UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY ANALYSIS OF ARIZONA STREAMFLOW-DATA NETWORK FOR REGIONAL INFORMATION

Open-File Report 81-920

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Tucson, Arizona
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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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ABSTRACT

An evaluation of the Arizona streamflow-gaging network was made to determine if the network efficiently produces information that can be transferred to ungaged sites. Arizona is divided into five numbered flood-frequency regions and a high-elevation flood-frequency region. Streamflow characteristics evaluated by regression analyses for the regions were annual mean discharge, standard deviation of the annual mean discharge, mean 1-day high flow, mean 7-day low flow, and 50-year peak discharge. Regression results are given for regions 1, 3, and 5 and for the high-elevation region. Data were sufficient for regression analyses of only 50-year peak-discharge characteristics for regions 2 and 4. The regression analyses did not produce useful information for mean 7-day low flows except for the high-elevation region. A statistical technique known as Network Analysis for Regional Information (NARI) was applied to data for the high-elevation region but was not used for the other five regions because the coefficient of variation was not constant.

INTRODUCTION

Effective water-resource planning requires regional streamflow information, which includes the transfer of information from gaged sites to ungaged sites. Stream gages are operated for one or more of the following reasons: (1) to provide data for current use, (2) to determine long-term trends, (3) to provide data for research and special studies, and (4) to provide data for regional information about streamflow characteristics. This report is an evaluation of the Arizona streamflow-gaging network to determine if the network produces information that can be transferred to ungaged sites. The report is not an evaluation of the network for purposes other than regional information; therefore, the information given in the report is only a partial analysis of the network.

Roeske (1978) divided Arizona into six flood-frequency regions; the same regions and gaging stations were used in this study. The potential use of other regions was not evaluated in this study. Regions 1 through 5 are each of a single area, but the high-elevation (HE) region includes several noncontiguous areas (fig. 1). The report includes a brief description of the hydrology and the gaging-station network in

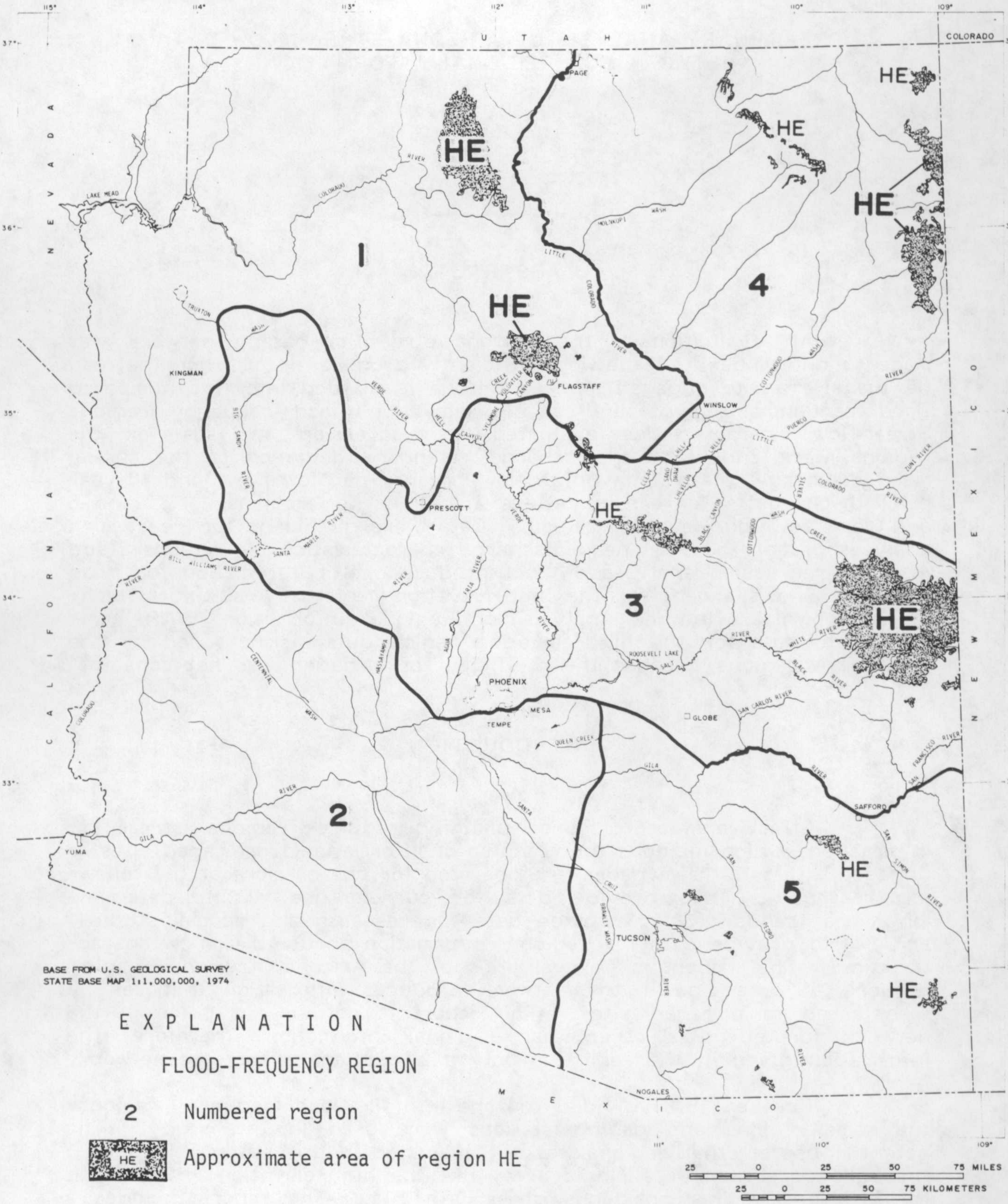


Figure 1.--Flood-frequency regions.

Arizona, a discussion of the gaging-station network in each region, results of regression analyses for selected streamflow characteristics, and a statistical evaluation of the gaging strategy in region HE. The study was made by the U.S. Geological Survey in cooperation with the Arizona Department of Water Resources—formerly the Arizona Water Commission.

SURFACE-WATER HYDROLOGY

Streamflow Characteristics

Obtaining regional information for Arizona streams is difficult and complex because of the highly variable streamflow characteristics. Although some streams are perennial, many streams are dry most of the year and flow only in response to precipitation and snowmelt. Most streams lose large quantities of water to infiltration.

Streamflow characteristics in small basins are more variable than those in large basins. For small basins, runoff can be highly variable from one area to another and from year to year. In large basins, the runoff tends toward the mean runoff of several of its smaller contributing basins.

Many gaged streams have some regulation—diversion or storage—upstream from the gaged site. The regulation has varying effects on streamflow characteristics, and the characteristics that are significantly affected by regulation are difficult to identify. An example is regulation for irrigation. During wet years, irrigation demands may have little or no effect on streamflow characteristics; however, during dry years, greater irrigation demands and reduced streamflow could combine to produce significant changes in streamflow characteristics.

Gaging-Station Network

An evaluation of a gaging-station network for regional information should determine if the network satisfies current data needs and if it will satisfy the data needs of the future. The evaluation is subjective, but being aware of past gaging practices and some of the problems observed in this study will help to develop gaging strategies that will better satisfy data needs.

The network consists of two categories of streamflow-gaging stations—continuous-record stations and crest-stage partial-record stations. At the continuous-record stations, the daily mean discharge, the peak discharge for the year, and other streamflow characteristics are determined. At the crest-stage partial-record stations, the peak discharge for the year is determined. Peak-discharge records are determined from both categories.

Streamflow characteristics are less reliable for small basins because the gages generally have short periods of record. Continuous-record gages were established first on streams that drain large areas and more recently on streams that drain small areas. Most peak-flow gages in Arizona were in operation during 1963-75 on the streams in small basins. Many gaging stations were established during that period because of then-current data needs. As a result, gaging stations are concentrated in areas in which water-resources development has already taken place, mainly central Arizona (region 3). Thus, in areas where areal coverage by the gaging network is limited, the gaged streams may not satisfactorily represent the streams in the area. Another tendency inherent in the network has been to gage perennial streams rather than streams that are commonly dry. When a gaging-station site is proposed for one of two basins that have similar physiographic characteristics, the basin that has the higher base flow or the greatest known flood tends to be the one in which the gage is installed. Because water managers want to know how much water is available, dry sites are of less interest. The resultant underrepresentation of dry sites in the network may bias regional information; the potential bias was not evaluated in this study.

