United States Department of the Interior

FISH AND WILDLIFE SERVICE
POST OFFICE BOX 1306
ALBUQUERQUE, N.M. 87103

MAY 30 1990

In Reply Refer To:
Region 2/FWE/HC

2-21-86-F-087

MEMORANDUM

TO: Regional Director, Lower Colorado Regional Office, Bureau of Reclamation, Boulder City, Nevada

FROM: Regional Director, Region 2

SUBJECT: Biological Opinion, Central Arizona Project, Water Exchange Project, Upper Verde River, Arizona

This responds to your request of October 24, 1988, for formal consultation pursuant to Section 7 of the Endangered Species Act (Act) of 1973, as amended, on your implementation of the Central Arizona Project (CAP) Water Exchanges on the Verde River in Yavapai County, Arizona. The species of concern is the threatened spikedace (Meda fulgida). Your consultation request indicated that project impacts to the bald eagle (Haliaeetus leucocephalus) and the experimental nonessential population of Colorado squawfish (Ptychocheilus lucius) would be addressed at a later date.

Because of the length and complexity of this biological opinion, the following table of contents and list of figures and tables have been included.

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CONSULTATION HISTORY

The 90-day consultation period for the spikedace began on October 26, 1988, the date your request was received in our office. A 45-day extension of the consultation period was requested by the Fish and Wildlife Service (Service) and was agreed to by the Bureau of Reclamation (Reclamation) on January 24, 1989. On March 7, 1989, the consultation was placed on indefinite suspension to allow the City of Prescott (Prescott) and Reclamation to develop additional alternatives. On January 4, 1990, the Service received your revised biological assessment containing the additional alternative and requesting reopening of consultation. Mutual agreement between Reclamation and the Service established a new consultation end-date of April 9, 1990. A draft biological opinion was sent to Reclamation on March 16, 1990 for review of the reasonable and prudent alternatives as requested by Reclamation. Your comments on that draft were received by the Service on April 16, 1990. By additional agreement between Reclamation and the Service, this biological opinion is due on or before May 31, 1990.

On April 14, 1986, the Service provided Reclamation with a conference report, under Section 7(a)(4) of the Act, addressing impacts of the Verde River CAP Water Exchanges on the spikedace, which was then proposed as threatened, and to its proposed critical habitat. That report found that the project would likely adversely modify proposed critical habitat and jeopardize the existence of the spikedace. No recommendations to minimize or avoid adverse impacts were made in the conference report due to a lack of engineering and biological information. This biological opinion amends the conference report.

The two alternative schedules on which Reclamation has requested consultation both entail joint water diversion by Prescott and the Yavapai-Prescott Indian Community (Yavapai-Prescott). However, the March 1988 biological assessment submitted by Reclamation also set forth limited data on separate diversion of only the Yavapai-Prescott allocation. Discussion with Reclamation and Yavapai-Prescott representatives on January 31, 1989 indicated that if the Yavapai-Prescott allocation were to be developed separately from that of Prescott a number of alternatives would need to be developed and analyzed regarding siting, diversion type, and other factors. At a March 16, 1989 meeting, Yavapai-Prescott representatives stated they wanted to complete this consultation without analysis of their options for separate water development. In addition, an October 2, 1989 letter from Prescott states that they are acting as agent for the Yavapai-Prescott pursuant to their comprehensive Water and Sewer Agreement of 1980 and have recently confirmed with the Yavapai-Prescott that the proposed diversion schedules would provide water for both Prescott and the Yavapai-Prescott. Therefore, the following biological opinion addresses only the joint project alternatives.

This biological opinion is based on information provided in Reclamation's March 1988 biological assessment, January 2, 1990 revised biological assessment, and February 2, 1990 supplemental information; information presented by Prescott/Yavapai-Prescott representatives at a March 16, 1989 meeting in Phoenix; a June 16, 1989 letter from Gookin Engineers (consultants to Prescott) to the Service; the Service's December 1989 Fish and Wildlife Coordination Act report; data in Service and Arizona Game and Fish Department (AGFD) files; and other sources of information.

BIOLOGICAL OPINION

It is my biological opinion that implementation of the proposed CAP Water Exchanges on the upper Verde River, including both the original (March 1988) and additional (January 1990) diversion schedules and sites, is likely to jeopardize the continued existence of the threatened spikedace. Reasonable and prudent alternatives are provided that would, if followed, remove the jeopardy.

CONFERENCE REPORT AMENDMENT

The April 14, 1986 conference report on the Verde River CAP Water Exchanges is amended as follows: "Implementation of the reasonable and prudent alternatives of the May 29, 1990, biological opinion on the Central Arizona Water Exchange Project, Upper Verde River, would remove the determination that the project would result in adverse modification of proposed spikedace critical habitat."

BACKGROUND INFORMATION

Species Description

The spikedace was listed as a threatened species on July 1, 1986. Critical habitat was proposed for the spikedace on June 18, 1985 for portions of 8 streams, including the Verde River from Sullivan Dam (NE 1/4 of the NW 1/4 Section 15, T.17N., R.2W.) downstream to 1.25 miles below the confluence with Sycamore Creek (south boundary of the NW 1/4 Section 17, T.17N., R.3E.) (Figure 1). That proposal is still pending.

The spikedace is a monotypic genus endemic to the Gila River basin. It is a small silvery minnow, reaching a maximum size of about 2.5 inches. Its historic distribution included the mainstream and moderate gradient perennial tributaries of the Gila River upstream from the site of present-day Phoenix (Minckley 1973) (Figure 2). Habitat destruction and/or competition and predation by introduced non-native fish have reduced that range by about 94 percent. The spikedace now exists in limited portions of the upper Gila River in New Mexico, and Aravaipa Creek, Eagle Creek, and the upper Verde River in Arizona.

In the upper Verde River, spikedace are known to occupy a stretch of the river in Yavapai County, extending from the most upstream end of perennial flow below Sullivan Dam (NE 1/4 of the NW 1/4 Section 15, T.17N., R.2W.) downstream to slightly below the confluence with Sycamore Creek (NW 1/4 Section 17, T.17N., R.3E.), a distance of about 36 miles (Figure 1). The Verde River population occupies approximately one-third of the existing stream miles of known spikedace habitat. Of the five remaining spikedace populations, only the Cliff/Gila Valley population in the upper Gila River in New Mexico contains a more substantial population than the upper Verde River.

