

**KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 1981-19**

Surface Water Supplies Available for
Cheyenne Bottoms Wildlife Area

by

Thomas J. McClain
P. Allen Macfarlane
Munir A. Butt

Disclaimer

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but is not intended to constitute final or formal publications.

Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

Surface Water Supplies Available
for
Cheyenne Bottoms Wildlife Area

Thomas J. McClain

P. Allen Macfarlane

Munir A. Butt

Kansas Geological Survey
Open-File Report 81-19

Contents

Purpose and Scope.....	1
Introduction.....	1
Setting.....	1
Previous Investigations.....	3
Hydrology.....	4
Arkansas River.....	4
Walnut Creek.....	8
Wet Walnut Watershed District.....	11
Blood Creek.....	12
Deception Creek.....	13
Canal Transmission Losses.....	16
Summary and Conclusions.....	16
References.....	21
Appendix A - Hydrologic Data for Selected Stream Gaging Stations....	23
Appendix B - Hydrologic Techniques.....	24

Figures

1. Kansas map showing location of Cheyenne Bottoms.
2. Diagram of Cheyenne Bottoms Wildlife Area.
3. U.S. Geological Survey gaging-station locations.
4. Annual streamflow in Arkansas River and 13-year moving average.
5. Streamflow loss on the Arkansas River between Syracuse and Dodge City.
6. Streamflow gain in the Arkansas River between Kinsley and Great Bend.
7. Streamflow gain from groundwater seepage.
8. Streamflow loss due to pumping wells.
9. Recurrence interval and probability of flows in the Arkansas River.
10. Recurrence interval and probability of low flows in the Arkansas River.
11. Annual streamflow in Walnut Creek with 7-year moving average.
12. Recurrence interval and probability of flows in Walnut Creek.
13. Mass curve of precipitation vs. baseflow in Walnut Creek.
14. Annual streamflow in Blood Creek and 7-year moving average.
15. Recurrence interval and probability of flows in Blood Creek.
16. Mean annual discharge vs. drainage area of selected streams in central Kansas.
17. Calculated recurrence interval of mean annual flow in Deception Creek.

Tables

1. Monthly streamflow as a percent of total annual streamflow - Arkansas River.
2. Recurrence intervals for the Arkansas River at Great Bend.
3. Monthly streamflow as a percent of annual streamflow - Walnut Creek.
4. Recurrence intervals for Walnut Creek at Albert.
5. Monthly streamflow as a percent of annual streamflow - Blood Creek.
6. Recurrence intervals for Blood Creek near Boyd.
7. Drainage area and mean annual discharge for streams in central Kansas.
8. Recurrence intervals for Deception Creek.
9. Summary of recurrence intervals for streams in the Cheyenne Bottoms vicinity.
10. Summary of monthly streamflow as a percent of annual streamflow.

Purpose and Scope

The purpose of this report is to review basic groundwater and surface water data relevant to the Cheyenne Bottoms Wildlife Area, and report to the Kansas Fish and Game Commission (KFGC) the status of present and future water supply for the Bottoms. The report is not meant to be an exhaustive discussion on the hydrology of the area, but a review and summary of generally available hydrologic data.

As a result of our discussions with KFGC staff, it was generally agreed that a study was needed to determine what hydrologic data were available and whether the amount and type were sufficient for further, more detailed studies of the hydrologic regime in the Bottoms area. Future studies could include further detailed work on the surface water-groundwater regimes in Walnut Creek and the Arkansas River and a simulation of the future operation of the Bottoms. If sufficient data are not available for the proposed further studies, the type and amount of needed data will be defined.

Introduction

The Cheyenne Bottoms Wildlife Area in central Kansas (Fig. 1) is an important fresh-water marsh that attracts many species of water fowl and wildlife. The marsh habitat comprises a series of pools separated by dikes (Fig. 2) and is maintained and managed through diversions of surface water from the Arkansas River and Walnut Creek and by natural inflow from Blood and Deception creeks. The major management tool in the marsh has been the manipulation of water levels in each of the pools. Water depth in the pools seldom exceeds 24 inches although five feet was the original design depth for pool #1. The greater depth is necessary at certain times of the year to keep out undesirable vegetation, but cannot be sustained for long periods with the

present design because wave action would destroy the existing dikes separating the pools. In addition, because of high evaporation rates, the lower water depths in the pools have necessitated more frequent inputs of water to maintain the current management depth. These problems have caused the Kansas Fish and Game Commission to consider redesigning the management pools to create pools with smaller surface area and greater depth capacity than the original pools. It will also allow them to develop a system that will more efficiently distribute water as it enters the management area. The smaller deeper pools will decrease the amount of water lost to evaporation and will make the transfer of water to all parts of the management area possible.

The feasibility of this new design depends largely upon the long-term availability of surface water to meet the management needs of the Bottoms area. In order to evaluate feasibility, the amount of water necessary to operate the facility as well as the amount available must be known. The former can be calculated from the design parameters, whereas the latter must be determined by reviewing streamflow records, and climatic and other pertinent data and projecting these into the future.

Setting

The Cheyenne Bottoms Wildlife Management Area is located in the Plains Border Section of the Great Plains Province in Barton County, Kansas (Fig. 1), in a structurally low area filled with sediment from Quaternary deposition (Bayne, 1977).

The climate of the area is subhumid continental and is marked by extremes of precipitation and temperature (Latta, 1950). The average annual precipitation at Great Bend is 25.70 inches. Potential evapotranspiration is

very much in excess of the average precipitation. The Kansas Water Atlas (KWRB, 1967) shows a mean annual lake evaporation rate of about 60 inches at Great Bend.

The Cheyenne Bottoms Wildlife Management Area covers approximately 20,000 acres and is divided into five pools separated by dikes (see Fig. 2). Unregulated flows from Blood and Deception creeks enter the area from the northwest and empty into pool #2. Regulated flows from the Arkansas River, Walnut Creek, and Dry Walnut Creek enter the Bottoms area from the southwest through an inlet canal that feeds into pools #1, #2, or #5. Water leaves the area through the outlet canal on the southeast side.

Previous Investigations

Previous geologic and hydrologic investigations in the region include a study of the geology and groundwater conditions in Barton and Stafford counties (Latta, 1950) and an investigation of the origin of Cheyenne Bottoms (Bayne, 1977). At present, an investigation of the groundwater resources in the Walnut Valley is being conducted by the Kansas Geological Survey.

Investigations in the Cheyenne Bottoms Wildlife Area have been conducted by The University of Kansas (1959) and Appel and others (1961). The former addressed overall management of the area, while the latter addressed control of surface water. The U.S. Corps of Engineers (1973) published a design memorandum for flood control in the Great Bend area for the Arkansas, Walnut, and Dry Walnut drainages.

Hydrology

Arkansas River

A stream-gaging station for the Arkansas River at Great Bend (07141300) is located south of town on the downstream side of the bridge on U.S. Highway 281 (Fig. 3). The water intake to the canal system that transports water to the Bottoms from the Arkansas River is located about seven miles upstream from this gage. Records of discharge compiled by the U.S. Geological Survey (USGS) at this station are available for the period September 1940 through September 1980 (see Appendix A). The recorded discharges are affected by water diversions for the Bottoms. The average annual flow volume at the gaging station for 39 complete years of record is 247,500 acre-feet/year. About 54 percent of this annual flow occurs in the five-month period, April through August (see Table 1). The maximum annual flow volume was 1,133,000 acre-feet in 1942 and the minimum annual flow volume was 16,720 acre-feet in 1977. The maximum monthly flow volume was 371,800 acre-feet and occurred in May 1942. The minimum monthly flow volume was 8 acre-feet and occurred in August 1946. A plot of annual flow versus time for the Arkansas River at Great Bend for the period 1941-1979 is shown on Figure 4. Table 1 summarizes monthly streamflow as a percent of the annual streamflow in the Arkansas River.

Table 1. Monthly Streamflow as a Percent of Total Annual Streamflow -
Arkansas River

	Month												Total	Total Years Record
	O	N	D	J	F	M	A	M	J	J	A	S		
Arkansas River	7	6	5	6	6	8	8	10	16	12	8	8	100	39

Because yearly variations make it difficult to see long-term trends in streamflow, a 13-year moving average of streamflow was computed. A moving average was used to "smooth" the annual fluctuations and get a "trend" to determine whether streamflow is increasing, decreasing, or remaining constant. This is shown on Figure 4 superimposed on the annual flow graph. The moving average shows a definite downward trend and ranges from a high of about 409,000 acre-feet to a low of about 124,000 acre-feet.

Upstream from the U.S. Geological Survey stream gage at Great Bend the drainage basin of the Arkansas River encompasses approximately 34,356 square miles (88,982 km²), of which an area of approximately 6,002 square miles (15,545 km²) probably does not contribute to streamflow (U.S. Geological Survey, 1979).

Eastward from the Kansas-Colorado border the drainage basin of the Arkansas River consists of sedimentary rocks and unconsolidated sediments ranging in age from Cretaceous to Recent. Many of these geologic units are considered aquifers and are known to be in hydraulic connection with the Arkansas River along its course. As a result, the river gains water from or loses water to the shallow groundwater system, depending on groundwater levels in adjacent aquifers and the stage of the stream. For example, examination of streamflow records on the Arkansas River between Syracuse, Kansas (station 0714000), and Dodge City (station 07139500) (Fig. 3 and Appendix A) shows a loss of streamflow ranging between 1,600 and 215,000 acre-feet per year (Fig. 5). The data for the graph were calculated by taking the annual streamflow (acre-feet) for each gage and subtracting the upstream value from the downstream value. If the flow was less at the downstream gage, there was a loss. Between the Kinsley gage (station 0714000) and the Great Bend gage

(station 07141300) the Arkansas River shows a gain of between 5600 and 558,000 acre-feet per year (Fig. 6). This gain is largely a result of inflow from the Pawnee River.

No exhaustive attempt was made to determine the cause of streamflow decline; however, several factors can be noted:

- 1) Arkansas River streamflow into Kansas from Colorado has generally declined during the period of record (see Appendix A). A 13-year moving average of annual flow in acre-feet per year at the Syracuse gage shows a high of 328,000 acre-feet per year from 1941-53, declining to 78,000 acre-feet per year from 1968-80.
- 2) A review of the National Oceanic and Atmospheric Administration (NOAA) precipitation records reveals the following variations in the long-term average precipitation for the following stations in central and western Kansas.

<u>Station</u>	Av. Precip. (in.)	Long-Term Av. Precip.
	<u>1951-80</u>	<u>(in.)</u>
a) Great Bend	25.42	24.97 (1923-80)
b) Dodge City WSO AP	20.63	21.11 (1900-80)
c) Garden City FAA AP/Exp Sta	19.05	18.83 (1890-1980)
d) Syracuse 2W	15.20	16.07 (1894-1980)

There does not seem to be a clear-cut increase or decrease in the general long-term averages for the four stations. Great Bend and Garden City have a slight increase (.45 and .22 inches, respectively) and Dodge city and Syracuse have declines (-.48 and -.87 inches respectively).

- 3) Irrigation use of both surface water and groundwater has increased along the Arkansas River both in Colorado and Kansas. Irrigation

removes water from the river and lowers the water levels in the aquifers across which the Arkansas River flows. Lowered water tables cause the river to lose water to the groundwater reservoir and diminish streamflow. For example, prior to irrigation development in the hypothetical case shown in Figure 7, the groundwater reservoir is contributing water to the stream. In Figure 8, however, the pumping well is withdrawing water from the aquifer, causing a change in head between the well and the nearby stream. This change in head causes water to flow from the stream to the well (see Appendix B.1).

- 4) Land-use practices, particularly in agriculture, have changed over the years. Koelliker and Zovne (1981) have shown that, for other areas of Kansas, groundwater withdrawals, watershed dams, and terracing and stubble mulching can reduce precipitation runoff to streams and decrease streamflow. This has to a great degree taken place in the Arkansas River basin. The long-term effect is to decrease streamflow in the Arkansas and is not easily reversible.

In order to estimate future streamflow, recurrence intervals and probabilities of given flow values were calculated (see Appendix B.2 for methods). The resulting recurrence intervals were plotted against annual streamflow on log probability paper (Fig. 9). A line plotted through the data can be used for extrapolation to predict the approximate values of floods with different return periods.

The annual flows listed in Table 2 were estimated from the straight line fit in Figure 9.

Table 2. Recurrence Intervals (T_r) for the Arkansas River at Great Bend

T_r	A.F./Year
Mean annual	190,000
5 years	350,000
10 years	560,000
20 years	900,000
50 years	1,650,000

The low-flow frequency curve for the Arkansas River at Great Bend is shown on Figure 10 (see also Appendix B.3). The concave upward shape is a common indication of groundwater contribution to streamflow (Carswell, 1981).

In undeveloped regions, streamflow varies from year to year in response to factors whose variation is random. We have assumed in our analysis that streamflow is a random variable (i.e., to each magnitude of streamflow, a probability may be assigned). Surface-water diversions, changing land-use practices, and groundwater irrigation are undoubtedly lowering the total volume of streamflow that moves past the Great Bend stream gage by introducing non-random variations. Therefore, the calculated values for maximum and low flow streamflow should be viewed with some skepticism if applied in assessing future water availability to Cheyenne Bottoms from the Arkansas River.

