Error Analysis of Streamflow Data for an Alluvial Stream

GEOLOGICAL SURVEY PROFESSIONAL PAPER 655-C

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GILA RIVER PHREATOPHYTE PROJECT

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ABSTRACT

Discharge measurements were used to determine the standard error in computed continuous records of discharge for two streamflow gaging stations on the Gila River. The major source of errors in computed discharge is from poor definition of the stage-discharge relation.

The standard errors of computation of discharge for the two stations were determined by randomly choosing a group of discharge measurements for use in rating analysis and using the remaining measurements as a control group. Discharge was computed corresponding to the stage and time of the measurements in the control group. The mean square difference (S^2_{m-c}) between measured and computed discharge was determined for different ranges of flow. S^2_{m-c} is the sum of the mean square difference of the measured discharge from true discharge (S^2_m) plus the mean square difference of computed discharge from true discharge (S^2_c). The variance (S^2_c) was obtained by subtracting the known variance S^2_m from S^2_{m-c}.

INTRODUCTION

The accuracy of discharge data obtained in a sand-channel stream is not known, and there is no direct and exact technique by which the accuracy can be evaluated. Because of the increasing importance of research and management problems in water development, the knowledge of errors in water data assumes great importance.

The general purpose of this report is to present a method by which errors in computing discharge for a stream that flows in a sand channel can be evaluated. A more specific purpose is to approximate the errors in the discharge of the Gila River near Globe, Ariz., in which the evapotranspiration from the alluvial flood plain is measured as a residual in a water-budget study. The method described can be used to determine the errors in instantaneous discharge as well as errors in average rates and volumes of discharge.

A water budget requires the measurement of all significant quantities of inflow and outflow in an area. The factors in the budget will vary seasonally; therefore, the relative significance of the surface flow in the determination of evapotranspiration will vary for different periods. In periods of floodflow, the surface inflow and outflow greatly exceed all other factors in the budget. Surface flow is the main source of ground-water recharge; therefore, the surface-flow data for many budget periods can be used to test evaluations of the change in ground-water storage, which is measured by neutron soil-moisture meters.

This report was prepared under the general supervision of H. M. Babcock, district chief of the Water Resources Division in Arizona, and is the result of evapotranspiration studies of the Gila River Phreatophyte Project under R. C. Culler, project chief.

BASIC DATA

GAGING SITES

The discharge data for the Gila River gaging stations near Bylas and at Calva, Ariz., were used in this study. The stations are at the ends of subreach 1 of the Gila River Phreatophyte Project (fig. 1).

The flood plain through subreach 1 is from about 3,000 to 4,000 feet wide. The present (1965) low- and median-flow channel, or main channel, is from 80 to 100 feet wide, has a slope of about 0.001, and is a normal pool-and-riffle type. The pools are generally full of sand that erodes easily during low flows, and the riffles are fairly stable gravel bars. The sand and gravel in the banks of the main channel and in the flood plain are stabilized by a dense cover of saltcedar and mesquite.

The surface-water stage is determined by the use of stilling-well-type gages, which are equipped with 15-minute digital recorders and continuous analog recorders that operate from the same float.

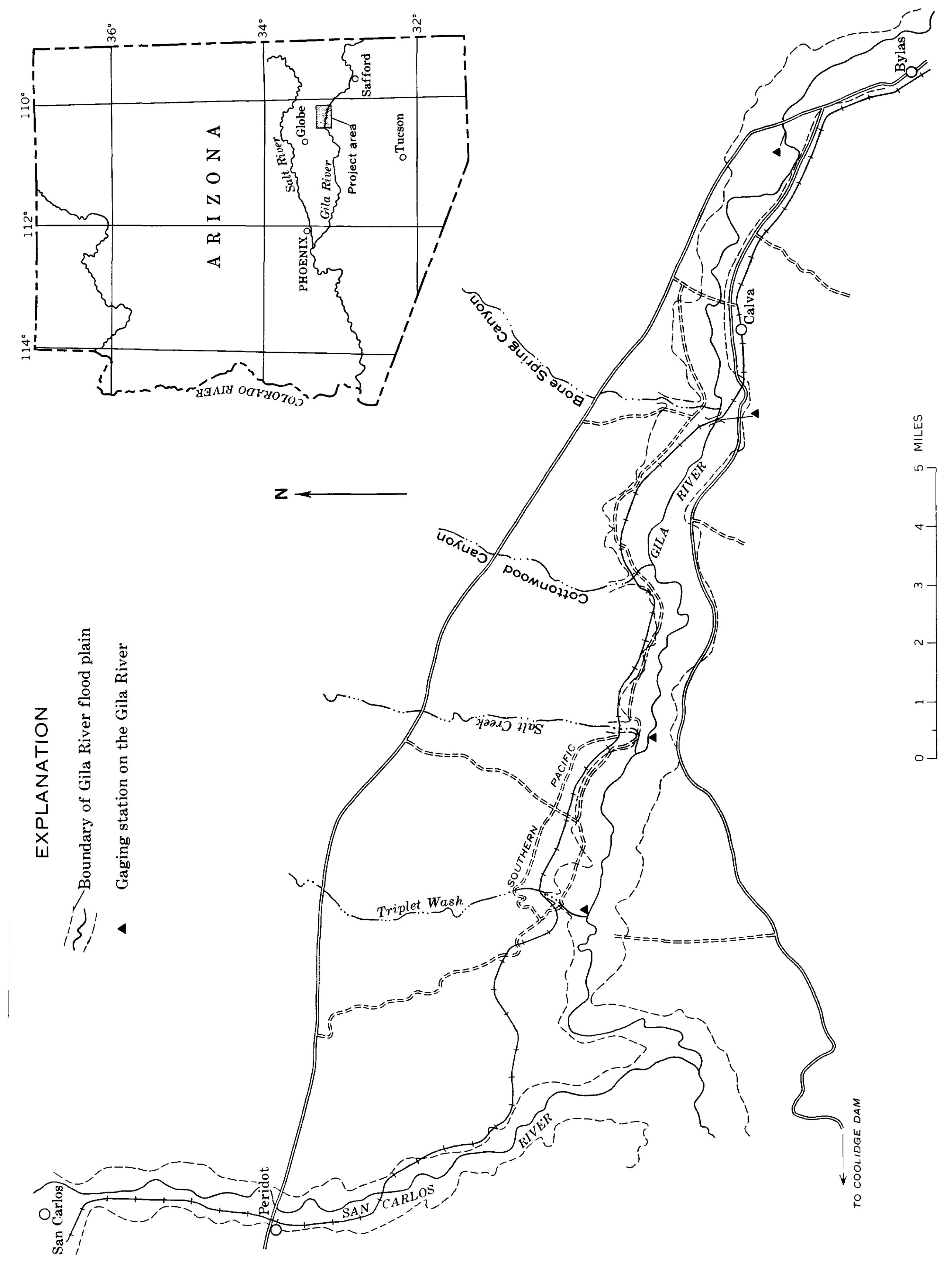

FIGURE 1.—Index map of project area and map showing instrumentation location.

