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AN APPROACH TO THE SELECTION OF A STREAMFLOW BASE PERIOD

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Abstract

Wyoming streamflow records were examined to determine if base periods exist. A base period is a shorter period of record which exhibits the same statistical characteristics as the longer record and can therefore be used in simplifying the study of water resource projects.

It was determined that, for twenty-three representative streamflow gaging stations selected, the twenty-year period 1948-1968 provides sufficient information for use as a base period.

Key Words: Statistics; streamflow; base period; synthetic hydrology; correlation; sample size; residual mass curves; computer analysis

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

CHAPTER I

INTRODUCTION

Objective

The objective of the study reported on herein is to determine if base periods exist for streamflow records in Wyoming. A base period is a selected portion of streamflow record which adequately represents the characteristics of data obtained from a longer period of record. Statistics such as the mean, standard deviation, and coefficient of variation for the base period should be reasonably similar to those calculated for the long term record.

Purpose

In any water resource investigation, it is necessary to assume that the past is an indicator of the future. Standard practice has been to use all available streamflow records for determining the adequacy of a water resource project. An irrigation or power project is presumed to have existed throughout the period for which streamflow data are available or can be estimated. The assumption is made that by using a long period of record:

- enough variation will be encountered to properly test the project.

It is of interest to the hydrologist to know how long streamflow records need to be before certain flow characteristics can be determined with assurance. If a base period for streamflow data for Wyoming streams exists, the task of studying the feasibility of a project would be considerably simplified, while yielding results comparable to using the historic period of record.

The State of Wyoming has instituted a statewide water planning program to provide the information required to utilize all available water as efficiently and effectively as possible. A major portion of the planning effort is an inventory of available water resources. Because the streamflow records are of varying length, the planning process could be facilitated if a period of record, available at many stations, could be selected to establish the base.

The reasons for undertaking the research discussed herein are:

1. For hydrologic work, streamflow values based upon continuously recorded water level data are more accurate and reliable than those obtained from daily stage observations. Over the last twenty or thirty years, continuous recording devices have become standard for obtaining streamflow data. Therefore, if a base period can be selected which utilizes the more recent records, it would have the advantage of the most reliable data.

2. To meet demands for more knowledge about the water resources of the State, the number of streams being gaged has increased significantly during the past few decades. Consequently, if it can be shown that a base period can be selected from these years, the problem of reconstructing flows for several years prior to the record would be obviated.

3. The hydrologist is able to more reliably reconstruct, to present modified flow,* records for more recent data. Accordingly, if a base period can be selected from the more recent data, the accuracy of modifying past records to present conditions is improved.

Data

Those streamflow records for Wyoming streams that will be utilized for this study:

- contain at least twenty years of continuous record;
- were in operation as of water year 1968;
- are generally subjected to a minimum of regulation or diversion, so that the measured streamflow represents nearly virgin flow conditions, without extensive reconstruction;
- are from all areas of the State and from streams with different quantities of discharge.

Streamflow refers to the measured flow of a stream, and includes the effects of regulation and/or diversion activities above the gage site. The streamflow is expressed as a quantity of water for a unit of time, the volume of flow for a water year (1 October to 30 September the following year) is conveniently expressed in terms of acre-feet.**

Data analyzed in this study will be as stored and utilized by the Surface Water System of the Wyoming Water Resources Research Institute (7, 8).***

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*Present modified flow is obtained by subtracting present consumptive use from virgin flow.

**An acre-foot is the quantity of water to cover one acre to a depth of one foot, or 43,560 cubic feet.

***Numbers refer to Selected References. Page numbers are given where applicable.

A map of the State of Wyoming, Figure 1, shows the location of gaging stations selected for this study. More complete data, including station name, may be found in Appendix II, Table X.

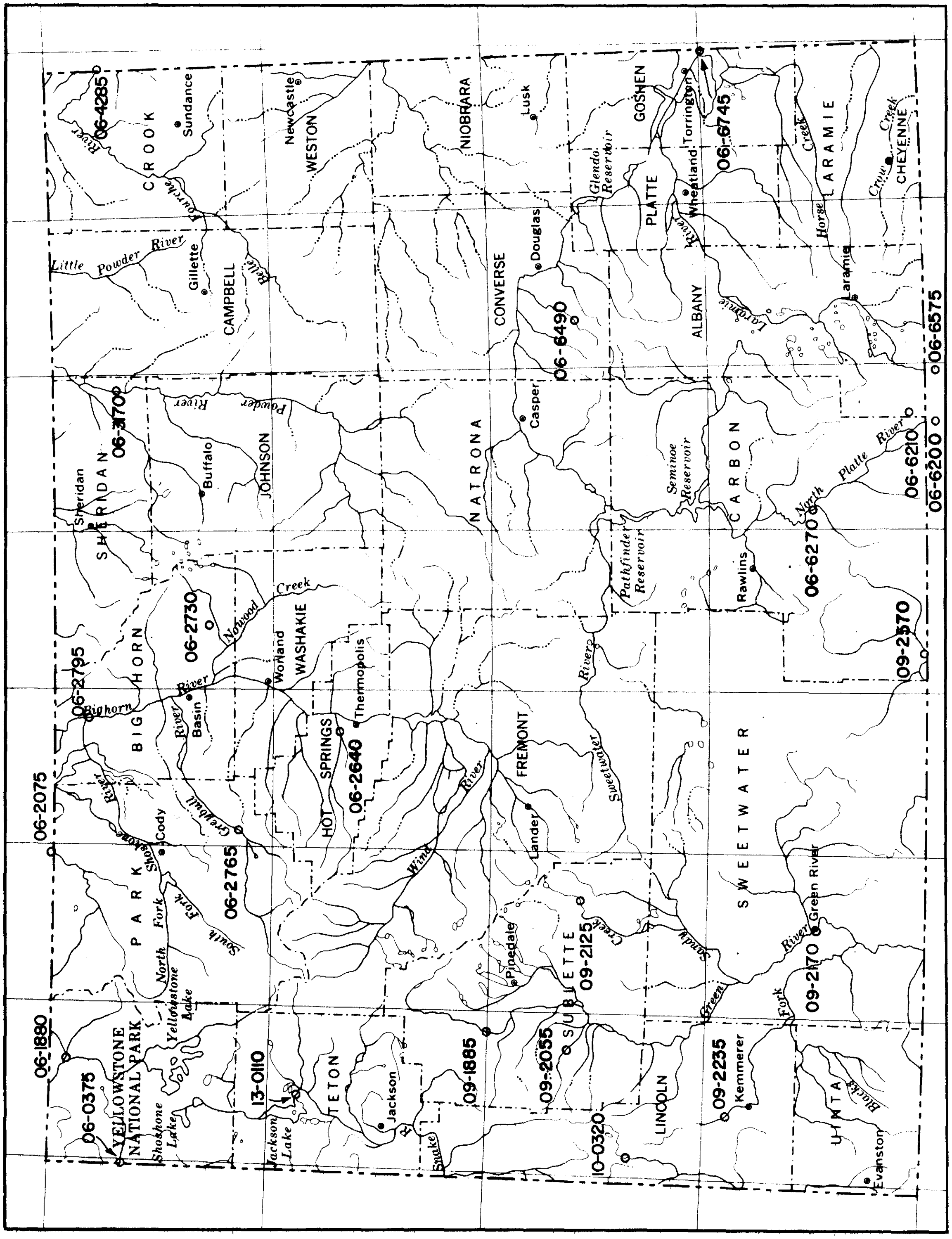


Figure 1. MAP OF WYOMING SHOWING LOCATION OF STREAMFLOW GAGING STATIONS USED IN STUDY.

CHAPTER II

RELATED RESEARCH

Introduction

There appears to have been little research in the area of determining a base period. This chapter will provide background information on research, looking in the opposite direction, relative to the study of the quantity of water available in the State.

Instead of attempting to select a short period of record which would adequately represent a longer period, some investigators have studied methods of extending the available records. The methods of obtaining long periods of record might be conveniently divided into two broad areas, synthetic hydrology and correlation. Synthetic hydrology is a relatively new field of study, whereas correlation techniques have been in use much longer.

Synthetic Hydrology

Benson and Matalas (3, p. 931) describe synthetic hydrology as the generation of a long series of events based on statistical parameters of a short sample. Brittan states that a long record, generated by some process, is considered just as likely to have occurred, and ". . . would be impossible to distinguish . . . by the usual statistical tests of significance . . ." from an actual sequence of data (4, p. 1). With the advent of modern computers, "A planner may simulate a system and investigate alternative plans in greater detail than previously possible." (17, p. 937)

Benson and Matalas (3) consider all long streamflow records in a region, and compute for each the mean, standard deviation, skew coefficient and first-order serial correlations. These statistics are considered dependent variables. Independent variables are the relative physical and climatological characteristics, including annual snowfall, drainage area, slope of main channel, etc. They related, separately, mean and standard deviation of monthly and annual flows to various combinations of six independent variables. Their application of regression techniques resulted in predictive errors ranging from 8 percent to 45 percent (3, p. 933). The author's proposal, then, is to use "statistics derived from (the) generalized relationships with hydrolgic characteristics of the drainage basin," (3, p. 932) rather than sample statistics derived solely from the data, for synthesizing hydrologic series.

Matalas (17, p. 937) describes mathematical generating models which could be applied to data to obtain synthetic hydrology, although he warns of obtaining biased estimates, because

> The parameters determined from the historic sequences are sample estimates of their respective population values, but the sample values act as population values for the synthetic sequences. Because the sample estimates are unlikely to equal their respective population values, the estimates are operationally biased. (17, p. 944)

The study of synthetic hydrology has not been confined to hydrologists--

statisticians, economists, and mathematicians have made important contributions also. References 3, 4, 13, 16, 17, 19 and 22 are representative of the work being done in this field. All of these studies are less than ten years old, and most are less than five.

Correlation

Whereas synthetic hydrology refers to mathematically generated sequences of data, longer periods of record may also be obtained through various statistical correlation and regression processes.

Statistics texts define regression as the estimation of one variable (dependent) from one or more related variables (independent), and correlation as the degree of relationship between variables. Correlation and regression, though closely related, have different interpretations. "Correlation . . . measures association between X and Y while (regression) measures the size of change in Y, which can be predicted when a unit change is made in X." (6, p. 35)

One major purpose of correlation and regression in hydrology is to fill in missing periods of record at one station based upon relationships established through correlating records for concurrent periods at a longer station. The hydrologist does not attempt a correlation without first investigating certain factors which may affect the relationship. Searcy (23, p. 70) indicates the most important factor is the "bond of climate" for correlating gaging-station records, and if this bond is missing, as might be expected between mountain and desert streams, "a useable correlation is impossible". Other factors to be considered would be distance between stations, relative size of the drainage basins, and surficial geology. Searcy cautions that one should base relationships between streams on hydrology, and use statistics to express and organize the results. References 1, 2, 5, 9, 18, and 23 provide more insight into the applications and problems of correlation analysis in hydrological problems.

CHAPTER III

METHODS OF ANALYSIS

Sample Size

Background Theory

The problem of length of record required to meet various planning needs is basically one of sample size. Hydrologic events may be treated as statistical variables, with a set of observations considered a sample from the population. For the purpose of this paper, an observation is the total streamflow in acre-feet during the water year, and the sample size is considered to be the period of record of annual observations.

The sample mean

$$\bar{x} = \frac{\Sigma (x_i)}{n} \tag{1}$$

is a common central measure of location of a set of observed data, and is the algebraic sum of the individual observations, x_i divided by the number of observations, n. A measure of the dispersion of data is the standard deviation,

$$s = \left[\Sigma (x_i - \bar{x})^2/n-1\right]^{\frac{1}{2}} \tag{2}$$

expressed as the positive square root of the summation of the deviations of each observation from the mean, divided by the sample size n less one, and expressed in the same units as $\bar{x}$. A measure of relative dispersion is the coefficient of variation,

$$CV = \frac{s}{\bar{x}} \tag{3}$$

which is dimensionless and can be expressed as a percentage.

When making inferences about populations from samples, one may make use of the standard normal distribution. However, for small samples, when $n < 30$, the normal distribution may not hold exactly and the t-distribution is used. The t-distribution may then be used for all sized sample populations, as its values approach those of the standard normal distribution for large n. To test hypotheses concerning the mean of a sample, the t-statistic is computed by

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} \qquad (4)$$

where μ is the population mean. This number is compared with an appropriate tabular value of t for the desired probability level and $n - 1$ degrees of freedom. The hypothesis that $\bar{x}$ equalled a certain value, for example, would be rejected if the computed t value is greater than the tabular value.

A confidence interval (C.I.) may be placed on the true value of μ. The relationship

$$P\left[\bar{x} - ts/\sqrt{n} < \mu < \bar{x} + ts/\sqrt{n}\right] = 0.95 \qquad (5)$$

is read that the probability that the true population mean is covered by the interval $\bar{x} \pm ts/\sqrt{n}$ is equal to 0.95. The error of the estimate is then $\leq ts/\sqrt{n}$. An error factor, p, may be introduced by requiring that

$$ts/\sqrt{n} \leq p\bar{x} \qquad (6)$$

which means requiring the error to be less than or equal to $.25\bar{x}$, for example.

Solving equation (6) for n yields

$$n > \frac{t^2 \frac{s^2}{\bar{x}^2}}{p^2} \quad \text{or} \quad n > \frac{t^2 \; CV^{\;2}}{p^2} \qquad (7)$$

A minimum value of n can be found using

$$n = \frac{t^2 \; CV^{\;2}}{p^2} \qquad (8)$$

For example, for a particular stream the following data are assumed:

$\bar{x}$ = 10,000 acre-feet (long term mean);

s = 5,000 acre-feet;

t = 2.093 assuming 20 years of record and 95% certainty; and

p = .25 accuracy;

then one would need at least 17.52 years of record to be 95% confident of being within 25% of the long term mean (L.T.M.).

<u>Procedure</u>

The ratio $\frac{s^2}{\bar{x}^2}$ in equation (8) or $\left[\frac{s}{\bar{x}}\right]^2$, can be synthesized to obtain hypothetical coefficients of variation (equation (3)). For ease of computation, CV values of .10 to .90 were used. Values of t were selected for various probabilities, from 50 percent to 99 percent for "periods of record" from 5 to 60 years. Accuracy values of p were varied from .10 to .50, the requirement that the estimate for a given t-value was to be within p of the mean value. Using one CV value, a table of minimum periods can be made by varying p and t, where t is based on a "period of record".

Results

The results are presented for various "periods of record" in Appendix I. The tables are ordered by "period of record", from five years to sixty. Values of p (accuracy) are in the left-hand vertical column, and values of t were derived from tabular values corresponding to the certainty percentage (across the top row) and period of record. The nine small tables represent the calculated sample sizes, for various CV values, to obtain the desired accuracy and certainty given the period of record designated.

Several observations can be made by inspection of the tables:

- reasonable estimates of sample mean from very short periods of record are difficult;
- to be very accurate and very confident, large sample sizes are generally required;
- the intuitive desire to use long periods of record to provide better estimates is demonstrated.

Wyoming streamflow records are analyzed in a similar manner, and the results are presented in Appendix II. The data are arranged in order by basin and station number. Elevation of gage, drainage area and length of continuous record are listed; as well as calculated values of the mean, standard deviation and coefficient of variation. An abbreviated table, similar to that presented in Appendix I and described above, was calculated for each station.

The tabular values for the actual data relate very closely to the calculated values when the CV and period of record are nearly equal. The actual data, in effect, fill in the gaps where synthetic values were used.

Minimum Period

Introduction and Procedure

Given a streamflow record, a confidence interval

$$C.I. = \bar{x} \pm \frac{ts}{\sqrt{n}} \qquad (9)$$

may be placed on the mean annual flow for various periods of time, n. The value of the mean for longer periods of time from the beginning approaches the long term value, and the two coincide on the last value. In a similar manner, the width of the confidence interval (C.I.) decreases quite rapidly, reaching a more or less stable state. The rapidity of convergence (stabilization) depends upon the mean of the period under study, and its associated standard deviation. The mean and standard deviation are computed as described in the preceding section, where all terms are based upon the number of years, n, in the group being studied. The appropriate t value is selected from tables according to the probability level desired, and n. The term $\frac{ts}{\sqrt{n}}$ from equation (9) can be considered the error of the mean. This value is minimized as the standard deviation becomes smaller, as the length of record, n, increases, and as more stringent certainty is imposed. The t value for a given probability approaches the normal distribution values after n = 30, and so has little over-all effect except for very small sizes. The principal effect of t depends upon the desired probability, that is, a C.I. for the same s and n is more narrow for a 50 percent probability than for a 95 percent probability.

Results

By plotting $\frac{\text{error of the mean}}{\text{long term mean}}$ vs years, the convergence and stabilization may be observed. For convenience, the left-hand part of the above relationship is shortened to "error/L.T.M." when presented in graphs, and will be referred to as possible error.

The upper part of Figure 2, Station 06-6490, LaPrele Creek near Douglas, Wyoming, shows the relationship of the width of the 95 percent and 50 percent confidence intervals with time for one gaging station. In this example, the 50 percent intervals seem to be reasonably uniform over the length of record; the 95 percent intervals converge quite rapidly and seem to stabilize also, and over an increased length of time.

The lower part of Figure 2 shows the possible error relationship for the same gaging station. The upper line shows the behavior of the error based upon 95 percent confidence, and the lower line based upon 50 percent confidence. This type of plot enables one to more easily observe the behavior of the width of the confidence interval with time.

In this example, Figure 2, the period of record is 49 years. After about 30 years of record, the possible error approaches .05 for 50 percent confidence, and is less than about .15 for 95 percent confidence.

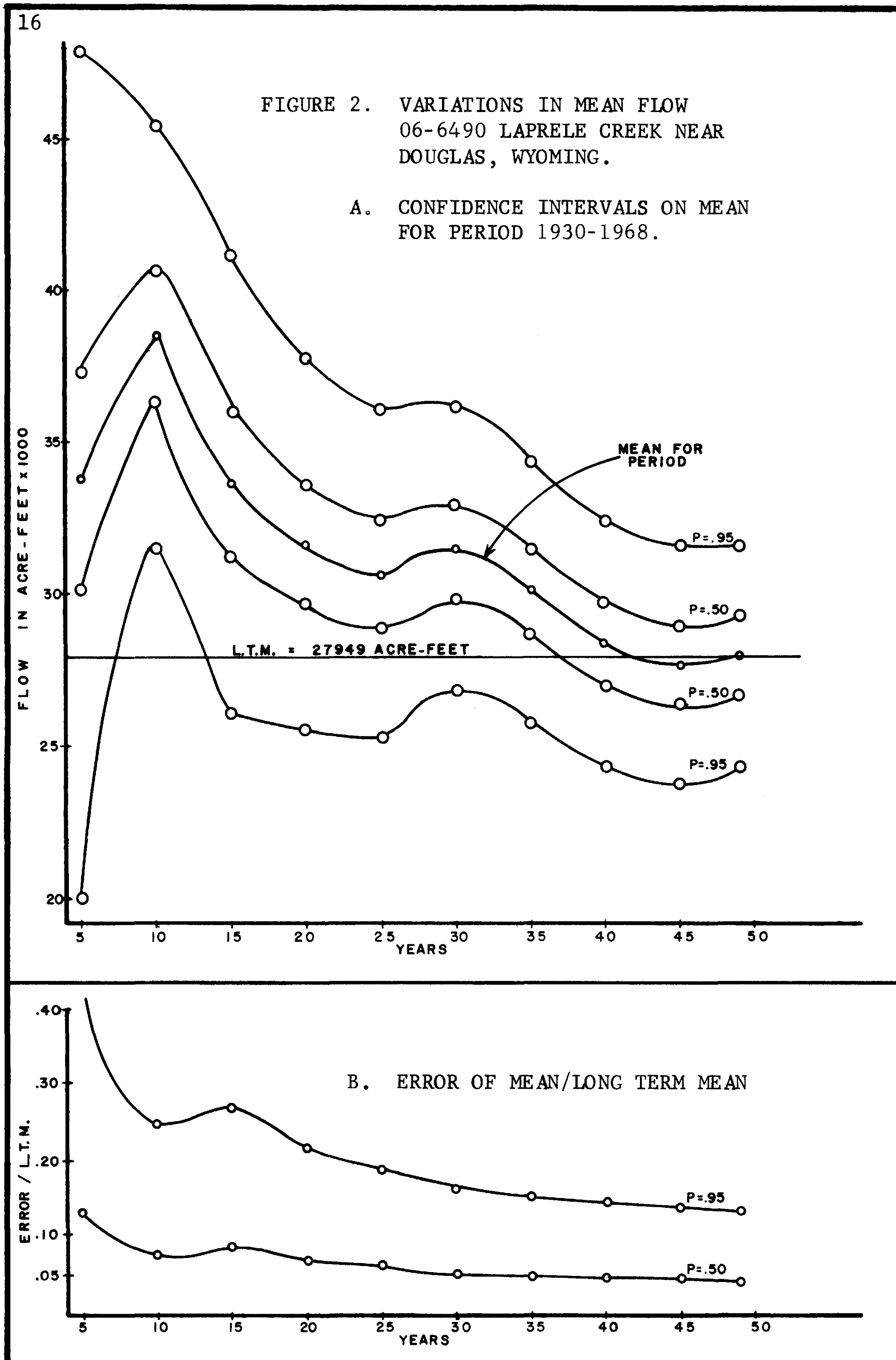


FIGURE 2. VARIATIONS IN MEAN FLOW
06-6490 LAPRELE CREEK NEAR
DOUGLAS, WYOMING.
A. CONFIDENCE INTERVALS ON MEAN
FOR PERIOD 1930-1968.
MEAN FOR PERIOD
P=.95
P=.50
P=.50
P=.95
L.T.M. = 27949 ACRE-FEET
FLOW IN ACRE-FEET x 1000
20
25
30
35
40
45
5
10
15
20
25
30
35
40
45
50
YEARS
B. ERROR OF MEAN/LONG TERM MEAN
ERROR / L.T.M.
.40
.30
.20
.10
.05
P=.95
P=.50
5
10
15
20
25
30
35
40
45
50
YEARS

Based on these data, one could then make the statement that the approximation of the long term mean for this station improves little after 30 years of record have been analyzed in the above manner. Benham (2, p. 118) in a similar study, concludes that 15 years is sufficient, based on his study of two rivers in New Zealand.

The upper graph for each gaging station studied, as presented in Appendix III, shows the possible error relationship; a more detailed discussion of results of this and following analyses will be given in Chapter IV.

An Alternate Method

Introduction

It became evident to the writer that the two approaches discussed in the preceding sections do not adequately lead to a definite base period selection. The first method, that of determining sample size, only leads to the conclusion that any n - year period from within the period of record provides certain accuracy and probability when applied to the long term mean. The second method indicates how much record, from the beginning of record, is needed to approach a certain probability of being within p - percent of the long term mean.

Although long periods of record, or in effect large sample sizes, provide statistically more reliable estimates, it seems reasonable to assume that the more recent past is a better indicator of the stability of estimates. Using recent records to make inferences on the long term mean is intuitively better because

- recent records are determined from recording devices operating on a continuous basis, whereas older records were based on infrequent staff gage readings; and

- consumptive use depletions have been more controlled and accountable in recent years, providing a more uniform record.

The method described in this section provides a more reasonable procedure to solving the problem of selecting a streamflow base period.

Procedure

The error of the mean, $\frac{ts}{\sqrt{n}}$ is computed for five-year cummulative periods working backwards from the 1968 water year. The relationship, $\frac{\text{error of the mean}}{\text{long term mean}}$ vs years is established following a procedure similar to that of the previous section, and is plotted in the lower graph, Figure 3. This graph is presented with years increasing from right to left ("backward"), to indicate that the relationship is working from the present to the past, in contrast to the graph above it, which is from past to present ("forward").

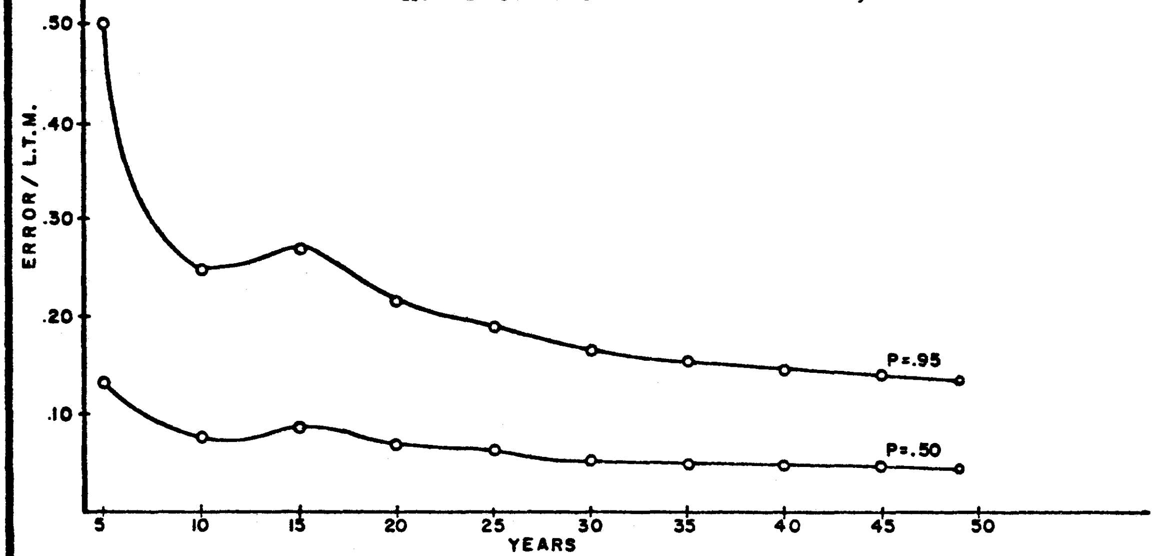
Results

The "backward" possible error is plotted against time in the lower half of Figure 3, using the same gaging station as in the previous example. The "forward" data are presented in the upper graph.

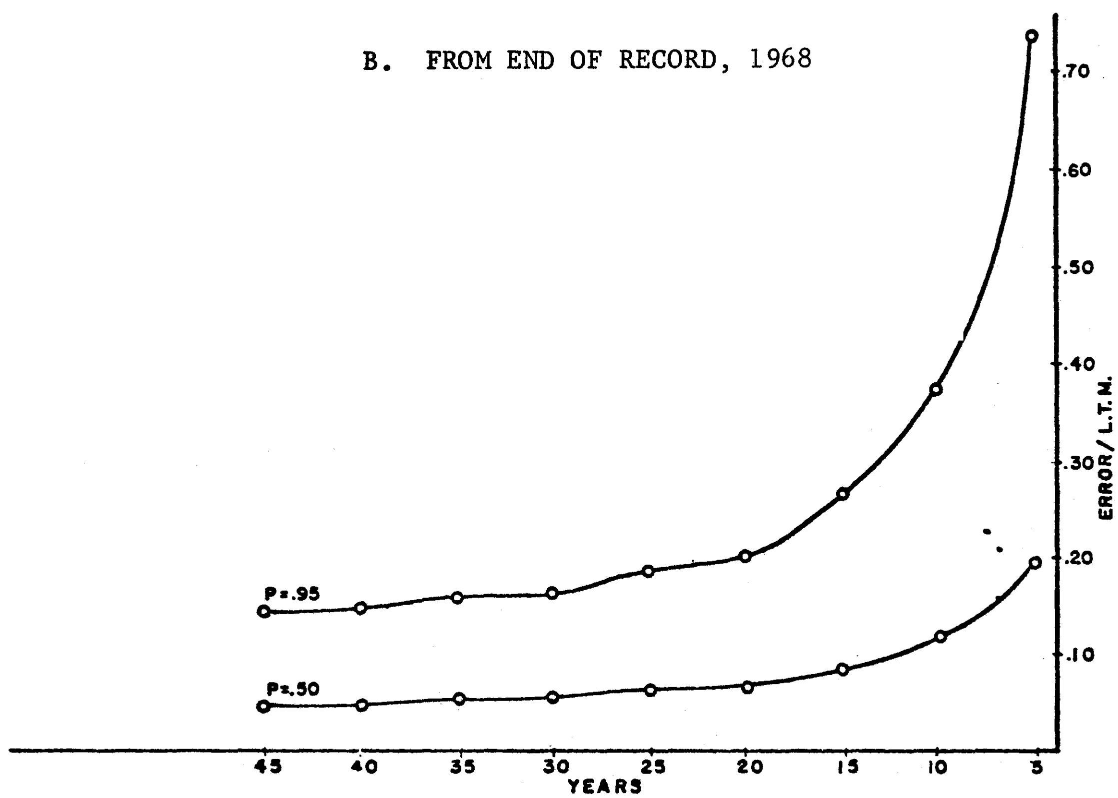
In this example, about 30 years is required for the possible error to reach .05 for 50 percent confidence and .15 for 95 percent confidence. Based upon these data, one could then assume that the period of record from about 1938 to present provides essentially the same information as the whole period, and that knowledge of the period 1920 to 1938 adds

FIGURE 3. ERROR OF MEAN/LONG TERM MEAN
06-6490 LAPRELE CREEK NEAR
DOUGLAS, WYOMING.