Walnut Creek

The Walnut Creek Valley is an elongated east-west-trending valley that lies west of Great Bend in central Kansas. The Creek begins in eastern Scott County and flows through Lane, Ness, and Rush counties before emptying into the Arkansas River near Great Bend in Barton County. The total watershed area is about 1,600 square miles.

Average annual precipitation ranges from about 20 inches in eastern Scott County to 25.70 inches at Great Bend.

A stream-gaging station for Walnut Creek at Albert (station 07141900), 14 miles northwest of Great Bend, is located on the downstream side of the highway bridge 0.2 mile north of Albert (Fig. 3). The average annual flow volume at that station for 21 complete years of record is 42,000 acre-feet. The maximum annual flow volume was 113,300 acre-feet in 1960. The minimum annual flow volume of 2,790 acre-feet occurred in 1977 (see Appendix A). Table 3 summarizes monthly streamflows as a percent of annual streamflow in Walnut Creek. A plot of annual flow volume for Walnut Creek at Albert for the period 1959-1979 is shown on Figure 11. Figure 11 also shows the 7-year moving average of streamflow at the Albert gage. A 7-year moving average was used because of the relatively short period of record. In this case, the trend of the moving average seems to show an increase during wet periods and a decrease during dry periods, which is what would be normally expected. There does not seem to be a distinct long-term downward or upward trend in the average streamflow. The flow probabilities and recurrence intervals for Walnut Creek were calculated using the previously discussed techniques. The flows listed below in Table 4 are interpolated from Figure 12. The acre-foot value for 50 years was not interpolated because of the lack of data for extremely high flows.

Table 3. Monthly Streamflow as a Percent of Total Streamflow - Walnut Creek

	Month												Total	Years Record
	O	N	D	J	F	M	A	M	J	J	A	S		
Walnut Creek	10	3	1	2	2	7	6	8	22	16	8	15	100	21

Table 4. Recurrence Intervals (T_r) for Walnut Creek at Albert

T_r	A.F./Year
Mean Annual	35,000
5 years	88,000
10 years	108,000
20 years	360,000
50 years	-----

Baseflow is that part of streamflow supplied by groundwater seepage from the aquifer. In the Walnut Creek case, baseflow is groundwater seepage into the stream from the sand, gravel, and clay of the alluvial aquifer. It is calculated by separating the runoff or overland flow from the groundwater part of the stream hydrograph (Busby and Armentrout, 1965). Baseflow fluctuates in relation to the amount of recharge the aquifer receives from various sources.

The amount of baseflow can be considered a relative measure of the groundwater in storage. Normally, the more groundwater in storage, the greater will be the baseflow. Conversely, baseflow declines as the amount of groundwater in storage declines.

Baseflow fluctuates with the amount of recharge from precipitation and should show a correlation even though there is a lag time between recharge and seepage to the stream. Figure 13 shows a double mass plot of accumulated baseflow and accumulated precipitation for the Walnut Valley from 1959 to 1979. The precipitation records for Bison and Ness City have been averaged to get a more representative precipitation for the basin. At various times (1964-72 and 1974 on) during the period 1959-1978 the curve flattens out, indicating a decline in baseflow, despite the fact that accumulated precipitation was increasing.

Baseflow can be affected by several factors such as land terracing, detention dams, evapotranspiration, and groundwater use for irrigation. In the Walnut Valley a combination of all these factors is probably causing baseflow declines.

Wet Walnut Watershed District

The Wet Walnut Watershed District was formed in 1965 for the primary purpose of flood control in the Walnut Creek Valley. In addition to flood control, land treatment, groundwater recharge, pollution control, and outdoor recreation are listed as objectives in the Modified General Plan of the Watershed District (U.S. Department of Agriculture, 1976). As of 1976 the District planned the following structural measures:

1) Flood-water retarding structures	44
2) Multiple-purpose structures	4
3) Detention dams	<u>51</u>
Total	99

The flood water and multipurpose structures will have a flood detention storage capacity of about 75,685 acre-feet. Total detention-dam storage will be about 24,452 acre-feet. Completion of the project was estimated at 15 years.

The watershed plan, along with future land treatment practices such as terracing, will probably decrease the average annual flow of Walnut Creek over the long term. Koelliker and Zovne (1981) estimate that a new pond (with no sediment) can deplete runoff yield by 60 percent in the South Fork Solomon River Valley where runoff is slightly more than one inch. This assumption is probably applicable to the Walnut Watershed as well since runoff varies from about .3 inch to about one inch. Since the Walnut Watershed structures are mainly on the tributaries rather than on the main stem, one structure in itself would have little effect on runoff. However, taken in aggregate, the 99 structures should have the effect of reducing a given flood crest (depending on precipitation amount and location) as well as reducing the average annual flow in the Creek.

Hydrology of Blood Creek

A stream gaging station for Blood Creek near Boyd (station 07142900) is located on the downstream side of the bridge on State Highway 4, 1.3 miles northwest of Boyd (Fig. 3) and 11.9 miles upstream from Cheyenne Bottoms. Blood Creek flows directly into pool #2 (Fig. 1). The average annual flow at that station for 17 complete years of record (1963 to 1979) is 5,355 acre-feet. The maximum discharge of 3,860 ft³/sec occurred June 29, 1967; the minimum is zero flow at times during most years (see Appendix A).

Figure 14 shows the plot of annual discharge in acre-feet. Superimposed on the annual discharge graph is a 7-year moving average of the streamflow

totals. Neither the plot of annual streamflow nor the moving average shows a distinctive trend for Blood Creek. The drainage area is so small (61 mi²) that runoff will vary closely with precipitation. Table 5 summarizes monthly streamflow as a percent of annual streamflow in Blood Creek.

Table 5. Monthly Streamflow as a Percent of Annual Streamflow - Blood Creek

	Month												Total	Years Record
	O	N	D	J	F	M	A	M	J	J	A	S		
Blood Creek	4	5	2	2	4	8	9	16	21	17	6	6	100	17

Figure 15 shows a graph of flow versus recurrence interval for Blood Creek. Table 6 lists recurrence intervals estimated from Figure 15. The acre-feet value for 50 years was not estimated due to lack of data for extremely high flows.

Table 6. Recurrence Intervals (T_r) for Blood Creek near Boyd

T_r	A.F./Year
Mean Annual	4,300
5-year	10,000
10-year	20,000
20-year	38,000
50-year	----

Hydrology of Deception Creek

The Deception Creek Drainage Basin is on the north side of Cheyenne Bottoms and flows unregulated into pool #2 (Fig. 1). The drainage area is approximately 44 square miles and is ungaged. Since it is ungaged, there are no flow records to determine high- and low-flow frequencies. Therefore, the volume and frequency of mean annual flow must be estimated. One way to do this is to use streamflow records from other comparable streams in the area. The streams used in this case are shown in Table 7.

Table 7. Drainage Area and Mean Annual Discharge for Streams in Central Kansas

	Drainage Area (mi ²)	Mean Annual Discharge (AF/Yr)
1. Pawnee River near Larned (07141200)	2,148	53,180
2. Guzzlers Gulch near Ness City (07140700)	58	1,540
3. Walnut Creek near Rush Center (07141780)	1,256	18,400
4. Walnut Creek at Albert (07141900)	1,410	42,380
5. Cow Creek near Claflin (07142860)	43	5,220
6. Blood Creek near Boyd (07142900)	61	5,360
7. Big Creek near Hays (06863500)	594	27,970
8. North Fork, Big Creek, near Victoria (06863900)	54	2,930

Drainage area and mean annual discharge were plotted on log-log paper and a curve showing the relationship between drainage area and mean annual flow was plotted (Fig. 16). Based on a drainage area of 44 square miles, Deception Creek should have a mean annual discharge of approximately 3.5 ft³/sec (2,500 AF/Yr).

As a check on the calculations by Hazen's method (Hazen, 1930), annual streamflow was calculated by estimating the runoff from the basin. The Kansas

Water Resources Board (1967) estimates annual runoff from the general area of Deception Creek to be approximately one inch. Since the basin area is 44 square miles (28,160 acres) and the average annual precipitation is about 26 inches, total precipitation falling on the basin would be:

$$\text{Total Precip.} = 26" \times 28160 \text{ A} = \frac{732160 \text{ acre-inches}}{12 \text{ inches}} = 61013 \text{ AF/yr}$$

$$\text{Runoff} = \frac{1 \text{ inch}}{26 \text{ inches}} = .038 \text{ or } 3.8\%$$

Therefore

$$.038 \times 61013 \text{ AF/yr} = 2318 \text{ AF/yr.}$$

2318 AF/yr compares well with 2500 AF/yr from the graph.

Since Deception Creek has no historical gaging record it is not possible to determine flood probabilities and recurrence intervals in the same manner as the Arkansas River, Walnut Creek, and Blood Creek. The flood probabilities and recurrence intervals must be estimated. A commonly accepted method is that of Hazen (1930). Briefly, Hazen calculates hydrologic characteristics of nearby, similarly gaged basins and applies those characteristics to the ungaged basins. The procedure is described in more detail in Appendix B.4 of this report. The results of the calculations are shown on Figure 17 and summarized in Table 8.

Table 8. Recurrence Intervals (T_r) for Deception Creek

T_r	A.F./Year
Mean Annual	2,500
5 years	4,200
10 years	5,300
20 years	6,200
50 years	-----

Canal Transmission Losses

Water from the Arkansas River and Walnut Creek is transported to Cheyenne Bottoms by way of an unlined canal. Total distance from the Arkansas River Diversion Dam to the discharge into Cheyenne Bottoms is 22.7 miles. The distance from the Walnut Creek Diversion Dam to the Cheyenne Bottoms discharge is 6.2 miles. Considerable water loss to seepage and evapotranspiration takes place. Much of the seepage can be assumed to recharge the local water table. While this recharge undoubtedly provides a service to groundwater users in the area, cutting the seepage losses would provide considerably more water to the Cheyenne Bottoms Wildlife area.

Summary and Conclusions

The purpose of this report is to document presently available data and advise the Kansas Fish and Game Commission on whether sufficient data are available for a detailed analysis of the water-supply availability for the Cheyenne Bottoms Wildlife Area.

The Cheyenne Bottoms Wildlife area is located in Barton County, Kansas near Great Bend. It is a natural marsh that depends on surface-water inflow to maintain habitat for water fowl. Two streams, Blood Creek and Deception

Creek, flow directly into the marsh from the northwest while water from Walnut Creek and the Arkansas River is conveyed to the Bottoms by means of an unlined canal about 23 miles long. Lake evaporation in the area is about 60 inches per year, which causes a rapid decline in any water that flows in from the streams feeding the Bottoms.

The Arkansas River gage at Great Bend has an average annual flow of 247,500 acre-feet, 54% of which comes between April and August. The trend of the long-term average flow at this gage is downward, ranging from a high of 409,000 acre-feet/year to a low of 124,000 acre-feet/year. However, in the reach between Kinsley and Great Bend, the river generally shows a gain in flow. The flow recurrence intervals for the Arkansas at Great Bend are summarized in Table 9 below.

Walnut Creek has an average annual flow of 42,000 acre-feet/year; 38% comes in June and July and 25% in September and October. The period of record for Walnut Creek is only 21 years, so long-term trends are not as obvious as on the Arkansas River. What record there is shows a fluctuation with precipitation and not a distinct upward or downward direction. Recurrence intervals for Walnut Creek are summarized in Table 9 below.

Table 9. Summary of Recurrence Intervals for Streams in the Cheyenne Bottoms Vicinity

	Streamflow Summaries (Acre-Feet)			
	Arkansas R	Walnut C	Blood C	Deception C
Mean Annual Return	190,000	35,000	4,300	2,500*
High-Flow (5 yrs) Return	350,000	88,000	10,000	4,200
High-Flow (10 yrs) Return	560,000	180,000	20,000	5,300
High-Flow (20 yrs) Return	900,000	360,000	38,000	6,200
High-Flow (50 yrs) Return	1,650,000	---	---	---
Low-Flow Mean Annual Return	6,300	---	---	---
Low-Flow (5 yrs) Return	2,800	---	---	---
Low-Flow (10 yrs) Return	2,000	---	---	---
Low-Flow (20 yrs) Return	300	---	---	---
Low-Flow (50 yrs) Return	---	---	---	---

*Estimated average annual value

Baseflow has been calculated for Walnut Creek and compared with precipitation. At various times during the period of record the amount of baseflow declined while precipitation continued to increase. The decline in baseflow was probably caused by such factors as land terracing, detention dams, evapotranspiration, and groundwater use for irrigation. The Wet Walnut Watershed District is constructing 99 water retention structures in the Walnut Valley. The structures should have the effect of reducing a given flood crest as well as reducing the average annual flow in the Creek.