The stilling well for the Gila River near Bylas gage (fig. 2) was established on the downstream side of the concrete bridge on U.S. Highway 70. There is some turbulence of flow past the stilling well, but its effect on the stage is small.

High-water measurements were made from the bridge from 1962 through the spring of 1964. However, because of large approach angles, turbulence, excessive scour around the piers, and uneven velocity distribution, the bridge site was not ideal for measurements of high flow. In the summer of 1964 a cableway that spans the main channel was installed 140 feet downstream. Flows in excess of the capacity of the main channel, about 4,000 cfs (cubic feet per second), are measured from the bridge, and low flows are measured in the channel near the gage. The measuring conditions for flow below bankfull stage are good.

The controlling section for flows ranging from 50 to 4,000 cfs is an old road crossing 150 feet downstream from the gaging station. The section of gravel, small rocks, and sandbanks stabilized by saltcedar is fairly stable. The low-water control is the shifting sandbars that form upstream from the old road crossing (fig. 2).

The gage at Calva was established in 1930. Prior to December 1962, the gage was equipped with a continuous analog recorder and was on the downstream side of the railroad bridge that spans the Gila River flood plain. In December 1962 the gage was moved to the left bank about 530 feet below the railroad bridge, and at that time a cableway spanning the main channel was constructed 400 feet downstream from the railroad bridge. Flows in excess of the capacity of the main channel, about 4,000 cfs, are measured from the railroad bridge, and measurements of low flows are made in the channel at several places near the gage. Measuring conditions for flow below bankfull stage are good.

The channel control of sand and gravel is unstable. There is a fairly stable gravel bar in the channel about 200 feet below the present gaging station that may act as a partial control during flows near bankfull stage. The vegetation along the banks also affects the stage-discharge relation at flows near bankfull stage or higher (fig. 3).

The stage-discharge relation is relatively unstable at all flows, although not excessively so when compared with ratings that are discontinuous (Dawdy, 1961). The major factor that contributes to the shifting of the stage-discharge relation is scouring and filling in the controlling reach of the river. Other less important factors are sediment in transport, which affects the fluid properties of the water, and seasonal vegetation changes, which cause a variable backwater condition.

In order to minimize errors caused by the shifting of the stage-discharge relation, the frequency of discharge measurements is geared to the movement of sediment, and the measurements are spaced so that shifts of rating through the total range of flow can be defined. A large amount of sediment is transported in the summer during the continual variation in flow rates. Generally, one measurement a week is made during winter flow, and two or more measurements a week are made during summer flow.

FIGURE 2.—View of the Gila River downstream from the Bylas gaging station. The old roadbed, which affects the stage-discharge relation, is about 50 feet downstream from the cableway. Photograph by C. S. English.

FIGURE 3.—View of the Gila River downstream toward the Calva gaging station. The gaging station, which is about 130 feet downstream from the cableway, is in the left center of the photograph. Photograph taken from the cableway by C. S. English.

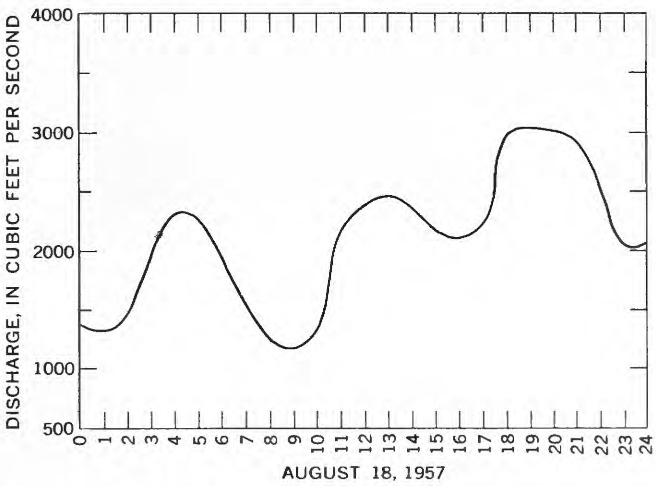

FIGURE 4.—Summer flow, August 18, 1957, Gila River at Calva.

FLOW CHARACTERISTICS

The flow in the Gila River originates from two types of storms—thunderstorms and frontal movements. Summer (July through October) streamflow is mainly from local thunderstorms. In the summer the rate of streamflow varies considerably in short periods of time (fig. 4), and the sediment concentration and the amount of floating debris are generally high (fig. 5).

Flow-duration curves for summer flow (fig. 6) show the frequency distribution of the daily mean flow for two periods, 1930–40 and 1951–61. These two periods represent "wet" and "dry" periods, respectively. The median flow—flow that is equaled or exceeded 50 percent of the time—was 45 cfs for the 1930–40 period but was only 5 cfs for the 1951–61 period. The frequency of occurrence of flow equaled or exceeded about 10 percent of the time was about the same for the two periods. The summer flow of Gila River at Calva ranged from a low of 2,530 acre-feet in 1960 to a high of 142,300 acre-feet in 1932, with an average of 50,340 acre-feet for the period 1930–61.

FIGURE 5.—Debris during rising limb of summer floodflow at Gila River near Calva gaging station, about 4 miles downstream from Gila River at Calva station. Photograph taken by J. S. Phelps about 20 minutes after the arrival of the flood.

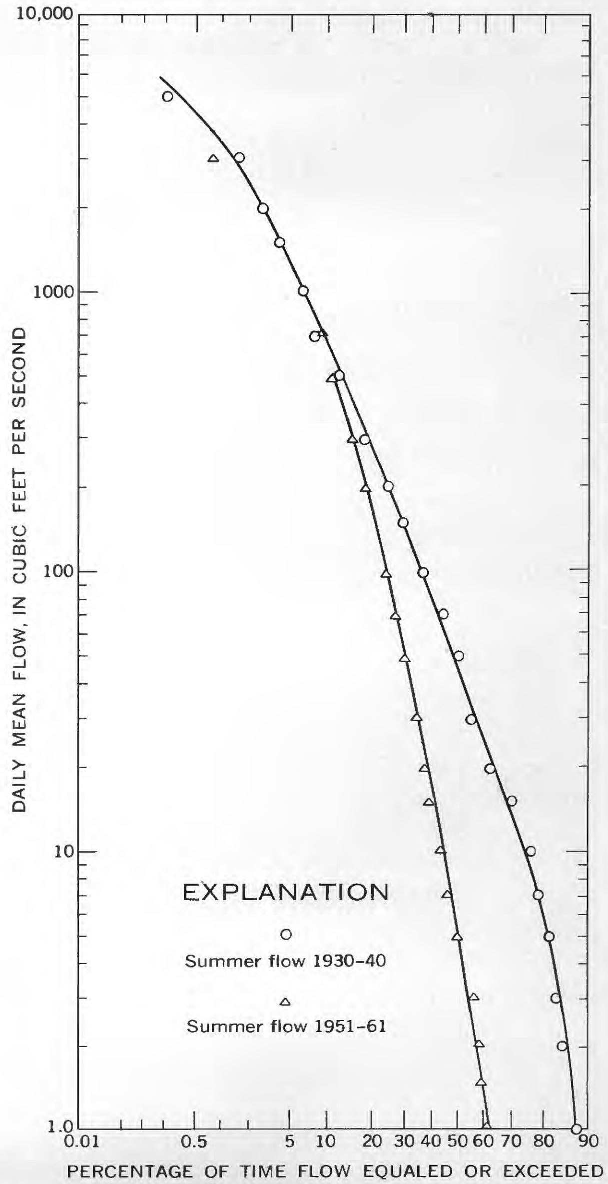

FIGURE 6.—Duration curves of summer flow, 1930–40 and 1951–61, Gila River at Calva.

