Baseflow Trends in the Upper Verde River Relative to Fish Habitat Requirements

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Although much attention has been given to the effects of stormflows on native fish in Arizona's rivers (Minckley 1973, Rinne and Minckley 1991), it is minimum baseflows that are most critical for fish survival. Concerns have been raised about the potentially negative effects of drought, consumptive water use, watershed management, and water diversion on native fish populations, but significantly reduced baseflows could also put these fish populations at risk. Because of the controversy over threatened and endangered fish such as the spikedace (*Meda fulgida*) in the upper Verde River, it is important to examine recent trends in minimum baseflows on this river.

Because of the vagaries of climate (Green and Sellers 1964), characteristic to the Basin and Range physiography of the Southwest (Nations and Stump 1981), and its aridity (Jaeger 1957, Dunbier 1968), patterns of streamflow are highly variable. An alternating pattern of floods and drought are the norm. The interactions of these factors result in definition of aquatic habitat or the lack of it in the region (Rinne 1995a). Because of the Southwest's climate pattern and frequent water shortages, damming of major rivers was extensive during the first 60 years of this century. Commencing with the completion of Roosevelt Dam, the first Bureau of Reclamation dam on the Salt River basin of Arizona in 1911, modification of rivers in this region and throughout the West has been widespread. Rinne (1994) reported that 70 percent of the mainstream rivers in Arizona have been modified by dams. Such modifications combined with rapid growth in population and economic activities have resulted in loss of surface flow and changes in the quantity and quality of streamflow across the landscape. Free flowing, un-dammed rivers are a rarity in this region.

The upper Verde River is one of the few remaining reaches of wild, free-flowing rivers in Arizona. Furthermore, this reach of river is a rarity in the Southwest because it supports a native fish community (Stefferud and Rinne 1995). Studies of the reach of river upstream from Sycamore Creek began in 1994 following major flooding events on the Verde in the winter of 1992–93. The main study objective is to examine the sustainability of the native fish fauna relative to abiotic and biotic factors, specifically the role of the changing hydrograph with time and space, and the effect of introduced fishes on the sustainability of the native fish fauna (Stefferud and Rinne 1995, Rinne and Stefferud 1996). Other components of the overall study effort are the definition of aquatic macrohabitats and their utilization by fishes (Rinne and Stefferud 1996, Neary et al. 1996, Rinne and Neary 1997, Sponholtz and Rinne 1998). Southwestern fishes are highly adapted to the varying cycles of water feast and famine (Minckley 1973, Deacon and Minckley 1974, Rinne and Minckley 1991). However, they are not able to adapt to the complete loss of surface flow, the obvious, critical component to their survival (Rinne 1995b).

Examination of baseflow hydrology in the upper Verde River basin was undertaken in the study reported here to determine the trends in minimum baseflows over the past three decades. Because of recent droughts and the extensive, rapidly increasing urban development in Chino Valley, the headwater of the Verde River drainage system, concerns have arisen over the ability of the river to sustain its native fish population. Understanding this trend is very important for resource managers, who must arrive at decisions regarding land use activities and sustainability of the Verde River spikedace and other native fish. This paper delineates the trends in the upper Verde River minimum mean daily flow, suggests probable mechanisms for the observed changes, and emphasizes the importance and significance of changing minimum flows to the native fish fauna.

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Methods

Streamflow records were obtained from the U.S. Geological Survey, Water Resources Division, Arizona District for the Paulden gage (number 9503700) from 1963 through 1995, the Clarkdale gage (number 9504000) from 1965 through 1995, and the Camp Verde gage (number 9506000). The Paulden gage is located on the Verde River (perennial flow) between the confluence of Granite Creek (ephemeral flow) and Hell Canyon (ephemeral flow), about 14 km below the beginning of perennial streamflow. Its contributing drainage is about 5,568 km^2, or 40 percent of the Verde's 14,000 km^2 basin area (House et al. 1995). The Clarkdale gage is located below the Verde's confluence with Sycamore Creek, about 42 km downstream of the Paulden gage. Its flow-contributing area is 8,148 km^2, or 60 percent of the total river drainage basin. The Camp Verde gage is located downstream of Camp Verde, with a drainage area of 12,028 km^2, or 85% of the total basin area. Flow data are available on the Verde River Watershed Association web site at http://www.verde.org. Monthly and annual discharge data were taken from U.S. Geological Survey gage summary tables. Mean daily flows were analyzed to determine the minimum mean daily flow on an annual basis.

Precipitation data were taken from the Prescott precipitation station (number 026796) for the period 1931 through 1994. The rain gage is about 46 km south of the Paulden streamflow gage.