Spikedace in the Verde River are generally least abundant in the most downstream end of their range and increase in abundance with distance traveled upstream, although populations fluctuate in distribution and numbers from year to year. There is a corresponding increase in predominance of native fish over non-native fish as you move upstream. At Tapco, downstream from the confluence with Sycamore Creek, native fish comprised only 61 percent of the fish collected during sampling conducted by the Service and Reclamation in 1986 (USFWS 1989), while at the most upstream collection site (Forest Road 638) native fish comprised 96 percent of the fish collected. Although spikedace populations naturally undergo frequent and relatively large fluctuations, the population in the Verde River appears to be stable within the bounds of those fluctuations.

Spikedace live in flowing water with slow to moderate water velocities over sand, gravel, and cobble substrate (Anderson 1978, Propst et al. 1984, Propst et al. 1986). Specific habitat for this species consists of shear zones

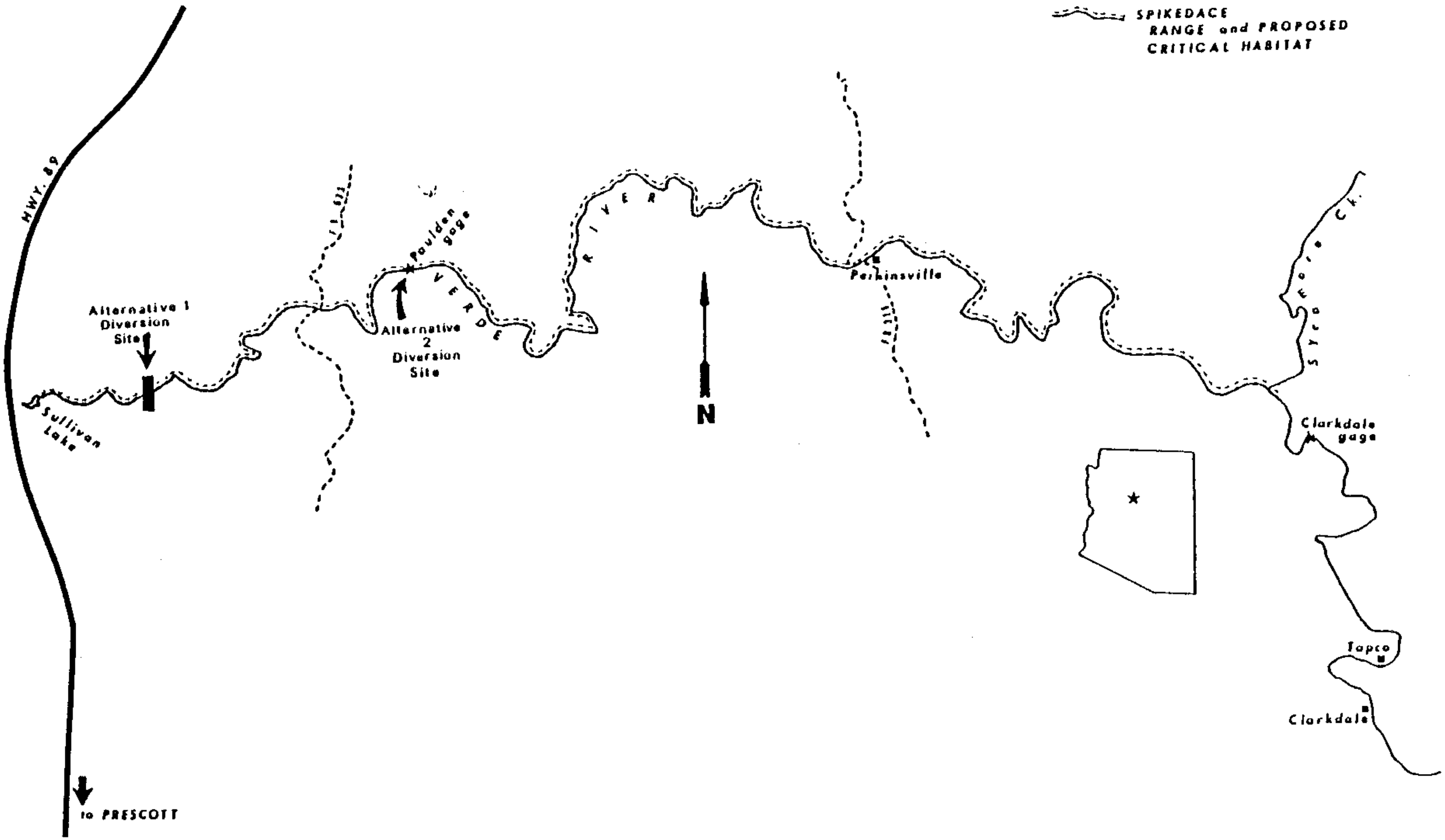

FIGURE 1. SPIKEDACE DISTRIBUTION, PROPOSED CRITICAL HABITAT, AND THE PROPOSED CENTRAL ARIZONA PROJECT WATER EXCHANGE PROJECT; UPPER VERDE RIVER, YAVAPAI COUNTY, ARIZONA