Blood Creek flows directly into Cheyenne Bottoms from the northwest. The average annual flow at the gaging station near Boyd is 5,355 acre-feet per year. This station has 17 years of record and the long-term (7 years) average of annual discharge shows a trend that fluctuates closely with precipitation; 63% of the flow comes during April through July. Recurrence intervals for Blood Creek are summarized in Table 9.

Deception Creek also flows directly into Cheyenne Bottoms from the northwest. Its drainage area is 44 square miles and it is ungaged. The average annual flow volume was estimated by Hazen's method and found to be approximately 2,500 acre-feet/year. A second method of estimation using estimated runoff from the soil types in the area gives an annual average of about 2,300 acre-feet. Recurrence intervals are summarized in Table 9. Monthly streamflows are a good indicator of what times of the year water will be available to flood the pools at the Bottoms (see Table 10).

Table 10. Summary of Monthly Streamflow as a Percent of Annual Streamflow

	Month												Total	Years Record
	O	N	D	J	F	M	A	M	J	J	A	S		
Arkansas River	7	6	5	6	6	8	8	10	16	12	8	8	100	39
Walnut Creek	10	3	1	2	2	7	6	8	22	16	8	15	100	21
Blood Creek	4	5	2	2	4	8	9	16	21	17	6	6	100	17

The transmission canal that moves water from the Arkansas River and Walnut Creek loses considerable water to seepage to the water table. Finding a means of reducing this loss would provide more water to the Bottoms.

In summary, the long-term surface-water supply for Cheyenne Bottoms should continue to decline, basically because streamflow is being lost to groundwater irrigation, small dams, and various agricultural practices that reduce runoff. This study is not detailed enough to provide specific values for the amount of water that could be expected to be available for operation of the Bottoms. Basic data such as groundwater levels, streamflow and precipitation are available; other information, more difficult to measure,

such as the effect of the watershed structures in the Walnut Valley, runoff depletion by agricultural practices in Blood and Deception creeks, and streamflow depletion in the Arkansas by irrigation, is not available. Listed below are further studies that would better define the hydrologic regime of the Bottoms and make more accurate estimates of future water supplies.

1) Agricultural practices. Blood Creek, Deception Creek, and Walnut Creek basins are small enough to allow study of agricultural practices, including a review of terracing, pond construction, and other methods to reduce runoff. Blood Creek and Deception Creek basins would be particularly important since they flow directly into the Bottoms. The study could be facilitated by using remote sensing methods to decrease survey time. The size and complexity of the Arkansas basin would preclude a detailed investigation; however, a limited survey could be done.

2) Groundwater use for irrigation. Groundwater use for irrigation seems to be contributing to streamflow decline; however, there are presently no definitive studies available in the Bottoms area. A study of groundwater use and streamflow is now under way in the Walnut Creek Valley. The results should provide estimates of stream depletion from groundwater use. Again, the Arkansas Basin is too large and complex for a comprehensive study, but the important reach between Kinsley and Great Bend could be studied for groundwater-streamflow interaction. Some of the data needed for such a study would be groundwater pumpage, groundwater contribution to baseflow, aquifer properties, stream-bed leakance, and streamflow records.

3) Transmission canal. A detailed study of how to decrease leakage from this canal needs to be done, including an analysis of the cost of canal

treatment versus water supplied to the Bottoms. Among the data needed for the study would be soil (bed) samples to quantify where water losses are the greatest.

4) Artificial recharge. Since there are times when excess water is available from Walnut Creek and the Arkansas River, a study needs to be done to determine if it is possible to store some of the excess water by recharging a local aquifer. The stored water could then be pumped out when needed to augment the supply in the Bottoms area. Among the data needed would be the properties of the proposed aquifer to be recharged and a source of water to recharge.

5) Cheyenne Bottoms Wildlife Area. When enough hydrologic information is available from 1) through 4) above to make acceptable estimates of inflow to the Bottoms, a model simulation of the operation of the Bottoms could then be done. Flow volumes and recurrence intervals could be taken into account.

References

- Appel, D.W., Jones, J.O., and Yu, Yun-Sheng, 1961, A study of the control of water at Cheyenne Bottoms Water Fowl Refuge: Progress Report, School of Engineering and Architecture, The University of Kansas, Lawrence.
- Bayne, Charles K., 1977, Geology and structure of Cheyenne Bottoms, Barton County, Kansas: Kansas Geological Survey Bulletin 211, part 2, 12 p. (including geologic map).
- Busby, M.W., and Armentrout, G.W., 1965, Kansas streamflow characteristics, Part 6A: baseflow data: Kansas Water Resources Board Technical Report 6A, 207 p.
- Carswell, William J., Jr., 1981, Selected Hydrologic Relationships for Soldier Creek, Northeastern Kansas: U.S. Geological Survey Water Resources Investigations 81-8.
- Hazen, A., 1930, Flood Flows: John Wiley and Sons, Inc., New York.

Kansas Water Resources Board, 1967, Kansas Water Atlas: Kansas Planning for Development "701" Project Number Kansas, p. 43, Report No. 16-a.

Koelliker, J.K., and Zovne, J.J., 1981, Agriculturally induced water yield changes: Water Forum '81, San Francisco, California, August 1981.

Latta, Bruce F., 1950, Geology and ground water resources of Barton and Stafford counties, Kansas: Kansas Geological Survey Bulletin 88, 228 p. (including geologic map).

National Oceanic and Atmospheric Administration, Environmental Data and Information Service, Climatological Data for Kansas.

U.S. Corps of Engineers (Albuquerque District), 1973, Great Bend local protection project, Great Bend, Kansas and vicinity: Design memorandum no. 1, serial no. 23.

U.S. Dept. of Agriculture, Soil Conservation Service and Kansas Soil Conservation Commission, 1976, Modified general plan for Wet Walnut Creek Watershed: Wet Walnut Creek Watershed Joint District No. 58, 38 p. (including map and illustrations).

U.S. Geological Survey, 1979, Water Resources Data for Kansas: U.S. Geological Survey Water Data Report KS-79-1.

University of Kansas, 1959, Cheyenne Bottoms: Use and management as a waterfowl refuge and public shooting area: The University of Kansas, Lawrence, Kansas (A report requested by the Kansas Forestry, Fish and Game Commission).

Appendix A
Hydrologic Data For Selected Stream Gaging Stations

Flow in Acre-Feet/Water Year

Year	07138000 Arkansas R at Syracuse	07139500 Arkansas R at Dodge City	07140000 Arkansas R nr Kinsley	07141300 Arkansas R at Great Bend	07141900 Walnut Cr at Albert	07142900 Blood Cr. nr. Boyd
1941	234,500			146,100		
1942	1,142,200			1,133,300		
1943	238,000			270,300		
1944	299,300			405,600		
1945	155,400	79,410	100,900	157,700		
1946	129,000	49,610	60,650	84,470		
1947	407,700	361,500	368,800	511,500		
1948	184,200	97,690	123,900	328,900		
1949	282,600	251,500	281,300	431,400		
1950	194,900	175,100	207,800	465,200		
1951	330,200	376,100	440,300	998,000		
1952	113,500	120,500	153,500	265,500		
1953	92,690	44,110	52,470	117,900		
1954	92,780	45,120	49,630	74,250		
1955	133,100	78,130	111,400	171,000		
1956	96,360	40,720	48,990	63,940		
1957	161,700	83,320	90,390	255,500		
1958	168,100	157,400	174,200	493,200		
1959	184,400	97,670	110,700	20,250	94,360	
1960	136,700	135,100	163,600	286,500	113,300	
1961	93,540	46,010	64,880	137,300	90,540	
1962	131,800	85,890	113,800	234,200	61,370	
1963	61,070	38,280	58,840	91,030	36,760	1,210
1964	77,390	42,740	44,540	35,690	9,480	3,280
1965	717,300	502,600	424,100	456,800	18,170	3,070
1966	280,200	202,500	235,700	249,100	10,790	1,410
1967	196,200	98,690	105,000	146,600	96,660	14,190
1968	113,100	66,800	77,280	61,100	14,900	1,270
1969	124,000	78,630	94,680	149,800	32,870	8,070
1970	145,200	100,100	106,700	137,700	27,440	4,040
1971	115,700	61,670	63,950	77,400	18,730	5,120
1972	113,600	52,690	82,160	166,200	25,350	7,100
1973	115,700	91,280	180,000	416,400	97,570	11,900
1974	67,010	32,090	83,180	225,600	51,200	17,430
1975	34,790	8,960	35,190	44,260	19,340	2,870
1976	18,640	5,140	20,080	35,520	14,070	1,290
1977	21,300	287	11,090	16,720	2,790	4,800
1978	32,870	1,250	46,180	54,310	12,330	1,910
1979	10,130	1,370	14,710	82,810	41,110	2,080
1980	101,600		14,450			

Appendix B

Hydrologic Techniques

1) The amount of flow to the well from a stream can be calculated by Darcy's law ($Q = -KA \frac{\Delta h}{\Delta x}$) where Q = amount of flow; K = permeability of aquifer; A = cross-sectional area of aquifer through which flow is taking place; Δh = change in head between stream and well; and Δx = distance between well and stream.

2) In order to estimate future streamflow, recurrence intervals (see further below) and probabilities of occurrence were calculated. The total annual streamflow in acre-feet for the period of record was ranked from highest to lowest. The probability of streamflow (X) equal to or greater than any of the ranked streamflows (x_n) was calculated using the plotting equation given below:

$$P(X > x_n) = \frac{n}{m+1}$$

where $P(X > x_n)$ = probability of occurrence of streamflow of value X greater than or equal to x_n ; n = rank number of streamflow with magnitude x_n ; and m = number of data points. The resulting probabilities were plotted against annual streamflow on log probability paper (Fig. 7). The recurrence interval (T_r) is the time period for flows of x_n to be equalled or exceeded on the average and is calculated as the inverse of $P(X > x_n)$ or

$$T_r = \frac{1}{P(X > x_n)}$$

3) In order to calculate low flows, the lowest flow discharge was determined for each year of record and assigned to a class interval. Each class interval spanned a flow rate of 5 ft³/sec (3,620 acre-feet/year). Cumulative percentages and the midpoint of each class interval were used to plot points on log probability paper.

4) Hazen (1930) calculates an annual discharge and frequency curve for ungaged streams by using a series of coefficients based on characteristics of gaged streams in nearby basins.

A) Mean values of annual flow versus respective drainage area for each of the streams are plotted on log-log paper (Fig. 16).

B) A mean line is drawn through the plotted points.

C) The mean annual flow of the ungaged area is estimated by plotting the area of the ungaged stream (44 square miles) on the x axis and reading 2,500 acre-feet from the y axis. The frequency curve for the mean annual flow was then drawn using the following steps.

D) Using the historical streamflow record from three adjacent basins (Blood Creek near Boyd [07142900], Cow Creek near Claflin [07142860], and Walnut Creek at Albert [07141900]), a mean coefficient of variation (C.V.) and coefficient of skewness (C.S.) are computed where

$$\text{Mean} = \frac{\text{total streamflow for period of record}}{\text{number of years of record}}$$

$$\text{CV} = \frac{\sum \left[\left(\frac{\text{any given year runoff}}{\text{mean runoff}} \right) - 1 \right]^2}{n-1}$$

$$CS = \frac{\sum \left[\left(\frac{\text{any given year runoff}}{\text{mean runoff}} \right) - 1 \right]^2 \times F}{(n-1) (CV)^2}$$

where n = number of years of record and $F = 1 + 8.5/n$

E) Data are tabulated as specified by Hazen and an average CV and SC are calculated.

F) A frequency curve for mean annual flow can then be drawn (Fig. 17) for the ungaged basin using

- a) mean 2,500 acre-feet/year
- b) average CS and CV (see D above)
- c) make remaining calculations using CV and CS as outlined by Hazen.

