyses were taken as part of routine maintenance trips. The measurements defined several rating curves during the period of record. For this analysis, the most recent rating was used for constant discharge, Q_c, to solve for relations in equation (2). The value of Q_c would be different for measurements prior to the most recent rating, consequently, adjustments to those measurements would be different. Because adjustments in measured discharges for most stations were less than 5 percent, it appears that differences in the adjustments caused by several ratings are insignificant.

The small adjustments in most of the measurements reflect, in part, efforts to measure the discharge when the stage is stable. Consequently, the rate of change in water-surface slope is small which requires less adjustment.

Examination of stage record at 10 stations showed that maximum change in stage during rises was considerably higher than the change in stage observed during the measurements. The maximum change in stage was determined at each station by examining several stage hydrographs. The stage hydrograph that included the maximum change in stage was used to develop a constant-stage discharge hydrograph. This constant-stage discharge hydrograph was subsequently adjusted by equation (2) using the factor-curve values of $1/US_c$. Hydrographs showing constant-stage discharge, adjusted discharge, and percentage of adjustment are shown in figures 3 through 12 for the 10 stations. These hydrographs show that large positive adjustments are usually required for a short period of time on the rising side and smaller negative adjustments are required for a longer period of time on the falling side. Results from comparisons of the constant-stage and adjusted discharge hydrographs are tabulated in table 2. The mean discharge for the adjusted and unadjusted hydrographs for every case are essentially equal (less than 1/2 of 1 percent difference). The maximum percentage of adjustment was less than 5 percent at three stations, between 20 and 30 percent at five stations, and about 43 and 57 percent at the other two stations. This may seem, at first glance, to demonstrate a very important need for discharge adjustments. However, examination of figures 3 through 12 reveal that in general differences in excess of 10 percent occur from about 1 to less than 6 hours except for Red River at Port Royal where the duration is about 9 hours (fig. 12). Averaged out on a daily basis the maximum differences are less than 9 percent. Therefore, unless an analysis requires discharge data for relatively short time intervals, it is unlikely that discharge adjustments would noticeably improve the end results.

Adjustment factors determined by using equation 2 are shown graphically for each of the 10 stations in figures 13 through 22. Adjustments can be determined from these graphs with the appropriate stage and rate of change in stage. The rate of change in stage, dh/dt, is the change in stage during the previous time interval expressed in feet per hour. Adjustments are

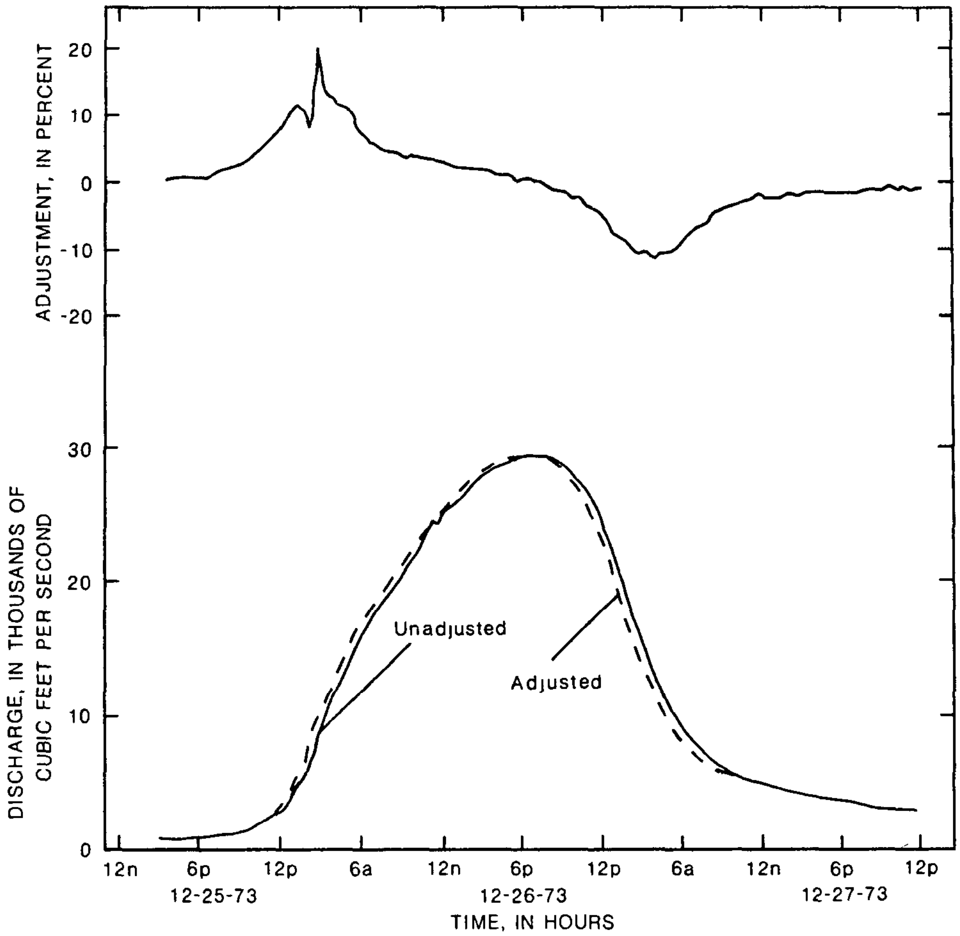

Figure 3.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 12-26-73 on New River at New River (03408500).