Computation Errors

Computation errors in streamflow data occur partly because streamflow in Arizona is highly variable; periods of flow in many streams are of short duration, and the annual flow may pass a gaged site in a few short periods. Many channels are unstable, and high flows can significantly change the hydraulic properties of a stream. An accurate determination of the relation between water elevation and discharge at a gaged site can be difficult because of the limited opportunity for obtaining current-meter discharge measurements and because of unstable channel conditions.

METHODS OF ANALYSIS

Streamflow Characteristics

The streamflow characteristics evaluated for this study were annual mean discharge, standard deviation of the annual mean discharge, mean 1-day high flow, mean 7-day low flow, and 50-year peak discharge. The discharge values for the 50-year flood are those used by Roeske (1978), and values for the other characteristics are those used by Anderson and White (1979). Although any streamflow characteristics could have been evaluated, these variables were considered to represent the main types of streamflow information needed.

The annual mean and the standard deviation of the annual mean discharge were analyzed because they are measures of the availability of water and the variation in availability that can be expected. Mean 1-day high flow was selected as a measure of flood volume. Although longer duration high-flow data are available, most floodflows are from short-duration rainstorms except in the high-elevation region and large rivers. Mean 7-day low flow was selected as a measure of the low-flow characteristics of a stream. Low-flow data are needed to evaluate water-supply and water-quality problems. The 50-year peak discharge was selected as a measure of the overall flood potential. Except for the 50-year flood, the streamflow characteristics analyzed are determined from continuous-record data. The 50-year flood analysis required peak-flow data, which are collected at continuous-record and crest-stage partial-record stations.

Regression Analyses

A common method of information transfer is the logarithmic regression analysis in the form

$$\log X = \log b_0 + b_1 \log Y_1 + b_2 \log Y_2 + \ . \ . \ . \ b_k \log Y_k ,$$

where

X=statistical estimate of a streamflow characteristic, such as annual mean discharge or T-year (recurrence interval) peak discharge;

$b_0, b_1, b_2, \ . \ . \ . \ , b_k$=constants defined by regression analysis; and

$Y_1, Y_2, \ . \ . \ . \ , Y_k$=physiographic characteristics of the basin.

A complete description of logarithmic regression analysis of streamflow information for Arizona was given by Moosburner (1970). As more streamflow data are collected—both years of record and number of gaging stations—the regression equation becomes a better predictor of streamflow characteristics. A measure of the predictive accuracy of the regression equation is the standard error of estimate.

Network Analysis for Regional Information

The Network Analysis for Regional Information, or NARI (Moss and Karlinger, 1974), can be used to evaluate the potential reduction in the standard error of estimate of the regression analysis. NARI evaluates the contributions to the uncertainty in regional regression owing to sampling problems in time and space, use of incomplete models, and variations inherent in the streamflow characteristics at specific sites. NARI estimates the potential improvement of regression results that would be expected by adding data from more sites, by increasing the length of record at existing sites, or by improving the regression model.

From observations of a streamflow characteristic at the number, NB, of gages used in the regression, NARI computes (1) NY, the harmonic mean record length, (2) CV, the coefficient of variation of the data at each site, and (3) ρc, the correlation of the data between sites. CV and ρc are assumed to be constant throughout a region but are known only with a limited degree of accuracy; their values are estimated by probability distributions. CV and ρc were estimated for annual mean discharge, 1-day high flow, and 7-day low flow from data collected through September 30, 1975. Data through September 30, 1977, were used for the floods, and the large floods in 1978 and 1979 may alter the conclusions contained in this report. The final phase of NARI incorporates λ, which is the standard error of the regression equation, with NB, NY, and the estimates of CV and ρc to estimate the standard error of regression based on data from many combinations of number of gages, length of record, and model used.

Regions 1, 3, and 5 and the HE region were evaluated by the NARI technique, but CV was not constant for all regions except HE. A discussion of the possible reasons is included in the section entitled "Results of Analyses." Insufficient data prevented the use of NARI in regions 2 and 4.

RESULTS OF ANALYSES

Regression equations for selected streamflow characteristics and the corresponding standard errors of estimate are given in table 1. The equations are estimates of the selected streamflow characteristics.

A transition zone between the HE flood-frequency region and the numbered flood-frequency regions is defined for sites where the mean basin elevation is between 7,300 and 7,500 ft. In the transition zone discharge should be computed using the equation for the numbered region in which the site is located and the equation for the HE region. The characteristics for the entire basin should be used in both computations, and then a weighted discharge should be computed on the basis of the mean basin elevation as

$$Q_{S(W)} = Q_{S(R)} \frac{7{,}500-\bar{E}}{200} + Q_{S(HE)} \frac{\bar{E}-7{,}300}{200},$$

where

$Q_{S(W)}$=weighted discharge, in cubic feet per second, for the selected streamflow characteristic;

$Q_{S(R)}$=discharge, in cubic feet per second, from numbered region equation for the selected streamflow characteristic;

$Q_{S(HE)}$=discharge, in cubic feet per second, from the HE region equation for the selected streamflow characteristic; and

$\overline{E}$=mean elevation of basin, in feet.

At a site where the stream flows from one numbered region into another, the discharge should be computed using the equations for both regions. The characteristics for the entire basin should be used in both computations, and then a weighted average should be computed on the basis of the amount of the drainage area in each region. The weighting techniques are those used by Roeske (1978).

The regression equations computed for the mean 7-day low flows were useless for all regions except the HE region. Complex hydrologic and geologic conditions that govern the amount of low flow cannot be satisfactorily described by simple indices for regional analysis.

As part of the NARI procedure, CV was computed for the annual mean discharge and the 1-day high flow for all the continuous-record stations using the equation

$$CV=(e^{s^2}-1)^{\frac{1}{2}},$$

where CV is as defined earlier in this report, and s^2 is the variance of the annual discharge transformed to natural logarithms. CV values versus size of drainage area for basins in regions HE, 1, 3, and 5 are shown on figures 2-5, respectively. Data for several streams were not plotted because the CV values were too large. The large values generally were a result of one or two outliers in a gage record of less than 15 years. The data points show considerable scatter, but a significant relation exists between CV value and size of drainage area for annual mean discharge for region 1 (fig. 3) and between annual mean discharge and mean 1-day high flow for regions 3 and 5 (figs. 4 and 5). A significant relation also exists between CV and record length for 1-day high flow in region 1 and between record length and size of drainage area in regions HE, 1, 3, and 5. Thus, record length and size of drainage area probably affect CV. The CV values for region HE show little or no relation to size of drainage area. Because there is little variation in record lengths, no attempt was made to investigate the relation between CV and record length. The NARI results for region HE are reasonable because at high elevations a large part of the streamflow is from widespread winter storms instead of from local summer thunderstorms.

The above discussion of the CV values gives general results and conclusions as part of the network evaluation and justification for the NARI results for only region HE. No attempt was made to evaluate ρc values or to obtain a better definition of the interrelation among CV, size of drainage area, and length of record.

Table 1.--Regression equations for selected streamflow characteristics and corresponding standard errors of estimate

[Peak-discharge equations from Roeske (1978)]

Q: Discharge in cubic feet per second for indicated streamflow characteristic:
- AM: Annual mean discharge.
- SD: Standard deviation of annual mean discharge.
- H1: Mean 1-day high flow.
- L7: Mean 7-day low flow.
- 50: Peak discharge, 50-year recurrence interval.

A: Drainage area in square miles.

S: Channel slope in foot per foot between two points at 10 and 85 percent of the distance from the gaging station to the basin divide.

P: Annual mean precipitation in inches.

E: Mean basin elevation in thousands of feet above National Geodetic Vertical Datum of 1929.

Equation	Standard error of estimate, in $\log_{10}$ units	Average percent
REGION HE (10 CONTINUOUS RECORDS; 17 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = 0.099A^{0.937}S^{0.401}$	0.088	20
$Q_{SD} = 0.69A^{0.814}$	.077	18
$Q_{H1} = 8.66A^{0.841}$	.108	25
$Q_{L7} = 1.26\times10^{-5}A^{1.263}S^{1.568}$	.221	54
$Q_{50} = 58.2A^{0.799}$	.175	42
REGION 1 (9 CONTINUOUS RECORDS; 17 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = 1.88\times10^{-6}A^{0.861}P^{3.866}$	0.339	91
$Q_{SD} = 1.18\times10^{-8}A^{0.931}P^{4.685}S^{0.470}$	.216	53
$Q_{H1} = 3.23\times10^{-2}A^{0.593}P^{2.238}$	.286	74
Q_{L7} = a	-----	--
$Q_{50} = 393A^{0.510}$	.323	86

See footnotes at end of table.