A. FROM BEGINNING OF RECORD, 1920



B. FROM END OF RECORD, 1968



little additional information, other than to establish the long term mean.

The length of time required, using either method, for the error of the mean to reach acceptable values is quite dependent upon the risk, or possible error, one is willing to accept. Appendix III presents both the "forward" and "backward" analyses for each of the gaging stations studied. A more detailed discussion of the comparison of these methods will be presented in Chapter IV.

Residual Mass Curve

Theory

The mass curve is the summation of the hydrograph over a period of time. When plotted on coordinate paper, the ordinate represents the total volume of streamflow up to any time point on the abscissa. Over a period of many years, long term trends in the streamflow are visible. The slope of the curve at a point is steeper when streamflow is great, and flatter when streamflow is low. The slope of a straight line joining any two points on the curve represents the uniform flow which would produce the same increment in volume as the actual, curved line. In fact, a straight line joining the first and last point on the curve represents the mean flow of the period.

A modification of this last idea results in the residual mass curve. This curve is obtained by accumulating the departures from the long term mean (14, p. 30). Using annual streamflow values, the second plotted value (the first is zero) would be obtained by finding the difference between the first annual value and the mean; the third value is the accumulation of the differences of the first two annual values; and so on. This curve may or may not cross the zero value with time, but it will always end at zero. Like the mass curve, a straight line between any two points represents an average streamflow. Furthermore, periods of time between zero crossings indicate the average streamflow, the same as do the first and last points.

Procedure

Tabular residual mass curves were prepared for the selected streams under study. In the tabulation, values of the residual mass curve which were above the zero line were written in black, and those below, written in red. A property of the residual mass curve is that an up-slope indicates relatively increasing flow, whether above or below the zero or mean line, and a down-slope represents a decrease in flow. These incremental variations were so indicated in the tabulation by orange or blue indicating loss or gain. The resulting red-black and orange-blue patterns were studied visually to determine if patterns existed.

A variation of the above method was tried, to determine if similar lengths of record produced any noticeable patterns. Residual mass curve tabulations were prepared for groups of stations. Several years were eliminated from some stations, and new means calculated, so that all stations being compared were based on the same period of years. The residual mass curves were calculated, and tabulated using the red-black and orange-blue coding to aid in visual interpretation.

Results

The first method, using all stations over their respective entire periods of record, yielded no definite results. However, the only streams which did exhibit slight similarity in either the red-black or orange-blue coding were those of gaging-stations on the same stream or that headed in the same small area.

To apply the second method, the station with the longest record, 13-0110, was shortened by twenty years. Four other stations were arbitrarily shortened, but by fewer numbers of years, and one with 44 years was used "as is". All six stations were set up in the color-coded tabulation. Examination of the patterns indicated no visual similarities in either the red-black or orange-blue patterns. It could be determined, however, that for the water years 1928 and 1952 the incremental change was blue, or that all six stations had an increase in flow over the previous year. For 1939, 1940, and 1960, the opposite was true. The red-black pattern was not consistent for each year, when orange or blue was. In this and other trials, zero crossings did not occur simultaneously, indicating no corresponding shorter periods of average streamflow.

CHAPTER IV

ANALYSIS OF RESULTS

Discussion of Data

Presented in Appendix IV are excerpts from Water Resources Data for Wyoming (24) which give a description of each station used in the study, including location, drainage area, records available, type and history of gages, and general remarks. Information concerning the accuracy of the data, as well as conditions affecting the natural flow at the gaging station, is given as "Remarks".

As stated in Chapter I, streamflow data were selected for study using several criteria. The most difficult requirement to satisfy was that of upstream regulation and diversion. Because it was desired to study some obviously important stations, some records were used even though the flow has been subjected to considerable modification. Streams that are heavily regulated include:

- 06-2795 Bighorn River at Kane,
- 06-4285 Belle Fourche River at Wyoming-South Dakota State Line,
- 06-6210 Douglas Creek near Foxpark,
- 06-6745 North Platte River at Wyoming-Nebraska State Line,
- 09-2170 Green River near Green River,
- 09-2235 Hams Fork near Frontier, and
- 13-0110 Snake River at Moran.

Streamflow gaging stations which have significant irrigation diversion upstream, but which are not completely regulated by reservoirs include:

'06-2640 Owl Creek near Thermopolis,
'06-2765 Greybull River at Meeteetse,
'06-6200 North Platte River near Northgate, Colorado,
'06-6270 North Platte River near Saratoga, Wyoming,
'06-6490 La Prele Creek near Douglas, and
'09-2055 North Piney Creek near Mason.

Significant irrigation diversion is presumed when possible daily irrigation requirements were greater than one-half the mean daily flow during the growing season. The irrigation requirement was estimated on the basis of one CFS diversion right for 70 acres of irrigated land. The information in Appendix IV was used in determining the irrigated lands.

Discussion of Methods Used

Residual Mass Curve

Of the four methods considered in the preceding chapter, the residual mass curve technique proved to be the least usable for determining a base period. Tabular residual mass curves were calculated from the annual flow values. Annual, accumulated values that were above zero were color coded black, those below were red, indicating overall above or below normal flow conditions. To observe the incremental annual variation, that is, whether the flow was greater or less than the previous annual value, incremental annual variations were color coded blue or orange, indicating gain or loss.

The observation from the color coding process was that very few of the stations studied showed similarities. Those that indicated some similarity for those portions of the record which were above or below (black-red), the mean flow were either:

- located on the same stream;
- in the same tributary system; or
- headed in the same relatively small area.

A slightly greater degree of similarity was indicated when comparing those years when the flows were greater or less than average (blue-orange).

Several streamflow records were truncated to provide groups of streams with the "same" period of record. These groups were examined using both color coding methods. Little additional information was obtained pertaining to the existence of common periods of record.

Sample Size

The sample size determination is useful only for estimating how many years of record are required, from a longer period, to be within certain limits of the long term mean. The advantage of this method is that the possibility of using a shorter period can be assessed with a certain accuracy and confidence when tables such as those in Appendix I are available. The coefficient of variation of the data is a good initial indicator of whether fewer years can be used. That is, a high CV precludes very small possible error figures, while a low CV results in low possible error values quite early in the period of record. This can be verified by using the graphs of Appendix III.

The method of determining sample size can be used within the tabular limitations to gain a quick insight as to whether the period of record may be shortened. This tabular value is actually only a first approximation, because it is necessary to assume an n value in order to enter the t-distribution table. If n turns out to be "widely different" from the first guess, a new value should be taken from the t-distribution table and n recomputed (15, p. 186).

Minimum Period and an Alternate Method

A measure of the behavior of a confidence interval with time may be obtained by dividing the error of the mean for a period by the long term mean and is called the possible error. The error of the mean is determined by $\frac{ts}{\sqrt{n}}$, and is one-half the width of the confidence interval. The graphical presentation of the possible error using all data from the period of record is included in Appendix III, Figures 4 through 26, for each gaging station studied. Tables XI and XII present the data used for plotting the graphs.

In selecting the incremental time period to use for calculating the possible error, careful consideration was given to periods other than five years. Periods shorter than five years tended to show quite a bit of fluctuation, and longer periods tended to become quite smoothed, over the length of record. By using five-year periods, a reasonable compromise was reached, and all graphs and tabulations have some degree of uniformity.

The p values of .50 and .95, representing the confidence that the value being calculated lies between certain limits (21, p. 91) were chosen to provide a good contrast in range. Any desired p-value may be selected, and the resulting curve will lie between the .50 and .95 curves, or above the .95 if very high confidence is desired.

Discussion of Results

Results are presented for the analysis of streamflow records using the Alternate Method as previously described. An examination of the annual flow series for all stations indicated that, for the period 1950-1961, the annual flows were less than the long term mean. A twenty-year period, 1948-1968, was selected as a trial base period, and all stations will be compared on this basis. Longer periods will be considered where it appears that a considerable increase in accuracy would be obtained by the addition of one or more five-year periods.

Yellowstone Park Area

The three streams in the vicinity of Yellowstone Park,

·06-0375 Madison River near West Yellowstone, Montana,
·06-1880 Lamar River near Tower Falls Ranger Station, Y.N.P.,
·06-2075 Clarks Fork Yellowstone River at Chance, Montana

will be studied as a group because they head in the same general area. The three streams all show relatively consistent flow patterns, that is there are no noticeable periods of low or high annual flow volume. There is some diversion activity on Clarks Fork, but not enough to significantly alter the streamflow.

For the Madison River, the 46-year mean is 337,000 acre feet, with a CV of 14.1 percent. The 20-year mean is within 6 percent of the long term mean with 95 percent confidence, and within 2 percent of the long term mean with 50 percent confidence. The 25-year mean, however, is within 4 percent of the long term mean with 95 percent confidence, and within 1.5 percent with 50 percent confidence. Very little improvement is made by going from 20 to 25 years, or in using the entire period of record, as there is only a 10 percent difference between the shorter and long term mean values.

For the Lamar River, the 45-year mean is 599,000 acre feet, with a CV of 23 percent, and for the Clarks Fork, the 47-year mean is 676,000 acre feet, with a CV of 21.6 percent. The 20-year means for both are within 9 percent of the long term mean for 95 percent confidence, and within 3 percent for 50 percent confidence. Very little improvement would be made by using longer periods of record, as the 20-year means are both within 10 percent of the long term values.

Bighorn River Basin

Of the streams selected in the Bighorn River Basin of the Yellowstone River,

- ·06-2640 Owl Creek near Thermopolis,
- ·06-2730 Medicine Lodge Creek near Hyattville,
- ·06-2765 Greybull River near Meeteetse, and
- ·06-2795 Bighorn River at Kane,

Owl Creek and Greybull River have diversions which affect the streamflow. For the Greybull River, the effect is questionable, so it will be included in the analysis. The Bighorn River has been regulated since 1951.

Medicine Lodge Creek has a 25-year mean of 25,000 acre feet, with a CV of 21.1 percent; for Greybull River, the 38-year mean is 242,000, with a CV of 32.2 percent; and Bighorn River, the 39-year mean is 1,626,000 with a CV of 28.8 percent. Using Medicine Lodge Creek, the 20-year mean is within 10 percent of the long term mean with 95 percent confidence, and within 3 percent with 50 percent confidence. No improvement is made using additional years. For Greybull River, the 20-year mean is within 16 percent of the long term mean with 95 percent confidence, and within 5 percent for 50 percent confidence. For the Bighorn River, the 20-year mean is within 13 percent of the long term mean with 95 percent confidence, and within 4 percent for 50 percent confidence. For the Greybull and Bighorn Rivers, little improvement is realized by using longer periods of record, as there is only about 1 percent difference in the 20-year and long term means.

Owl Creek is heavily depleted for irrigation, and has a CV of 75.2 percent. These conditions indicate that consideration should be given to reconstructing the flow to present modified before making this type of analysis.

Tongue River Basin

The stream used in this area,

06-3170 Powder River at Arvada

has an unspecified amount of irrigation diversion, as well as "poor" (24) records. For 34 years of record, the mean is 193,000 acre feet, and the CV is 46.6 percent. The 20-year mean is within 25 percent of the long term mean with 95 percent confidence, and within 8 percent of the long term mean with 50 percent confidence. Slight improvement is made by using the 30-year period, 1938-1968, as the 30-year mean is within 18 percent of the long term mean with 95 percent confidence, and within 6 percent of the long term mean with 50 percent confidence. There is less than 1 percent difference between the 20- and 30-year means and the long term mean, indicating little gain in using longer periods.

Cheyenne River Basin

The stream in this area,

- 06-4285 Belle Fourche River at Wyoming-South Dakota State Line,

has a high CV, 63.4 percent and is regulated by a reservoir. During the 1950's, streamflow was below normal, and in the 1940's and 1960's was well above the mean for the period. For this stream, it would be just as reasonable to either:

- reconstruct flow to present modified and continue the analysis, or
- use the record as is.

The base period would then be the entire 20-year period of record, with a long term mean of 56,400 acre feet.

North Platte River Basin

Six streams are studied in this area,

- 06-6200 North Platte River near Northgate, Colorado
- 06-6210 Douglas Creek near Foxpark, Wyoming,
- 06-6270 North Platte River near Saratoga,
- 06-6490 La Prele Creek near Douglas,
- 06-6575 Laramie River near Glendevy, Colorado, and
- 06-6745 North Platte River at Wyoming-Nebraska State Line.

Douglas Creek is regulated, and North Platte at Wyoming-Nebraska State

Line is regulated by several power and irrigation projects. North Platte near Saratoga and La Prele Creek have considerable irrigation diversions.

Douglas Creek has a 22-year mean of 54,000 acre feet with a CV of 31.3 percent, North Platte near Saratoga has a 53-year mean of 806,000 acre feet with a CV of 36.6 percent, and Laramie River near Glendevy has a 56-year mean of 51,800 acre feet with a CV of 33.4 percent. The three streams have nearly the same prediction characteristics after 20 years of record; for all three, the 20-year means are nearly 15 percent of their long term means with 95 percent confidence, and within 5 percent of the long term mean with 50 percent confidence. At most, the 20-year mean is less than 10 percent different from the long term mean. Therefore, there is little improvement by using more than 20 years for establishing the mean of these three stations.

For North Platte near Northgate, the 53-year mean is 311,000 acre feet, with a CV of 41.4 percent. The 20-year mean is within 19 percent of the long term mean with 95 percent confidence, and within 6 percent of the long term mean with 50 percent confidence. By using another 5 years of record, 1943-1968, the 25-year mean comes within 16 percent of the long term mean with 95 percent confidence, and 5 percent with 50 percent confidence. The 20-year and 25-year means are about the same and are within 1 percent of the long term mean. Thus little is gained using an additional 5 years of record.

La Prele Creek has a 49-year mean of 28,000 acre feet and a CV of 46 percent. Irrigation depletions may be significant. Using the streamflow records as is, the 20-year mean is nearly 20 percent of the long term mean with 95 percent confidence, and less than 7 percent with 50 percent confidence. There is less than an 8 percent difference between the long term mean and the 20-year mean at this point. Going to 25 years, the mean then is 18 percent of the long term mean with 95 percent confidence, and 6 percent for 50 percent confidence, with about 4 percent difference in the 25-year mean and the long term mean. Thus, little is gained in using longer periods, due to the high CV.

The North Platte River at the Wyoming-Nebraska State Line is heavily regulated. Above the gage there are several storage reservoirs and power projects, built over many years. The most recent is Glendo Reservoir, completed in 1958. By using only a twenty-year period, this would be the only major change in the streamflow. Most importantly, these 20 years provide the best indication of existing conditions. For the 39-year long term period of record, the CV is 29.5 percent, and the mean is 481,000 acre feet. The 20-year mean is within 11 percent of the long term mean with 95 percent confidence, and within 4 percent for 50 percent confidence. By using only the period, 1953-1968, the 15-year mean is within 8 percent of the long term mean with 95 percent confidence, and within 3 percent for 50 percent confidence. Using periods of record longer than 20 years improves the estimate somewhat, but for the 20-year period, there is less than a 5 percent difference between the short period and the long term mean. The difference is nearly 10 percent when using the 15-year period.

Green River Basin

The five streams in the Green River Basin,

- ·09-1885 Green River at Warren Bridge, near Daniel,
- ·09-2055 North Piney Creek near Mason,
- ·09-2125 Big Sandy Creek at Leckie Ranch near Big Sandy,
- ·09-2170 Green River near Green River, and
- ·09-2235 Hams Fork near Frontier

have generally short periods of record and high CV values. Diversions for irrigation purposes are insignificant, except North Piney Creek, for all stations.

Green River at Green River is affected by considerable storage reservoirs, power developments, and transbasin diversions above the gage; and Hams Fork is regulated by a power reservoir and a water supply reservoir. Because of these conditions, and the shortness of record, the long term mean is an adequate predicter for base period.

Using the data available gives these results: For Green River near Green River, with a 17-year mean of 1,173,000 acre feet and a 30 percent CV, the 15-year mean is within 17 percent of the long term mean with 95 percent confidence, and within 6 percent for 50 percent confidence. For Hams Fork, with a 23-year mean of 10,300 acre feet and CV of 40.5 percent, the 15-year mean is within 19 percent of the long term mean with 95 percent confidence, and within 6 percent for 50 percent confidence.

For Green River at Warren Bridge, the 37-year mean is 367,000 acre feet, with a CV of 19.4 percent. The 20-year mean is within

10 percent of the long term mean with 95 percent confidence, and 3 percent of the long term mean with 50 percent confidence. The mean for the 20-year period is less than 8 percent greater than the long term mean. Thus, little would be gained by using a longer period of record.

North Piney Creek has a 37-year mean and is 40,700 acre feet and for Big Sandy Creek the 29-year mean is 61,600 acre feet. The CV values are nearly the same -- 30 percent for North Piney Creek, and 29 percent for Big Sandy Creek. Diversions above the gage on North Piney Creek may be significant. For both stations, the 20-year mean for the period is less than 15 percent of the long term mean with 95 percent confidence, and less than 5 percent for 50 percent confidence. Using an additional 5-year period for both stations does not provide any more information.

Yampa River Basin

The stream in this area,

09-2570 Little Snake River near Dixon

has a 30-year mean of 330,000 acre feet and a CV of 31.8 percent. The mean for the 20-year period is within 17 percent of the long term mean with 95 percent confidence, and less than 6 percent with 50 percent confidence. By using 25 years, the mean for the period is 14 percent of the long term mean with 95 percent confidence, and less than 5 percent for 50 percent confidence. There is no gain in using 30 years. Since the difference between the 20-year mean and long term mean is less than 4 percent, the 20-year mean is adequate.

Bear River Basin

The station selected in this area,

•10-0320 Smiths Fork near Border,

has a 26-year mean of 138,600 acre feet and a CV of 21.9 percent. The mean for the 20-year period is within 10 percent of the long term mean, with 95 percent confidence, and within 3 percent with 50 percent confidence. There is no significant gain in using 25 years, as both the 20- and 25-year means are nearly the same, and both are less than 1 percent smaller than the long term mean.

Snake River Basin

The station selected in this area,

•13-0110 Snake River at Moran,

has the longest continuous record in Wyoming. However, the stream has been completely regulated during the period of record for irrigational use in Idaho. The 65-year mean is 1,029,000 acre feet, with a CV of 20.4 percent. The mean for the 20-year period is less than 10 percent of the long term mean with 95 percent confidence, and within 3 percent of the long-term mean for 50 percent confidence. With such a long period of record, it is possible to cut the error in half by using 55 years of record. However, since the 20-year mean is nearly 10 percent of the long term mean, the use of longer period of record does not provide sufficiently greater amounts of information.

CHAPTER V

CONCLUSIONS

The best approach to the determination of a streamflow base period is to consider the most recent period of record. The period 1948-1968 was shown to provide sufficient information to make statements concerning how well the twenty years represent the long term period of record for Wyoming streams.

The selection of the period 1948-1968 for all gaging stations resulted in twenty-year means which are very nearly the same as the long term means. For most streams the difference was 10 percent or less. Sufficient information is available to enable one to declare, in a more meaningful way, that "the twenty-year mean is within 6 percent of the long term mean with 95 percent confidence, and within 2 percent of the long term mean with 50 percent confidence" for the Madison River, as an example.

It was shown that selecting periods longer than twenty years provided generally small increases in prediction information.

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A P P E N D I X I

Tables of Sample Sizes Required to Obtain Selected Accuracies and Certainties for Varying Lenths of Record.

TABLE I

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
FIVE YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	21	7	4.5	2.3	.5	84	30	18	9.4	2.1	190	69	40	21	4.8
.15	9.4	3.4	2.0	1.0	.2	37	13	8	4.1	.9	84	30	18	9.4	2.1
.25	3.3	1.2	.7	.3	.08	13	4.9	2.9	1.5	.3	30	11	6	3.3	.7
.50	.8	.3	.2	.1	.02	3.3	1.2	.7	.3	.08	7	2.7	1.6	.8	.2
	CV = 40%					CV = 50%					CV = 60%				
.10	339	123	72	37	8	529	192	113	58	13	762	277	163	84	19
.15	150	54	32	16	3.8	235	85	50	26	6	339	123	72	37	8
.25	54	19	11	6	1.3	84	30	18	9	2.1	122	44	26	13	3.1
.50	13	4.9	2.9	1.5	.3	21	7	4.5	2.3	.5	30	11	6	3.3	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	1038	377	222	115	26	1356	492	290	150	34	1716	623	367	190	43
.15	461	167	98	51	11	602	219	129	66	15	762	277	163	84	19
.25	166	60	35	18	4.2	216	78	46	24	5	274	99	58	30	6.9
.50	41	15	8	4.6	1.0	54	19	11	6	1.3	68	24	14	7.6	1.7

TABLE II

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
TEN YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	10	5.1	3.3	1.9	.5	42	20	13	7.6	1.9	95	46	30	17	4.4
.15	4.6	2.2	1.4	.8	.2	18	9.0	5.9	3.3	.8	42	20	13	7.6	1.9
.25	1.6	.8	.5	.3	.07	6.7	3.2	2.1	1.2	.3	15	7.3	4.8	2.7	.7
.50	.4	.2	.1	.07	.01	1.6	.8	.5	.3	.07	3.8	1.8	1.2	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	168	81	53	30	7.8	264	127	83	47	12	380	183	120	68	17
.15	75	36	23	13	3.4	117	56	37	21	5.4	168	81	53	30	7.8
.25	27	13	8.5	4.8	1.2	42	20	13	7.6	1.9	60	29	19	11	2.8
.50	6.7	3.2	2.1	1.2	.3	11	5.1	3.3	1.9	.4	15	7.3	4.8	2.7	.7
	CV = 70%					CV = 80%					CV = 90%				
.10	517	250	164	93	24	675	327	214	122	31	855	413	271	154	39
.15	229	111	72	41	10	300	145	95	54	13	380	183	120	68	17
.25	82	40	26	14	3.8	108	52	34	19	5.0	136	66	43	24	6.3
.50	20	10	6.5	3.7	.9	27	13	8.5	4.8	1.2	34	16	10	6.1	1.5

TABLE III

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
FIFTEEN YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	8.8	4.6	3.1	1.8	.4	35	18	12.4	7.2	1.8	79	41	27	16	4.2
.15	3.9	2.0	1.3	.8	.2	15	8.1	5.5	3.2	.8	35	18	12.4	7.2	.6
.25	1.4	.7	.4	.28	.07	5.6	2.9	1.9	1.5	.3	12.7	6.6	4.4	2.5	.6
.50	.3	.2	.1	.07	.01	1.4	.7	.4	.2	.07	3.1	1.6	1.1	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	141	73	49	28	7.5	221	115	77	45	11.7	318	165	111	64	16
.15	63	32	22	12.8	3.3	98	51	34	20	5.2	141	73	49	28	7.5
.25	22	11.7	7.9	4.6	1.2	35	18	12.4	7.2	1.8	51	26	17	10.3	2.7
.50	5.6	2.9	1.9	1.1	.3	8.8	4.6	3.1	1.8	.4	12.7	6.6	4.4	2.5	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	434	225	151	88	23	567	294	198	115	30	717	372	251	145	38
.15	192	100	67	39	10.2	252	130	88	51	13.3	318	165	111	64	16
.25	69	36	24	14.1	3.6	90	47	31	18	4.8	114	59	40	23	6.0
.50	17	9.0	6.0	3.5	.9	22	11.7	7.9	4.6	1.2	28	14.9	10.0	5.8	1.5

TABLE IV

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
TWENTY YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	8.1	4.3	2.9	1.7	.4	32	17.5	11.9	7.0	1.8	73	39	26	15.8	4.2
.15	3.6	1.9	1.3	.7	.2	14.5	7.7	5.2	3.1	.8	32	17.5	11.9	7.0	1.8
.25	1.3	.7	.4	.2	.07	5.2	2.8	1.9	1.1	.3	11.7	6.3	4.2	2.5	.6
.50	.3	.2	.1	.07	.01	1.3	.7	.4	.2	.07	2.9	1.5	1.0	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	130	70	47	28	7.5	204	109	74	44	11.7	294	157	107	63	16.9
.15	58	31	21	12.5	3.3	90	48	33	19.5	5.2	130	70	47	28	7.5
.25	20.9	11.2	7.6	4.5	1.2	32	17.5	11.9	7.0	1.8	47	25	17.1	10.1	2.7
.50	5.2	2.8	1.9	1.1	.3	8.1	4.3	2.9	1.7	.4	11.7	6.3	4.2	2.5	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	400	214	146	86	23	523	280	190	112	30	662	354	241	142	38
.15	178	95	64	38	10.3	232	124	84	50	13.3	294	157	107	63	16.9
.25	64	34	23	13.7	3.6	83	44	30	18.0	4.8	106	56	38	22	6.0
.50	16.0	8.5	5.8	3.4	.9	20.9	11.2	7.6	4.5	1.2	26	14.1	9.6	5.7	1.5

TABLE V

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
TWENTY-FIVE YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	7.8	4.2	2.9	1.7	.4	31	17.0	11.6	6.9	1.8	70	38	26	15.5	4.1
.15	3.4	1.8	1.2	.7	.2	13.9	7.5	5.1	3.0	.8	31	17.0	11.6	6.9	1.8
.25	1.2	.6	.4	.2	.07	5.0	2.7	1.8	1.1	.2	11.2	6.1	4.2	2.4	.6
.50	.3	.2	.1	.06	.01	1.2	.6	.4	.2	.07	2.8	1.5	1.0	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	125	68	46	27	7.3	195	106	73	43	11.5	281	153	105	62	16.5
.15	55	30	20.7	12.3	3.2	86	47	32	19.2	5.1	125	68	46	27	7.3
.25	20	10.9	7.4	4.4	1.1	31	17.0	11.6	6.9	1.8	45	24.5	16.8	9.9	2.6
.50	5.0	2.7	1.8	1.1	.2	7.8	4.2	2.9	1.7	.4	11.2	6.1	4.2	2.4	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	383	208	143	84	22.5	500	272	186	110	29	633	345	236	140	37
.15	170	92	63	37	10.0	222	121	83	49	13.0	281	153	105	62	16.5
.25	61	33	22.8	13.5	3.6	80	43	29	17.7	4.7	101	55	37	22.4	5.9
.50	15.3	8.3	5.7	3.3	.9	20.0	10.9	7.4	4.4	1.1	25	13.8	9.4	5.6	1.4

TABLE VI

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
THIRTY YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	7.5	4.1	2.8	1.7	.4	30	16.7	11.5	6.8	1.8	68	37	25.9	15.3	4.1
.15	3.3	1.8	1.2	.7	.2	13.4	7.4	5.1	3.0	.8	30.3	16.7	11.5	6.8	1.8
.25	1.2	.6	.4	.2	.07	4.8	2.6	1.8	1.0	.3	10.9	6.0	4.1	2.4	.6
.50	.3	.2	.1	.06	.01	1.2	.6	.4	.2	.07	2.7	1.5	1.0	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	121	66	46	27.3	7.3	189	104	72	42	11.5	273	150	103	61	16.5
.15	53	29.7	20.4	12.1	3.2	84	46	32	19.0	5.1	121	66	46	27.3	7.3
.25	19.4	10,7	7.3	4.3	1.1	30	16.7	11.5	6.8	1.8	43	24	16.5	9.8	2.6
.50	4.8	2.6	1.8	1.0	.3	7.5	4.1	2.8	1.7	.4	10.9	6.0	4.1	2.4	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	371	204	141	83	22.5	485	267	184	109	29.4	614	338	233	138	37
.15	165	91	62	37	10.0	215	118	81	48	13.0	273	150	103	61	16.5
.25	59	32	22.5	13.4	3.6	77	42	29.4	17.5	4.7	98	54	37	22.1	5.7
.50	14.8	8.1	5.6	3.3	.9	19.4	10.7	7.3	4.3	1.1	24.5	13.5	9.3	5.5	1.4