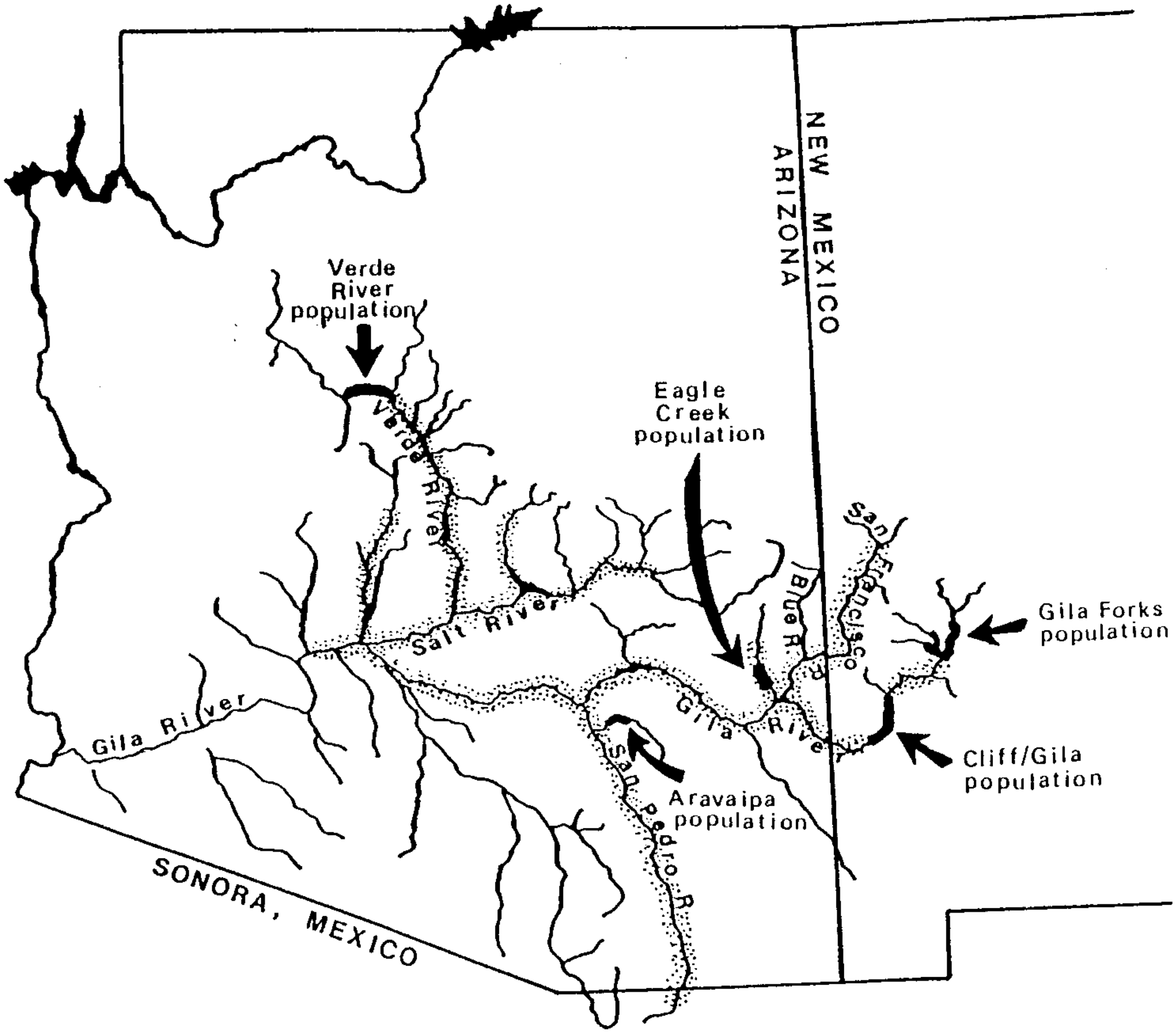

FIGURE 2. HISTORIC AND PRESENT RANGE OF THE SPIKEDACE (Historic range shown as stippling; present populations shown in solid black)

where rapid flow borders slower flow, areas of sheet flow at the upper ends of mid-channel, sand/gravel bars, and eddies at downstream riffle edges. However, habitat use varies geographically, seasonally, and ontogenetically. Studies indicate that in general adult spikedace primarily use water velocities of about 0 to 3 feet per second in depths of about 0.1 to 1.25 feet, while juveniles generally use slightly slower water (0 to 2 feet per second) and a wider range of depths (0.1 to 2.25 feet), and larvae use much slower (0 to 1 feet per second) and slightly shallower water (0.1 to 1 feet) (Anderson 1978, Barber and Minckley 1966, Propst et al. 1986, Turner and Tafanelli 1983, USFWS 1988, USFWS 1989).

Some differences have been noted in habitat use between geographical portions of remaining spikedace range. Propst et al. (1986) found that spikedace in the Gila River used slower and deeper water in the Forks area than in the Cliff/Gila Valley area. Comparison of habitat preference curves developed for the upper Verde River spikedace population (USFWS 1989) and the Cliff/Gila Valley population of Gila River spikedace (USFWS 1988) indicates that adult spikedace in the Verde River use slightly shallower water than in the Gila River, that juvenile spikedace in the Verde River use slightly faster and deeper water than in the Gila River, and that spikedace larvae in the Verde River use shallower and slower water than in the Gila River.

Propst et al. (1986) also noted shifts in spikedace habitat use between seasons. In the Gila River in the Cliff/Gila Valley, spikedace moved to slower velocities during cold periods, although those velocities were still higher than those generally occupied by spikedace in the Forks portion of the Gila River. However, they found that in the Forks area, the fish moved to shallower water during cold periods, thus occupying slower water of about the same depth as spikedace in the Cliff/Gila population. The differing responses to cold temperatures appear to be due to differences in thermal cover offered by the two areas; slow-velocity areas in the lee of sand/gravel bars in the Cliff/Gila Valley and cobbled banks in the Forks area.

Spikedace spawn from March through May with some yearly and geographic variation (Anderson 1978, Barber et al. 1970, Propst et al. 1986), based on studies of egg development and observation of males in breeding coloration. Actual spawning has not yet been observed in spikedace, but spawning behavior has been observed and it is presumed that the eggs are laid over gravel and cobble where they adhere to the substrate. No data are available on incubation and hatching times or needs. Both Barber et al. (1970) in Aravaipa Creek and Anderson (1978) in the Gila River found that spawning appeared to occur when maximum daytime water temperatures reached 19° C. Both of those studies also indicated that some spikedace spawn a second time in May. Propst et al. (1986) did not find any evidence of such a second spawning in their studies in the Gila River. Spikedace in breeding condition have been noted in the Verde River at Forest Road 638 on March 7, 1986 in water 22° C, on April 23, 1986 just upstream from Sycamore Creek in water 19° C, and on May 5, 1987 at Forest Road 638 in water 23° C (USFWS unpublished data). Arizona Game and Fish Department (AGFD) personnel have observed spikedace in spawning coloration in the Verde River only at Forest Road 638 (D. Hendrickson, AGFD, pers. com., February 9, 1989). Forest Road 638 is only a few miles below one of the alternative diversion sites and is in the portion of the Verde River which would be most severely impacted by that diversion.