Table 1.--Regression equations for selected streamflow characteristics and corresponding standard errors of estimate—Continued

Equation	Standard error of estimate, in $\log_{10}$ units	Average percent
REGION 2 (26 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = b$	-----	--
$Q_{SD} = b$	-----	--
$Q_{H1} = b$	-----	--
$Q_{L7} = b$	-----	--
$Q_{50} = 815A^{0.494}$	0.281	72
REGION 3 (39 CONTINUOUS RECORDS; 87 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = 2.36 \times 10^{-7} A^{0.954} P^{4.385}$	0.151	36
$Q_{SD} = 1.01 \times 10^{-6} A^{0.916} P^{3.951}$	.160	38
$Q_{H1} = 2.73 \times 10^{-3} A^{0.824} P^{2.758}$	.158	38
$Q_{L7} = a$	-----	--
$Q_{50} = 329A^{0.617} E^{-1.22} P^{0.933}$	.244	61
REGION 4 (21 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = b$	-----	--
$Q_{SD} = b$	-----	--
$Q_{H1} = b$	-----	--
$Q_{L7} = b$	-----	--
$Q_{50} = 3.27 \times 10^{-2} A^{0.383} E^{5.60}$	0.320	85

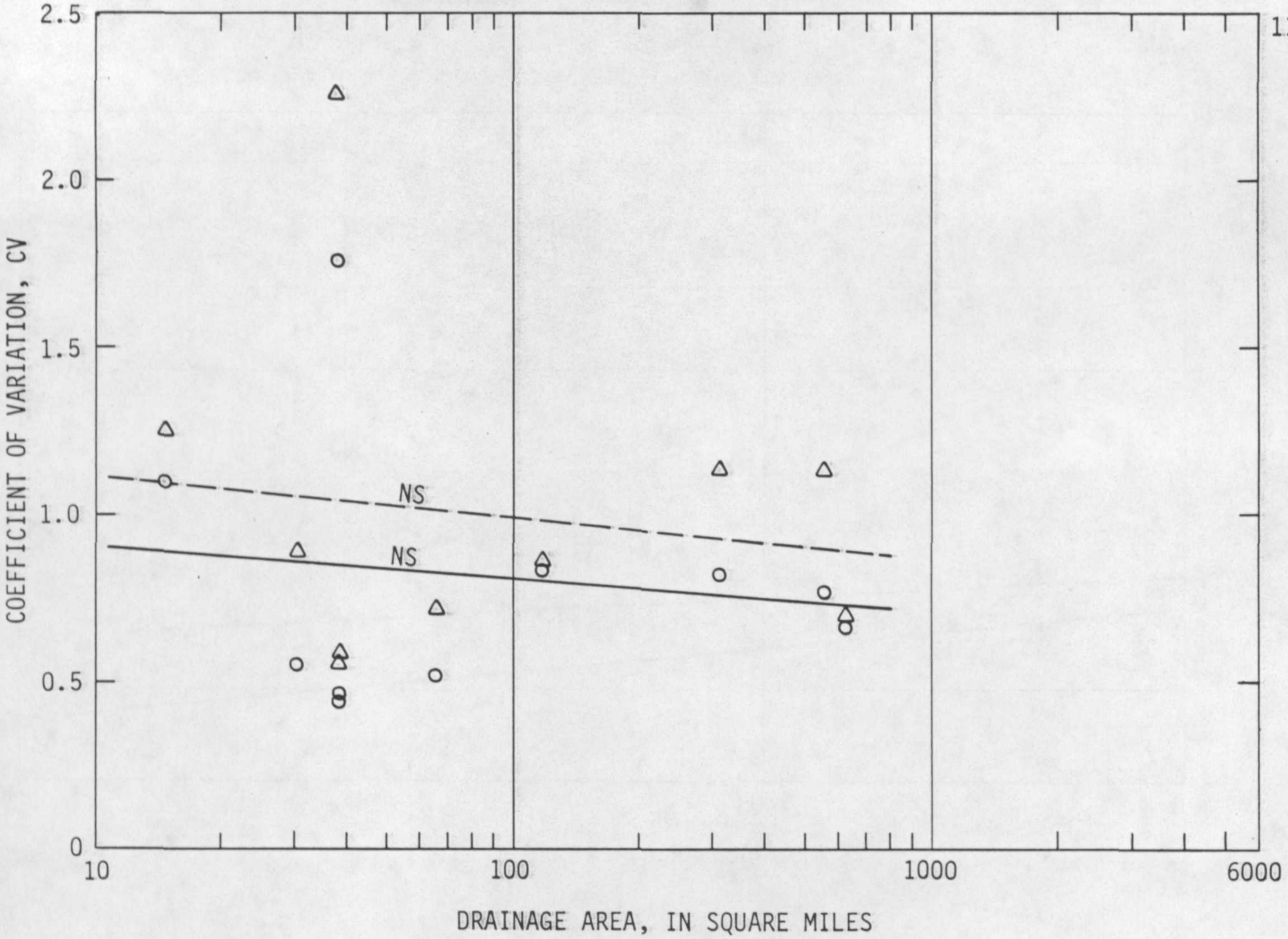
See footnotes at end of table.

Table 1.--Regression equations for selected streamflow characteristics and corresponding standard errors of estimate—Continued

Equation	Standard error of estimate, in $\log_{10}$ units	Average percent
REGION 5 (20 CONTINUOUS RECORDS; 61 PEAK-DISCHARGE RECORDS)		
$Q_{AM} = 3.58\times10^{-5}A^{0.610}P^{3.214}$	0.285	73
$Q_{SD} = 2.25\times10^{-5}A^{0.532}P^{3.457}$	.232	57
$Q_{H1} = 1.23\times10^{-1}A^{0.621}P^{1.812}$	.179	43
Q_{L7} = [a]	-----	--
$Q_{50} = 937A^{0.458}$	.302	79

[a]Standard error of regression analysis was greater than 0.362 (average percent, 100).

[b]Insufficient data for regression analysis.



EXPLANATION

○ COEFFICIENT OF VARIATION OF ANNUAL MEAN DISCHARGE

△ COEFFICIENT OF VARIATION OF 1-DAY HIGH FLOW

——— LEAST SQUARES FIT OF ANNUAL MEAN DISCHARGE

— — — LEAST SQUARES FIT OF 1-DAY HIGH FLOW

NS RELATION NOT SIGNIFICANT AT THE 0.95 CONFIDENCE LEVEL

Figure 2.--Coefficient of variation of annual mean discharge and 1-day high flow versus drainage area for selected streams in region HE.