TABLE VII

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
FORTY YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	7.3	4.0	2.8	1.7	.4	29.2	16.3	11.3	6.8	1.8	65	36.7	25.4	15.3	4.1
.15	3.2	1.8	1.2	.7	.2	12.9	7.2	5.0	3.0	.8	29.2	16.3	11.3	6.8	1.8
.25	1.1	.6	.4	.2	.07	4.6	2.6	1.8	1.0	.3	10.5	5.8	4.0	2.4	.6
.50	.3	.2	.1	.06	.01	1.1	.6	.4	.2	.07	2.6	1.4	1.0	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	116	65	45	27.2	7.3	182	102	70	42	11.5	263	146	101	61	16.5
.15	51	29.0	20.1	12.0	3.2	81	45	31.4	18.8	5.1	116	65	45	27.2	7.3
.25	18.7	10.4	7.2	4.3	1.1	29.2	16.3	11.3	6.8	1.8	42	23.5	16.3	9.7	2.6
.50	4.6	2.6	1.8	1.0	.2	7.3	4.0	2.8	1.7	.4	10.5	5.8	4.0	2.4	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	358	199	138	83	22.5	467	261	181	108	29.4	592	330	229	137	37.2
.15	159	88	61	37	10.0	207	116	80	48	13.0	263	146	101	61	16.5
.25	57	31.9	22.1	13.3	3.6	74	41	28.9	17.4	4.7	94	52	36.6	22.0	5.9
.50	14.3	7.9	5.5	3.3	.9	18.7	10.4	7.2	4.3	1.1	23.6	13.2	9.1	5.5	1.4

TABLE VIII

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
FIFTY YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	7.2	4.0	2.8	1.6	.4	28.9	16.1	11.2	6.7	1.8	65	36.3	25.2	15.2	4.1
.15	3.2	1.7	1.2	.7	.2	12.8	7.1	4.9	3.0	.8	28.9	16.1	11.2	6.7	1.8
.25	1.1	.6	.4	.2	.07	4.6	2.5	1.7	1.0	.3	10.4	5.8	4.0	2.4	.6
.50	.2	.1	.1	.06	.01	1.1	.6	.4	.2	.07	2.6	1.4	1.0	.6	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	115	64	44.9	27.0	7.3	181	101	70	42.2	11.5	260	145	101	60	16.5
.15	51	28.7	19.9	12.0	3.2	80	44.8	31.2	18.7	5.1	115	64	44.9	27.0	7.3
.25	18.5	10.3	7.1	4.3	1.1	28.9	16.1	11.2	6.7	1.8	41.7	23.2	16.1	9.7	2.6
.50	4.6	2.5	1.7	1.0	.2	7.2	4.0	2.8	1.6	.4	10.4	5.8	4.0	2.4	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	354	197	137	82	22.5	463	258	179	108	29.4	586	327	227	136	37.2
.15	157	87	61	36.8	10.0	205	114	79	48	13.0	260	145	101	60	16.5
.25	56	31.6	22.0	13.2	3.6	74	41.3	28.7	17.3	4.7	93	52	36.4	21.9	5.9
.50	14.1	7.9	5.5	3.3	.9	18.5	10.3	7.1	4.3	1.1	23.4	13.0	9.1	5.4	1.4

TABLE IX

SAMPLE SIZES REQUIRED TO OBTAIN VARIOUS
ACCURACIES AND CERTAINTIES
SIXTY YEARS OF RECORD

	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%	99%	95%	90%	80%	50%
	CV = 10%					CV = 20%					CV = 30%				
.10	7.0	4.0	2.7	1.0	.4	28.2	16.0	11.1	4.3	1.8	63	36.0	25.1	9.8	4.1
.15	3.1	1.7	1.2	.4	.2	12.5	7.1	4.9	1.9	.8	28.2	16.0	11.1	4.3	1.8
.25	1.1	.6	.4	.1	.07	4.5	2.5	1.7	.7	.3	10.1	5.7	4.0	1.5	.6
.50	.2	.1	.1	.04	.01	1.1	.6	.4	.1	.07	2.5	1.4	1.0	.4	.1
	CV = 40%					CV = 50%					CV = 60%				
.10	113	64	44.6	17.4	7.3	176	100	69	27.2	11.5	254	144	100	39.2	16.5
.15	50.2	28.4	19.8	7.7	3.2	78	44.4	31	12.1	5.1	113	64	44.6	17.4	7.3
.25	18.0	10.2	7.1	2.7	1.1	28.2	16.0	11.1	4.3	1.8	40.7	23	16.0	6.2	2.6
.50	4.5	2.5	1.7	.6	.2	7.0	4.0	2.8	1.0	.4	10.1	5.7	4.0	1.5	.6
	CV = 70%					CV = 80%					CV = 90%				
.10	346	196	136	53.4	22.5	452	256	178	69	29.4	572	324	225	88	37.2
.15	153	87	60.7	23.7	10.0	201	113	79	31	13.0	254	144	100	39.2	16.5
.25	55.4	31.3	21.8	8.5	3.6	72	40.9	28.5	11.1	4.7	91	51.8	36.1	14.1	5.9
.50	13.8	7.8	5.4	2.1	.9	18.0	10.2	7.1	2.7	1.1	22.9	12.9	9.0	3.5	1.4

APPENDIX II

Statistical Information and Sample Size Required to Approximate Given Mean Values Assuming Various Accuracies and Certainties.

TABLE X

GENERAL STATISTICAL DATA AND SAMPLE SIZE

06-0375 MADISON RIVER NEAR
WEST YELLOWSTONE, WYOMING

			99%	95%	90%	50%
Period of Record 46 Years	Mean 337532 A.F.	.10	14.4	8.1	5.6	.9
Drainage Area 420 Sq.Mi.	Std. Dev. 47758 A.F.	.25	2.3	1.3	.9	.1
Elevation 6650 Ft.	Coeff. of Var. 14.1%	.50	.5	.3	.22	.03

06-1880 LAMAR RIVER NEAR TOWER FALLS
RANGER STA., Y. N. P., WYOMING

			99%	95%	90%	50%
Period of Record 45 Years	Mean 598884 A.F.	.10	39.4	22.1	15.3	2.5
Drainage Area 660 Sq.Mi.	Std. Dev. 139637 A.F.	.25	6.3	3.5	2.4	.4
Elevation 5910 Ft.	Coeff. of Var. 23.3%	.50	1.5	.8	.6	.1

06-2075 CLARKS FORK YELLOWSTONE RIVER
AT CHANCE, MONTANA

			99%	95%	90%	50%
Period of Record 47 Years	Mean 676410 A.F.	.10	33.6	18.8	13.0	2.1
Drainage Area 1154 Sq.Mi.	Std. Dev. 146034 A.F.	.25	5.3	3.0	2.0	.3
Elevation 3980 Ft.	Coeff. of Var. 21.6%	.50	1.3	.7	.5	.08

TABLE X (Continued)

06-2640 OWL CREEK NEAR
THERMOPOLIS, WYOMING

Period of Record	27 Years	Mean 19993 A.F.		99%	95%	90%	50%
Drainage Area	478 Sq.Mi.	Std. Dev. 15025 A.F.	.10	433	237	163	25.9
			.25	69	38	26.2	4.1
Elevation	4560 Ft.	Coeff. of Var. 75.2%	.50	17.3	9.5	6.5	1.0

06-2730 MEDICINE LODGE CREEK NEAR
HYATTVILLE, WYOMING

Period of Record	25 Years	Mean 24747 A.F.		99%	95%	90%	50%
Drainage Area	86.8 Sq.Mi.	Std. Dev. 5210 A.F.	.10	34	18.7	12.8	1.7
			.25	5.5	3.0	2.0	.2
Elevation	4770 Ft.	Coeff. of Var. 21.1%	.50	1.3	.7	.5	.1

06-2765 GREYBULL RIVER AT
MEETEETSE, WYOMING

Period of Record	38 Years	Mean 241712 A.F.		99%	95%	90%	50%
Drainage Area	681 Sq.Mi.	Std. Dev. 77938 A.F.	.10	75	41	29.1	4.1
			.25	12.1	6.6	4.6	.6
Elevation	5741 Ft.	Coeff. of Var. 32.2%	.50	3.0	1.6	1.1	.1

TABLE X (Continued)

06-2795 BIGHORN RIVER
KANE, WYOMING

			99%	95%	90%	50%
Period of Record 39 Years	Mean 1626532 A.F.	.10	60	33.3	23.3	3.3
Drainage Area 15765 Sq.Mi.	Std. Dev. 469332 A.F.	.25	9.7	5.3	3.7	.5
Elevation 3660 Ft.	Coeff. of Var. 28.8%	.50	2.4	1.3	.9	.1

06-3170 POWDER RIVER AT
ARVADA, WYOMING

			99%	95%	90%	50%
Period of Record 34 Years	Mean 193350 A.F.	.10	160	89	60	8.6
Drainage Area 6050 Sq.Mi.	Std. Dev. 90158 A.F.	.25	25.7	14.2	9.7	1.3
Elevation 3622 Ft.	Coeff. of Var. 46.6%	.50	6.4	3.5	2.4	.3

06-4285 BELLE FOURCHE RIVER AT
WYOMING-SOUTH DAKOTA STATE LINE

			99%	95%	90%	50%
Period of Record 22 Years	Mean 56439 A.F.	.10	321	172	116	16
Drainage Area 3280 Sq.Mi.	Std. Dev. 35796 A.F.	.25	51	27	18.6	2.5
Elevation 3095 Ft.	Coeff. of Var. 63.4%	.50	12.8	6.9	4.6	.6

TABLE X (Continued)

06-6200 NORTH PLATTE RIVER NEAR
NORTHGATE, COLORADO

			99%	95%	90%	50%
Period of Record 53 Years	Mean 311452 A.F.	.10	121	68	47.9	6.8
Drainage Area 1431 Sq.Mi.	Std. Dev. 128888 A.F.	.25	19.4	10.9	7.6	1.0
Elevation 7810 Ft.	Coeff. of Var. 41.4%	.50	4.8	2.7	1.9	.2

06-6210 DOUGLAS CREEK NEAR
FOXPARK, WYOMING

			99%	95%	90%	50%
Period of Record 22 Years	Mean 54038 A.F.	.10	78	42	28	3.9
Drainage Area 120 Sq. Mi.	Std. Dev. 16918 A.F.	.25	12.5	6.7	4.5	.6
Elevation 8200 Ft.	Coeff. of Var. 31.3%	.50	3.1	1.6	1.1	.1

06-6270 NORTH PLATTE RIVER
NEAR SARATOGA, WYOMING

			99%	95%	90%	50%
Period of Record 53 Years	Mean 805907 A.F.	.10	96	54	37.4	5.3
Drainage Area 2840 Sq.Mi.	Std. Dev. 294704 A.F.	.25	15.3	8.6	5.9	.8
Elevation 6772 Ft.	Coeff. of Var. 36.6%	.50	3.8	2.1	1.4	.2

TABLE X (Continued)

06-6490 LAPRELE CREEK NEAR
DOUGLAS, WYOMING

			99%	95%	90%	50%
Period of Record 49 Years	Mean 27949 A.F.	.10	153	86	60	8.6
Drainage Area 135 Sq. Mi.	Std. Dev. 12978 A.F.	.25	24.4	13.7	9.6	1.3
Elevation 5600 Ft.	Coeff. of Var. 46.4%	.50	6.1	3.4	2.4	.3

06-6575 LARAMIE RIVER NEAR
(AT) GLENDEVY, COLORADO

			99%	95%	90%	50%
Period of Record 56 Years	Mean 51815 A.F.	.10	79	44.6	31.2	4.4
Drainage Area 101 Sq.Mi.	Std. Dev. 17320 A.F.	.25	12.6	7.1	5.0	.7
Elevation 8230 Ft.	Coeff. of Var. 33.4%	.50	3.1	1.7	1.2	.1

06-6745 NORTH PLATTE RIVER AT
WYOMING-NEBRASKA STATE LINE

			99%	95%	90%	50%
Period of Record 39 Years	Mean 481287 A.F.	.10	63	34.9	24.4	3.4
Drainage Area 26177 Sq.Mi.	Std. Dev. 142176 A.F.	.25	10.1	5.5	3.9	.5
Elevation 4024 Ft.	Coeff. of Var. 29.5%	.50	2.5	1.3	.9	.1

TABLE X (Continued)

09-1885 GREEN RIVER AT WARREN BRIDGE
NEAR DANIEL, WYOMING

			99%	95%	90%	50%
Period of Record 37 Years	Mean 366824 A.F.	.10	27.5	10.5	6.4	1.5
Drainage Area 468 Sq.Mi.	Std. Dev. 71278 A.F.	.25	4.4	1.6	1.0	.2
Elevation 7468 Ft.	Coeff. of Var. 19.4%	.50	1.1	.4	.2	.06

09-2055 NORTH PINEY CREEK NEAR
MASON (MARBLETON), WYOMING

			99%	95%	90%	50%
Period of Record 37 Years	Mean 40679 A.F.	.10	66	36.7	25.4	4.1
Drainage Area 58 Sq.Mi.	Std. Dev. 12223 A. F.	.25	10.6	5.8	4.1	.6
Elevation 7520 Ft.	Coeff. of Var. 30.0%	.50	2.6	1.4	1.0	.1

09-2125 BIG SANDY CREEK AT LECKIE RANCH
NEAR BIG SANDY, WYOMING

			99%	95%	90%	50%
Period of Record 29 Years	Mean 61589 A.F.	.10	64	35	24.3	3.8
Drainage Area 94 Sq.Mi.	Std. Dev. 17869 A.F.	.25	10.2	5.6	3.8	.61
Elevation 7800 Ft.	Coeff. of Var. 29.0%	.50	2.5	1.4	1.0	.1

TABLE X (Continued)

09-2170 GREEN RIVER NEAR
GREEN RIVER, WYOMING

			99%	95%	90%	50%
Period of Record 17 Years	Mean 1172955 A.F.	.10	76	40	27	4.2
Drainage Area 10000 Sq.Mi.	Std. Dev. 351893 A.F.	.25	12.2	6.4	4.3	.6
Elevation 6050 Ft.	Coeff. of Var. 30.0%	.50	3.0	1.6	1.1	.1

09-2235 HAMS FORK NEAR
FRONTIER, WYOMING

			99%	95%	90%	50%
Period of Record 23 Years	Mean 102771 A.F.	.10	130	70	48	7.6
Drainage Area 298 Sq.Mi.	Std. Dev. 41593 A.F.	.25	20.8	11.2	7.7	1.2
Elevation 6970 Ft.	Coeff. of Var. 40.5%	.50	5.2	2.8	1.9	.3

09-2570 LITTLE SNAKE RIVER
NEAR DIXON, WYOMING

			99%	95%	90%	50%
Period of Record 30 Years	Mean 329719 A.F.	.10	76	42	29.1	4.6
Drainage Area 988 Sq.Mi.	Std. Dev. 104791 A.F.	.25	12.2	6.7	4.6	.7
Elevation 6331 Ft.	Coeff. of Var. 31.8%	.50	3.0	1.6	1.1	.2

TABLE X (Continued)

10-0320 SMITHS FORK NEAR
BORDER, WYOMING

			99%	95%	90%	50%
Period of Record 26 Years	Mean 138610 A.F.	.10	35	19.4	13.3	2.1
Drainage Area 165 Sq.Mi.	Std. Dev. 29669 A.F.	.15	5.6	3.1	2.1	.3
Elevation 6650 Ft.	Coeff. of Var. 21.4%	.50	1.4	.7	.5	.08

13-0110 (SOUTH FORK) SNAKE RIVER
AT MORAN, WYOMING

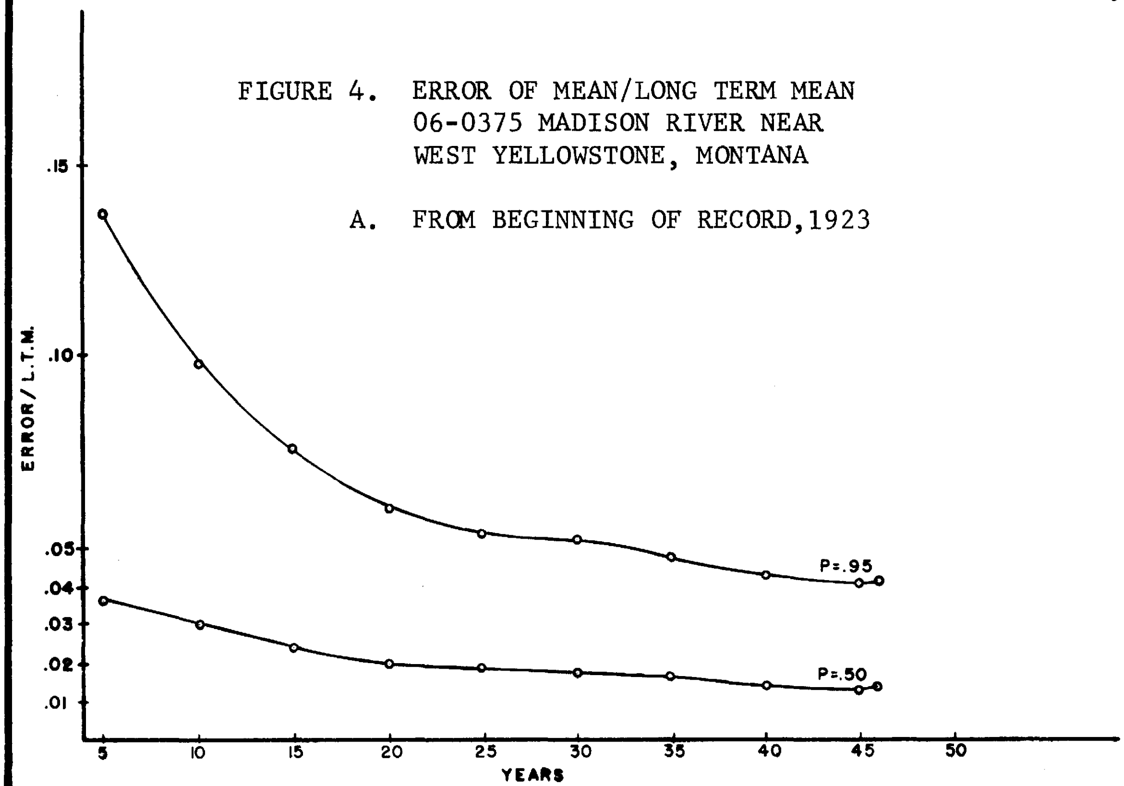
			99%	95%	90%	50%
Period of Record 65 Years	Mean 1029374 A.F.	.10	29.2	16.5	11.5	1.9
Drainage Area 824 Sq.Mi.	Std. Dev. 209831 A.F.	.25	4.6	2.6	1.8	.3
Elevation 6727 Ft.	Coeff. of Var. 20.4%	.50	1.1	.6	.4	.07

A P P E N D I X III

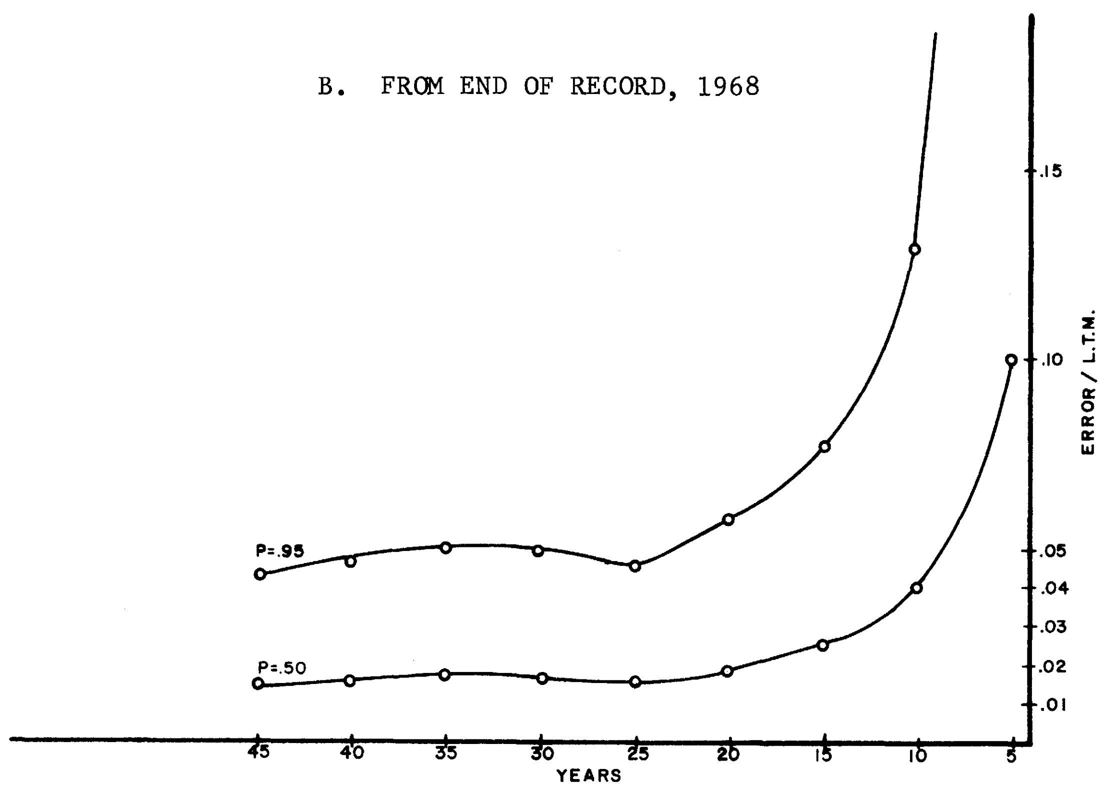
Graphs and Tabulations Showing Ratios of Probable Error of Short Term Mean to Long Term Mean, for Fifty Percent and Ninety-five Percent Probabilities.

FIGURE 4. ERROR OF MEAN/LONG TERM MEAN
06-0375 MADISON RIVER NEAR
WEST YELLOWSTONE, MONTANA

A. FROM BEGINNING OF RECORD, 1923



B. FROM END OF RECORD, 1968



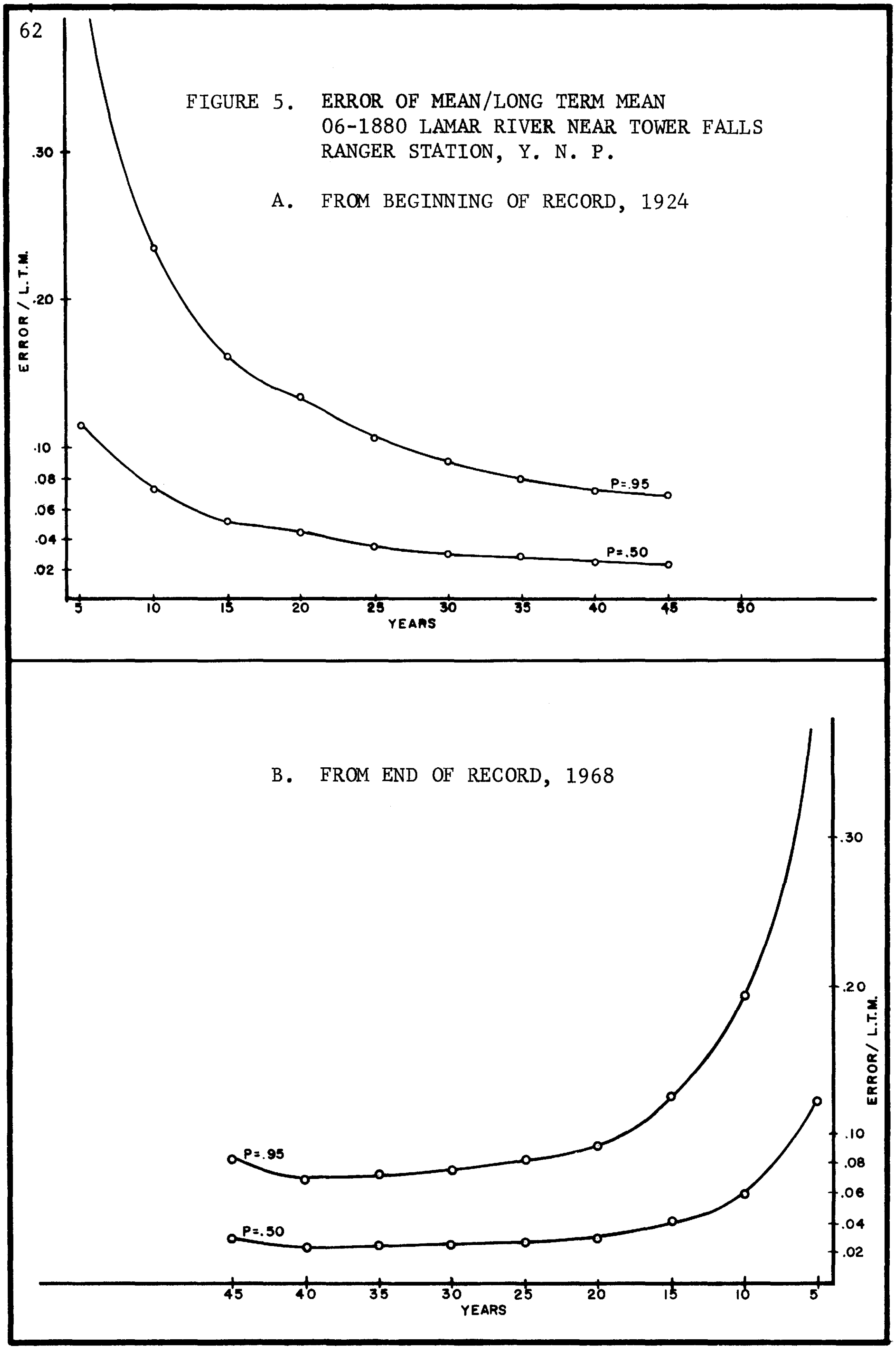


FIGURE 5. ERROR OF MEAN/LONG TERM MEAN
06-1880 LAMAR RIVER NEAR TOWER FALLS
RANGER STATION, Y. N. P.

