2114

HYDROLOGY STUDY

FOR

DEBEQUE CANYON

I 70-1(19)PE

By

HYDRAULICS UNIT

COLORADO DIVISION OF HIGHWAYS

SEPTEMBER 1972

ABSTRACT

The Colorado Division of Highways plans to build I 70 through DeBeque Canyon near Grand Junction. A preliminary alignment has been proposed. The Hydraulics Unit was requested by District III to estimate a design flood, set maximum permissible encroachments, and recommend the necessary stabilization for the Colorado River through the canyon.

It was decided that a 50 year frequency flood would be used for design. The design discharge was obtained from analysis of stream gaging station records. Except for gage 9-0725, the records were generally for two periods of time. The first period was in the early part of the century when diversions had little effect on peak discharges, and the second was more recently when controls and diversions had some effect on peak discharges. Gage 9-0725, with records for both periods of time, showed a 33% reduction in the 50 year flood calculated for years 1934 - 1966 as compared to the 50 year flood calculated for the years 1900 - 1933.

Three additional gages in the basin were found that had enough years of record to include both time periods and were not affected by controls or diversions. There appeared to be an 8% drop in the statistical 50 year flood computed for the two time periods. It was assumed that

Gage 9-0725 would have experienced an equal 8% drop in the 50 year flood without controls. That left a 25% reduction due to controls and diversions. The 50 year flood was computed before controls and diversions and then reduced 25% to give a design discharge of 41,000 cfs.

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INTRODUCTION

The west end of DeBeque Canyon is approximately 20 miles northeast of Grand Junction where present highway I 70 construction has temporarily ended. From this point the canyon continues in a northeast direction for about 10 miles then widens out into a broad valley near the town of DeBeque. The canyon is generally meandering with one bend that appears to nearly form an oxbow. A tunnel is proposed at this location. The canyon walls consist of steep talus slopes and vertical rock faces. In 1958 a portion of the east wall failed and covered US Highway 6 and 40. The scar is quite visible on aerial photos and from the roadway.

As in several reaches along the Colorado River, DeBeque Canyon must accommodate The Denver and Rio Grande Western Railroad, the Colorado River at flood stage, and the proposed four lanes of Interstate highway. Because of the limited width of the canyon, it is necessary for the highway designer to carefully consider the minimum roadway profile along the river as well as maximum encroachment. It is important that neither the railroad nor the highway is damaged by a nominal flood.

The portion of the Colorado River that the Hydraulics Unit studied for this report started at the Grand Valley Diversion Dam and continued upstream for 10 miles. Within this reach there are four proposed bridge crossings. The locations are shown on figure 1.

The object of this report is to estimate a design discharge which will be used to set channel encroachments, minimum roadway profile, protection requirements, and study the effects on side drainage. Considering Department policy and the initial cost compared to the cost of repair or replacement the 50 year flood was considered to give a balanced design.

MAP OF STUDY REACH

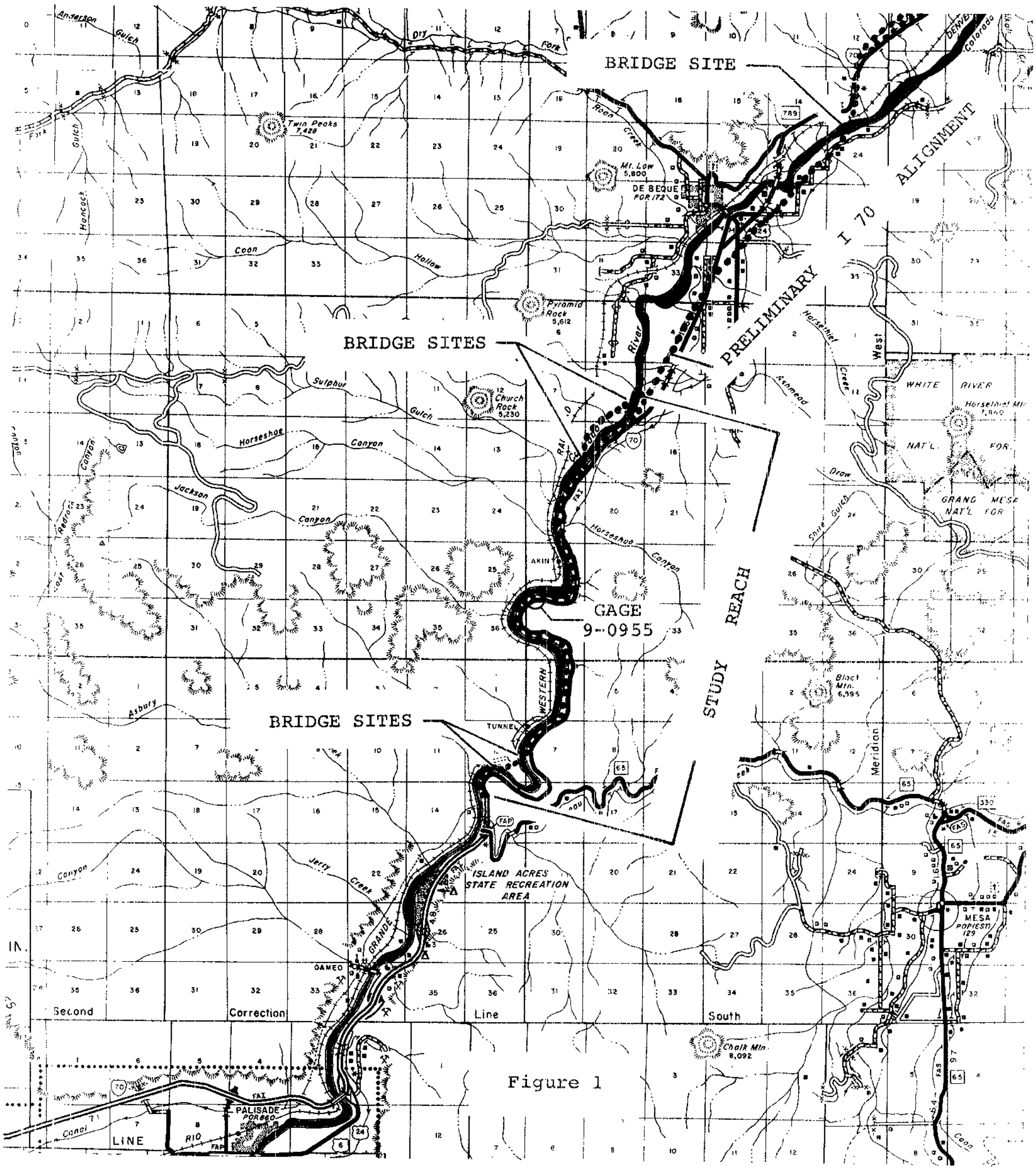

Figure 1

DRAINAGE BASIN

The headwaters of the Colorado River originate along the Continental Divide high in the Colorado Rocky Mountains. Many of the mountain peaks tower above 14,000 feet. From Rocky Mountain National Park on the north to Independence Pass on the south, snow fed streams collect and flow in a southwesterly direction toward Grand Junction, then into Utah.

The upper reaches are alpine areas with large stands of pine and fir timber on steep rocky slopes. Some of the area is above timberline where tundra, barren rock and occasional snowdrifts prevail. At lower elevations, sparcely scattered pinon trees cover the rolling hills. The land is semi-arrid with prairie grass and sage brush covering the areas between the pinon stands.

There are no major drainages that discharge into the Colorado River in DeBeque Canyon. Therefore one drainage area and one design discharge was considered adequate for the entire study reach. The drainage area of 8,050 square miles for gage 9-0955 was used for the study reach. Some of major inflowing streams above DeBeque Canyon are the Roaring Fork, Eagle, Piney, Blue, Williams Fork and Fraser Rivers. The boundaries of the drainage basin are shown on figure 2.

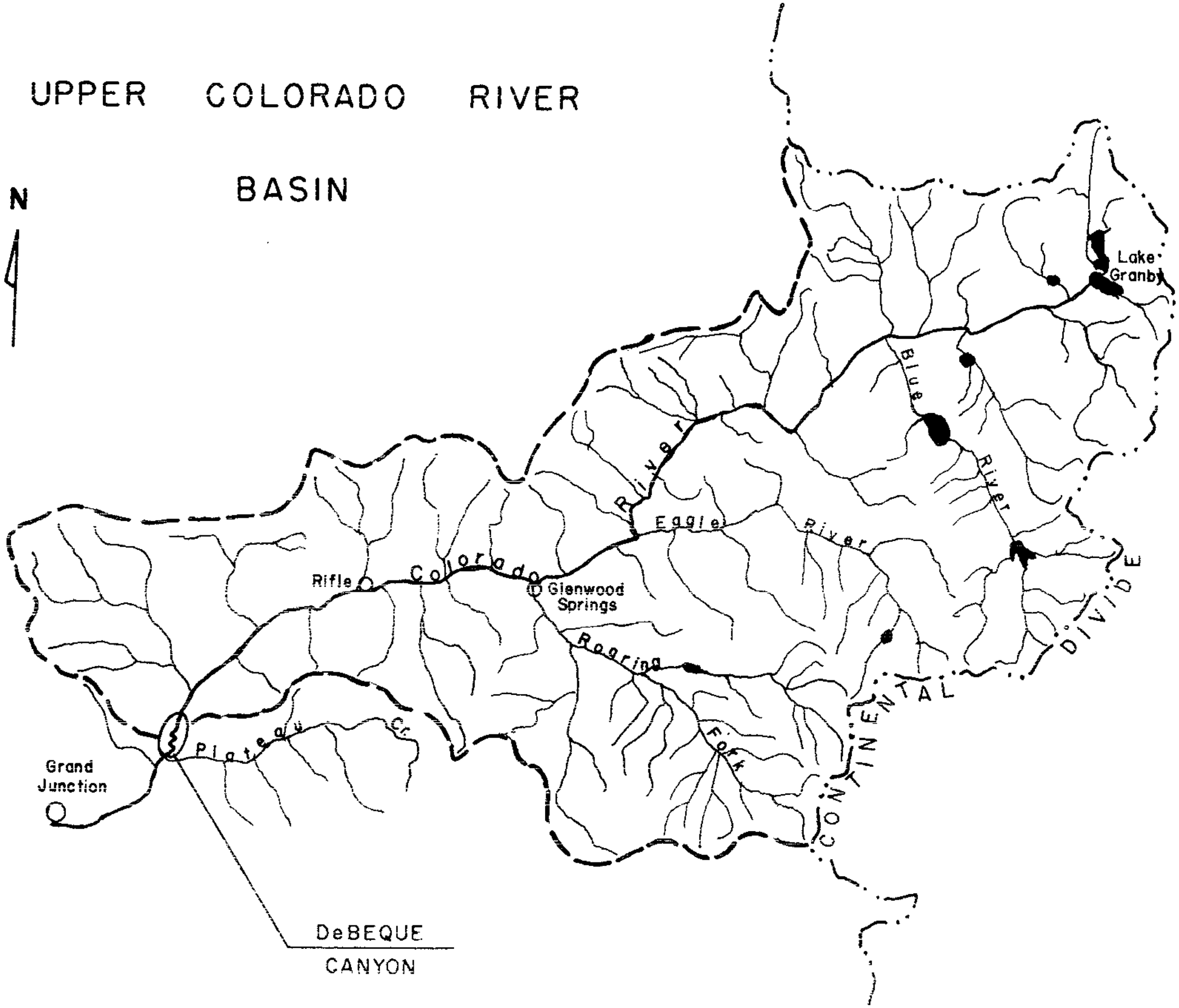
UPPER COLORADO RIVER
BASIN
N
Lake
Granby
Blue
River
Colorado
River
Eagle
River
Rifle
Glenwood
Springs
Roaring
Fork
Plateau
Cr.
Grand
Junction
CONTINENTAL
DIVIDE
DeBEQUE
CANYON

Figure 2

PRECIPITATION

The precipitation in the drainage basin ranges from 10 inches to 50 inches annually. The higher elevations receive the greater amounts in the form of winter snowfall. This is orographic precipitation which results from mechanical lifting of moisture inflowing from the western coast against the western slope of the Rocky Mountains. The Rockies are the first major moisture barrier after the Cascades. The orographic effect does not occur at the lower elevations which results in less precipitation for these areas.

The 6-hour 50 year precipitation is 1.6 inches at DeBeque Canyon and 2.2 inches in the higher mountains. Local summer thunderstorms can be very intense but of short duration along the river canyons. Summer thunderstorms in the high elevations are generally of medium to light intensity. The Weather Bureau precipitation gages at Glenwood Springs, Aspen and Fraser show the greater precipitation occuring during the first four months of the year with a gradual decrease thru the end of the year.

Future precipitation amounts may be increased 5% to 15% by weather modification as indicated by Patrick Hurley[1] in the months from November through April at elevations above 9,500 feet. The winter season along with high elevations help insure freezing temperatures which are necessary for snowflakes to form around silver-iodide particles. The increase in snow pack will increase the probability of raising the peak runoff. Colorado State University has been conducting tests at Climax, Colorado, but extensive weather modification has not started.

FACTORS INFLUENCING RUNOFF

There is a wide range of hydrological conditions influencing runoff in the Upper Colorado River Basin. The upper reaches are in the mountains where heavy forest cover retards rainfall runoff. In the lower portion of the basin, there are areas of open pasture and rangeland where rainfall runs off rapidly. The highest peak runoff can result when a spring rain storm falls on snowpack. The ground is still partially frozen so the water cannot infiltrate plus the rain melts some of the snow to give a combined runoff. Normally the magnitude of the peak flow depends only on the amount of snowfall and the spring thawing temperatures.

Since 1937, eight reservoirs have been built in the Upper Colorado River Basin. None were built for flood control but they have affected peak runoff through normal operation. In general the operators draw down the pool level enough to hold the volume of spring runoff as predicted by the winter snow surveys. Limiting drawdown factors in specific cases are minimum pool level for hydroelectric operation, allowable pool level fluctuation, and water right requirements. The eight reservoirs are:

Reservoir	Stream	D.A. Sq Mi	Usable[2] Storage AC-FT	Year*
Williams Fork	Williams Fork	234	94,000	1937
Green Mountain	Blue	600	147,000	1942
Shadow Mtn & Granby	Upper Colorado	322	471,000	1949
Willow Creek	Willow Creek	134	9,000	1953
Dillon	Blue	129	NA	1963
Rifle Gap	Rifle	140	11,000	1967
Homestake	Eagle	59	44,000	1968
Ruedi	Frying Pan	240	100,000	1968

* Year Reservoirs Began Storage

Presently there are 23 diversion tunnels and major ditches in the Upper Colorado River Basin above DeBeque. The first diversion was the Grand River Ditch constructed in 1892.[3] Some of the better known diversions are the Moffat Tunnel finished in 1936 and the Harold D. Roberts Tunnel finished in 1963. It is our opinion that these diversions affect total annual volume of runoff rather than the peak runoff.

U.S.G.S. Hydrologist, Clifford Jenkins, has stated that rainfall could greatly influence the peak flows on the Colorado River at Grand Junction. There is enough drainage area between Grand Junction and the high areas that a rain storm could produce a higher peak flow than the snow melt peak flow. It is possible that as more controls are built to store snow melt runoff, more of the runoff peaks will result from rainfall.

The Flood Control Work Group of the Upper Colorado Region State-Federal Interagency Group has proposed Una Reservoir[4] between Rifle and DeBeque on the Colorado River. If this flood control dam is built, the flood situation would change below the dam. The time schedule proposes that the project will be completed before the year 2000. See figure 3 for the reservoirs and diversion tunnels within the drainage basin.

UPPER COLORADO RIVER RESERVOIRS AND DIVERSION TUNNELS

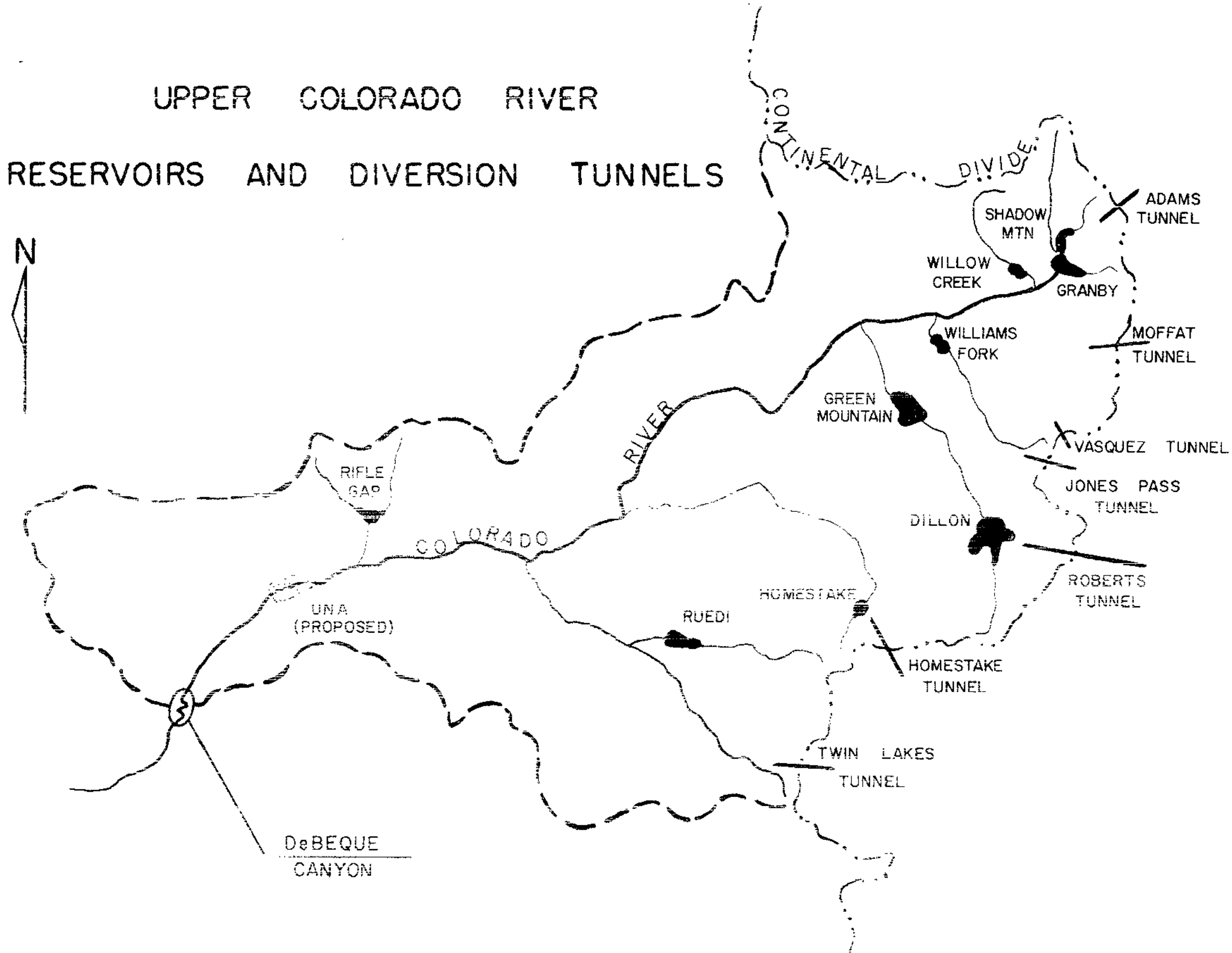

Figure 3

FLOOD RECORDS

Two documented floods of 1853 and 1884 are reported in Water-Supply Paper 997[5]. The 1853 flood was reported in George H. Heap's journal on his trip from Westport to California. He reported the Colorado River, near the confluence with the Gunnison River, was "laden with uprooted trees." This occurs only during major floods. The 1884 flood's highwater mark was located at Fruita by the Weather Bureau. In 1917 the Geological Survey ran levels across the flooded area. By extending the rating curve of the nearby Fruita gage 9-1530, a peak discharge of 125,000 cfs was determined.