This preliminary analysis investigates trends in water flow data to guide a more complete analysis of water flow parameters at a later date. It considers only annual minimum daily baseflows and annual maximum daily peakflows.

Baseflow Trends

Mean monthly discharges at Paulden range from 0.67 to 3.62 m^3/s. The mean maximum discharge of 40.77 m^3/s normally occurs in February, and the mean minimum discharge of 0.45 m^3/s occurs in May. During the period of record (1963–1995), the maximum mean daily flow was 387.85 m^3/s in 1993. An instantaneous peakflow of 657 m^3/s occurred during the 20 February 1993 storm (House et al. 1995). The minimum mean daily flow was 0.42 m^3/s in 1964.

The annual minimum daily flows for the period of record that represent the lowest baseflow during each year are shown in Figure 1. They range from a low of 0.42 m^3/s in 1964 to a high of 0.71 m^3/s in 1985, 1986, 1994, and 1995. There is a trend of increasing annual minimum daily flows over this period. The 5-year running average rose from 0.52 m^3/s in 1967 to 0.67 m^3/s in 1995, a 29 percent increase. As of 1995, there does not appear to be any evidence to indicate that water use in the upper Verde River watershed over the past three decades has affected the annual minimum daily flow.

Mean monthly discharges at Clarkdale range from 1.81 to 14.64 m^3/s. The mean maximum discharge of 98.80 m^3/s normally occurs in February, and the mean minimum discharge of 1.76 m^3/s occurs in June. During the period of record (1965–1995), the maximum mean daily flow was 849.30 m^3/s in 1993. An instantaneous peakflow of 1,507 m^3/s occurred during the 20 February 1993 storm (House et al. 1995). The annual minimum mean daily flow was 1.70 m^3/s in 1978.

The annual minimum daily flows at the Clarkdale gage for the period of record are shown in Figure 2. They range from a low of 1.81 m^3/s in 1966, 1967, 1972, and 1981 to a high of 2.32 m^3/s in 1993. Similar to the trend higher up the Verde River at Paulden, there is also a trend of increasing annual minimum daily flows over this period. The 5-year running average rose from 1.88 m^3/s in 1969 to 2.18 m^3/s in 1995, a 16 percent increase.

As streamflow gaging at Paulden and Clarkdale did not start until 1963, it is difficult to determine where the current trends in minimum daily baseflow fit in the long-term pattern of minimum daily baseflow. Data from the incomplete streamflow record at Camp Verde (Figure 3) indicate that annual minimum daily flows in recent times (1989–1994) have been less than those during the 1934–1945 period. It is also interesting to note that the annual minimum daily baseflow decreases between the Clarkdale gage and the Camp Verde gage. This decline is indicative of not only the water diversions that occur in the Clarkdale–Camp Verde reach, but also water surface evaporation, transpiration by riparian vegetation, and seepage into the alluvium of the river.

Mechanisms

The trend of increasing annual minimum daily flows at both the Paulden and Clarkdale stream gaging sites suggests that baseflows in the upper Verde River watershed are increasing in response to either increases in precipitation or reductions in evapotranspirational losses. There is no evidence of the latter, and no major vegetation management programs have occurred in the past three decades that would reduce transpirational losses of water. The remaining mechanism that might explain