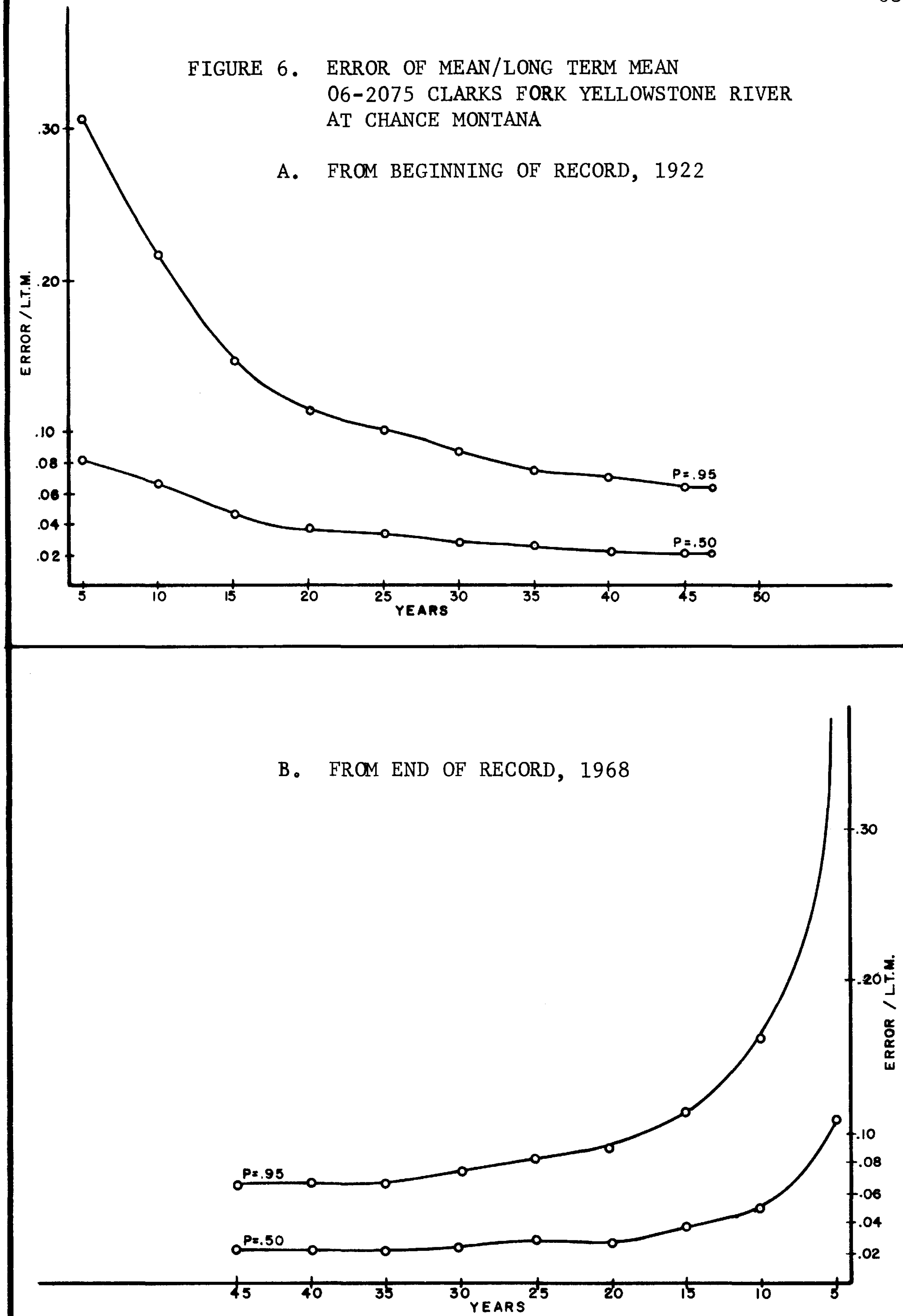
A. FROM BEGINNING OF RECORD, 1924

B. FROM END OF RECORD, 1968

FIGURE 6. ERROR OF MEAN/LONG TERM MEAN
06-2075 CLARKS FORK YELLOWSTONE RIVER
AT CHANCE MONTANA

A. FROM BEGINNING OF RECORD, 1922

B. FROM END OF RECORD, 1968



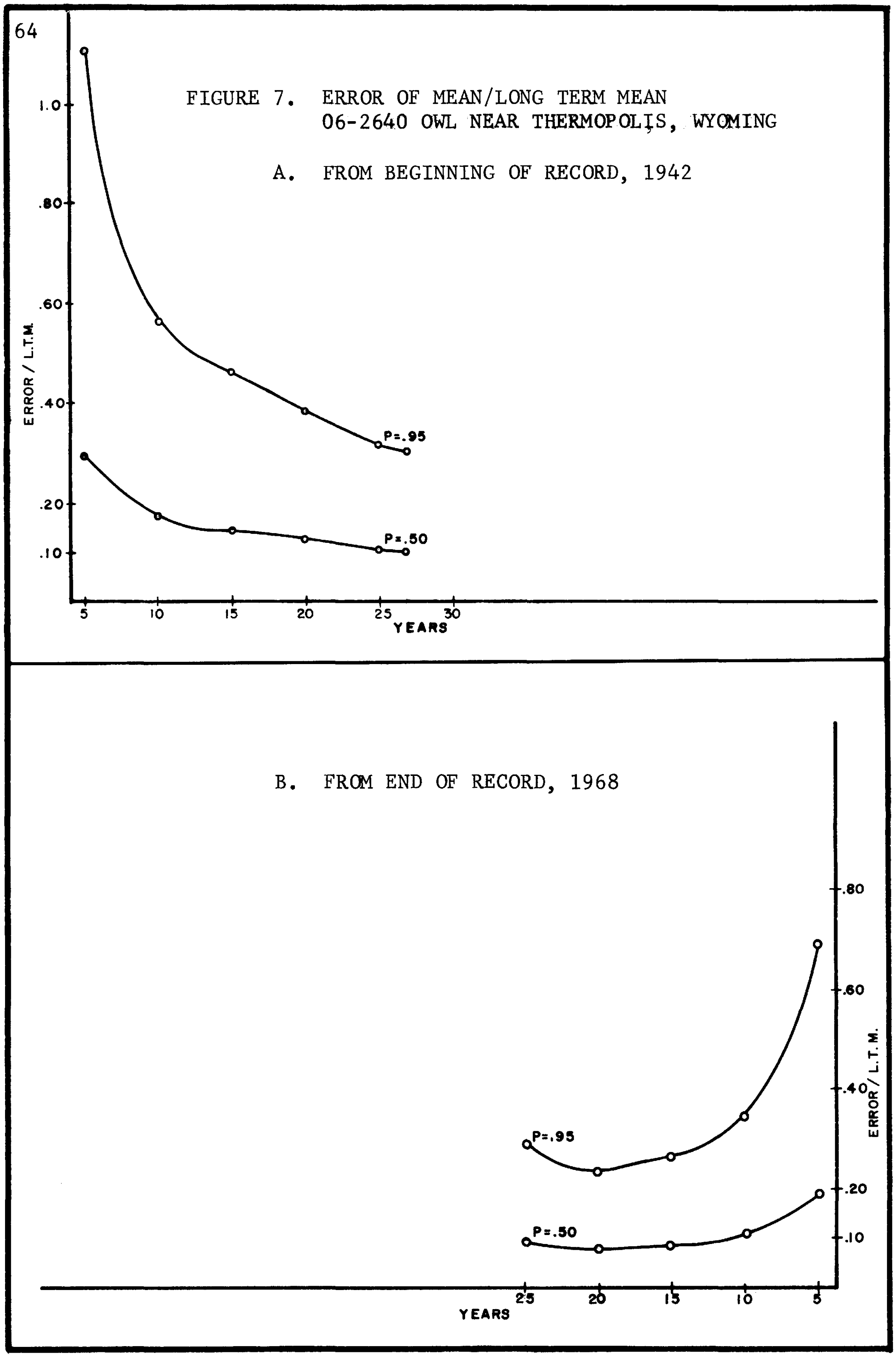


FIGURE 7. ERROR OF MEAN/LONG TERM MEAN
06-2640 OWL NEAR THERMOPOLIS, WYOMING

A. FROM BEGINNING OF RECORD, 1942

B. FROM END OF RECORD, 1968

FIGURE 8. ERROR OF MEAN/LONG TERM MEAN
06-2730 MEDICINE LODGE CREEK NEAR
HYATTVILLE, WYOMING

A. FROM BEGINNING OF RECORD, 1944

B. FROM END OF PERIOD, 1968

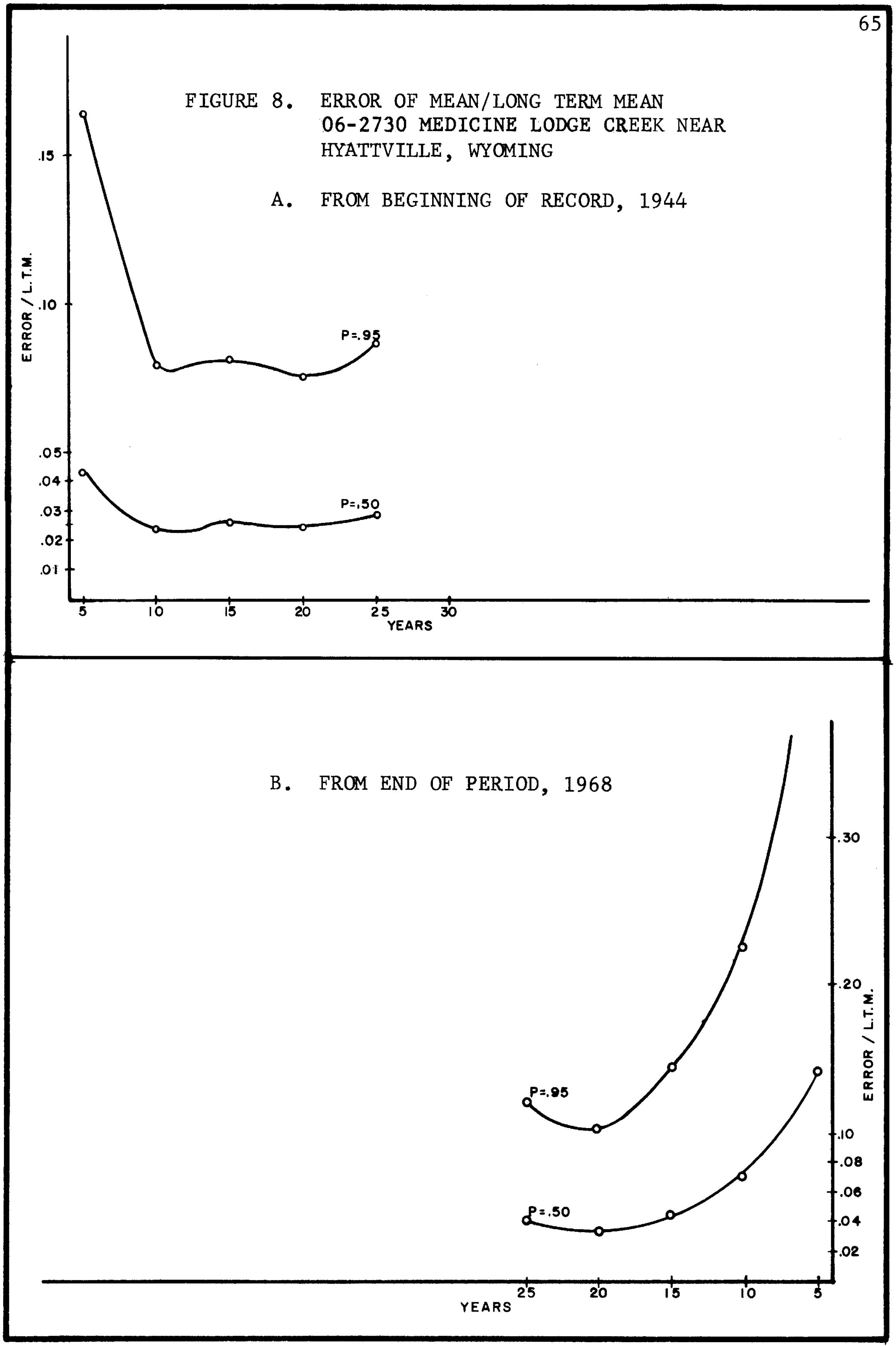
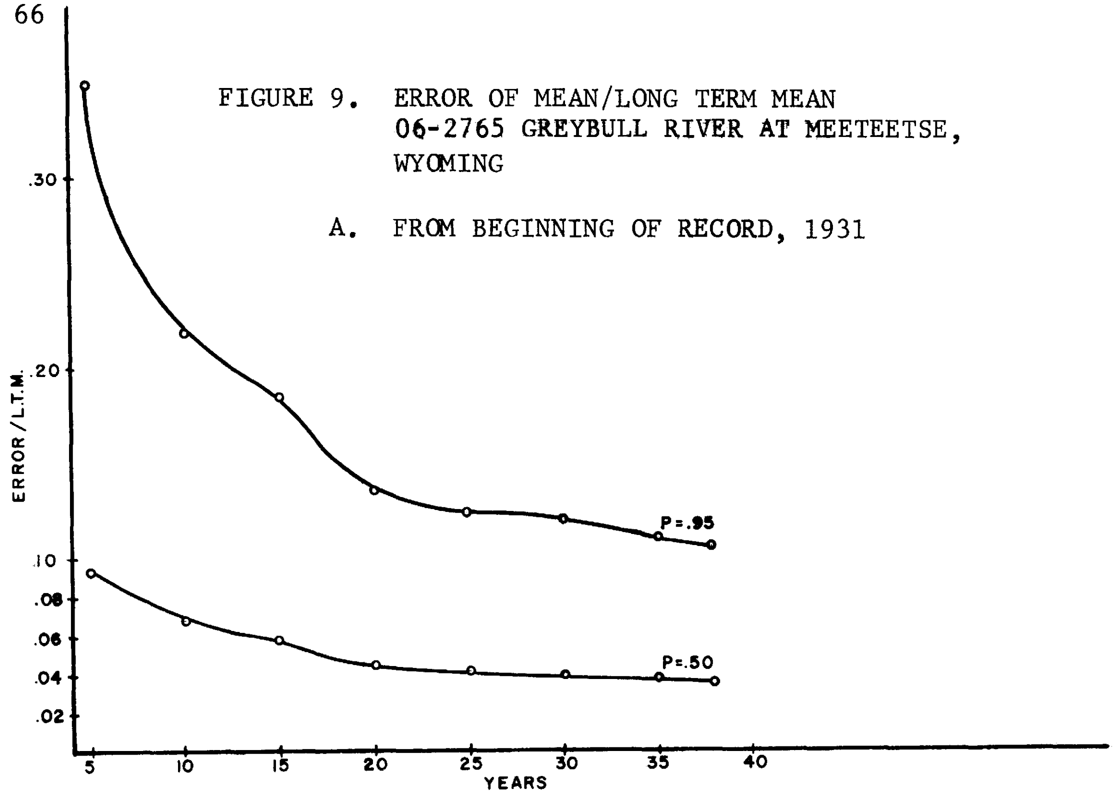


FIGURE 9. ERROR OF MEAN/LONG TERM MEAN
06-2765 GREYBULL RIVER AT MEETEETSE, WYOMING

A. FROM BEGINNING OF RECORD, 1931



B. FROM END OF RECORD, 1968

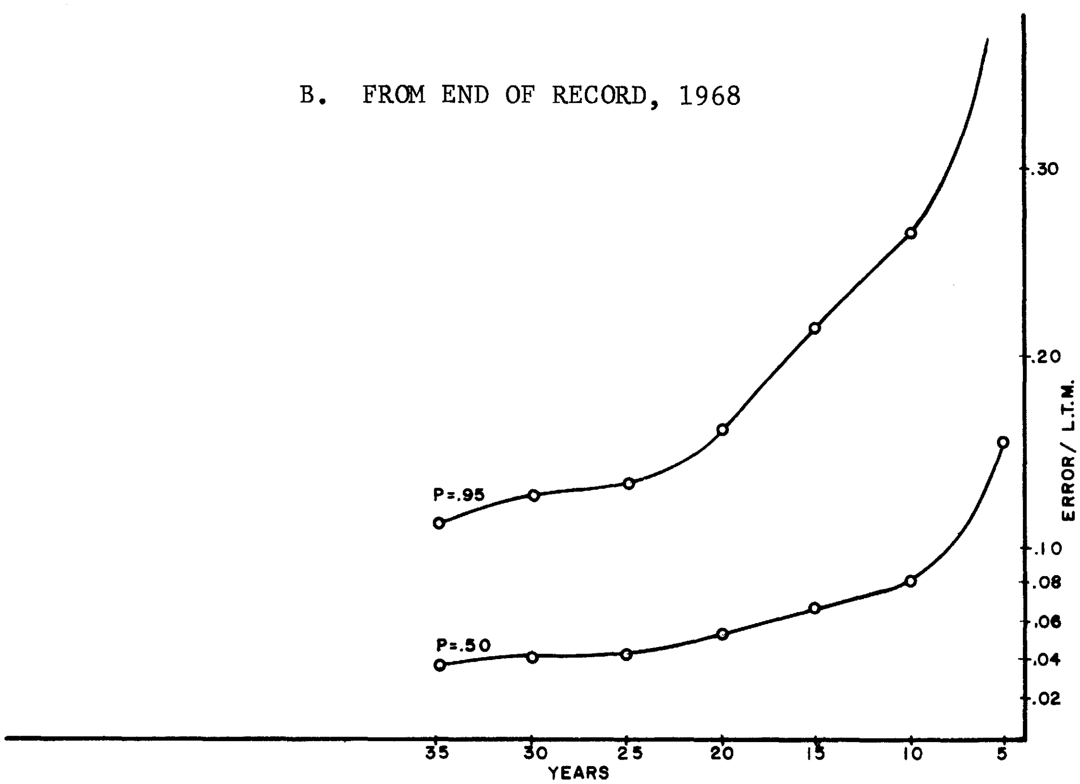
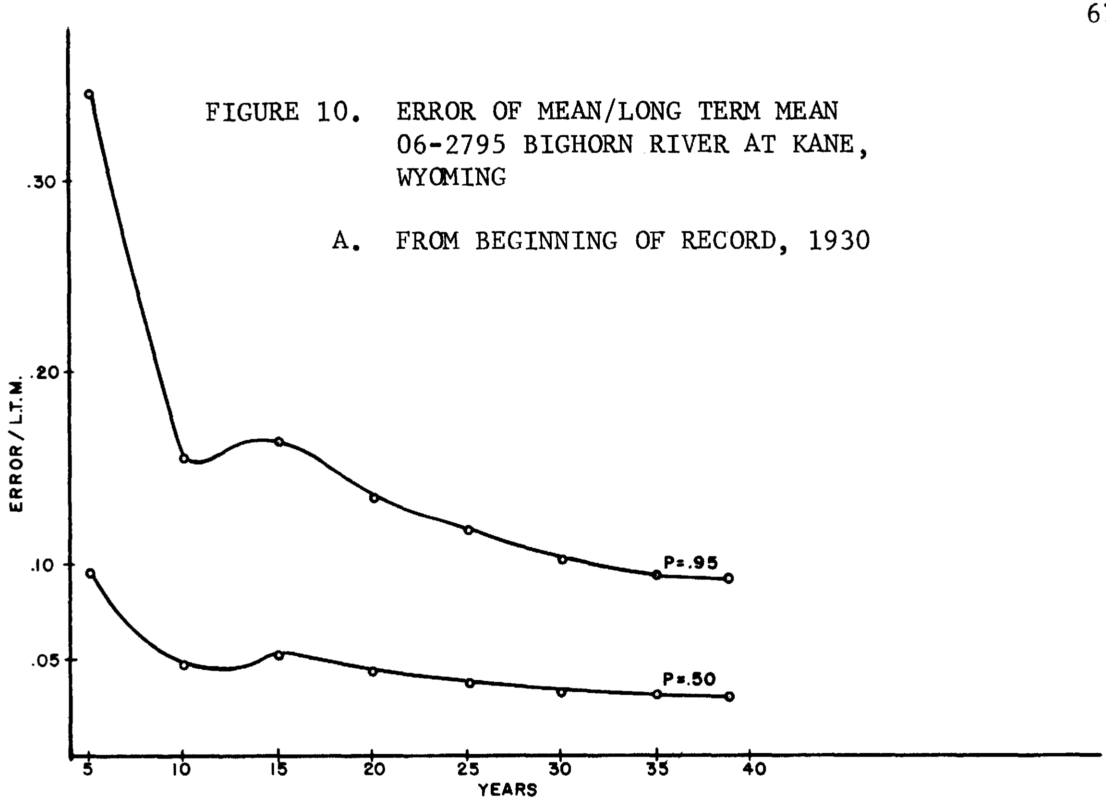


FIGURE 10. ERROR OF MEAN/LONG TERM MEAN
06-2795 BIGHORN RIVER AT KANE,
WYOMING

A. FROM BEGINNING OF RECORD, 1930



B. FROM END OF RECORD, 1968

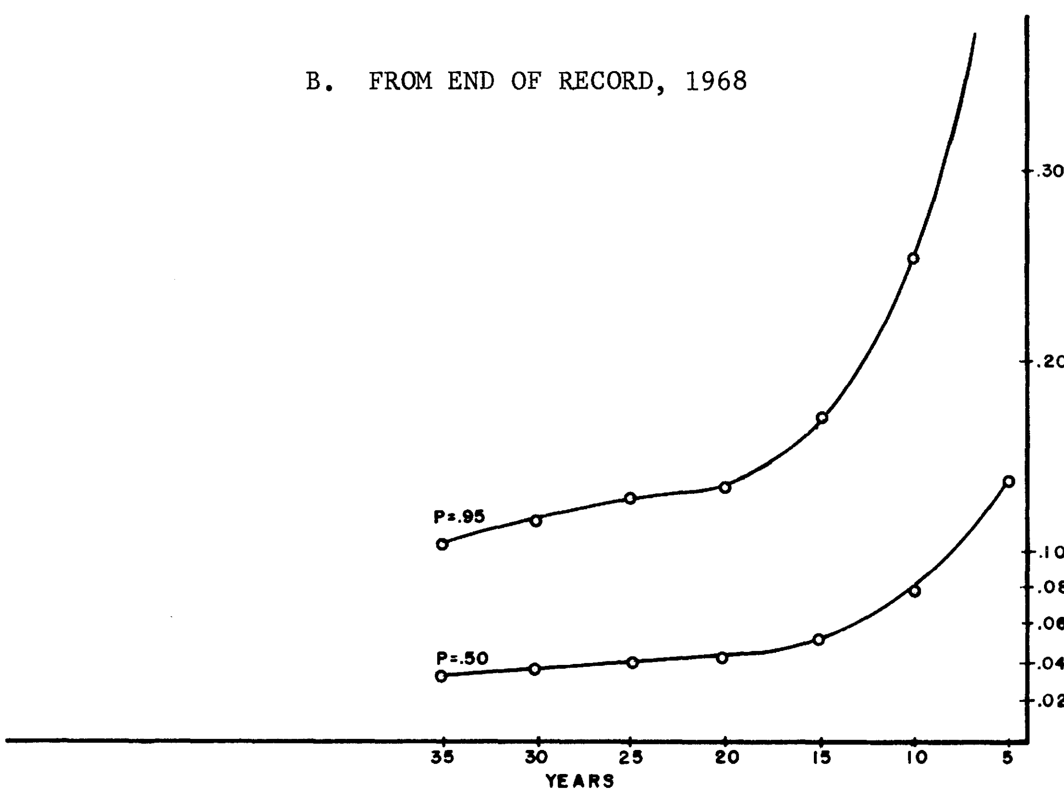


FIGURE 11. ERROR OF MEAN/LONG TERM MEAN
06-3170 POWDER RIVER AT ARVADA, WYOMING

A. FROM BEGINNING OF RECORD, 1935

B. FROM END OF RECORD, 1968

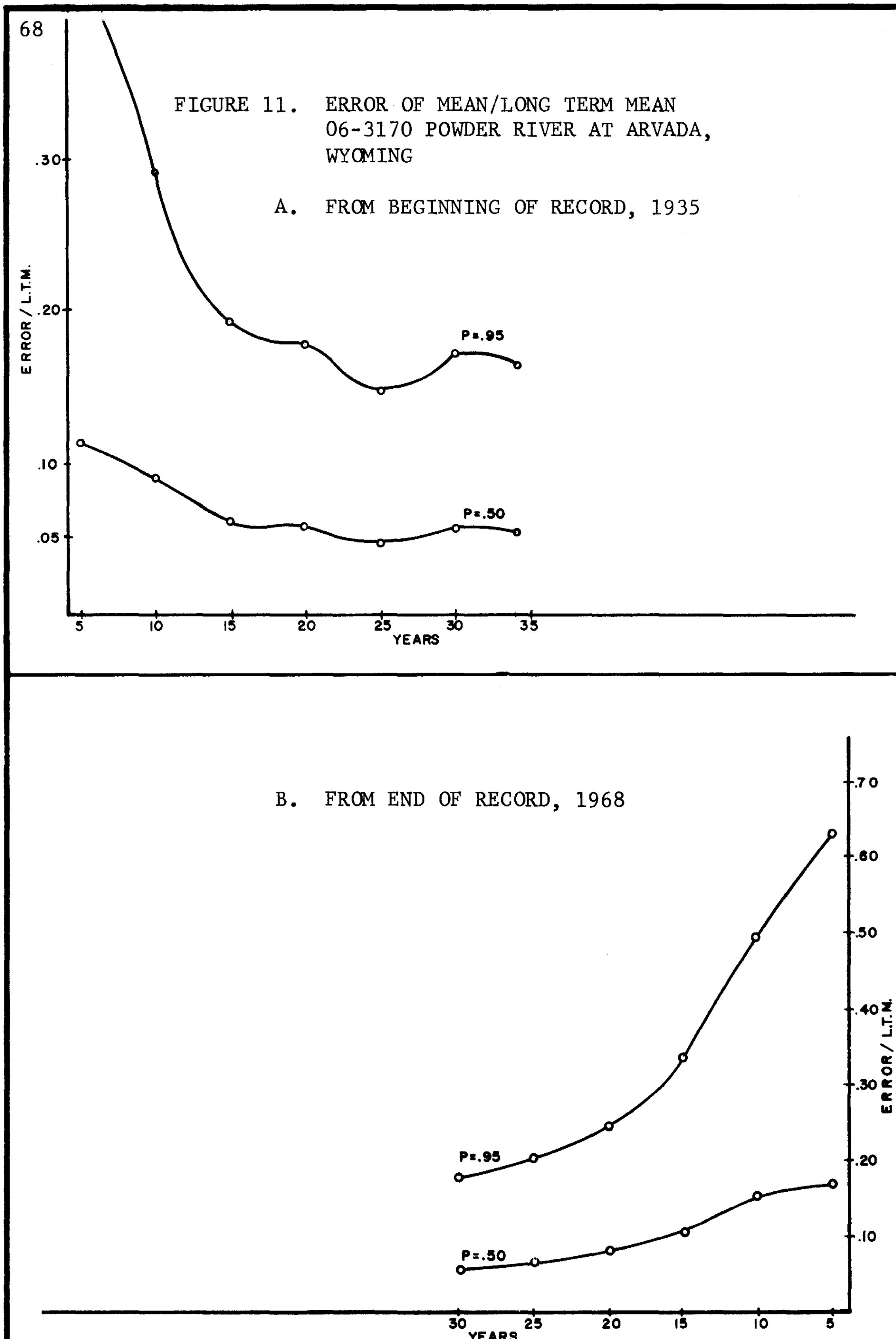
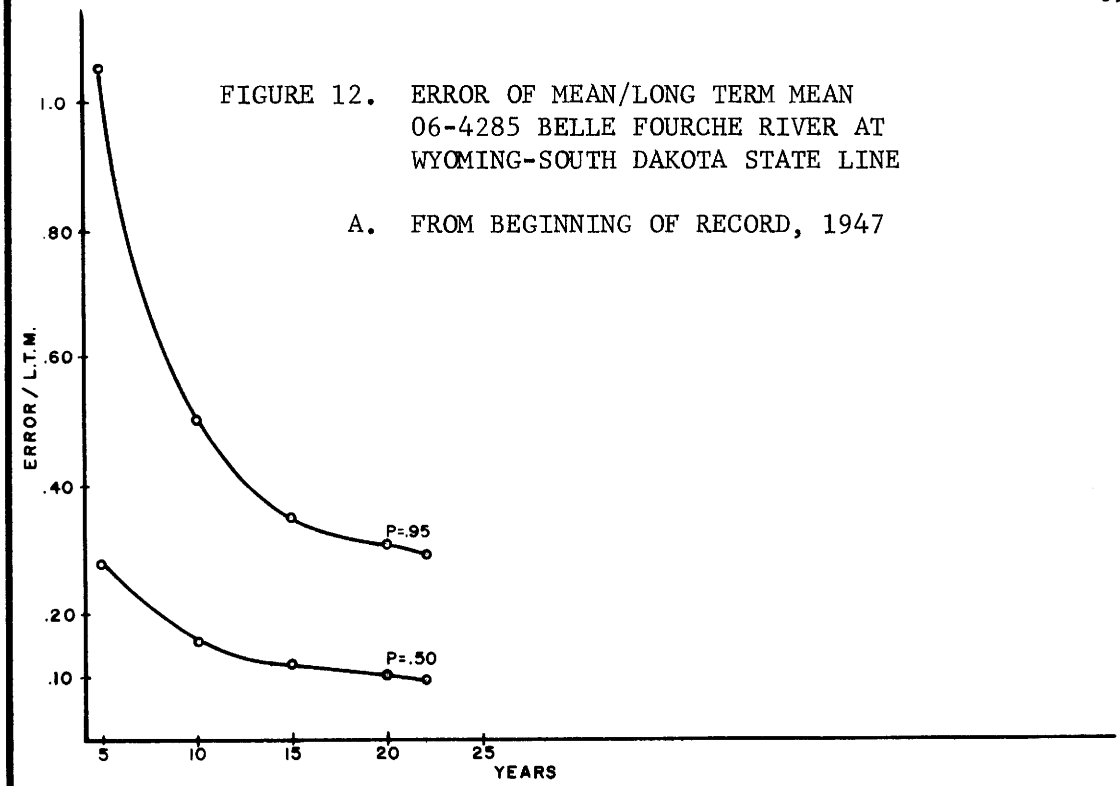