The winter (November through June) flow is mainly from frontal storms, snowmelt, ground-water storage, or a combination of the three. The flow rate may be fairly constant for several days (fig. 7). The total winter flow of Gila River at Calva was 75 percent of the total

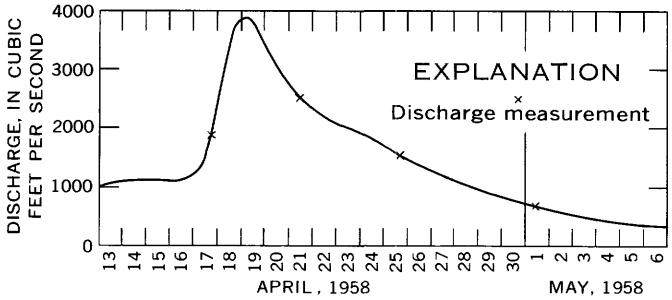

FIGURE 7.—Winter flow, April 13 through May 6, 1958, Gila River at Calva.

flow for the period 1930–61. From 1930 through 1961 the winter flow ranged from a low of 6,200 acre-feet in 1956 to a high of 737,900 acre-feet in 1941.

Flow-duration curves for winter flow (fig. 8) show the frequency distribution of the daily mean flow for two periods, 1930–40 and 1951–61. The customary steep slopes of the flow-duration curves for ephemeral streams are apparent. The median flow was 125 cfs for the 1930–40 period and 25 cfs for the 1951–61 period.

DISCUSSION OF ERRORS

Most errors in streamflow data are related to the definition of the stage-discharge relation; this paper is concerned mainly with these errors. Relatively smaller errors may result from the incorrect recording of stage and time. If a stable stage-discharge relation exists at a gaging site, a rating defined by a large number of current-meter measurements—assuming that the measurement errors have a mean of zero—would approach the true stage-discharge relation. Discharge computed by applying a correct stage record to the rating thus defined would have a small error. However, the rating conditions in most alluvial channels are not perfect or stable. Changes in the hydraulic resistance to flowing water may introduce large adjustments or shifts in the stage-discharge relation.

The general practice in computing discharge in a sand-channel stream is to determine a basic stage-discharge relation by using all available measurements at the gaging site. The shape of the basic rating curve is defined by the measurements and is the result of the hydraulic conditions at the section of the stream that controls the stage-discharge relation. Adjustments to the rating at the time of a given discharge measurement are determined by comparing the measured stage with that of the basic rating that corresponds to the measured discharge. The indicated shift of rating, in feet, at the time of measurement contains a correction of the basic rating to a true rating plus a possible measurement error. In terms of discharge in cubic feet per second the equation is:

$$Q_m - Q_b = R_m - R_b$$

in which

Q_m = measured discharge,
Q_b = base rating discharge for the measured stage,
R_m = difference between Q_m and true discharge Q_t, and
R_b = difference between Q_b and Q_t.

The shifts of rating between measurements are determined by correlating the indicated shifts of rating at the time of measurement with stage and (or) time. Con-

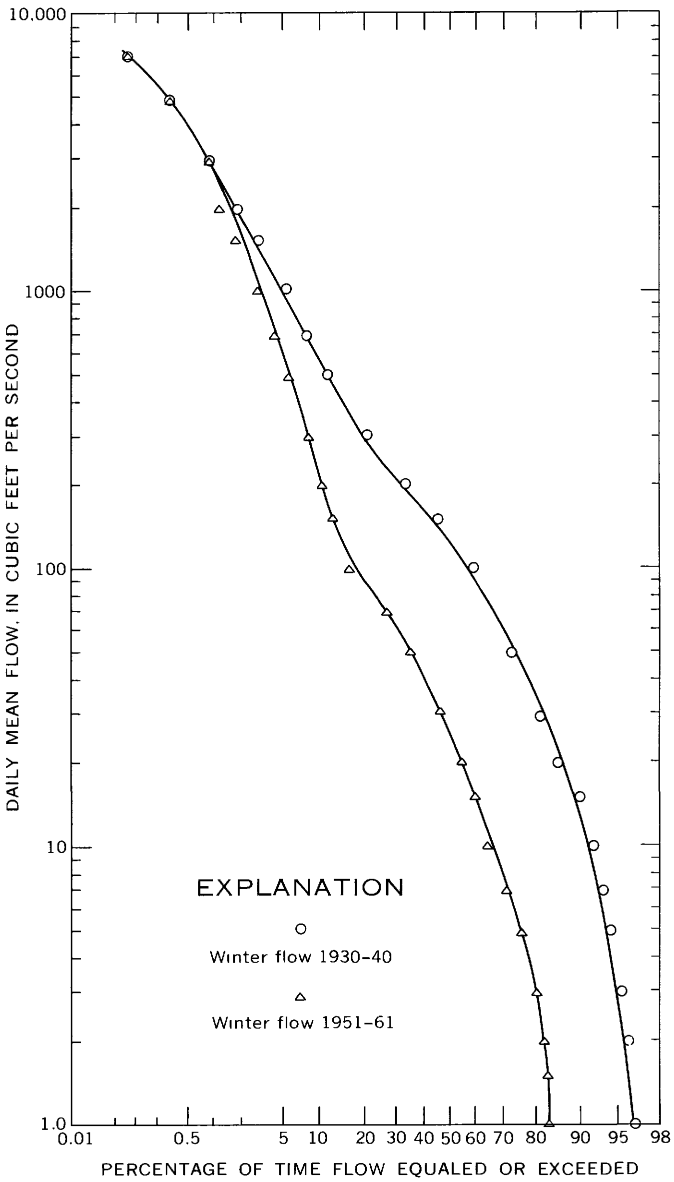

FIGURE 8.—Duration curves of winter flow, 1930–40 and 1951–61, Gila River at Calva.

siderable judgment is needed when applying the shifts in order that large errors are not introduced into the computation. How well the applied shifts represent the actual shifts in the computation of discharge in a sand-channel stream is unknown.

If a shifting-control method is used in a discharge computation in which each current-meter measurement is given full weight, the minimum possible standard error of computation (S_c) would equal the standard error of measurement (S_m). The minimum standard error of computation would be realized when there are an unlimited number of current-meter measurements. Because unlimited measurements are not available, the standard error of computation is greater than the standard error of measurement. The value of the standard error of computation is desired for all Gila River flow pertinent to the Gila River phreatophyte study.

