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Appendix 14

"FLOOD FLOW FREQUENCY TECHNIQUES"

REPORT SUMMARY

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Following is a summary of "Flood Flow Frequency Techniques," a report by Leo R. Beard, Technical Director, Center for Research in Water Resources, The University of Texas at Austin, for the Office of Water Resources Research and the Water Resources Council. Much of the text and a majority of the exhibits are taken directly from the report.

The study was made at the Center for Research in Water Resources of The University of Texas at Austin at the request of and under the general guidance of the Work Group on Flood Flow Frequency, Hydrology Committee, of the Water Resources Council through the auspices of the Office of Water Resources Research. The purpose was to provide a basis for development by the Work Group of a guide for flood frequency analysis at locations where gage records are available which would incorporate the best technical methods currently known and would yield greater reliability and consistency than has heretofore been available in flood flow frequency determinations.

The study included: (a) a review of the literature and current practice to select candidate methods and procedures for testing, (b) selection of long-record station data of natural streamflows in the United States and development of data management and analysis computer programs for testing alternate procedures, (c) testing eight basic statistical methods for frequency analysis including alternate distributions and fitting techniques, (d) testing of alternate criteria for managing outliers, (e) testing of procedures for treating stations with zero flow years, (f) testing relationships between annual maximum and partial-duration series, (g) testing of expected probability adjustment, (h) testing to determine if flood data exhibit consistent long-term trends, and (i) recommendations with regard to each procedure tested and development of background material for the guides being developed by the Work Group.

Data

In all, 300 stations were used in the testing. Flows were essentially unregulated. Record length exceeded 30 years with most stations having records longer than 40 years. The stations were selected to give the best feasible coverage of drainage area size and geographic location and to include a substantial number of stations with no flow for an entire year. Table 14-1 lists the number of stations by size and geographic zone.

Split Record Testing

A primary concern of the study was selection of a mathematical function and fitting technique that best estimates flood flow frequencies from annual peak flow data. Goodness of fit of a function to the data used in the fitting process is not necessarily a valid criterion for selecting a method that best estimates flood frequencies. Consequently, split record testing was used to simulate conditions of actual application by reserving a portion of a record from the fitting computation and using it as "future" events that would occur in practice. Goodness of fit can nevertheless be used, particularly to eliminate methods whose fit is very poor.

Each record of annual maximum flows was divided into two halves, using odd sequence numbers for one half and even for the other in order to eliminate the effect of any general trend that might possibly exist. This splitting procedure should adequately simulate practical situations as annual events were tested and found independent of each other. Frequency estimates were made from each half of a record and tested against what actually happened in the other half.

Development of verification criteria is complicated, because what actually happens in the reserved record half also is subject to sampling irregularities. Consequently, reserved data cannot be used as a simple, accurate target and verification criteria must be probabilistic. The test procedure, however, simulates conditions faced by the planner, designer, or operator of water resource projects, who knows neither that past events are representative nor what future events will be.

The ultimate objective of any statistical estimation process is not to estimate the most likely theoretical distribution that generated the observed data, but rather to best forecast future events for which a decision is formulated. Use of theoretical distribution functions and their attendant reliability criteria is ordinarily an intermediate step to forecasting future events. Accordingly, the split record technique of testing used in this study should be more rigorous and direct than alternative theoretical goodness-of-fit tests.

Frequency Computation Methods

Basic methods and fitting techniques tested in this study were selected by the author and the WRC Work Group on Flood Flow Frequency after careful review of the literature and experience in the various agencies represented; those that were tested are listed below. Numbering corresponds to the identification number of the methods in the computer programs and in the attached tables.

1. Log-Pearson Type III (LP3). The technique used for this is that described in (35). The mean, standard deviation, and skew coefficients for each data set are computed in accordance with the following equations:

$$\bar{X} = \frac{\Sigma X}{N} \qquad (14\text{-}1)$$

$$S^2 = \frac{\Sigma X^2 - (\Sigma X)^2/N}{N-1} \qquad (14\text{-}2)$$

$$g = \frac{N^2 \Sigma X^3 - 3N\Sigma X \Sigma X^2 + 2(\Sigma X)^3}{N(N-1)\ (N-2) S^3} \qquad (14\text{-}3)$$

where

X = logarithm of peak flow

N = number of items in the data set

$\bar{X}$ = mean logarithm

S = standard deviation of logarithms

g = skew coefficient of logarithms

Flow logarithms are related to these statistics by use of the following equation:

$$X = \overline{X} + kS \qquad (14\text{-}4)$$

Exceedance probabilities for specified values of k and values of k for specified exceedance probabilities are calculated by use of the normal distribution routines available in computer libraries and the approximate transform to Pearson deviates given in reference (31).

2. Log Normal (LN). This method uses a 2-parameter function identical to the log-Pearson III function except that the skew coefficient is not computed (a value of zero applies), and values of k are related to exceedance probabilities by use of the normal distribution transform available in computer libraries.

3. Gumbel (G). This is the Fisher-Tippett extreme-value function, which relates magnitude linearly with the log of the log of the reciprocal of exceedance probability (natural logarithms). Maximum likelihood estimates of the mode and slope (location and scale parameters) are made by iteration using procedures described by Harter and Moore in reference (36). The initial estimates of the location and scale statistics are obtained as follows:

$$M = \overline{X} - 0.45005\ S \qquad (14\text{-}5)$$

$$B = .7797\ S \qquad (14\text{-}6)$$

Magnitudes are related to these statistics as follows:

$$X = M + B(-\ln(-\ln P)) \qquad (14\text{-}7)$$

where

M = mode (location statistic)
B = slope (scale statistic)
X = magnitude
P = exceedance probability
S = standard deviation of flows

Some of the computer routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

4. Log Gumbel (LG). This technique is identical to the Gumbel technique except that logarithms (base 10) of the flows are used.

5. Two-parameter Gamma (G2). This is identical to the 3-parameter Gamma method described below, except that the location parameter is set to zero. The shape parameter is determined directly by solution of Nörlund's (37) expansion of the maximum likelihood equation which gives the following as an approximate estimate of α:

$$\alpha = \frac{1 + \sqrt{1 + \frac{4}{3}\left(\ln\overline{Q} - \frac{1}{N}\Sigma \ln Q\right)}}{4\left(\ln \overline{Q} - \frac{1}{N}\cdot\Sigma \ln Q\right)} - \Delta\alpha \qquad (14\text{-}8)$$

where

$\overline{Q}$ = average annual peak flow

N = number of items in the data set

Q = peak flow

$\Delta\alpha$ = correction factor

β is estimated as follows:

$$\beta = \frac{1}{\alpha} \cdot \frac{1}{N}\Sigma Q \qquad (14\text{-}9)$$

6. Three-parameter Gamma (G3). Computation of maximum likelihood statistics for the 3-parameter Gamma distribution is accomplished using procedures described in reference (38). If the minimum flow is zero, or if the calculated lower bound is less than zero, the statistics are identical to those for the 2-parameter Gamma distribution. Otherwise, the lower bound, γ, is initialized at a value slightly smaller than the lowest value of record, and the maximum likelihood value of the lower bound is derived by iteration using criteria in reference (38). Then the parateters α and β are solved for directly using the equations above replacing Q with Q-γ. Probabilities corresponding to specified magnitudes are computed directly by use of a library gamma routine. Magnitudes corresponding to specified

probabilities are computed by iteration using the inverse solution.

7. Regional Log-Pearson Type III (LPR). This method is identical to the log-Pearson Type III method, except that the skew coefficient is taken from Figure 14-1 instead of using the computed skew coefficient. Regionalized skew coefficients were furnished by the U.S. Geological Survey.

8. Best Linear Invariant Gumbel (BLI). This method is the same as for the Gumbel method, except that best linear invariant estimates (BLIE) are used for the function statistics instead of the maximum likelihood estimates (MLE). An automatic censoring routine is used for this method only, so there are no altenative outlier techniques tested for this method. Statistics are computed as follows:

$$M = \Sigma(X(I) \cdot U(N,J,I)) \qquad (14\text{-}10)$$

$$B = \Sigma(X(I) \cdot V(N,J,I)) \qquad (14\text{-}11)$$

where

U = coefficient UMANN described in reference (39)
V = coefficient BMANN described in reference (39)
J = number of outliers deleted plus 1
I = order number of flows arranged in ascending-magnitude order
N = sample size as censored.

