Estimation of Mean Annual Average Flows

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Introduction

Mean annual average flow is used in wasteload allocations for human health criteria implementation, agriculture criteria implementation and in determining the potential for an unlisted water to be assigned the habitat limited aquatic community beneficial use. Additional uses for the mean annual average flow may be identified in the future. Consequently, methods to easily estimate mean annual average flows are needed to advance Oklahoma's water quality standards implementation and management. The purpose of this report is to develop methods to easily estimate mean annual average flow.

Mean Annual Average Flows On Streams With Gages

Mean annual average flow is published by USGS as annual mean discharge in the USGS Statistical Summaries (1987). The appropriate period of record for regulated flows should be used below dams. It is possible to estimate mean annual average flow, A, on gaged streams. A is the observed mean annual average flow if the discharge is in close proximity to the USGS gage.

If the discharge is between gages, a weighted average of A may be used.

$$\therefore A = \frac{A_1(x_1 - x) + A_2(x - x_2)}{x_1 - x_2},$$

where A_1 is the mean annual average flow observed at the downstream gage, x_1 is contributing drainage area above this gage, x is drainage area above the discharge, A_2 is mean annual average flow at the upstream gage and x_2 is drainage area above the upstream gage.

Estimating Mean Annual Average Flows On Streams Without USGS Gages

Because flow values are only recorded at USGS stream gages, there is a need to estimate mean annual average flow on streams without gages. Mean annual average flow is more difficult to estimate on ungaged streams. Sophisticated techniques can yield accurate mean annual flows on ungaged streams, but consume more resources than are generally available, and this sort of accuracy is not generally necessary for most water quality management applications. Water quality management is adequately served by an estimate which requires fewer resources. Therefore, an easy method to estimate mean annual average flow on ungaged streams was developed. Because most large streams in Oklahoma have gages, this method is only meant to be applied to small, unimpounded streams.

The simplest way to estimate A (mean annual average flow), is from a map of isopleths of A/A_D, where A_D is the drainage area of the receiving stream. When A/A_D is obtained from the map, multiplication by A_D yields A.

Three resources were used to produce isopleths of A/A_D. First, the runoff pattern in "Appraisal of the Water and Related Land

Resources of Oklahoma" (1973) was used because the runoff pattern and isopleths of A/A_D should be similar. These patterns are not identical because more factors affect mean flow than runoff (e.g. springs, effluent discharges and water diversions).

Secondly, the hydrologic investigations commissioned by the OWRB were utilized. These investigations have been completed for all major basins in Oklahoma except the Grand and Poteau Rivers. Figure 1 shows the basins and sub-basins into which Oklahoma has been divided. For the purposes of this Technical Report, sub-basins will refer to the smallest drainage units in Figure 1 (e.g. 2-7 and 2-9-1). Mean annual average flows leaving many of these sub-basins have been determined from hydrologic investigations. Subtraction of the mean annual average flow entering a sub-basin from that leaving it yields the mean annual average flow generated in the sub-basin. Division of the flow generated in a sub-basin by the sub-basin area yields an estimate of A/A_D. This estimate is not valid throughout a sub-basin because A generally increases from west to east. Therefore the estimate is assumed to be valid at the center of the sub-basin.

Estimates of the mean annual flow generated in the Arkansas and Red River sub-basins are not useful in determining A/A_D, because these rivers are not representative of small, ungaged receiving streams. The hydrology of the Arkansas River is extremely complex, while the Red forms the southern boundary of Oklahoma, and is therefore not representative of Oklahoma basins. Similarly, sub-basins which are dominated by large lakes (e.g. Eufaula) could not be used.

Thirdly, the Bureau of Reclamation published a map of A/A_D for southeast Oklahoma in its hydrologic investigations of that region. This map has been modified and combined with the rest of the data to produce the isopleths in Figure 2. Due to the diverse nature of the very limited data the isopleths are hand drawn, rather than produced by a computer driven contouring routine. The map should be considered best professional judgement, based on hydrologic investigations.

The map in Figure 2 does not include the panhandle, where A/A_D is always less than 0.1. It is suggested that $A/A_D = 0.05$ be used for the entire panhandle.