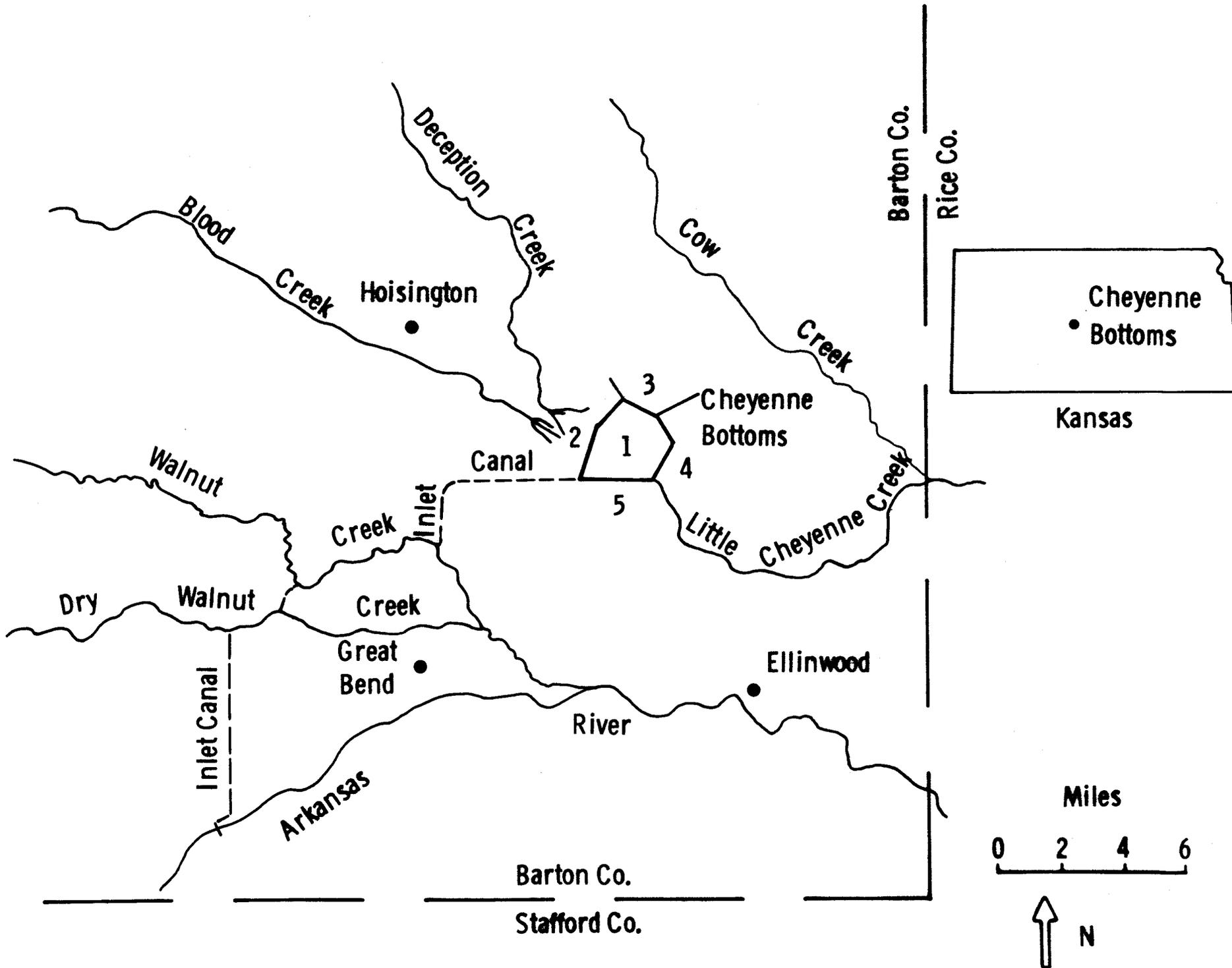


Fig. 1. Location Map For Cheyenne Bottoms Wildlife Area

KANSAS FISH & GAME COMMISSION
**CHEYENNE BOTTOMS
 WILDLIFE AREA**

LEGEND

- DIKE WITH GRAVEL SURFACE ROADWAY
- BITUMINOUS SURFACE ROADWAY
- GRAVEL SURFACE ROADWAY
- IMPROVED EARTH ROADWAY
- UNIMPROVED EARTH ROADWAY
- PROPERTY LINE
- DIKE
- NORMAL POOL ELEVATION
- DUCK BLIND
- FOOT CROSSING
- PARKING AREA
- MOTORIZED WATERCRAFT ACCESS LANE

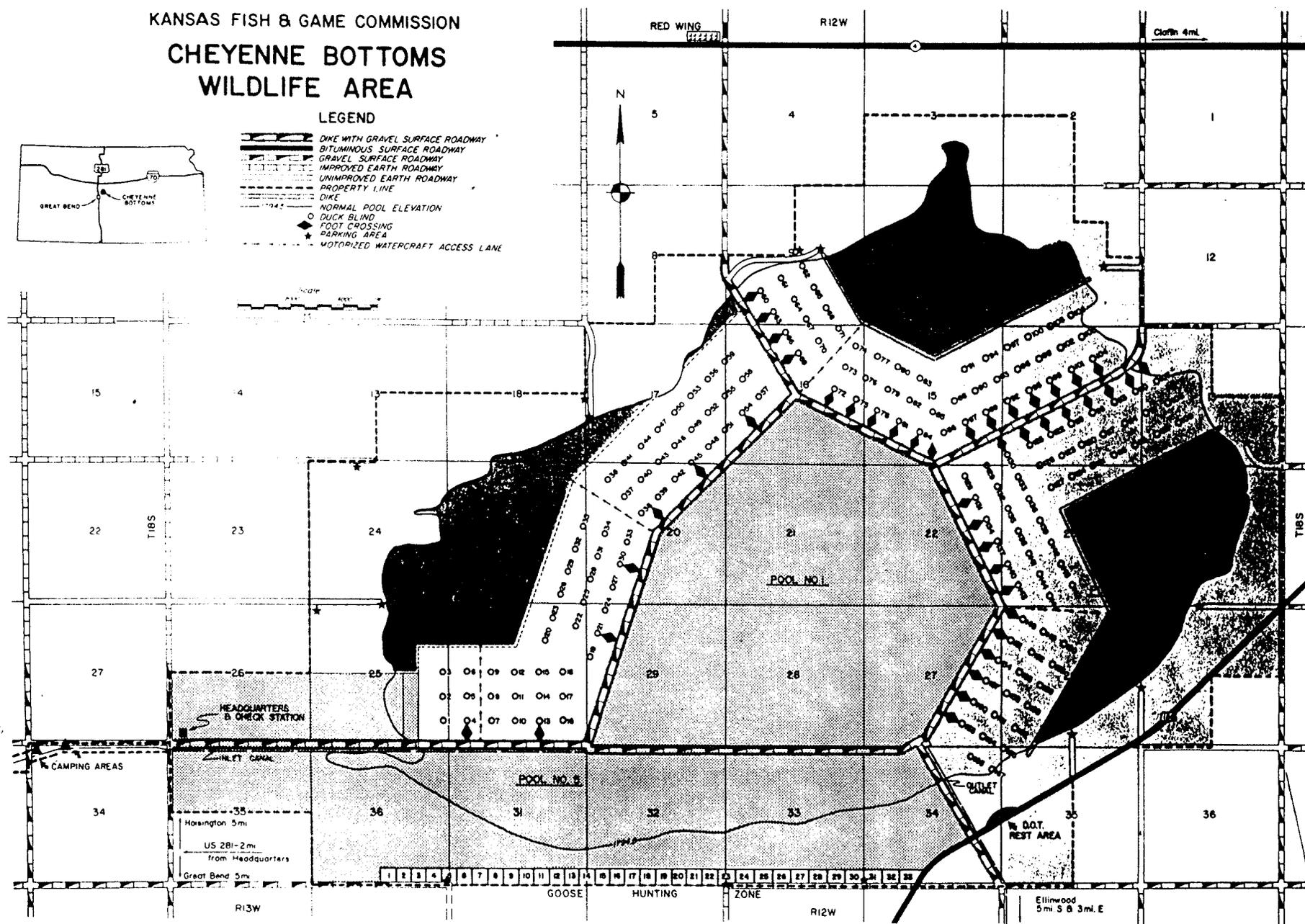
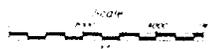
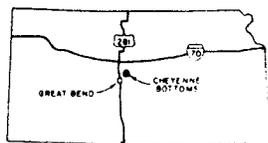
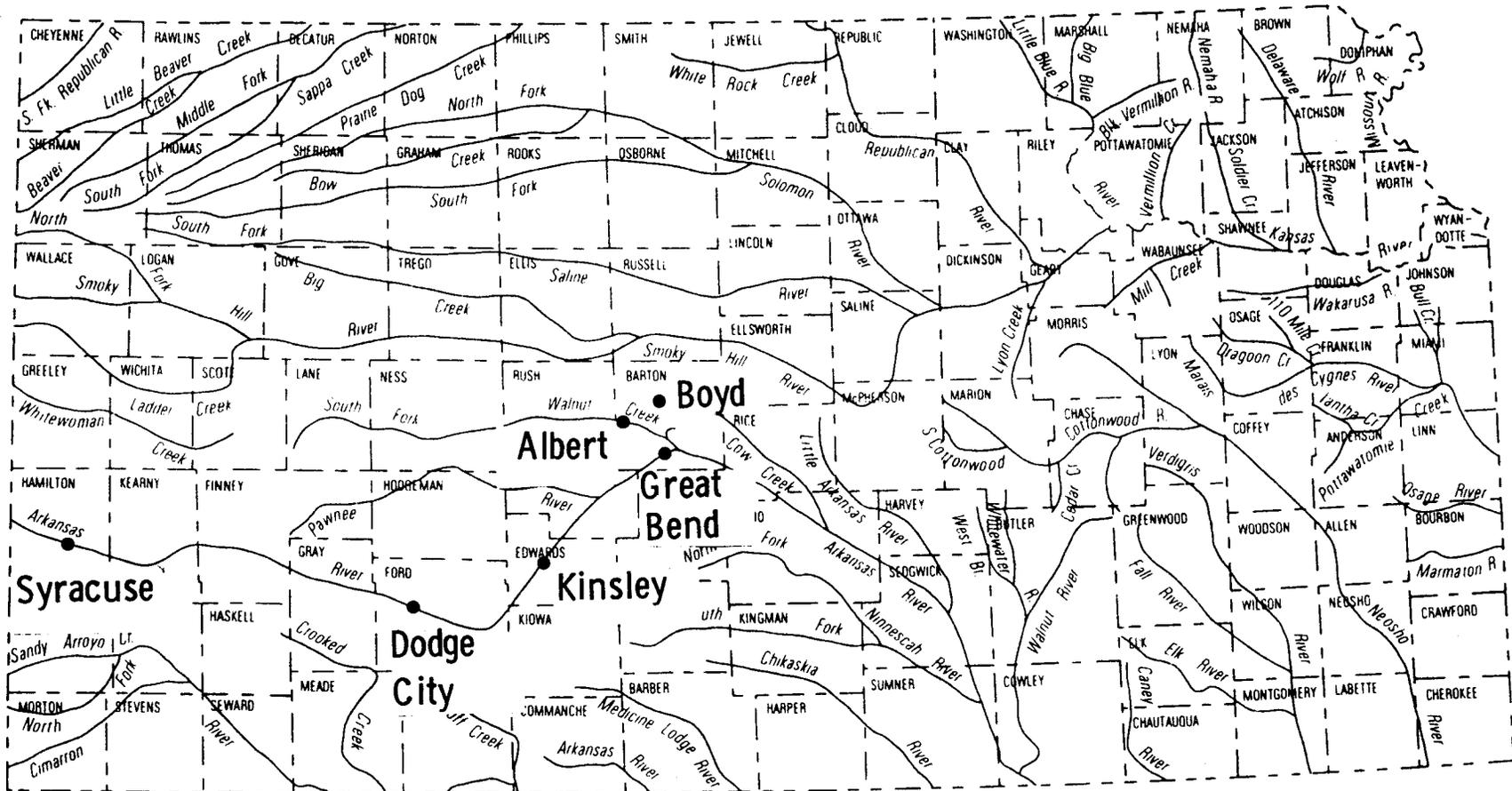


Fig. 2. Diagram of Cheyenne Bottoms Wildlife area.



- Blood Creek Near Boyd 07142900**
- Walnut Creek At Albert 07141900**
- Arkansas River At Great Bend 07141300**
- Arkansas River Near Kinsley 07140000**
- Arkansas River At Dodge City 07139500**
- Arkansas River At Syracuse 07138000**