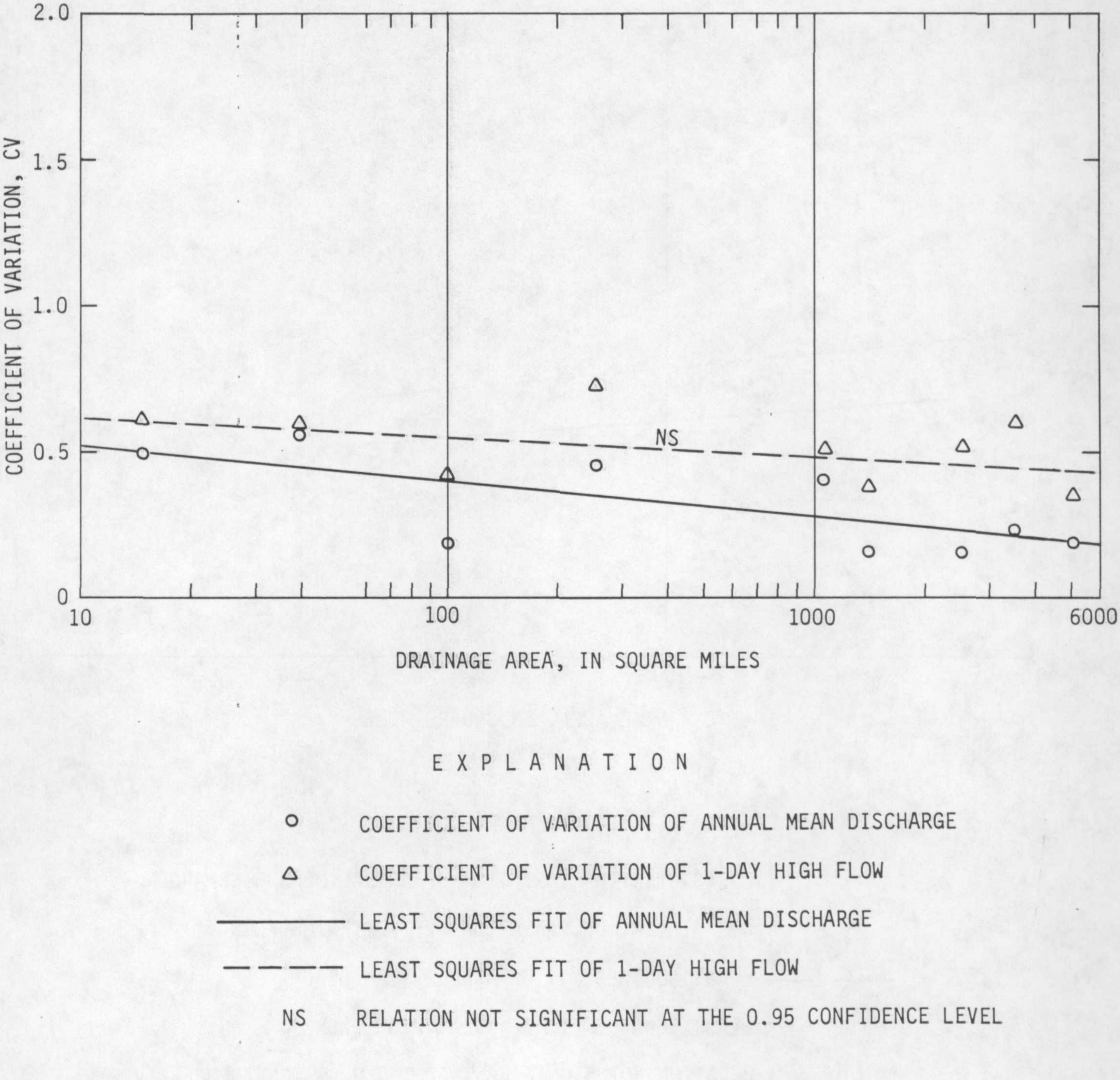


Figure 3.--Coefficient of variation of annual mean discharge and 1-day high flow versus drainage area for selected streams in region 1.

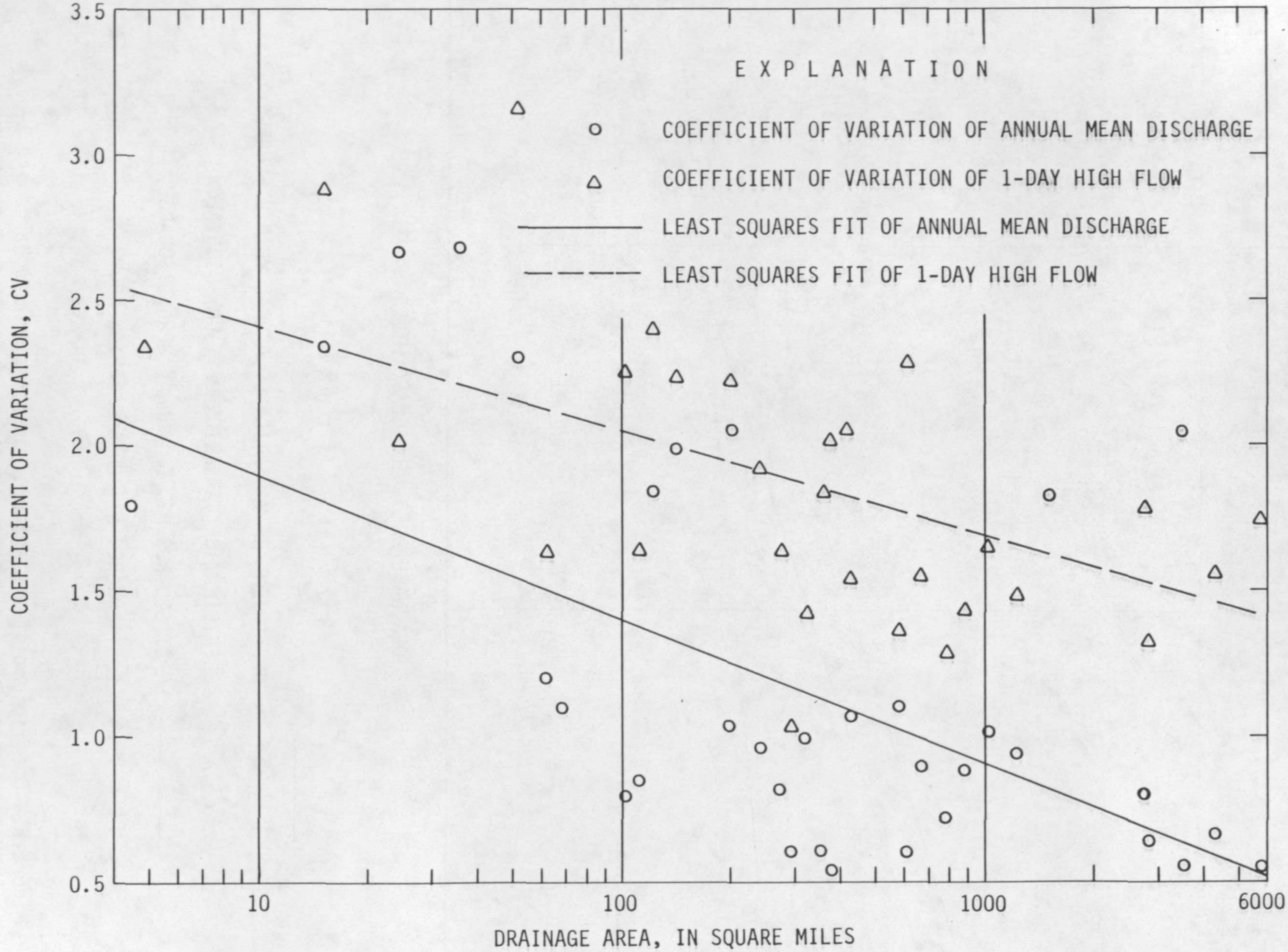


Figure 4.--Coefficient of variation of annual mean discharge and 1-day high flow versus drainage area for selected streams in region 3.