Veracity Of Estimated Mean Annual Flows

The isopleths in Figure 2 are only useful if they help obtain adequate estimates of mean annual flows. Although there is no completely independent data set with which to test the isopleth map, data in the USGS Statistical Summaries were used to test its utility. Since the map is designed for use on small streams only, gages with a mean annual average flow of less than 500 cfs or a drainage area less than 5000 square miles were used in the comparison. The locations of the gages used are shown in Figure 3. Values for Q_u/A_D are estimated at the gage by interpolating between isopleths. These values of Q_u/A_D are multiplied by the drainage areas at the gages to obtain estimates of the mean annual average flow.

The estimates are compared with the observed mean annual average flows in Figure 4. The line represents the estimate equal to the observed flow. For example, if the estimated and observed flows are both 200 cfs, the resulting point will fall on the line. The estimated flow is greater than the observed flow if the point is above the line, and the estimated flow is less than that observed if the point is below the line. Figure 4 shows that the isopleth method yields relatively unbiased estimates of the observed flow.

The isopleth method may not yield an appropriate regulatory flow at some sites. Even though isopleth estimated flows are close to those observed, there are too many factors unaccounted for to be assured that a flow appropriate for wasteload allocation will always be obtained. The estimate should not be used downstream from impoundments in western Oklahoma. Much of the water in these reservoirs is lost to evaporation or used for agricultural or municipal purposes. Therefore, estimated flow is much greater than the dam discharge observed. An assumption in the permitting process of such a large mean annual flow on a stream with a small dilution capacity allows for very high instream concentrations at low flows.

Conclusions

The OWRB and other agencies invested considerable resources in the Hydrologic Investigations. An ancillary benefit of these studies is information useful in developing estimates of mean annual average flows. The method developed is very easy to use, and has been shown to be fairly accurate when applied to small unimpounded streams. However, in situations where environmental and economic consequences warrant, a more resource intensive method to obtain a better estimate of mean annual average flow should be used.

References

Appraisal of the Water and Related Land Resources of Oklahoma Regions 1-12, 1967-1973. Oklahoma Water Resources Board, Oklahoma City, Ok.

Hydrologic Investigation of the Beaver Creek. Tulsa District, Corps of Engineers. OWRB Technical Report 86-3.

Hydrologic Investigation of the Blue River. Bureau of Reclamation. OWRB Technical Report 91-2.

Hydrologic Investigation of the Cache Creek. Tulsa District, Corps of Engineers. OWRB Technical Report 87-4.

Hydrologic Investigation of the Canadian River and Little River. Oklahoma Water Resources Board. OWRB Technical Report 86-4.

Hydrologic Investigation of the Cimarron River. Tulsa District, Corps of Engineers. OWRB Technical Report 91-1.

Hydrologic Investigation of the Deep Fork River, Oklahoma Water

Resources Board. OWRB Technical Report 86-1.

Hydrologic Investigation of the Kiamichi River. Bureau of Reclamation. August, 1986.

Hydrologic Investigation of the Little River. Bureau of Reclamation May, 1987.

Hydrologic Investigation of the Main Stem of the Arkansas River. Tulsa District, Corps of Engineers. OWRB Technical Report 92-1.

Hydrologic Investigation of the Muddy Boggy River. Tulsa District, Corps of Engineers. OWRB Technical Report 86-5.

Hydrologic Investigation of the North Canadian River. Oklahoma Water Resources Board. OWRB Publication #103, 1980.

Hydrologic Investigation of the North Fork and Elm Fork of the Red River. Oklahoma Water Resources Board. OWRB Publication # 114, 1983.

Hydrologic Investigation of the Prairie Dog Town Fork of the Red River. Oklahoma Water Resources Board. OWRB Technical Report 90-3.

Hydrologic Investigation of the Salt Fork of the Arkansas River and the Chikaskia River. Galveston District, Corps of Engineers. OWRB

Technical Report 87-6.

Hydrologic Investigation of the Salt Fork of the Red River. Oklahoma Water Resources Board. OWRB Technical Report 86-2.