The Colorado River has been gaged since 1900. The Colorado River has better gage records than any major river in Colorado. Five principal gages were chosen for this study because of their proximity to the study area. The flood records were obtained from the USGS "Water Supply Paper 1683"[6] and updated from the USGS "Water Resources Data for Colorado"[7]. The five principal gages used were:

GAGE NO.	RIVER	LOCATION	YEARS RECORD	D. A. SQ. MI.
9-0725	Colorado	Glenwood SPgs	1900-1966	4,560
9-0955	Colorado	Cameo	1934-1970	8,050
9-1060	Colorado	Palisade	1902-1933	8,790
9-1530	Colorado	Fruita	1908-1923	17,100
9-1635	Colorado	Colo-Utah	1951-1970	17,900

Since 1937, these gages have been affected by diversions and reservoirs. To estimate what the runoff would have been on the Colorado River without controls, three other gages were studied. These gages were operating about the same period as the five principal gages. The three gages within the study reach drainage basin not affected by controls or diversions were:

GAGE NO.	RIVER	LOCATION	YEARS RECORD	D. A. SQ. MI.
9-0470	Blue	Dillon	1911-1960	120
9-0630	Eagle	Red Cliff	1911-1925 1940-1970	72
9-0850	Roaring Fork	Glenwood Spgs	1906-1970	1,450

The locations of the eight gaging stations are shown on figure 4.

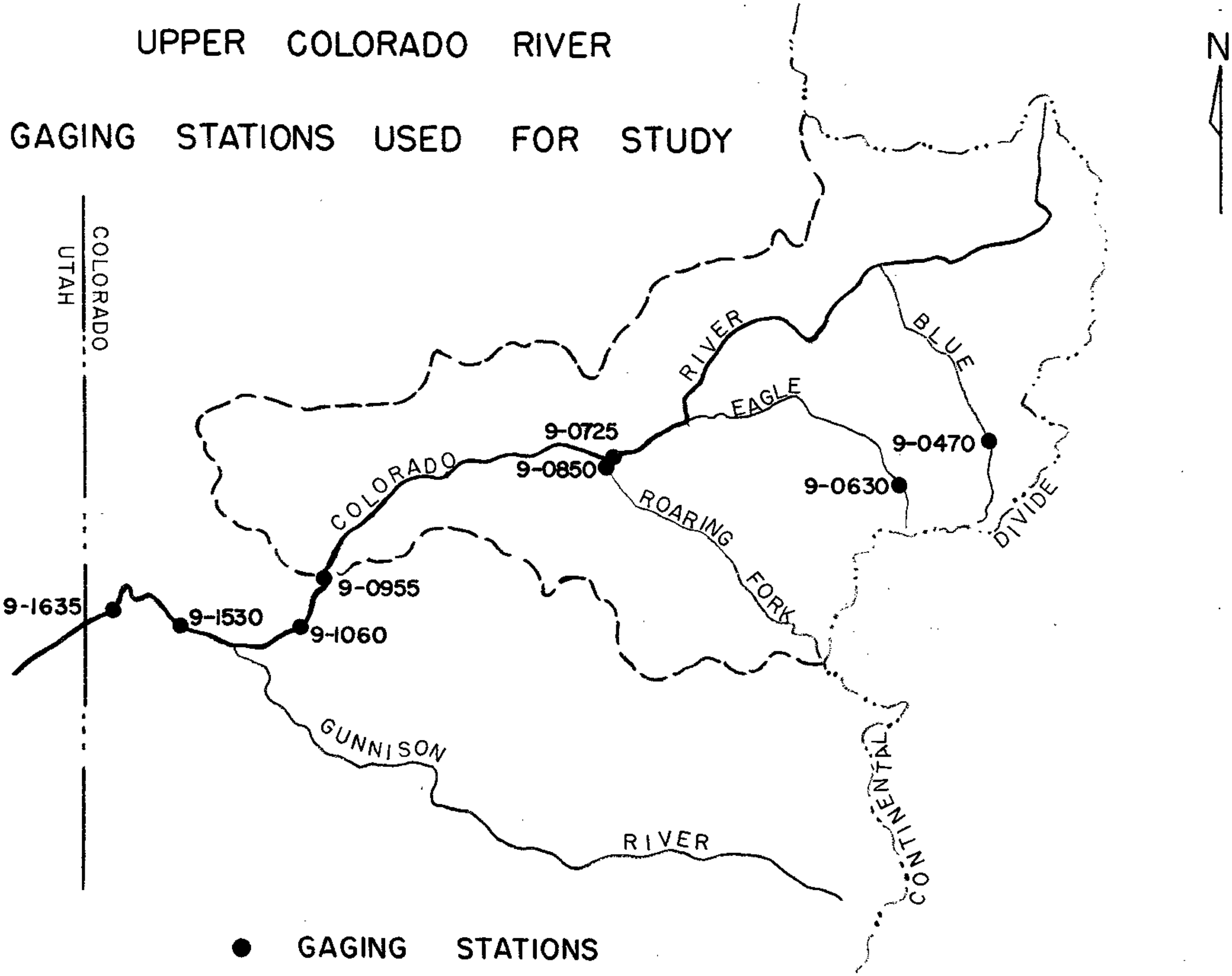
UPPER COLORADO RIVER
GAGING STATIONS USED FOR STUDY
N
UTAH
COLORADO
COLORADO
RIVER
EAGLE
BLUE
ROARING FORK
GUNNISON
RIVER
CONTINENTAL
DIVIDE
9-0725
9-0850
9-0470
9-0630
9-0955
9-1635
9-1530
9-1060
GAGING STATIONS

Figure 4

DESIGN DISCHARGES BY OTHERS

Mr. Fred Bartel of the Bureau of Reclamation Flood Study Group, said via telephone, that in 1964 they used a 50 year flood of 44,000 cfs and a 100 year flood of 48,000 cfs for the design of a pumping plant at Silt. In 1970 at Grand Valley (Palisades), they used a 50 year flood of 56,000 cfs and a 100 year flood of 63,000 cfs. Mr. Bartel said that the gage records since 1949 were adjusted to account for the effect that retention and diversion had on the peak flow in the Colorado River.

The USGS "Water-Supply Paper 1683",[6] Figure 19, page 16 under Special Application gave a 50 year flood of 51,000 cfs through DeBeque Canyon. This paper contains records through 1962 therefore does not include the effect of recent dams. Homestake, Rifle Gap and Ruedi dams have been built since then.

ANALYSIS OF GAGING STATION RECORDS

Gaging station records were used in the analysis to predict the design discharge for DeBeque Canyon. The Log Pearson Type III procedure was used to determine the recurrence interval curve for each station. The observed discharges were plotted, using the $\frac{N+1}{M}$ recurrence interval, along with the Log Pearson Type III curve. See figures 7 thru 11 in the appendix.

Two periods of time were studied; records before and after 1934. The year 1934 was picked for two reasons. One, that was about the time the first retention structure (Williams Fork Reservoir) was built. Secondly, that year was the approximate time there was a break in the principal gaging station records. Gage 9-1060 records stopped in 1933 and gage 9-0955 records started in 1934.

Gage 9-0725 at Glenwood Springs is the only gage on the Colorado River near the study reach that had many years of records in both periods of time; 34 years before 1934 and 33 years after 1933. There was a difference of 11,500 cfs (33%) between the 50 year floods calculated for the two time periods. See figure 7 in the appendix for the recurrence interval plot. A graph of the peak flows for gage 9-0725, figure 12, readily illustrates a trend of lower annual peak flows in recent years.

The two periods of gage records were plotted in figure 5 to form a Discharge vs. Drainage Area Curve. A straight line was drawn through the points of each time period. The discharge relationship from the records after 1934 is parallel but one third lower than the discharge before 1934.

Gages 9-0470, 9-0630 and 9-0850 were analyzed to see if the areas without controls showed a similar decrease. Again the same time periods before and after 1934 were used to study possible change in the calculated 50 year discharges. See Annual Peak Flow graphs figures 17 thru 19 in the appendix. The results of the comparison were:

	Q_{50}		
GAGE NO.	BEFORE 1934	AFTER 1934	REDUCTION
9-0470	1,450 cfs	985 cfs	32%
9-0630	1,120	805	28%
9-0850	17,990	16,700	7%

These gaging stations represent about one-fifth of the drainage area above DeBeque Canyon. The most significant gage is 9-0850 at Glenwood Springs because it is the largest drainage area of the three gages not affected by controls and diversions. Using the drainage area as a basis to proportion the reduction, these gages have an average reduction of 8% in the peak flows.

It is logical to attribute this reduction to climatological change. Therefore the 33% reduction of the 50 year flood as calculated from the Colorado River gaging stations is not entirely from diversions and controls. At least 8% can be attributed to climatological change. Thus diversions and controls account for a 25% reduction in the 50 year flood. In our opinion, however, the present controls and diversions would have less influence on a high frequency (100 year or greater) flood than a low frequency (2 to 5 year) flood. A complicated model basin study would be required to relate the effect of diversion and controls on a particular frequency flood. For lack of more data, the 25% reduction of floods due to controls was applied to the 50 year flood frequency. The small difference in final design discharge would not warrant a more detailed study.

The period of records before 1934 are relatively unaffected by diversions or controls. Using this as a base for unaffected flood peaks, a 25% reduction was made from the Discharge vs. Drainage Area Curve (figure 5) to predict the 50 year flood. This discharge read from figure 5 is 54,000 cfs. Therefore the 50 year design flood for DeBeque Canyon would be 25% less than 54,000 cfs or 41,000 cfs.

A design recurrence interval curve, figure 6, was constructed using figures 12 thru 16. The design mean annual flow is 22,000 cfs.

The flood records used in analysis did not reflect any reduction that the most recent reservoirs may have on peak discharges. By the same token, neither was increased runoff due to weather modification included. Since both of these factors are difficult to predict and could be offsetting, they were neglected in the final analysis.

DISCHARGE VS DRAINAGE AREA CURVE
COLORADO RIVER

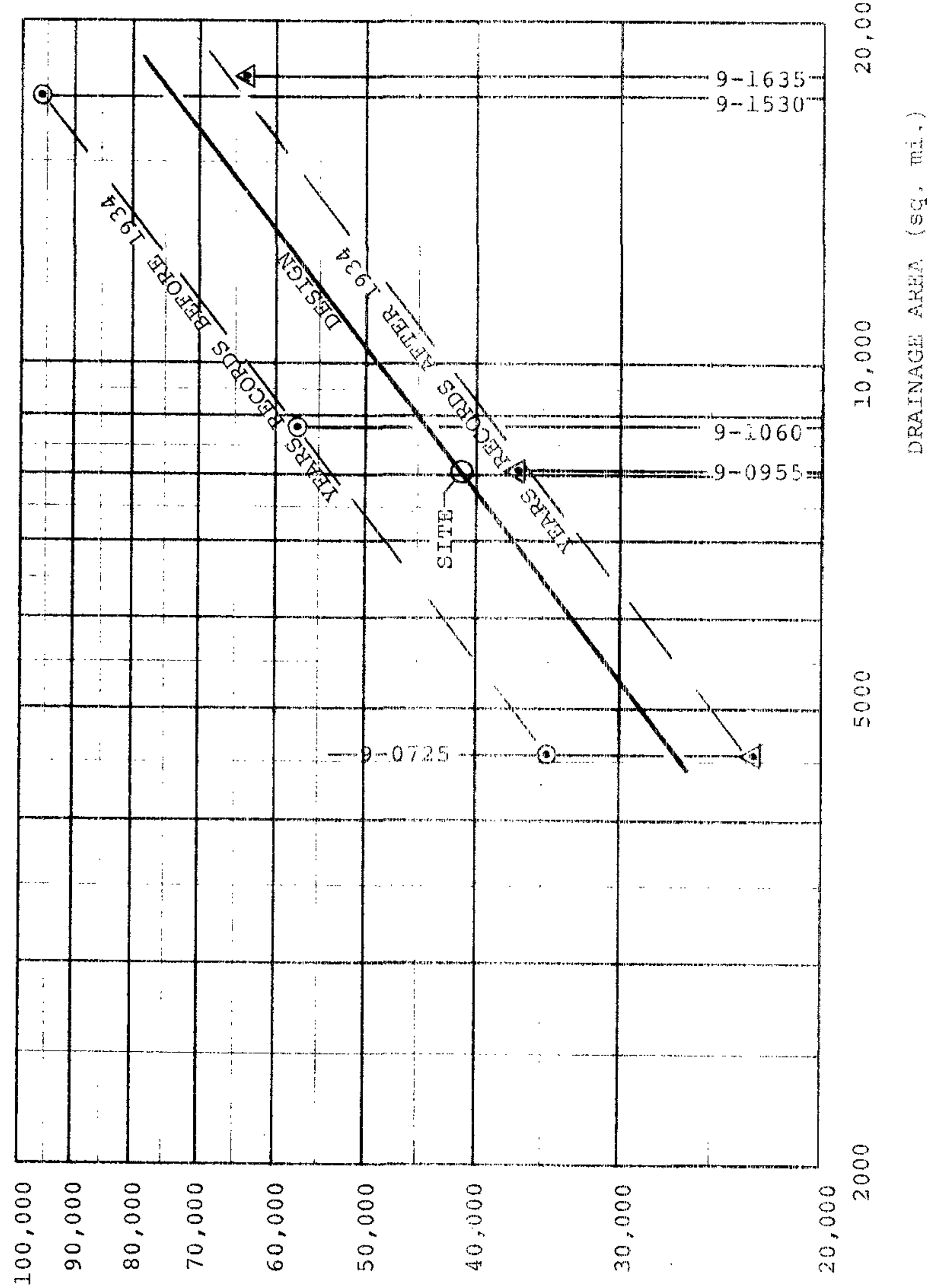

Figure 5

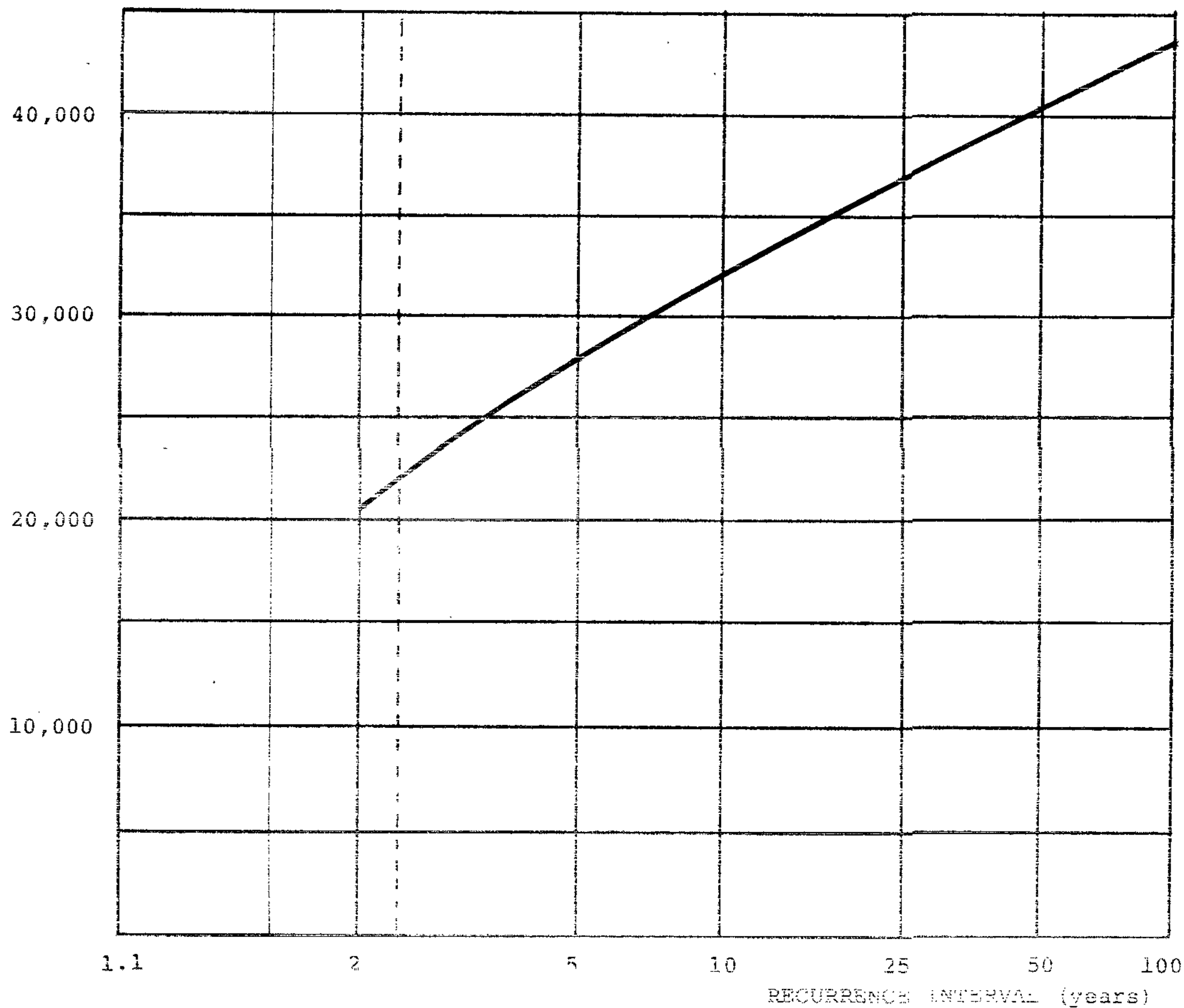

Figure 6

RECURRENCE INTERVAL CURVE
USED FOR DESIGN
DeBEQUE CANYON

CONCLUSION

The peak discharges recorded by the gaging stations along the Colorado River show a downward trend during the past 30 years. Several reservoirs and diversions that affect peak flow have been built during this time period. Their effect was estimated by analyzing gaging station records of tributaries unaffected by controls. The period before 1934 was considered unaffected by controls. This base period's 50 year flood was reduced by 25% to arrive at the design 50 year flood of 41,000 cfs for DeBeque Canyon.