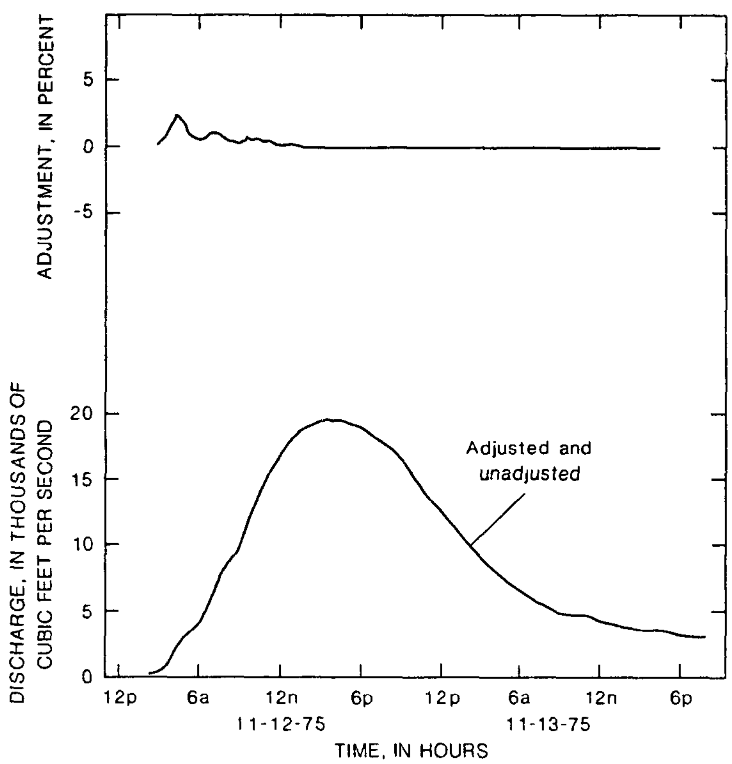

Figure 4.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 11-12-75 on Clear Creek near Robbins (03409500)

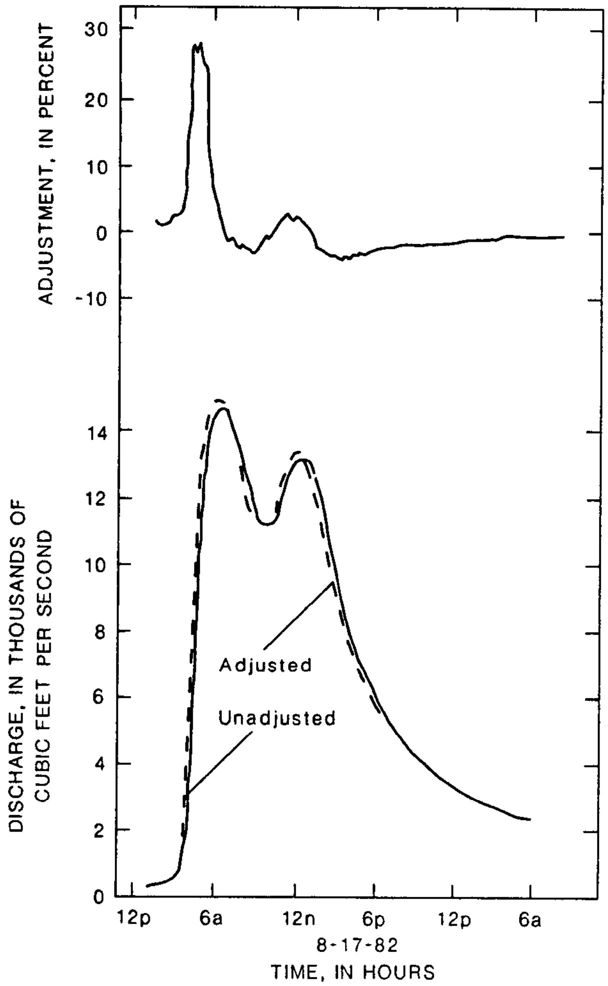

Figure 5.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 8-17-82 on East Fork Obey River near Jamestown (03414500).

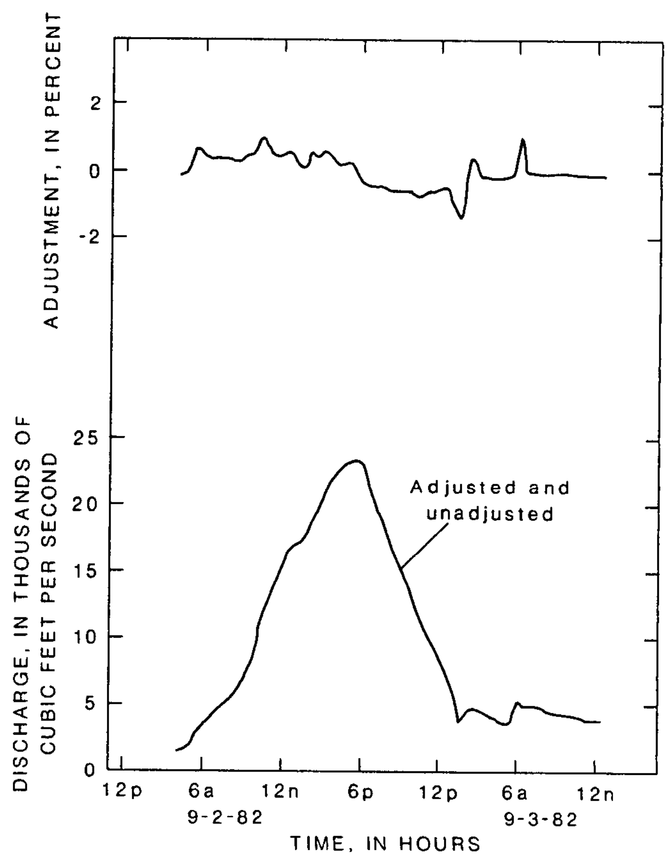

Figure 6.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 9-2-82 on Wolf River near Byrdstown (03416000).