Since weighting coefficients U and V were made available in this study only for sample sizes ranging from 10 to 25, 5-year samples are not treated by this method, and records (or half records) of more than 25 years are divided into chronological groups and weighted average coefficients used in lieu of coefficients that might otherwise be obtained if more complete sets of weighting coefficients were available. Up to two outliers are censored at the upper end of the flow array. Each one is removed if sequential tests show that a value that extreme would occur by chance less than 1 time 10 on the basis of the BLIE statistics. Details of this censoring technique are contained in reference (40). Weighting coefficients and most of the routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

Outliers

Outliers were defined for purpose of this study as extreme values whose ratio to the next most extreme value in the same (positive or negative) direction is more extreme than the ratio of the next most extreme value to the eighth most extreme value.

The techniques tested for handling outliers consisted of

a. keeping the value as is,

b. reducing the value to the product of the second largest event and the ratio of the second largest to eighth largest event,

c. reducing the value to the product of the second largest event and the square root of that ratio, and

d. discarding the value.

In the cases of outliers at the low end, the words largest in (b) and (c) should be changed to smallest.

Zero Flow

Two techniques were tested for handling stations with some complete years of no flow as follows:

(a) Adding 1 percent of the mean magnitude to all values for computation purposes and subtracting that amount from subsequent estimates, and

(b) removing all zeros and multiplying estimated exceedance frequencies of the remaining by the ratio of the number of non-zero values to the total number of values. This is the procedure of combining probabilities described in reference (27).

Partial-Duration Series

A secondary concern of the study was the relationship between annual maximum flow frequencies and partial-duration flow frequencies.

Because a partial-duration series consists of all events above a specified magnitude, it is necessary to define separate events. The definition normally depends on the application of the frequency study as well as the hydrologic characteristics of the stream. For this study separate events were arbitrarily defined as events separated by at least as many days as five plus the natural logarithm of the square miles of drainage area, with the requirement that intermediate flows must drop below 75 percent of the lower of the two separate maximum daily flows. This is considered representative of separation criteria appropriate for many applications.

Maximum daily flows were used for this part of the study, because there were insufficient readily available data on instantaneous peak flows for events smaller than the annual maximum. There is no reason to believe that the frequency relationship would be different for peak flows than for daily flows.

The relationship between the maximum annual and partial-duration series was expressed as a ratio of partial-duration to annual event frequencies at selected annual event frequencies. In order to develop partial-duration relationships independent of any assumptions as to frequency functions, magnitudes corresponding to annual-maximum event exceedance probabilities of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, and 0.7 are established for complete records at each station by linear interpolation between expected probability plotting positions ($M/(n+1)$) for the annual maximum events. Corresponding frequencies of partial-duration flows are established simply by counting the total number of independent maximum daily flows at each station above each magnitude and dividing by the total number of years at that station. Ratios of partial-duration to annual event frequencies were averaged for all stations in each USGS zone and compared with ratios derived for certain theoretical conditions by Langbein (9).

Expected Probability Estimation

The expected probability is defined as the average of the true probabilities of all magnitude estimates for any specified flood frequency that might be made from successive samples of a specified size. For any specified flow magnitude, it is considered to be the most appropriate estimate of probability or frequency of future flows for water resources planning and management use.

It is also a probability estimate that is theoretically easy to verify, because the observed frequencies in reserved data at a large number of stations should approach the computed probability or frequency estimates as the number of stations increases. Accordingly, it was considered that expected probability estimates should be used in the split record tests.

A method of computing expected probabilities has been developed for samples drawn from a Gaussian normal distribution as described in (21).

Similar techniques are not available for the other threoretical distribution functions. Consequently, an empirical transform is derived for each distribution. To do this a calibration constant was determined which, when multiplied by the theoretical normal transform adjustment, removed the observed average bias in estimating probabilities for the 300 stations used in this study. This empirical transform was used in making the accuracy tests that are the main basis for judging the relative adequacy of the various methods tests.

Trends and Cycles

There is some question as to whether long-term trends and cycles (longer than 1 year) exist in nature such that knowledge of their nature can be used to improve forecasts of flood flow frequencies for specific times in the future. As a part of this research project, lag 1 autocorrelation coefficients of annual peak flows for all stations were computed. If trends or cycles exist in any substantial part of the data, there should be a net positive average autocorrelation for all stations. A statistically significant positive average autocorrelation was not found.

Accuracy and Consistency Tests

Criteria used in judging the adequacy of each method for fitting a theoretical distribution were as follows:

Accuracy tests consisted of the following comparisons between computed frequencies in one-half the record with frequencies of events that occurred in the reserved data.

a. Standard deviation of observed frequencies (by count) in reserved data for magnitude estimates corresponding to exceedance probabilities of 0.001, 0.01, 0.1, and 0.5 computed from the part of the record used. This is the standard error of a frequency estimate at individual stations that would occur if a correction is made for the average observed bias in each group of stations for each selected frequency and method.

b. Root-mean-square difference between expected probability plotting position (M/(n+1)) of the largest, upper decile and median event in a half record and the computed expected probability exceedance frequency of that respective event in the other half. This is the standard error of a frequency estimate at individual stations without any bias adjustment for each method and for the frequency of each selected event.

c. Root-mean-square difference between 1.0 and the ratio of the computed probability of flow in the opposite half of a record to the plotting position of the largest, upper decile and median event (in turn) in a half record. This criterion is similar to that of the preceding paragraph except that methods that are biased toward predicting small frequencies are not favored.

Consistency tests involved the following comparisons between computed frequencies in each half of the record with the total record.

a. Root-mean-square difference between computed probabilities from the two record halves for full record extreme, largest, upper decile and median events, in turn. This is an indicator of the relative uniformity of estimates that would be made with various random samples for the same location.

b. Root-mean-square value of 1.0 minus the ratio of the smaller to the larger computed probabilities from the two record halves for full record extreme, largest, upper decile and median events, in turn. This is essentially the same as the preceding criterion, except that methods that are biased toward predicting small frequencies are not favored.

The extreme event used in the consistency tests is an arbitrary value equal to the largest multiplied by the square root of the ratio of the largest to the median event for the full record.

It should be recognized that sampling errors in the reserved data are as large or larger for the same sample size as are sampling errors of computed values. Similarly, sampling errors are comparable for estimates based on opposite record halves used for consistency tests. Consequently, a great number of tests is necessary in order to reduce the uncertainty due to sampling errors in the reserved data. Further, a method that is biased toward estimating frequencies too low may have a small standard error of estimating frequencies in comparison with a method that is biased toward high frequencies, if the bias is not removed. The latter may have smaller percentage errors. Accordingly, consideration of the average frequency estimate for each of the eight methods must be a component of the analyses.

As a further means of evaluating alternate procedures the complete record results, computed curve without any expected probability adjustment, and the plotted data point were printed out.

Evaluation of Distributions

Table 14-2 shows for each method and each USGS zone the number of stations where an observed discharge exeeeded the computed 1,000-year discharge. With 14,200 station-years of record, it might be expected that about 14 observed events would exceed true 1,000-year magnitudes. This comparison indicates that the log-Pearson Type III (method 1), log normal (method 2), and log-Pearson Type III with generalized skew (method 7), are the most accurate.

Table 14-3 shows average observed frequencies (by count) in the reserved portions of half records for computed probabilities of 0.001, 0.01, 0.1, and 0.5 and the standard deviations (accuracy test a) of the observed frequencies from their averages for each computed frequency. It is difficult to draw conclusions from these data. Figure 14-2 shows a plotting of the results for the 0.01 probability estimates which aids in comparison. This comparison indicates that the log normal and log-Pearson Type III methods with generalized skew have observed frequencies closest to those computed and the smallest standard deviations except for method 4.