Temperature requirements of spikedace are poorly known. Studies have shown spikedace to occur in temperatures from 5.6 to 26.7° C with significant seasonal and geographical variation (Barber and Minckley 1966, Propst et al. 1986). Spikedace live about two years with reproduction occurring primarily in one-year old fish. Spikedace tend to move in aggregations but do not appear to move large distances. They drift only when discharge volumes are very high. They feed primarily on aquatic and terrestrial insects (Anderson 1978, Barber and Minckley 1983, Propst et al. 1986).

Project Description

In 1983, the Secretary of Interior allocated water from the CAP to 120 Arizona users. Eight of those users are located on the upper Verde River in central Arizona. Those eight users plan to exchange their CAP water allocations with downstream holders of state-permitted Verde River basin water rights. This would allow them to divert their allocations directly from the Verde River (Gookin and Assoc. 1983). Diversions of two of those users are expected to affect spikedace; the Prescott allocation of 7,127 acre-feet per year (af/yr), and the Yavapai-Prescott allocation of 500 af/yr (7,627 af/yr total diversion). These two entities have submitted a joint proposal to Reclamation to divert their allocation from the Verde River near the upstream end of spikedace range. Two alternative diversion sites and water withdrawal schedules have been proposed and are analyzed here: 1) as proposed in the March 1988 biological assessment; and, 2) as proposed in the January 2, 1990 revised biological assessment and February 2, 1990 supplement.

Alternative 1 would divert water from the Verde River in T.17N., R.2W., SW 1/4 Section 12, Yavapai County, Arizona (Figure 3), approximately 2 miles downstream from the beginning of perennial flow at Sullivan Dam. The water would be removed from the river by an infiltration gallery buried in the streambed (also known as a French drain) (Figure 4). The subsurface flow would be partially blocked downstream from the gallery with sheet piling to aid in water capture. Water would be piped from the river up the north side of the canyon, west to the Santa Fe railroad, and south along the railroad to a point near the Little Chino Valley well field (Figure 3). Existing pipelines would then be used to transport the water to the City of Prescott and Yavapai-Prescott Reservation. The diversion schedule proposed for alternative 1 is based on seasonal demand with the highest demand during June and July (Table 1). The maximum instantaneous diversion capacity of the system would be 15.05 cubic feet per second (cfs). The proposed monthly diversion rates are those which would normally occur and actual diversion for any given month may be substantially different, potentially ranging from 0 up to the 15 cfs maximum diversion capacity. Several important aspects of the construction and operation of the alternative 1 diversion were not specified in the biological assessment or other supporting documents. Therefore, for the purposes of this analysis we have made several assumptions regarding alternative 1. If further development of this proposal makes these assumptions invalid, then additional analysis of impacts and reinitiation of consultation would be necessary. Assumptions are as follows:

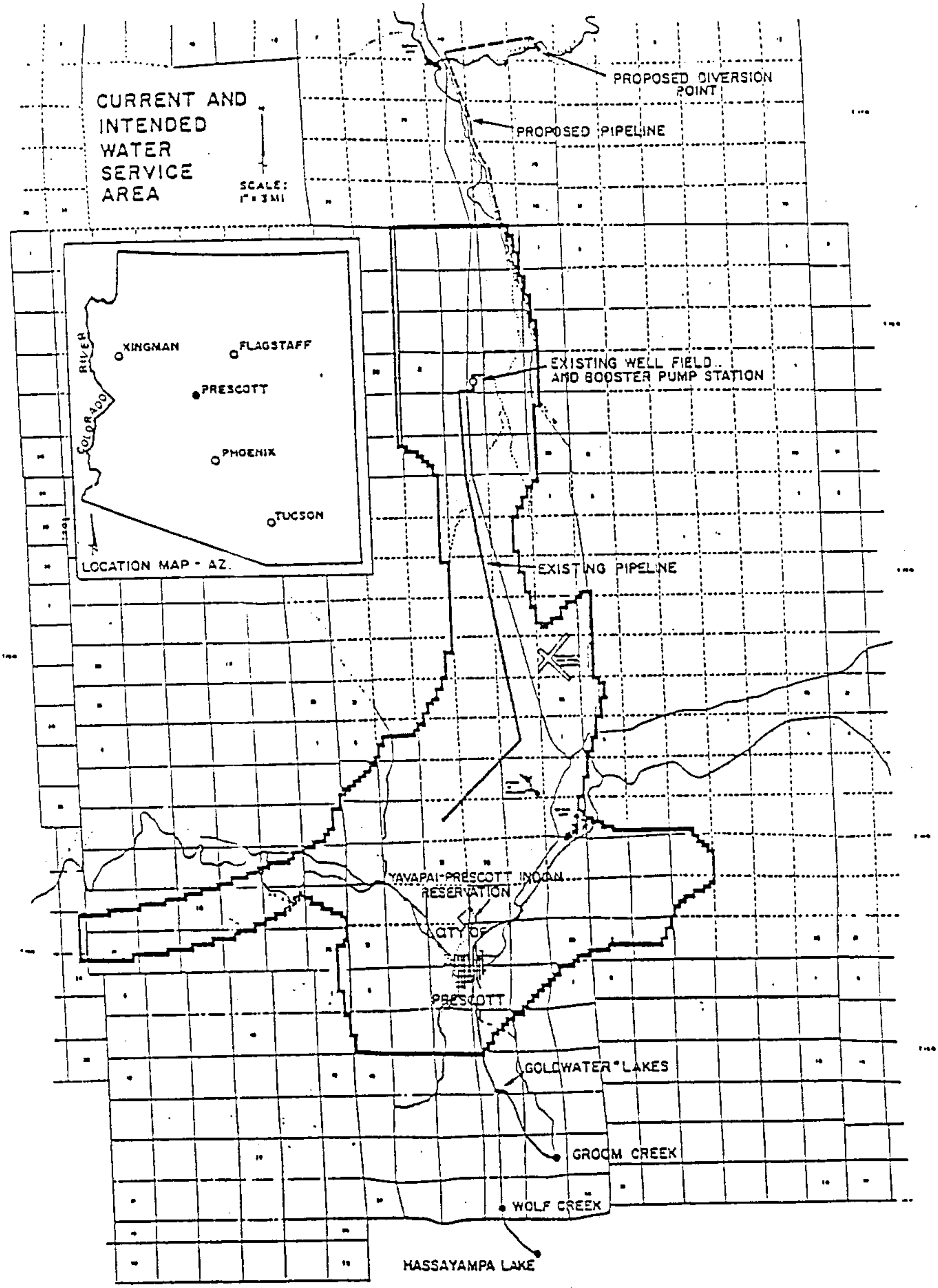

FIGURE 3. LOCATION OF ALTERNATIVE 1 - PRESCOTT/YAVAPAI-PRESCOTT INDIAN COMMUNITY PROPOSED CAP DIVERSION SITE AND PIPELINE, VERDE RIVER, ARIZONA (from Gookin and Assoc. 1983)

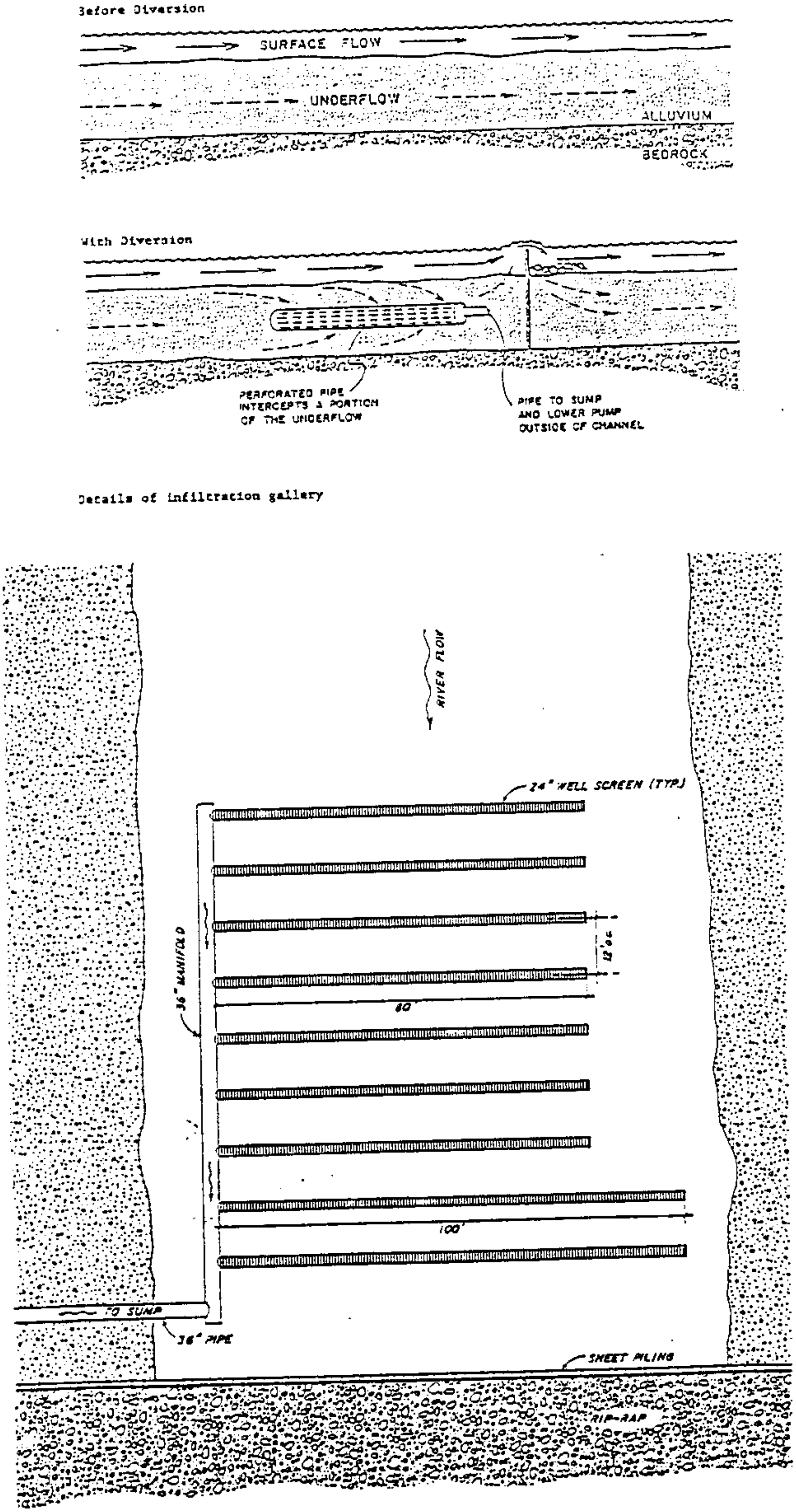

FIGURE 4. DIVERSION STRUCTURE, ALTERNATIVES 1 AND 2 - PRESCOTT/ YAVAPAI-PRESCOTT INDIAN COMMUNITY PROPOSED CAP DIVERSION, VERDE RIVER, ARIZONA (from Gookin and Assoc. 1983)

TABLE 1. PROPOSED DIVERSION SCHEDULES FOR CITY OF PRESCOTT/YAVAPAI-PRESCOTT INDIAN COMMUNITY CAP WATER DIVERSION FROM THE VERDE RIVER, ARIZONA