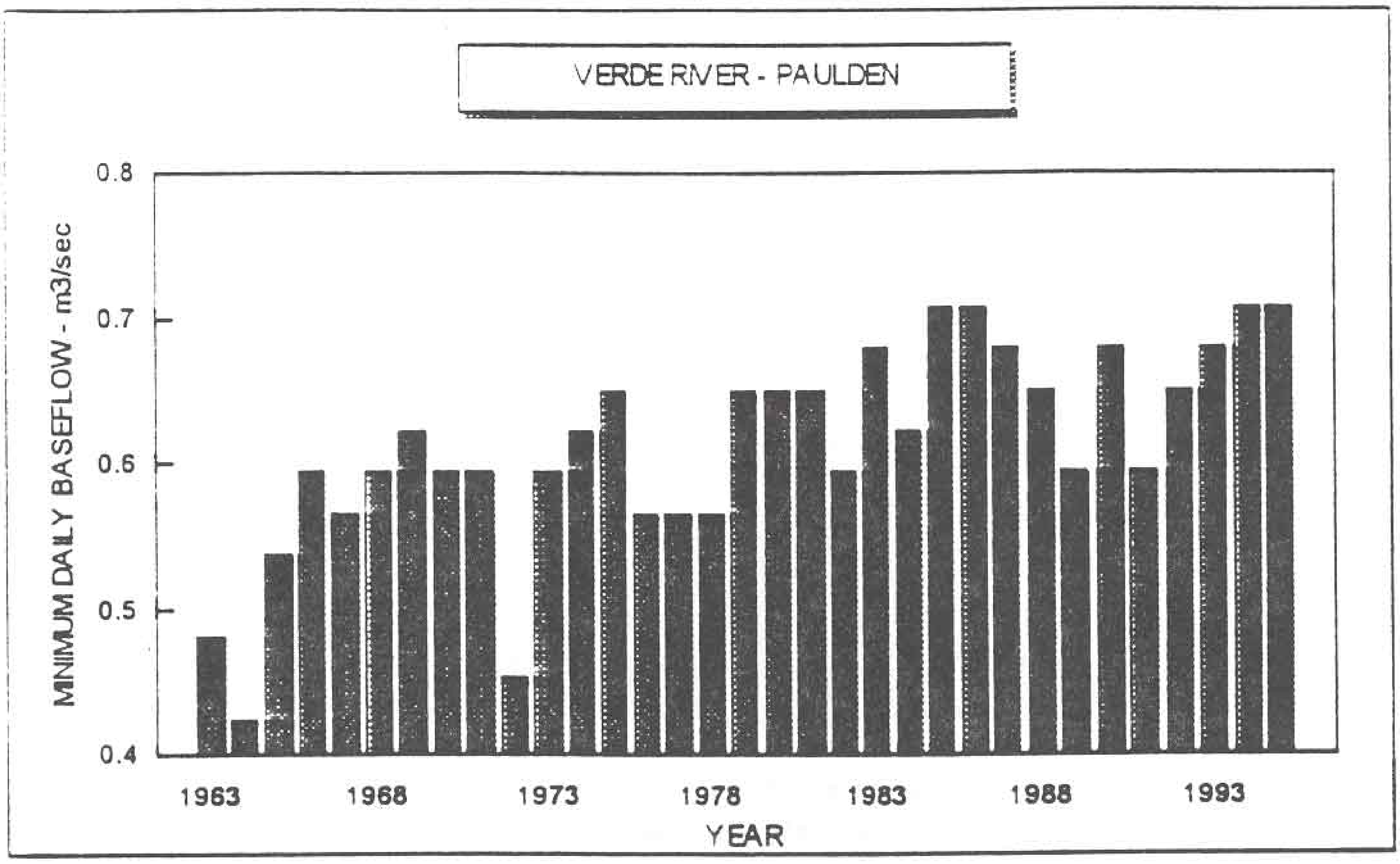

Figure 1. Annual minimum daily baseflows on the Verde River at the Paulden streamflow gage (1963–1995).