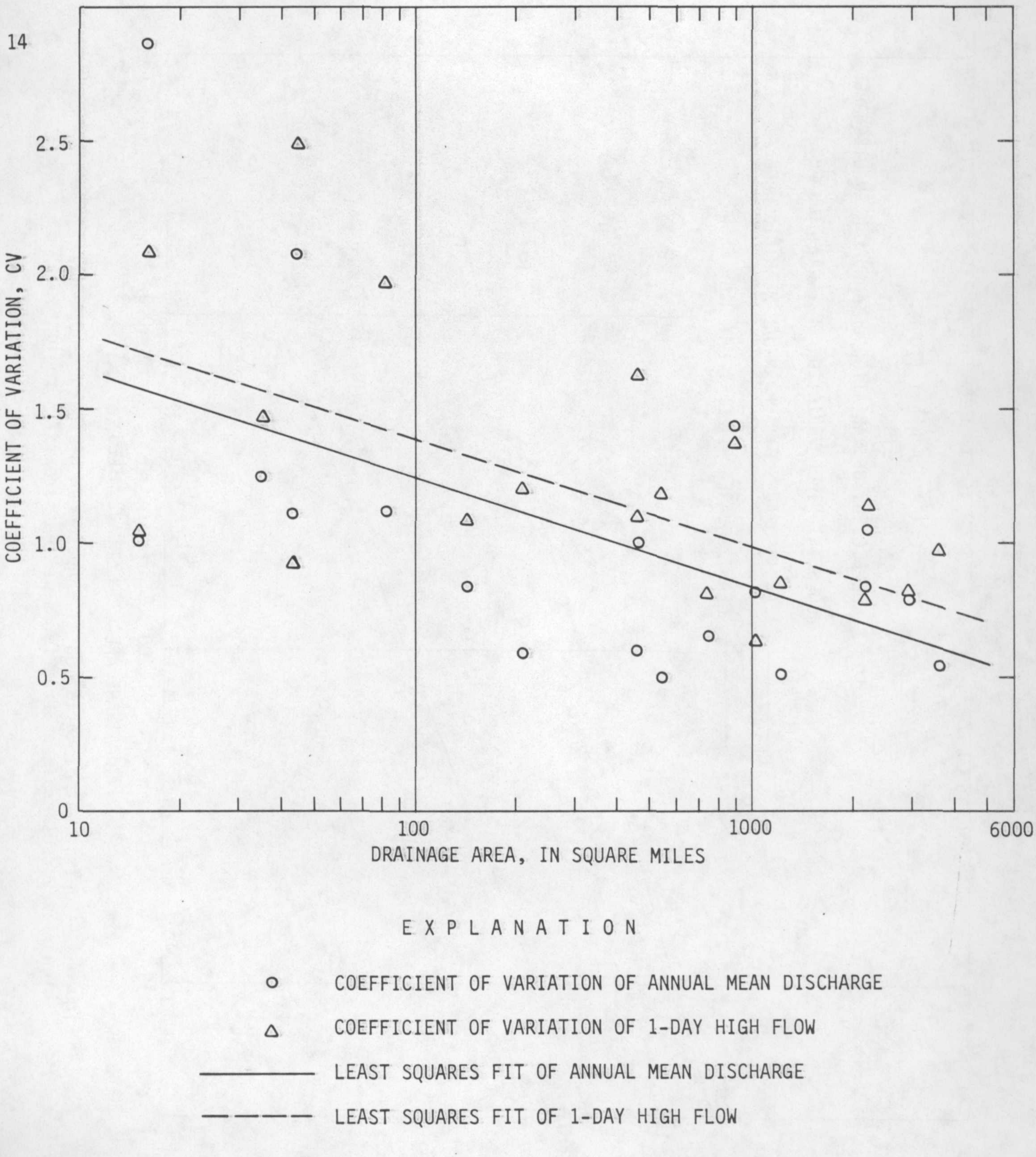


Figure 5.--Coefficient of variation of annual mean discharge and 1-day high flow versus drainage area for selected streams in region 5.

Region HE

Region HE includes drainage areas in which the mean basin elevation is greater than 7,500 ft. Records are available for 17 streamflow-gaging stations, of which 14 are continuous-record stations and 3 are crest-stage partial-record stations. Four continuous records were not used because of regulation upstream from the gaged site. Thus, 10 continuous and 17 peak-discharge records were used. The records are from drainage areas of more uniform size than those of the drainage areas in the other regions. The regression analysis gave small standard errors, which support the premise that streamflow characteristics are more homogeneous in region HE than those in the other regions.

Because the coefficient of variation showed little or no relation to size of drainage area or length of record, NARI was used to statistically define time, space, and model errors in the regression analysis. The solid lines in figures 6-10 show the expected standard error of a regression analysis using the current regression model and different combinations of number of gaging stations and the harmonic mean record length of the gaging-station network. Harmonic mean record length is used instead of arithmetic mean record length because the former is related directly to the time-sampling variability that is an integral part of the NARI procedure. The expected standard error estimated by NARI accounts for the time-sampling errors in the dependent variables; therefore, the expected standard error differs from the standard error of the regression that retains the time-sampling errors. The dashed lines in figures 6-10 show the expected standard error assuming no model error—the independent variables in the model perfectly describe the streamflow characteristics.

The graphs can be used to determine efficient ways of improving the regression model. Additional gages and additional years of record would slowly improve the regression results for annual mean discharge (fig. 6), mean 1-day high flow (fig. 8), and 50-year peak discharge (fig. 10), and development of a better model would give greater improvement. The standard deviation of annual mean discharge (fig. 7) indicates that data from additional basins would improve the regression results more slowly than additional years of record from the existing gaging-station network; a better model also would improve the regression results. The mean 7-day low flow (fig. 9) indicates that additional years of record would not improve the regression results and that additional basins would help only slightly. Nearly all the error is caused by model error; therefore, development of a better model would greatly improve the regression results.

In region HE, gages operated only for regional information are not providing more information than gages operated for other purposes; gages operated for other purposes may continue to give usable regional information. Discontinuing stations originally established for regional information in region HE or any other region may not be the best solution to the problem because data from the stations may be valuable in the

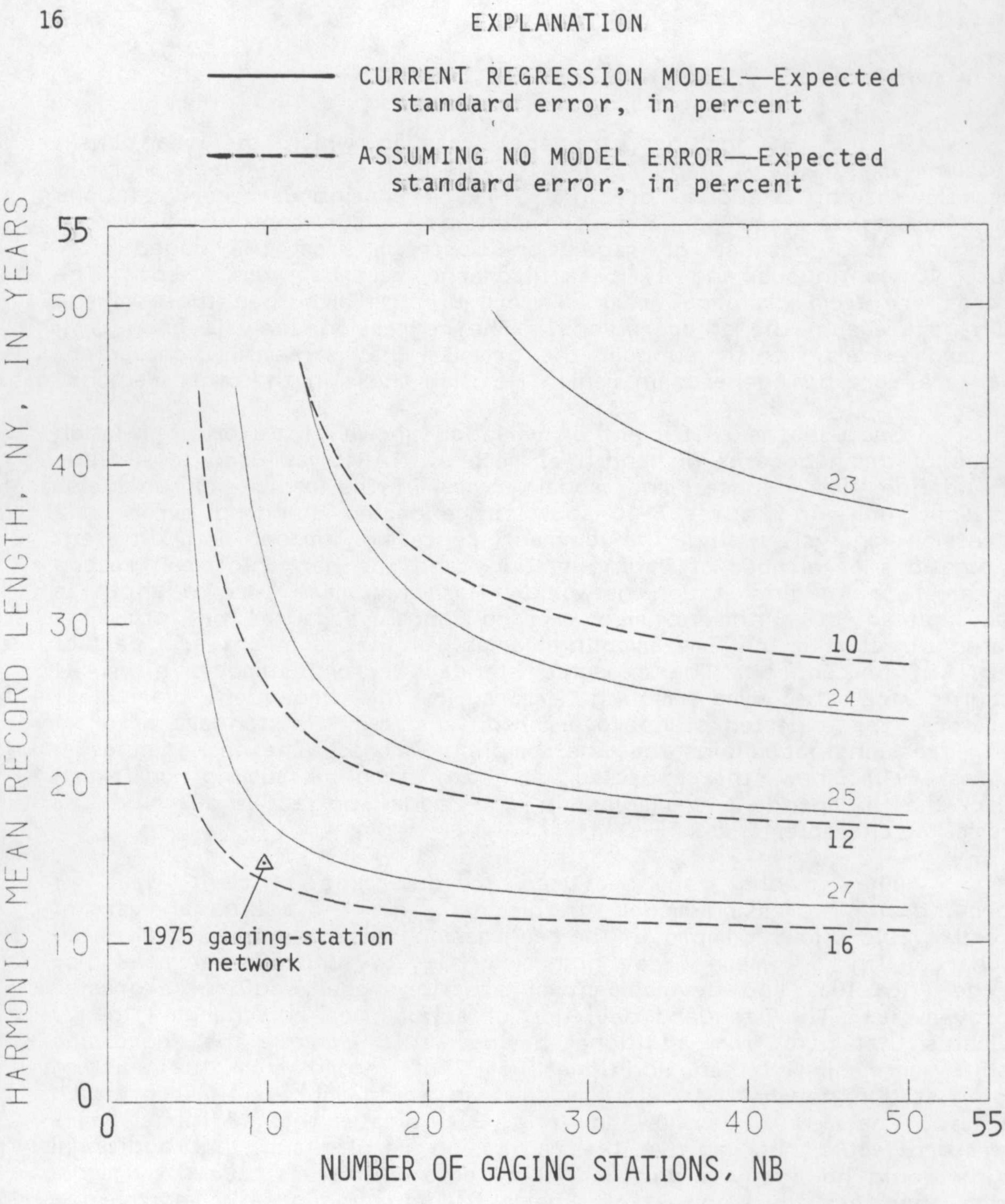


Figure 6.--Expected standard error for annual mean discharge as a function of NB and NY for region HE.