FIGURE 12. ERROR OF MEAN/LONG TERM MEAN
06-4285 BELLE FOURCHE RIVER AT
WYOMING-SOUTH DAKOTA STATE LINE

A. FROM BEGINNING OF RECORD, 1947



B. FROM END OF RECORD, 1968

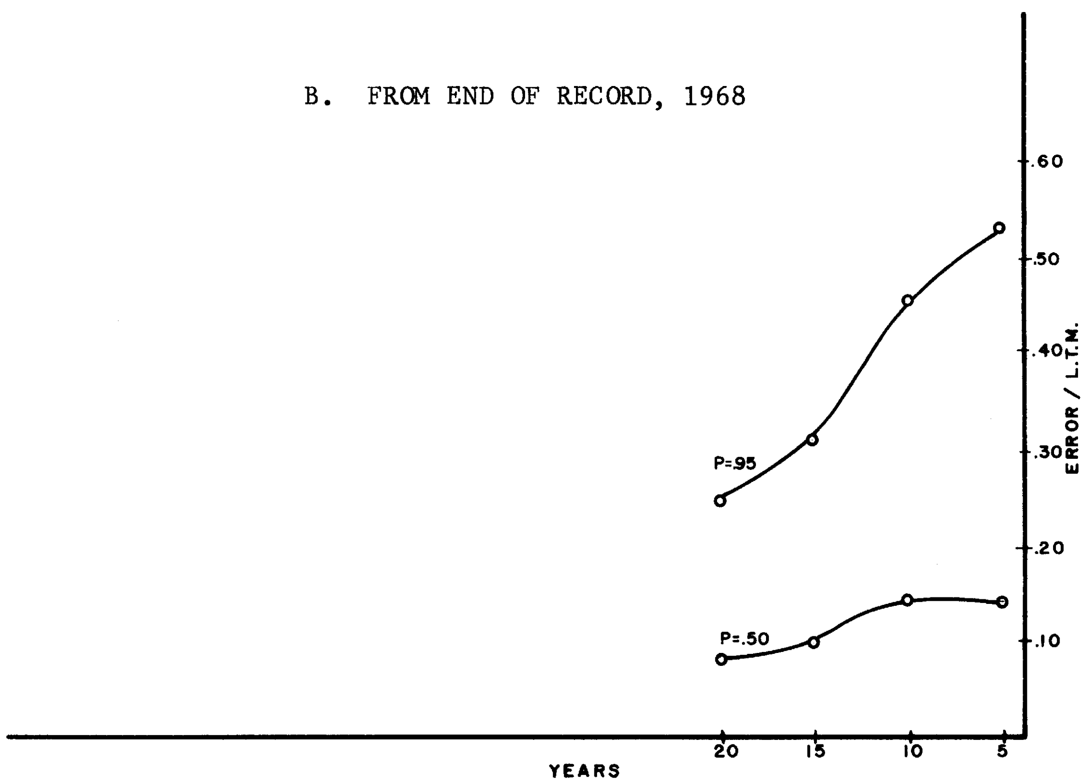


FIGURE 13. ERROR OF MEAN/LONG TERM MEAN 06-6200 NORTH PLATTE RIVER NEAR NORTHGATE, COLORADO

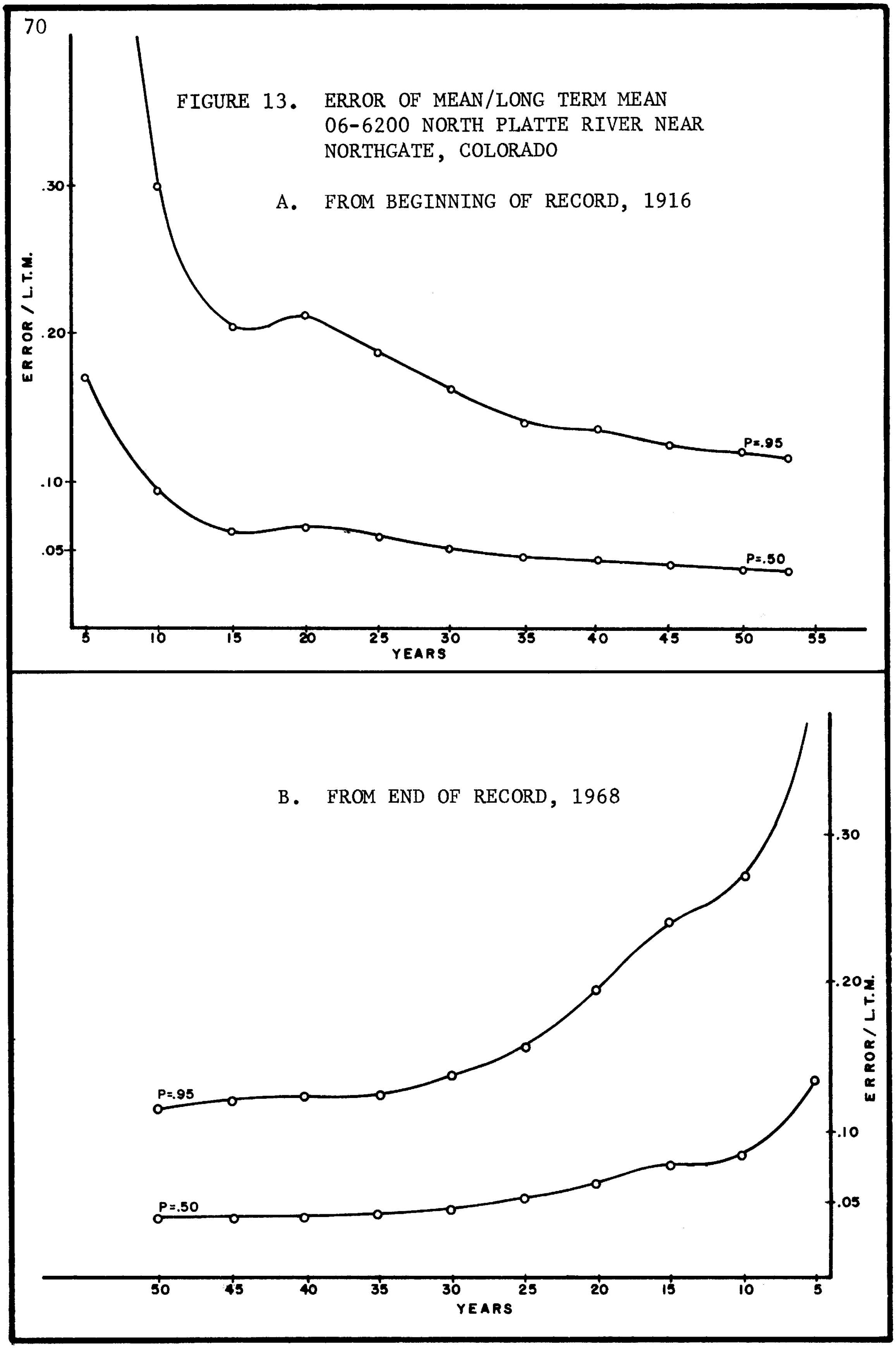
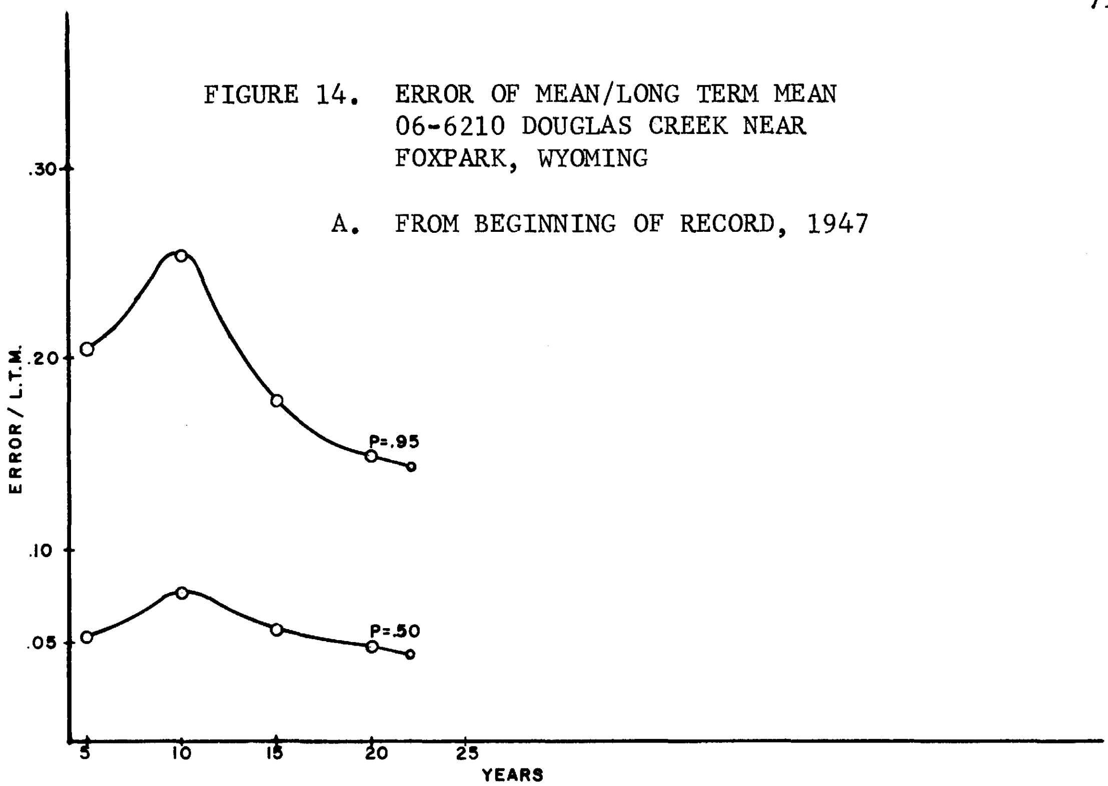


FIGURE 14. ERROR OF MEAN/LONG TERM MEAN
06-6210 DOUGLAS CREEK NEAR
FOXPARK, WYOMING

A. FROM BEGINNING OF RECORD, 1947



B. FROM END OF RECORD, 1968

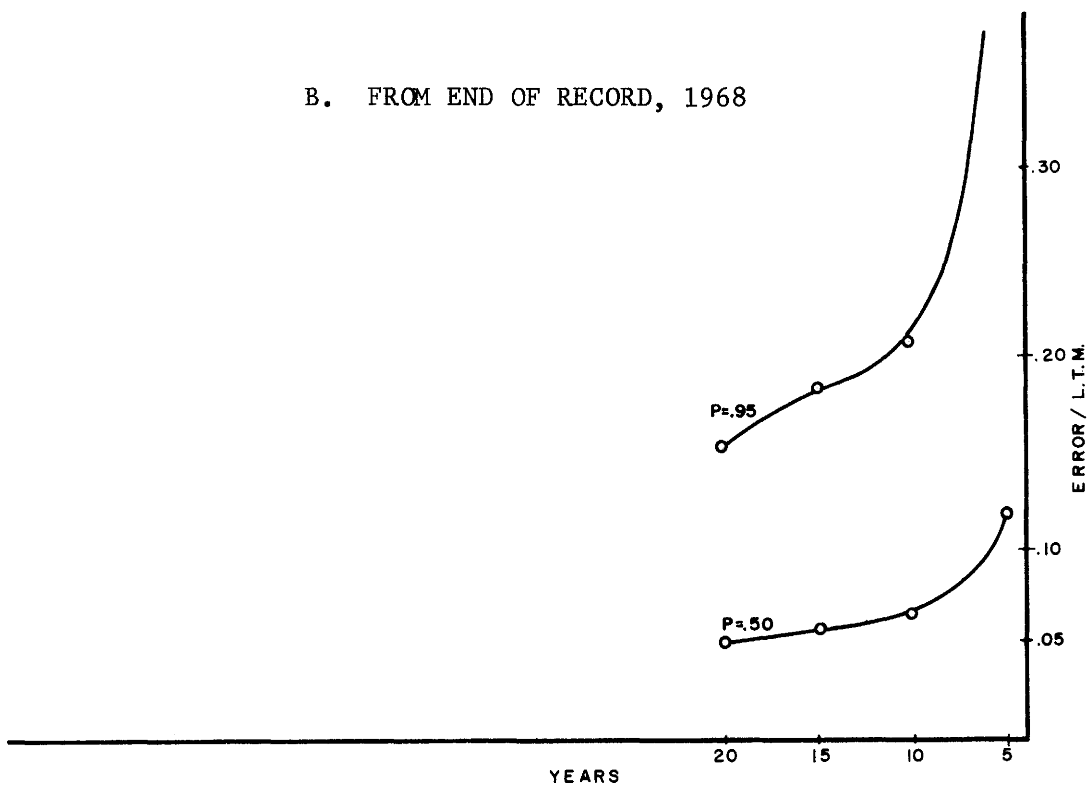
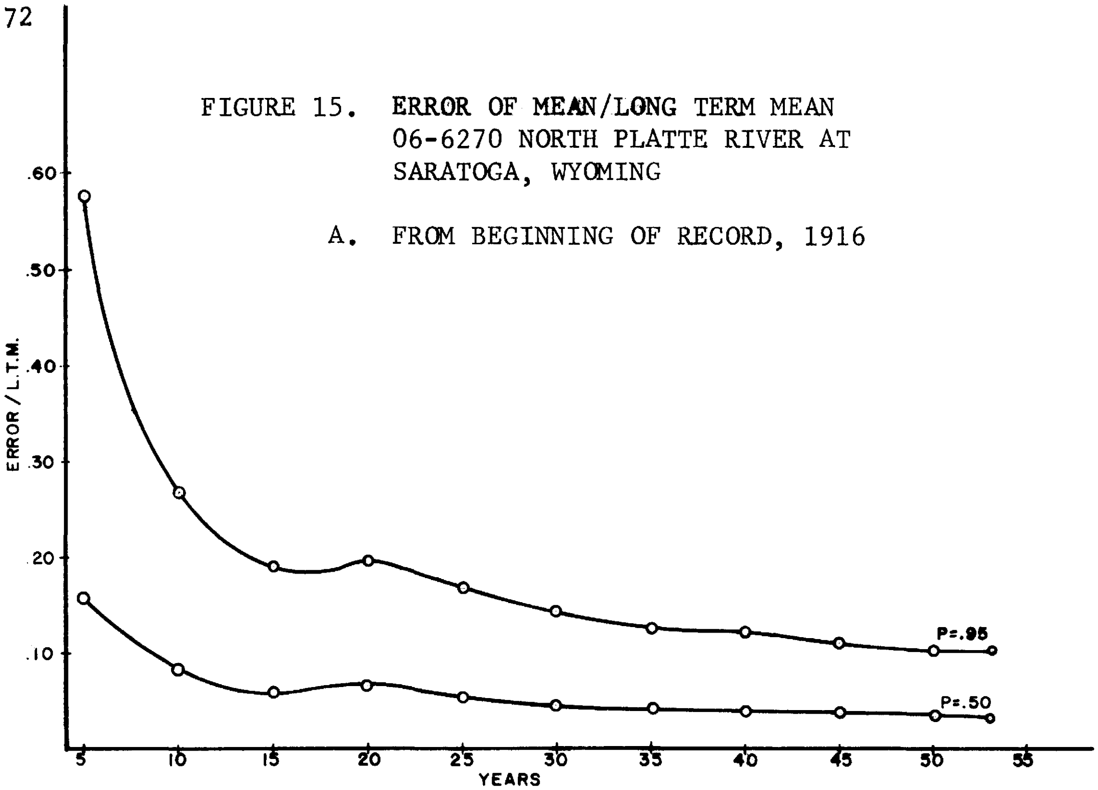


FIGURE 15. ERROR OF MEAN/LONG TERM MEAN
06-6270 NORTH PLATTE RIVER AT
SARATOGA, WYOMING

A. FROM BEGINNING OF RECORD, 1916



B. FROM END OF RECORD, 1968

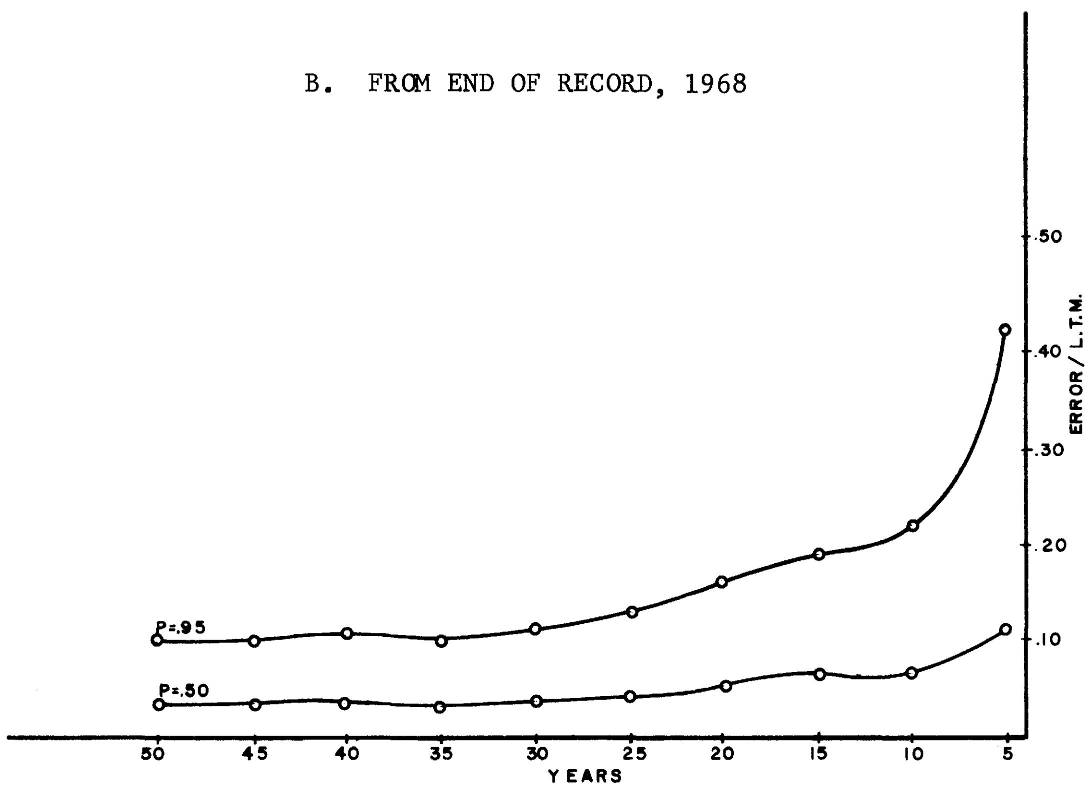
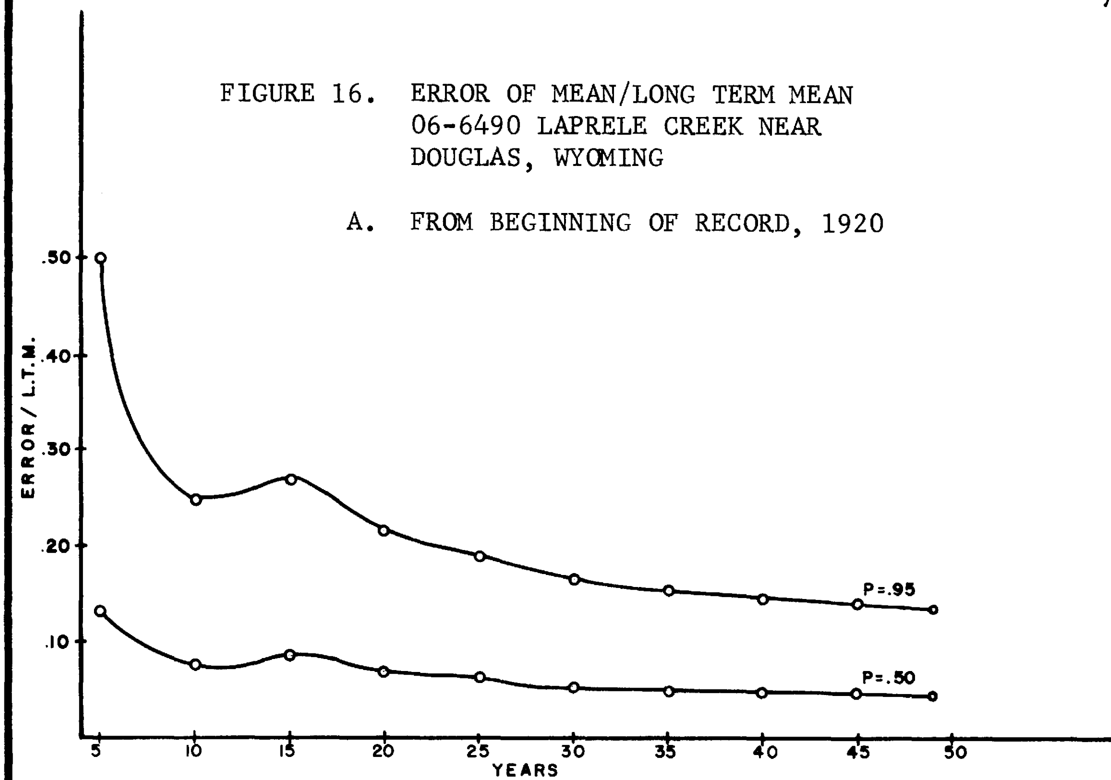


FIGURE 16. ERROR OF MEAN/LONG TERM MEAN
06-6490 LAPRELE CREEK NEAR
DOUGLAS, WYOMING

A. FROM BEGINNING OF RECORD, 1920



B. FROM END OF RECORD, 1968

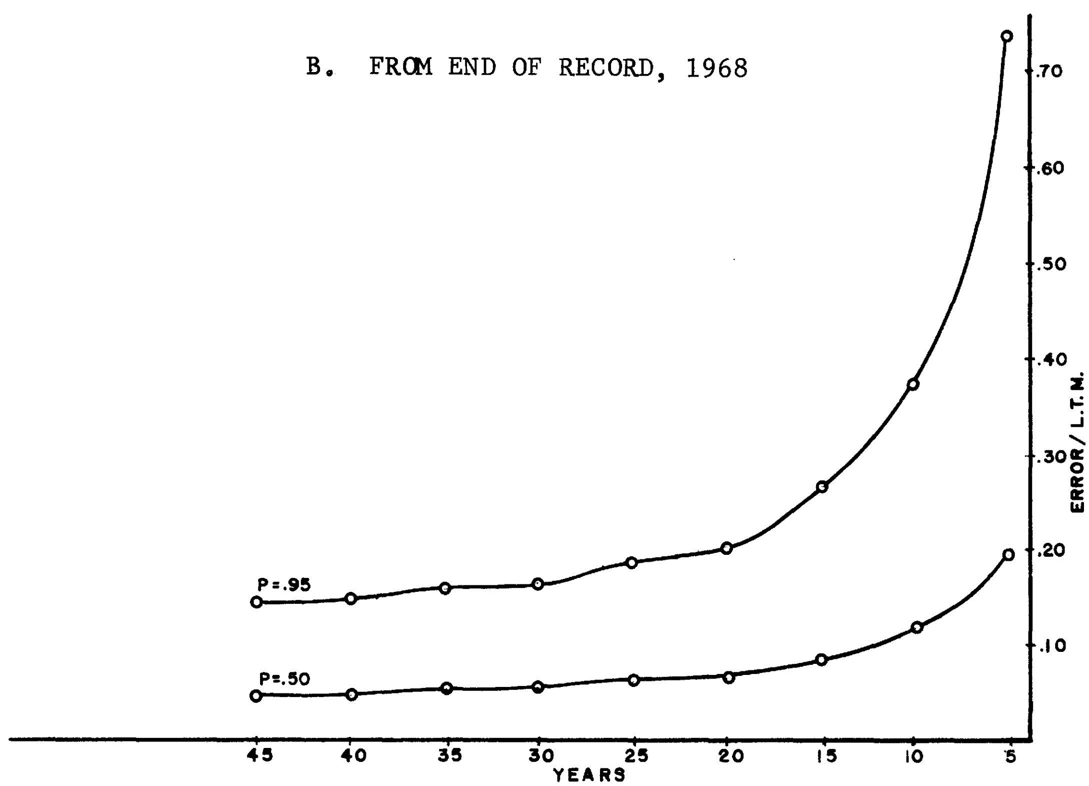
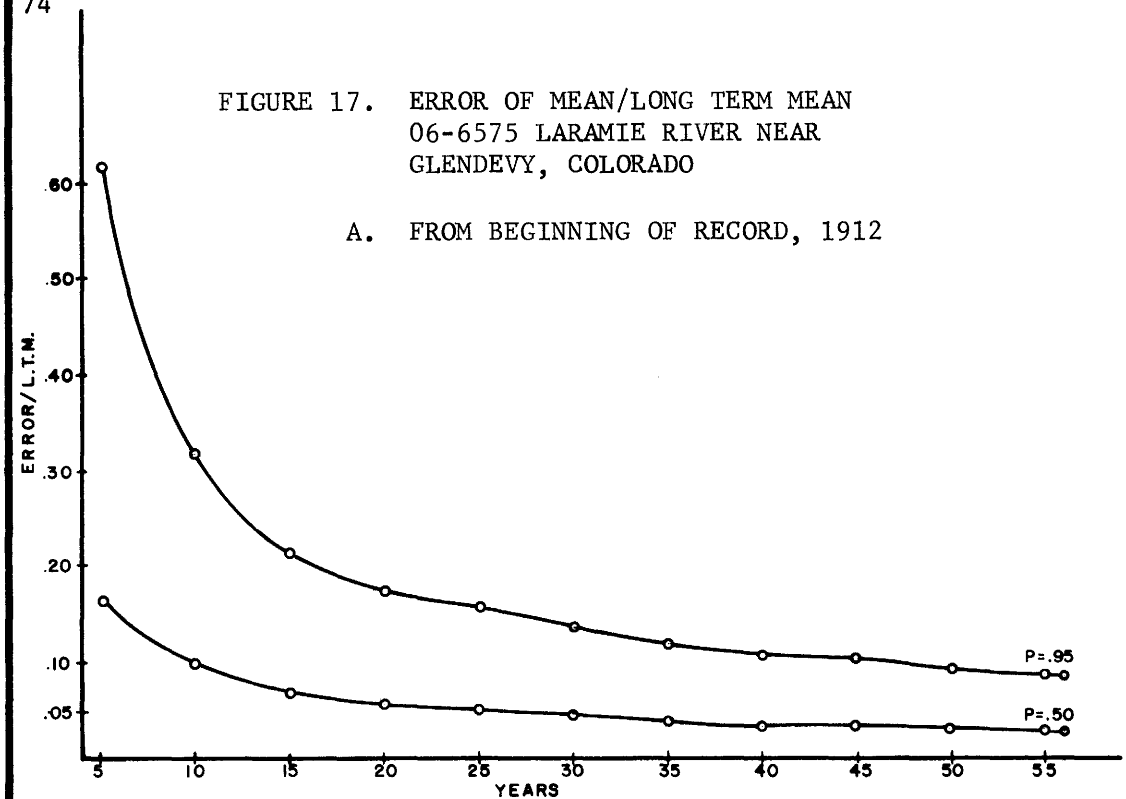


FIGURE 17. ERROR OF MEAN/LONG TERM MEAN
06-6575 LARAMIE RIVER NEAR
GLENDEVY, COLORADO

A. FROM BEGINNING OF RECORD, 1912



B. FROM END OF RECORD, 1968

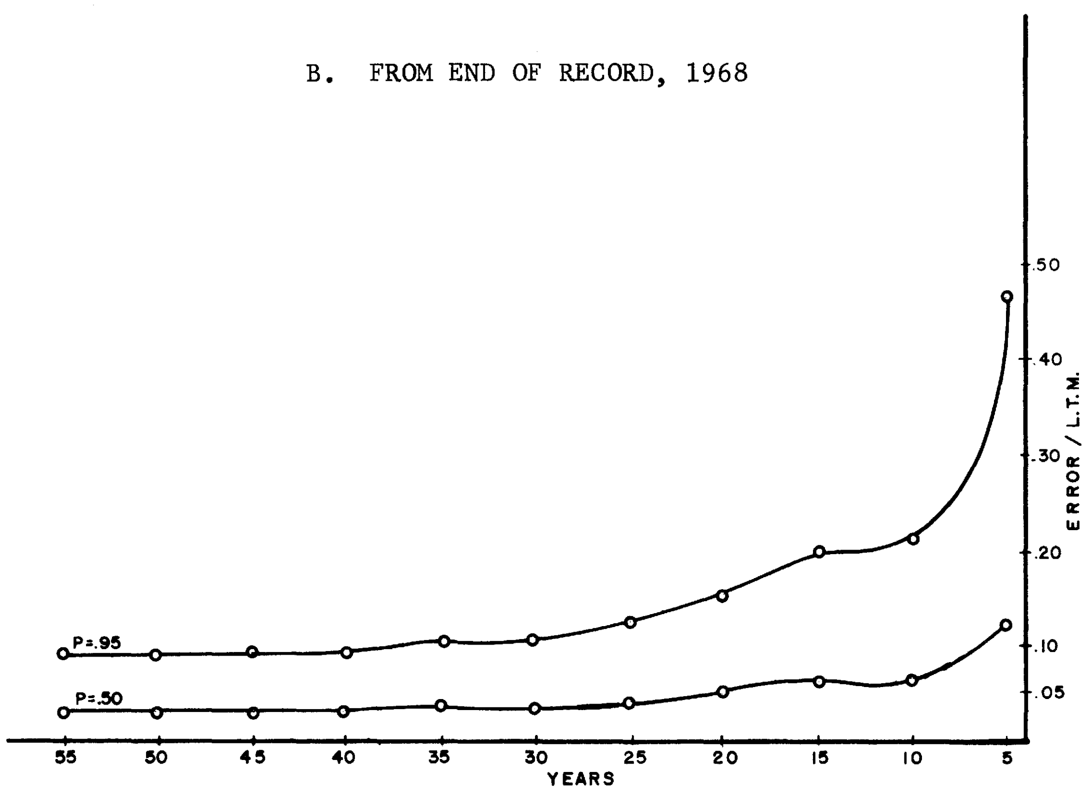
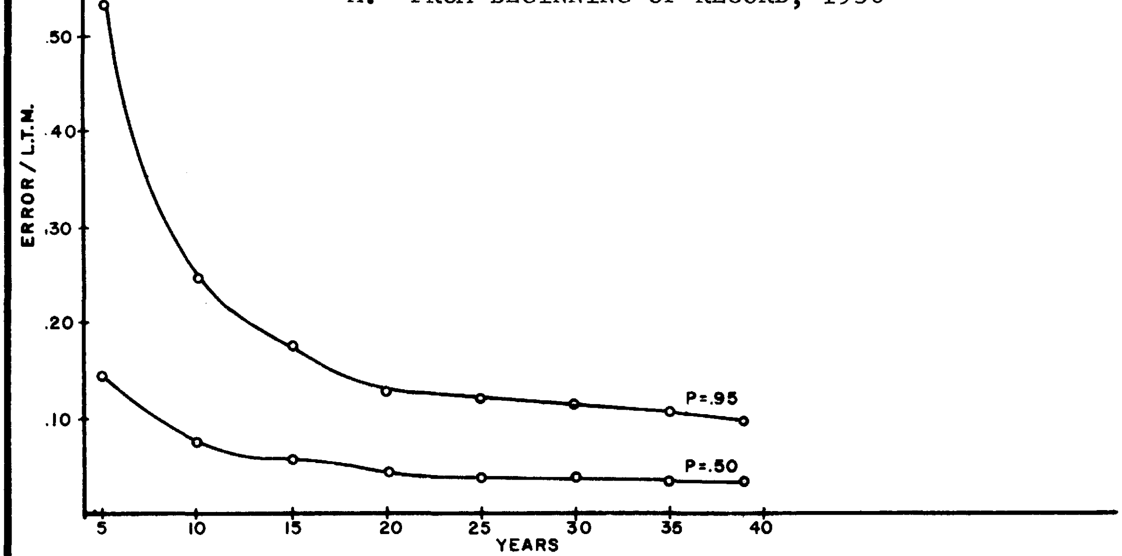