APPROACH TO SOLUTION

The standard error of computation (S_c) for instantaneous[1] flow is determined by comparing computed discharge with measured discharge where the standard error (S_m) of the measured discharge is known. To accomplish this, a group of measurements is chosen, and the record of discharge is computed as if these were the only measurements available. All measurements not included in the group chosen are used as a control group. A progressively larger number of the total measurements available at the two Gila River gaging stations was used in the rating analysis, and variances were computed for the difference between the measured discharge for the control group and the discharge computed for the time of the measurements. The assumption was made that the errors in the measurements (R_m) not used in the rating analysis are independent of the computational errors (R_c). The variance of the difference between computed discharge and measured discharge (S^2_{m-c}) includes the variance of the difference between measured discharge and true discharge.

The variance of the difference between measured and computed instantaneous discharge may be estimated as follows:

$$S^2_{m-c}=\frac{\sum[(Q_t+R_m)-(Q_t+R_c)]^2}{N}=\frac{\sum(R_m-R_c)^2}{N}$$

in which N is the number of measurements in the control group, R_c is the difference between computed and true discharge, and R_m and Q_t are as previously defined. The expected value is:

$$E[S^2_{m-c}]=\sigma^2_m+\sigma^2_c=\sigma^2_{m-c}$$

[1] Instantaneous flow is not entirely correct because the standard error is determined for average discharge through the time of measurement.

if the measurement errors in the control group are independent of the computation errors. Therefore, $\sigma^2_c=\sigma^2_{m-c}-\sigma^2_m$ where σ^2 denotes a "true" or population variance as opposed to S^2, which is estimated on the basis of the data. The computational error, which includes a measurement error plus an error in applying rating shifts, is based on measurements. However, the errors are independent because S^2_{m-c} is defined only for the time of the measurements in the control group.

The standard error (S_m) of the measured discharge can be obtained from Carter and Anderson (1963, fig. 1). The average number of verticals—the term "vertical" is the same as the Carter and Anderson "station"—for the discharge measurements in this study was 22, and a six-tenths-depth method was used in most of the measurements. Therefore, the standard error of measurement (S_m) is about 4 percent (Carter and Anderson, 1963, fig. 1). Using this value with the S^2_{m-c} determined from the control group, the error of rating analysis (S_c) may be obtained.

ANALYSIS OF DATA

The same analytical procedure was used to determine S_c for the data of both stations. Analyses for the determination of S_c were made using 1/4, 1/2, and 3/4 of the total measurements in the rating studies. The set of data are overlapping, and, therefore, the results are not entirely independent. No corrections for this lack of independence are included in the analyses. The measurements were arranged in groups of four by time. From each group one measurement was selected randomly and used in a rating analysis. The remaining measurements were retained as a control group. After the basic stage-discharge relation was developed and shifts were computed from the measurements used in the rating analysis, discharge was computed corresponding to the stage and time of the measurements in the control group. The discharges, computed and measured, were then grouped into summer and winter flows. The groups were separated further into three ranges: 10–100 cfs; 100–1,000 cfs; and 1,000 cfs or more. The mean square difference between the logarithms of the computed and measured discharges was determined for each range of flow. Similar analyses were made for the studies in which 1/2 and 3/4 of the total measurements were used in the rating analysis. Because analyses were made using logarithms of discharges, the standard errors of estimates can be stated as percentages.

In this study 144 discharge measurements from the Bylas record and 164 discharge measurements from the Calva record were used. The measurements were made during the 1963 and 1964 water years. They included 83 measurements made during summer flow near

Bylas and 89 measurements made during summer flow at Calva. The results of the analysis are shown in tables 1 and 2.

ERRORS IN INSTANTANEOUS DISCHARGE

The relation of the average time between measurements to percent error in the instantaneous discharge for the different ranges in flow is shown in figures 9 and 10. The trend lines drawn through the points and extended to a minimum value of 4 percent illustrate the improvement in determining shifts with decrease of time between measurements. Only a relatively few measurements were available for summer flows in the range from 1,000 to 4,000 cfs. Therefore, the curves in the 1,000 to 4,000 cfs range of flow were drawn giving about equal weight to the plotted points.

The standard error in percentage for instantaneous summer flow is not the same for the three ranges of flow. The relation of discharge to percentage error for the different number of measurements in the rating analysis is shown in figures 11 and 12. The discharges used in the plot are the average of the measured discharges in the different ranges of study.

TABLE 1.—*Error analysis of streamflow, Gila River near Bylas, Ariz.*

Fraction of measurements used in stage-discharge rating analysis	Number of measurements in control group	Standard error in percent of instantaneous discharge		Class (cfs)	Season
		Plus	Minus		
One-fourth	23	26.6	21.0	10–100	Summer.
	25	16.2	14.0	100–1,000	Do.
	11	8.0	7.4	1,000–up	Do.
	24	20.7	17.3	10–100	Winter.
	12	7.3	6.8	100–1,000	Do.
One-half	16	19.4	16.3	10–100	Summer.
	16	13.0	11.5	100–1,000	Do.
	7	8.6	7.8	1,000–up	Do.
	14	8.2	7.5	10–100	Winter.
	10	5.7	5.3	100–1,000	Do.
Three-fourths.	7	14.5	12.7	10–100	Summer.
	11	9.7	9.0	100–1,000	Do.

TABLE 2.—*Error analysis of streamflow, Gila River at Calva, Ariz.*

Fraction of measurements used in stage-discharge rating analysis	Number of measurements in control group	Standard error in percent of instantaneous discharge		Class (cfs)	Season
		Plus	Minus		
One-fourth	27	22.2	18.2	10–100	Summer.
	31	14.7	12.9	100–1,000	Do.
	6	11.3	10.2	1,000–up	Do.
	38	26.8	21.2	10–100	Winter.
	18	7.8	7.2	100–1,000	Do.
One-half	14	9.0	8.3	10–100	Summer.
	22	7.3	6.8	100–1,000	Do.
	5	9.3	8.7	1,000–up	Do.
	16	11.6	10.4	10–100	Winter.
	14	9.3	8.4	100–1,000	Do.
Three-fourths.	8	5.9	5.6	10–100	Summer.
	13	6.4	6.0	100–1,000	Do.

Extrapolating the relations to obtain a result by using all measurements—average time between measurements is 3.1 days—for the rating analysis, the relation for the Bylas gage suggests that there is a standard error of about 12 percent for the instantaneous summer flows ranging from 40 to 100 cfs and a standard error of about 8.5 percent for flows from 100 to 1,000 cfs. Although it is not defined, the standard error is probably about 5 percent for instantaneous summer flows ranging from 1,000 to 4,000 cfs (figs. 9 and 10). The standard error of computation for summer flow at Calva is about 5 percent for flows from 40 to 100 cfs and about 6 percent for flows from 100 to 1,000 cfs. Although it is not defined, the standard error is probably 7 percent for flows from 1,000 to 4,000 cfs. At Calva the relation of discharge to standard error of computation suggests an error of about 5 percent for winter flows from 40 to 1,000 cfs (figs. 13 and 14). The standard error for the Bylas winter data is perhaps 1 percent better than that at Calva.