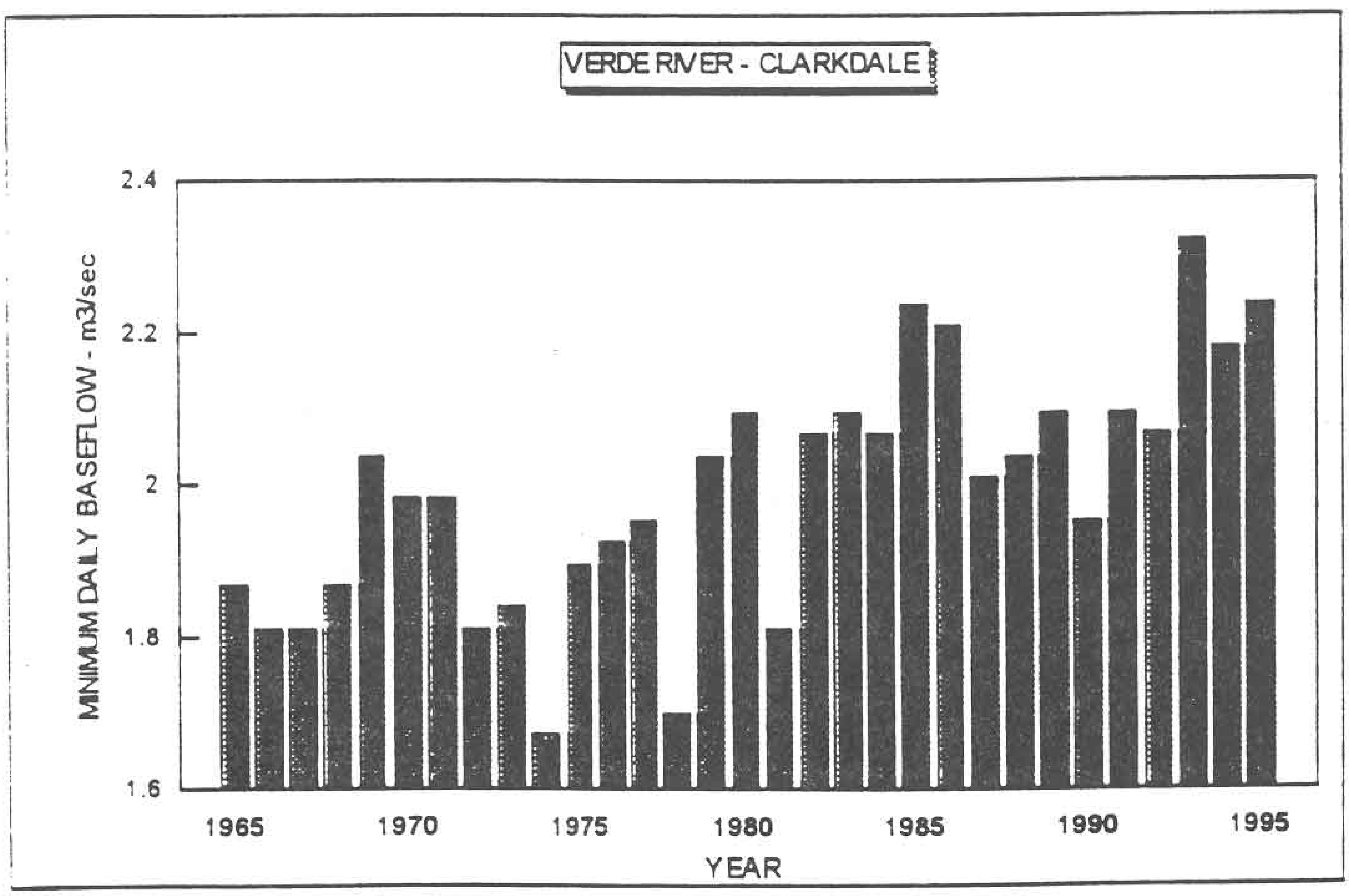

Figure 2. Annual minimum daily baseflows on the Verde River at the Clarkdale streamflow gage (1965–1995).

increases in minimum daily baseflows is precipitation.

Figure 4 shows rainfall at Prescott as a departure from the 1932–1994 mean of 1933 mm. During this time frame there have been wetter and drier periods as indicated by the cumulative departure curve (e.g. wetter, 1932–1946; drier, 1946–1964; wetter, 1965–1972; drier, 1973–1981; wetter, 1981–1988; drier, 1989–1994). The 1964–1994 segment shows a general wetting trend during the period of increasing minimum daily flows in that cumulative departures from the mean have become more positive since the −2,180 mm low point in 1964. This indicates that annual minimum daily flows still seem to generally respond to oscillations in precipitation and not some other hydrologic process such as evapotranspiration. A downward trend in vegetation density in the watershed could possibly reduce evapotranspiration and increase baseflows. Based on photographic evidence, vegetative cover in the upper Verde River riparian zone over the past 30 years has been increasing, not decreasing. There is not enough evidence on upland areas to argue one way or the other.

During the period of time in which annual minimum daily baseflows at the Paulden and Clarkdale gages have been increasing, annual maximum daily peakflows have also been increasing (Figures 5 and 6). Since peakflows have a high degree of year-to-year variability, they are more indicators of an increasingly wetter climate than controlling factors in rising minimum daily flow. Peakflows have definitely increased over the period of record for both the Paulden and Clarkdale gages, culminating in the high flows of February 1993 that were estimated to have a return period of 70 years.

Significance to Fishes

Miller (1961) first reported the decline of native southwestern fishes as a result of man's activities. Dam construction, diversion, and groundwater mining were listed as major factors resulting in aquatic habitat alteration and loss in the Southwest. Rinne and Minckley (1991) further emphasized the continuing decline of the native desert fishes in the region. The upper Verde has been largely spared from the first two major impacts; the influence of the last, groundwater pumping, may be yet to come. Nevertheless, the recorded increase in baseflow on the upper Verde is not only surprising but certainly beneficial to the native fish fauna. Just as floods have been documented to be beneficial to native fishes in this reach of river (Rinne and Stefferud 1996), baseflows are critical to sustaining the native fish community in times of reduced precipitation and runoff. The quantity and quality of streamflow, in time and space, strongly dictate fish habitat and in turn fish populations.