	ALTERNATIVE 1				ALTERNATIVE 2				
	EXISTING FLOWS AT PROPOSED DIVERSION SITE (cfs)[1]		DIVERSION AMOUNT		EXISTING FLOWS AT PROPOSED DIVERSION SITE (cfs)[2]		DIVERSION AMOUNT		GUARANTEED MINIMUM IN-STREAM FLOW
MONTH	Median	Historic low	cfs	af/mth[a]	Median	Historic low	cfs	af/mth	cfs
January	17.3	13.6	8.37	498	25.5	20	15	893	10
February	18.1	12.2	7.85	467	26.6	18	15	893	10
March	18.2	10.9	7.63	454	26.8	16	0	0	25
April	17.3	12.9	10.59	630	25.4	19	0	0	25
May	16.9	10.2	12.29	731	24.9	15	0	0	25
June	16.4	12.2	15.05	896	24.1	18	0	0	24
July	16.7	13.6	14.93	888	24.5	20	12	714	12
August	17.2	11.6	11.54	687	25.3	17	13	774	12
September	16.3	12.9	11.02	656	24.0	19	13	774	12
October	16.3	12.2	9.54	568	24.0	18	15	893	10
November	16.7	13.6	9.22	549	24.6	20	15	893	10
December	17.1	13.6	9.12	543	25.2	20	15	893	10
Ave.	17.0		10.6		25.1		9.4		15.4
Total				7567[4] (af/yr)				6727 (af/yr)	

[1]Proposed diversion site for Alternative 1 is about 2 miles downstream from Sullivan Lake. Flows for this site are calculated at 68% of those at the Paulden gage.

[2]Proposed diversion site for Alternative 2 is near Paulden gage. Flow data are from USGS gage records at Paulden gage; period of record 1964-1986.

[a]Acre-feet per month = cubic feet per second x 59.5.

[4]Total CAP allocation is 7627 acre-feet per year.

1. Gookin and Assoc. (1983) indicate that the sheet piling may be installed to block all subsurface flow; or, may either be perforated or raised above bedrock to allow some subsurface flow to continue downstream. We have assumed that a substantial amount of the existing subsurface flow would be passed by the sheet piling.
2. The sheet piling would extend a short distance above the existing channel surface. We have assumed that this would not result in any significant pooling of water behind the sheet piling.
3. The temporary coffer dam used during construction would not result in significant impoundment of water and would not alter the downstream flow regime.
4. The size of the infiltration gallery would be similar to that outlined in Gookin and Assoc. (1983).
5. The monthly diversion rate would remain constant throughout the month and would not fluctuate on a hourly, daily, or weekly basis.

Alternative 2 would divert water from the Verde River at the site of the U.S. Geologic Survey (USGS) Paulden gaging station, approximately 10 miles downstream from Sullivan Dam in T.18N., R.1W., SE 1/4 Section 34 (T.18N., R.1W., Section 39), Yavapai County, Arizona (Figure 5). The water would be removed from the river by the same method as in alternative 1 (Figure 4). Water would be piped from the river up the south side of the canyon and would follow existing Forest Service roads to U.S. Highway 89. It would then follow the highway to the Little Chino Valley well field where it would merge with the existing water transport system. The proposed diversion schedule for alternative 2 is oriented toward accommodating some of the biological needs of the spikedace with no water being diverted during the spawning and larval periods and the highest diversions occurring in the fall and winter (Table 1). Although this schedule would withdraw higher amounts of water during the months of lowest demand, no storage facilities would be necessary other than a minor amount to be accommodated by storage tanks within the town of Prescott. Monthly diversion rates would vary from those on Table 1 according to conditions; however, only flows greater than the "guaranteed minimum" flow would be diverted. The maximum instantaneous diversion capacity of the system has not been determined. Assumptions made regarding unspecified aspects of the alternative 2 diversion are as follows:
1. Assumptions one through four under alternative 1 also apply to alternative 2.
2. The maximum instantaneous diversion capacity of the system would not exceed 25 cfs.
3. Specified minimum flows would remain constant throughout the month and would not fluctuate on a hourly, daily, or weekly basis. When natural flows exceed 25 cfs maximum instantaneous diversion capacity, then hourly, daily, and weekly fluctuations would reflect the pre-project hydrograph.
4. The instantaneous instream flow rate below the diversion would not be allowed to drop below the specified minimum flow at any time during the month. If the natural flow of the river at the diversion site is less than the guaranteed minimum then the guaranteed minimum flow downstream from the diversion would equal the natural flow and no diversion would take place.

Invalidation of any one of the above assumptions due to additional project development would require addition Section 7 consultation.