Table 14-4 shows the average results for all stations of accuracy tests b and c. Results are not definitive, but again the log normal (method 2) and log-Pearson Type III with generalized skew (method 7) show results as favorable as any other method as illustrated for test b in Figure 14-3.

Table 14-5 shows the results of the consistency tests. Figure 14-4 displays the results graphically for test a. The consistency test results are not substantially different from or more definitive than the accuracy results. From Figure 14-4 it appears that the log-Pearson Type III method with generalized skew yields considerably more consistent results than the log normal.

Results of Outlier Testing

Table 14-6 shows results for all stations of the accuracy and consistency tests for the four different outlier techniques. Results of these tests show that for the favorable methods [log normal (method 2) and log-Pearson Type III with generalized skew (method 7)], outlier techniques a and b are most favorable. Unfortunately, no discrimination was made in the verification tests between treatment of outliers at the upper and lower ends of the frequency arrays. Outliers at the lower end can greatly increase computed frequencies at the upper end. Average computed frequencies for all half records having outliers at the upper or lower end are generally high for the first three outlier techniques and low for the fourth.

It is considered that this is caused primarily by outliers at the lower end. Values observed are as follows:

Average plotting position of maximum flow	0.042
Average computed probability, method a	0.059
Average computed probability, method b	0.050
Average computed probability, method c	0.045
Average computed probability, method d	0.038

Until more discriminatory outlier studies are made, method a appears to be the most logical and justifiable to use.

Results of Zero Flow Testings

Table 14-7 shows the average for all stations of the results of accuracy and consistency tests for the two different zero flow techniques.

These test comparisons indicate that for the favorable methods [log normal (method 2) and log-Pearson Type III with generalized skew (method 7)], technique b is slightly better than a.

Results of Partial-Duration Studies

Results of partial-duration studies are shown in Table 14-8. It can be seen that there is some variation in values obtained for different zones and that the average of all zones is somewhat greater than the theoretical values developed by Langbein. The theoretical values were based on the assumption that a large number of independent (random) events occur each year. If the number of events per year is small, the average values in Table 14-8 would be expected to be smaller than the theoretical values. If the events are not independent such that large events tend to cluster in some years and small events tend to cluster in other years, the average values in Table 14-8 would be expected to be larger than the theoretical values.

It was concluded that values computed for any given region (not necessarily zones as used in this study) should be used for stations in that region after smoothing the values such that they have a constant relation to the Langbein theoretical function.

Expected Probability Adjustment Results

The ratios by which the normal expected probability theoretical adjustment must be multiplied in order to compute average probabilities equal to those observed for each zone are shown in Tables 14-9, 14-10, and 14-11. It will be noted that these vary considerably from zone to zone and for different exceedance intervals. Much of this variation, however, is believed due to vagaries of sampling. Average ratios for the 100-year flood shown on the last line in Table 14-10 were adopted for each distribution for the purpose of comparing accuracy and the various methods. These are as follows:

1. Log-Pearson Type III	2.1
2. Log Normal	0.9
3. Gumbel, MLE	3.4
4. Log Gumbel	-1.2
5. 2-parameter gamma	3.4

6. 3-parameter gamma 2.3
7. Regional log-Pearson Type III 1.1
8. Gumbel, BLIE 5.7

Results of this portion of the study indicate that only the log normal (method 2) and log-Pearson Type III with regional skew (method 7) are free of substantial bias because zero bias should correspond approximately to a coefficient of 1.0 as would be the case if the distribution characteristics do not greatly influence the adjustment factor. The following tabulation for log-Pearson Type III method with regional skew indicates that the theoretical expected probability adjustment for the normal distribution applies approximately for this method. Coefficients shown range around the theoretical value of 1.0 and, with only one exception, do not greatly depart from it in terms of standard-error multiples. It is particularly significant that the most reliable data (the 100-year values) indicate an adjustment factor near 1.0.

Expected Probability Adjustment Ratios for All Zones

Sample	10-Yr		100-Yr		1000-Yr	
Size	Avg.	Std. Err.	Avg.	Std. Err.	Avg.	Std. Err.
5	0.81	0.17	0.94	0.12	1.01	0.13
10	0.60	0.22	1.12	0.20	1.45	0.27
23	0.17	0.27	1.14	0.23	1.68	0.28

Results of Test for Trends and Cycles

Results of lag I autocorrelation studies to test for trends are shown in Table 14-12. It is apparent that there is a tendency toward positive autocorrelation, indicating a tendency for flood years to cluster more than would occur in a completely random process. The t values shown are multiples of the standard error of the lag I correlation coefficient, and it is obvious that extreme correlation coefficients observed are not seriously different from variations that would occur by chance. It is considered that annual peak flows approximate a random process in streams used in this study.

Conclusions

Although split record results were not as definitive as anticipated, there are sufficient clearcut results to support definite recommendations. Conclusions that can be drawn are as follows:

a. Only method 2 (log normal) and method 7 (log-Pearson Type III with regional skew) are not greatly biased in estimating future frequencies.

b. Method 7 gives somewhat more consistent results than method 2.

c. For methods 2 and 7, outlier technique "a" (retaining the outlier as recorded) is more accurate in terms of ratio of computed to observed frequencies than methods that give less weight to outliers.

d. For methods 2 and 7, zero flow technique "b" (discarding zero flows and adjusting computed frequencies) is slightly superior to zero flow technique "a."

e. Streamflows as represented by the 300 stations selected for this study are not substantially autocorrelated; thus, records need not be continuous for use in frequency analysis.

f. Partial-duration frequencies are related to annual event frequencies differently in different regions; thus, empirical regional relationships should be used rather than a single theoretical relationship.

Of particular significance is the conclusion that frequencies computed from theoretical functions in the classical manner must be adjusted to reflect more frequent extreme events if frequencies computed in a great number of cases are to average the same as observed frequencies. For the recommended method, adjustment equal to the theoretical adjustment for estimates made from samples drawn from a normal population is approximately correct.

Of interest from a research standpoint is the finding that split record techniques require more than 300 records of about 50 events each to be definitive. This study showed that random variations in the reserved data obscure the results to greater degree than would be the case if curve-fitting functions could reduce uncertainty to a greater degree than has been possible.

In essence, then, regardless of the methodology employed, substantial uncertainty in frequency estimates from station data will exist, but the log-Pearson type III method with regional skew coefficients will produce unbiased estimates when the adjustment to expected probability is employed, and will reduce uncertainty as much as or more than other methods tested.

Recommendations for Future Study

It is considered that this study is an initial phase of a more comprehensive study that should include

a. Differentiation in the treatment of outliers at the upper and lower ends of a frequency curve;

b. Treatment of sequences composed of different types of events such as flood flows resulting from rainfall and those from snowmelt, or hurricane and nonhurricane floods;

c. Physical explanation for great differences in frequency characteristics among streams in a given region;

d. Development of systematic procedures for regional coordination of flood flow frequency estimates and applications to locations with recorded data as well as to locations without recorded data;

e. Development of procedures for deriving frequency curves for modified basin conditions, such as by urbanization;

f. Development of a step-by-step procedure for deriving frequency curves for locations with various amounts and types of data such that progressively reliable results can be obtained on a consistent basis as the amount of effort expended is increased; and

g. Preparation of a text on flood flow frequency determinations for use in training and practical application.