FIGURE 18. ERROR OF MEAN/LONG TERM MEAN
06-6745 NORTH PLATTE RIVER AT
WYOMING-NEBRASKA STATE LINE

A. FROM BEGINNING OF RECORD, 1930



B. FROM END OF RECORD, 1968

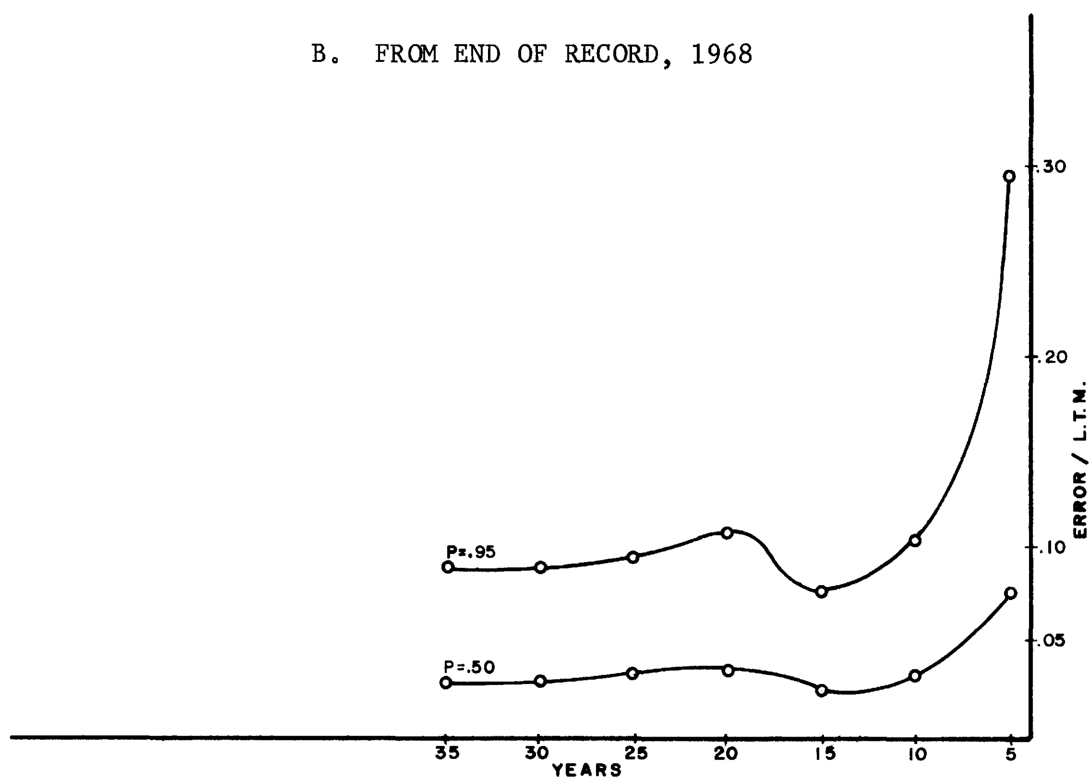
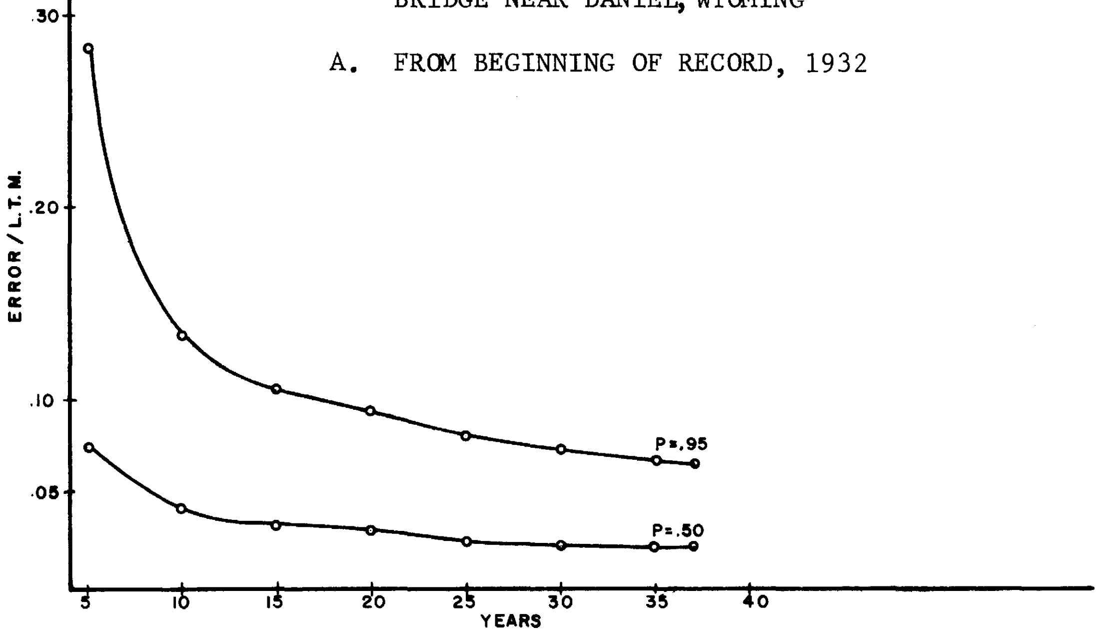


FIGURE 19. ERROR OF MEAN/LONG TERM MEAN
09-1885 GREEN RIVER AT WARREN
BRIDGE NEAR DANIEL, WYOMING

A. FROM BEGINNING OF RECORD, 1932



B. FROM END OF RECORD, 1968

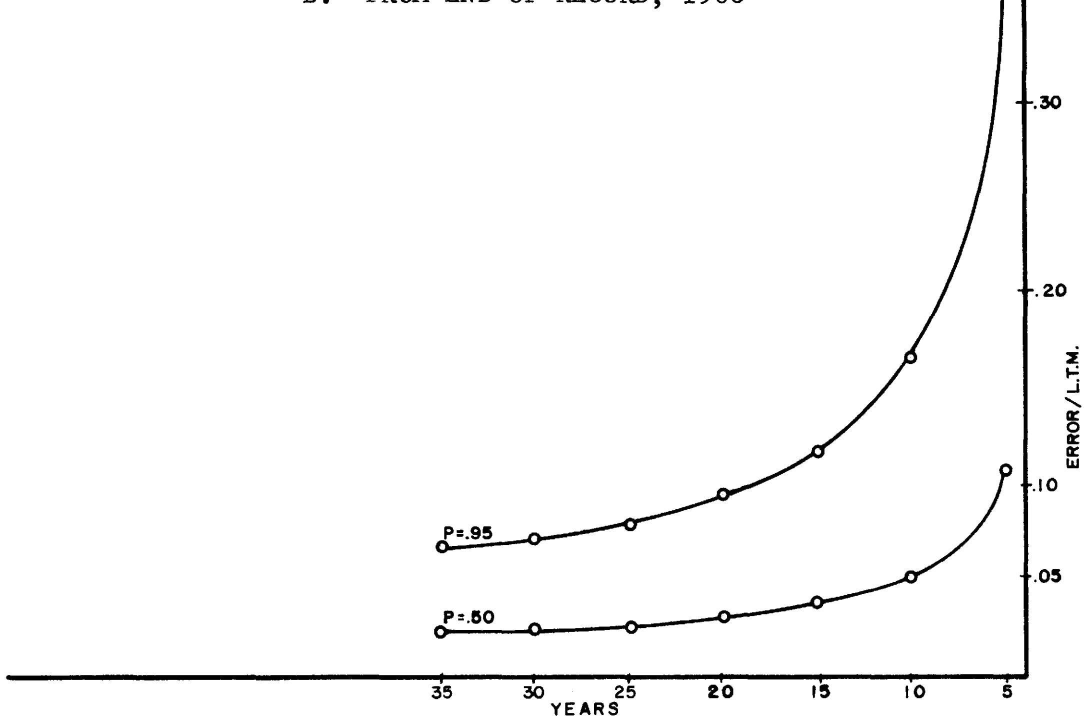


FIGURE 20. ERROR OF MEAN/LONG TERM MEAN 09-2055 NORTH PINEY CREEK NEAR MASON, WYOMING

A. FROM BEGINNING OF RECORD, 1932

B. FROM END OF RECORD, 1968

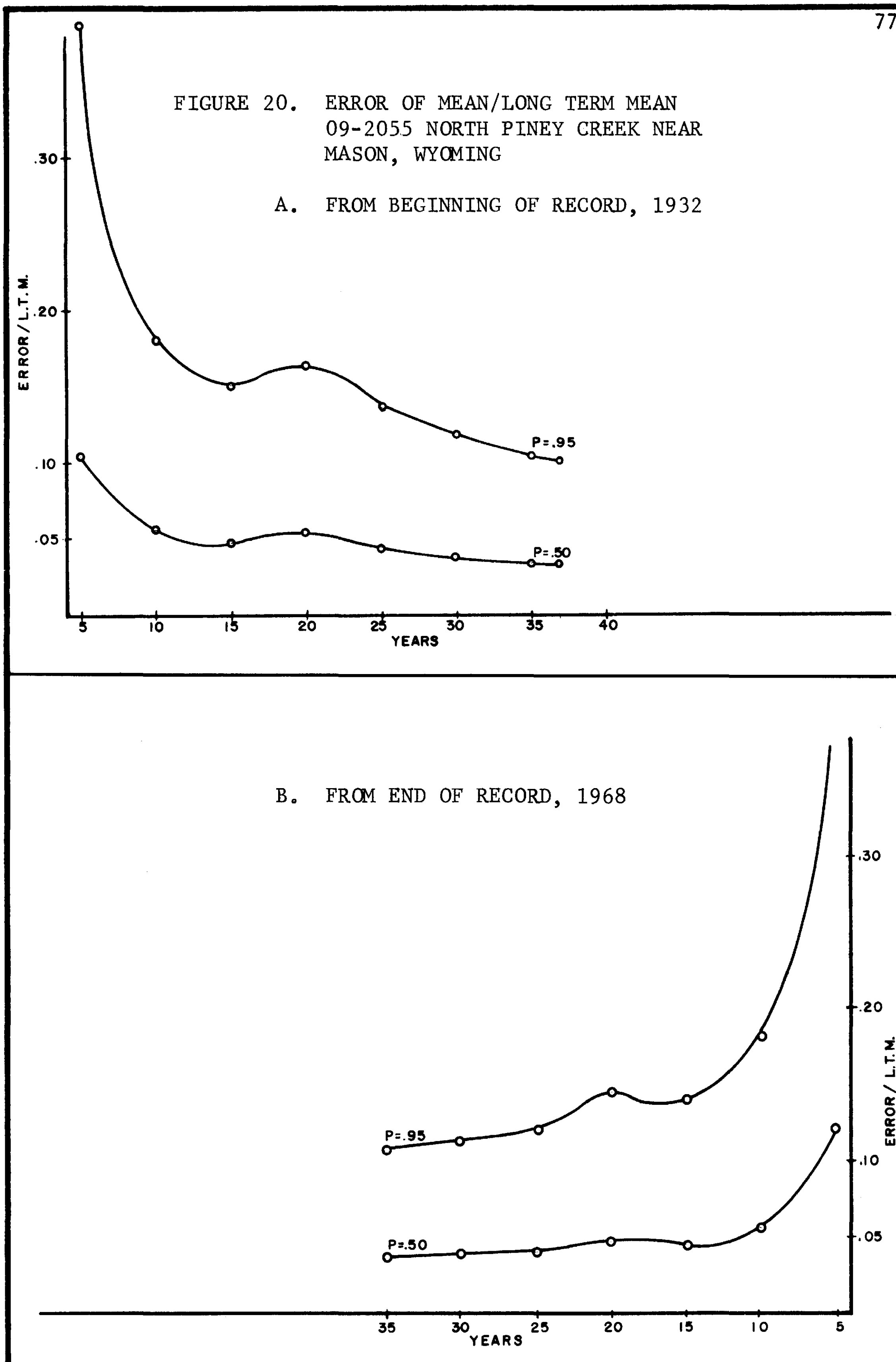
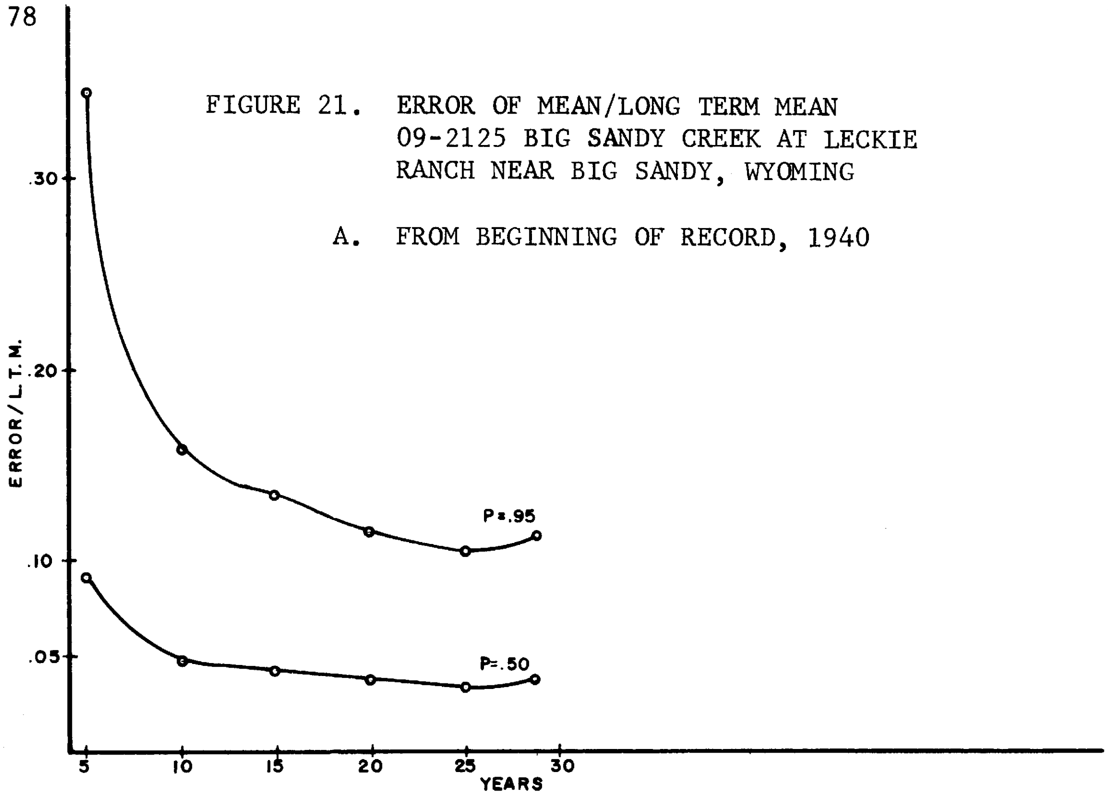


FIGURE 21. ERROR OF MEAN/LONG TERM MEAN
09-2125 BIG SANDY CREEK AT LECKIE
RANCH NEAR BIG SANDY, WYOMING

A. FROM BEGINNING OF RECORD, 1940



B. FROM END OF RECORD, 1968

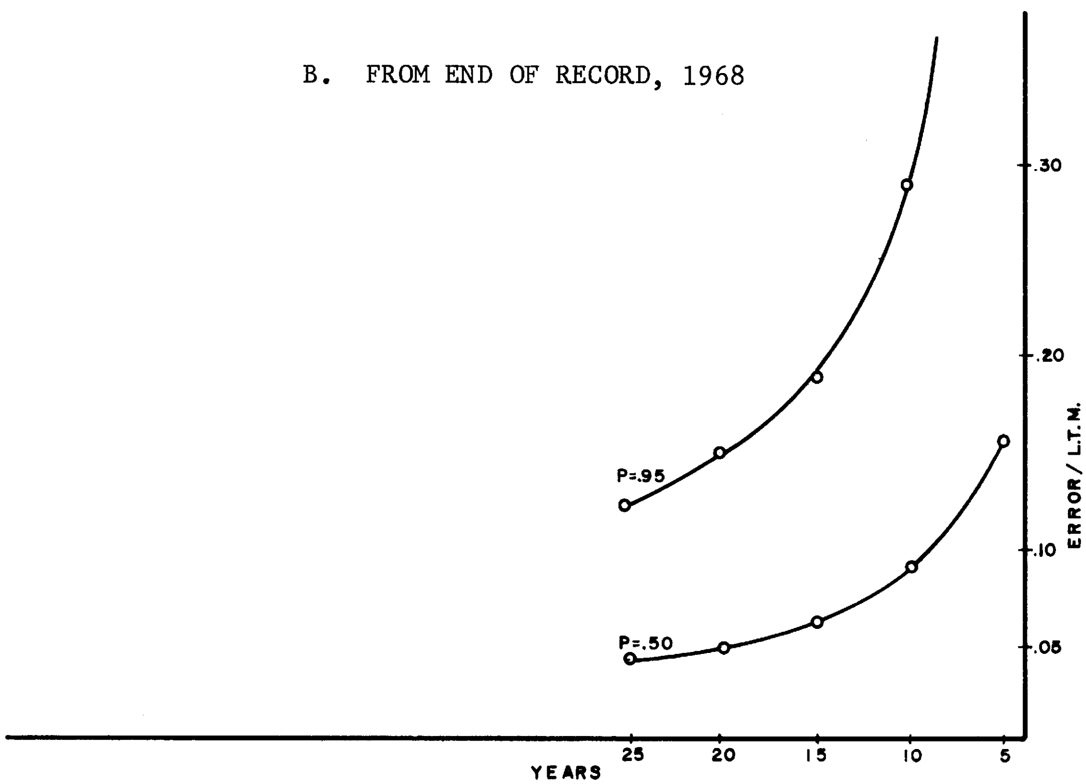
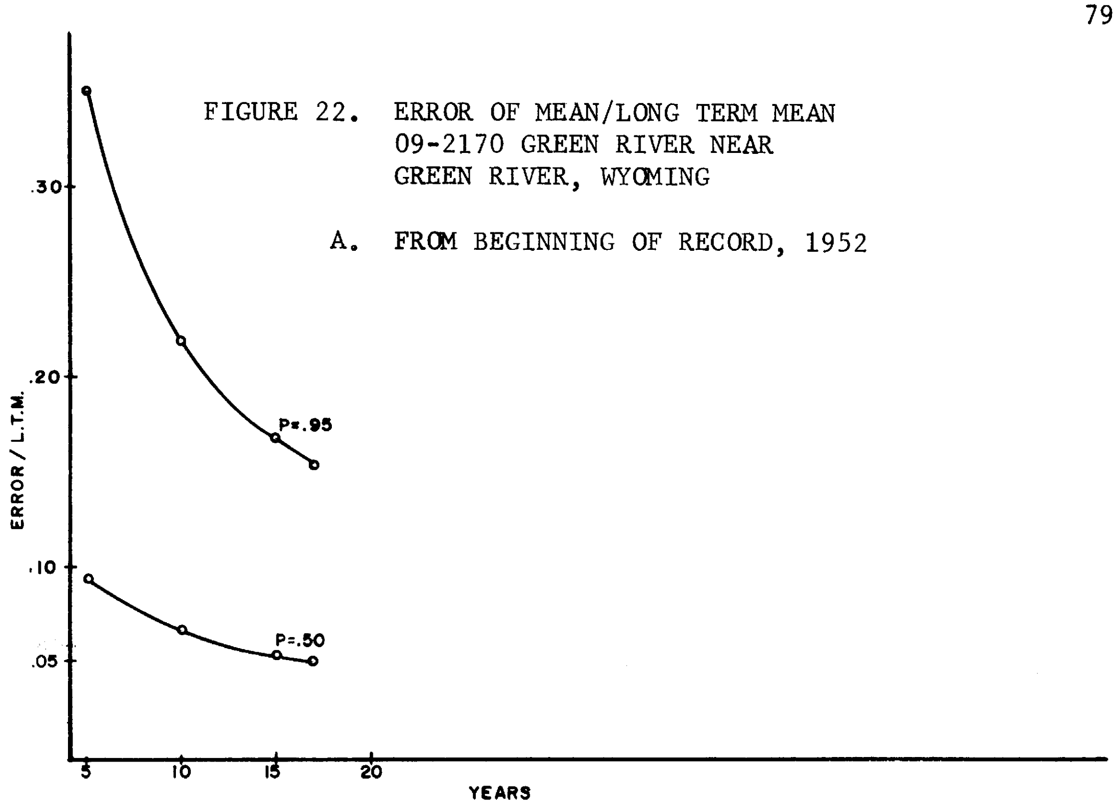


FIGURE 22. ERROR OF MEAN/LONG TERM MEAN
09-2170 GREEN RIVER NEAR
GREEN RIVER, WYOMING

A. FROM BEGINNING OF RECORD, 1952



B. FROM END OF RECORD, 1968

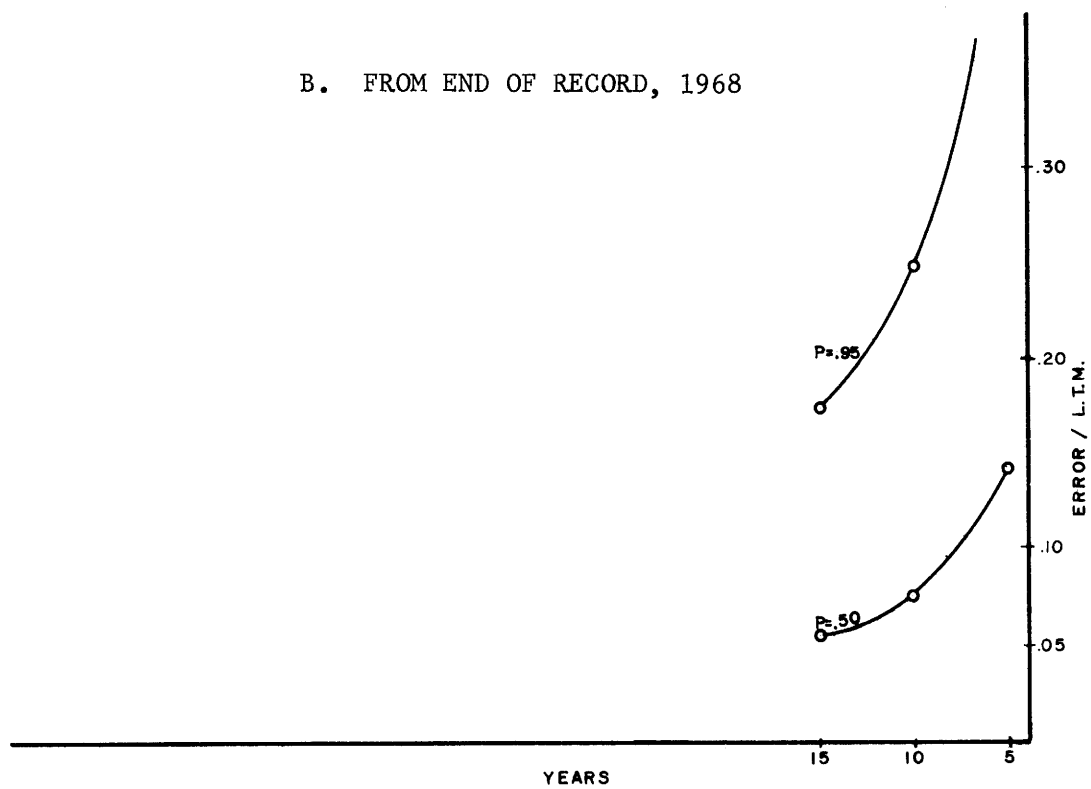
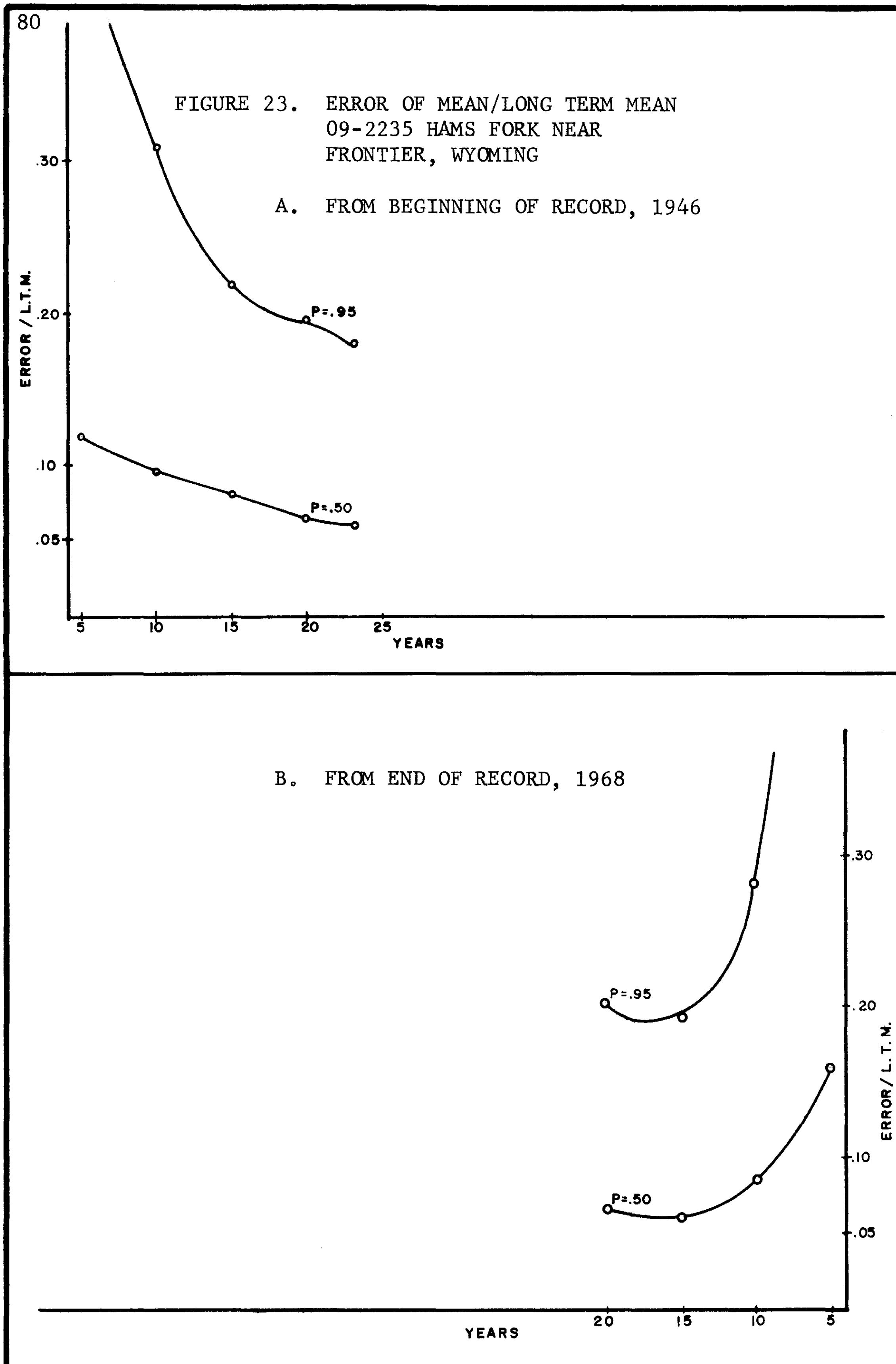