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2. Federal Power Commission, "Water Resource Appraisals for Hydroelectric Licensing," Planning Status Report, Upper Colorado River Basin, Wyoming-Colorado-Utah-New Mexico-Arizona, Bureau of Power 1967.

3. Barton, Stoddard, Milhollin & Higgins, Inc., "Hydrologic Report Colorado River-Glenwood Canyon," August, 1969.

4. Upper Colorado Region State-Federal Interagency Group, "Appendix IX Flood Control," Flood Control Group for the Pacific Southwest Interagency Committee Water Resources Council, June, 1971.

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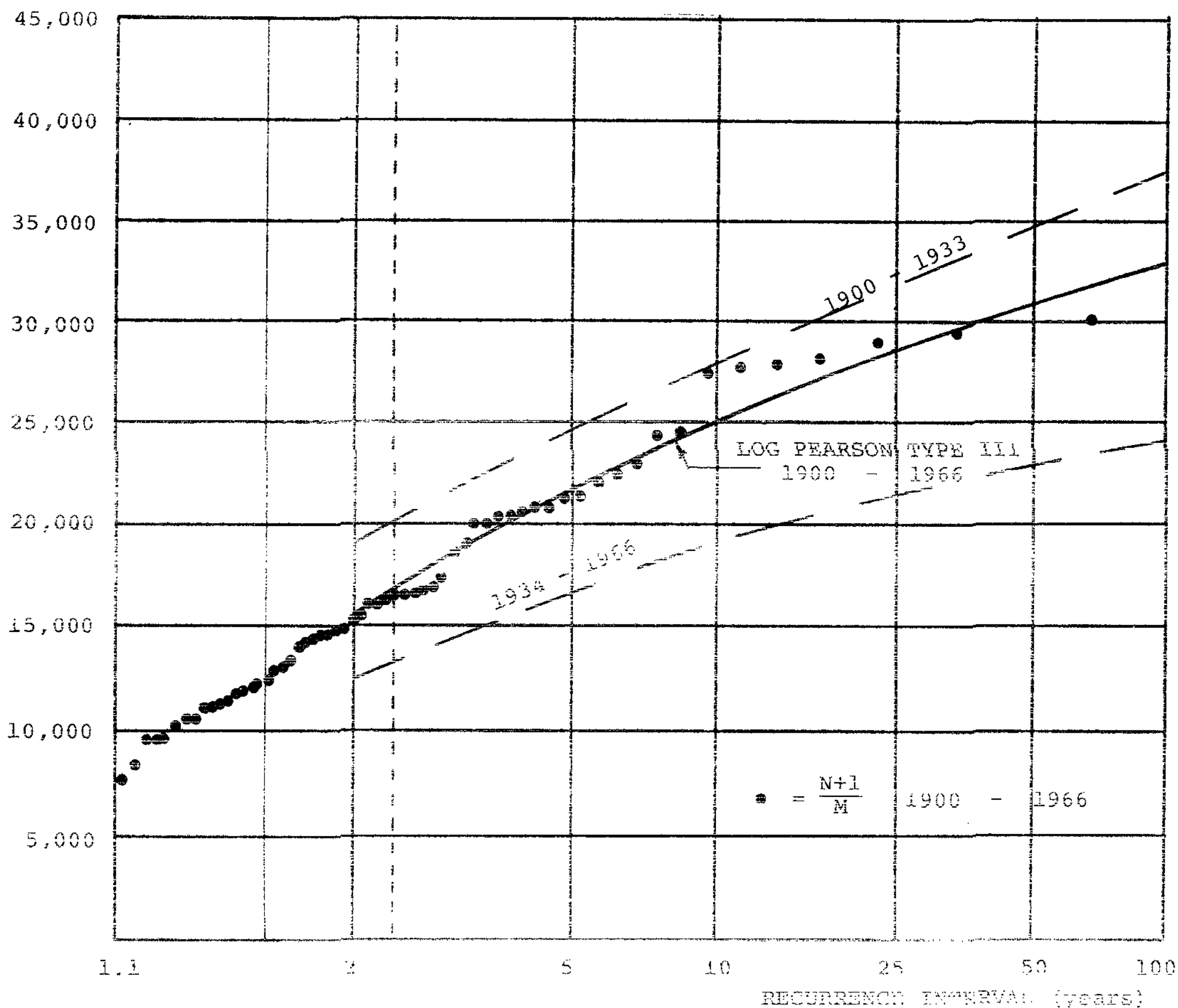
6. United States Department of the Interior, "Geological Survey Water-Supply Paper 1683," Magnitude and Frequency of Floods in the United States, Part 9. Colorado River Basin, United States Government Printing Office, Washington, 1966.

7. United States Department of the Interior, "Part 1. Surface Water Records," Water Resources Data for Colorado, U.S. Geological Survey, Denver, Colorado, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970.

APPENDIX

Figure 7



RECURRENCE INTERVAL CURVE
GAGE 9-0725
COLORADO RIVER AT GLENWOOD

RECURRENCE INTERVAL CURVE
GAGE 9-0955
COLORADO RIVER NEAR CAMEO

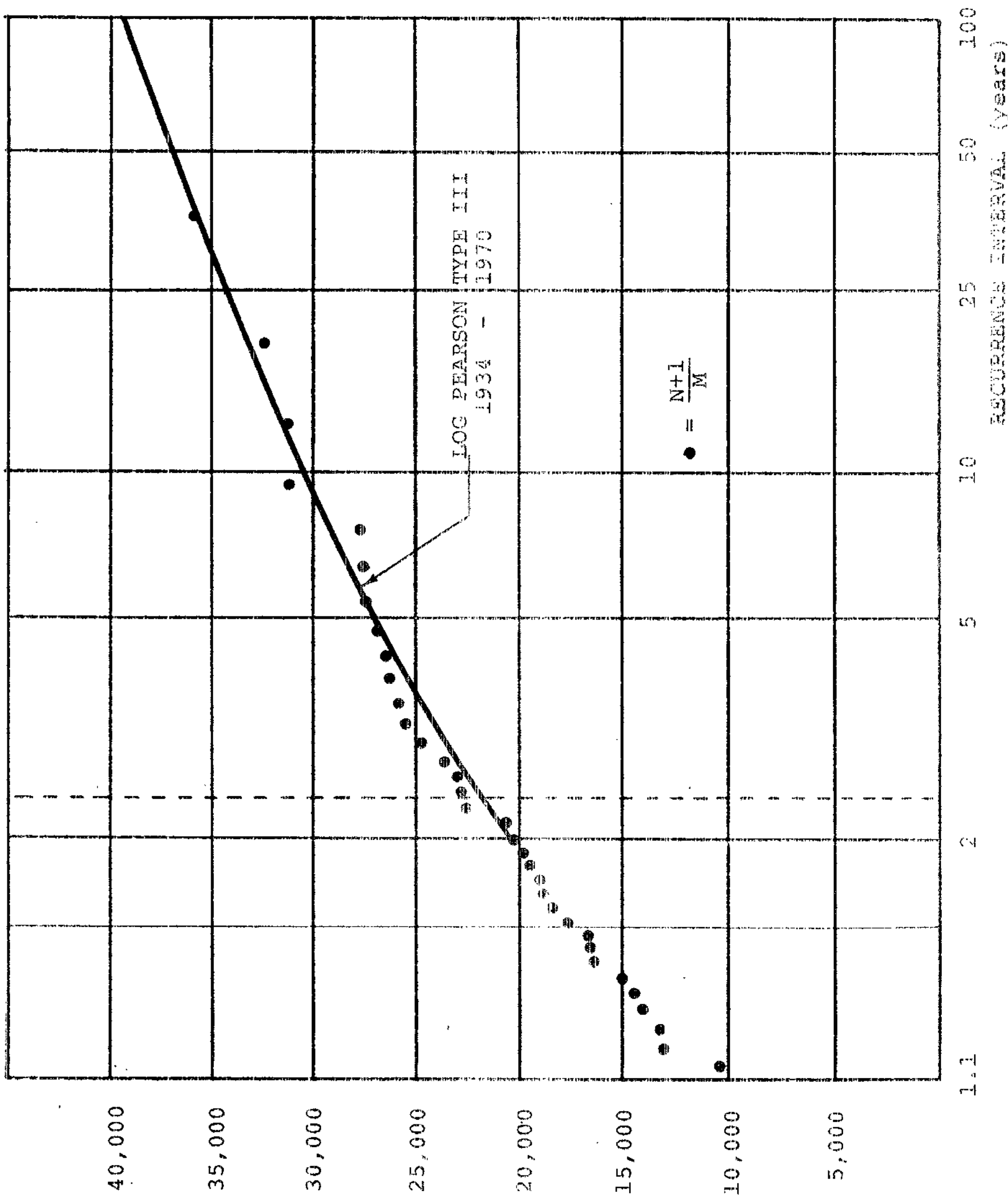


Figure 8

RECURRENCE INTERVAL CURVE

GAGE 9-1060
COLORADO RIVER NEAR PALISADE

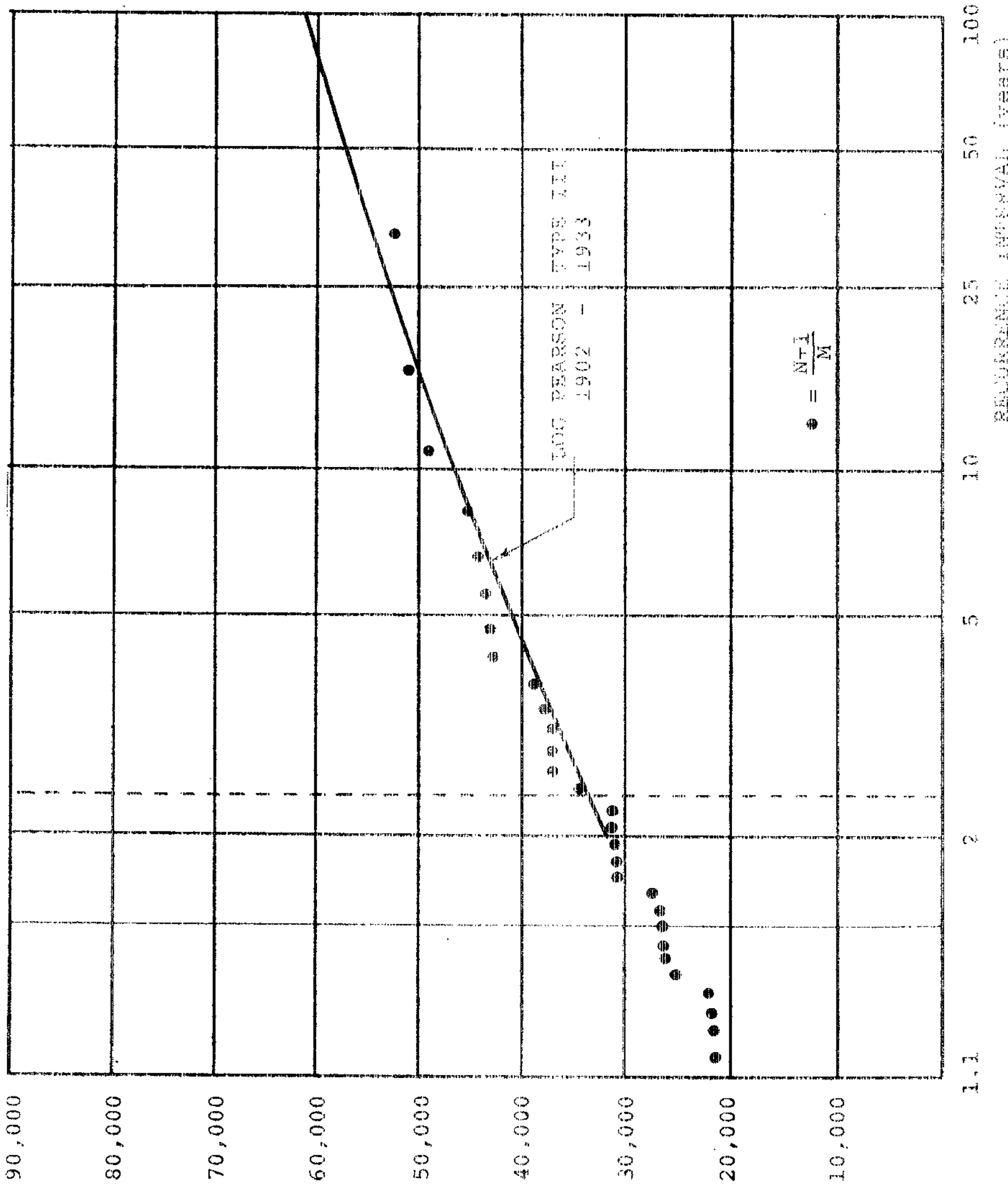


Figure 9 DISCHARGE (cfs)