The relation of discharge to percentage error for instantaneous summer flows suggests better accuracy for the low-flow data near Calva than for the data at Bylas (figs. 9–12). The reason for this apparent difference in accuracy is not known, but it probably is the result of the effect of the old roadbed about 150 feet downstream from the Bylas gage.

The sediment moves through the channel at Calva without being affected by artificial conditions. The changes in resistance to flow as a result of scour or fill, changes in bed configuration, or vegetation growing in the channel generally vary directly with discharge and velocity or change slowly with time. By the use of the measurements and good judgment, the changes in resistance are properly reflected in the discharge computation. However, the artificial control (roadbed) at Bylas has introduced a changing resistance to flow that cannot be identified correctly by use of the available measurements. The shifting sandbar that forms behind the old roadbed and gradually moves downstream presents an unpredictable changing condition that is reflected in the computed discharge data. The sandbars may affect the velocity of approach to the control and result in a change in discharge for a given stage. The shifting sandbar may result in bed configurations that cause variable resistance to flow.

The indicated better accuracy of the data at Bylas over the data at Calva for flows in the 1,000 to 4,000 cfs range is probably the direct result of the stable condi-

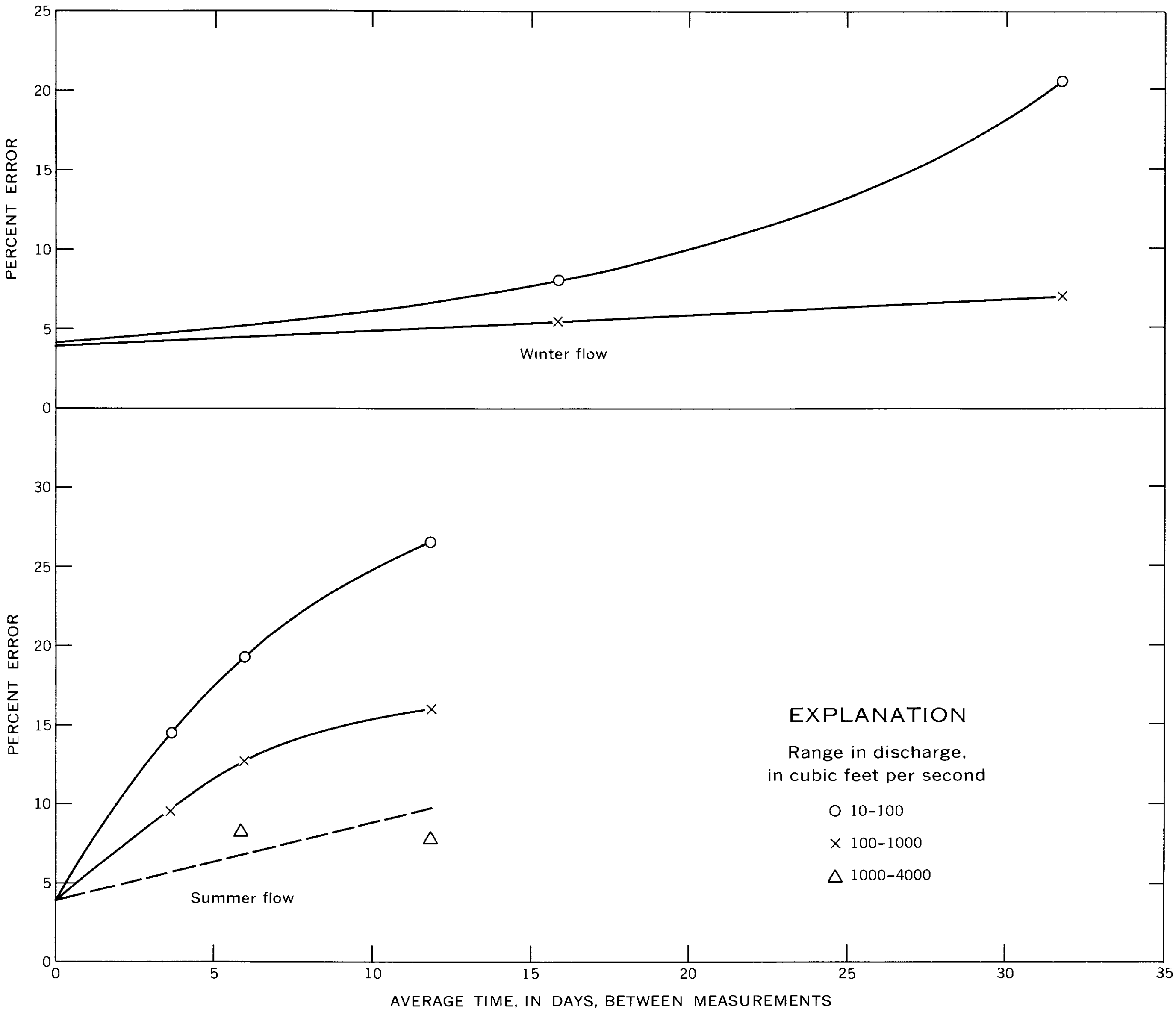

FIGURE 9.—Standard error of computed discharge for different ranges of discharge, Gila River near Bylas.

tion at the road crossing below the Bylas gage. Scour and fill affect the high-flow rating more at Calva than at Bylas.

There is very little, if any, difference in the accuracy of data of instantaneous discharge at the two stations for winter flows ranging from 10 to 100 cfs. The amount of sediment in winter flows ranging from 10 to 100 cfs is small.

ERRORS IN VOLUMES OF DISCHARGE

The standard error of computation in average flows or volumes, because of compensating effects, is less than the standard error in instantaneous discharge. The standard error of computation in the volume of discharge should decrease inversely with the square root of the number of independent observations of error. The rate of increase with time in the number of independent observations of error in the discharge data must be determined.

As previously discussed, the indicated shift or discharge difference at time of measurements is equal to $R_m - R_b$, and the variance S^2_c is equal to the sum $(S^2_s) + (S^2_m)$. The error in the measurements (R_m) is assumed to be random with a mean of zero. The R_m then will be compensating with time.