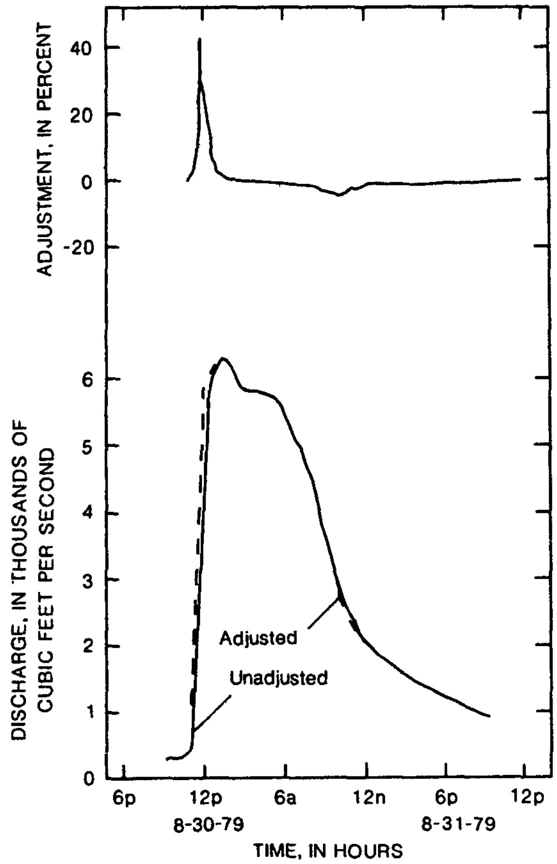

Figure 7.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 8-31-79 on Roaring River above Gainesboro (03418070).

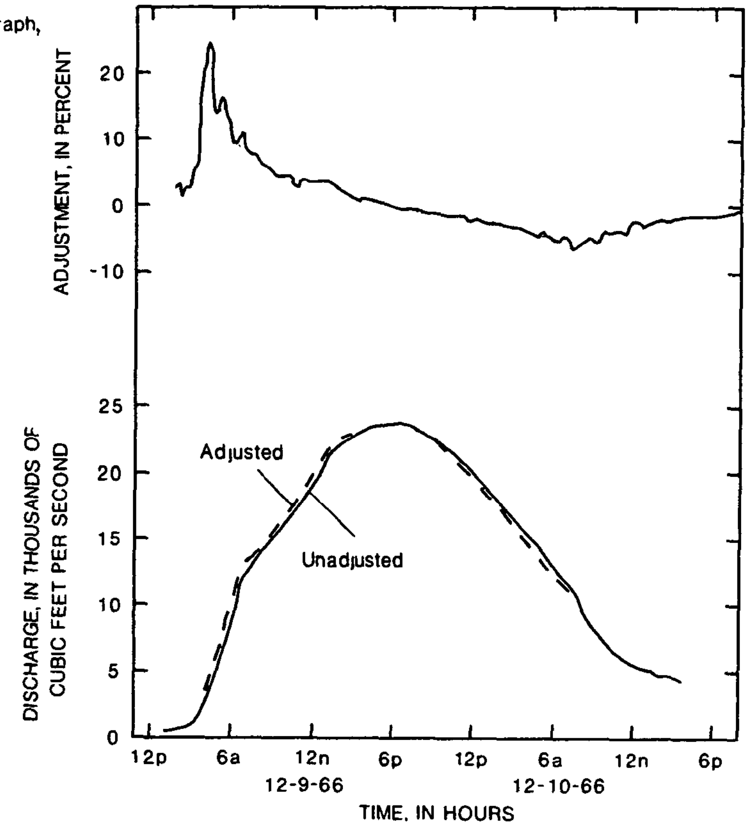

Figure 8.-- Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 12-9-66 on East Fork Stones River near Lascassas (03427500).