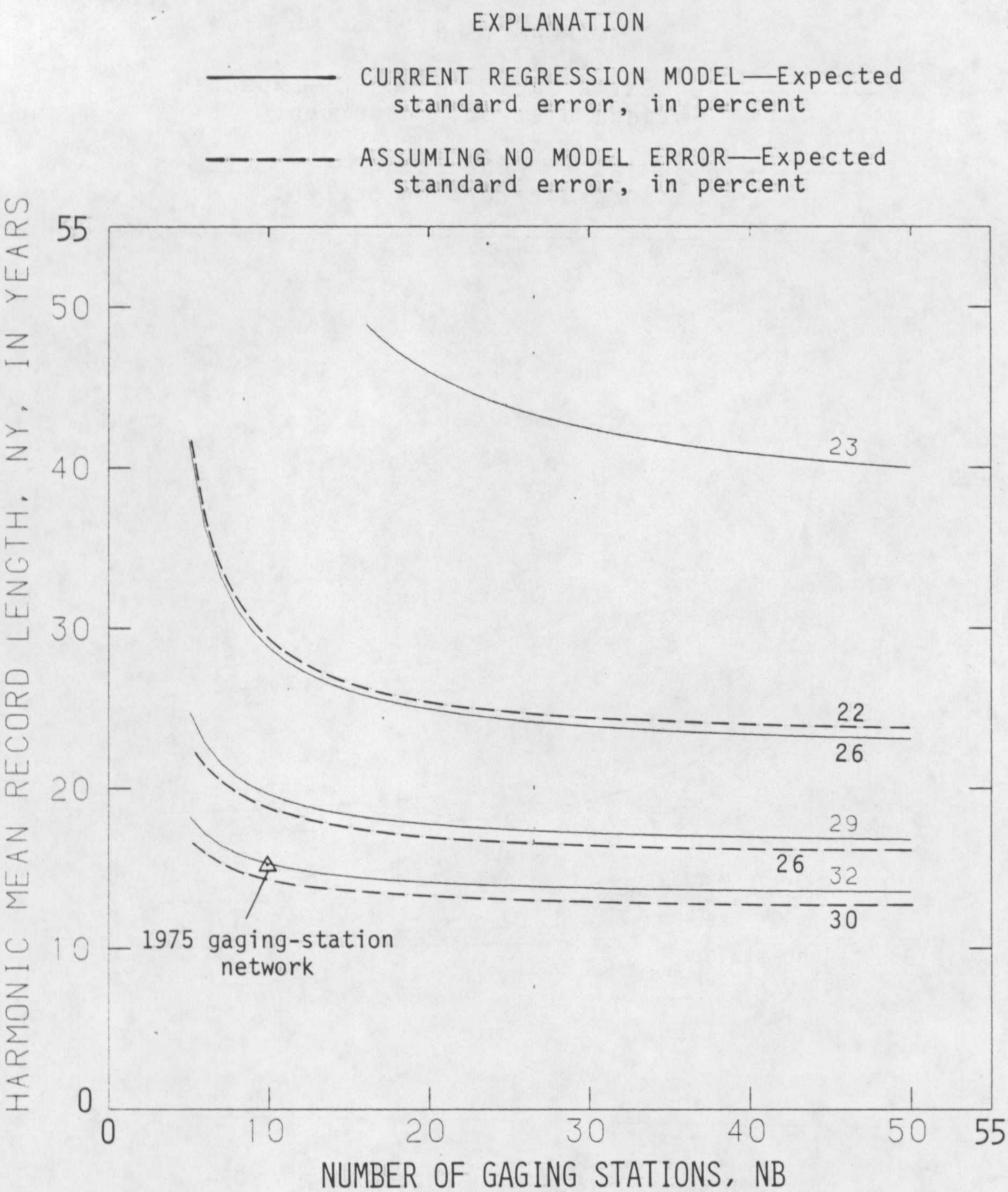


Figure 7.--Expected standard error for standard deviation of annual mean discharge as a function of NB and NY for region HE.

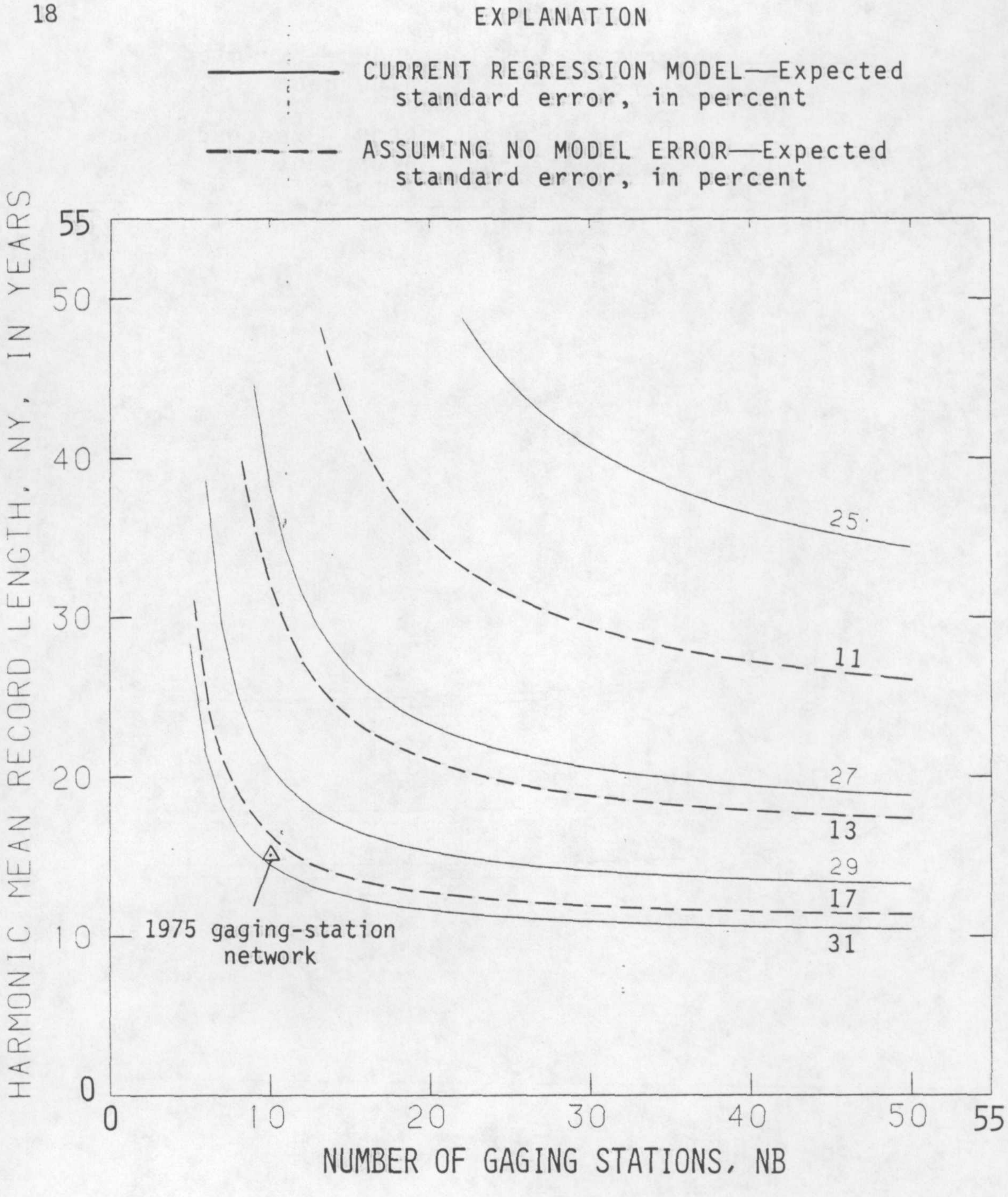


Figure 8.--Expected standard error for mean 1-day high flow as a function of NB and NY for region HE.