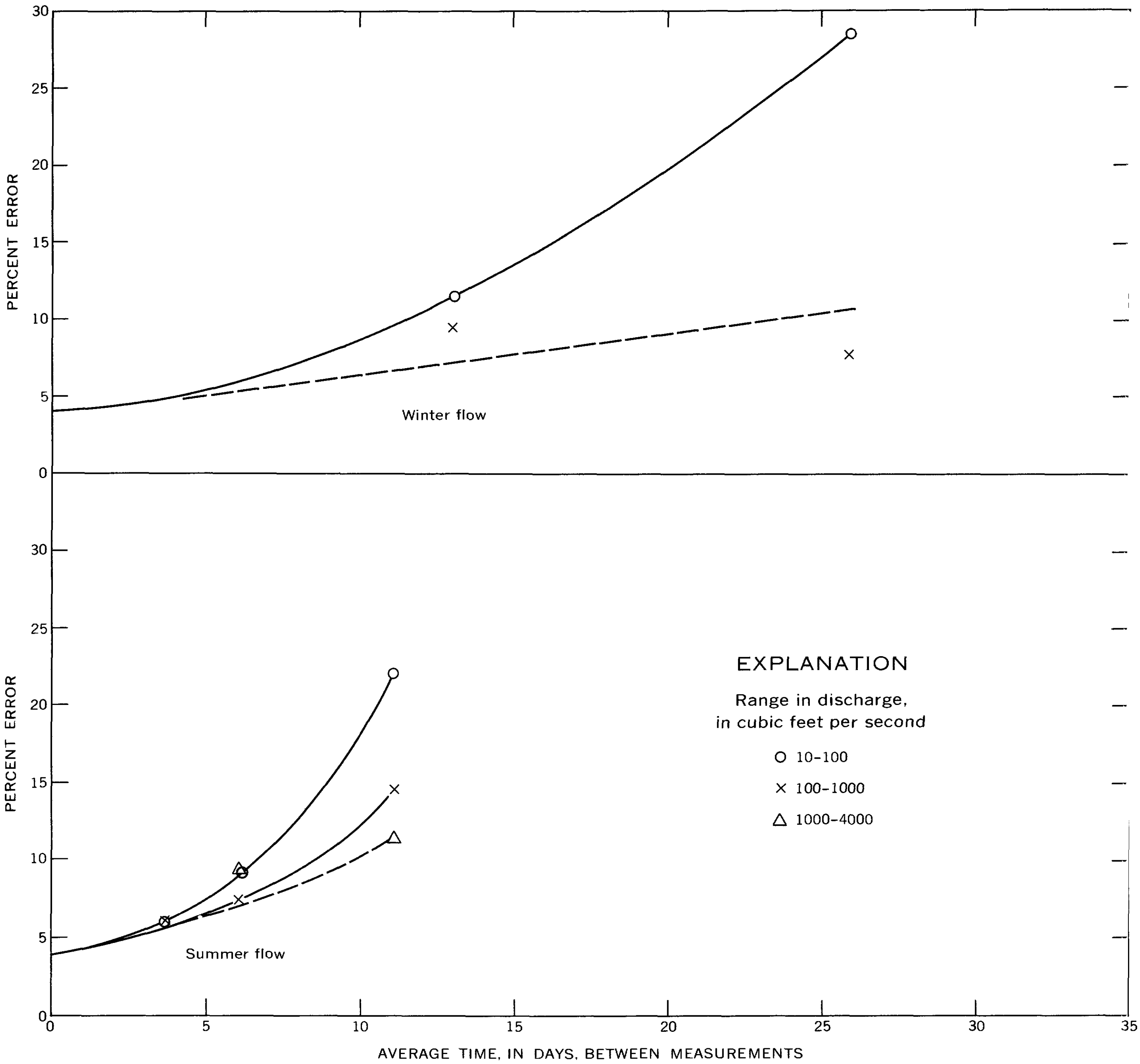

FIGURE 10.—Standard error of computed discharge for different ranges of discharge, Gila River at Calva.

Considerable personal judgment goes into the application of the shift corrections between measurements. The errors involved as the result of personal judgment probably compensate somewhat from measurement to measurement because judgment is independently adjusted to each measurement.

There may be periods when large flows are from one flood wave during which the shifts are not defined by measurements. The error in the data, as a result of personal judgment, may be all in one direction for a given storm. The errors in the data for another storm may be in the opposite direction. Therefore, in this report the computational error (R_c) is assumed to be random with a mean of zero. The number of independent observations of R_c then would equal the number of discharge measurements made during the period.

The standard error in the surface-flow data would be:

$$S_d = \sqrt{\frac{S_c^2}{N_1}}$$

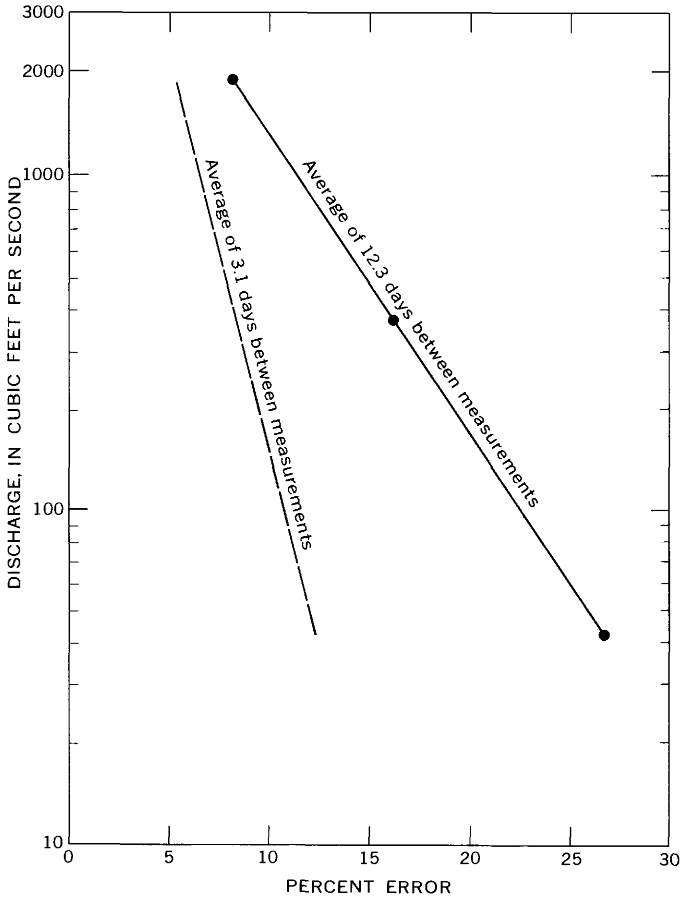

FIGURE 11.—Standard error of computed discharge for summer flow, Gila River near Bylas.