FIGURE 14-1

GENERALIZED SKEW COEFFICIENTS OF ANNUAL MAXIMUM STREAMFLOW LOGARITHMS

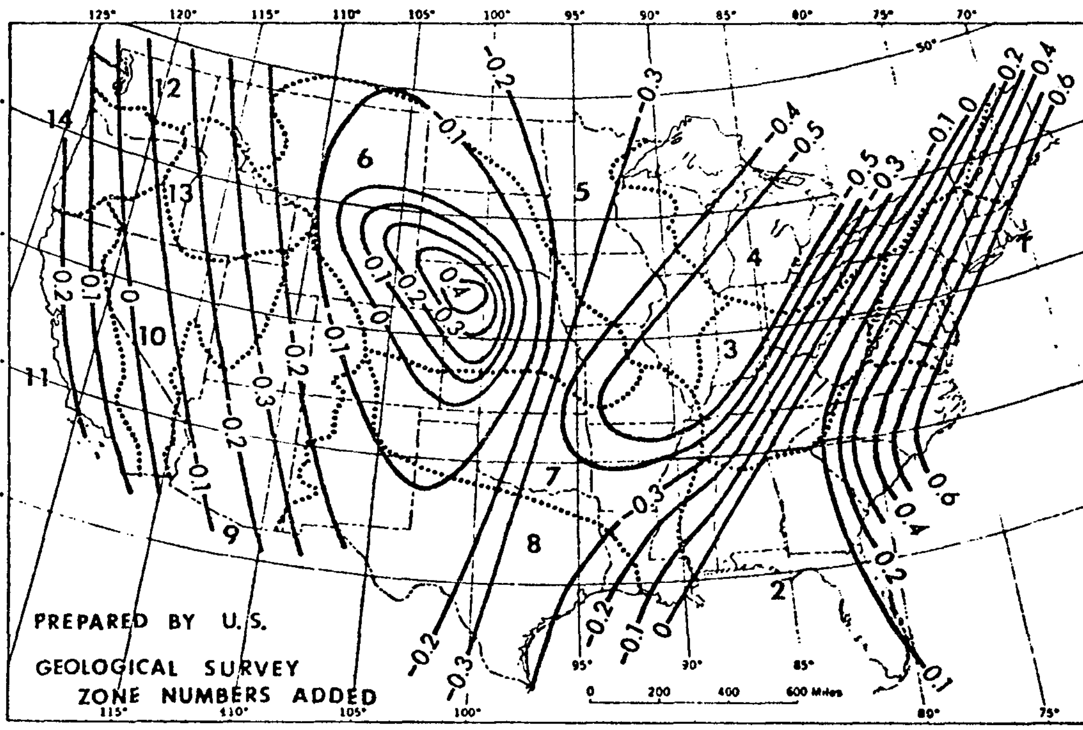
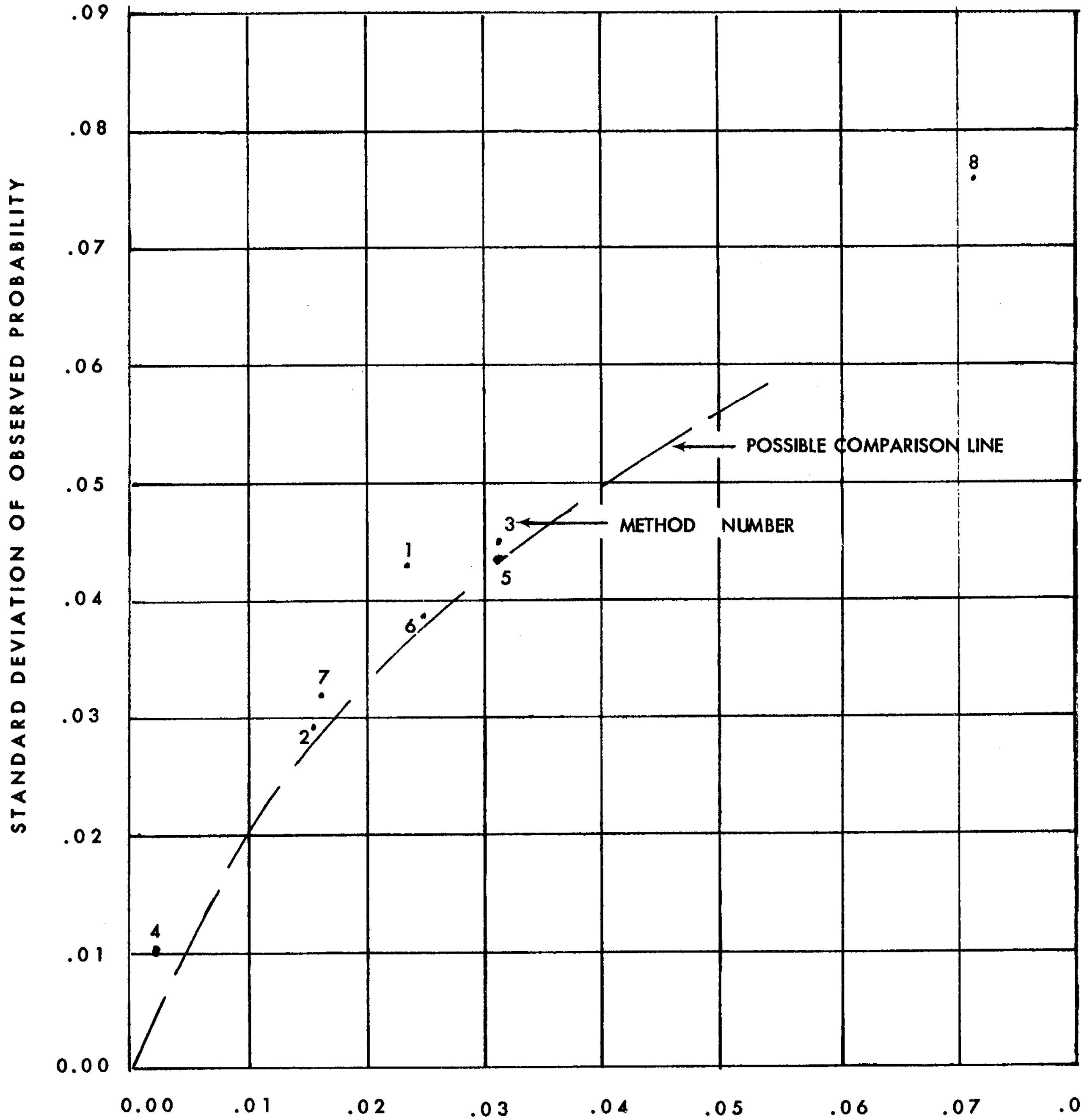


FIGURE 14-2

ACCURACY COMPARISON FOR 0.01 PROBABILITY ESTIMATE (TABLE 14-3)



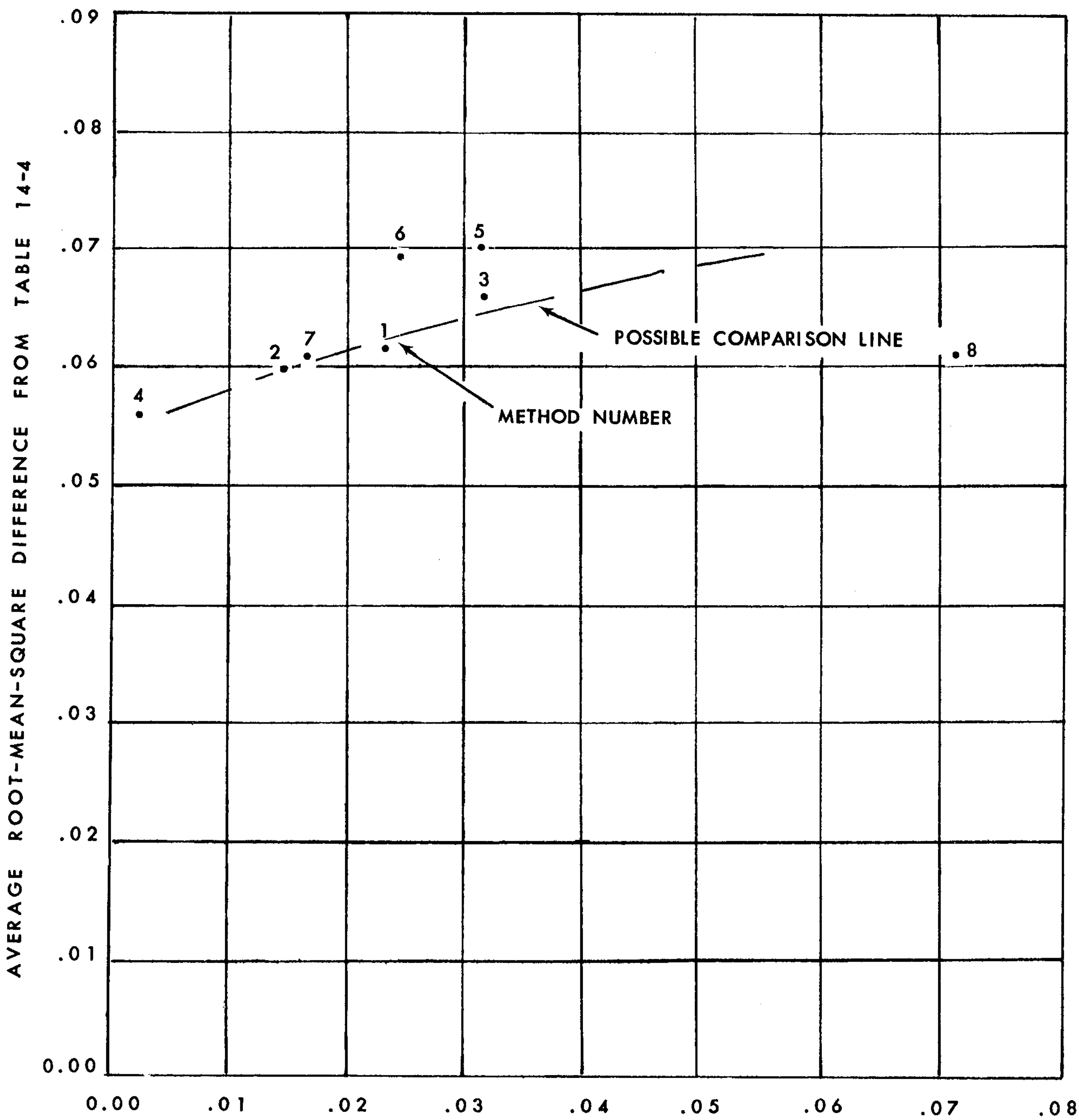
AVERAGE OBSERVED PROBABILITY IN TABLE 14-3