Hydrologic Investigation of the Verdigris River, Caney River and Bird Creek. Oklahoma Water Resources Board. OWRB Technical Report 87-1.

Statistical Summaries Of Streamflow Records In Oklahoma And Parts Of Arkansas, Kansas, Missouri And Texas Through 1984. U.S. Geological Survey Water Resources Investigations Report 87-4205

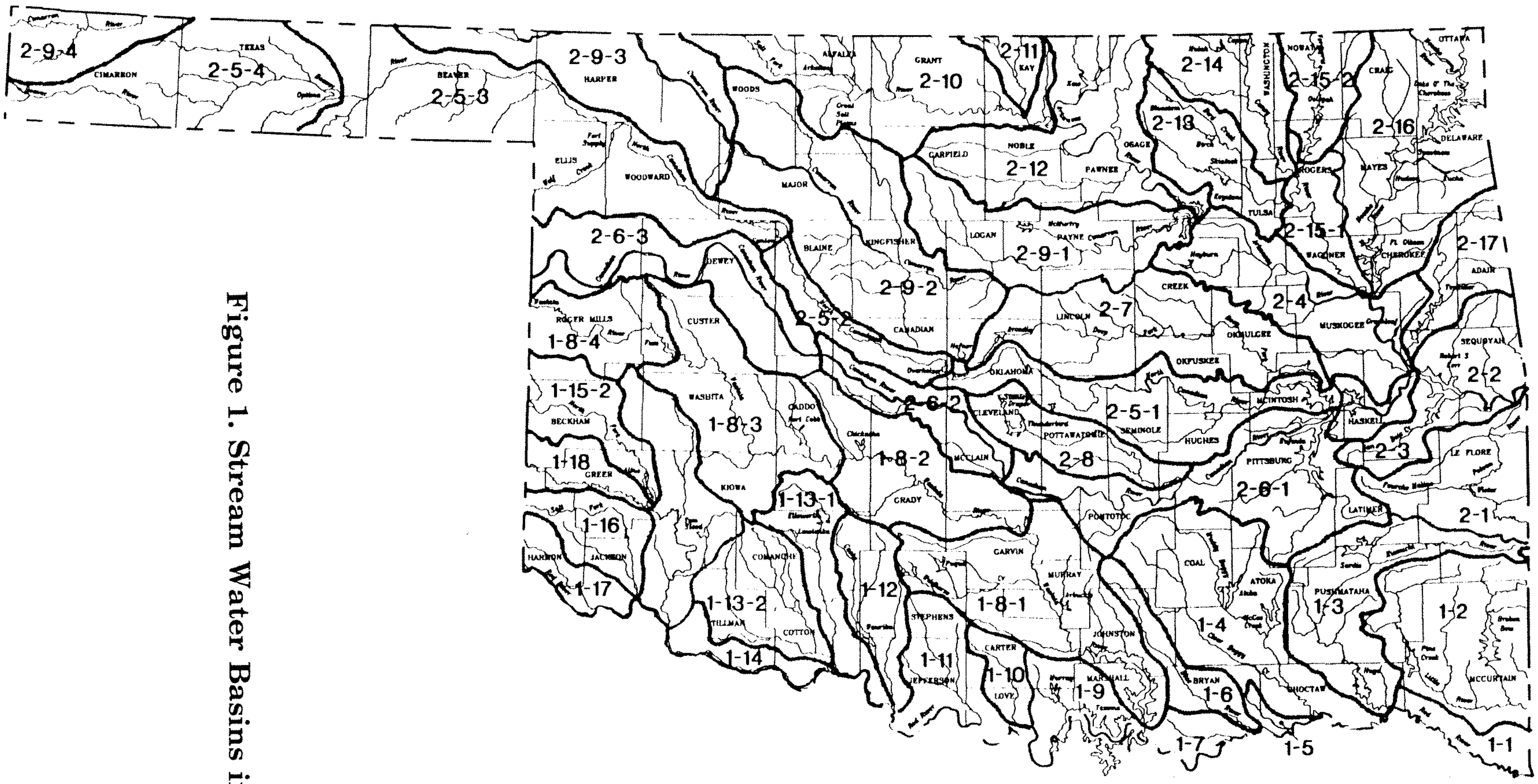

Figure 1. Stream Water Basins in Oklahoma

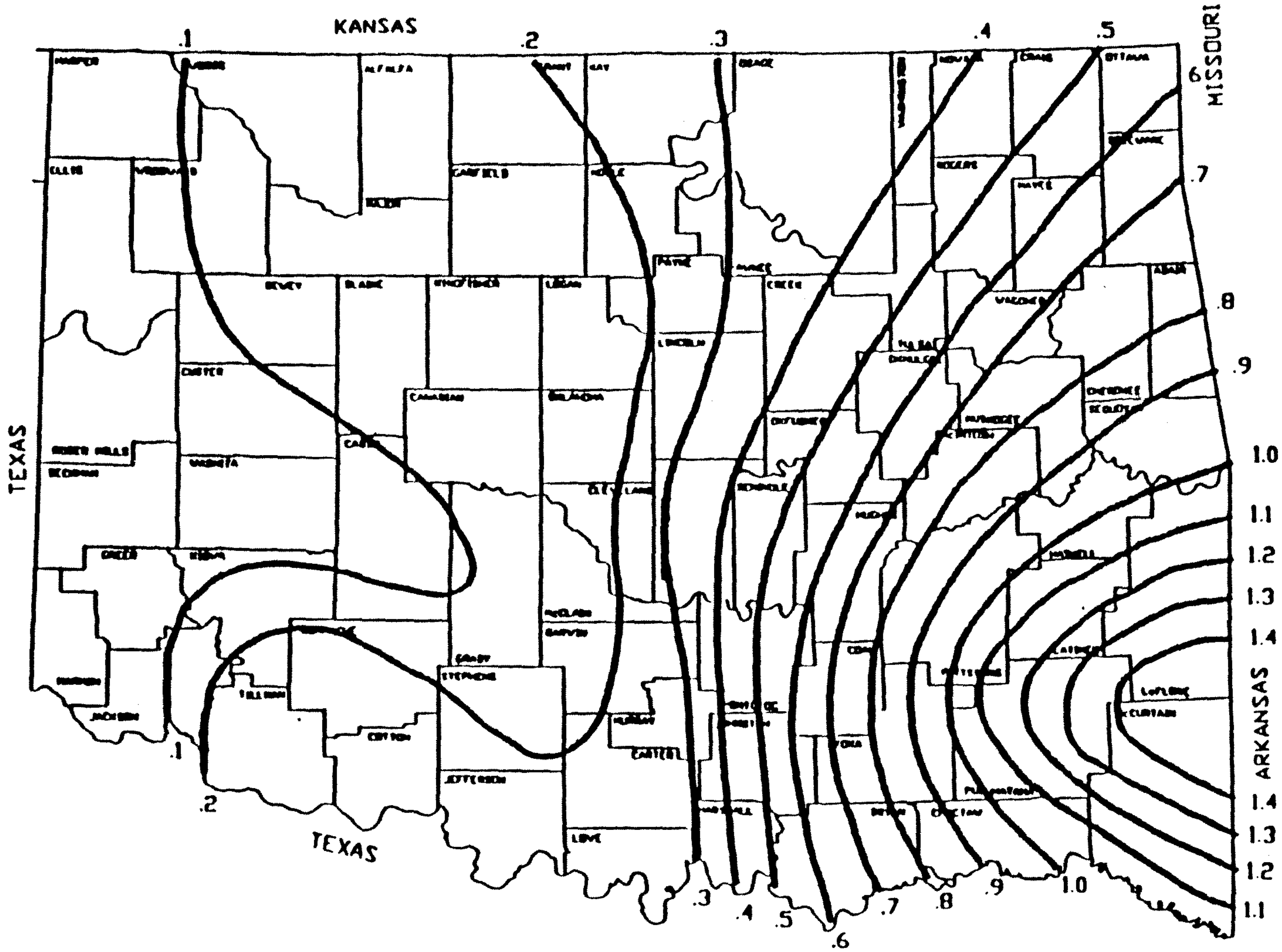

Figure 2. Isopleths of Q_U/A_D(CFS/Mi^2)