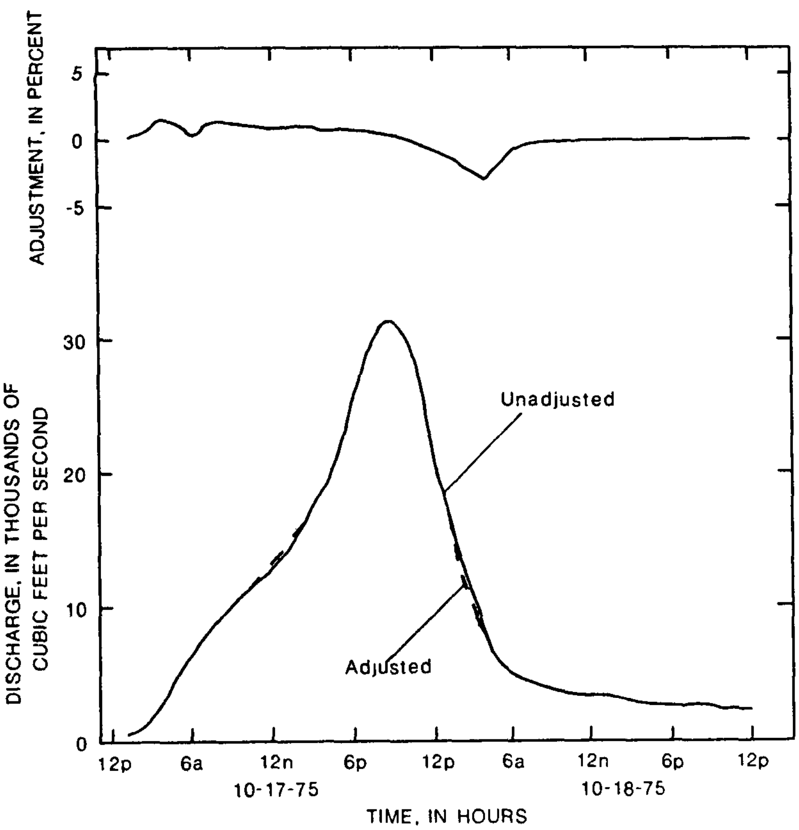

Figure 9.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 10-17-75 on West Fork Stones River near Smyrna (03428500)

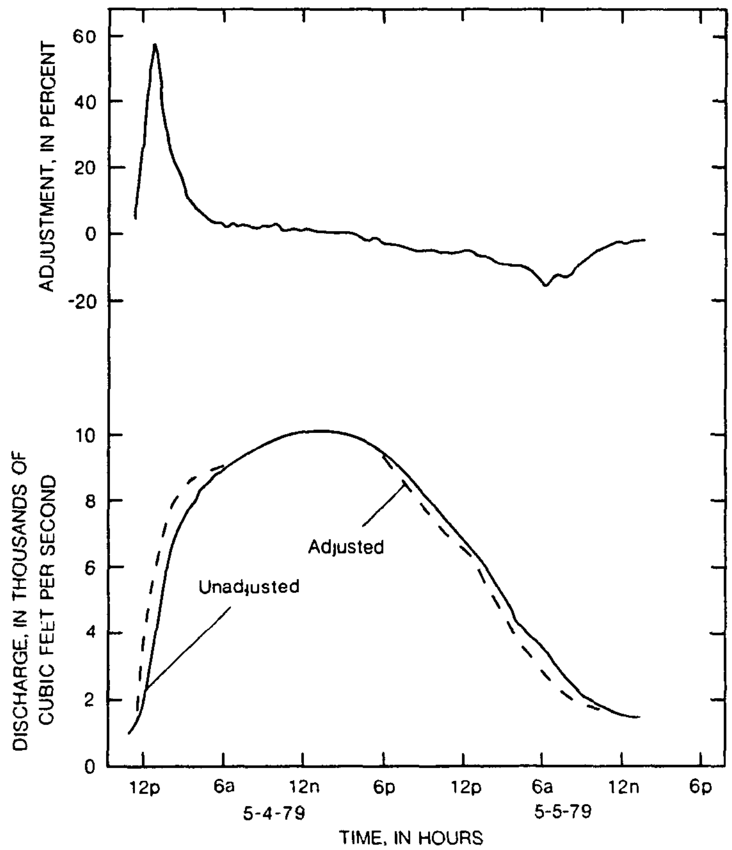

Figure 10.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 5-4-79 on Harpeth River at Franklin (03432350).