FOR 0.01 COMPUTED PROBABILITY

FIGURE 14-3

ACCURACY COMPARISON FOR MAXIMUM OBSERVED FLOW

(TABLE 14-4, TEST B)



AVERAGE OBSERVED PROBABILITY IN TABLE 14-3

FOR 0.01 COMPUTED PROBABILITY

FIGURE 14-4

CONSISTENCY COMPARISON FOR MAXIMUM OBSERVED FLOW

(TABLE 14-5, TEST A)

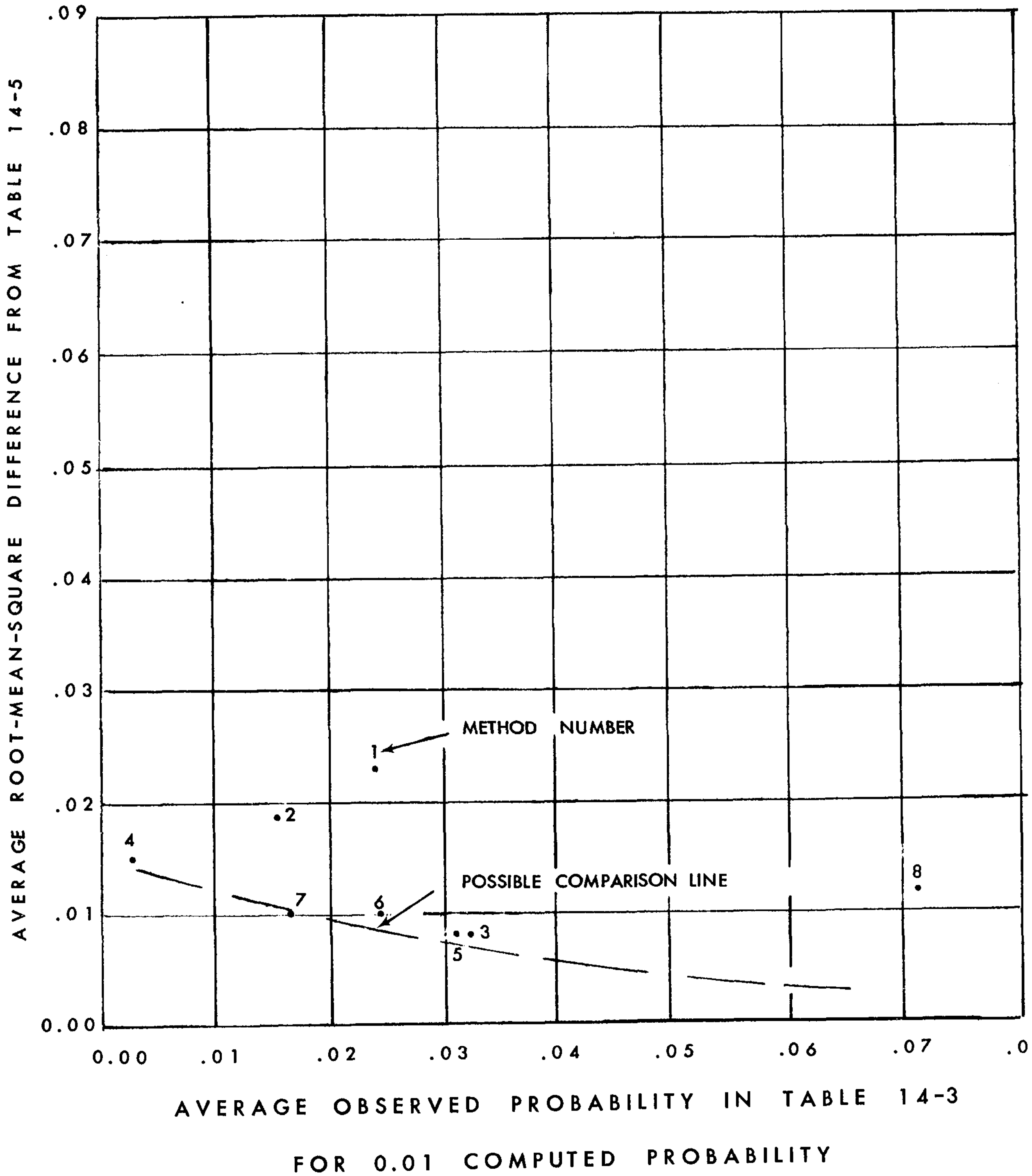


Table 14-1

Numbers of Verification Stations by Zones and Area Size

USGS ZONE	Drainage area category (sq. mi.) 0-25	25-200	200-1000	1000+	Total
1	4	8	10	5	27
2	2	5	12	5	24
3	5	3	16	1	25
4	1	6	8	0	15
5	3	2	14	1	20
6	4	3	13	4	24
7	5	2	12	2	21
8	8	2	11	2	23
9	1	7	8	2	18
10	0	8	4	0	12
11	2	5	6	0	13
12	0	5	9	3	17
13	0	2	10	5	17
14	0	6	8	1	15
15	2	1	0	0	3
16	12	1	0	0	13
*	4	7	1	1	13
Total	53	73	142	32	300

*Zero-flow stations (zones 8, 10 & 11 only)

Table 14-2

NUMBER OF STATIONS WHERE ONE OR MORE OBSERVED FLOOD EVENTS EXCEEDS THE 1000-YR FLOW COMPUTED FROM COMPLETE RECORD

ZONE	STATION-YEARS OF RECORD	METHOD 1	2	3	4	5	6	7	8
1	1414	0	1	8	0	10	7	2	26
2	1074	0	3	9	0	10	7	1	19
3	1223	1	3	7	0	9	8	4	22
4	703	1	2	3	0	3	3	2	12
5	990	2	1	7	0	4	4	0	19
6	1124	0	2	4	0	4	4	1	18
7	852	1	2	5	1	3	4	3	17
8	969	1	1	10	0	3	3	1	19
9	920	3	0	4	0	3	3	1	16
10	636	1	0	2	0	1	1	0	10
11	594	1	1	6	0	4	4	0	11
12	777	0	2	2	0	2	2	2	9
13	911	1	0	1	0	4	2	2	14
14	761	0	0	3	0	4	1	1	15
15	120	0	0	0	0	0	0	0	2
16	637	1	0	4	0	4	3	0	12
*	495	1	0	2	0	0	0	0	12
TOTAL	14,200	14	18	77	1	68	56	20	253

Based on the 14,200 station-years of record, it might be expected that about 14 observed events would exceed the true 1000-year magnitudes.