RECURRENCE INTERVAL CURVE

GAGE 9-1530
COLORADO RIVER NEAR FRUITA

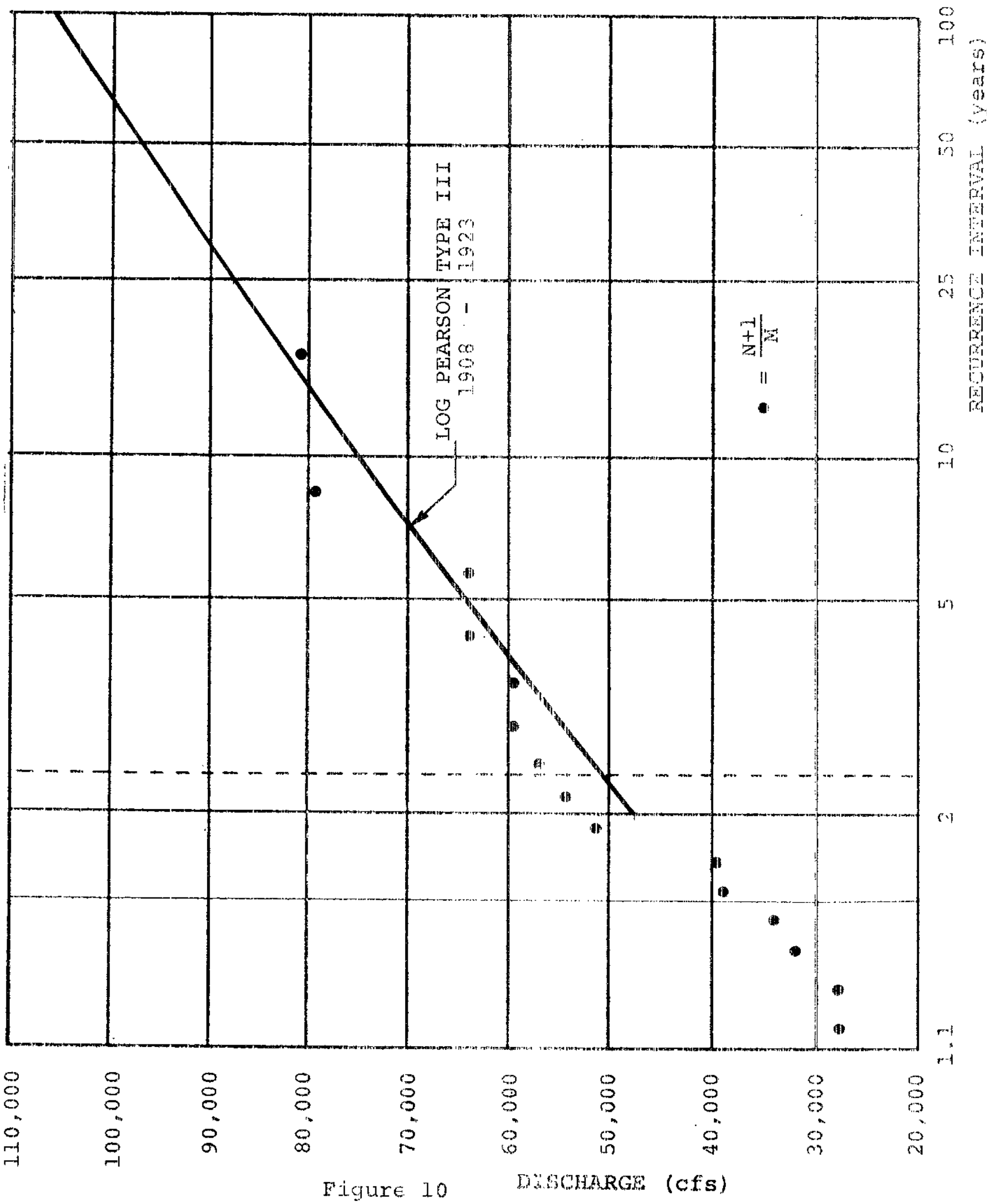


Figure 10

RECURRENCE INTERVAL CURVE
GAGE 9-1635
COLORADO RIVER AT STATE LINE

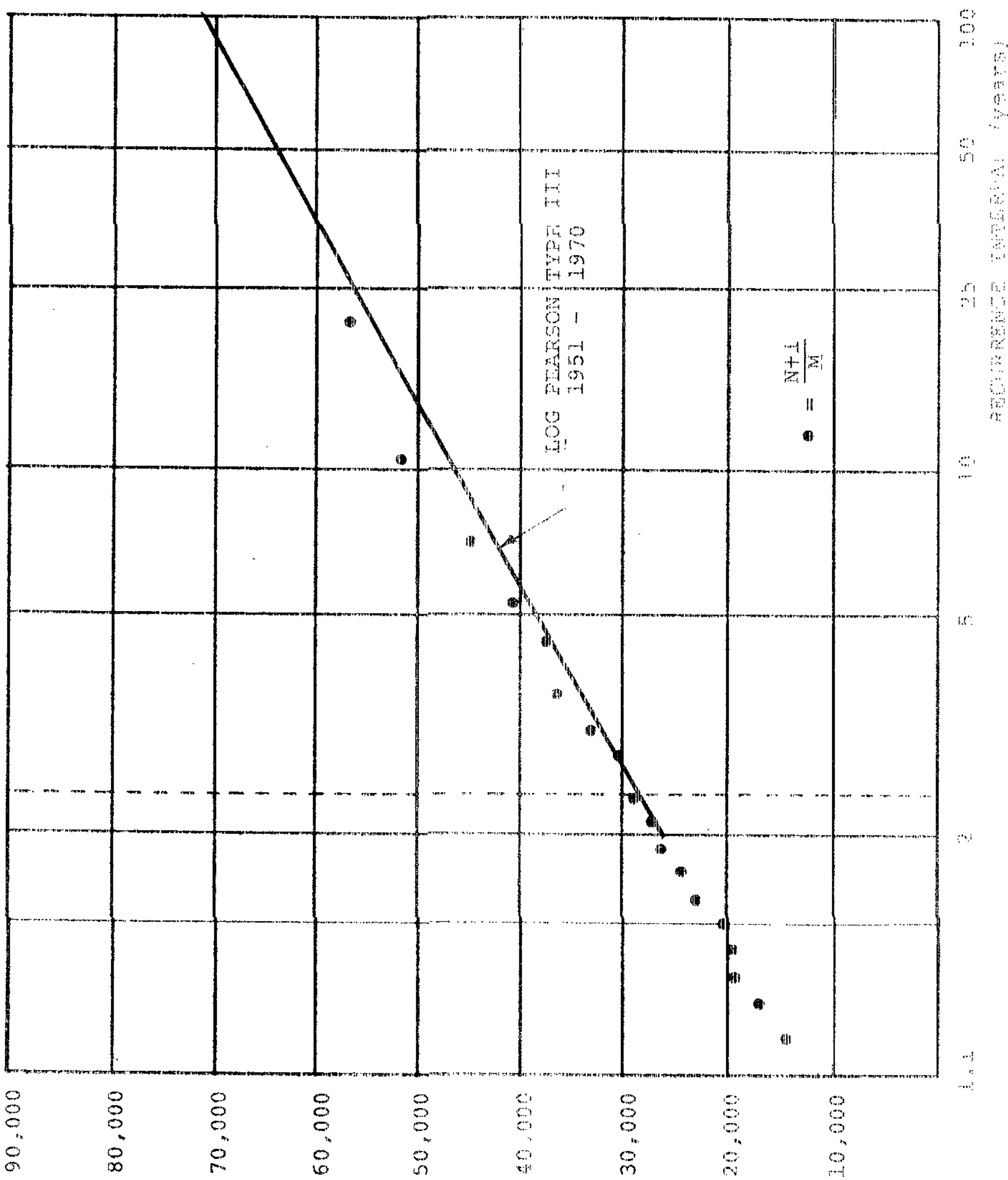


Figure 11

ANNUAL PEAK DISCHARGES GAGE 9-0725 AT GLENWOOD SPRINGS

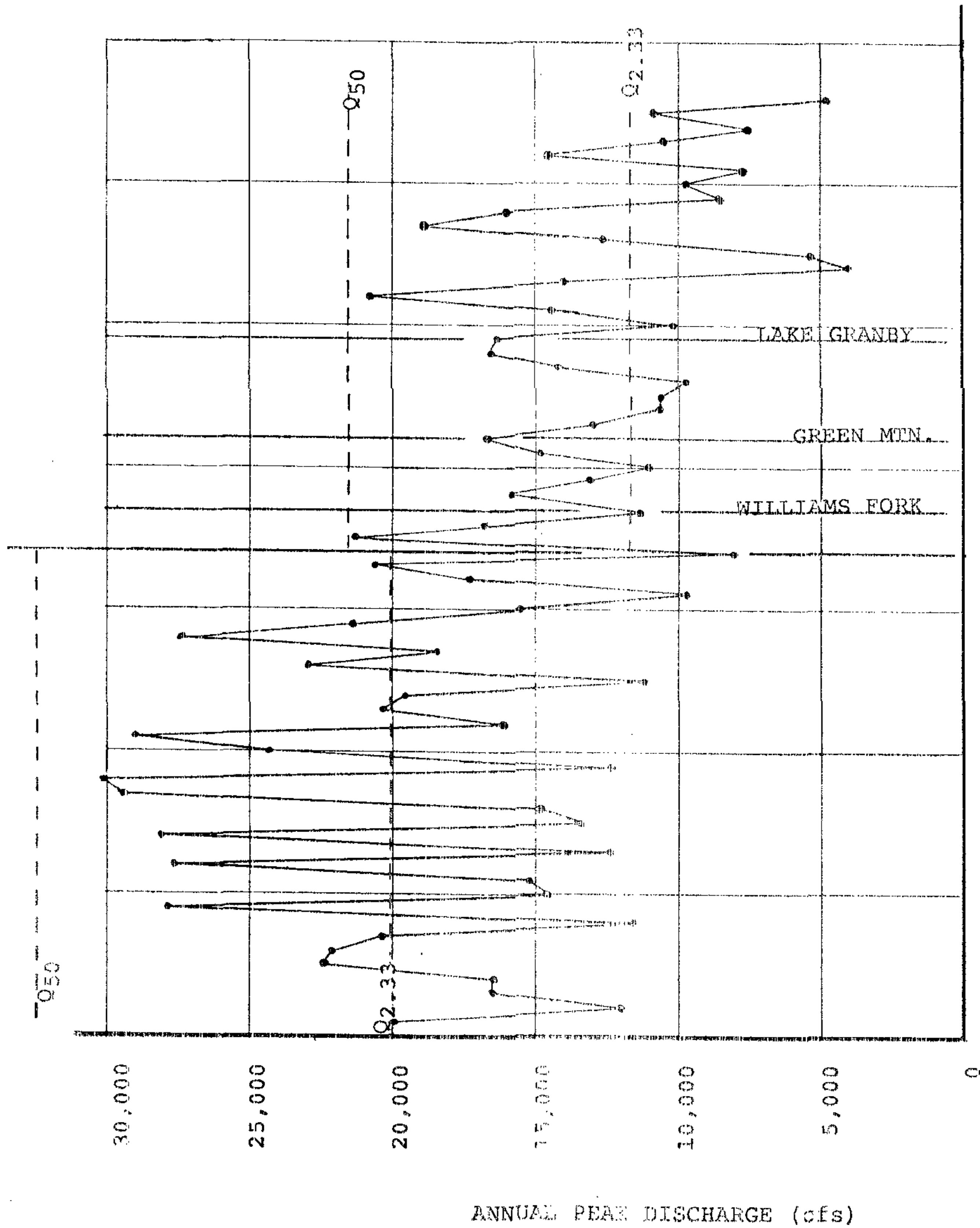


Figure 12

ANNUAL PEAK DISCHARGES GAGE 9-0955

NEAR CAMEO

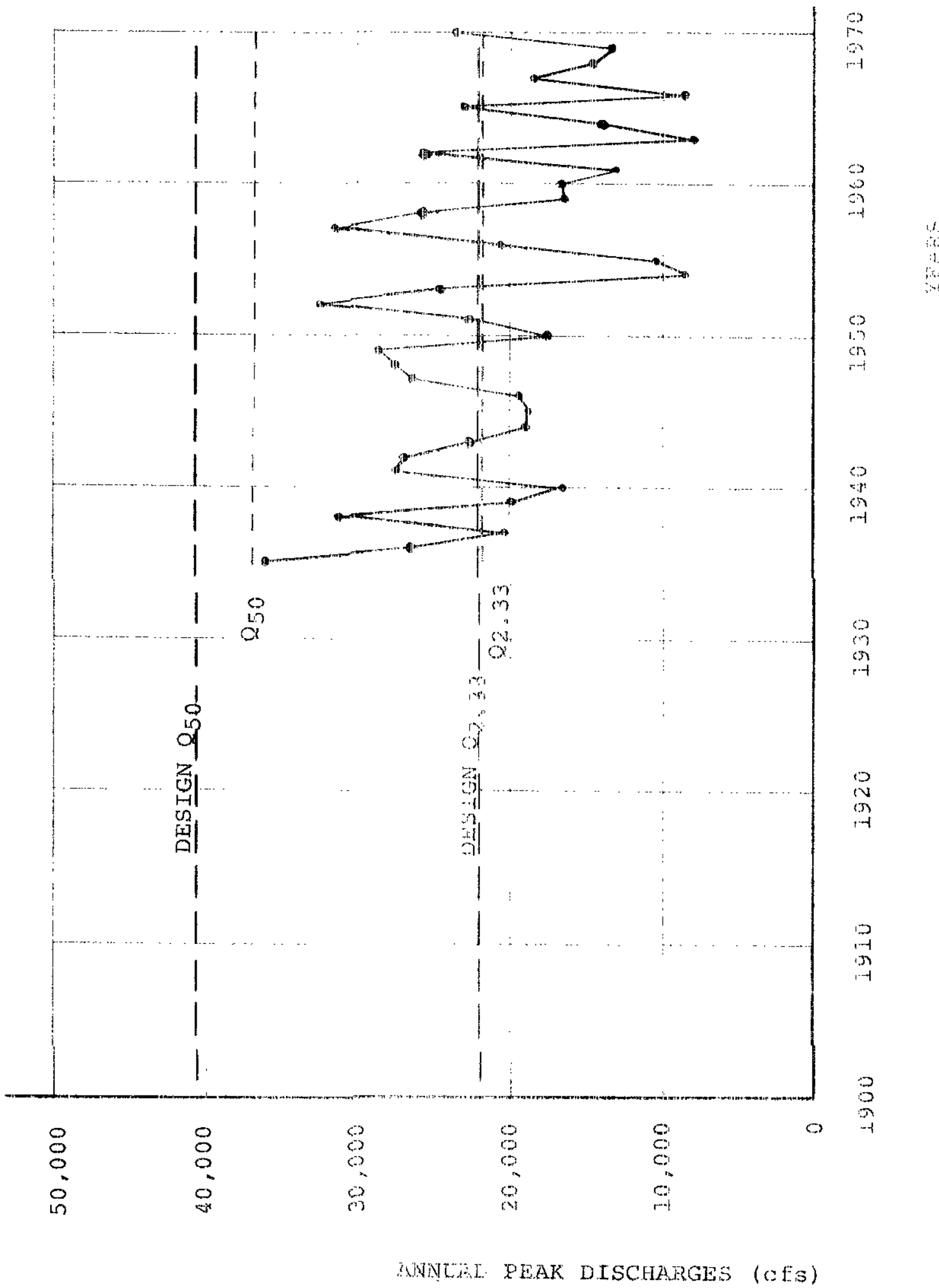


Figure 13

ANNUAL PEAK DISCHARGES GAGE 9-1060

NEAR PALISADE

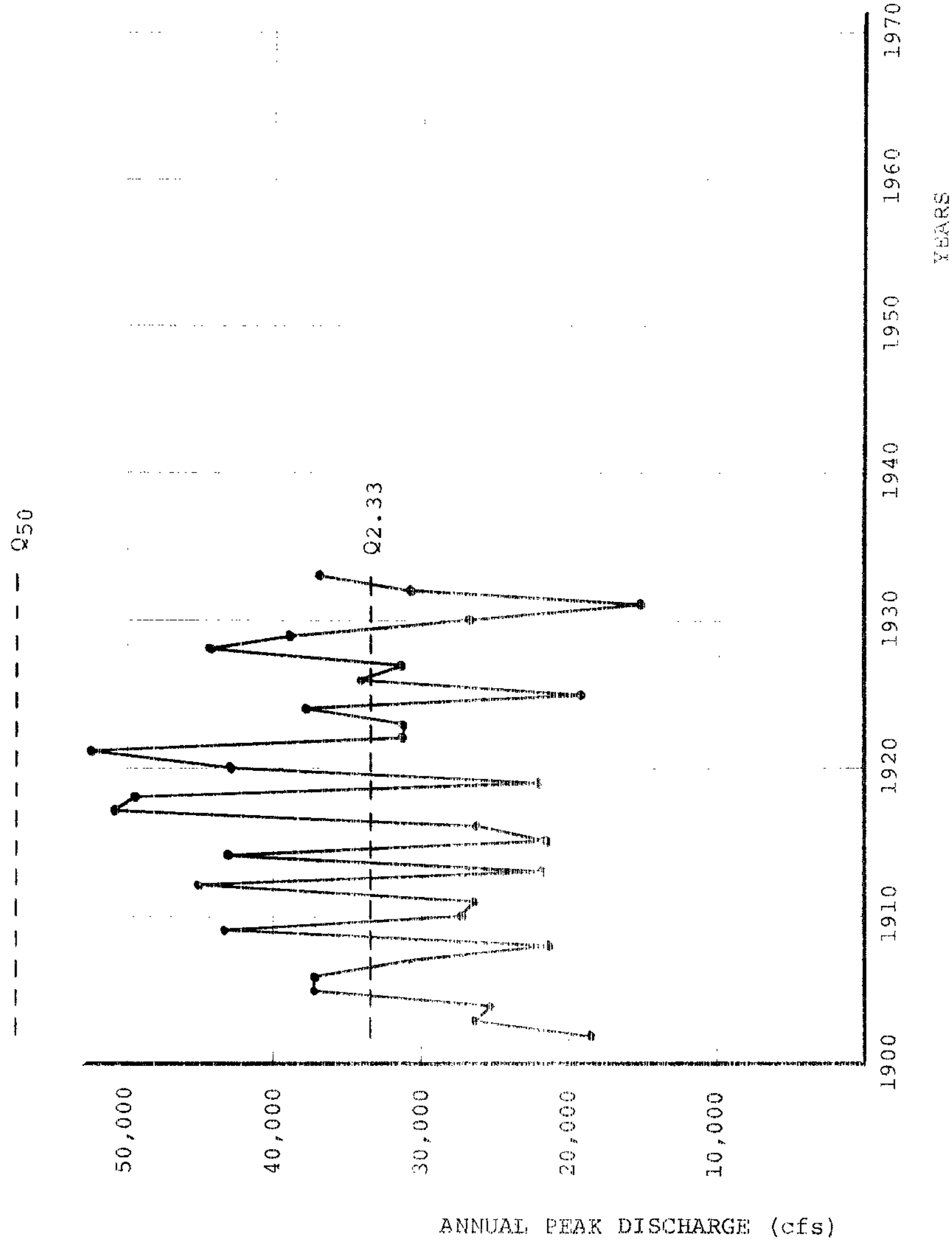


Figure 14

ANNUAL PEAK DISCHARGES GAGE 9-1530

NEAR FRUITA

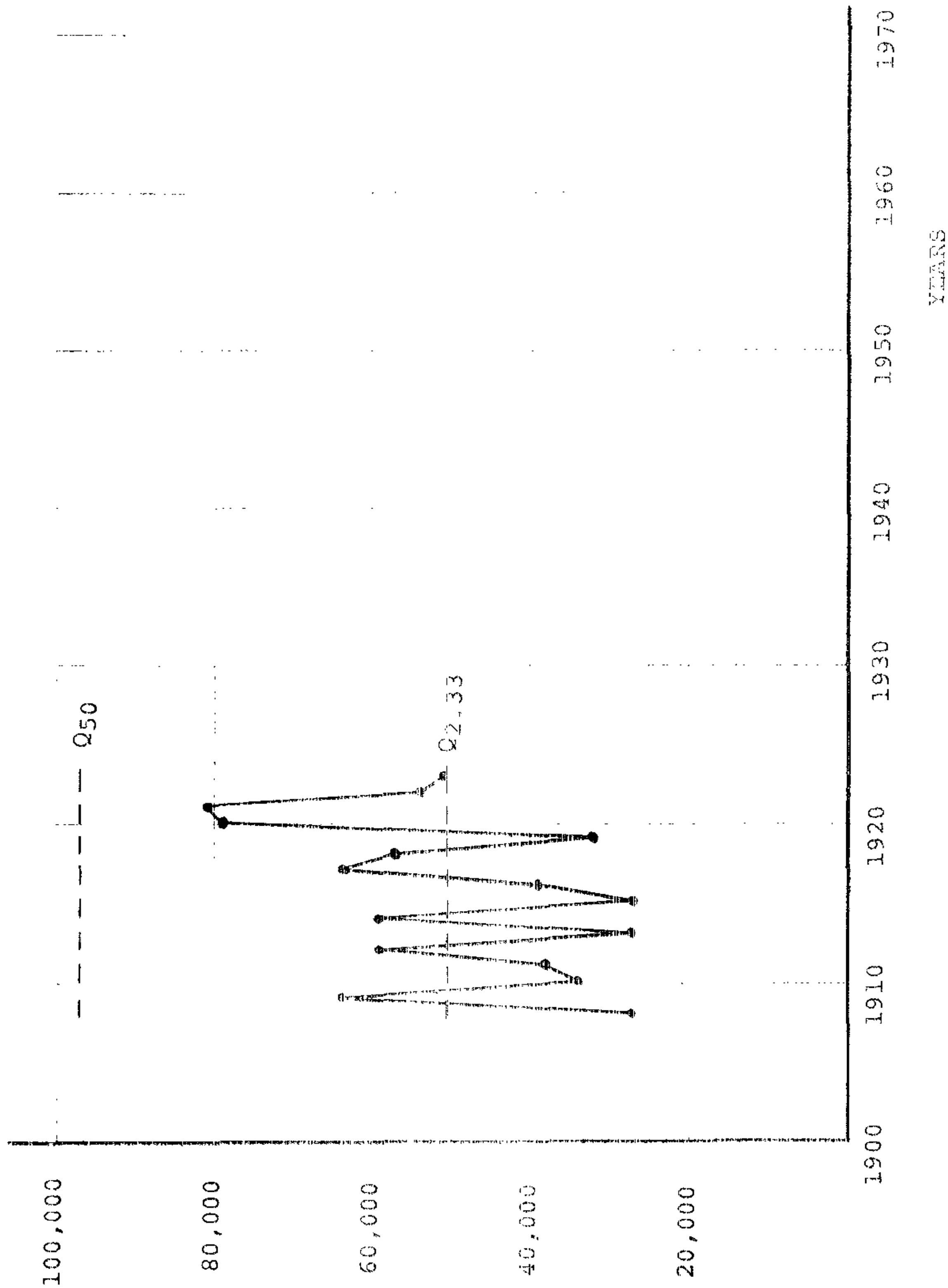


Figure 15

ANNUAL PEAK DISCHARGES GAGE 9-1635

COLORADO-UTAH STATE LINE

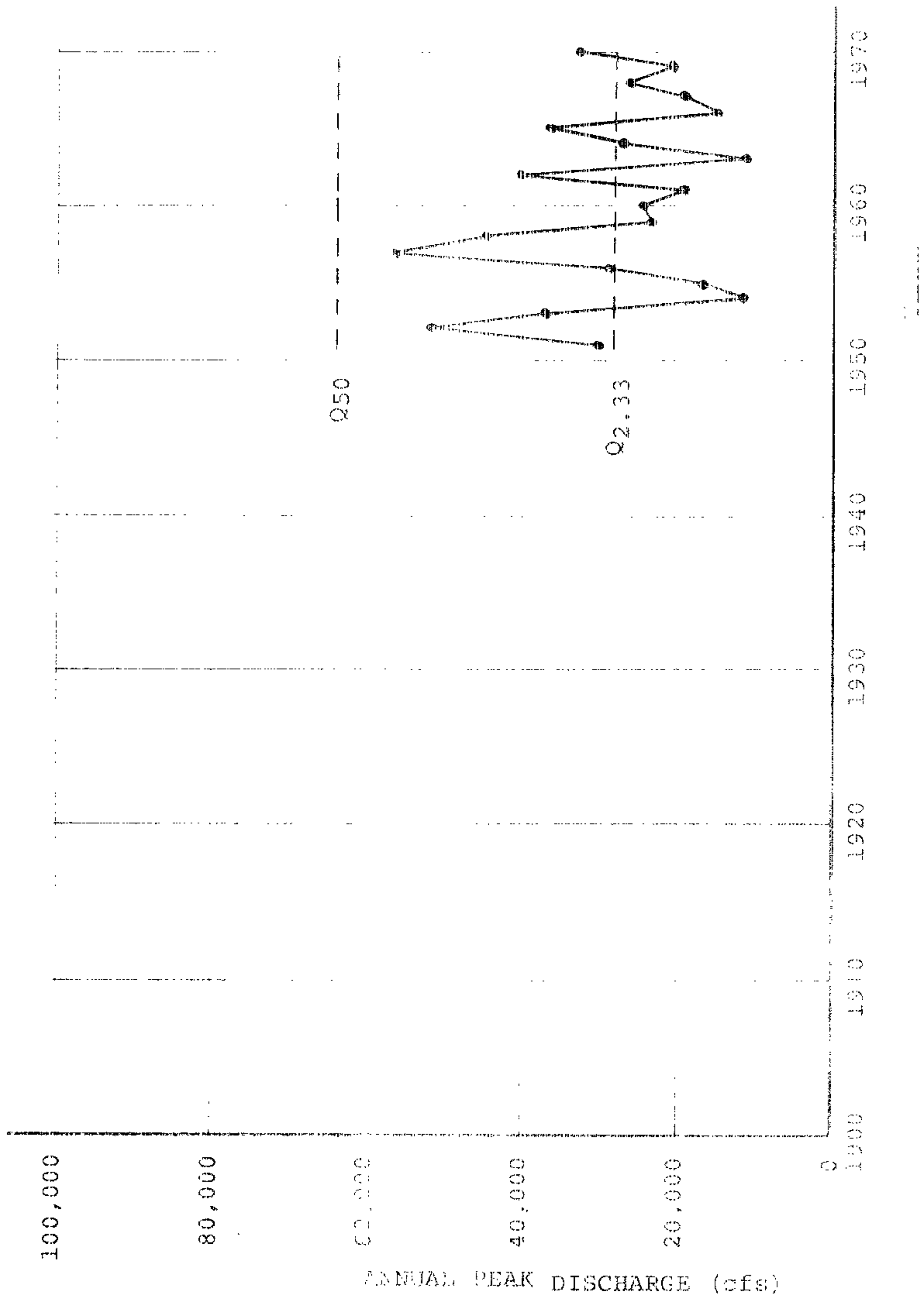
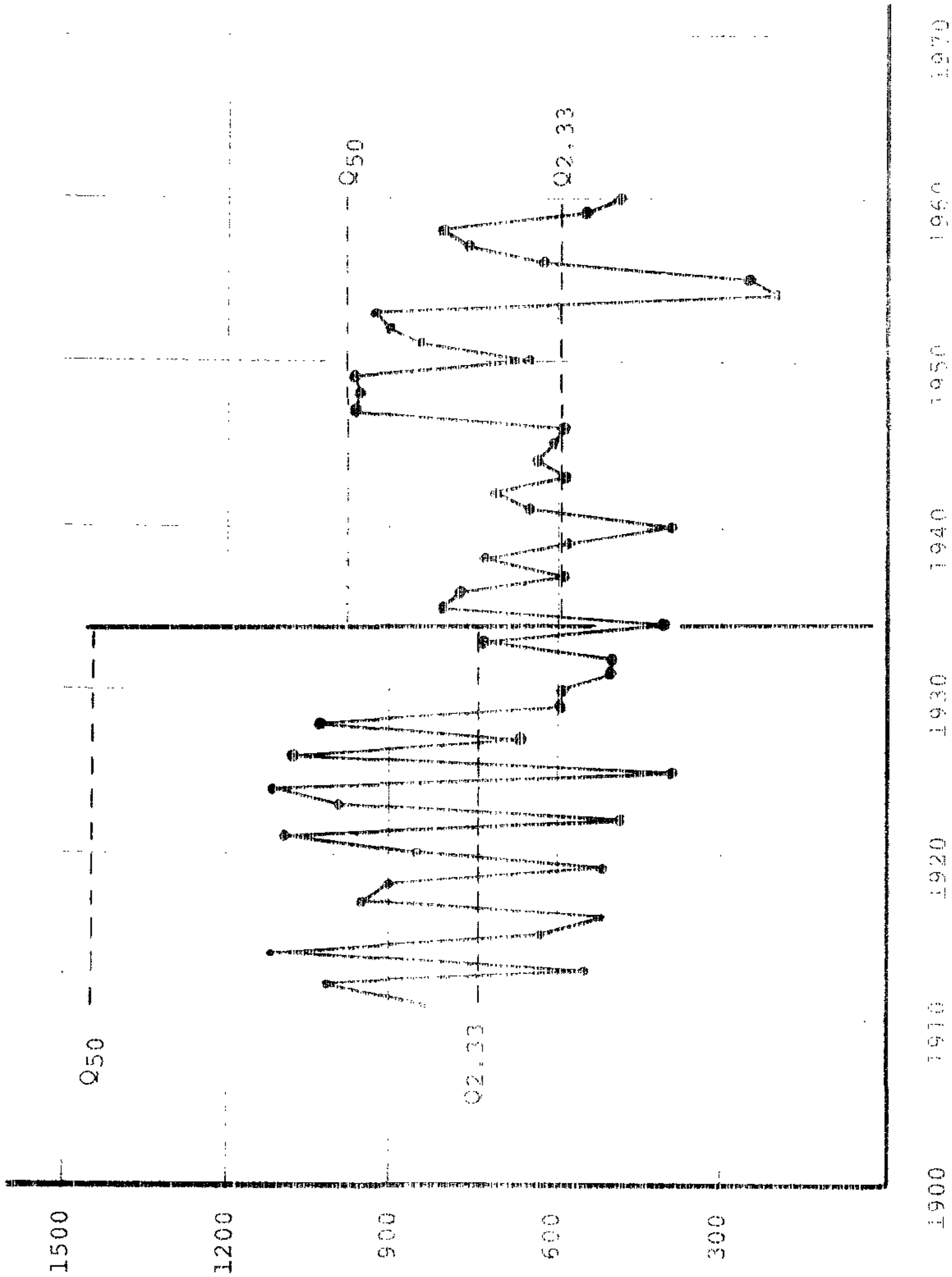


Figure [illegible]