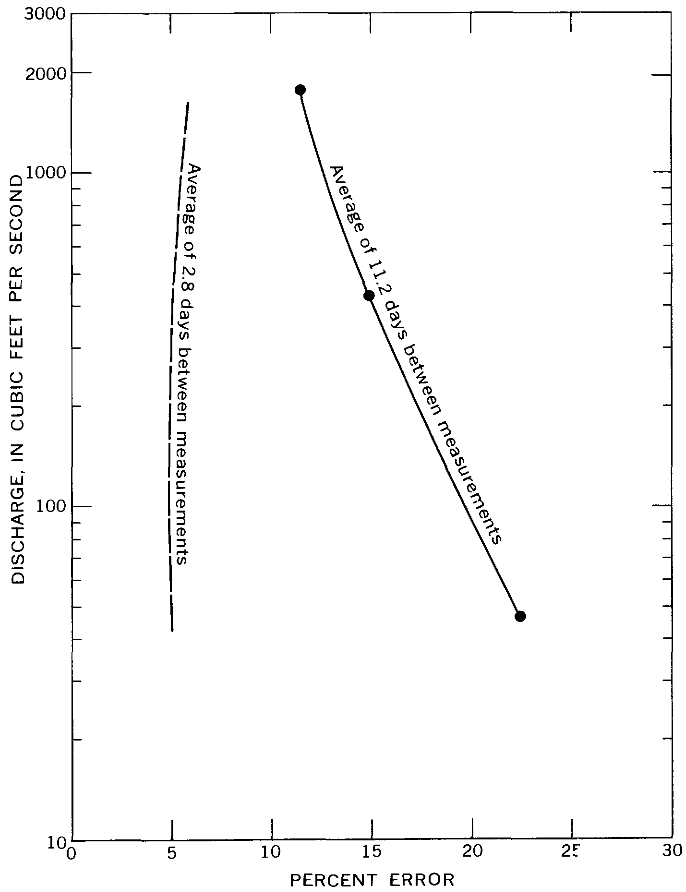

FIGURE 12.—Standard error of computed discharge for summer flow, Gila River at Calva.

where N_1 is the number of independent measurements in the period of interest and S_c is the standard error in the instantaneous discharge. Although it is not done in this report, standard errors for any length of record for the different ranges of flow can be determined.

ERRORS IN WATER BUDGET

The volume of flow for 3-week periods at the downstream end of subreach 1—Gila River near Bylas to Gila River at Calva (fig. 1)—will be subtracted from that at the upper end to give the net surface-water component for the water budget in the study reach. Assuming that the errors at the two stations are independent, the error of the difference equals the square root of the sum of the squared standard errors of computation in flow data for the two stations. Thus, the standard error of computation for the difference in flows would be

$$S_{c_{1-2}}=\sqrt{(S^2{}_{c_1})+(S^2{}_{c_2})},$$

which can be evaluated for instantaneous flow from the relations of figures 9 through 14 for any given frequency of measurement within the range studied.

The standard error in the surface-flow budget data would be:

$$S_{d_{1-2}}=\sqrt{\frac{(S_{c_1})^2}{N_1}+\frac{(S_{c_2})^2}{N_2}}$$

where N_1 and N_2 equal the number of measurements in the period at the upstream and downstream stations, respectively. In order for the foregoing equations to apply, the errors must be in compatible units and must be about normally distributed. This most nearly applies to discharge measurements if errors are in terms of logarithmic units rather than in natural units such as cubic feet per second or acre-feet per day. For the relatively small errors usually observed in stream gaging, percentage errors may be substituted for errors in natural units. For ease in presentation, percentage errors have been used throughout this report. If the standard error in percentage is used in the equation, the resulting evaluation is the error in the difference in flow at the

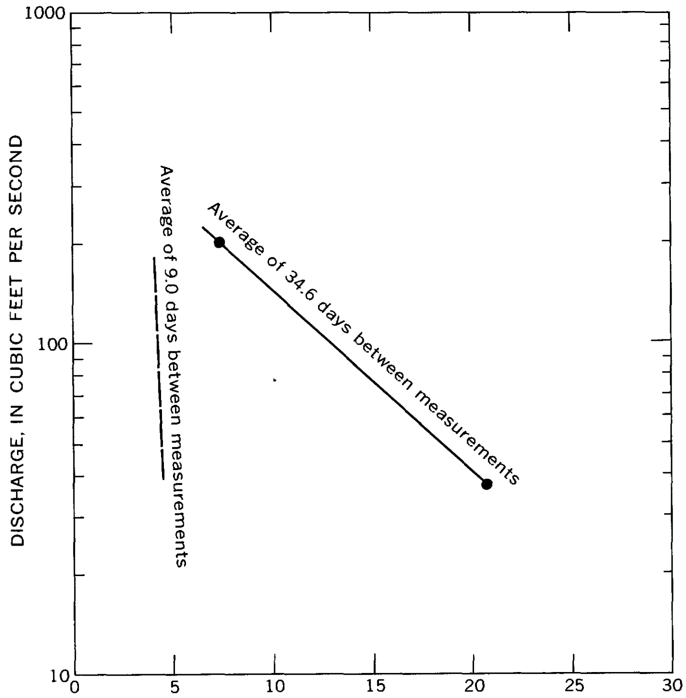

Figure 13.—Standard error of computed discharge for winter flow, Gila River near Bylas.

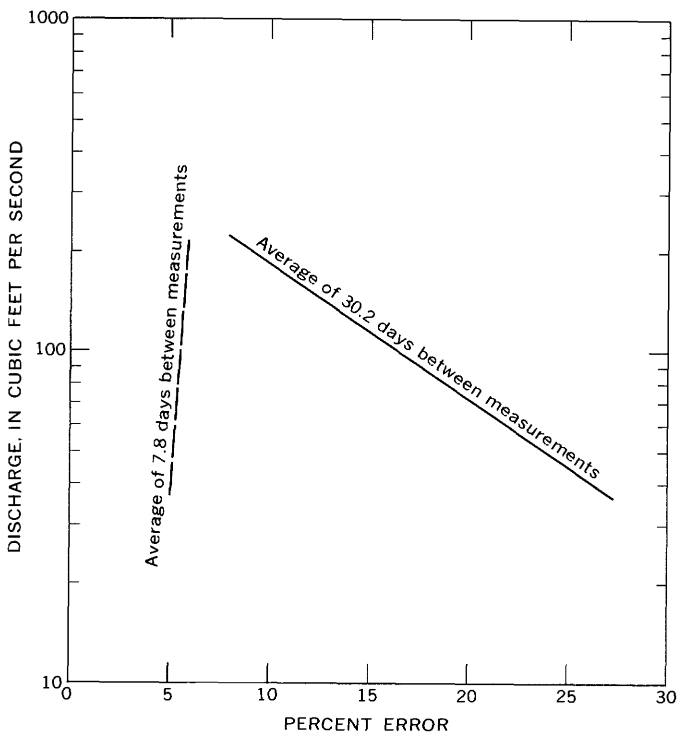

Figure 14.—Standard error of computed discharge for winter flow, Gila River at Calva.

two sites expressed as a percentage of an average discharge and must be converted to natural units for use in a budget. The standard error thus computed is not entirely correct for budget periods in which there are losses or gains in streamflow. If the difference in flow between the two gaging sites becomes large relative to the average flow in the reach, then the standard error of estimate must be derived using natural units. For relatively small differences in flow at the two sites, the standard error computed by the two methods is about the same. For instance, when $N_1 = N_2 = 8$, the standard error is given in table 3.

Table 3.—*Standard error of estimate*

Gage	Average discharge (cfs)	Standard error in instantaneous flows		Standard error in 3-week period	
				$S_{c_1}=8.4$ cfs $S_{c_2}=3.0$ cfs	$S_{c_1}=12$ percent $S_{c_2}=5$ percent
		Percent	Cfs	Cfs	Cfs
Bylas	70	12	8.4	-----	-----
Calva	60	5	3.0	[1] 3.15	[1] 3.0

[1] From the equation $S_{d_{1-2}}=\sqrt{\frac{(S_{c_1})^2}{N_1}+\frac{(S_{c_2})^2}{N_2}}$.