*Zero-flow stations

Table 14-3

STANDARD DEVIATION COMPARISONS

AVERAGE FOR ZONES 1 TO 16

COMPUTED	METHOD							
PROBABILITY	1	2	3	4	5	6	7	8
	AVERAGE OBSERVED PROBABILITIES							
.001	.0105	.0041	.0109	.0001	.0110	.0092	.0045	.0009
.01	.0232	.0153	.0315	.0023	.0309	.0244	.0170	.0015
.1	.1088	.1007	.1219	.0707	.1152	.1047	.1020	.0029
.5	.5090	.5149	.4576	.6152	.4713	.4950	.5108	.0037
	STANDARD DEVIATION OF OBSERVED PROBABILITIES FOR SPECIFIED COMPUTED PROBABILITIES							
.001	.0290	.0134	.0244	.0025	.0239	.0218	.0150	.0222
.01	.0430	.029	.045	.010	.043	.039	.032	.035
.1	.086	.084	.089	.074	.089	.084	.084	.067
.5	.132	.131	.142	.133	.133	.141	.130	.123

Note: Averages and standard deviations are of observed frequencies in the reserved portion of each record corresponding to computed mangitudes based on half records. Low standard deviations in relation to averages indicate more reliable estimates.

Table 14-4

Evaluation of Alternative Methods

Accuracy Tests b and c, Average Values, All Stations

Test b--Root mean square difference between plotting position and computed probability in other half of record.

	Method							
	1	2	3	4	5	6	7	8
Maximum	.062	.060	.067	.056	.070	.069	.061	.061
Decile	.084	.080	.097	.063	.098	.094	.081	.082
Median	.254	.105	.657	.193	.518	.295	.120	.727

Test c--Root mean square difference bewteen 1.0 and ratio of computed probability of flow in opposite half of record to plotting position. A zero value would indicate a perfect forecast.

	Method							
	1	2	3	4	5	6	7	8
Maximum	.53	.51	.56	.45	.56	.56	.51	.59
Decile	.37	.34	.38	.27	.37	.37	.34	.40
Median	.40	.12	.65	.19	.59	.44	.14	.52

Table 14-5

Evaluation of Alternative Methods

Consistency Tests a and b, Average Values, All Stations

Test a--Root mean square difference between computed probabilities from the two record halves for full record extreme, largest, upper decile and median events. A zero value would indicate perfect consistency.

Event	Method 1	2	3	4	5	6	7	8
Extreme	.003	.006	.001	.010	.001	.002	.003	.002
Maximum	.023	.019	.008	.016	.008	.010	.010	.012
Upper Decile	.072	.047	.043	.025	.037	.033	.025	.048
Median	.119	.076	.072	.047	.049	.045	.041	.131

Test b--Root mean square value of (1.0 minus the ratio of the smaller to the larger computed probabilities from the two record halves) for full record extreme, largest, upper decile and median events. A zero value would indicate perfect consistency.

Event	Method 1	2	3	4	5	6	7	8
Extreme	.87	.54	.46	.26	.39	.35	.29	.75
Maximum	.74	.45	.41	.21	.34	.30	.24	.72
Upper Decile	.50	.32	.31	.16	.24	.21	.17	.58
Median	.21	.14	.12	.10	.08	.08	.07	.24

Table 14-6
Evaluation of Outlier Techniques
Average Values, All Stations

Method

Accuracy Test b

Outlier Technique	1	2	3	4	5	6	7
a	.061	.062	.071	.057	.074	.073	.062
b	.056	.055	.060	.053	.063	.062	.055
c	.052	.050	.054	.048	.057	.055	.051
d	.047	.045	.048	.044	.051	.050	.045

Accuracy Test c

Outlier Technique	1	2	3	4	5	6	7
a	.53	.55	.57	.47	.58	.58	.54
b	.57	.59	.59	.49	.62	.60	.58
c	.58	.61	.60	.52	.64	.63	.60
d	.65	.65	.64	.38	.68	.65	.64

Consistency Test a

Outlier Technique	1	2	3	4	5	6	7
a	.002	.005	.001	.009	.000	.002	.002
b	.002	.004	.001	.008	.000	.002	.002
c	.003	.003	.000	.007	.000	.002	.002
d	.003	.003	.000	.007	.000	.002	.001

Consistency Test b

Outlier Techniques	1	2	3	4	5	6	7
a	.87	.56	.46	.27	.39	.36	.30
b	.86	.56	.45	.28	.38	.35	.30
c	.85	.56	.45	.29	.38	.35	.30
d	.88	.59	.45	.31	.38	.35	.32

A zero value would indicate perfect consistency.

Method 8 includes its unique technique for outliers and was, therefore, not included in these tests.

Table 14-7

Evaluation of Zero Flow Techniques

Average Values, All Stations

Accuracy Test b

Technique	Method 1	2	3	4	5	6	7
a	.057	.057	.059	.057	.062	.055	.059
b	.064	.060	.070	.057	.068	.061	.061

Accuracy Test c

Technique	Method 1	2	3	4	5	6	7
a	.46	.32	.59	.32	.40	.40	.32
b	.51	.30	.59	.30	.40	.41	.31

Consistency Test a

Technique	Method 1	2	3	4	5	6	7
a	.007	.012	.000	.014	.001	.000	.006
b	.007	.008	.000	.012	.000	.001	.004

Consistency Test b

Technique	Method 1	2	3	4	5	6	7
a	.89	.43	.44	.21	.39	.34	.24
b	.86	.43	.44	.19	.40	.38	.23

Method 8 was not tested because logarithms are not used in its fitting computations and therefore zero flows are not a problem.

Table 14-8

Summary of Partial-Duration Ratios

Zone	Partial-duration frequencies for annual-event frequencies of						
	.1	.2	.3	.4	.5	.6	.7
1 (21 sta)	.094	.203	.328	.475	.641	.844	1.10
2 (17 sta)	.093	.209	.353	.517	.759	1.001	1.30
3 (19 sta)	.094	.206	.368	.507	.664	.862	1.18
4 (8 sta)	.095	.218	.341	.535	.702	.903	1.21
5 (17 sta)	.093	.213	.355	.510	.702	.928	1.34
6 (16 sta)	.134	.267	.393	.575	.774	1.008	1.33
7 (9 sta)	.099	.248	.412	.598	.826	1.077	1.42
8 (12 sta)	.082	.211	.343	.525	.803	1.083	1.52
9 (15 sta)	.106	.234	.385	.553	.765	.982	1.26
10 (12 sta)	.108	.248	.410	.588	.776	1.022	1.34
11 (12 sta)	.094	.230	.389	.577	.836	1.138	1.50
12 (12 sta)	.103	.228	.352	.500	.710	.943	1.21
13 (16 sta)	.095	.224	.372	.562	.768	.986	1.30
14 (14 sta)	.100	.226	.371	.532	.709	.929	1.22
15 (3 sta)	.099	.194	.301	.410	.609	.845	1.05
16 (13 sta)	.106	.232	.355	.522	.696	.912	1.27
Average	.099	.243	.366	.532	.733	.964	1.28
Langbein	.105	.223	.356	.510	.693	.917	1.20

Note: Data limited to 226 stations originally selected for the study.