ANNUAL PEAK DISCHARGES GAGE 9-0470

AT DILLON

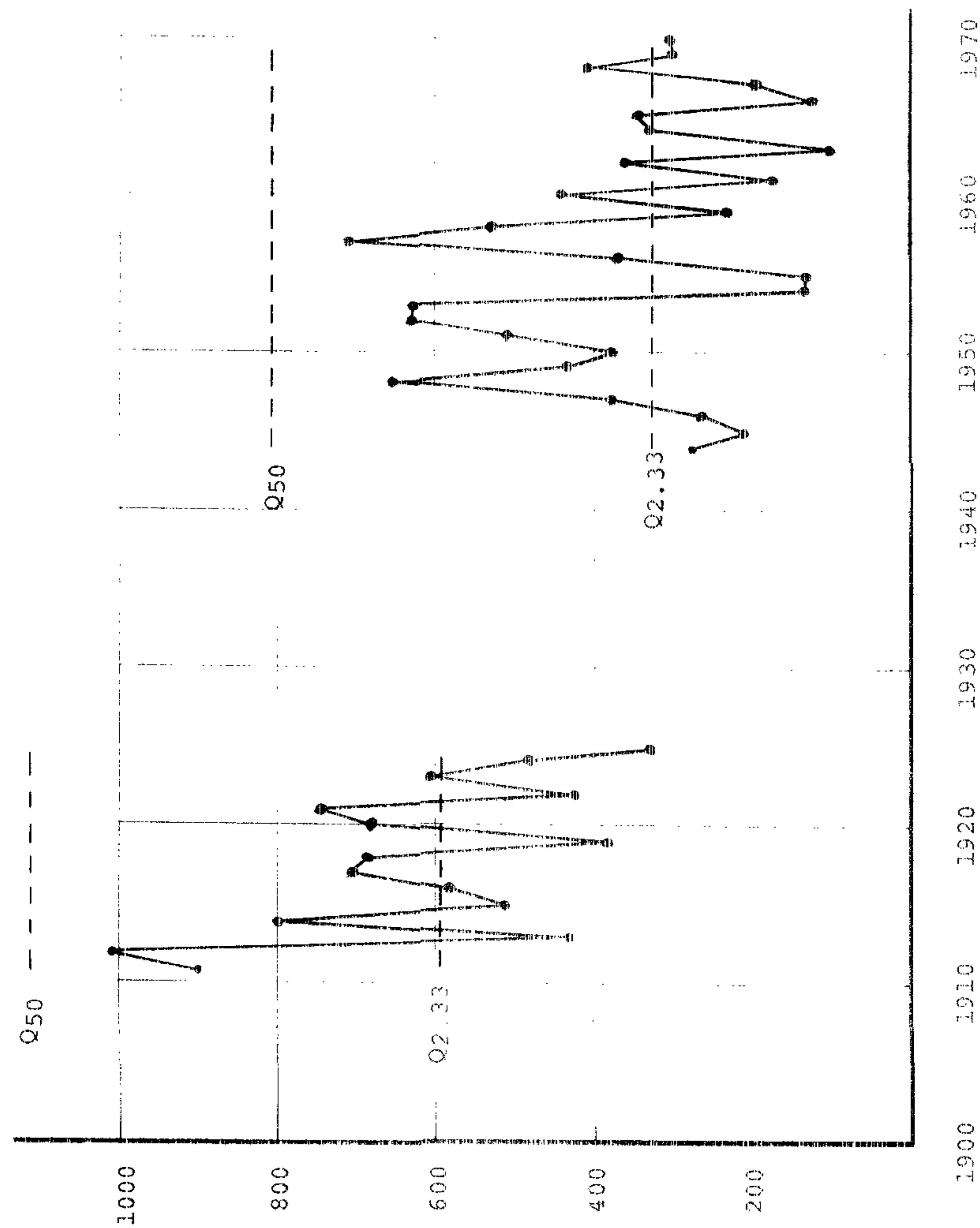


ANNUAL PEAK DISCHARGES (cfs)

Figure 37

ANNUAL PEAK DISCHARGES GAGE 9-0630

AT RED CLIFF

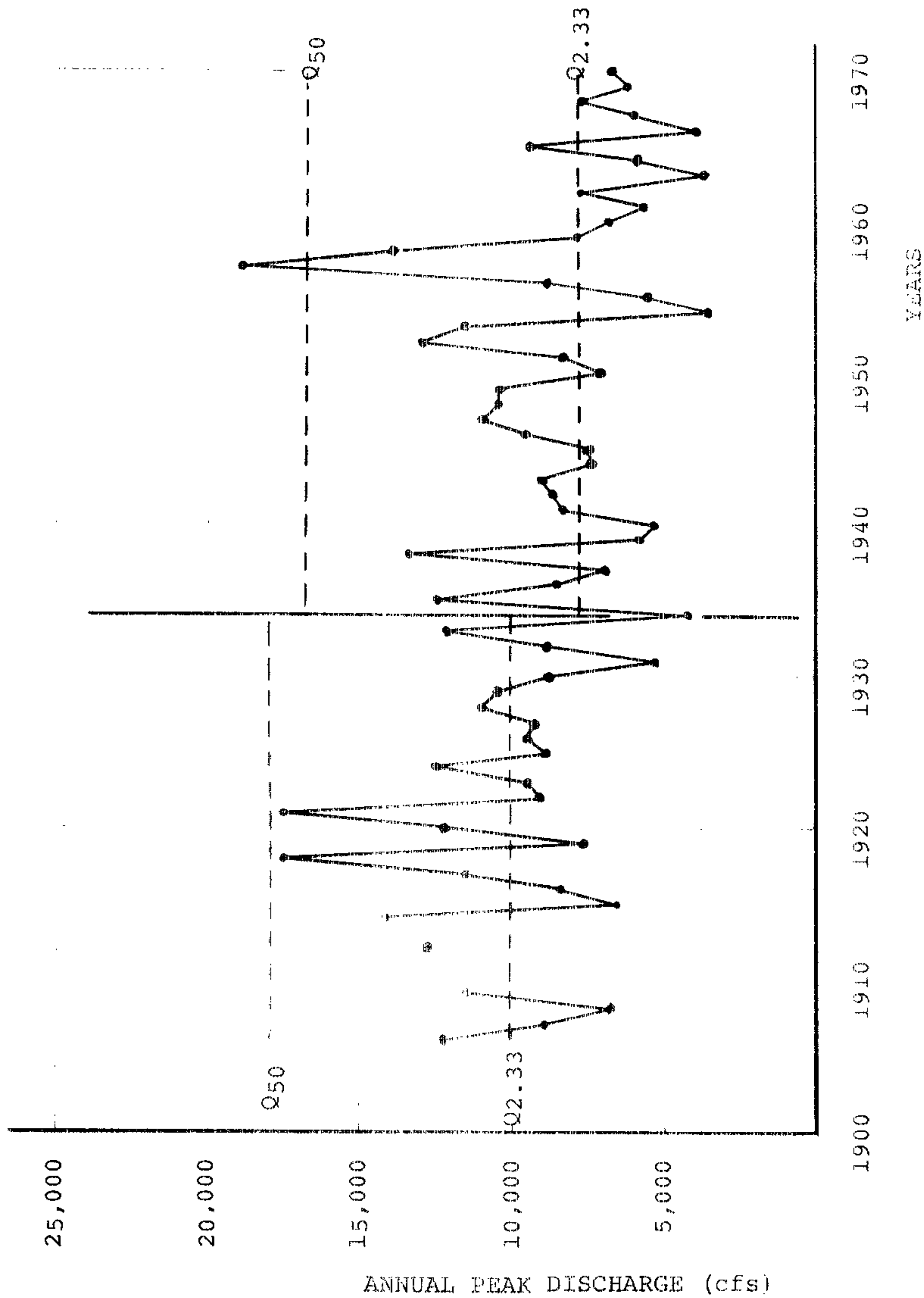


ANNUAL PEAK DISCHARGES (cfs)

Figure 18

ANNUAL PEAK DISCHARGES GAGE 9-0850

AT GLENWOOD SPRINGS



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A design recurrence interval curve, figure 6, was constructed using figures 12 thru 16. The design mean annual flow is 22,000 cfs.

The flood records used in analysis did not reflect any reduction that the most recent reservoirs may have on peak discharges. By the same token, neither was increased runoff due to weather modification included. Since both of these factors are difficult to predict and could be offsetting, they were neglected in the final analysis.