FIGURE 23. ERROR OF MEAN/LONG TERM MEAN
09-2235 HAMS FORK NEAR
FRONTIER, WYOMING

A. FROM BEGINNING OF RECORD, 1946

B. FROM END OF RECORD, 1968



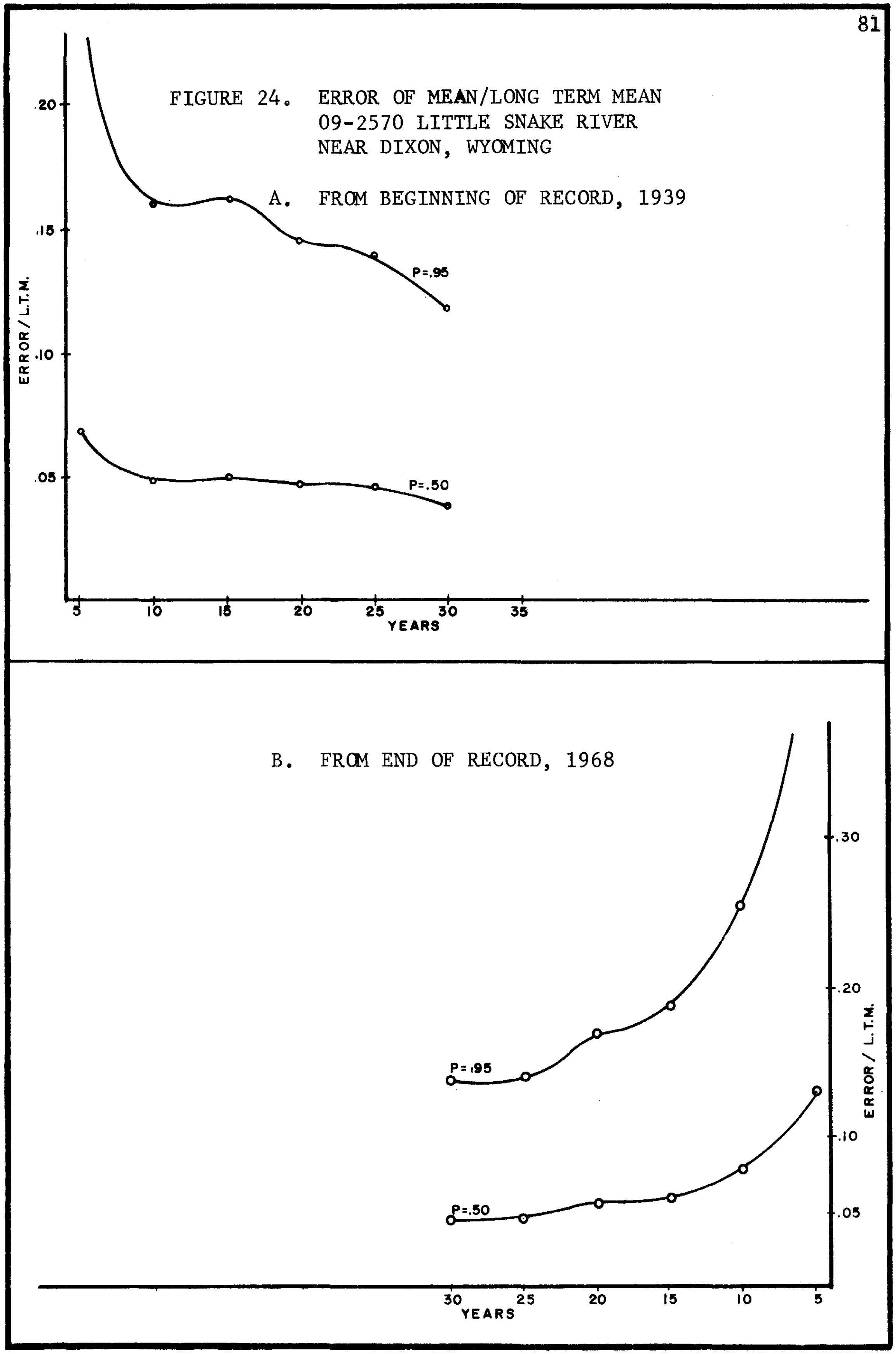


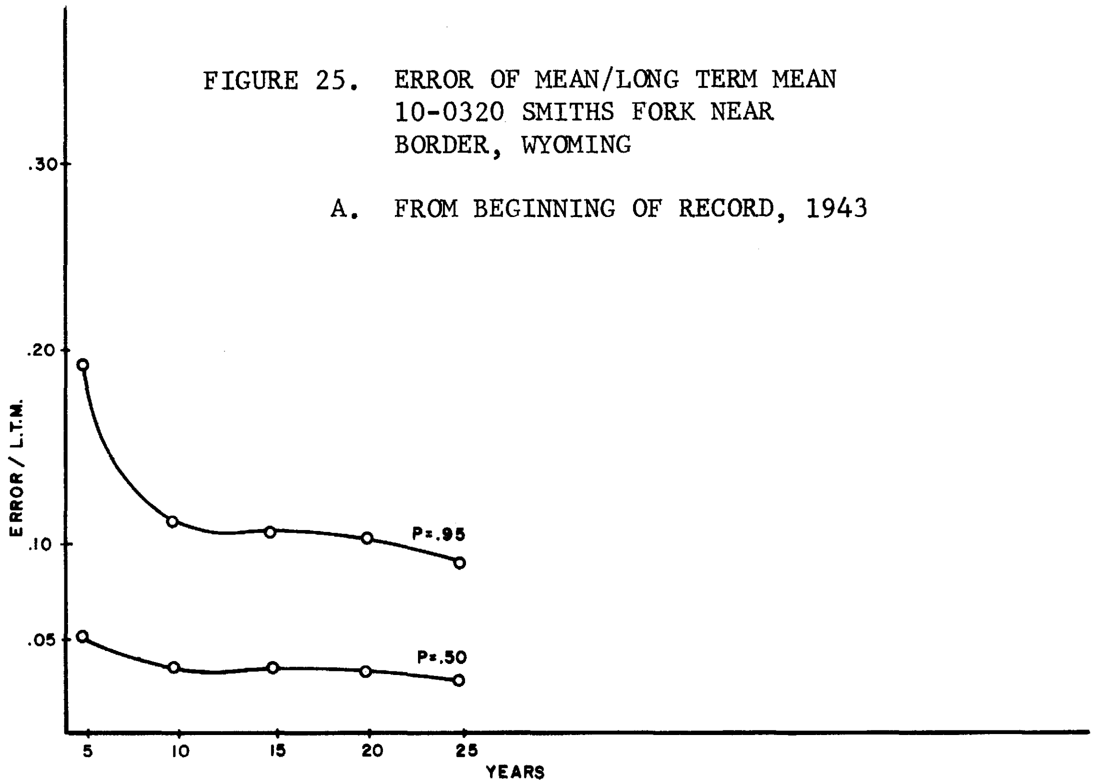
FIGURE 24. ERROR OF MEAN/LONG TERM MEAN
09-2570 LITTLE SNAKE RIVER
NEAR DIXON, WYOMING

A. FROM BEGINNING OF RECORD, 1939

B. FROM END OF RECORD, 1968

FIGURE 25. ERROR OF MEAN/LONG TERM MEAN
10-0320 SMITHS FORK NEAR
BORDER, WYOMING

A. FROM BEGINNING OF RECORD, 1943



B. FROM END OF RECORD, 1968

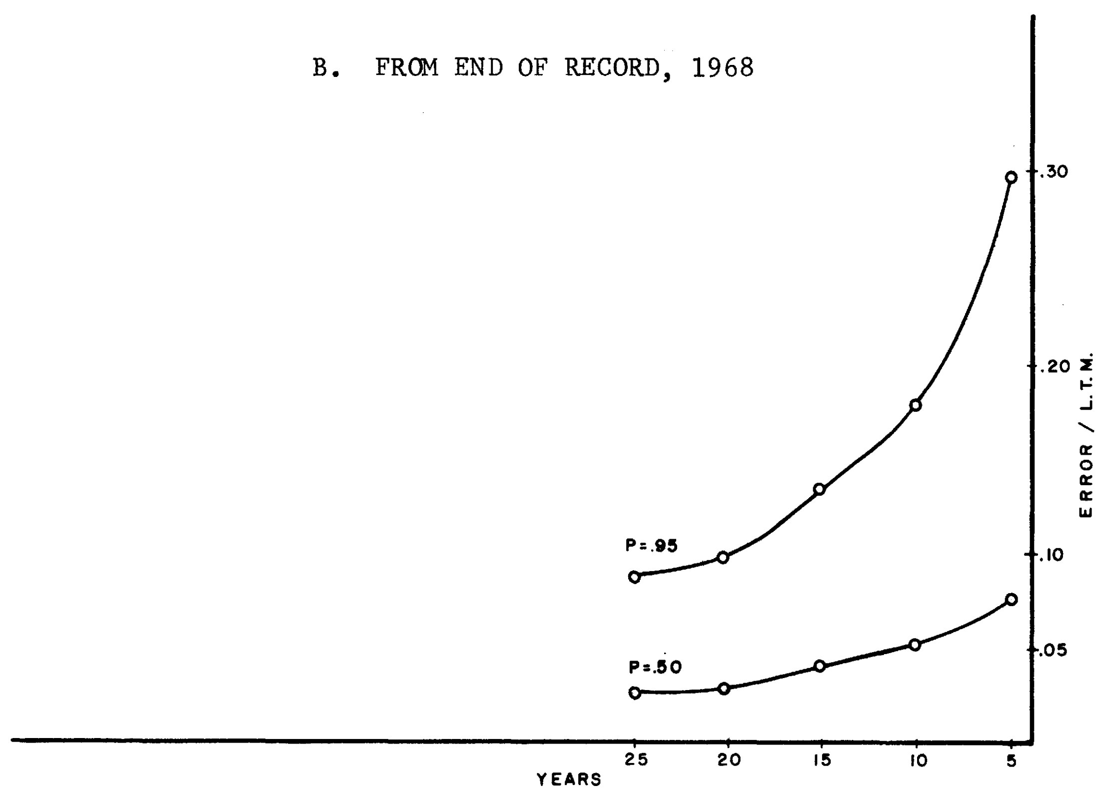


FIGURE 26. ERROR OF MEAN/LONG TERM MEAN
13-0110 (SOUTH FORK) SNAKE RIVER
AT MORAN, WYOMING

A. FROM BEGINNING OF RECORD, 1904

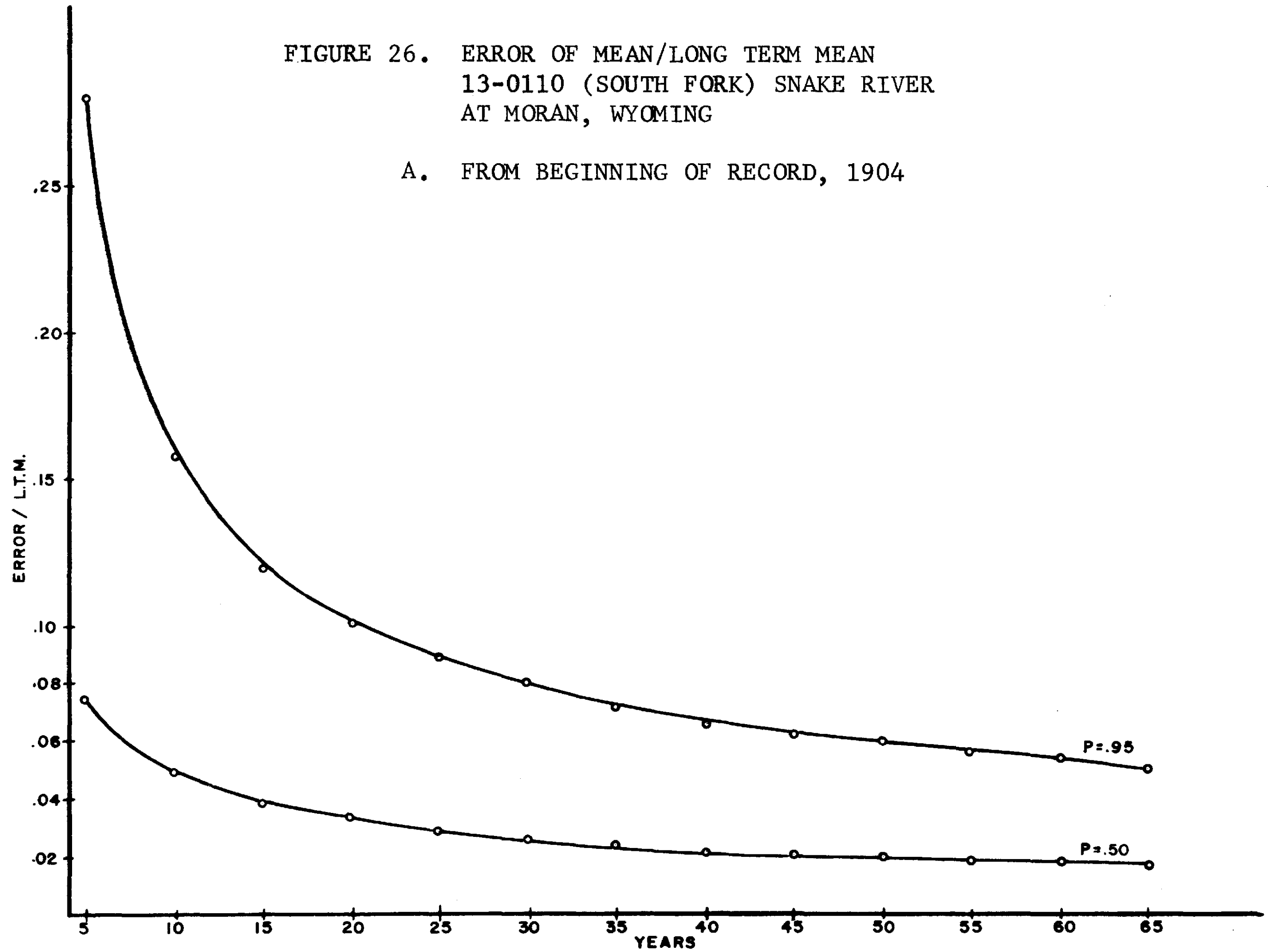


FIGURE 26. ERROR OF MEAN/LONG TERM MEAN
13-0110 (SOUTH FORK) SNAKE RIVER
AT MORAN, WYOMING

B. FROM END OF RECORD, 1968

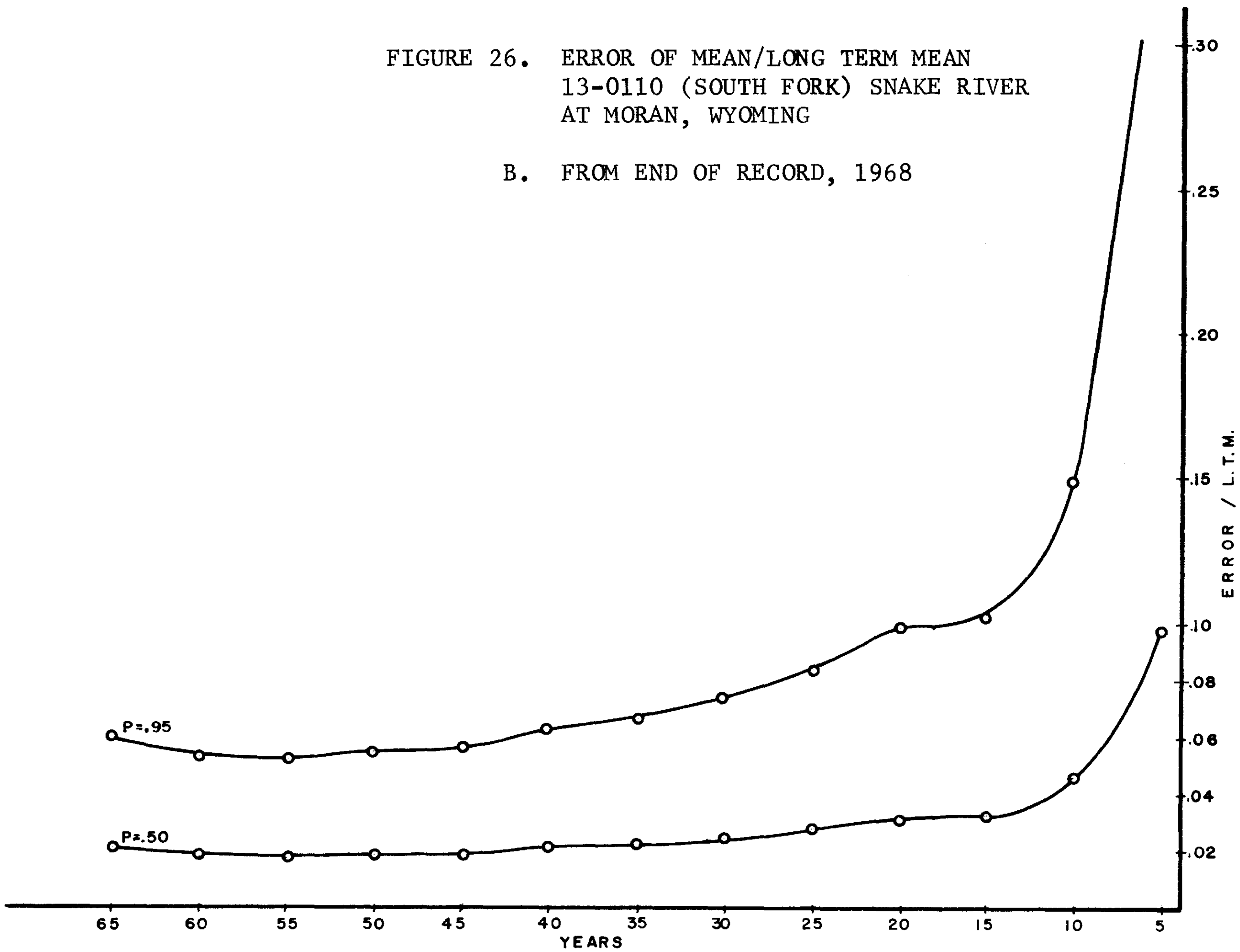


TABLE XI

ERROR OF MEAN AND POSSIBLE ERROR, FROM BEGINNING OF RECORD

STATION NUMBER	YEARS OF RECORD L T M	PROBA-BILITY		YEARS IN PERIOD FROM BEGINNING OF RECORD												
				5	10	15	20	25	30	35	40	45	50	55	60	65
06-0375	46	.95	Error	46556	33095	25928	20314	18381	17601	16115	14198	13996				
			Error/LTM	.137	.098	.076	.060	.054	.052	.047	.042	.041				
		.50	Error	12427	10285	8364	6677	6100	5878	5411	4781	4723				
	337532		Error/LTM	.036	.030	.024	.019	.018	.017	.016	.014	.013				
06-1880	45	.95	Error	261610	140755	96754	80331	64433	54871	48349	44073	41944				
			Error/LTM	.436	.235	.161	.134	.107	.091	.080	.073	.070				
		.50	Error	69831	43744	31214	26406	21384	18326	16235	14843	14154				
	598884		Error/LTM	.116	.073	.052	.044	.035	.030	.027	.024	.023				
06-2075	47	.95	Error	207431	147613	99618	78441	68881	59726	52552	48198	43947				
			Error/LTM	.306	.218	.147	.115	.101	.088	.077	.071	.064				
		.50	Error	55369	45876	32137	25784	22860	19947	17646	16232	14830				
	676410		Error/LTM	.081	.067	.047	.038	.033	.029	.026	.023	.021				
06-2640	27	.95	Error	22146	11269	9257	7679	6326								
			Error/LTM	1.107	.563	.463	.384	.316								
		.50	Error	5911	3502	2986	2524	2099								
	19993		Error/LTM	.295	.175	.149	.126	.105								
06-2730	25	.95	Error	4075	1967	2018	1875	2150								
			Error/LTM	.164	.079	.081	.075	.086								
		.50	Error	1087	611	651	616	713								
	24747		Error/LTM	.043	.024	.026	.024	.028								
06-2765	38	.95	Error	84498	53107	44703	33077	30119	29114	26750						
			Error/LTM	.349	.219	.184	.136	.124	.120	.110						
		.50	Error	22555	16505	14421	10873	9996	9723	8982						
	241712		Error/LTM	.093	.068	.059	.044	.041	.040	.037						
06-2795	39	.95	Error	576008	252735	265132	219333	192232	165023	156965						
			Error/LTM	.354	.155	.163	.134	.118	.101	.096						
		.50	Error	153754	78546	85534	72098	63798	55115	52708						
	1626532		Error/LTM	.094	.048	.052	.044	.039	.033	.032						
06-3170	34	.95	Error	82430	56323	37483	34509	28452	33499							
			Error/LTM	.426	.291	.193	.178	.147	.173							
		.50	Error	22003	17504	12092	11343	9442	11188							
	193350		Error/LTM	.113	.090	.062	.058	.048	.057							

TABLE XI (Continued)

STATION NUMBER	YEARS OF RECORD / L T M	PROBA-BILITY		YEARS IN PERIOD FROM BEGINNING OF RECORD 5	10	15	20	25	30	35	40	45	50	55	60	65
06-4285	22	.95	Error	59367	28593	20613	17371									
			Error/LTM	1.051	.506	.365	.307									
		.50	Error	15847	8886	6650	5710									
	56439		Error/LTM	.280	.157	.117	.101									
06-6200	53	.95	Error	197878	93411	63513	66023	57463	50198	43642	41794	39020	37193			
			Error/LTM	.635	.299	.203	.211	.184	.161	.140	.134	.125	.119			
		.50	Error	52819	29031	20490	21702	19071	16765	14654	14076	13168	12582			
	311452		Error/LTM	.169	.093	.065	.069	.061	.053	.047	.045	.042	.040			
06-6210	22	.95	Error	10990	13660	9671	8093									
			Error/LTM	.203	.252	.178	.149									
		.50	Error	2933	4245	3120	2660									
	54038		Error/LTM	.054	.078	.057	.049									
06-6270	53	.95	Error	462939	216817	153301	158410	135734	116812	101511	97581	90235	85356			
			Error/LTM	.575	.269	.190	.196	.168	.145	.126	.121	.112	.106			
		.50	Error	123572	67383	49456	52071	45047	39013	34087	32865	30451	28876			
	805097		Error/LTM	.153	.083	.061	.064	.055	.048	.042	.040	.037	.035			
06-6490	49	.95	Error	13985	6946	7550	6117	5395	4678	4269	4112	3919				
			Error/LTM	.500	.248	.270	.218	.193	.167	.152	.147	.140				
		.50	Error	3733	2158	2435	2011	1790	1562	1433	1385	1322				
	27949		Error/LTM	.133	.077	.087	.071	.064	.055	.051	.049	.047				
06-6575	56	.95	Error	31768	16431	11134	9052	8249	7155	6229	5538	5484	5020	4725		
			Error/LTM	.613	.317	.214	.174	.159	.138	.120	.106	.105	.096	.091		
		.50	Error	8480	5106	3592	2975	2737	2389	2091	1865	1850	1698	1600		
	51815		Error/LTM	.163	.098	.069	.057	.052	.046	.040	.035	.035	.032	.030		
06-6745	39	.95	Error	255103	118874	84407	61866	57503	55697	51110						
			Error/LTM	.530	.246	.175	.128	.119	.115	.106						
		.50	Error	68094	36944	27230	20336	19084	18602	17162						
	481278		Error/LTM	.141	.076	.056	.042	.039	.038	.035						
09-1885	37	.95	Error	103836	48786	38835	34622	29758	27274	24879						
			Error/LTM	.283	.132	.105	.094	.081	.074	.067						
		.50	Error	27717	15162	12528	11380	9876	9109	8354						
	366824		Error/LTM	.075	.041	.034	.031	.026	.024	.022						

TABLE XI (Continued)

STATION NUMBER	YEARS OF RECORD L T M	PROBA-BILITY		YEARS IN PERIOD FROM BEGINNING OF RECORD 5	10	15	20	25	30	35	40	45	50	55	60	65
09-2055	37	.95	Error	15767	7360	6169	6716	5597	4852	4303						
			Error/LTM	.387	.180	.151	.165	.137	.119	.105						
		.50	Error	4208	2287	1990	2207	1857	1620	1445						
	40679		Error/LTM	.103	.056	.048	.054	.045	.039	.035						
09-2125	29	.95	Error	21186	9694	8275	7084	6491								
			Error/LTM	.343	.157	.134	.115	.105								
		.50	Error	5655	3013	2669	2328	2154								
	61589		Error/LTM	.091	.048	.043	.037	.034								
09-2170	17	.95	Error	410495	257517	199154										
			Error/LTM	.349	.219	.169										
		.50	Error	109573	80033	64249										
	1172955		Error/LTM	.093	.068	.054										
09-2235	23	.95	Error	46073	31627	22423	20065									
			Error/LTM	.448	.307	.218	.195									
		.50	Error	12298	9829	7234	6595									
	102771		Error/LTM	.119	.095	.070	.064									
09-2570	30	.95	Error	84924	52894	53135	48028	45938	39124							
			Error/LTM	.257	.160	.161	.145	.139	.118							
		.50	Error	22673	16438	17142	15787	15246	13067							
	329719		Error/LTM	.068	.049	.051	.047	.046	.039							
10-0320	26	.95	Error	26515	15484	14521	14000	12384								
			Error/LTM	.191	.111	.104	.101	.089								
		.50	Error	7077	4812	4759	4602	4110								
	138610		Error/LTM	.051	.034	.034	.033	.029								
13-0110	65	.95	Error	288518	162610	123155	103948	89784	83100	74795	68278	64824	62619	57984	55698	52052
			Error/LTM	.280	.157	.119	.100	.087	.080	.072	.066	.062	.060	.056	.054	.050
		.50	Error	77014	50537	39731	34169	29797	27754	25116	22996	21876	21184	19636	18909	17671
	1029374		Error/LTM	.074	.049	.038	.033	.028	.026	.024	.022	.021	.020	.019	.018	.017

NOTES: C. I. = $\overline{X} \pm \frac{ts}{\sqrt{n}}$ L T M = $\overline{X}$, Long Term Mean, in Acre Feet ERROR = $\frac{ts}{\sqrt{n}}$, in Acre Feet

TABLE XII

ERROR OF MEAN AND POSSIBLE ERROR, FROM END OF RECORD, 1968

STATION NUMBER	YEARS OF RECORD L T M	PROBA-BILITY		YEARS IN PERIOD, PRIOR TO 1968 65	60	55	50	45	40	35	30	25	20	15	10	5
06-0375	46	.95	Error					14689	16157	17271	17206	15830	19705	26329	43853	128509
			Error/LTM					.043	.047	.051	.050	.046	.058	.078	.129	.380
		.50	Error					4957	5441	5799	5746	5253	6477	8494	13629	34303
	337532		Error/LTM					.014	.016	.017	.017	.015	.019	.025	.040	.101
06-1880	45	.95	Error					49947	42195	43049	45155	49946	55623	74682	114855	270768
			Error/LTM					.083	.070	.071	.075	.083	.092	.124	.191	.452
		.50	Error					16855	14211	14455	15081	16576	18284	24093	35695	72276
	598884		Error/LTM					.028	.023	.024	.025	.027	.030	.040	.059	.120
06-2075	47	.95	Error					44870	45102	44702	50239	56349	61509	76930	110799	278441
			Error/LTM					.066	.066	.066	.074	.083	.090	.113	.163	.411
		.50	Error					15142	15190	15010	16779	18701	20218	24818	34435	74324
	676410		Error/LTM					.022	.022	.022	.024	.027	.029	.036	.050	.109
06-2640	27	.95	Error									5793	4767	5229	6928	13830
			Error/LTM									.289	.238	.261	.346	.691
		.50	Error									1922	1567	1687	2153	3691
	19993		Error/LTM									.096	.078	.084	.107	.184
06-2730	25	.95	Error									2994	2620	3627	5627	13074
			Error/LTM									.121	.105	.146	.227	.528
		.50	Error									993	861	1170	1749	3490
	24747		Error/LTM									.040	.034	.047	.070	.141
06-2765	38	.95	Error							27775	31102	32301	39258	52220	63978	139990
			Error/LTM							.114	.128	.133	.162	.216	.264	.579
		.50	Error							9327	10387	10720	12904	16846	19883	37367
	241712		Error/LTM							.038	.042	.044	.053	.069	.082	.154
06-2795	39	.95	Error							169568	189444	210435	217851	274847	410062	837230
			Error/LTM							.104	.116	.129	.133	.168	.252	.514
		.50	Error							56940	63271	69839	71611	88668	127441	223482
	1626532		Error/LTM							.035	.038	.042	.044	.054	.078	.137
06-3170	34	.95	Error								35124	39637	47737	63509	95897	122524
			Error/LTM								.181	.205	.246	.328	.495	.633
		.50	Error								11731	13154	15691	20488	29803	32705
	193350		Error/LTM								.060	.068	.081	.105	.154	.169