Although unequivocable, quantitative definitions of aquatic macrohabitats in the upper Verde are yet in process (Sponholtz and Rinne 1998), utilization of riffles versus pool habitats has been relatively well defined for members of the native fish community inhabiting the upper Verde River (Rinne 1989, 1991, 1992, Rinne and Stefferud 1996). Shallower water, riffle-dwelling species such as loach minnow (*Rhinichthys cobitis*), spikedace (*Meda fulgida*), speckled dace (*R. osculus*), and longfin dace (*Agosia chyrsogaster*) would be affected first if streamflow is decreased. Speckled dace, longfin dace and spikedace, a threatened species, currently inhabit the upper Verde (Stefferud and Rinne 1995). All three species have been demonstrated to inhabit low-gradient riffles (Rinne 1992, Neary et al. 1996, Rinne and Stefferud 1996) and would be the first to be negatively impacted if streamflow is decreased. Initially, a decrease in flow would reduce reproductive potential in riffles and ultimately would force these two species into pools inhabited by the native predatory species, roundtail chub (*Gila robusta*; Rinne 1992), and introduced smallmouth bass (*Micropterus dolomieui*) and yellow bullhead (*Ictalurus nebulosus*; Rinne and Neary 1997). Fortunately, the increase in baseflow can only be considered as a critical, positive effect on populations of these two species.

Conclusions and Recommendations

At the USGS Paulden gage, near the beginning of perennial flow on the Verde River, mean daily minimums range from 0.42 to 0.71 m^3/sec. The annual minimum mean daily flow at this gage exhibits a trend of increasing minimum flows over the past three decades. At the Clarkdale gaging station above Cottonwood, mean daily minimums vary from 1.70 to 2.32 m^3/sec. Similarly to Paulden, the trend in annual minimum mean daily flows at Clarkdale since 1965 is towards increasing annual minimum daily flows. At the present time, these increases in minimum baseflows on the upper Verde River appear to indicate that adequate flows will be available in the near future to sustain the Verde's fish population. This trend will require future evaluation and monitoring to determine if rapid urbanization of the Prescott and Chino Valley areas in future years will impact baseflow of the upper Verde River.