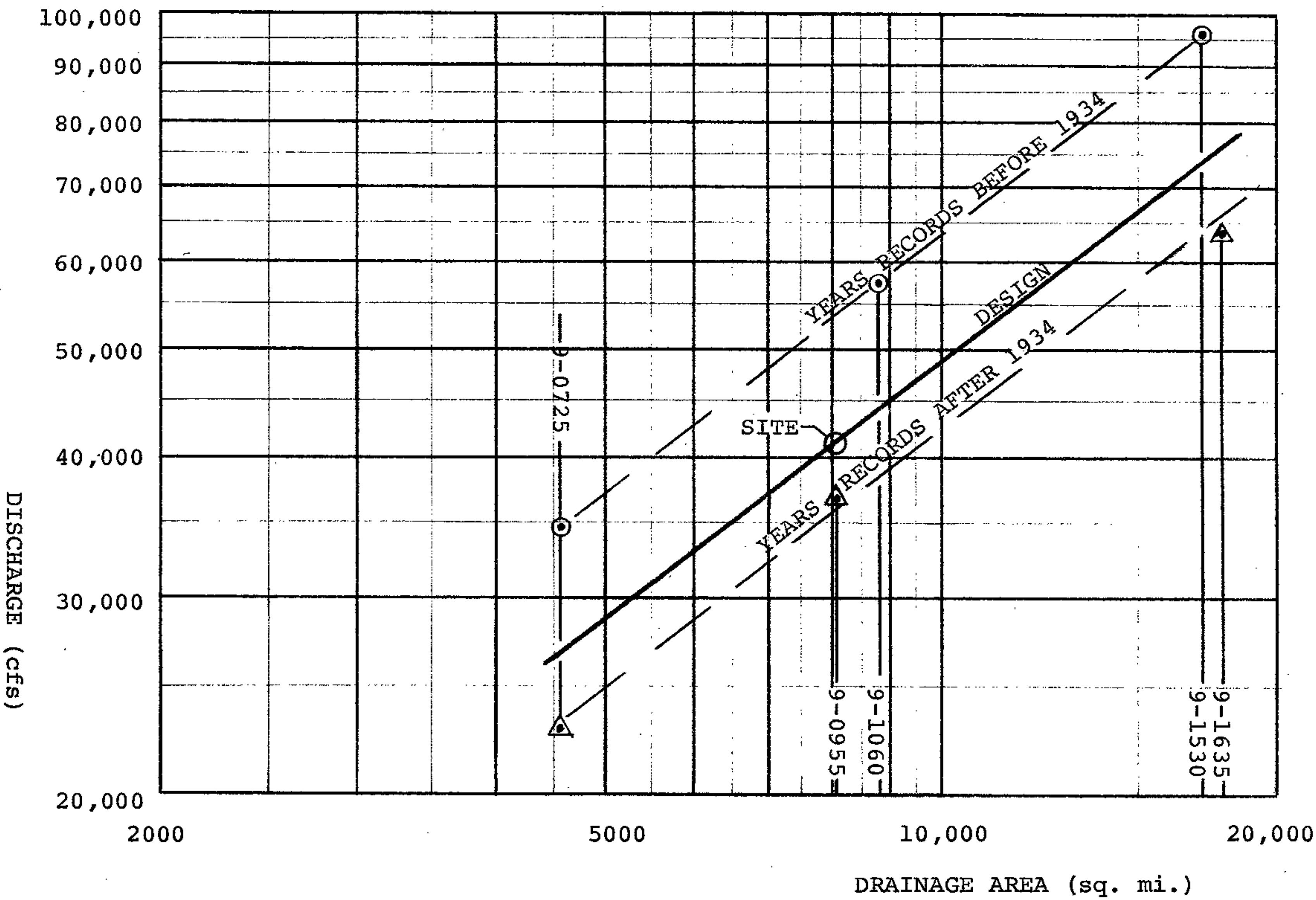

Figure 5

DISCHARGE VS DRAINAGE AREA CURVE
COLORADO RIVER

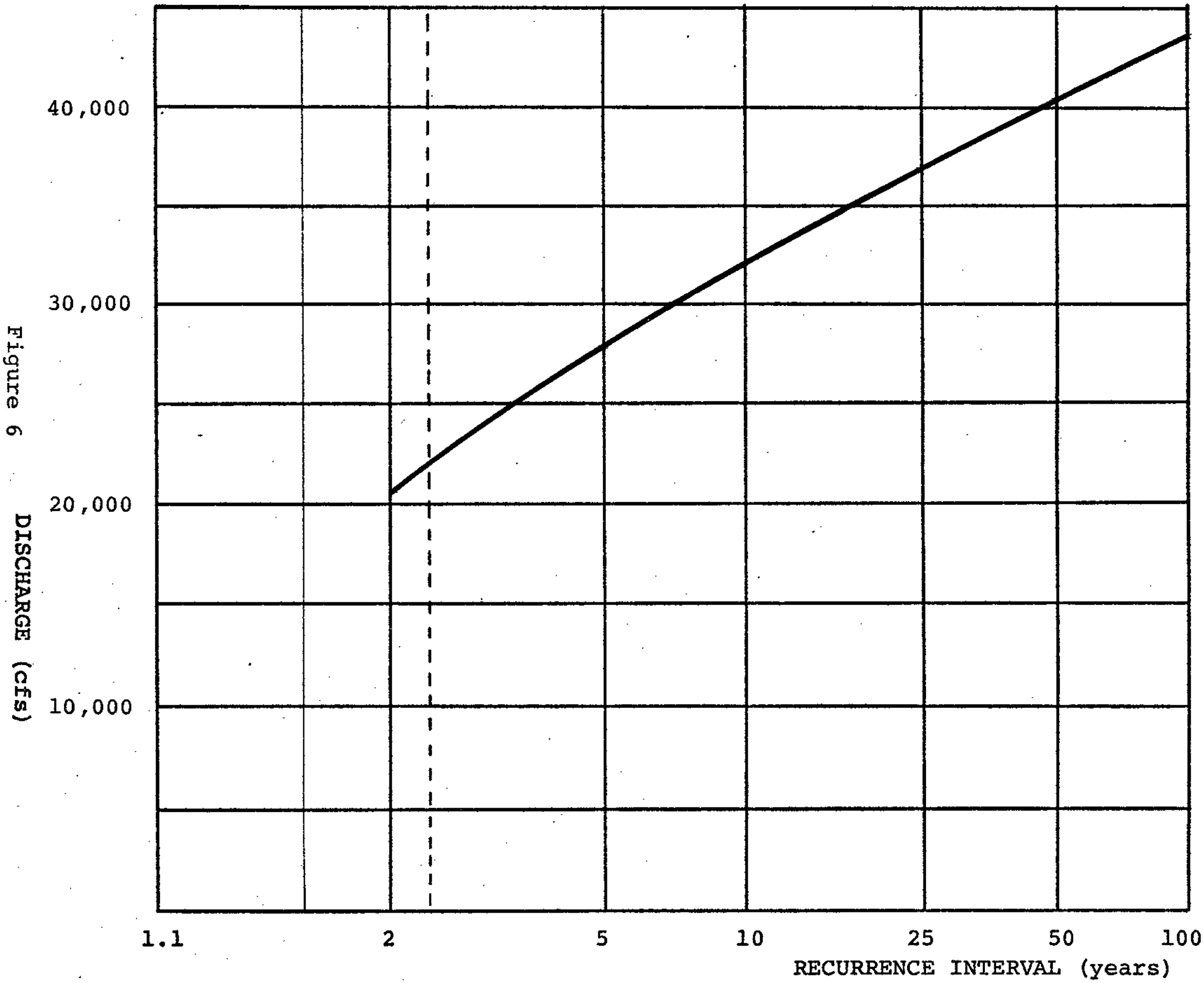

Figure 6

RECURRENCE INTERVAL CURVE
USED FOR DESIGN
DeBEQUE CANYON

CONCLUSION

The peak discharges recorded by the gaging stations along the Colorado River show a downward trend during the past 30 years. Several reservoirs and diversions that affect peak flow have been built during this time period. Their effect was estimated by analyzing gaging station records of tributaries unaffected by controls. The period before 1934 was considered unaffected by controls. This base period's 50 year flood was reduced by 25% to arrive at the design 50 year flood of 41,000 cfs for DeBeque Canyon.

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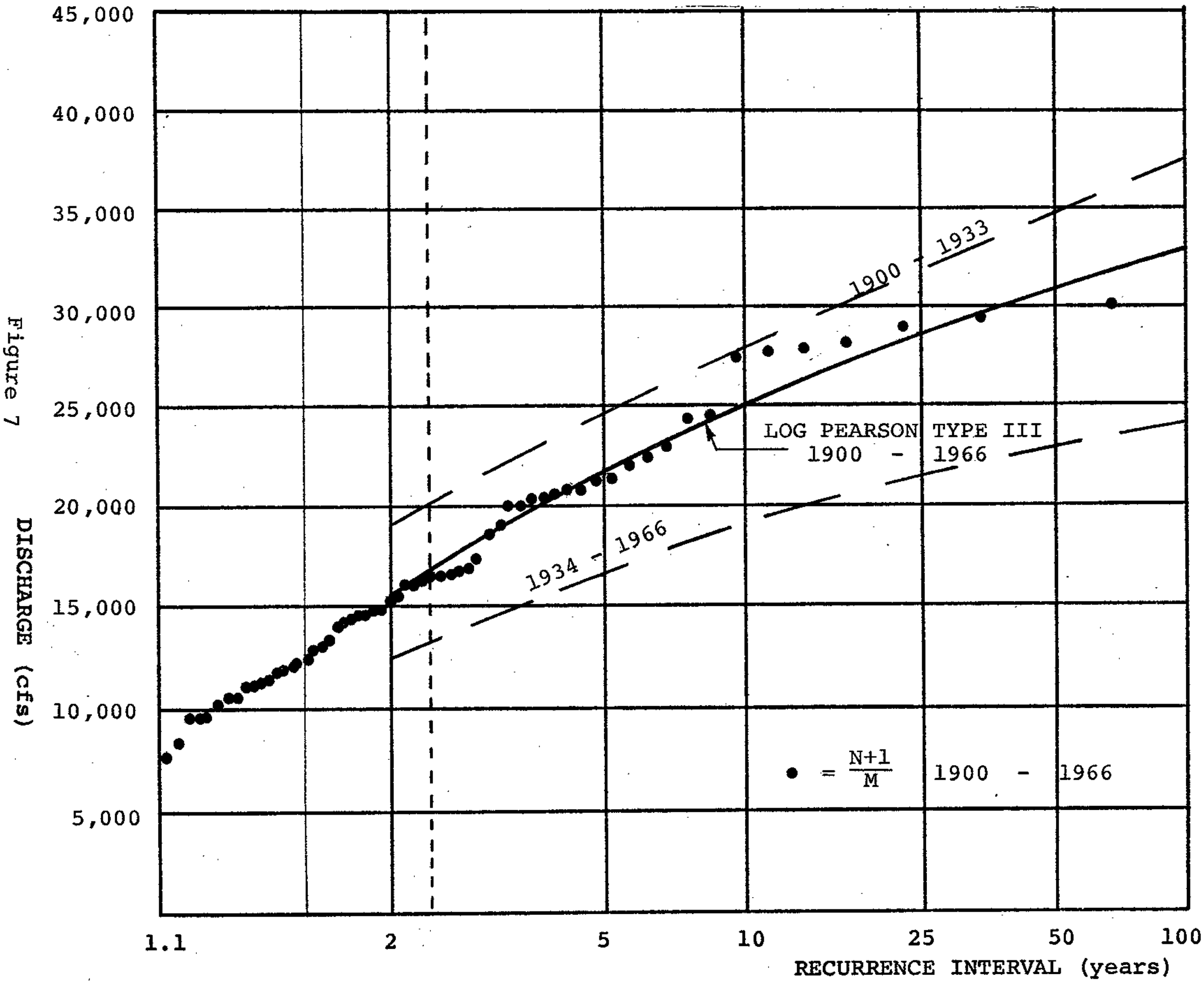
APPENDIX