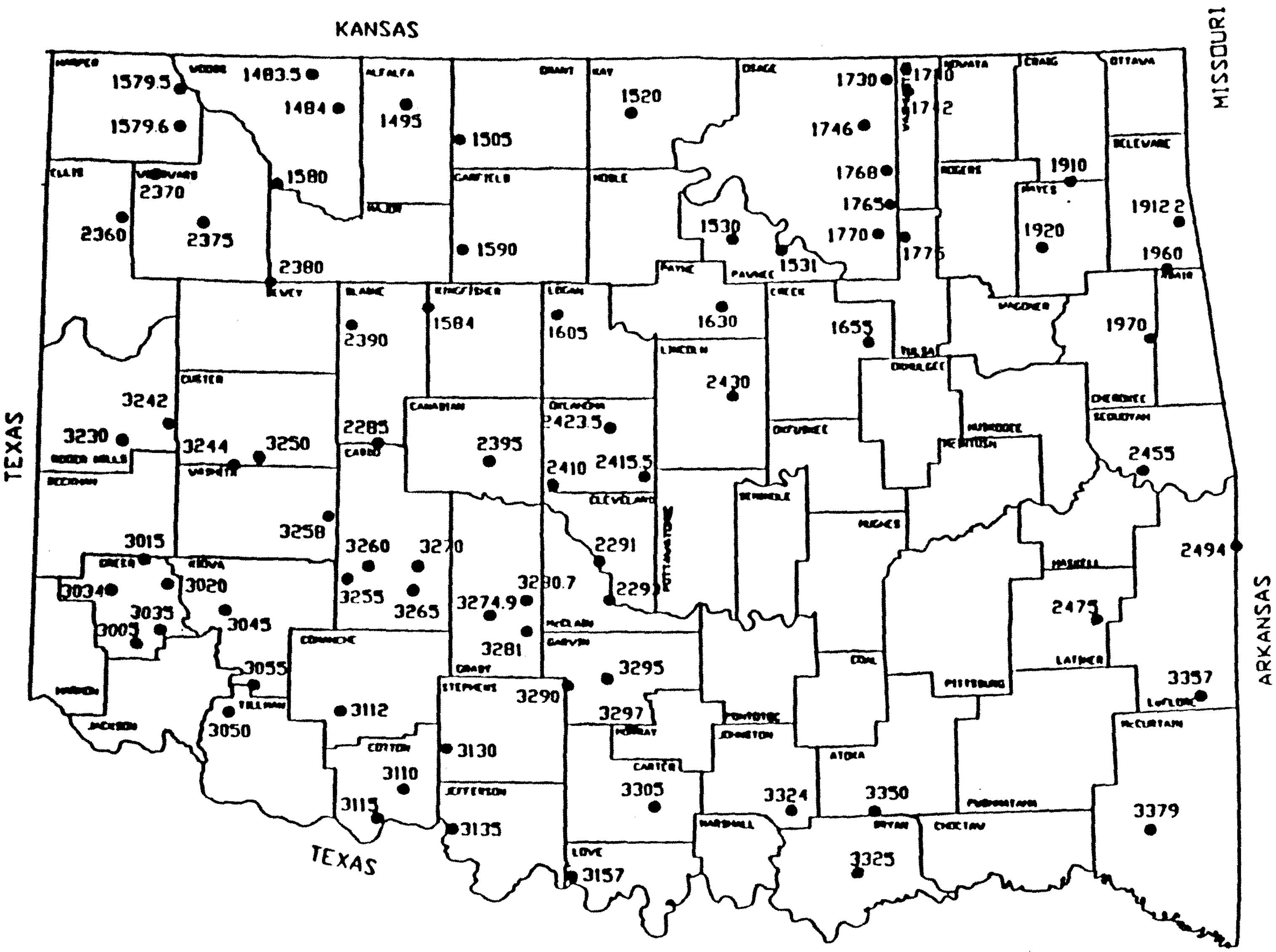

Figure 3. Gages at Which Mean Annual Flows Were Estimated