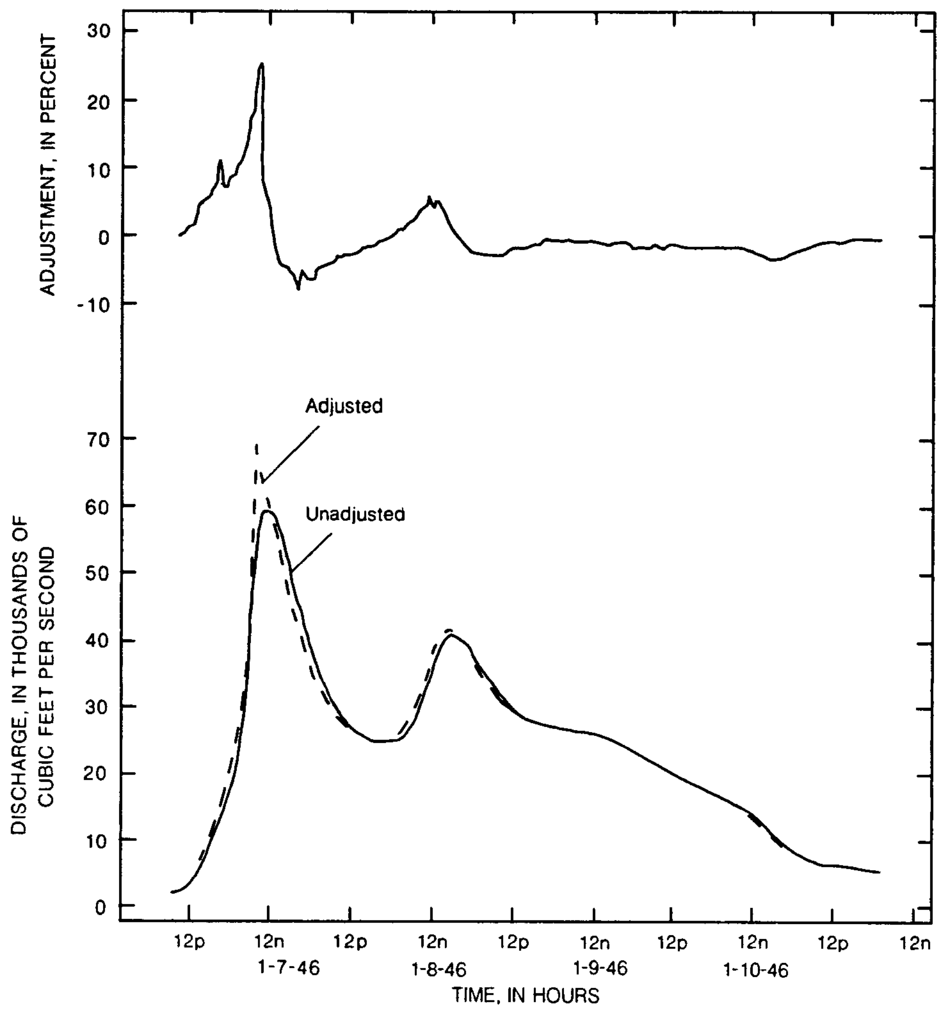

Figure 11.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 1-7-46 on Harpeth River near Kingston Springs (03434500).

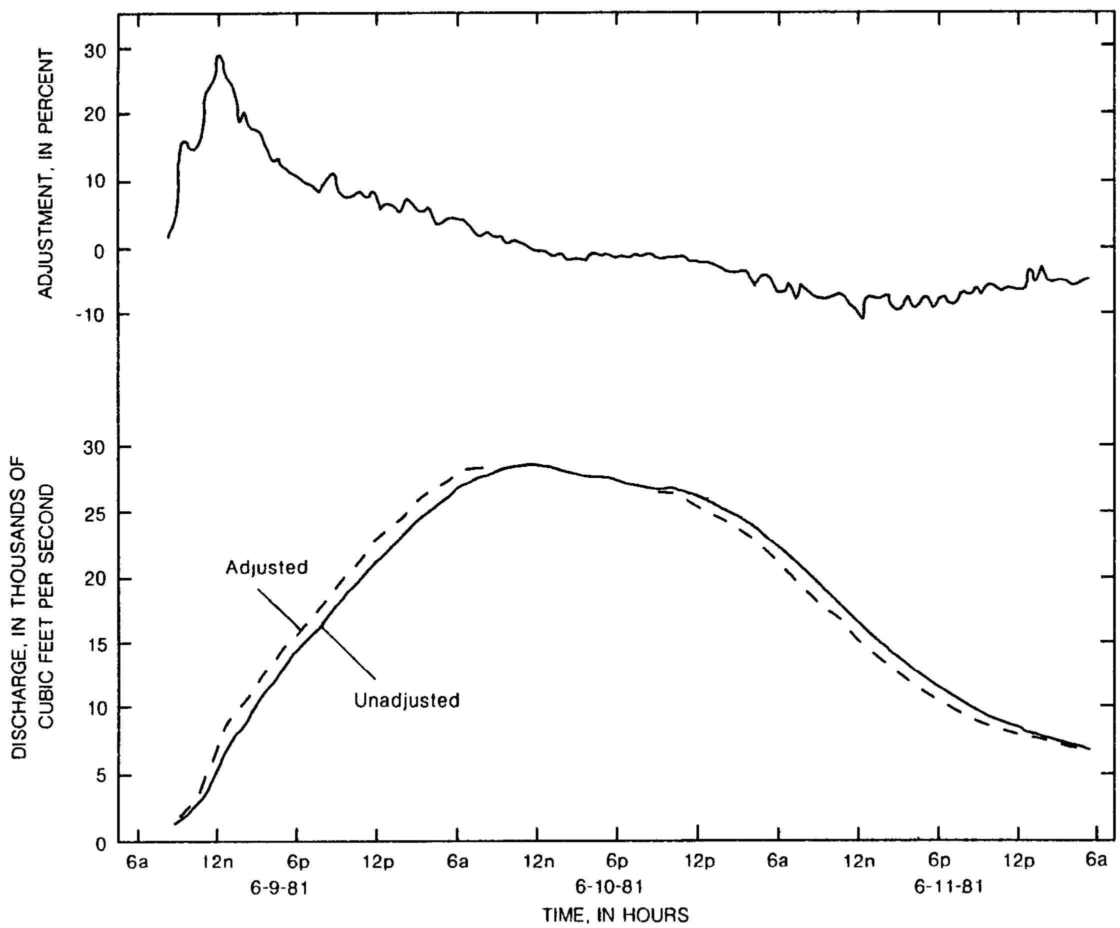

Figure 12.--Discharge hydrograph, adjusted discharge hydrograph, and percent of adjustment for flood of 6-10-81 on Red River at Port Royal (03436100)

determined by entering each figure with stage on the vertical scale and dh/dt on the horizontal scale. The adjustments can be read by interpolating between the appropriate lines of equal value. For example, if the stage on New River at New River (fig. 13) is 20 feet and the rate of change in stage is 1.50 feet, the adjustment of 8 percent can be determined by entering figure 13 with 20 feet on the vertical scale and 1.50 feet on the horizontal scale.