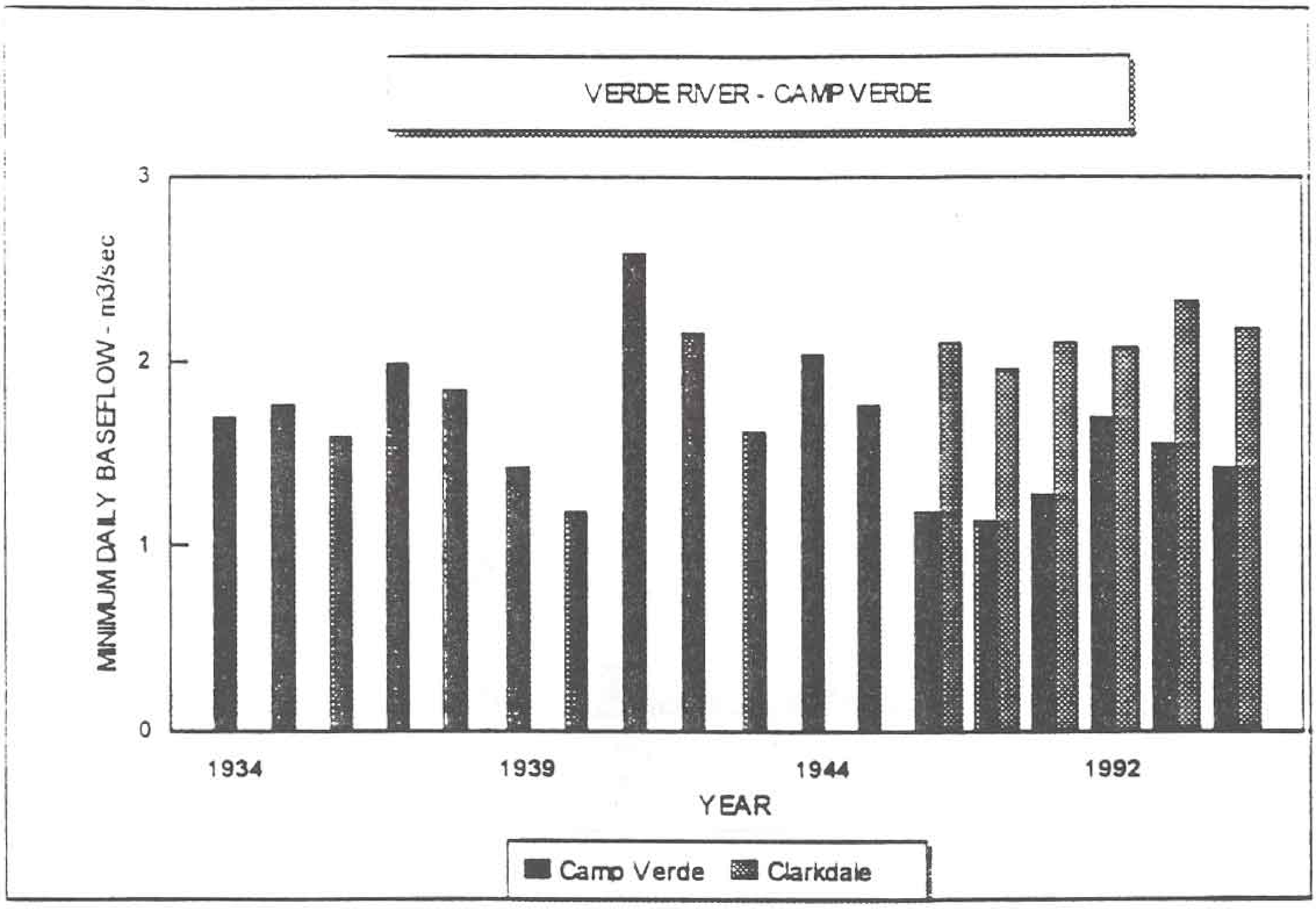

Figure 3. Annual minimum daily baseflows on the Verde River at the Camp Verde streamflow gage (1934–1945 and 1989–1994)).