TABLE XII (Continued)

STATION NUMBER	YEARS OF RECORD L T M	PROBA-BILITY		YEARS IN PERIOD, PRIOR TO 1968												
				65	60	55	50	45	40	35	30	25	20	15	10	5
06-4285	20	.95	Error										14064	17606	25798	29872
			Error/LTM										.249	.311	.457	.529
		.50	Error										4623	5679	8017	7973
	56439		Error/LTM										.081	.100	.142	.141
06-6200	53	.95	Error				35273	36848	37930	38209	42499	48448	60341	74277	84096	153165
			Error/LTM				.113	.118	.121	.122	.136	.155	.193	.238	.270	.491
		.50	Error				11933	12435	12774	12830	14194	16079	19835	23962	26136	40884
	311452		Error/LTM				.038	.039	.041	.041	.045	.051	.063	.076	.083	.131
06-6210	22	.95	Error										8246	9851	11267	23729
			Error/LTM										.152	.182	.208	.439
		.50	Error										2710	3178	3501	6334
	54038		Error/LTM										.050	.058	.064	.117
06-6270	53	.95	Error				80746	80876	84598	84390	92583	106927	131649	155806	180304	345784
			Error/LTM				.100	.100	.105	.104	.114	.132	.163	.193	.223	.429
		.50	Error				27114	27293	28492	28337	30921	35487	43275	50264	56036	92300
	805097		Error/LTM				.033	.033	.035	.035	.038	.044	.053	.062	.069	.114
06-6490	49	.95	Error					3995	4141	4466	4666	5155	5665	7456	10262	20642
			Error/LTM					.142	.148	.159	.166	.184	.202	.266	.367	.738
		.50	Error					1348	1394	1499	1558	1711	1862	2405	3189	5510
	27949		Error/LTM					.048	.049	.053	.055	.061	.066	.086	.114	.197
06-6575	56	.95	Error			4733	4671	4672	4866	5276	5676	6483	7901	10319	10952	24134
			Error/LTM			.091	.090	.090	.093	.101	.109	.125	.152	.199	.211	.465
		.50	Error			1603	1580	1576	1639	1771	1896	2151	2597	3329	3403	6442
	51815		Error/LTM			.030	.030	.030	.031	.034	.036	.041	.050	.064	.065	.124
06-6745	39	.95	Error							41997	42625	46512	52008	37483	50202	141131
			Error/LTM							.087	.088	.096	.108	.077	.104	.293
		.50	Error							14102	14236	15436	17096	12092	15602	37672
	481278		Error/LTM							.029	.029	.032	.035	.025	.032	.078
09-1885	37	.95	Error							25444	26476	29665	35279	43736	61261	148704
			Error/LTM							.069	.072	.080	.096	.119	.167	.405
		.50	Error							8544	8842	9845	11596	14109	19039	39693
	366824		Error/LTM							.023	.024	.026	.031	.038	.051	.108

TABLE XII (Continued)

STATION NUMBER	YEARS OF RECORD L T M	PROBA-BILITY		YEARS IN PERIOD, PRIOR TO 1968												
				65	60	55	50	45	40	35	30	25	20	15	10	5
09-2055	37	.95	Error							4334	4629	4955	5902	5725	7401	18385
			Error/LTM							.106	.113	.121	.145	.140	.181	.451
		.50	Error							1455	1546	1644	1940	1846	2300	4907
	40679		Error/LTM							.035	.038	.040	.047	.045	.056	.120
09-2125	29	.95	Error									7515	9292	11655	17905	36104
			Error/LTM									.122	.150	.189	.290	.586
		.50	Error									2494	3054	3760	5564	9637
	61589		Error/LTM									.040	.049	.061	.090	.156
09-2170	17	.95	Error											204268	291902	632667
			Error/LTM											.174	.248	.539
		.50	Error											65899	90719	168878
	1172955		Error/LTM											.056	.077	.143
09-2235	23	.95	Error										20685	19671	28666	61710
			Error/LTM										.201	.191	.278	.600
		.50	Error										6799	6346	8909	16472
	102771		Error/LTM										.066	.061	.086	.160
09-2570	30	.95	Error								45313	46378	56303	62144	84368	161504
			Error/LTM								.137	.140	.170	.188	.255	.489
		.50	Error								15133	15391	18507	20048	26220	43110
	329719		Error/LTM								.045	.046	.056	.060	.079	.130
10-0320	26	.95	Error									12332	13906	18900	24974	41453
			Error/LTM									.088	.100	.136	.180	.299
		.50	Error									4089	4571	6097	7761	11065
	138610		Error/LTM									.029	.032	.043	.055	.079
13-0110	65	.95	Error	61060	54432	54475	55956	58497	64554	68265	77108	87488	100108	104678	153750	374260
			Error/LTM	.059	.052	.052	.054	.056	.062	.066	.074	.084	.097	.101	.149	.363
		.50	Error	20729	18479	18448	18930	19741	21741	22923	25753	29035	32907	33770	47783	99901
	1029374		Error/LTM	.020	.017	.017	.018	.019	.021	.022	.025	.028	.031	.032	.046	.097

NOTES: C.I. = $\overline{X} \pm \frac{ts}{\sqrt{n}}$ L T M = $\overline{X}$, Long Term Mean, in Acre Feet ERROR = $\frac{ts}{\sqrt{n}}$, in Acre Feet

A P P E N D I X   IV

Description of Gaging Stations

TABLE XIII

DESCRIPTION OF GAGING STATIONS

MADISON RIVER BASIN

6-0375. Madison River near West Yellowstone, Mont.

Location.--Lat 44°39'20", long 111°04'00", in SW¼ sec.36, T.13 S., R.5 E., (unsurveyed), on left bank a quarter of a mile upstream from Riverside ranger station, 1½ miles east of West Yellowstone and west boundary of Yellowstone National Park, 12½ miles downstream from confluence of Firehole and Gibbon Rivers, and at mile 120.

Drainage area.--420 sq mi.

Records available.--June 1913 to December 1917, July 1918 to October 1921, June 1922 to September 1968. Monthly discharge only for some periods.

Gage.--Water-stage recorder. Altitude of gage is 6,650 ft (from topographic map). Prior to Oct. 20, 1918, staff gage, and Oct. 20, 1918, to June 29, 1930, staff gage or water-stage recorder, at sites 2½ miles upstream at different datums. Supplementary staff gage at site a quarter of a mile downstream at different datum used at times during 1927-30.

Remarks.--Records excellent. No regulation or diversion above station.

YELLOWSTONE RIVER BASIN

6-1880. Lamar River near Tower Falls ranger station, Yellowstone National Park

Location.--Lat 44°55'40", long 110°23'35", on left bank 0.5 mile northeast of Cooke City highway, half a mile upstream from mouth, and 1½ miles northeast of Tower Falls ranger station.

Drainage area.--660 sq mi.

Records available.--September 1922, April 1923 to September 1968. Monthly discharge only for some periods.

Gage.--Water-stage recorder. Altitude of gage is 5,910 ft (from topographic map). Prior to Sept. 16, 1925, staff gages, and Sept. 16, 1925, to July 29, 1927, water-stage recorder, at same site at datum 1.00 ft higher.

Remarks.--Records good except those for winter period, which are poor. No regulation or diversion.

6-2075. Clarks Fork Yellowstone River at Chance, Mont.

Location.--Lat 45°00'40", long 109°04'00", in E½NE¼ sec.31, T.9 S., R.22 E., on left bank 0.4 mile upstream from Sand Coulee, three-quarters of a mile north of Wyoming-Montana State line, and at mile 78.5.

Drainage area.--1,154 sq mi.

Records available.--July 1921 to September 1968. Monthly discharge only for some periods. Prior to October 1956, published as Clarks Fork at Chance.

Gage.--Water-stage recorder. Altitude of gage is 3,980 ft (from topographic map). Prior to Nov. 15, 1934, staff gage, and Nov. 15, 1934, to July 26, 1951, water-stage recorder at bridge 0.4 mile downstream at different datum. July 27, 1951, to Sept. 30, 1953, water-stage recorder at present site at datum 0.98 ft higher.

Remarks.--Records good. Diversions for irrigation of about 10,000 acres above station.

TABLE XIII (Continued)

6-2640. Owl Creek near Thermopolis, Wyo.

Location.--Lat 43°41'09", long 108°18'08", in NW¼NE¼ sec.19 (revised), T.43 N., R.95 W., on right bank at McCumber Ranch, 1½ miles downstream from Mud Creek, and 6 miles northwest of Thermopolis.

Drainage area.--478 sq mi.

Records available.--July 1910 to November 1917, November 1931 to November 1932, May 1938 to September 1968. No winter records prior to 1932. Monthly discharge only for some periods.

Gage.--Digital water-stage recorder. Altitude of gage is 4,560 ft (by barometer). July 30, 1910, to July 31, 1912, staff gage and Aug. 1, 1912, to Apr. 7, 1914, chain gage, at site a quarter of a mile upstream at different datum. Apr. 8, 1914, to Nov. 30, 1917, staff or chain gages within 50 ft of present site at various datums. Nov. 18, 1931, to Nov. 30, 1932, and May 10 to Oct. 10, 1938, chain gage at site 24 ft downstream at same datum. Oct. 11, 1938, to Aug. 2, 1966, graphic water-stage recorder at same site and datum.

Remarks.--Records good except those for winter months and those for periods of no gage-height record, which are poor. Flow regulated by Anchor Dam since November 1960. Diversions for irrigation of about 14,000 acres above station.

6-2730. Medicine Lodge Creek near Hyattville, Wyo.

Location.--Lat 44°17'37", long 107°32'23", in NE¼SE¼NE¼ sec.21, T.50 N., R.89 W., on left bank 0.3 mile downstream from Dry Medicine Lodge Creek and 4½ miles northeast of Hyattville.

Drainage area.--86.8 sq mi.

Records available.--October 1942 to September 1968. Monthly discharge only for some periods.

Gage.--Digital water-stage recorder. Altitude of gage is 4,780 ft (from topographic map). Prior to June 24, 1943, staff gage at different datum. June 24, 1943, to Nov. 21, 1965, graphic water-stage recorder at datum 2.00 ft higher. Nov. 21, 1965, to June 5, 1968, digital water-stage recorder at datum 2.00 ft higher.

Remarks.--Records good. Small diversion for irrigation of hay meadows above station.

6-2765. Greybull River at Meeteetse, Wyo.

Location.--Lat 44°09'20", long 108°52'35", in sec.4, T.48 N., R.100 W., on right bank at Meeteetse, 1,800 ft upstream from bridge on State Highway 120, and 3 miles upstream from Meeteetse Creek. Prior to May 9, 1967, at site 100 ft downstream.

Drainage area.--681 sq mi.

Records available.--June to December 1897, April to October 1903 (gage heights and discharge measurements only), July 1920 to September 1968. Monthly discharge only for some periods.

Gage.--Digital water-stage recorder with pressure-recording bubbler system. Datum of gage is 5,739.42 ft above mean sea level, datum of 1929, supplementary adjustment of 1943. Prior to Oct. 31, 1903, staff gage at site 1,800 ft downstream at different datum. Aug. 29, 1920, to July 25, 1926, graphic water-stage recorders near present site; July 26, 1926, to Apr. 14, 1929, at site 700 ft downstream; Apr. 15, 1929, to July 29, 1934, and July 30, 1934, to Apr. 27, 1938, at sites about three-eighths of a mile downstream, all at different datums. Apr. 28, 1938, to May 24, 1961, on left bank at datum 2.00 ft higher. May 25, 1961, to May 9, 1967, at site 100 ft downstream at same datum.

Remarks.--Records fair except those for winter months, which are poor. Slight regulation by Sunshine Reservoir beginning May 1940 (capacity, 53,000 acre-ft). Diversions for irrigation of about 6,000 acres above station.

TABLE XIII (Continued)

6-2795. Bighorn River at Kane, Wyo.

Location.--Lat 44°45'31", long 108°10'51", in NW¼NE¼SW¼ sec.9, T.55 N., R.94 W., on right bank 1.3 miles upstream from Five Springs Creek and 6½ miles south of Kane.

Drainage area.--15,765 sq mi. Area at sites prior to May 17, 1956, 15,846 sq mi.

Records available.--August 1928 to September 1968.

Gage.--Water-stage recorder. Altitude of gage is 3,660 ft (from Fairchild Aerial Survey map made for Bureau of Reclamation). Prior to Apr. 25, 1932, chain gage. Apr. 25, 1932, to May 16, 1956, water-stage recorders. All at site 12½ miles downstream at different datum.

Remarks.--Records good except those for winter months, which are poor. Diversions for irrigation of about 275,000 acres above station. Some regulation by Boysen Reservoir since October 1951

6-3170. Powder River at Arvada, Wyo.

Location.--Lat 44°39', long 106°08', in NE¼NW¼ sec.21, T.54 N., R.77 W., on left bank 2,500 ft upstream from highway bridge, half a mile southwest of Arvada, and three quarters of a mile upstream from Wild Horse Creek.

Drainage area.--6,050 sq mi, approximately.

Records available.--May 1919 to September 1968 (no winter records 1919-30, 1934). Records for Feb. 16-23, 1930 have been found to be unreliable and should not be used.

Gage.--Digital water-stage recorder with pressure-recording bubbler system. Datum of gage is 3,622.01 ft above mean sea level, datum of 1929. Prior to Oct. 24, 1938, chain gage at bridge 2,500 ft downstream at datum 0.14 ft lower. Oct. 24, 1938, to Sept. 17, 1966, graphic water-stage recorder at present site and datum.

Remarks.--Records poor. Diversions for irrigation above station

CHEYENNE RIVER BASIN

6-4285. Belle Fourche River at Wyoming-South Dakota State line

Location.--Lat 44°45'00", long 104°02'45", in NE¼NW¼NW¼ sec.18, T.9 N., R.1 E., on left bank a quarter of a mile downstream from State line, 3½ miles downstream from Oak Creek, and 11 miles northwest of Belle Fourche, S. Dak.

Drainage area.--3,280 sq mi, approximately.

Records available.--December 1946 to September 1968. Records for water year 1947 incomplete.

Gage.- Water-stage recorder. Datum of gage is 3,095.7 ft above mean sea level, datum of 1929.

Remarks.--Records good except those for the winter months, which are poor. Small diversions above station for irrigation. Flow regulated by Keyhole Reservoir (capacity, 199,900 acre-ft).

TABLE XIII (Continued)

PLATTE RIVER BASIN

6-6200. North Platte River near Northgate, Colo.

Location.--Lat 40°56'10", long 106°20'21", in SW¼SE¼ sec.11, T.11 N., R.80 W., on right bank 350 ft downstream from bridge on State Highway 125, 0.8 mile upstream from Camp Creek, 4.2 miles northwest of Northgate, and 4.4 miles south of Colorado-Wyoming State line.

Drainage area.--1,431 sq mi.

Records available.--May to November 1904 (published as "near Pinkhampton"), May 1915 to September 1968. Monthly discharge only for some periods.

Gage.--Water-stage recorder. Datum of gage is 7,810.39 ft above mean sea level, adjustment of 1912. May 11 to Nov. 9, 1904, staff gage 0.8 mile downstream at different datum. Apr. 30, 1915, to May 12, 1916, staff gage, May 13, 1916, to Sept. 17, 1917, chain gage, Sept. 18, 1917, to Apr. 7, 1918, staff gage, and Apr. 8, 1918, to Aug. 21, 1961, water-stage recorder, at site 0.8 mile downstream at datum 3.36 ft lower.

Remarks.--Records good except those for winter period, which are poor. Diversions for irrigation of about 130,000 acres of hay meadows above station. Transbasin diversions above station to Cache la Poudre River basin

6-6210. Douglas Creek near Foxpark, Wyo.

Location.--Lat 41°04'52", long 106°18'25", in NE¼SE¼ sec.19, T.13 N., R.79 W., on left bank three-quarters of a mile downstream from Pelton Creek and 8 miles west of Foxpark.

Drainage area.--120 sq mi. Area at mouth, 153 sq mi.

Records available.--July 1946 to September 1968.

Gage.--Digital water-stage recorder. Altitude of gage is 8,200 ft (from topographic map). Prior to Sept. 28, 1967, graphic water-stage recorder at same site and datum.

Remarks.--Records good except those for period of no gage-height record and those for winter months, which are poor. Minor diversion above station for domestic use. Transbasin diversions above station to Lake Owen for municipal use by cities of Cheyenne and Laramie began November 1963. Flow regulated by Rob Roy Reservoir (capacity, 8,900 acre-feet). Average discharge for water years 1964-66 was adjusted for diversion to Lake Owen.

6-6270. North Platte River at Saratoga, Wyo.

Location.--Lat 41°27'18", long 106°48'16", in SE¼SE¼ sec.11, T.17 N., R.84 W., on left bank 1,000 ft upstream from bridge on State Highway 130 in Saratoga and 1 mile downstream from Spring Creek.

Drainage area.--2,840 sq mi.

Records available.--June 1903 to October 1906, April to December 1909, October 1910 to September 1968. Monthly discharge only for some periods.

Gage.--Water-stage recorder. Datum of gage is 6,772.69 ft above mean sea level, datum of 1929. Prior to Apr. 25, 1911, staff gage at site 250 ft downstream at different datum. Apr. 25, 1911, to Nov. 1, 1930, chain gage at bridge 35 ft upstream at same datum.

Remarks.--Records good except those for winter months, which are poor. Diversions above station for irrigation of about 290,000 acres, part of which is above station and part below. Transbasin diversions above station.

TABLE XIII (Continued)

6-6490. La Prele Creek near Douglas, Wyo.

Location.--Lat 42°40', long 105°36', in sec.5, T.31 N., R.73 W., on right bank 13 miles southwest of Douglas. This station is above La Prele Reservoir.

Drainage area.--135 sq mi.

Records available.--August 1919 to September 1968.

Gage.--Digital water-stage recorder. Altitude of gage is about 5,600 ft (from nearby line of levels). Prior to Apr. 29, 1966, graphic water-stage recorder at same site and datum.

Remarks.--Records poor except those for April through June, which are fair. Diversions for irrigation of about 7,200 acres above station. Several small reservoirs above station (combined capacity, about 140 acre-ft) for irrigation.

6-6575. Laramie River near Glendevey, Colo.

Location.--Lat 40°48'00", long 105°52'40", in NW¼ sec.25, T.10 N., R.76 W., on left bank just upstream from Stub Creek, 180 ft downstream from bridge on county road, 250 ft downstream from Nunn Creek, and 1½ miles north of Glendevey Post Office.

Drainage area.--101 sq mi.

Records available.--June 1904 to October 1905, August 1910 to September 1968. Monthly discharge only for some periods. Published as "at Glendevey" 1905, 1910-18.

Gage.--Water-stage recorder. Altitude of gage is 8,230 ft (from topographic map). Prior to Nov. 7, 1910, staff gage. Prior to Sept. 21, 1922, at datum 1.22 ft higher, Sept. 21, 1922, to Sept. 26, 1923, at datum 1.94 ft higher, July 9, 1929, to July 22, 1931, at datum 2.73 ft higher, and July 23, 1931, to Sept. 19, 1935, at datum 2.09 ft higher; all at site 180 ft upstream. Sept. 27, 1923, to July 8, 1929, at site 140 ft upstream at datum 1.35 ft higher.

Remarks.--Records good. Diversions for irrigation of about 700 acres of hay meadows above station. Transbasin diversions above station to Cache la Poudre River and tributaries

6-6745. North Platte River at Wyoming-Nebraska State line

Location.--Lat 41°59'14", long 104°03'25", in SW¼SE¼ sec.3, T.23 N., R.60 W., on left bank 0.3 mile upstream from Wyoming-Nebraska State line and 1.0 mile southwest of Henry, Nebr.

Drainage area.--26,177 sq mi, of which 5,888 sq mi (including 3,959 sq mi, in Great Divide basin in southern Wyoming) is probably noncontributing.

Records available.--April 1929 to September 1968.

Gage.--Digital water-stage recorder. Datum of gage is 4,024.77 ft above mean sea level, datum of 1929, supplementary adjustment of 1940. Prior to Nov. 6, 1929, chain gage and Nov. 6, 1929 to Dec. 14, 1942, graphic water-stage recorder at site 200 ft upstream. Dec. 15, 1942, to July 11, 1966, graphic water-stage recorder at present site. Prior to Oct. 1, 1959, at datum 1.00 ft higher.

Remarks.--Records fair. Natural flow of stream affected by transbasin diversions, storage reservoirs, power developments, ground-water withdrawals and diversions for irrigation, and return flow from irrigated areas.

TABLE XIII (Continued)

GREEN RIVER BASIN

9-1885. Green River at Warren Bridge, near Daniel, Wyo.

Location.--Lat 43°01'00", long 110°07'20", in sec.8, T.35 N., R.111 W., on left bank 100 ft upstream from bridge on U. S. Highway 187 and 189, 3 miles upstream from Beaver Creek, and 12 miles north of Daniel.

Drainage area.--468 sq mi.

Records available.--October 1931 to September 1968. Monthly discharge only for some periods.

Gage.--Digital water-stage recorder. Datum of gage is 7,468.09 ft above mean sea level, datum of 1929. Prior to July 20, 1966, graphic water-stage recorder at same site and datum.

Remarks.--Records good except those for period of no gage-height record and those for winter months, which are poor. Diversion above station for irrigation of about 6,900 acres

9-2055. North Piney Creek near Mason, Wyo.

Location.--Lat 42°39'20", long 110°20'40", in sec.19, T.31 N., R.113 W., on left bank 3 miles west of Mason and 15 miles northwest of Big Piney.

Drainage area.--58 sq mi, approximately.

Records available.--May 1915 to October 1916, October 1931 to September 1968. Monthly discharge only for some periods. Published as "near Marbleton" 1915-16.

Gage.--Water-stage recorder. Altitude of gage is 7,520 ft (from topographic map). Prior to Oct. 12, 1931, at datum 1.05 ft lower.

Remarks.--Records good except those for period of no gage-height record and those for winter months, which are poor. Diversions above station for irrigation of about 1,600 acres

9-2125. Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo.

Location.--Lat 42°35', long 109°17', in sec.18, T.30 N., R.104 W., on left bank at Leckie Ranch, half a mile downstream from Squaw Creek, and 9 miles southeast of Big Sandy.

Drainage area.--94 sq mi, approximately.

Records available.--July to November 1910, May to August 1911, July 1939 to September 1968. Monthly discharge only for some periods. Published as "near Big Sandy" 1910-11, and in WSP 618.

Gage.--Digital water-stage recorder. Altitude of gage is 7,800 ft (by barometer). July 26 to Sept. 26, 1910, staff gage at site near present location at different datum. Sept. 27, 1910, to Aug. 31, 1911, chain gage 575 ft downstream at different datum. July 24, 1939, to Oct. 12, 1967, graphic water-stage recorder; prior to June 1, 1961, at site 75 ft downstream at same datum

Remarks.--Records good except those for winter months, which are poor. Diversions above station for irrigation of about 480 acres

TABLE XIII (Continued)

9-2170. Green River near Green River, Wyo.

Location.--Lat 41°30'59", long 109°26'54", in NW¼NE¼ sec.26, T.18 N., R.107 W., on right bank a quarter of a mile downstream from Bitter Creek, 1 mile southeast of town of Green River, and 4 miles upstream from high-water line of Flaming Gorge Reservoir.

Drainage area.--About 10,000 sq mi, of which 300 sq mi is probably noncontributing.

Records available.--April 1951 to September 1968.

Gage.--Digital water-stage recorder. Altitude of gage is 6,050 ft (from river-profile map). Prior to Apr. 12, 1966, graphic water-stage recorder at same site and datum.

Remarks.--Records good except those for winter months, which are poor. Natural flow of stream affected by transbasin diversions, storage reservoirs, power developments, diversions for irrigation, and return flow from irrigated areas. Flow partly regulated by Fontenelle Reservoir since August 1963 (capacity, 345,400 acre-ft)

9-2235. Hams Fork near Frontier, Wyo.

Location.--Lat 41°51'26", long 110°33'45", in lot 39, NE¼SE¼ sec.27, T.22 N., R.116 W., in right bank 800 ft upstream from highway bridge, 1½ miles upstream from Willow Creek, and 3½ miles northwest of Frontier.

Drainage area.--298 sq mi.

Records available.--May 1945 to September 1968.

Gage.--Digital water-stage recorder. Altitude of gage is 6,970 ft (by barometer). May 8 to July 23, 1945, staff gage at highway bridge 800 ft downstream at same datum. July 24, 1945, to July 23, 1966, graphic water-stage recorder at present site and datum.

Remarks.--Records good except those for winter months, which are poor. Diversions above station for irrigation of about 7,000 acres
Flow regulated by Kemmerer water supply reservoir (capacity, 1,058 acre-ft) and Utah Power and Light Company reservoir (capacity, 28,000 acre-ft, approximately) (completed in May 1961) above station.

9-2570. Little Snake River near Dixon, Wyo.

Location.--Lat 41°01'45", long 107°32'55", in NW¼ sec.8, T.12 N., R.90 W., on left bank 775 ft upstream from Willow Creek, 25 ft downstream from highway bridge, and 0.8 mile west of Dixon.

Drainage area.--988 sq mi.

Records available.--May 1910 to September 1923, March 1938 to September 1968. Monthly discharge only for some periods.

Gage.--Water-stage recorder. Datum of gage is 6,331.22 ft above mean sea level, datum of 1929. May 27, 1910, to Sept. 30, 1923, chain gage on highway bridge 25 ft upstream at datum 2.98 ft higher. Mar. 15, 1938, to Sept. 30, 1957, water-stage recorder at present site at datum 2.98 ft higher. Oct. 1, 1957, to June 6, 1968, water-stage recorder at site 625 ft downstream at present datum.

Remarks.--Records fair except those for period of no gage-height record and those for winter months, which are poor. Diversions for irrigation of about 9,500 acres above station. One diversion above station for irrigation of about 3,000 acres below. Transbasin diversions above station.

TABLE XIII (Continued)

BEAR RIVER BASIN

10-0320. Smiths Fork near Border, Wyo.

Location.--Lat 42°17', long 110°52', in NW$\frac{1}{4}$ sec.33, T.27 N., R.118 W., on left bank 4.5 miles upstream from Howland Creek, 6 miles downstream from Hobble Creek, and 12 miles northeast of Border.

Drainage area.--165 sq mi.

Records available.--May 1942 to September 1968.

Gage.--Water-stage recorder. Altitude of gage is 6,650 ft (from topographic map). Prior to Oct. 16, 1945, at site 0.8 mile downstream at different datum.

Remarks.--Records good except those for winter months, which are fair. One diversion for irrigation of about 200 acres above station.

SNAKE RIVER MAIN STEM

13-0110. Snake River at Moran, Wyo.

Location.--Lat 43°51', long 110°35', in sec.18, T.45 N., R.114 W., on left bank at Moran, 1,000 ft downstream from Jackson Lake Dam, and at mile 1,000.1.

Drainage area.--824 sq mi. Mean altitude, 8,040 ft.

Records available.--September 1903 to September 1968. Monthly discharge only for some periods. Prior to October 1910, published as South Fork Snake River at Moran.

Gage.--Water-stage recorder. Datum of gage is 6,727.84 ft above mean sea level, unadjusted. Prior to June 13, 1917, staff gage, and June 14, 1917, to May 20, 1940, water-stage recorder, at site 1$\frac{1}{2}$ miles downstream at different datums.

Remarks.--Records excellent. Flow regulated by Jackson Lake