TABLE 14-9

ADJUSTMEMT RATIOS FOR 10-YEAR FLOOD

SAMPLE SIZE	ZONE 1		27 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.54	.38	.76	.29	.82	.57	.28	-1.85
10-YR	.75	.45	1.02	-.27	.95	.37	.34	4.56
1/2-REC	1.21	1.11	2.21	-1.04	2.01	1.01	1.03	4.49
	ZONE 2		24 STATIONS			AVG 1/2 RECORD = 22 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.48	.42	1.06	.64	1.03	.93	.41	-1.85
10-YR	1.01	.94	1.91	.68	1.60	1.31	.80	5.70
1/2-REC	1.33	1.33	2.76	-1.58	1.90	.49	.54	7.14
	ZONE 3		25 STATIONS			AVG 1/2 RECORD = 24 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.41	1.32	1.92	1.02	1.95	1.79	1.40	-1.85
10-YR	1.41	.81	1.80	.00	1.87	.96	1.01	5.39
1/2-REC	.98	.14	1.65	-1.88	1.17	.21	.39	4.80
	ZONE 4		15 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.05	.94	1.20	.85	1.29	1.15	.94	-1.85
10-YR	-.52	-.50	.12	-.85	-.01	-.54	-.45	3.68
1/2-REC	.45	.02	1.63	-3.07	1.63	.46	.25	5.57
	ZONE 5		20 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.55	.35	1.03	.15	.98	.88	.47	-1.85
10-YR	.40	-.03	1.40	-.96	.61	.42	.19	7.37
1/2-REC	.81	-.40	2.91	-3.61	1.42	.99	.67	6.23
	ZONE 6		24 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.80	.36	1.19	.15	1.11	.95	.45	-1.85
10-YR	1.43	.18	2.26	-.98	1.78	.96	.33	5.64
1/2-REC	1.08	-.45	2.94	-3.93	1.94	.07	-.04	6.14
	ZONE 7		21 STATIONS			AVG 1/2 RECORD = 20 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.15	1.19	1.69	1.29	1.62	1.59	1.29	-1.85
10-YR	1.58	1.36	2.34	.12	1.99	1.62	1.57	5.78
1/2-REC	1.97	1.00	2.45	-.74	2.07	.92	1.17	7.11
	ZONE 8		23 STATIONS			AVG 1/2 RECORD = 21 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.89	.79	1.71	.79	1.41	1.36	.79	-1.85
10-YR	-.66	-1.02	.29	-2.04	-.35	-.43	-1.02	4.52
1/2-REC	-.13	-.87	2.28	-3.08	.74	.66	-.87	7.88

TABLE 14-9 CONTINUED

	ZONE 9		18 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.38	1.02	2.05	.96	1.96	1.78	1.10	-1.85
10-YR	1.95	1.54	2.54	.75	2.49	2.22	1.69	5.76
1/2-REC	.45	-.36	.97	-3.36	.45	-.07	-.27	4.07

	ZONE 10		12 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	-.79	-.80	-.41	-.83	-.43	-.43	-.77	-1.85
10-YR	-.03	-.42	.90	-1.16	.71	.35	-.22	4.24
1/2-REC	.08	-1.27	1.24	-5.10	.58	-.27	-1.27	2.97

	ZONE 11		13 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.29	1.21	1.89	1.20	1.93	1.75	1.11	-1.85
10-YR	1.11	1.03	2.21	.04	1.87	1.25	1.03	6.78
1/2-REC	.04	-.23	1.99	-2.93	1.20	1.20	-.23	5.32

	ZONE 12		17 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.34	.73	1.34	.57	1.51	1.03	.80	-1.85
10-YR	.79	.41	.86	-.45	.92	-.44	.57	4.06
1/2-REC	.19	-.31	.54	-2.94	.92	-.35	-.19	2.81

	ZONE 13		17 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.27	1.16	1.65	.96	1.77	1.52	1.19	-1.85
10-YR	.26	.22	.88	-.83	.67	.42	.38	4.60
1/2-REC	-.31	-1.52	.21	-4.89	.17	-.97	-1.12	2.88

	ZONE 14		15 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.72	1.65	2.12	1.61	2.19	2.00	1.65	-1.85
10-YR	2.60	2.50	3.17	1.88	2.82	1.87	2.56	6.80
1/2-REC	.51	.61	1.83	-1.47	1.30	.29	.75	5.22

	ZONE 15		3 STATIONS			AVG 1/2 RECORD = 20 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	2.47	2.47	2.74	2.55	2.66	2.28	2.28	-1.85
10-YR	1.27	1.27	1.58	1.27	1.58	1.58	1.27	2.65
1/2-REC	3.29	3.29	3.29	2.79	3.29	1.90	3.29	6.33

	ZONE 16		13 STATIONS			AVG 1/2 RECORD = 24 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.69	.75	1.03	.66	1.09	1.05	.75	-1.85
10-YR	.58	.42	.83	-.21	.76	.07	.42	4.24
1/2-REC	1.41	.07	1.68	-3.43	1.25	.64	.07	5.29

	ALL ZONES		287 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.94	.79	1.38	.71	1.37	1.21	.81	-1.85
10-YR	.87	.52	1.52	-.29	1.26	.72	.60	5.27
1/2-REC	.77	.04	1.93	-2.66	1.34	.40	.17	5.36

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.1 probability to average observed probabilities in the reserved data. See note table 14-11.

TABLE 14-10
ADJUSTMENT RATIOS FOR 100-YEAR FLOOD

SAMPLE SIZE								
	ZONE 1		27 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.35	1.11	1.27	.39	1.61	1.12	.88	-.25
10-YR	1.50	1.10	2.05	-.25	2.42	1.73	.73	3.42
1/2-REC	2.83	2.84	3.90	-1.06	4.89	3.67	1.66	5.28
	ZONE 2		24 STATIONS			AVG 1/2 RECORD = 22 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.91	.79	1.05	.31	1.27	1.13	.63	-.25
10-YR	1.44	1.40	2.48	.63	2.41	2.07	1.37	5.40
1/2-REC	1.00	1.08	3.69	-.82	2.97	2.46	.14	7.16
	ZONE 3		25 STATIONS			AVG 1/2 RECORD = 24 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.80	1.18	1.76	.41	2.05	1.86	1.29	-.25
10-YR	2.42	1.15	2.43	-.04	2.84	1.62	1.32	4.79
1/2-REC	2.90	1.41	3.36	-1.12	3.71	2.76	2.30	5.53
	ZONE 4		15 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.67	1.48	1.45	.59	2.27	2.02	1.64	-.25
10-YR	.67	.35	.56	-.48	1.07	.46	.42	1.50
1/2-REC	1.86	.48	1.54	-1.15	2.83	.88	1.03	3.81
	ZONE 5		20 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.03	.64	1.37	.24	1.19	1.12	.82	-.25
10-YR	1.22	.57	1.42	-.29	1.27	1.09	.80	5.65
1/2-REC	2.97	.21	4.38	-1.24	2.97	2.39	1.68	7.25
	ZONE 6		24 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.15	.67	1.02	.04	1.17	.88	.76	-.25
10-YR	2.30	.55	1.67	-.27	1.78	1.10	.66	4.43
1/2-REC	1.20	-.23	3.22	-1.24	2.45	.79	.46	5.09
	ZONE 7		21 STATIONS			AVG 1/2 RECORD = 20 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.04	1.07	2.23	.28	2.20	2.16	1.20	-.25
10-YR	1.18	1.09	2.66	-.19	2.54	2.20	1.53	5.40
1/2-REC	3.10	.47	3.92	-.80	2.99	2.29	1.74	8.33
	ZONE 8		23 STATIONS			AVG 1/2 RECORD = 21 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.57	.27	2.08	.01	1.66	1.52	.27	-.25
10-YR	1.30	.14	1.59	-.35	1.15	.93	.14	4.17
1/2-REC	.82	-.32	4.36	-1.13	2.16	2.16	-.32	8.49