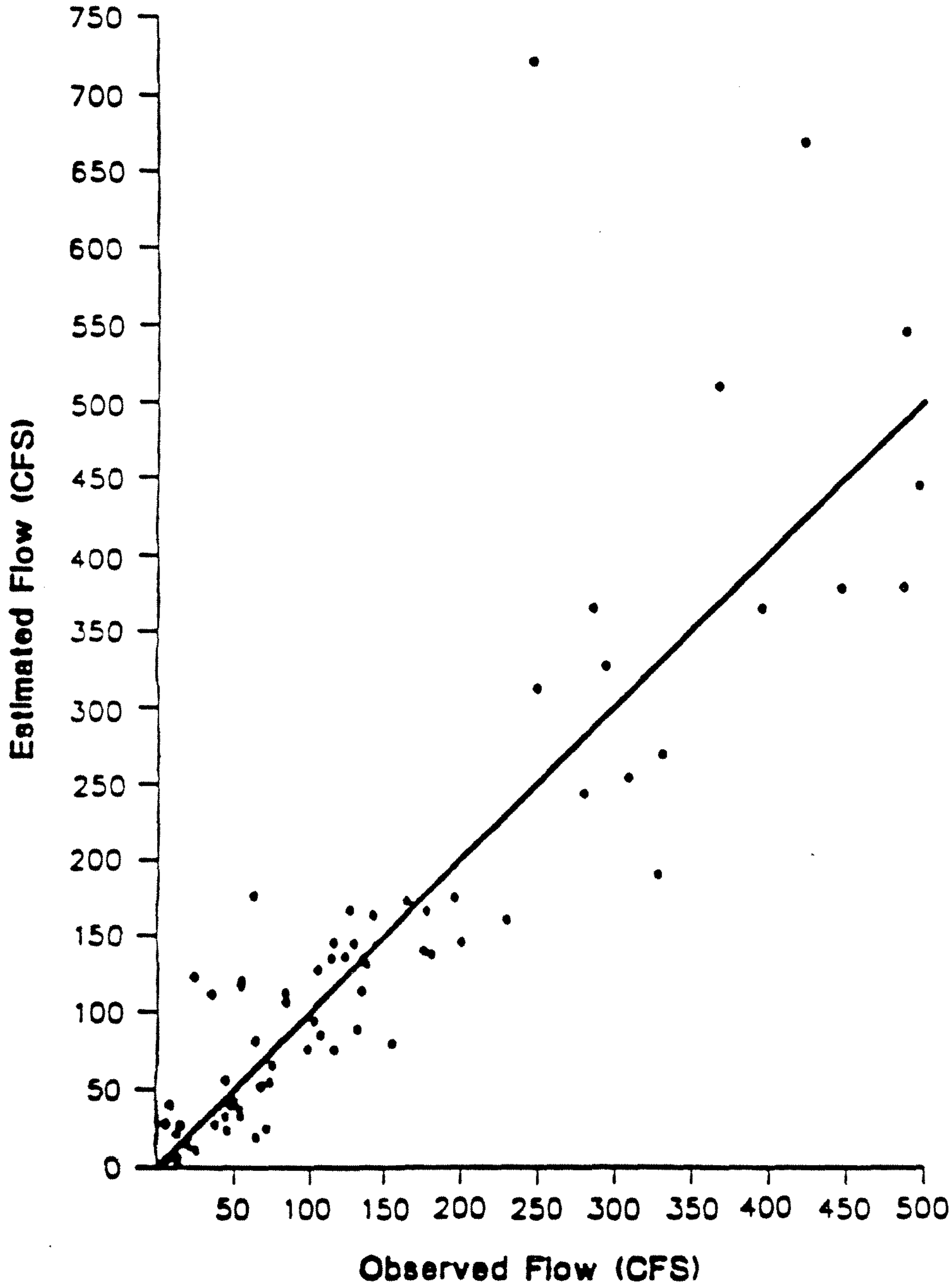

Figure 4. Comparison of Observed and Estimated Mean Annual Flows