Figure 7

RECURRENCE INTERVAL CURVE
GAGE 9-0725
COLORADO RIVER AT GLENWOOD



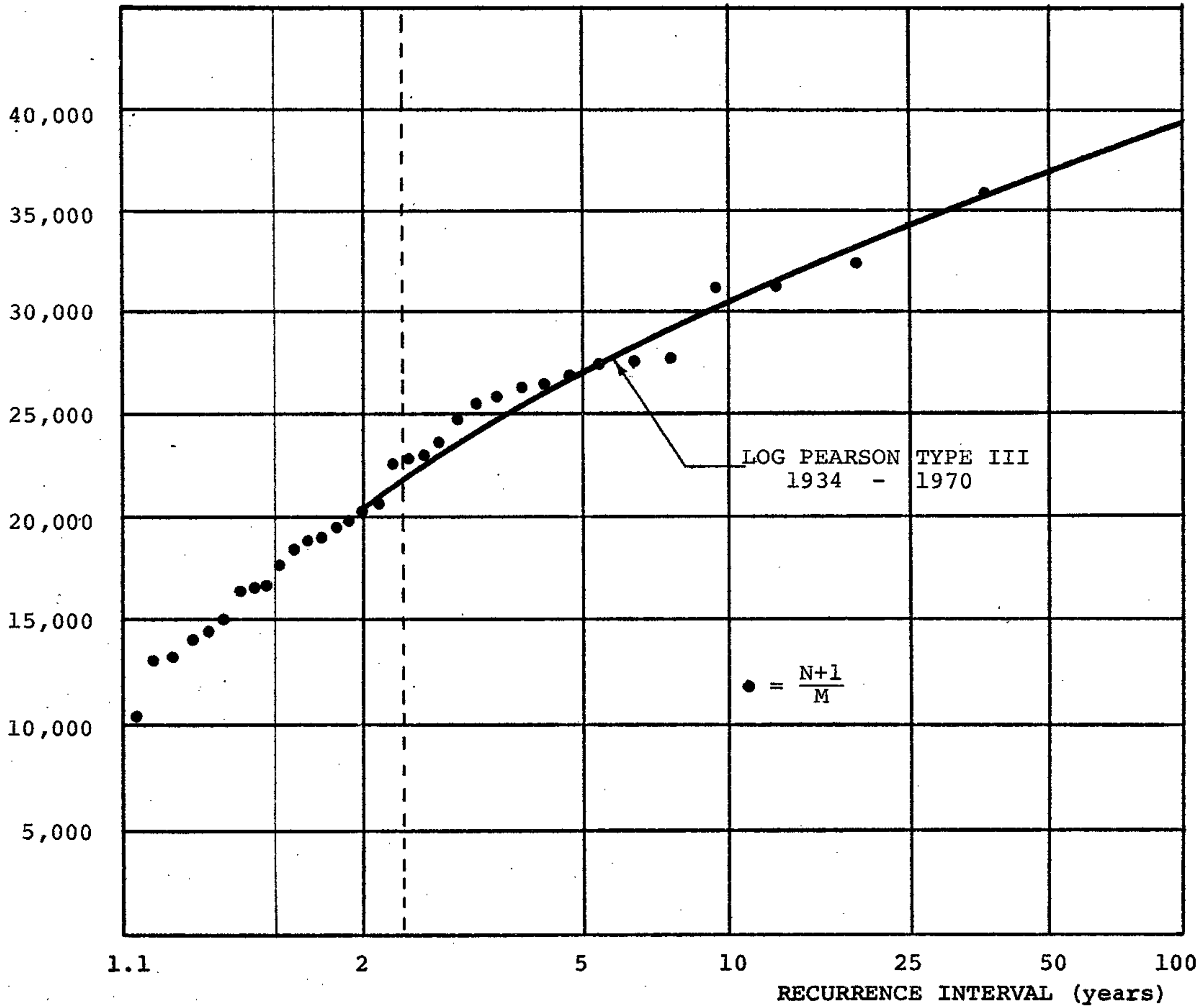


Figure 8

RECURRENCE INTERVAL CURVE
GAGE 9-0955
COLORADO RIVER NEAR CAMEO

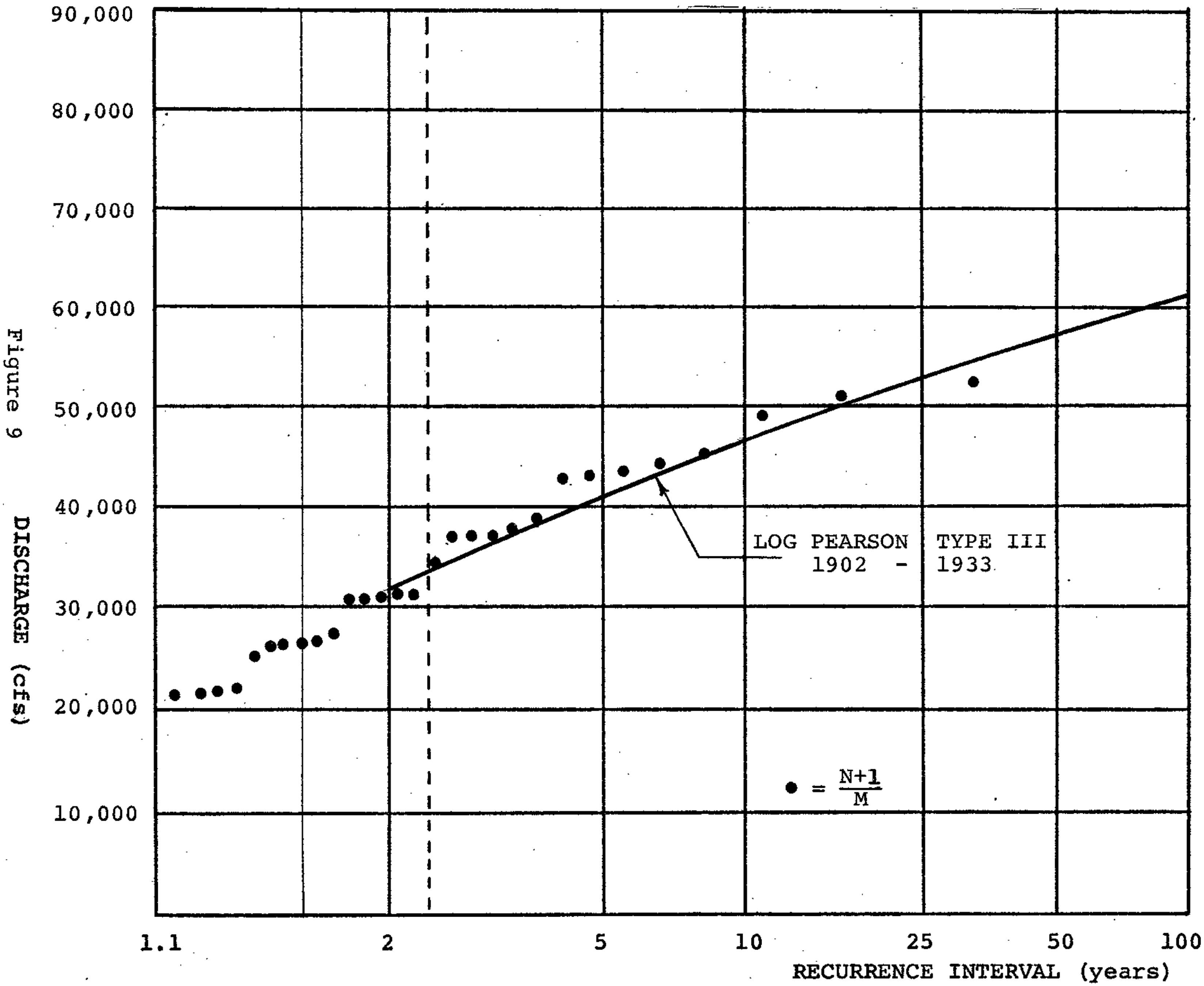


Figure 9

RECURRENCE INTERVAL CURVE
GAGE 9-1060
COLORADO RIVER NEAR PALISADE

RECURRENCE INTERVAL CURVE
GAGE 9-1530
COLORADO RIVER NEAR FRUITA

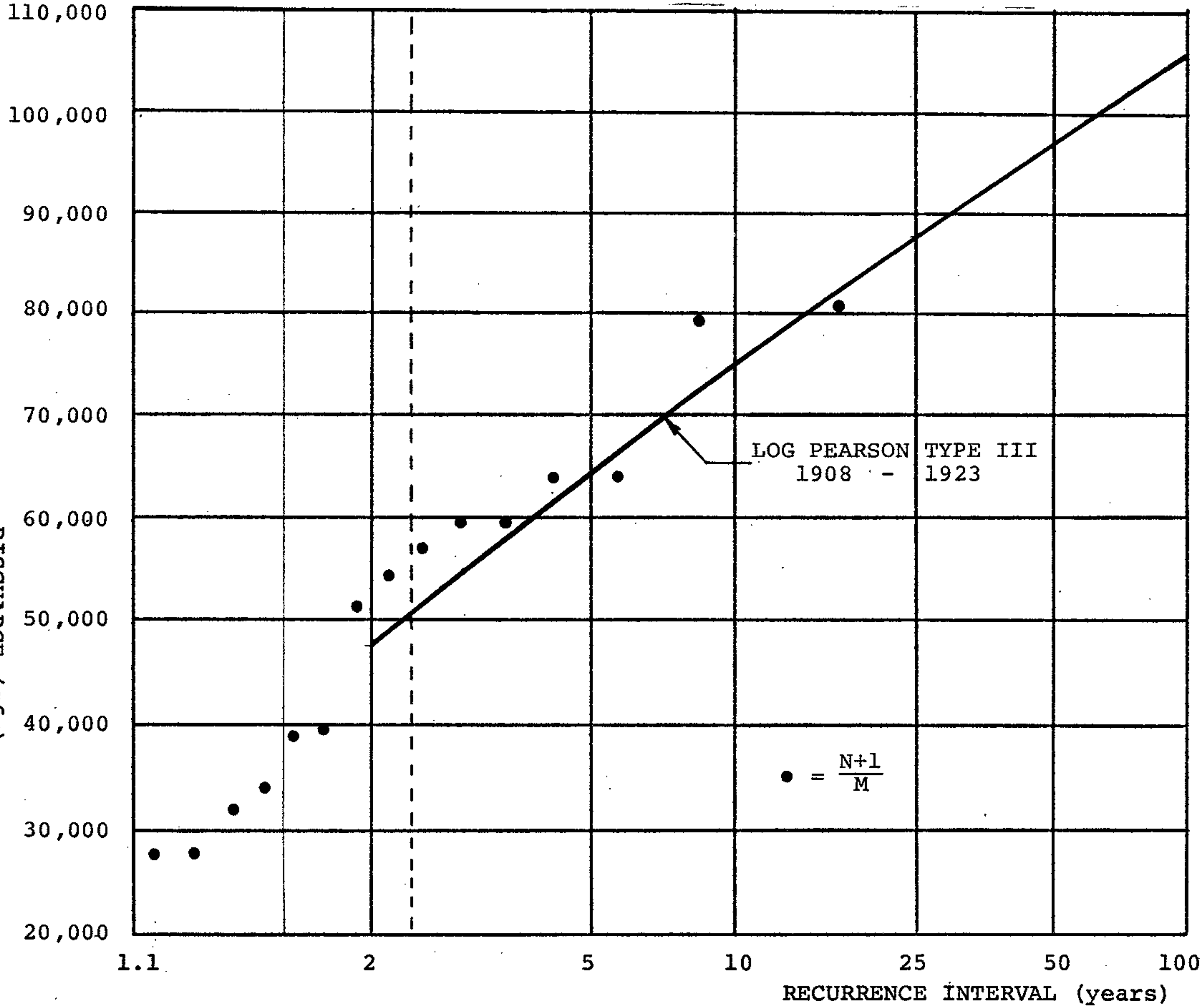


Figure 10

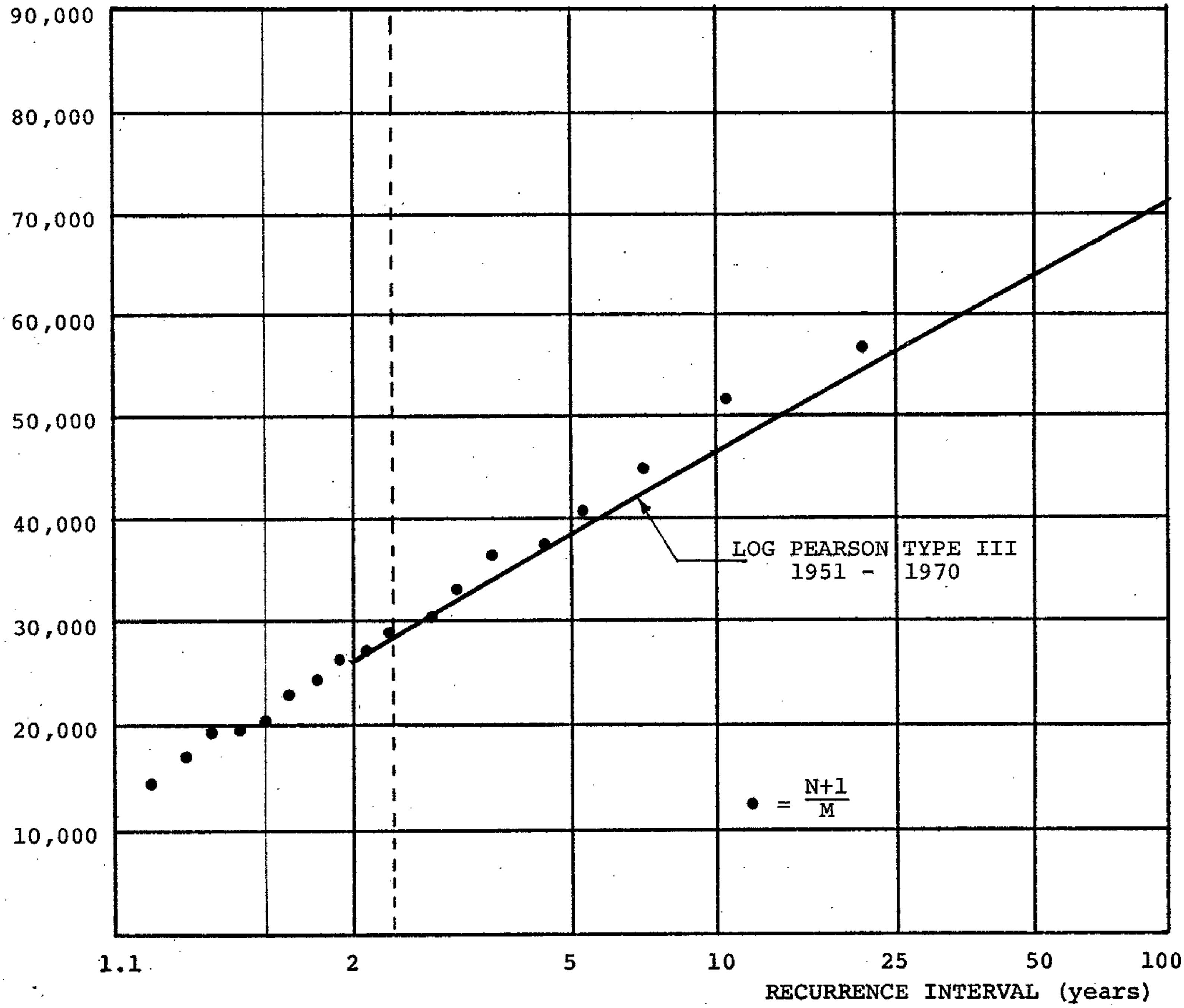


Figure 11

RECURRENCE INTERVAL CURVE
GAGE 9-1635
COLORADO RIVER AT STATE LINE

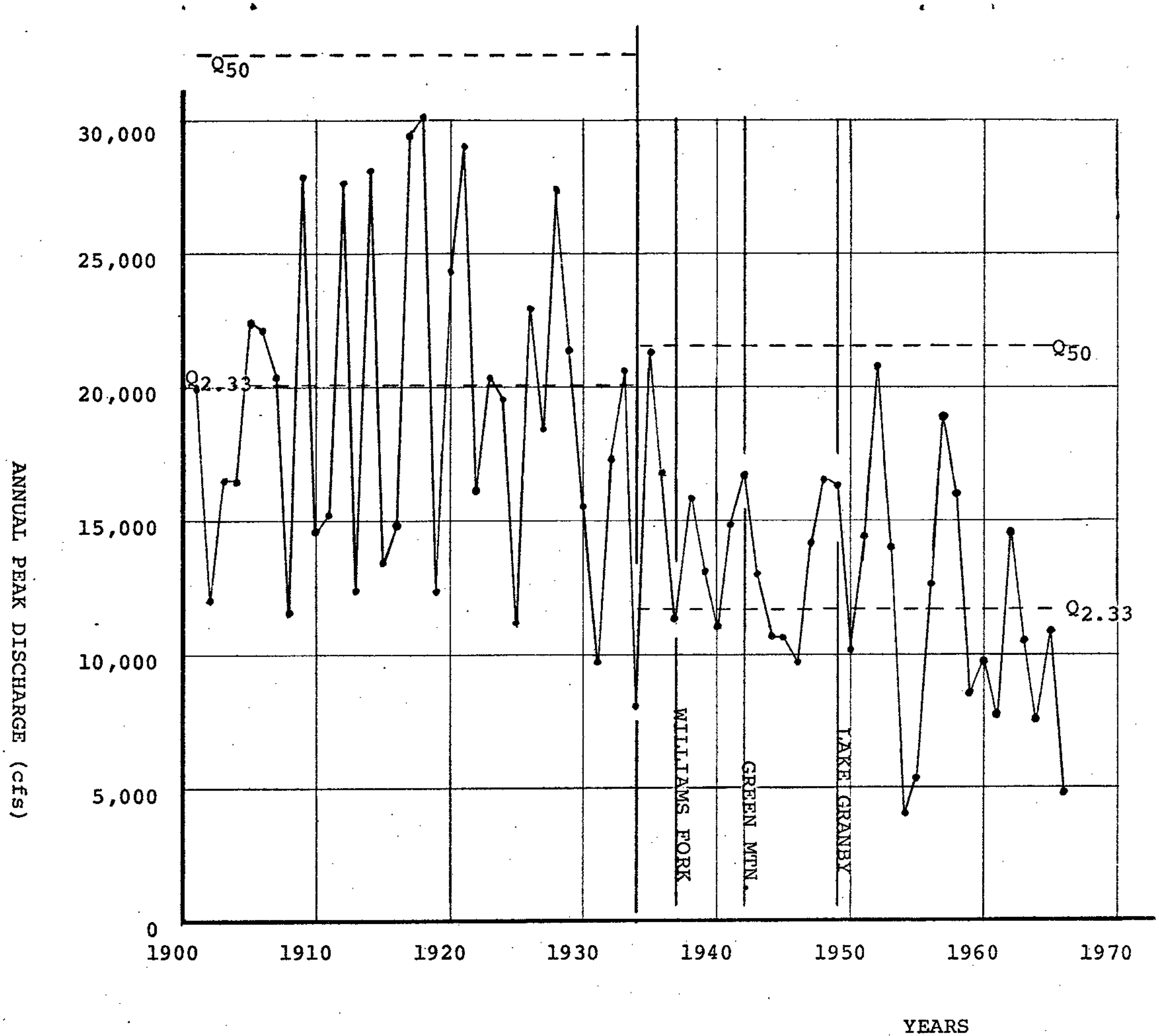


Figure 12

ANNUAL PEAK DISCHARGES GAGE 9-0725
AT GLENWOOD SPRINGS

ANNUAL PEAK DISCHARGES GAGE 9-0955