Table 2.--Summary of discharge hydrographs used in analyses and resulting adjustments during the maximum rate of change in stage

No.	Name	Date of flood	Maximum adjustment, in percent	Mean discharge, in ft^3/s		Maximum difference for 24-hour period, in percent	
				Unadjusted	Adjusted		
03408500	New River at New River	12-26-73	20.9	9,460	9,460	+5.1	-6.4
03409500	Clear Fork near Robbins	11-12-75	2.4	9,460	9,460	+ .1	- .2
03414500	East Fork Obey River near Jamestown.	8-17-82	28.6	6,820	6,830	+ .2	-1.5
03416000	Wolf River near Byrdstown	9- 2-82	1.5	9,910	9,910	0	- .1
03418070	Roaring River above Gainesboro.	8-31-79	42.8	3,010	3,020	+ .2	0
03427500	East Fork Stones River near Lascassas.	12- 9-66	24.3	12,100	12,100	+1.6	-3.3
03428500	West Fork Stones River near Smyrna.	10-17-75	3.0	9,870	9,880	+ .4	-1.0
03432350	Harpeth River at Franklin	5- 4-79	57.4	6,560	6,550	+2.1	-5.1
03434500	Harpeth River near Kingston Springs.	1- 7-46	26.3	23,800	23,800	+1.8	-2.2
03436100	Red River at Port Royal	6-10-81	29.2	18,400	18,400	+8.4	-7.1

Storage Method

The storage method of adjustment is applicable when discharge variation is related to channel storage. The adjustments are made using the following equation:

$$Q_c = Q_m - (\Delta Q/J)\ J \tag{3}$$

where

Q_c = discharge, in cubic feet per second from rating curve;
Q_m = measured discharge, in cubic feet per second;
ΔQ = $Q_m - Q_c$, in cubic feet per second;
$\Delta Q/J$ = rate of change in storage, in cubic feet per second per feet per hour; and
J = rate of change in stage, in feet per hour.

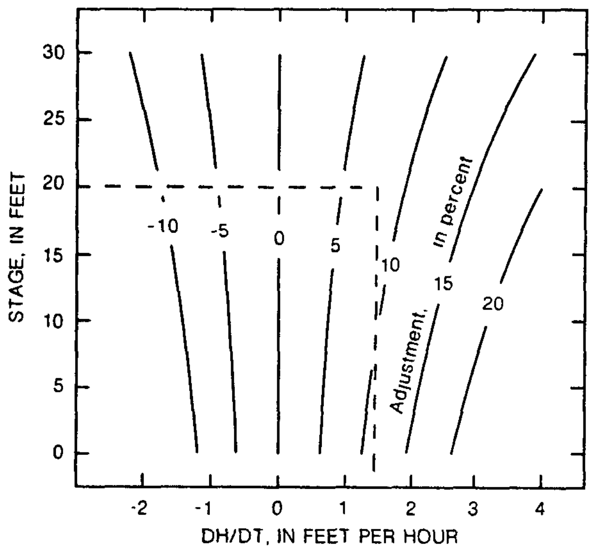

Figure 13--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for New River at New River (03408500)

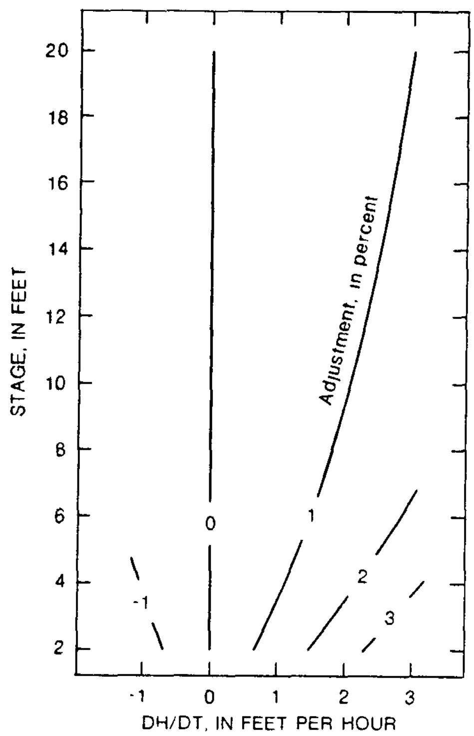

Figure 14--Nomograph to determine relation of discharge to stage and rate of change in stage dh/dt, for Clear Creek near Robbins (03409500)

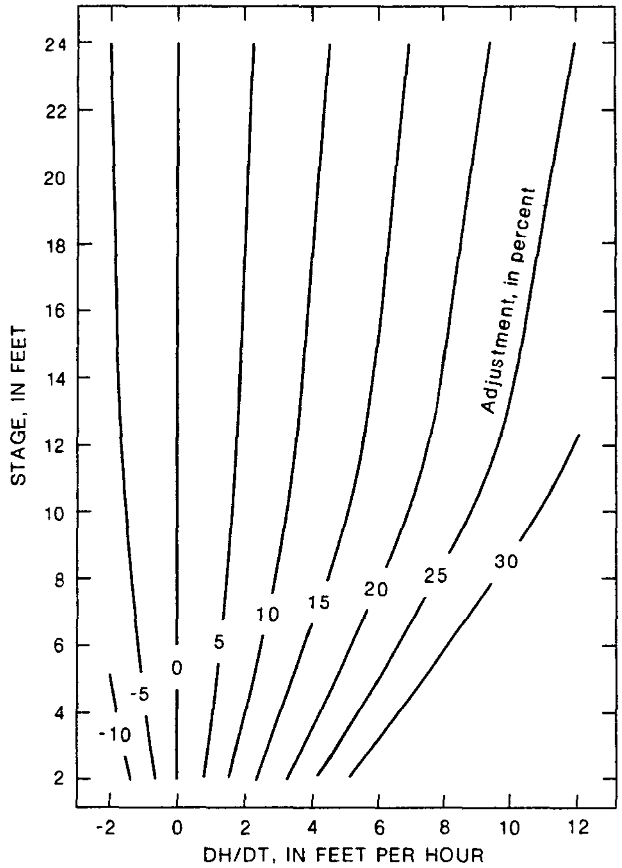

Figure 15.--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for East Fork Obey River near Jamestown (03414500)