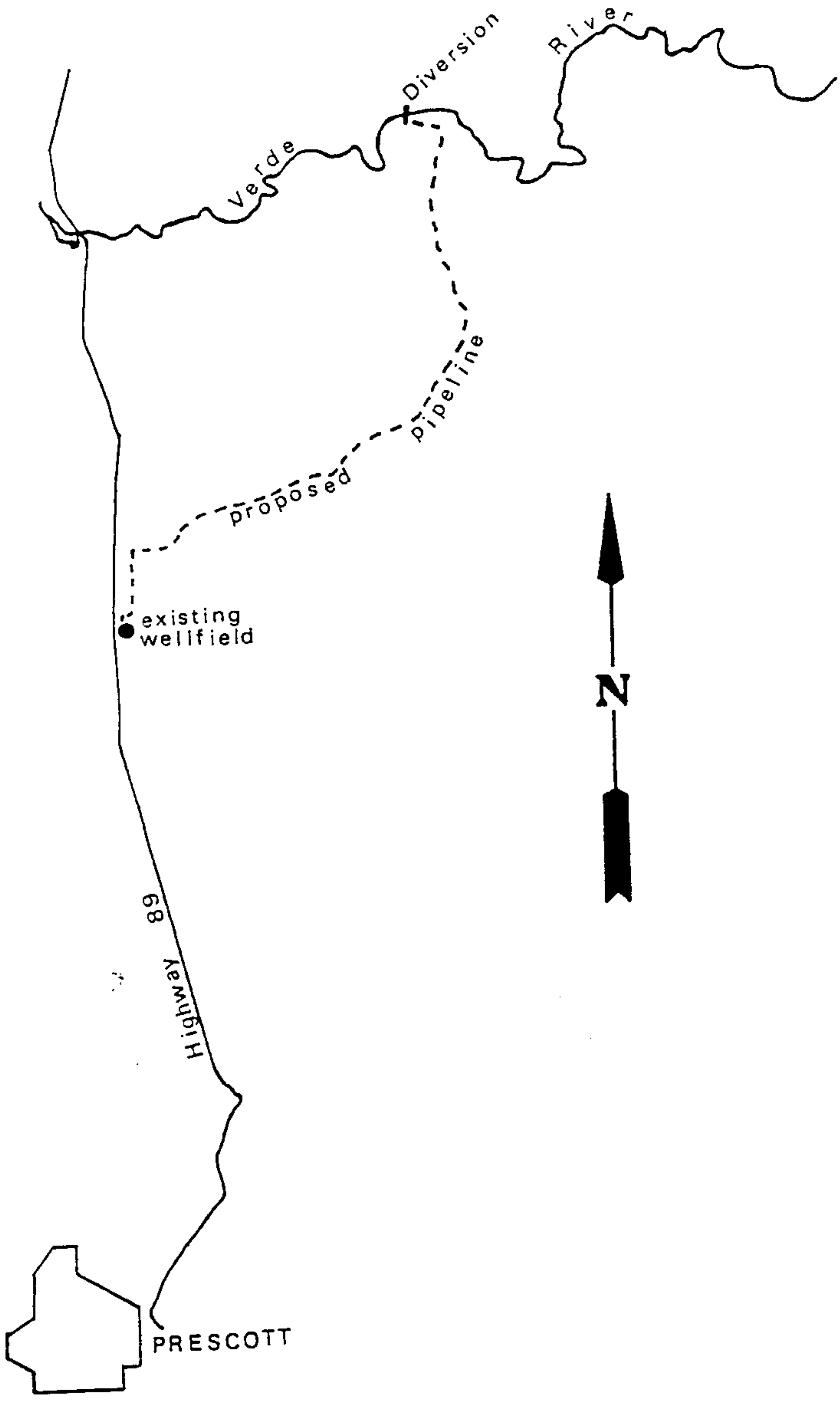

FIGURE 5. LOCATION OF ALTERNATIVE 2 - PRESCOTT/YAVAPAI-PRESCOTT INDIAN COMMUNITY PROPOSED CAP DIVERSION SITE AND PIPELINE, VERDE RIVER, ARIZONA

IMPACTS OF THE ACTION

The proposed CAP Water Exchange Project would severely reduce or eliminate the spikedace population in the Verde River under either alternative. This would occur as a result of direct and indirect impacts and through cumulative effects of this and other ongoing or future actions. Adverse impacts of the proposed action would result from two facets of the project, the construction and operation of the diversion facility and the changes in volume and timing of water flow in the river within the range of the spikedace. Analysis of these impacts must be based on the change from the existing situation (environmental baseline) which may differ significantly from the conditions which existed in the upper Verde River prior to settlement of the area by people of European descent.

Environmental Baseline

Although all streams in the American southwest have been affected to some extent by human-caused disturbances, the existing spikedace habitat in the upper Verde River remains comparatively unimpacted. Lands adjacent to the upper Verde River are rugged and are primarily managed by the Prescott National Forest, thus limiting access and development. It is the relatively undisturbed character of the aquatic and riparian ecosystems in this area that has enabled the majority of the historic native fish species to survive. Of the ten fish species known to historically inhabit this portion of the Verde River, six remain. In the entire Gila River basin, only four other areas still maintain that many native fishes; the San Francisco/Blue Rivers in Arizona/New Mexico, the Forks area and Cliff/Gila Valley of the Gila River in New Mexico, and Aravaipa Creek in Arizona. The common factor between the five areas, four of which support spikedace, is the relatively intact, unaltered nature of the streams, their channels, and the aquatic and riparian habitat.

However, the upper Verde River and its watershed have not been entirely exempt from human uses that cause direct or indirect negative effects on the spikedace and other native fish species. These impacts are cumulative, both spatially and temporally, and have collectively resulted in the elimination of four of the original native fish species from the river. This portion of the proposed critical habitat of the spikedace has already been subjected to adverse alterations and it is likely that the remaining spikedace population now persists under less than optimal habitat conditions with substantial stress due to various human-caused habitat alterations. Historic and current livestock grazing, mining, road construction, railroad construction, off-road vehicle (ORV) use, recreation, agriculture, groundwater pumping, and urban development within the watershed have altered runoff patterns, soil erosion patterns, and riparian and upland vegetation; thus affecting river sediment loads, water temperatures, nutrient loads, substrate, water chemistry, channel morphology, and volume and timing of flows. Present patterns of rapid growth in the communities of the watershed threaten to impact the river indirectly through increased groundwater pumping, increased upstream watershed disturbances and pollution, and increased recreational use of the river and riparian zone.

Non-native fish species have been introduced by man into the Verde River system and have adversely affected spikedace and other native fish populations through competition and predation. Non-native species currently reported to exist within the upper Verde River spikedace range include red shiner (Cyprinella [formerly Notropis] lutrensis), mosquitofish (Gambusia affinis), yellow bullhead (Ictalurus natalis), carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), smallmouth bass (Micropterus dolomieui), green sunfish (Lepomis cyanellus), and flathead catfish (Pylodictis olivaris). While native species form the majority of the fish community in the headwaters of the Verde River above Sycamore Creek, non-native fish now predominate in the Verde River downstream from the head of the Verde Valley. Native and non-native fishes maintain an unstable ratio in the stretch of river between the upper end of the Verde Valley and the mouth of Sycamore Creek. During 1986 sampling, native species formed only 61 percent of the population in that stretch. However, in 1988-89 native species were much more prevalent than non-native species, (D. Hendrickson, AGFD, pers. com., February 9, 1989). This resurgence in native species is thought to be a result of several heavy floods which had disproportionately higher adverse impacts on non-native fishes. Upstream from Sycamore Creek, in the area still occupied by spikedace, the habitat retains enough of its historic condition and natural hydrograph to keep non-native species to a low level and allow native species to remain dominant. The habitat is relatively unsuitable for non-native fish and they are generally confined to backwater areas. Any further changes to the river and the habitat of the native species may create conditions which are more favorable to the non-native species and would thus be detrimental to the survival of the natives, including the spikedace.