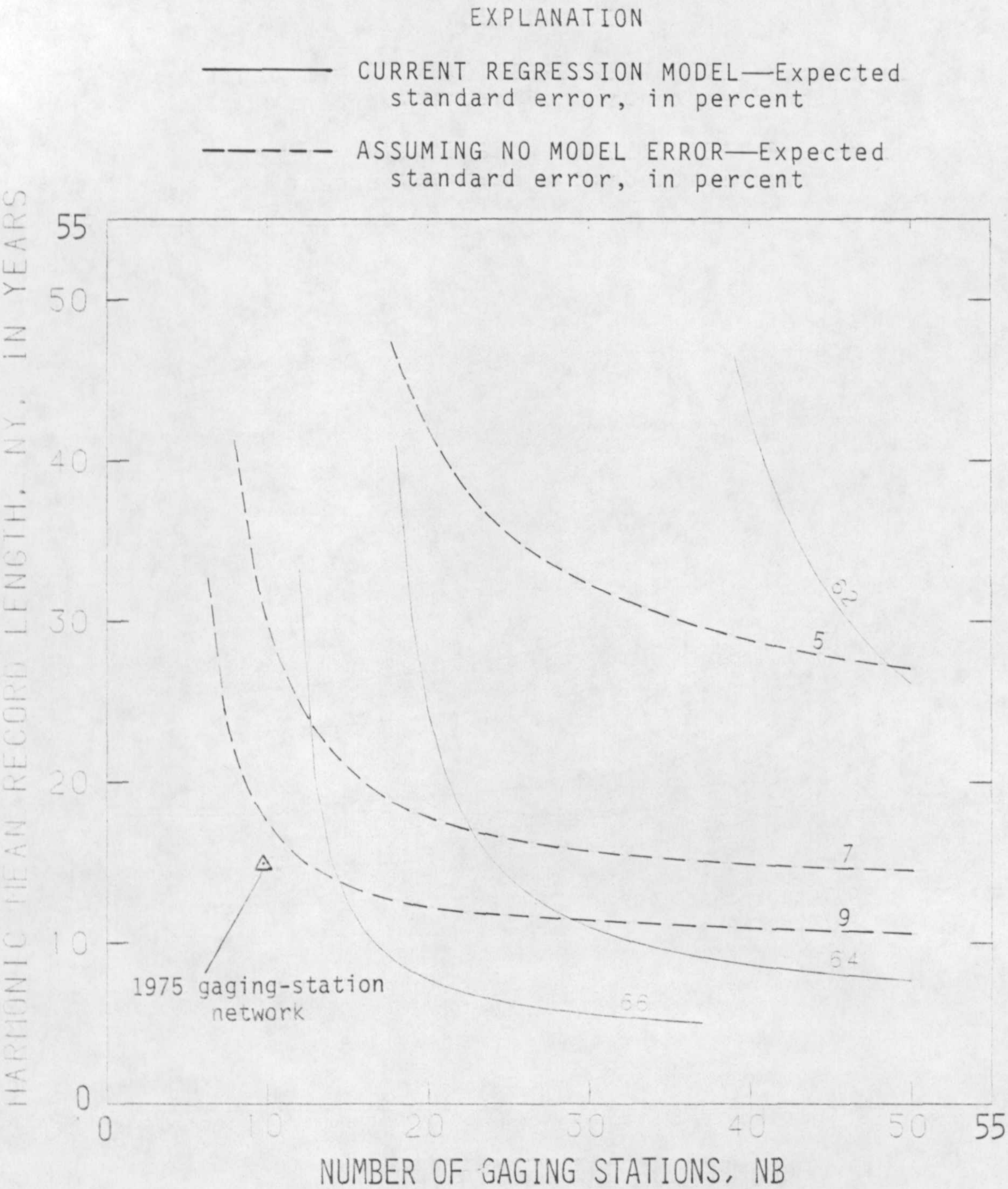


Figure 9.--Expected standard error for mean 7-day low flow as a function of NB and NY for region HE.

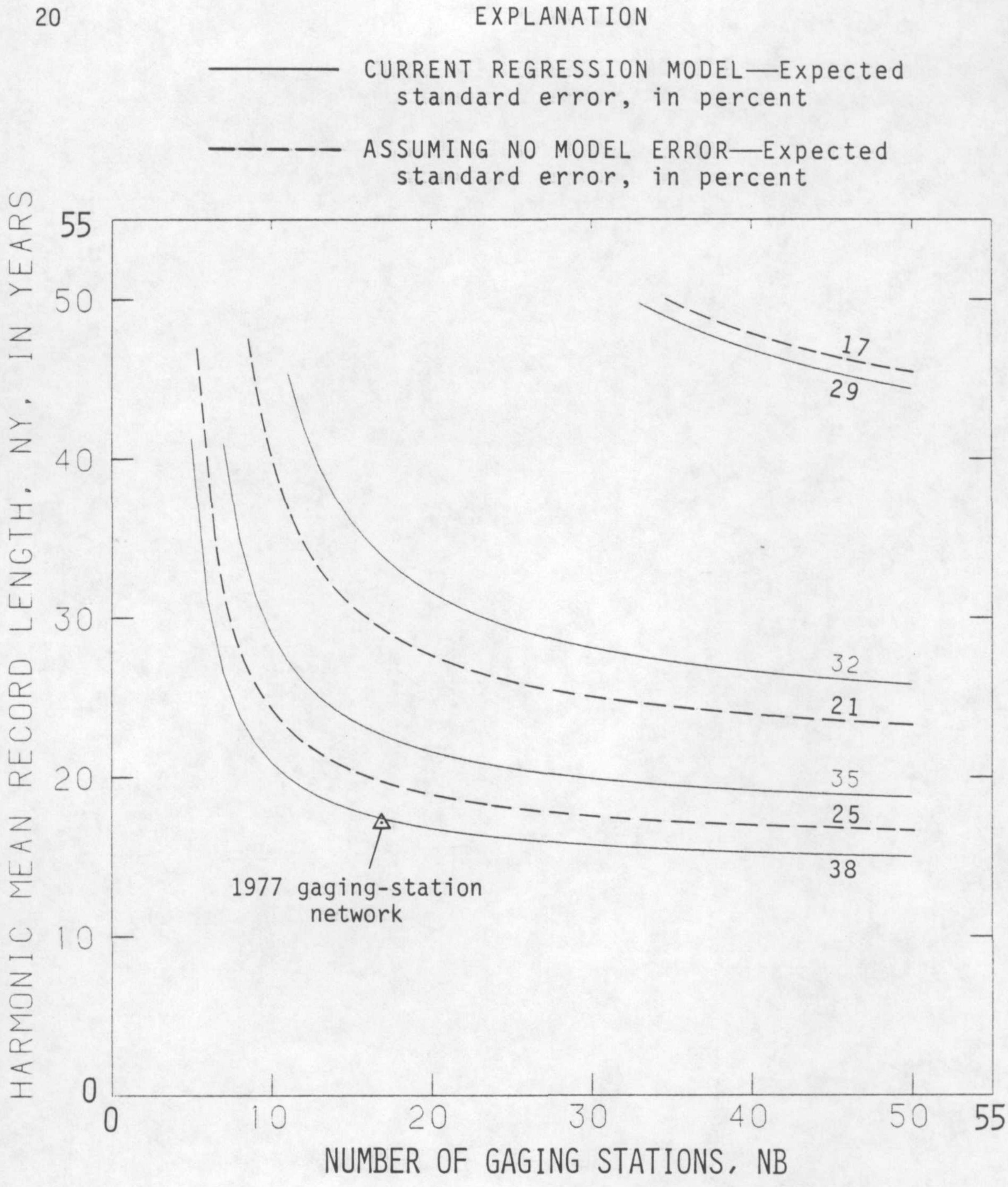


Figure 10.--Expected standard error for 50-year peak discharge as a function of NB and NY for region HE.

future when better transfer mechanisms are developed. The tradeoff would be to compare the cost of additional gages, additional years of record, or development of a better model against the savings that could accrue if more accurate estimates of streamflow characteristics were available.

Region 1

Region 1 includes northwestern Arizona, and records are available for 17 streamflow-gaging stations, of which 9 are continuous-record stations and 8 are crest-stage partial-record stations. The length of record ranges from 7 to 51 years, and six gages have 15 or fewer years of record. The regression equations for the selected streamflow characteristics have large standard errors. Figure 11 shows annual mean discharge versus size of drainage area. The annual mean discharge for streamflow-gaging station 09403000—Bright Angel Creek near Grand Canyon—is an outlier when compared to the annual mean discharge at the other gages, partly because of geologic differences that affect the streamflow. Gaging station 09403000 is near the bottom of the canyon, and the base flow is maintained by springs that drain an area much larger than that of the surface drainage. Geologic effects were not incorporated in the regression analysis because of the difficulty in quantifying the effects and the limited understanding of the hydrologic systems.

Preliminary NARI results indicate that most of the standard error of the regression was the result of model error, which means that the regression model is unable to describe the streamflow characteristics using the basin characteristics described by the simple indices or that the model is inappropriate. Streamflow-gaging stations at additional sites and longer periods of record at existing sites will help improve the regression models, but better models are necessary before large reductions in standard error can be realized.

Region 2

Region 2 includes southwestern Arizona, and records are available for 26 streamflow-gaging stations. Only three are continuous records, one of which is only 8 years long, and the other two are for basins with drainage areas of about 1,800 mi^2. The continuous records were not usable for regression analysis.