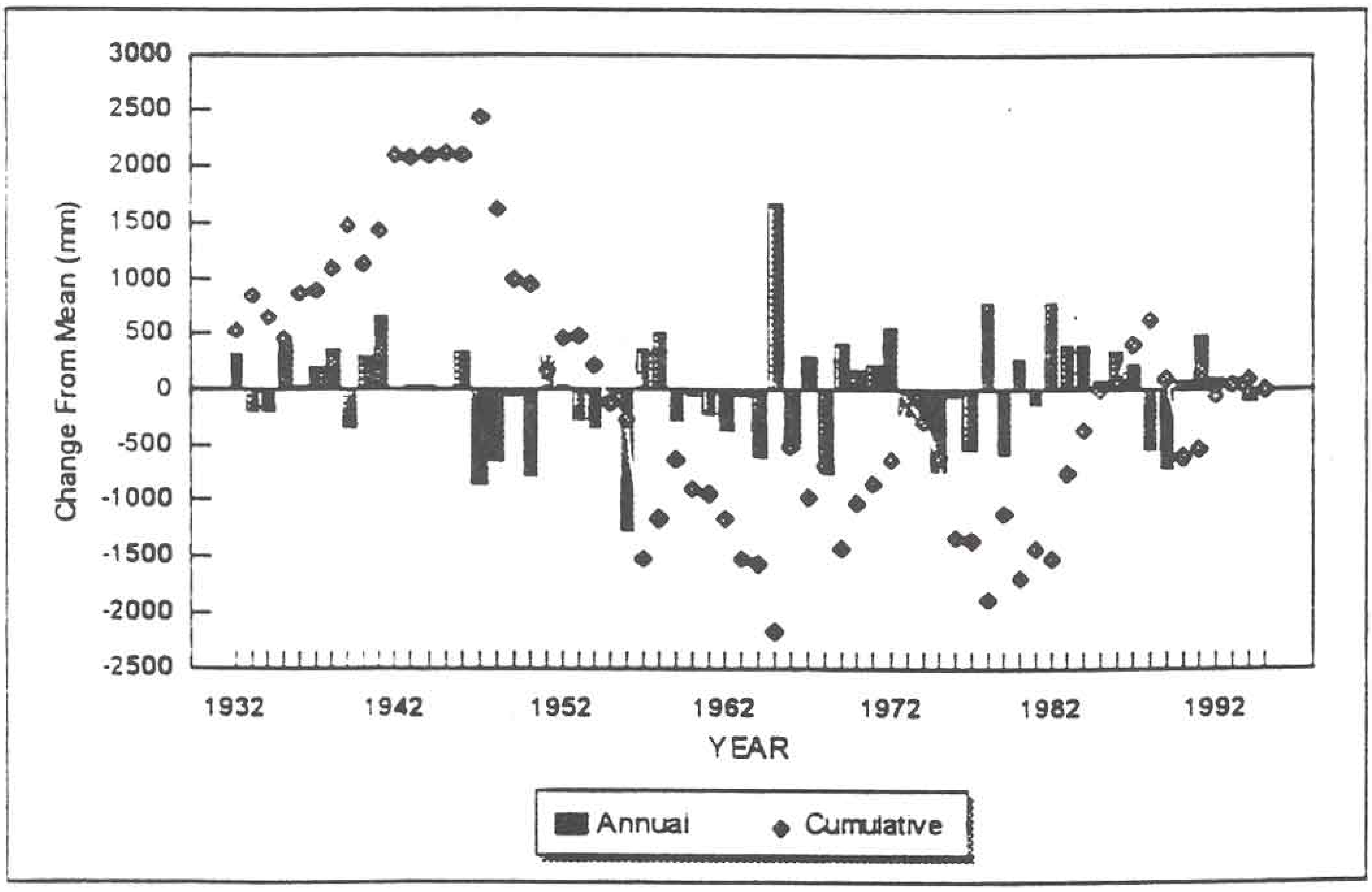

Figure 4. Annual and cumulative rainfall departure from the 1932–1994 mean, Prescott, Arizona, precipitation gage.

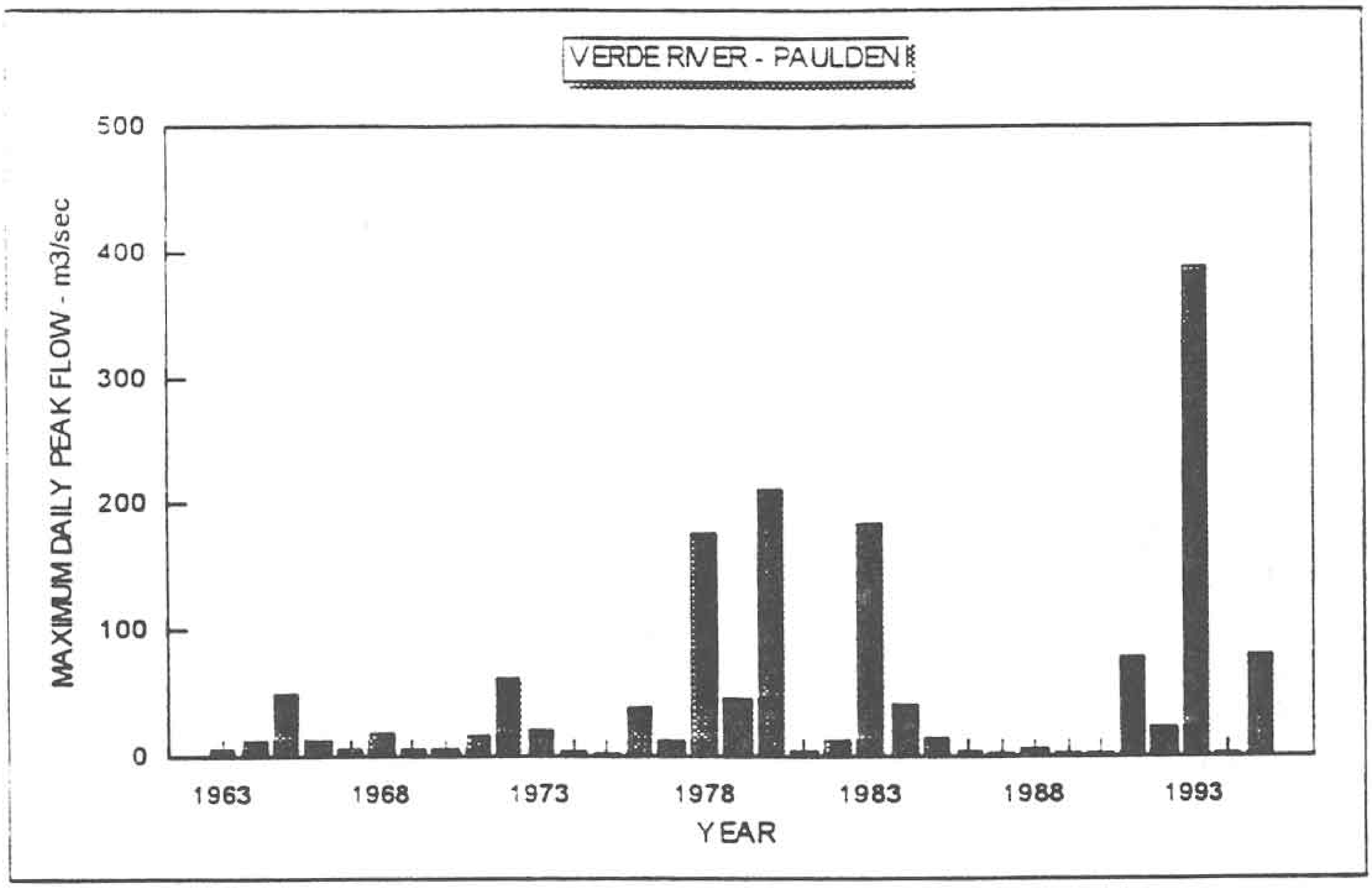

Figure 5. Annual maximum daily peakflows on the Verde River at the Paulden gage (1963–1995).