The average daily loss in surface flow in reach 1 for the period of record through water year 1965 is about 11 cfs (discharge of Gila River near Bylas plus tributary flow minus Gila flow at Calva). The average daily loss in surface flow in reach 1 during the water years 1963 through 1965 ranged from zero at flows below 20 cfs in the winter to a high of about 500 cfs at bankfull flows of about 4,000 cfs in the summer.

In this report the standard error for the 3-week budget data was computed using standard errors in percent from the relations of figures 11 through 14 in the equation:

$$S_d=\sqrt{\frac{(S_{c_1})^2}{N_1}+\frac{(S_{c_2})^2}{N_2}}$$

An average of eight measurements in the summer and an average of three measurements in the winter were made at each station per budget period. The standard errors in the 3-week budget data for summer and winter flows are shown in figure 15.

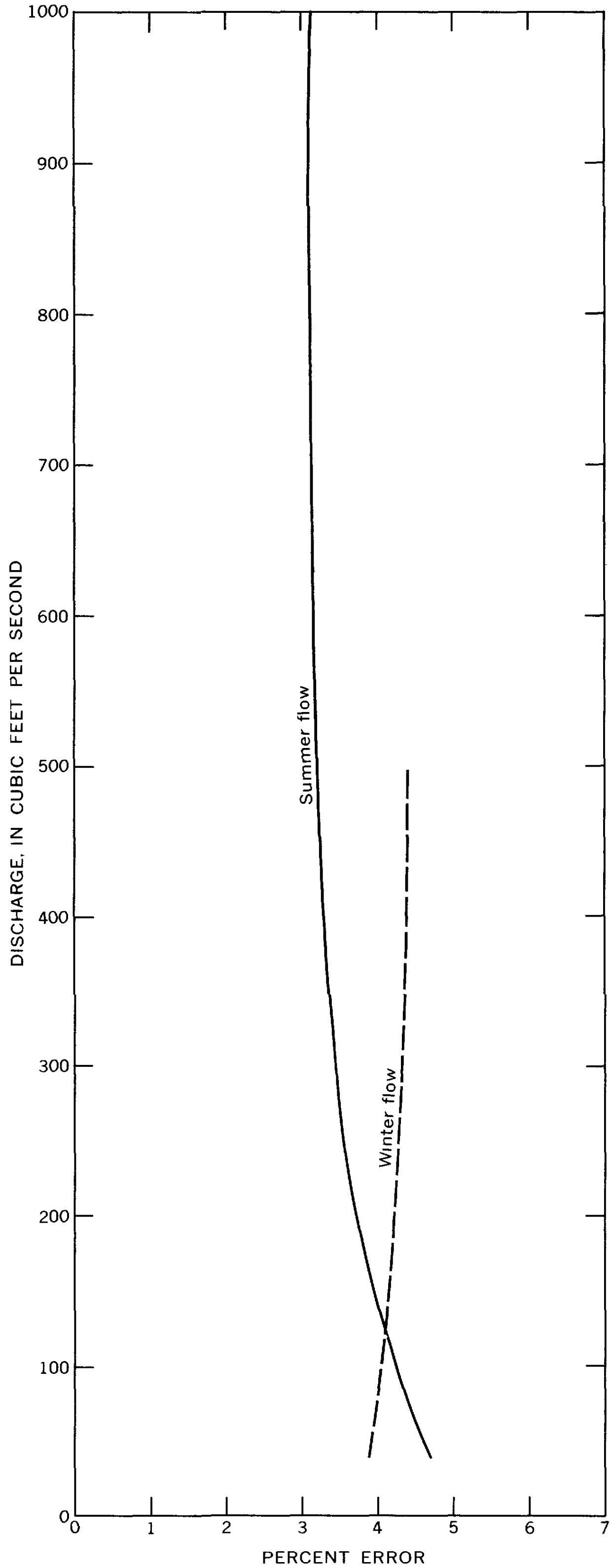

FIGURE 15.—Standard error in percentage of average discharge in 3-week streamflow data for subreach 1, Gila River near Bylas to Gila River at Calva.

SUMMARY

Discharge measurements made in 1963 and 19?4 were used to determine the standard error in the computed discharge for two stations—Gila River near Bylas and Gila River at Calva. The standard errors of computation for instantaneous discharge and for the difference in volume flow for the two stations for a 3-week period are approximated. The standard errors in the difference in volume flows were desired for water-budget studies.

The channel at the gaging stations is primarily a pool-and-riffle type, and the banks are stabilized by the dense growth of saltcedar. Sediment movement during summer flow is high.

The standard errors of computation were determined by using some of the discharge measurements in the rating analysis and the remainder as a control group. Discharge was computed corresponding to the stage and time of the discharge measurements in the control group. The assumptions were made that the measurement errors in the discharge measurements in the control group were independent of the measurement errors in the computed discharge and that they had a mean of zero.

The mean square difference (S^2_{m-c}) between computed and measured discharge was determined for different ranges in instantaneous flow. The mean square difference (S^2_{m-c}) is the sum of the variance (S^2_m) of the difference of measured discharge from true discharge plus the variance (S^2_c) of the difference of computed discharge from true discharge. The desired variance (S^2_c) was obtained by subtracting the measured variance (S^2_m) from the total variance (S^2_{m-c}).

The results of the analyses suggest a standard error of computation for instantaneous summer flow at the Calva station of about 5 percent for flows ranging from 40 to 500 cfs. The standard error of computation increases to about 6 percent for instantaneous flows ranging from 500 to 2,000 cfs. The standard error of computation for instantaneous summer flow at the Bylas station is from about 14.5 to 7.5 percent in flows ranging from 40 to 500 cfs. The standard error of computation for instantaneous summer flow at Bylas is about 7.0 percent for flows ranging from 500 to 2,000 cfs. The apparent difference in accuracy of data for the two stations for flows in the 40 to 500 cfs range is accredited to an old roadbed about 150 feet downstream from the Bylas gage. The sediment moves through the controlling reach at the Calva station without being affected by artificial conditions. The changes in the resistance of flow are reflected properly in the discharge computation. However, the artificial control (roadbed) at Bylas has introduced a changing resistance to flow that cannot be predicted accurately by use of the available measurements.

The standard error of computation for instantaneous winter flows ranging from 30 to 220 cfs was about 5 percent at both stations.

The difference in volume flow at the two stations contains the square root of the sum of the squared errors in flow data at the stations if errors at the stations are independent. The standard error of computation for instantaneous discharge is adjusted to a 3-week period by assuming that the number of independent observations during a period is equal to the number of discharge measurements made during the period. The standard error of computation for summer flow in a 3-week budget period is from about 5 to 3 percent of the average flow in the channel for flows ranging from about 30 to 1,000 cfs. The standard error of computation for winter flow in the 3-week period is from about 3.8 to 4.4 percent of the average flow for flows ranging from 30 to 500 cfs.

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