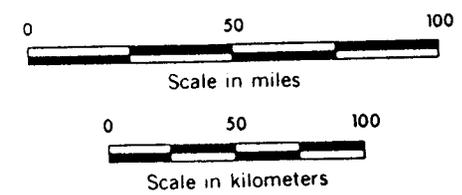


Fig. 3. Locations Of U. S. Geological Survey Stream Gaging Stations

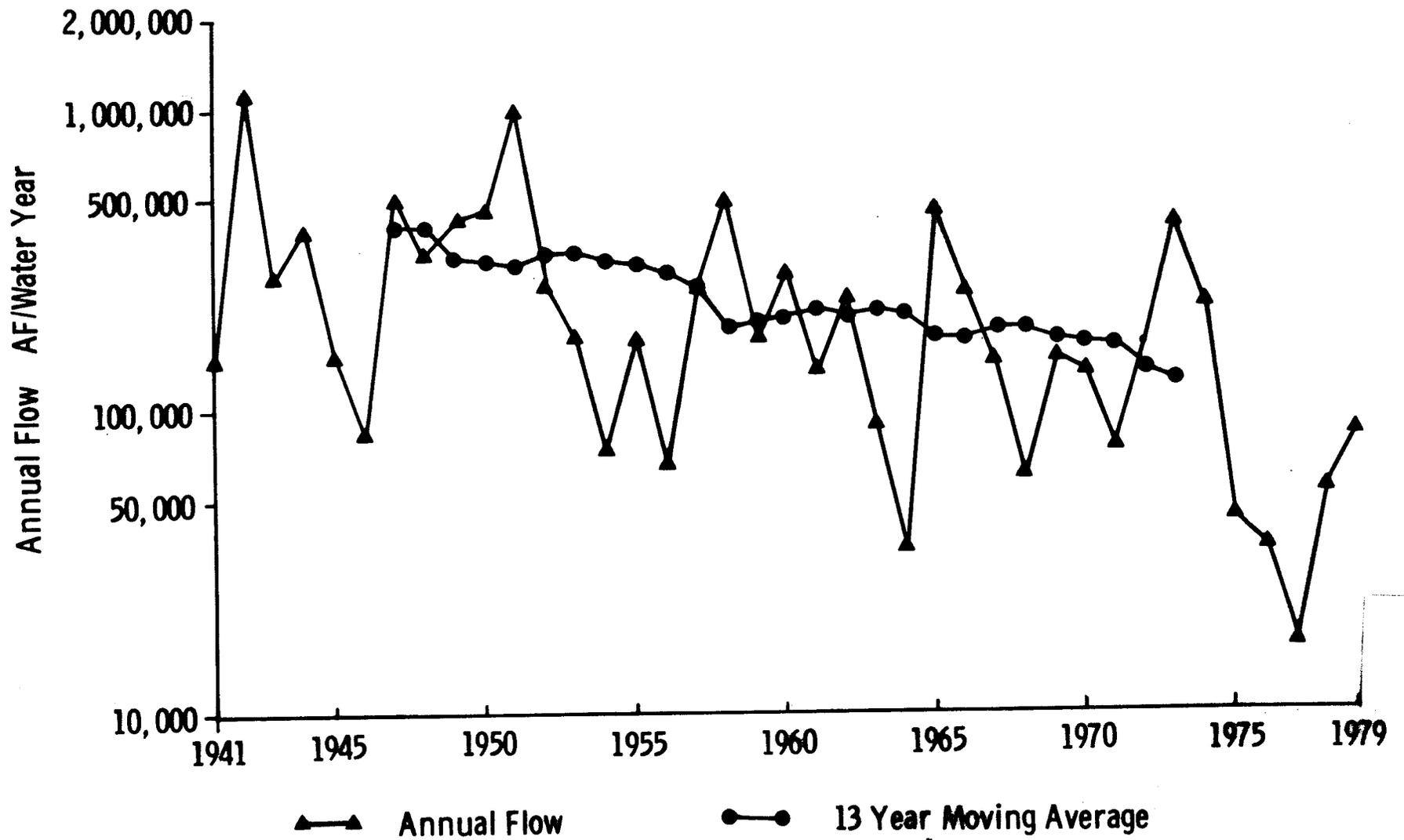


Fig. 4. Arkansas River At Great Bend. Annual Flow 1941-1979 And 13 Year Moving Average.

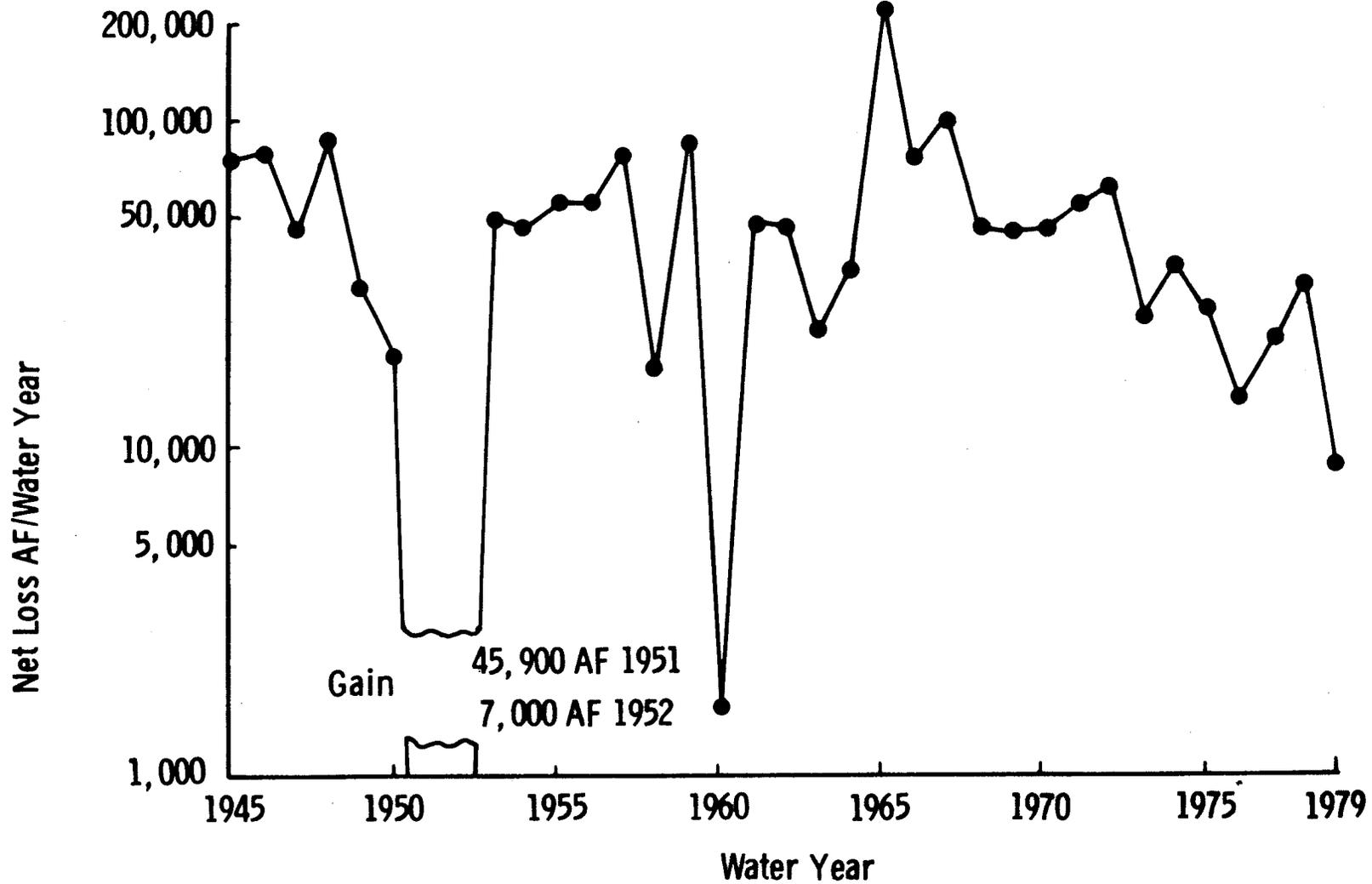


Fig. 5. Net Loss of Streamflow between Syracuse and Dodge City Gages
 (Flow at Syracuse — Flow at Dodge City) in AF/Water Year.

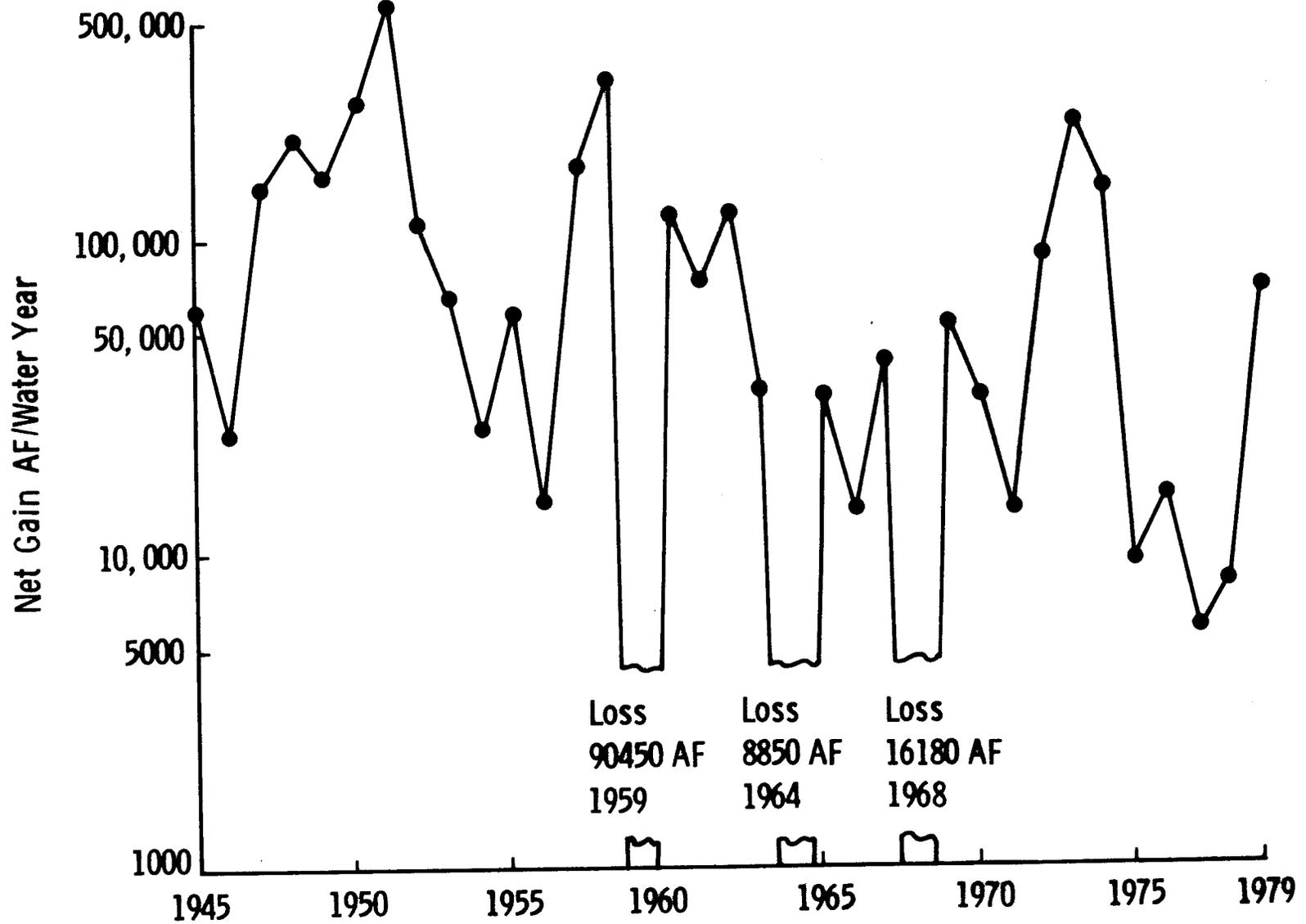


Fig. 6. Net Gain of Streamflow between Kinsley and Great Bend Gages
 (Flow at Great Bend — Flow at Kinsley) in AF/Water Year.