NEAR CAMEO

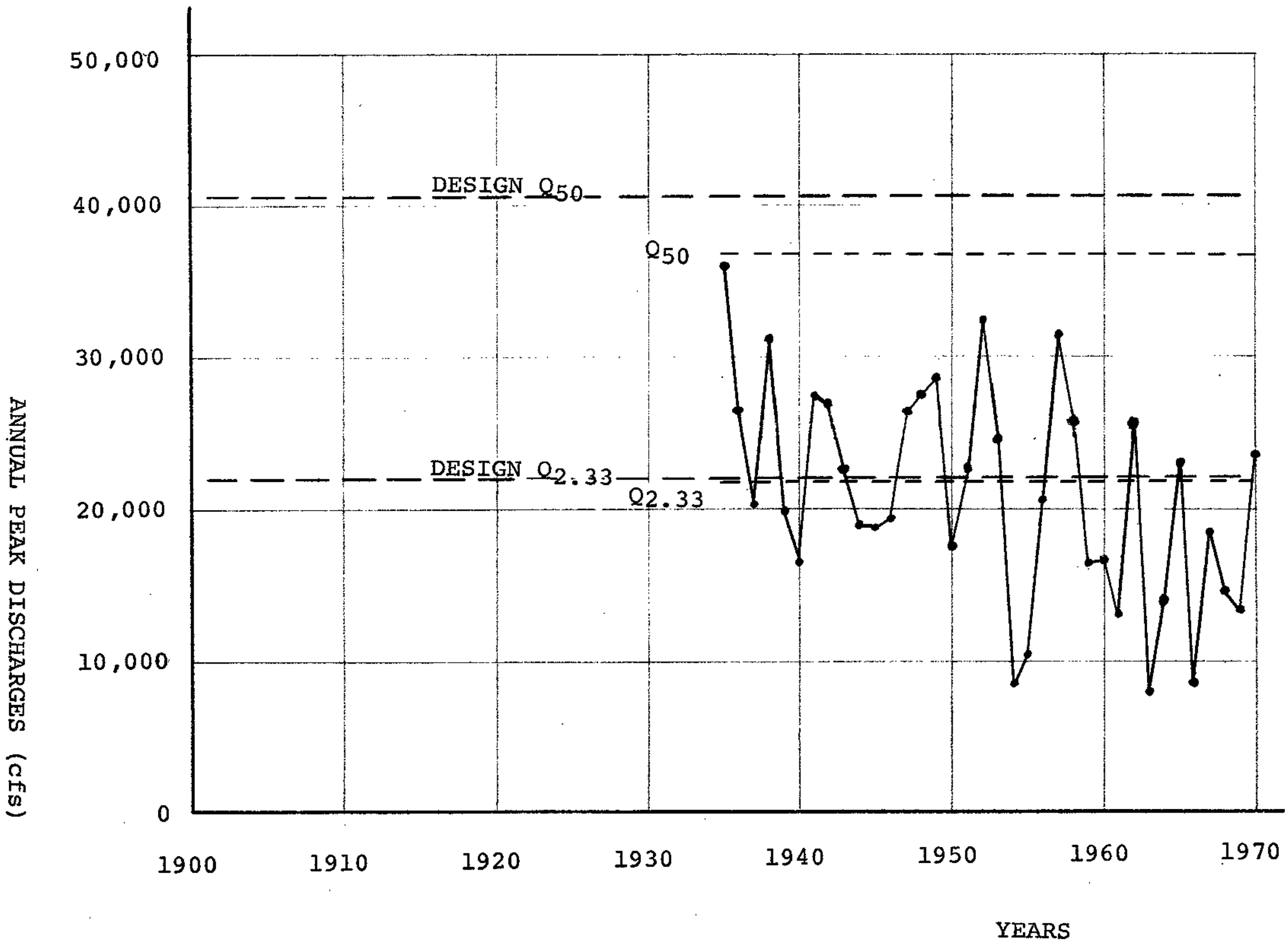


Figure 13

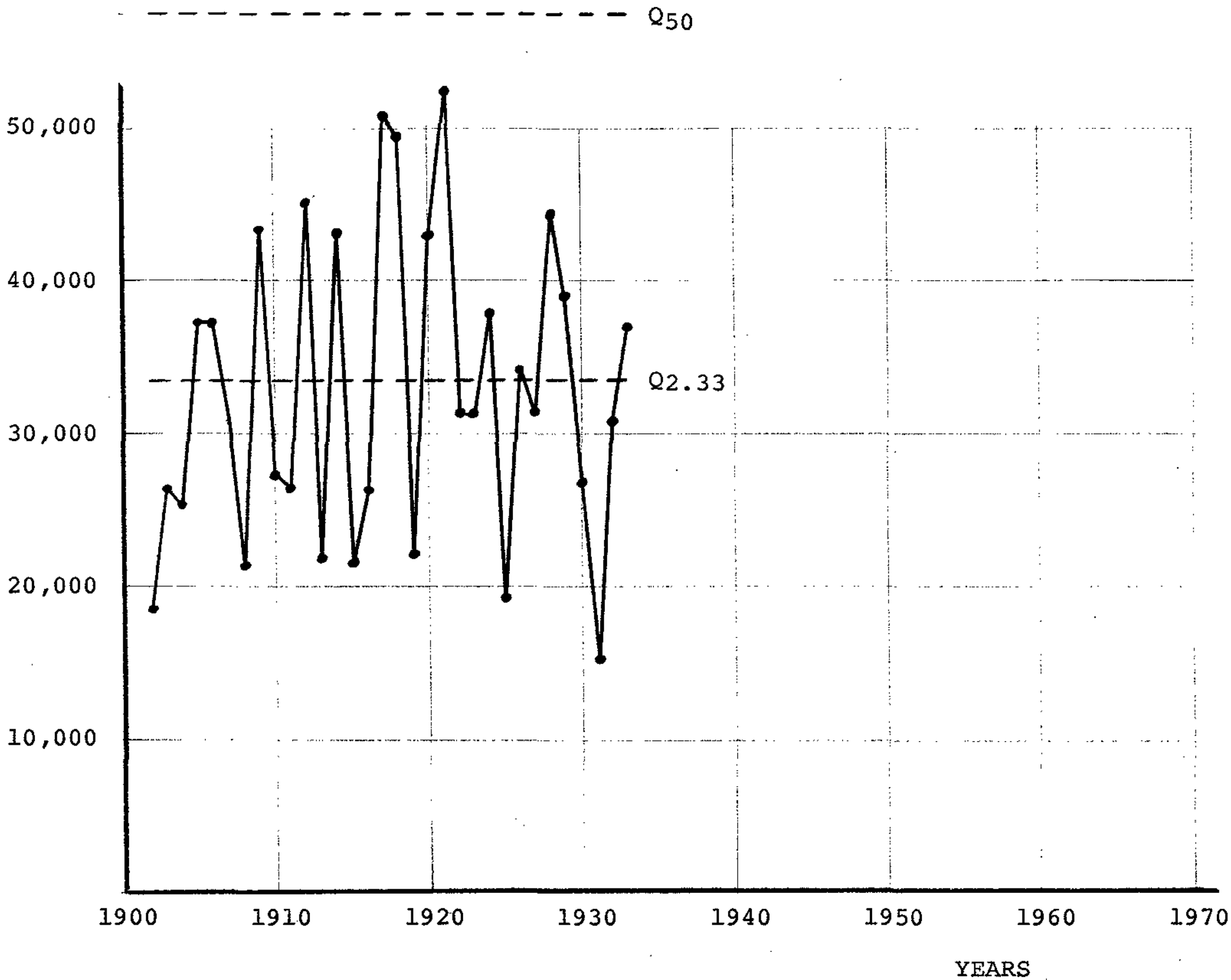


Figure 14

ANNUAL PEAK DISCHARGES GAGE 9-1060
NEAR PALISADE

ANNUAL PEAK DISCHARGES GAGE 9-1530

NEAR FRUITA

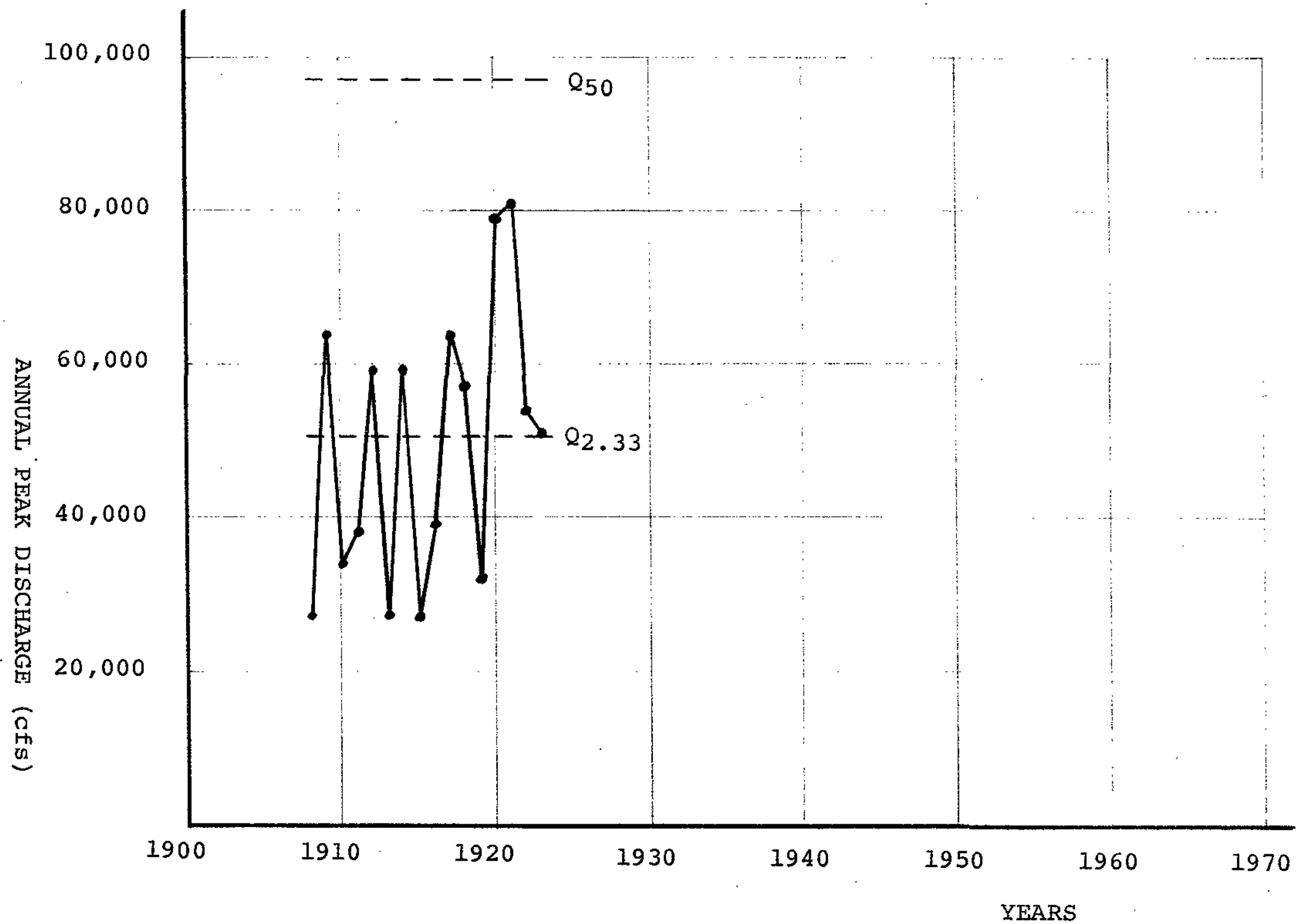


Figure 15

ANNUAL PEAK DISCHARGES GAGE 9-1635

COLORADO-UTAH STATE LINE

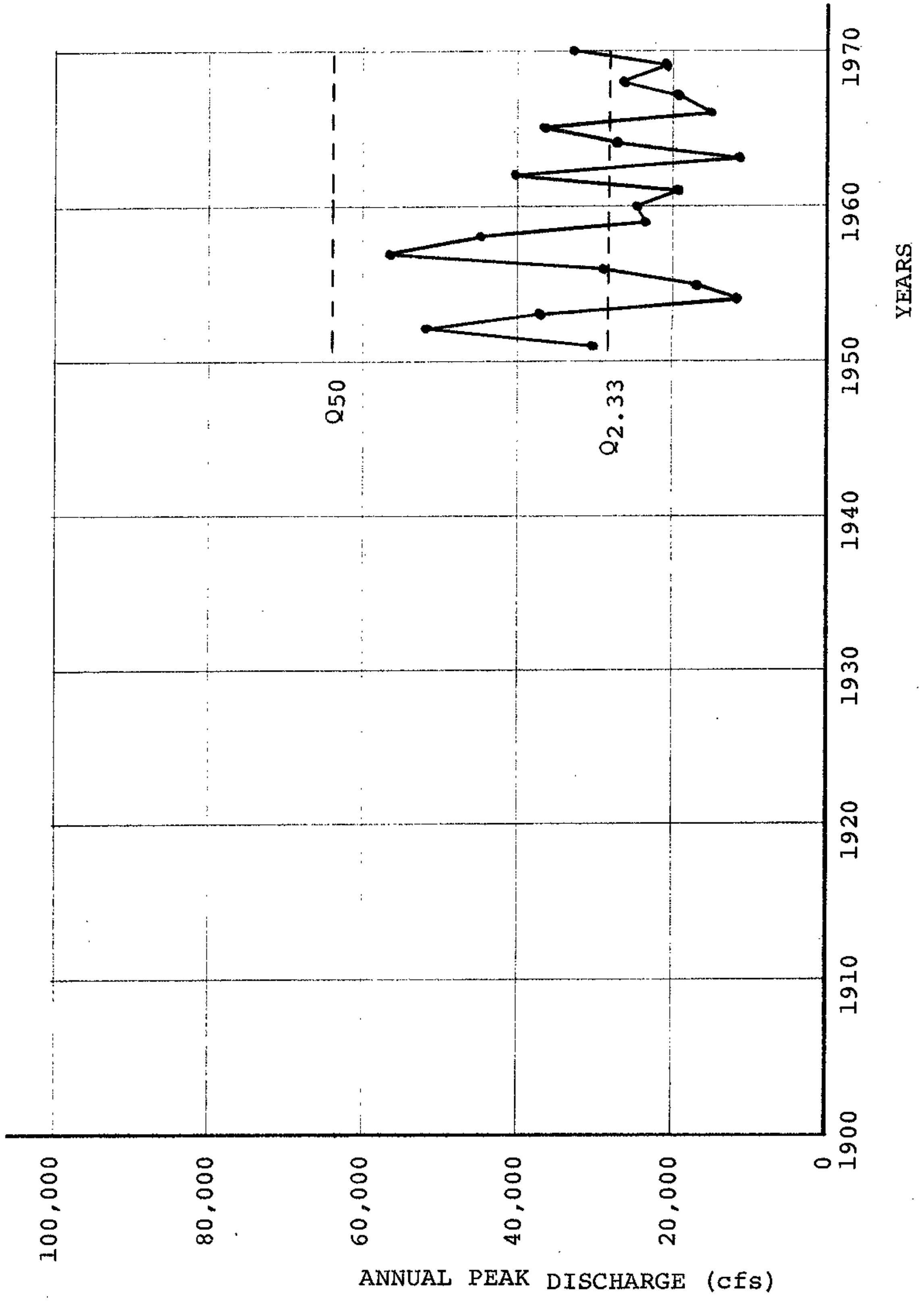


Figure 16

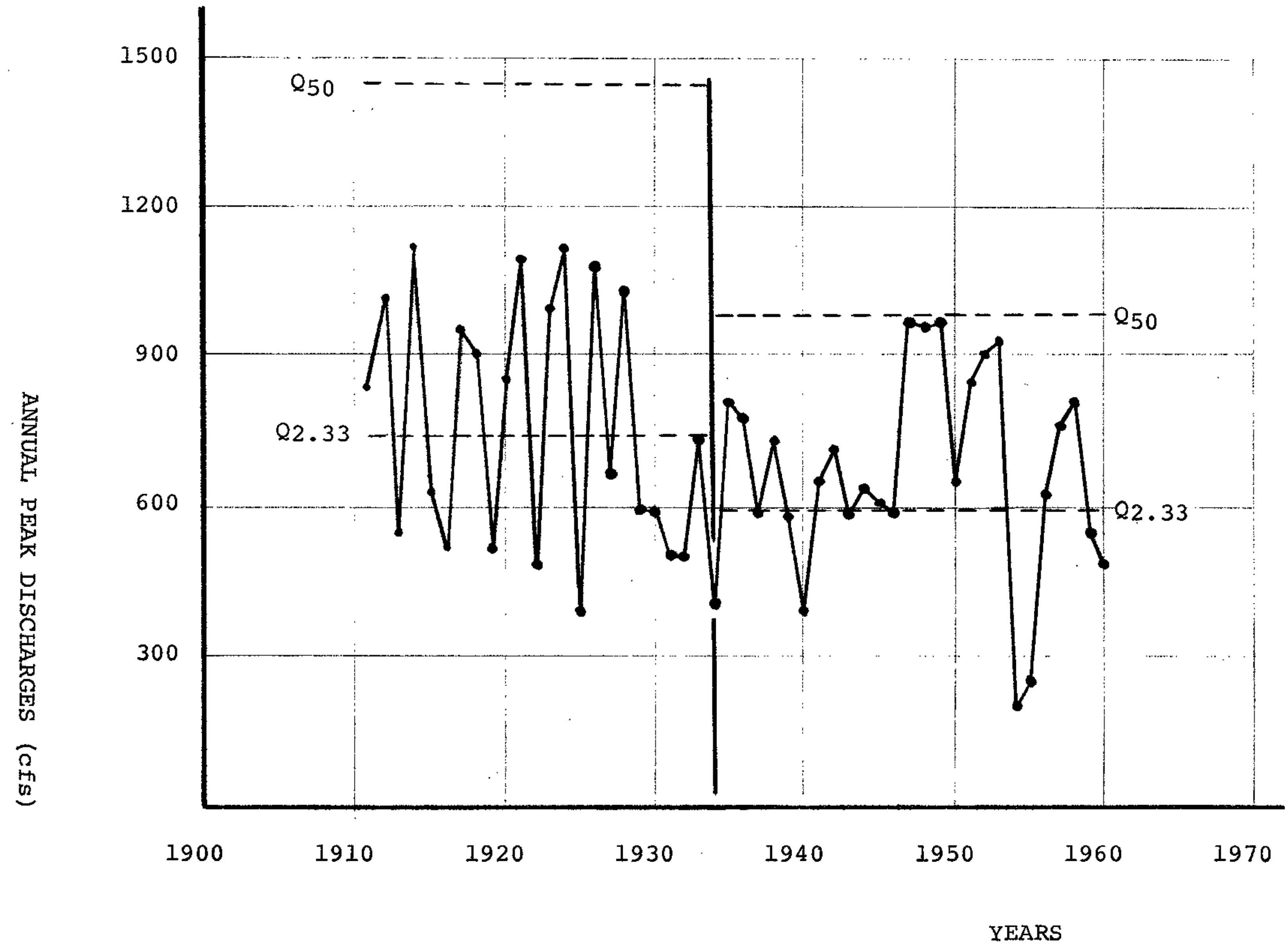


Figure 17

ANNUAL PEAK DISCHARGES GAGE 9-0470
AT DILLON

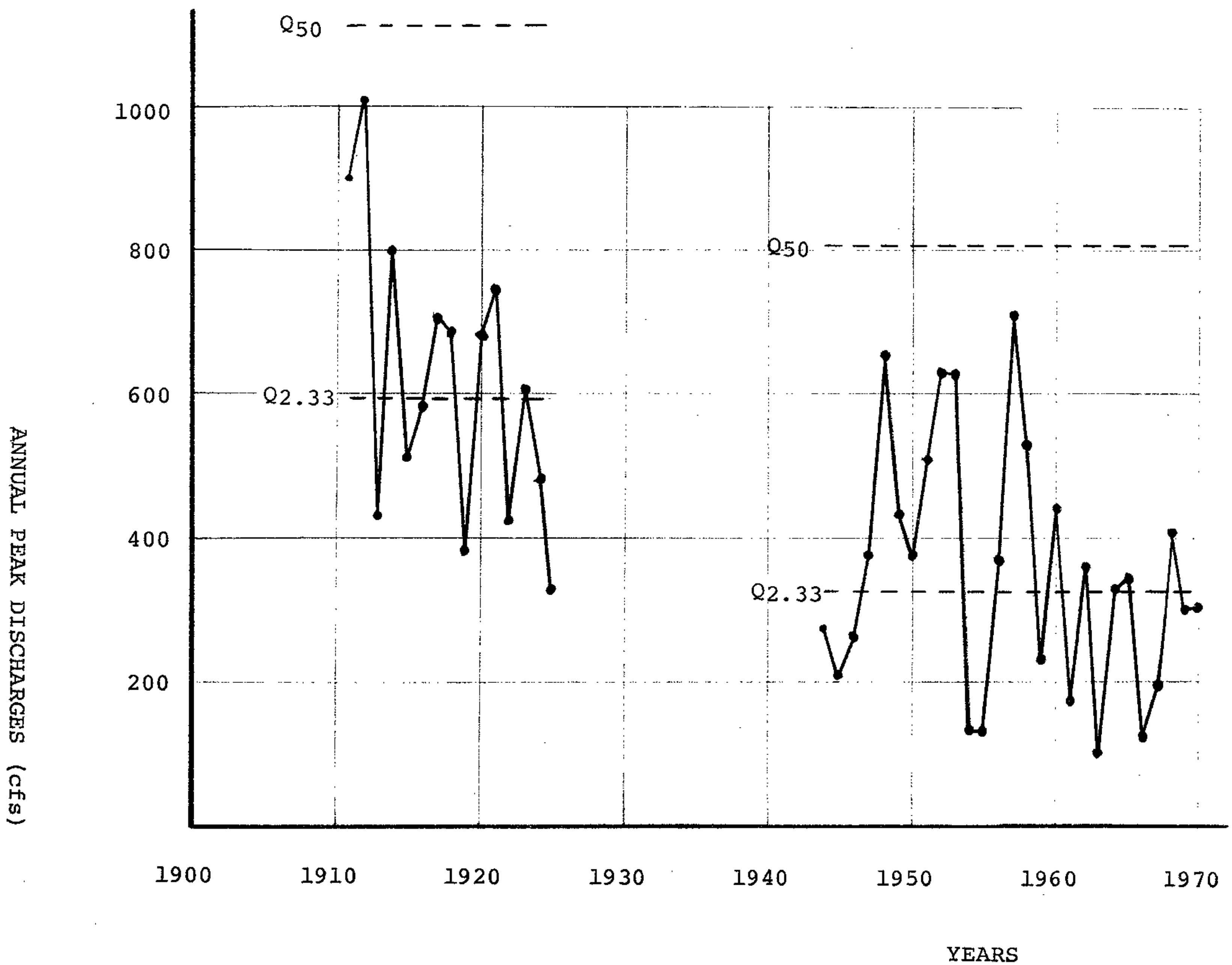


Figure 18

ANNUAL PEAK DISCHARGES GAGE 9-0630
AT RED CLIFF

ANNUAL PEAK DISCHARGES GAGE 9-0850
AT GLENWOOD SPRINGS

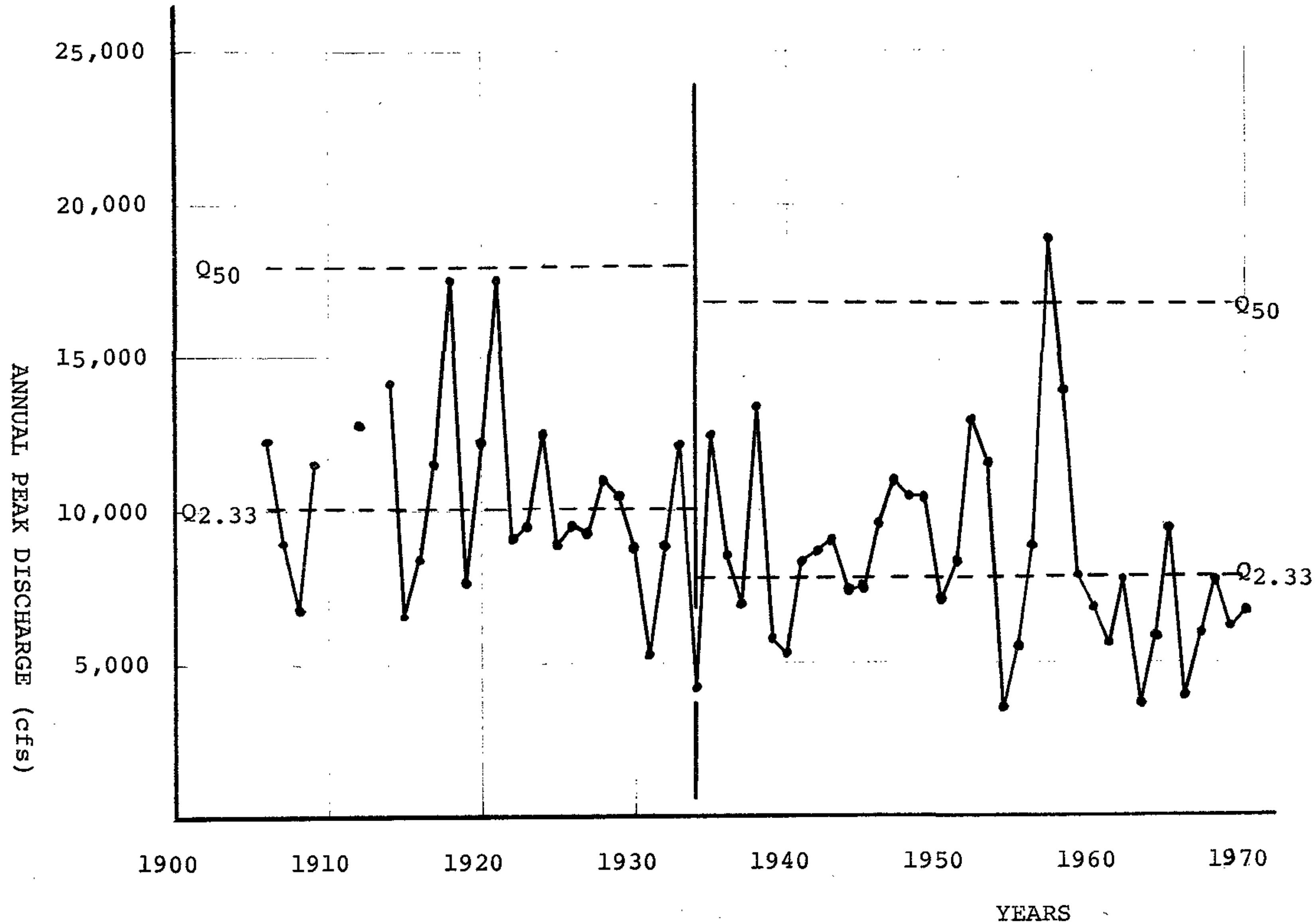


Figure 19