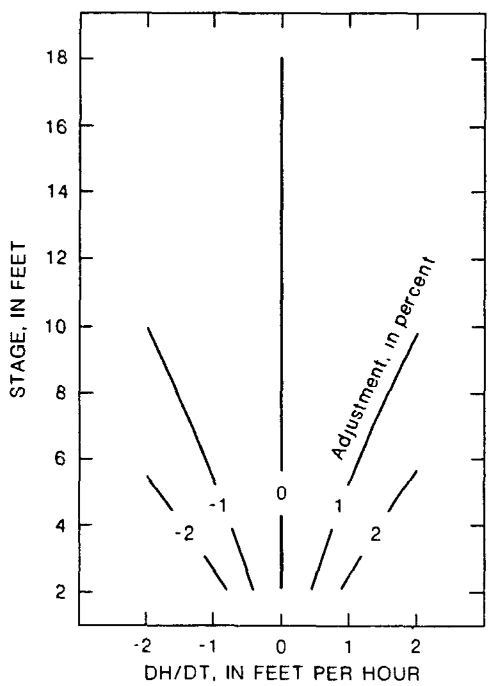

Figure 16--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for Wolf River near Byrdstown (03406000)

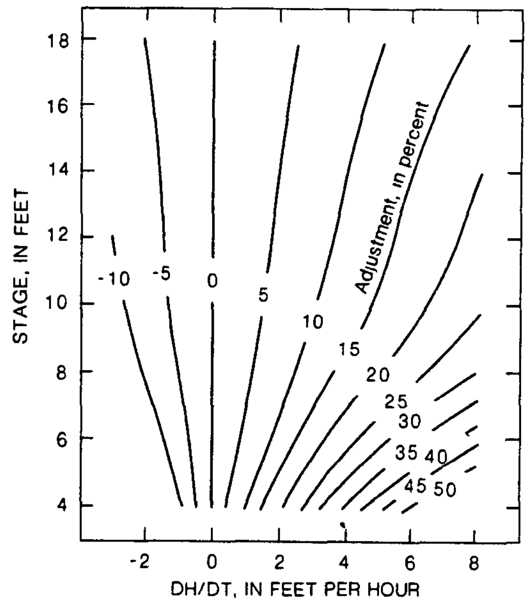

Figure 17.--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for Roaring River above Gainesboro (03418070).

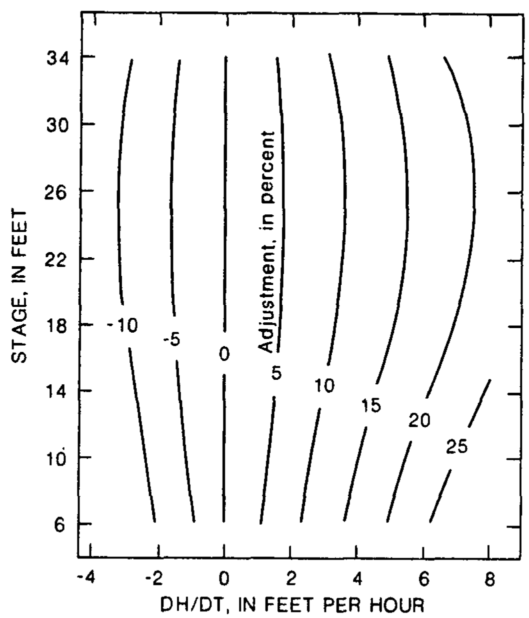

Figure 18.--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for East Fork Stones River near Lascassas (03427500)

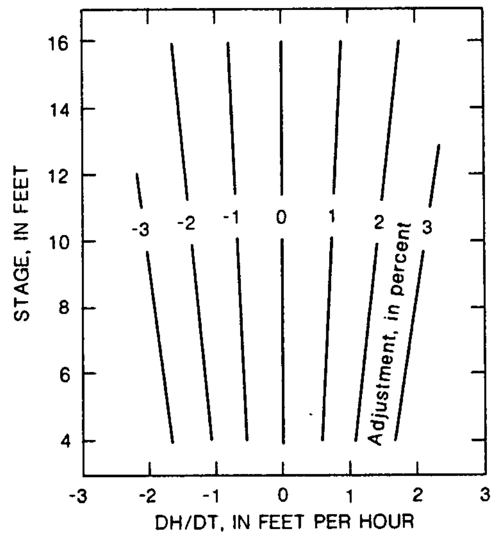

Figure 19.--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for West Fork Stones River near Smyrna (03428500).

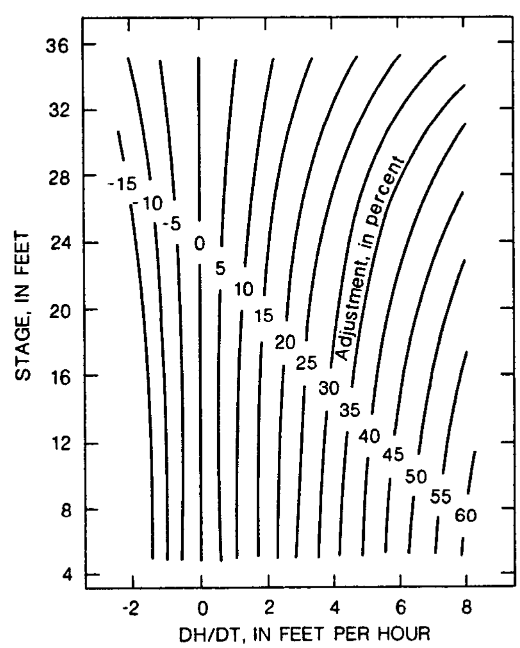

Figure 20--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for Harpeth River at Franklin (03432350)