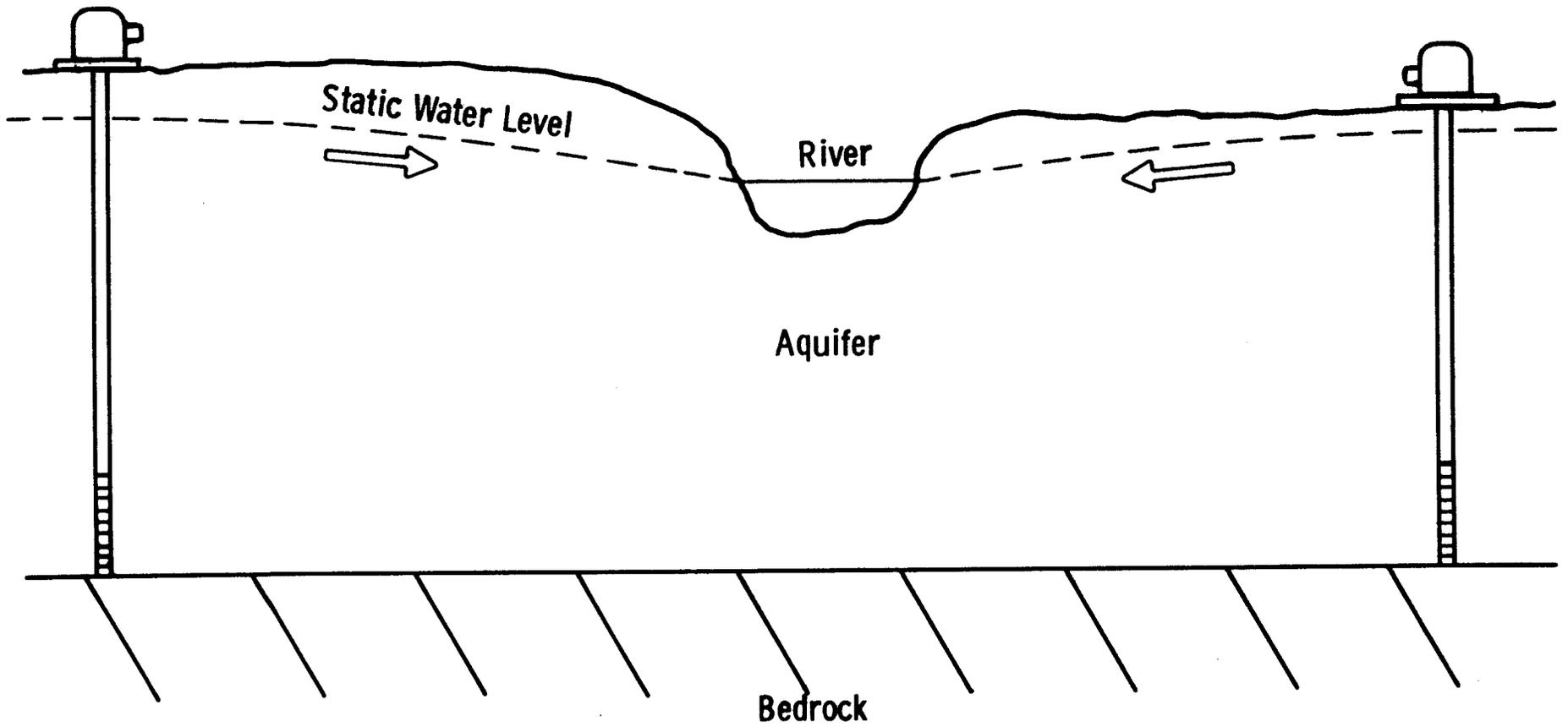


Fig. 7. Streamflow Gain from Groundwater Seepage

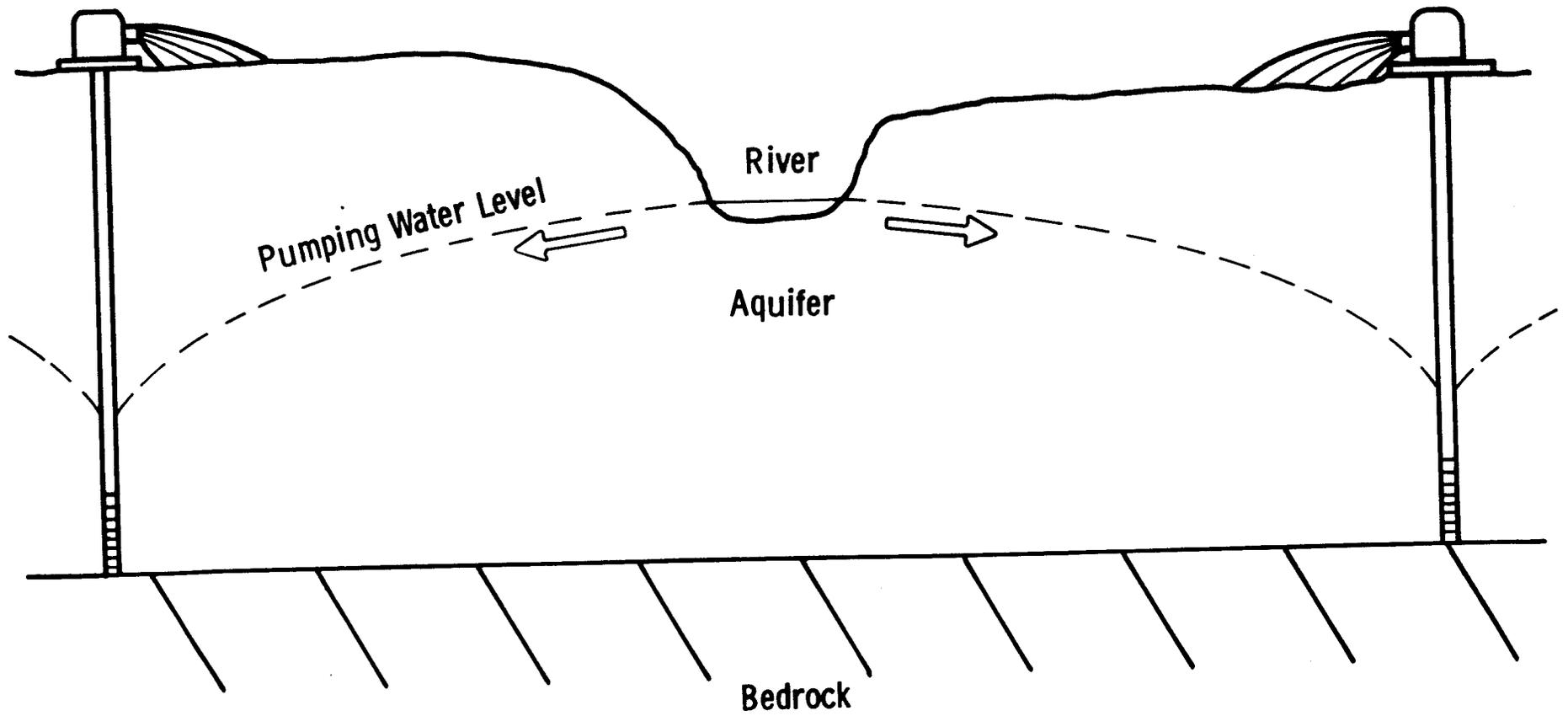


Fig. 8. Streamflow Loss Due to Wells

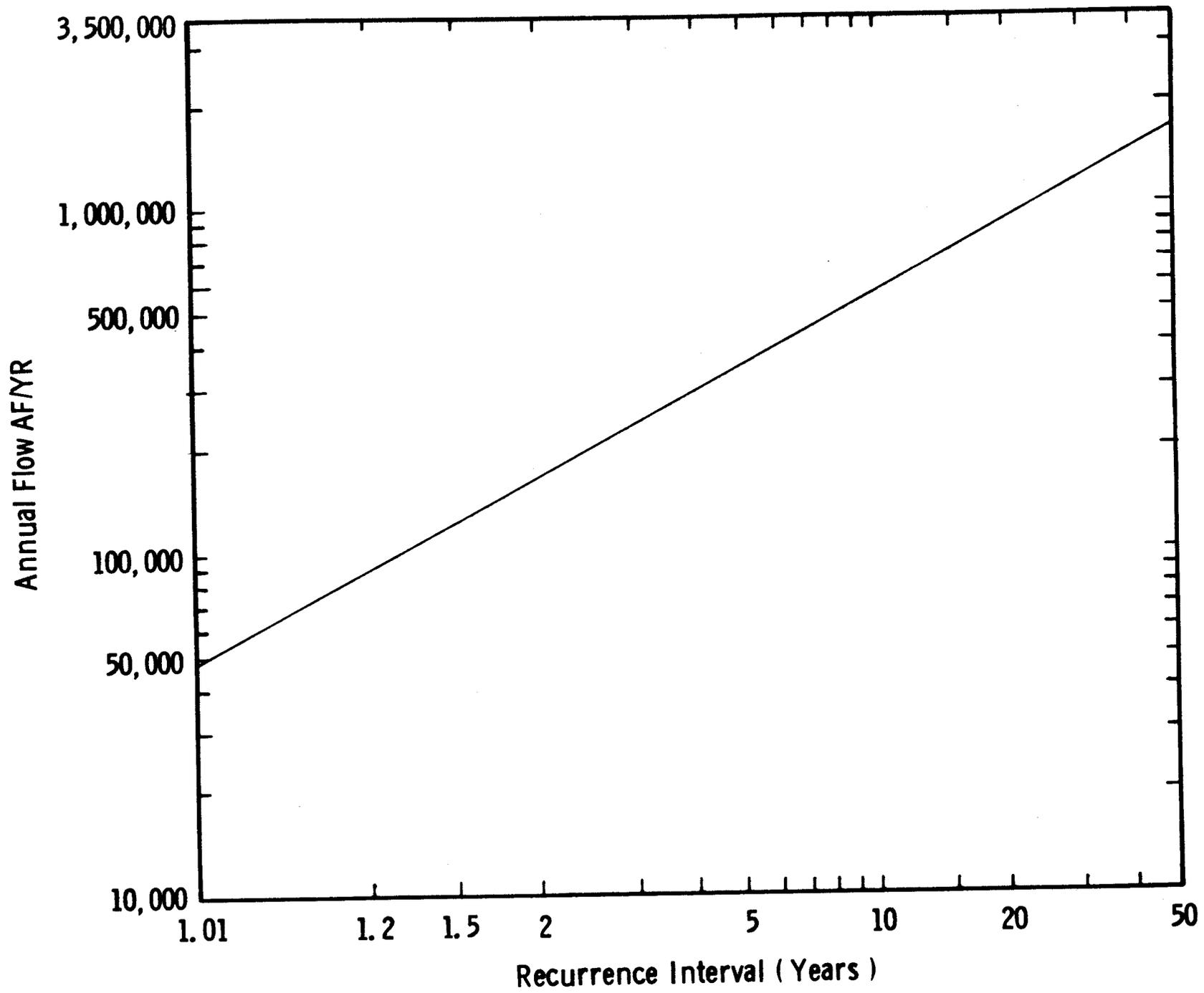


Fig. 9. Recurrence Interval of Annual Flows, Arkansas River at Great Bend, 1941-1979