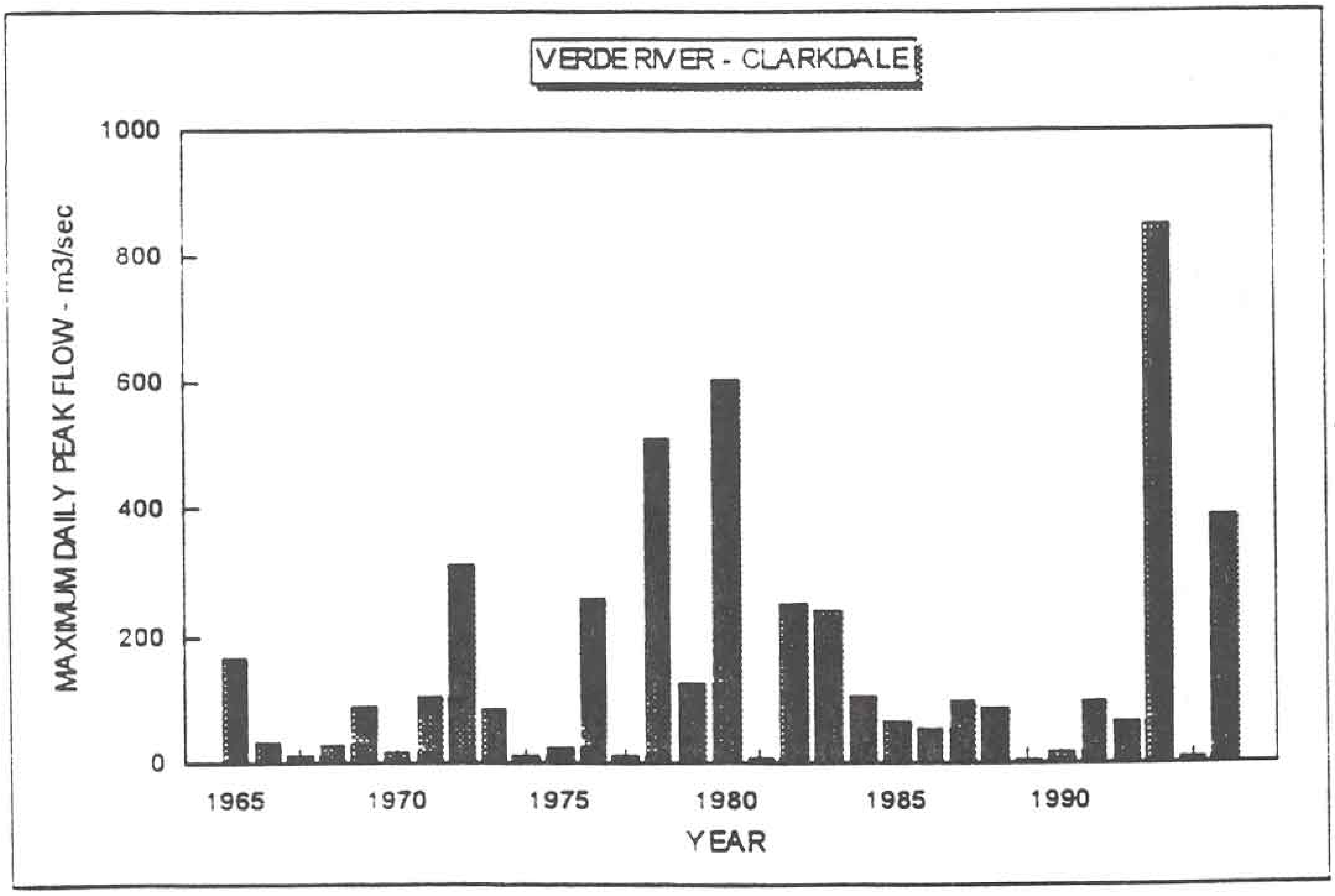

Figure 6. Annual maximum daily peakflows on the Verde River at the Clarkdale gage (1965–1995).

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