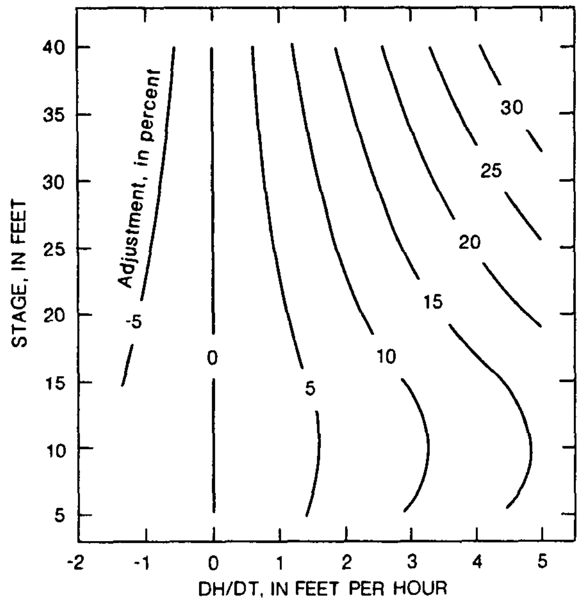

Figure 21.--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for Harpeth River near Kingston Springs (03434500)

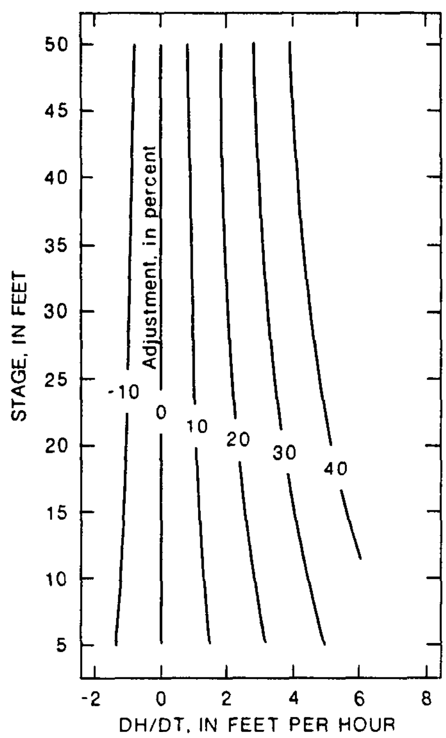

Figure 22--Nomograph to determine relation of discharge adjustment to stage and rate of change in stage, dh/dt, for Red River at Port Royal (03436100)

An attempt was made to measure channel storage between each gaging station and its control. The channel serves as control for most of the stations, consequently, a specific location of the control could not be determined.

$\Delta Q/J$ is determined from each discharge measurement and plotted against stage to develop a factor curve. To convert a constant-stage discharge to actual discharge, $\Delta Q/J$ from factor curve times appropriate change in stage provides the adjustment.

A value of $\Delta Q/J$ was computed for each measurement by using equation (3); values of other terms in the equation were known. An attempt was made to plot the values of $\Delta Q/J$ against stage and average the points with a smooth curve. For most stations, a smooth curve could not be drawn because of too much scatter in the plotted points. Many of the values were either negative, which indicates that adjustments of the measured discharges were in the wrong direction, or the magnitude of the values differed by large amounts and a specific trend in plotted points could not be defined. The storage method of adjustment was deleted from successive analyses because channel storage at each site could not be adequately determined, and a specific trend in results could not be defined.

SUMMARY

Measured discharge during changing stage and channel storage should be adjusted to refine constant-stage rating curves (stage-discharge relations) for the gaged site. Forty-two selected gaging stations on Tennessee streams were analyzed to determine amounts of adjustments needed in measured discharges at each station. The stations were selected because of considerable scatter of plotted stage versus discharge points about the rating curve.

The slope method, commonly referred to as the Boyer method, was used to adjust the discharge for changing stage during the measurement. The storage method which accounts for changes in channel storage as related to changing stage was tested for selected sites in Tennessee, but the results were inconclusive because channel storage between each selected site and its control could not be adequately determined, and a specific trend in the results could not be defined. Adjustments in measured discharges using the Boyer method were small because most of the measurements were made when the stage was relatively stable. However, adjustments required for stage changes of several feet per hour could be considerably larger than the adjustments given in this report.

Stage records analyzed at 10 stations showed that maximum change in stage during rises were considerably higher than the change in stage observed during the measurements. Large adjustments are usually required for a short period of time on the rising side of a hydrograph and smaller adjustments are required for a longer period of time on the falling side. The mean discharge for the adjusted and unadjusted hydrographs are about the same. Even the larger adjustments are insignificant unless discharges for time intervals of one-quarter day or less are required for analyses.

REFERENCES CITED

Corbett, D. M., and others, 1943, Stream-gaging procedure - a manual describing methods and practices of the Geological Survey: U.S. Geological Survey Water-Supply Paper 888, 245 p.

Kennedy, E. J., 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A-10, 59 p.

Rantz, S. E., and others, 1982, Measurement and computation of streamflow: Volume 2. Computation of Discharge: U.S. Geological Survey Water-Supply Paper 2175, p. 285-630

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