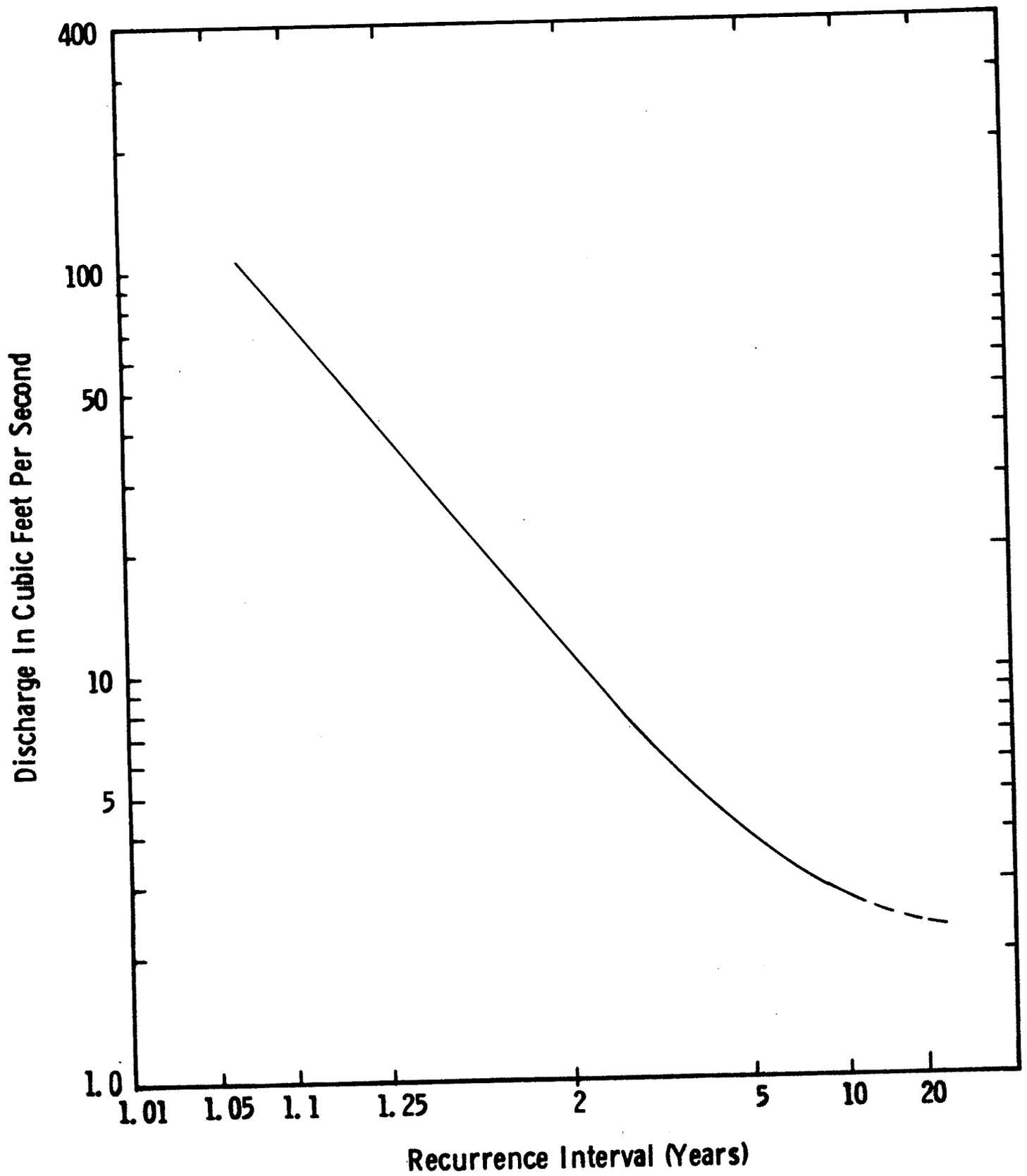


Fig. 10. Recurrence Interval Of Low Flows , Arkansas River At Great Bend

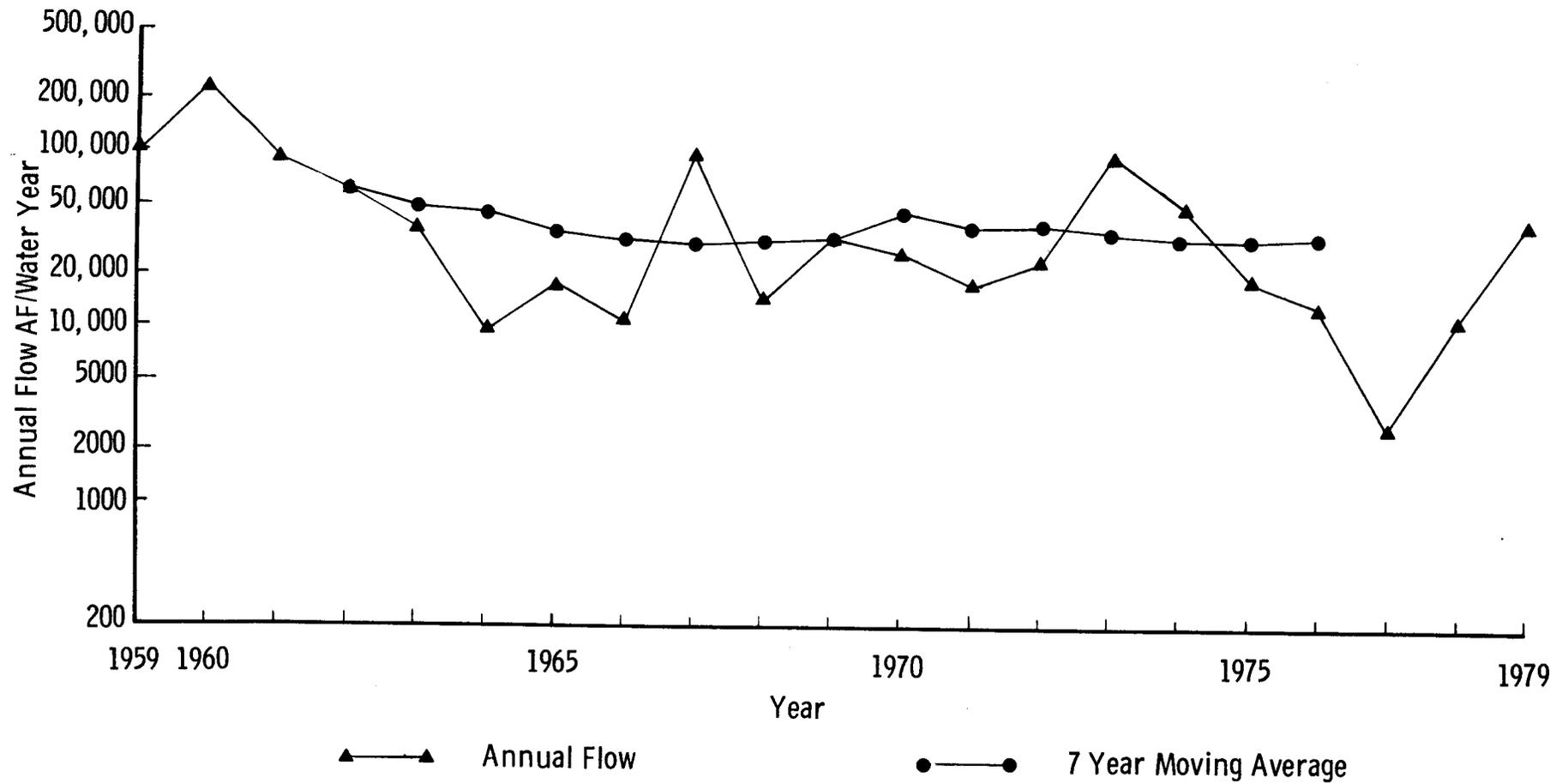


Fig. 11. Walnut Creek At Albert. Annual Flow 1959-1979 And ⁷/₁₃ Year Moving Average.

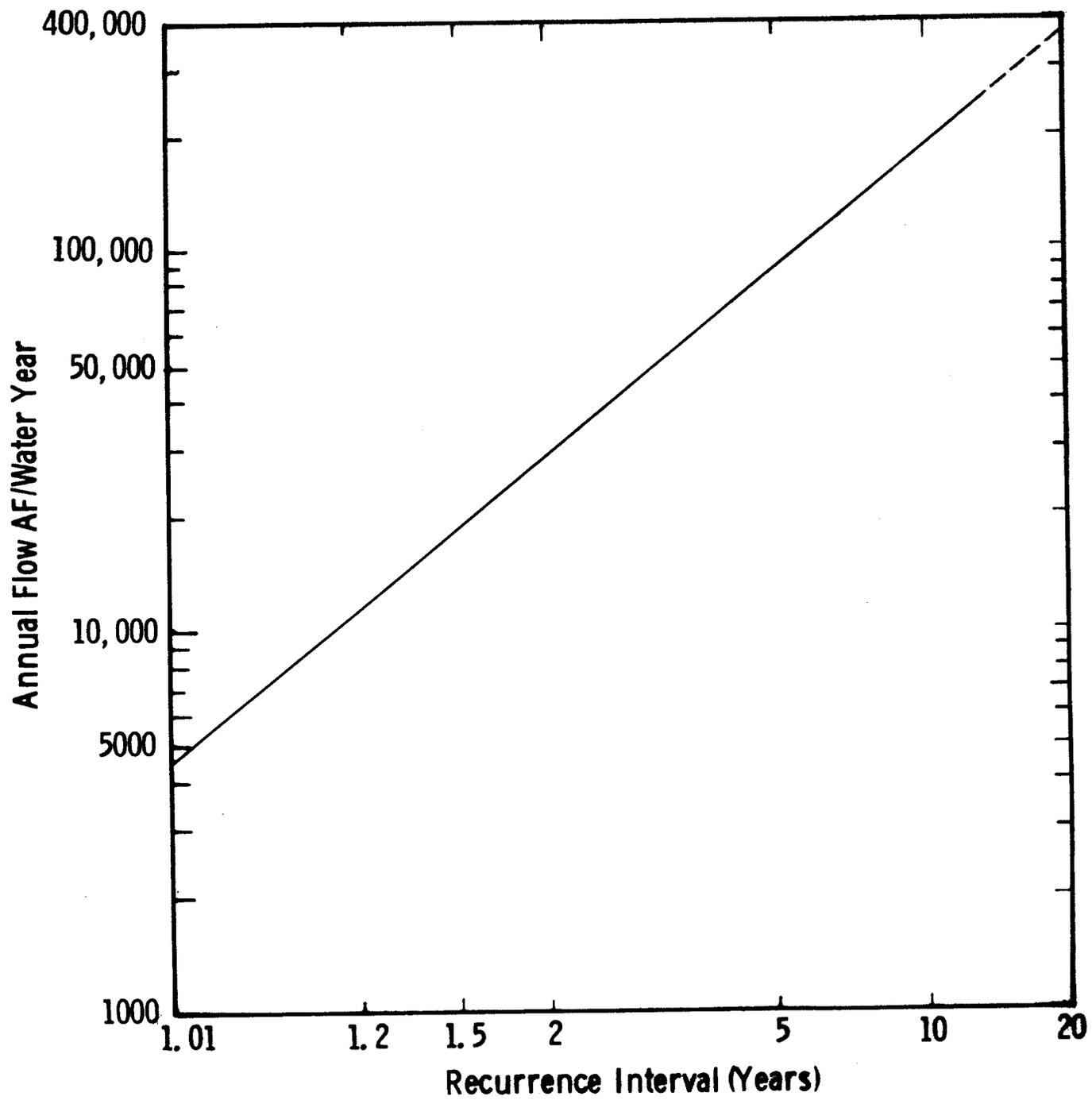


Fig. 12. Recurrence Interval of Annual Flows, Walnut Creek At Albert, 1959-1979.