Although the regression equation for the 50-year flood is shown in table 1, the gaging-station records are not a good sample of basin size. Twelve stations (46 percent) are on streams that drain areas of less than 10 mi^2, and 18 stations (77 percent) are on streams that drain areas of less than 90 mi^2. Large basins are not well represented; no gages have been installed on drainage areas of 400 to 1,400 mi^2. Care

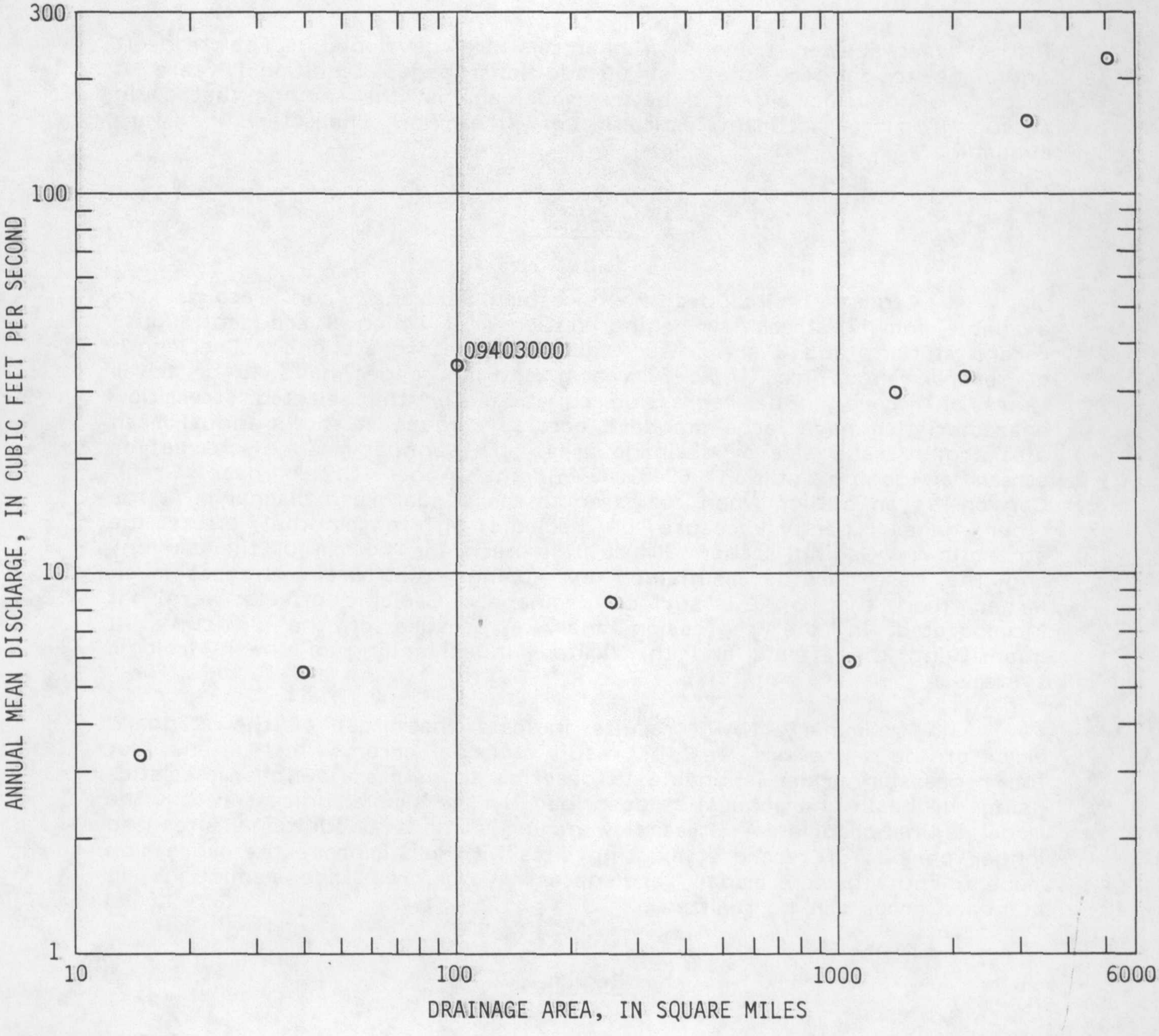


Figure 11.--Annual mean discharge versus size of drainage area for gaged streams in region 1.

should be taken when using the peak-discharge equation for large basins because the regression analysis may be biased by the large sampling of small basins and because large basins may have different hydrologic characteristics than small basins. If better regional information is needed, continuous-record stations would have to be established, and more sampling of large basins would be necessary.

Region 3

Region 3 includes central Arizona and has the largest number of streamflow-gaging stations. Records are available for 87 streamflow-gaging stations, of which 54 are continuous-record stations and 33 are crest-stage partial-record stations. The regression analyses of the annual mean discharge, standard deviation of the annual mean discharge, and mean 1-day high flow were made using 39 continuous records. Records for 15 continuous-record stations were not used because of diversion or regulation upstream from the gaged site, records less than 10 years long, or high correlation between one record and another record used in the analysis. Standard errors of estimate of the regression equations were small. Records of peak discharge were available at all 87 gaging stations.

Results of the regression analysis for mean 7-day low flow were not useful. Because many station records are available, several additional logarithmic regressions were made using different groups of gage records. The analyses did not produce usable results; one reason was the inability to define the geology of the basin as an independent variable to the regression analysis. Several streams are spring fed, and base flow is from zero to large amounts of flow. Until better models are developed, streamflow data at the specific site are needed to determine the low-flow characteristics.

Nearly 40 percent of the gaging stations in Arizona are in region 3, where most stations were established to obtain water-management data. Regional information now is available from the many gages operated for other purposes. Gages operated only for regional information can be discontinued if the tradeoff discussed in the section entitled "Region HE" is viable.

Region 4

Region 4 includes northeastern Arizona, and records are available for 21 streamflow-gaging stations, of which 6 are continuous-record stations and 15 are crest-stage partial-record stations. The drainage areas of the continuous-record stations range from 607 to 3,300 mi^2, and there is regulation upstream from at least three of the gages. Insufficient data prevented useful analyses of streamflow characteristics on the basis of the continuous records. Data are not available for streams that drain areas of 81 to 607 mi^2. As in region 2, care should be taken when the regression equation for the 50-year flood is applied to streams that drain large basins. Fifteen of the twenty-one peak-discharge records are for streams that drain small basins. Nine records are from areas of less than 2 mi^2, four records are from areas between 2 and 16 mi^2, and two records are from areas of 57 and 81 mi^2.

Region 5

Region 5 includes southeastern Arizona, and records are available for 61 streamflow-gaging stations, of which 24 are continuous-record stations and 37 are crest-stage partial-record stations. Four of the continuous-record stations are along the San Pedro River, and five are along the Santa Cruz River. The gages are operated for several reasons. Stations that gage much of the same water on a stream cannot be considered independent; therefore, care must be taken in using and extrapolating the gaging-station data. Records from three continuous-record stations were not used because of the lack of independence. Although the three records would increase the data base, the reliability of the analysis would not be improved. One record was not used because of a change in the size of drainage area during the period of record. Thus, 20 continuous records and 61 peak-discharge records were available for this study.

In region 5 there is uniform distribution of size of drainage areas. The regression analyses for the selected streamflow characteristics give large standard errors. The preliminary NARI results indicate that much of the standard error is model error, which means that the model is unable to describe the streamflow characteristics in the region.

CONCLUSIONS

Obtaining regional information for Arizona streams is difficult and complex because of the highly variable physiographic and streamflow characteristics and the scarcity of data for many regions. The regression results are estimates of the selected streamflow characteristics based on the available data. Good regional information is available for region HE; however, estimates of the streamflow characteristics for region 1 are marginal. In regions 2 and 4, continuous-record data are insufficient for regional regression analysis. Region 3 has many gaging stations, and the regression results are reasonable. Regression results for region 5 are only slightly better than those for region 1. The NARI procedure was applied to data for the HE region but was not used for the other five regions because the coefficient of variation was not constant or because of insufficient data. Although the streamflow characteristics can be computed for any site using the regression equations, the experienced user will recognize that judgment must be used in the application of the appropriate equations. Future studies using different models, different independent variables, or different regions may improve the reliability of estimated streamflow characteristics for ungaged sites. Additional sites and longer periods of record at existing sites are needed to obtain better regional information in areas where data are scarce.

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