TABLE 14-10 CONTINUED

	ZONE 9		18 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.07	1.33	1.90	.72	2.11	2.11	1.50	-.25
10-YR	2.45	2.23	3.21	.90	3.75	3.55	2.57	4.39
1/2-REC	1.07	.39	2.90	-1.72	3.78	2.38	.66	4.49
	ZONE 10		12 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	-.10	-.10	.27	-.25	.29	.29	-.06	-.25
10-YR	.21	-.15	.96	-.59	1.06	.75	.15	2.55
1/2-REC	3.29	-.27	1.63	-1.79	2.42	1.32	-.27	4.40
	ZONE 11		13 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.68	.70	1.79	.11	1.58	1.54	.66	-.25
10-YR	2.41	1.51	4.14	.17	3.76	3.43	1.28	6.64
1/2-REC	.30	.79	5.40	-1.08	3.05	2.43	.50	9.77
	ZONE 12		17 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.81	1.10	1.16	.44	1.56	1.19	1.19	-.25
10-YR	1.99	1.93	1.55	.13	2.27	1.04	2.11	2.60
1/2-REC	3.77	1.65	2.12	-1.33	4.39	2.57	1.86	1.82
	ZONE 13		17 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.63	.87	1.12	.50	1.63	1.26	1.04	-.25
10-YR	.58	.37	1.27	-.28	1.41	1.25	.60	3.28
1/2-REC	1.01	-.07	2.20	-1.81	2.57	1.61	.81	2.69
	ZONE 14		15 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.64	1.44	1.79	.65	2.43	2.21	1.44	-.25
10-YR	2.92	2.22	2.58	.23	3.53	1.98	2.32	5.16
1/2-REC	2.11	2.80	3.76	-1.52	4.40	3.10	2.80	5.37
	ZONE 15		3 STATIONS			AVG 1/2 RECORD = 20 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	2.09	2.24	2.24	1.24	2.76	1.98	1.50	-.25
10-YR	.26	.26	.26	-.59	1.84	1.84	.26	1.72
1/2-REC	1.80	1.80	.93	-1.31	4.37	3.16	.93	.93
	ZONE 16		13 STATIONS			AVG 1/2 RECORD = 24 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.61	.55	.90	.18	1.30	1.22	.62	-.25
10-YR	1.87	1.23	1.63	-.59	1.83	.99	1.33	3.64
1/2-REC	4.21	1.17	3.96	-1.27	4.41	2.90	2.13	4.46
	ALL ZONES		287 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.16	.90	1.45	.32	1.65	1.45	.94	-.25
10-YR	1.64	1.03	2.01	-.07	2.20	1.62	1.12	4.25
1/2-REC	2.12	.87	3.40	-1.23	3.35	2.30	1.14	5.66

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.01 probability to average observed probabilities in the reserved data. See note table 14-11.

TABLE 14-11

ADJUSTMENT RATIOS FOR 1000-YEAR FLOOD

SAMPLE SIZE	ZONE 1		27 STATIONS			AVG 1/2 RECORD = 26 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	2.03	1.10	1.19	.21	2.12	1.44	.85	-.04
10-YR	2.30	.88	2.21	-.14	2.98	1.87	.52	4.06
1/2-REC	5.01	4.13	6.94	-.56	10.11	8.16	1.66	8.54
	ZONE 2		24 STATIONS			AVG 1/2 RECORD = 22 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.31	.83	1.18	.15	1.57	1.35	.68	-.04
10-YR	1.98	2.85	3.85	.64	4.45	3.66	2.07	7.41
1/2-REC	1.93	2.11	4.47	-.45	3.56	3.56	1.58	8.81
	ZONE 3		25 STATIONS			AVG 1/2 RECORD = 24 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	2.42	1.22	2.18	-.01	2.54	2.08	1.24	-.04
10-YR	6.06	2.20	3.06	-.14	3.89	1.82	2.20	7.11
1/2-REC	7.41	2.44	6.77	-.51	7.06	4.82	2.77	11.16
	ZONE 4		15 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.88	1.50	1.46	.30	2.48	2.05	1.63	-.04
10-YR	1.24	.54	.47	-.14	1.13	.36	.71	1.33
1/2-REC	2.86	.80	2.11	-.48	3.60	3.60	2.40	2.81
	ZONE 5		20 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.84	.94	1.36	.49	1.92	1.45	1.32	-.04
10-YR	2.75	.56	2.90	-.14	2.43	2.00	.91	6.02
1/2-REC	5.51	1.39	5.76	-.52	5.89	5.30	3.22	11.70
	ZONE 6		24 STATIONS			AVG 1/2 RECORD = 23 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.91	.61	1.08	.07	1.54	1.13	.79	-.04
10-YR	3.99	.57	1.73	-.06	2.33	1.57	1.12	4.53
1/2-REC	2.88	1.38	2.47	-.48	2.06	1.63	1.24	8.92
	ZONE 7		21 STATIONS			AVG 1/2 RECORD = 20 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	1.19	.82	1.91	.19	2.18	1.89	1.40	-.04
10-YR	2.33	.96	3.58	.13	3.25	2.15	1.53	6.52
1/2-REC	5.99	1.48	5.36	.16	3.90	3.90	2.34	12.51
	ZONE 8		23 STATIONS			AVG 1/2 RECORD = 21 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.83	.09	1.28	-.01	.83	.83	.14	-.04
10-YR	2.79	.42	2.68	-.14	1.78	1.78	.42	5.90
1/2-REC	2.70	.84	7.62	-.41	3.54	3.54	1.32	13.61
	ZONE 9		18 STATIONS			AVG 1/2 RECORD = 25 YRS		
METHOD	1	2	3	4	5	6	7	8
5-YR	.90	1.30	1.37	.49	2.33	2.33	1.55	-.04
10-YR	3.61	3.59	3.22	.42	5.85	5.85	3.90	6.24
1/2-REC	3.59	.59	3.97	-.53	2.68	1.04	1.07	6.92

TABLE 14-11 CONTINUED

ZONE 10		12 STATIONS			AVG 1/2 RECORD = 26 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.02	-.04	.25	-.04	.22	.22	-.04	-.04
10-YR	.44	-.14	.70	-.14	.67	.43	-.14	3.79
1/2-REC	7.21	.27	3.04	-.56	1.95	1.95	.27	4.50
ZONE 11		13 STATIONS			AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.13	1.01	2.15	.20	2.13	1.78	.94	-.04
10-YR	4.31	2.44	5.95	.72	5.06	3.58	1.90	10.41
1/2-REC	1.74	.91	6.38	-.46	5.01	4.24	.91	15.65
ZONE 12		17 STATIONS			AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	2.84	1.22	1.31	.45	2.03	1.51	1.27	-.04
10-YR	4.30	2.17	2.52	.10	4.27	1.40	2.17	3.37
1/2-REC	8.58	.75	.75	-.46	2.20	1.34	.75	4.59
ZONE 13		17 STATIONS			AVG 1/2 RECORD = 26 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.89	1.21	1.11	.32	1.92	1.79	1.21	-.04
10-YR	1.27	.36	1.39	-.14	1.77	1.77	.53	3.56
1/2-REC	4.01	-.57	2.83	-.57	3.65	2.43	.55	4.96
ZONE 14		15 STATIONS			AVG 1/2 RECORD = 25 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.91	1.45	1.56	.47	2.66	2.03	1.45	-.04
10-YR	5.41	2.35	2.81	-.14	4.63	2.17	2.35	5.56
1/2-REC	3.45	1.04	5.12	-.53	9.90	6.99	1.04	6.69
ZONE 15		3 STATIONS			AVG 1/2 RECORD = 20 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	2.67	3.00	2.54	-.04	3.51	1.25	1.77	-.04
10-YR	-.14	-.14	-.14	-.14	1.87	1.87	-.14	-.14
1/2-REC	2.17	2.17	-.38	-.38	6.15	6.15	-.38	-.38
ZONE 16		13 STATIONS			AVG 1/2 RECORD = 24 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.69	.62	1.15	-.04	1.40	1.18	.69	-.04
10-YR	4.02	1.56	3.05	-.14	3.90	1.97	2.01	4.46
1/2-REC	8.74	2.37	7.24	-.51	8.30	6.21	3.76	7.24
ALL ZONES		287 STATIONS			AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.60	.95	1.40	.21	1.89	1.54	1.01	-.04
10-YR	3.13	1.40	2.66	.04	3.22	2.19	1.45	5.36
1/2-REC	4.66	1.49	4.81	-.45	4.99	4.02	1.68	8.80

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.001 probability to average observed probabilities in the reserved data.

Table 14-11 CONTINUED

Values in table 14-11 are obtained as follows:

a. Compute the magnitude corresponding to a given exceedance probability for the best-fit function.

b. Count proportion of values in remainder of record that exceed this magnitude.

c. Subtract the specified probability from b.

d. Compute the Gaussian deviate that would correspond to the specified probability.

e. Compute the expected probability for the given sample size (record length used) and the Gaussian deviate determined in d.

f. Subtract the specified probability from e.

g. Divide f by c.

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