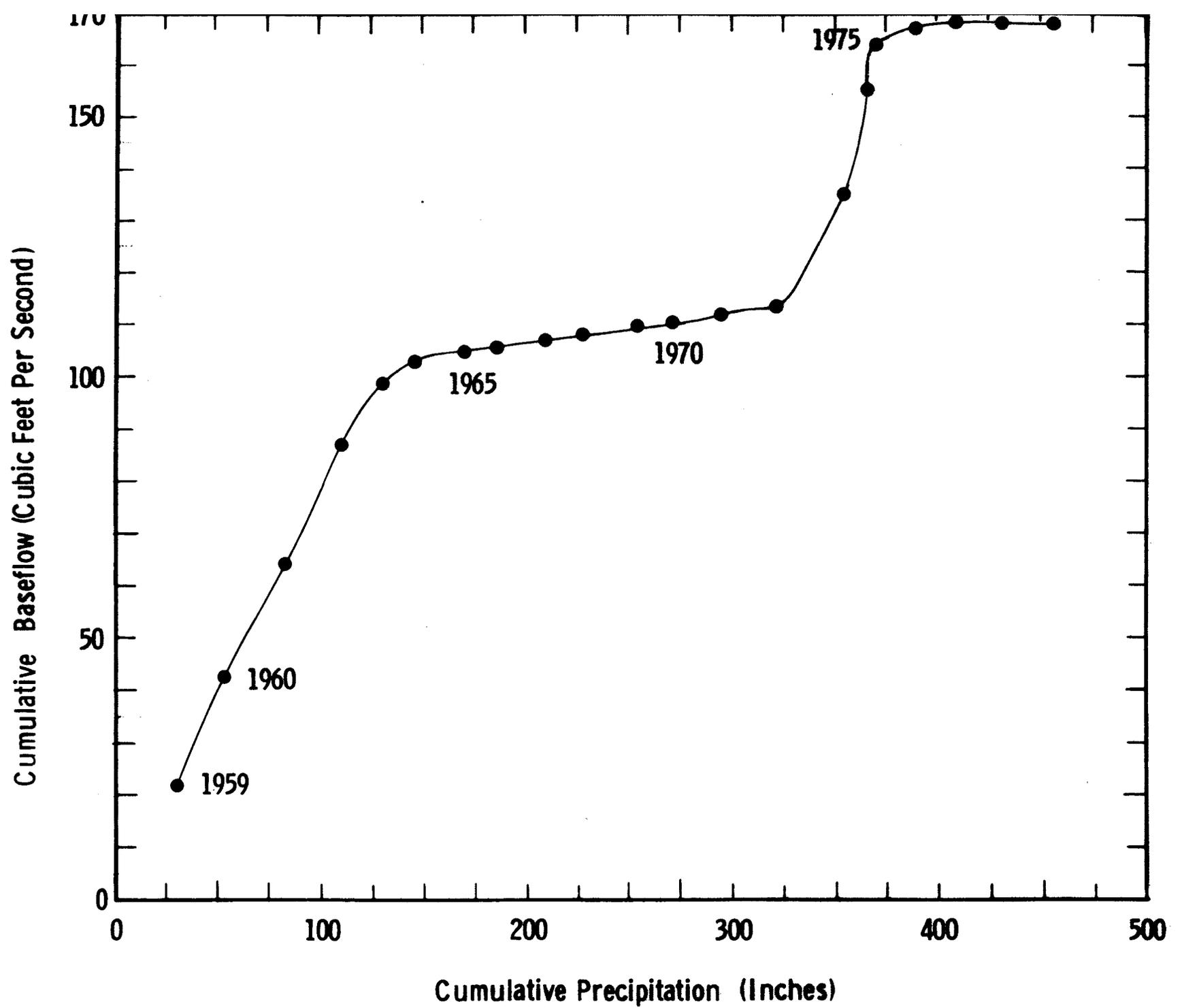


Fig. 13. Mass Curve Of Precipitation Vs Baseflow For Walnut Creek

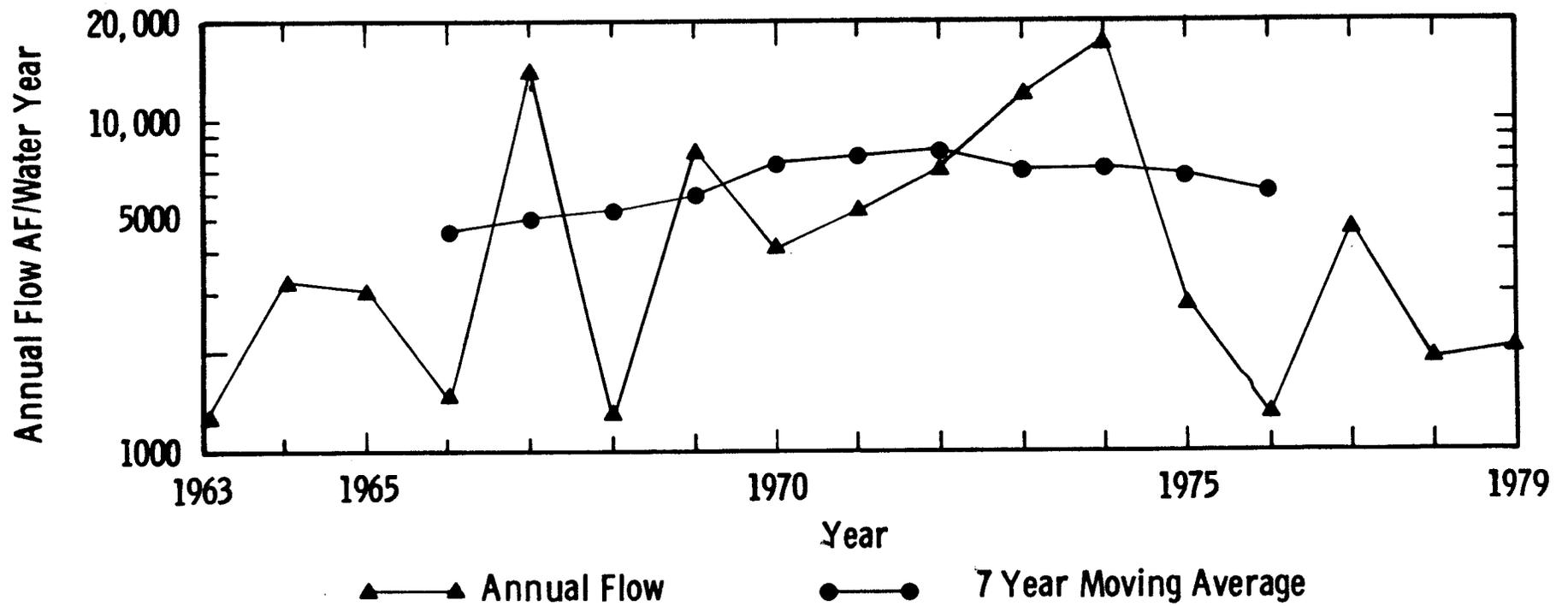


Fig. 14. Annual Streamflow In Blood Creek And 7 Year Moving Average

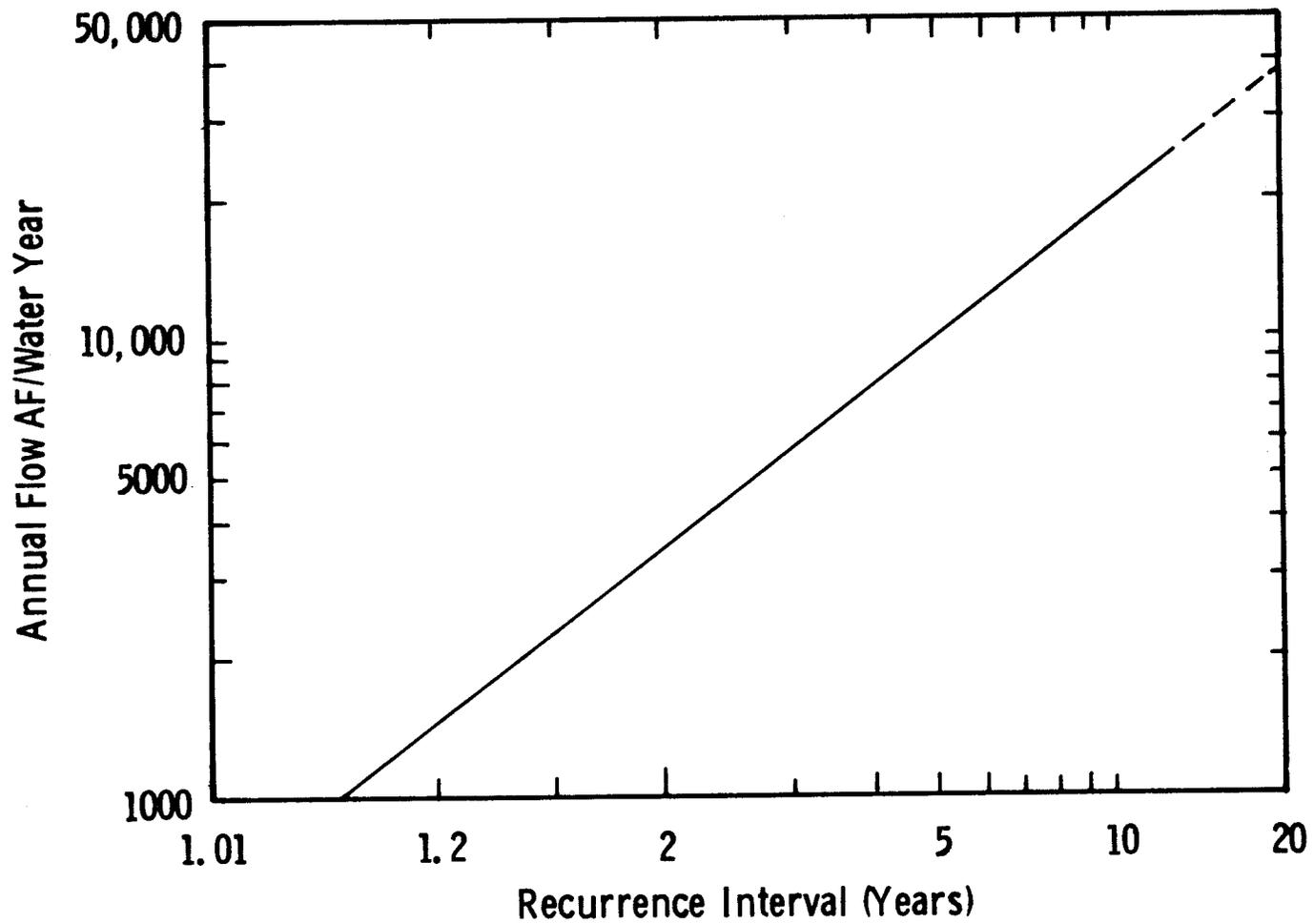


Fig. 15. Recurrence Interval Of Annual Flows, Blood Creek Near Boyd, 1963-1979.

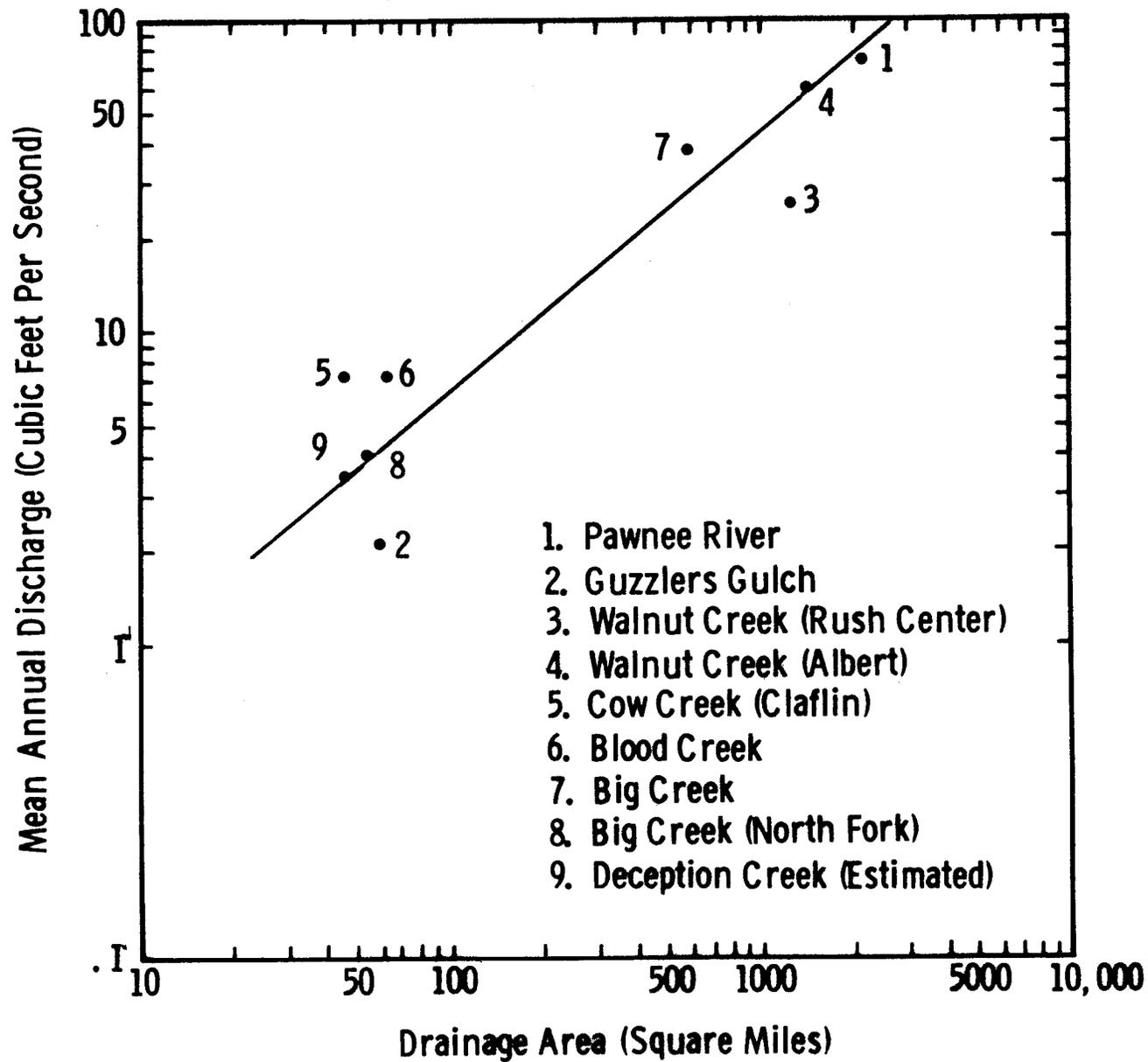


Fig. 16. Mean Annual Discharge Vs Drainage Area Of Selected Streams In Central Kansas.

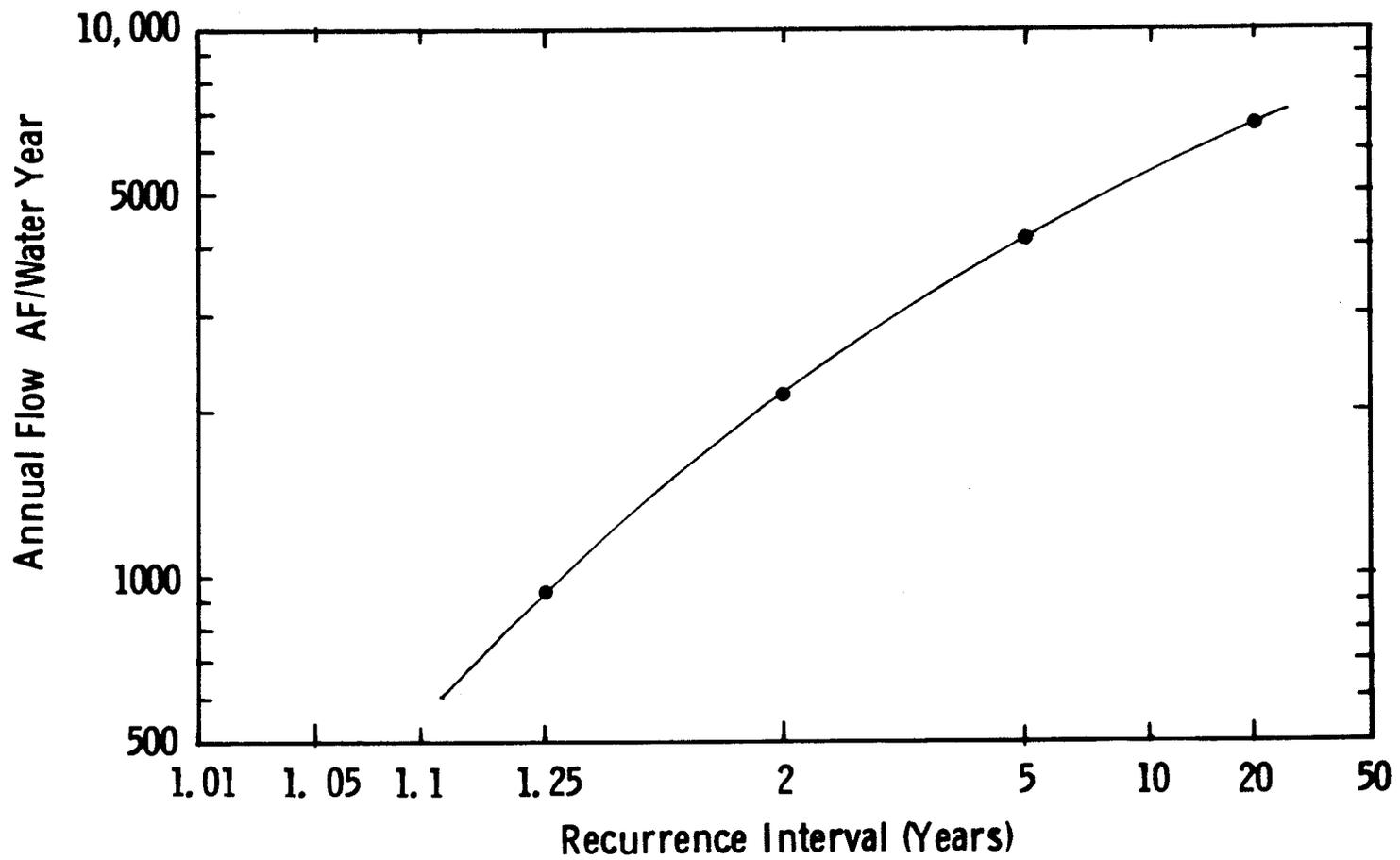


Fig. 17. Calculated Recurrence Interval Of Mean Annual Flow In Deception Creek