Although most of the non-native fish have some negative impacts upon the spikedace, it is particularly the red shiner that may pose a significant threat (Marsh et al. 1989). Red shiner have been implicated in the decline of spikedace in other portions of its range, and the upper Verde River is the only known site at which red shiner and spikedace have been able to coexist for more than a few years. Red shiner were first found in the Verde River in 1963, although the population was well established at that time and had likely been introduced as bait several years previously (Arizona State University fish collection). Study of the mechanisms which allow coexistence of the two species is vital to the survival and recovery of the spikedace as a whole. The Verde River population may be the key to discovering that mechanism.

The effects of historic and present perturbations in the project area and downstream in the Verde, Salt, and Gila Rivers have resulted in the isolation of the existing Verde River remnant population of spikedace. The nearest known extant population of spikedace, in terms of connecting river passages, is the population in Aravaipa Creek; a distance of several hundred miles. Historically, the spikedace occurred in suitable habitat throughout the intervening river reaches but have since been extirpated. The Verde River spikedace population is now the only remaining remnant of the northern portion of the historic range.

Impacts to Spikedace from Construction and Operation of the Diversion Facility

Construction and operation of the proposed diversion facility itself would have adverse impacts on the spikedace under both alternatives 1 and 2. Because water removal would be accomplished by means of an infiltration gallery embedded in the stream bottom, the actual impact of daily operation of the diversion facility on the spikedace would be limited. No entrainment, entrapment, or impingement of fish would occur, and because no impoundment is necessary, habitat losses would be localized. However, some adverse effects would occur, primarily as a result of construction and maintenance.

Construction of the infiltration gallery would destroy a small section of the aquatic habitat of the Verde River. The infiltration gallery is expected to be about 100 feet wide by 100 feet long (Gookin and Assoc. 1983). From that we have estimated that approximately 300-500 linear feet of riverbed would be subjected to excavation and heavy machinery traffic. This would likely directly destroy some spikedace habitat, although the extent of loss would depend upon the exact siting of the structure. Because the average width of the wetted area of the stream at base flow at the alternative 1 diversion site is about 12 feet and at the alternative 2 diversion is about 30 feet, the stream channel would need to be considerably widened at the diversion site to accommodate the infiltration gallery. This channel restructuring would create short-term suspended sediment as well as necessitating the removal and dumping of dirt and rock. It would also result in removal of the riparian vegetation at the diversion structure and for some distance upstream and downstream. The sediment caused by the excavation and widening would impact spikedace habitat by increased short-term turbidity and substrate sedimentation and the raw banks created would continue to deliver sediment into the system until they become revegetated. The extent of those impacts would depend upon exact excavation plans and may be partially controlled through careful planning and execution and use of sediment catchment mechanisms. Introduction of contaminants, such as machine oils, into the river during construction is also a potential source of adverse impacts to spikedace; however, proper observance of state and federal laws and guidelines regarding water quality would minimize or eliminate these impacts.

Infiltration galleries generally require continued long-term maintenance. Although maintenance needs were not specified in either proposed alternative, we have assumed that such maintenance would be periodically required to remove fine sediments which may clog the gallery and would probably be accomplished through a backwashing process. Any maintenance activity would create sediment that would be washed downstream and might also introduce pollutants. If the fine sediments removed during maintenance were washed or placed into the river downstream from the diversion or placed onto the floodplain, the impacts of increased river sediment load would be even greater.

Impacts to the spikedace and its proposed critical habitat may occur as a result of changes to the stream channel caused by the diversion facility. Whenever the stream channel and bed are altered and a structure is placed into the river, the potential exists for radiating morphologic changes in the adjacent channel until stabilization is reached under the new conditions. Although such radiating changes could potentially cause major losses to or extirpation of the spikedace in the Verde River, the probability of reaching that level is low.

The use of sheet piling to capture a portion of the subsurface flow may have adverse impacts for an undeterminable distance downstream. Capture of subsurface flow may result in loss of all or a portion of the surface flow through increased percolation into the substrate downstream from the sheet piling. The extent of this impact depends upon the amount of subsurface flow at the diversion point and upon the portion of that flow captured by the diversion structure. The depletion or elimination of surface flow below the diversion structure would result in direct losses of spikedace habitat and impede upstream movement of spikedace.

Changes in Volume and Timing of River Flow from Proposed Diversion

The year-round flow (base flow) in the upper portion of the Verde River is relatively constant (Figures 6 and 7) reflecting its origin from mildly thermal springs in the approximate 2 miles above the alternative 1 diversion site. Several flood events occur yearly, causing isolated peaks in an otherwise relatively flat hydrograph. Figure 8 illustrates the yearly flow pattern at the Paulden gage. However, Figure 8 depicts the average of all mean daily flows throughout the period of record; therefore, the number of floods shown per year is greater than would normally occur in any given year and the flood peaks shown are lower than many instantaneous peaks on record because they are averaged peaks. Snowmelt runoff contributes only partially to the flood flows and does not occur every year. Flood events are most likely in February, March, and August, with winter events having a longer duration and generally larger volume than the thunderstorm events of August. May and June have the lowest probability of flood occurrence.

The flow of the upper Verde River is composed of two radically different components. The base flows, as represented by median flow data, originate from steady groundwater discharge through springs and exhibit very little variability in flow; flow at the Paulden gage is between 20 and 30 cfs for approximately 85 percent of the year (Figure 6). The base flow provides a relatively flat, stable hydrograph over which is superimposed the flood events. Flood flows originate from surface runoff due to precipitation and are highly variable both in volume and timing; flood events at Paulden gage vary from just over base flow up to the maximum recorded historic peak of 15,700 cfs.

The upper Verde River gains water as it progresses downstream. The average of the monthly median flows at the alternative 1 diversion site is estimated at 17 cfs. Moving in a downstream direction from the headwaters, little increase in flow occurs for the first 29 miles; the average monthly median flow at the Paulden gage is 25 cfs. Then, shortly below Perkinsville, substantial increases occur in the discharge as the river enters a canyon (Carson 1986). These increases are apparently due to channel constriction by bedrock which forces upwelling of subsurface flow and results in an average monthly median flow in the lower seven miles of spikedace habitat that is over three times the flow at the proposed alternative 1 diversion site (62

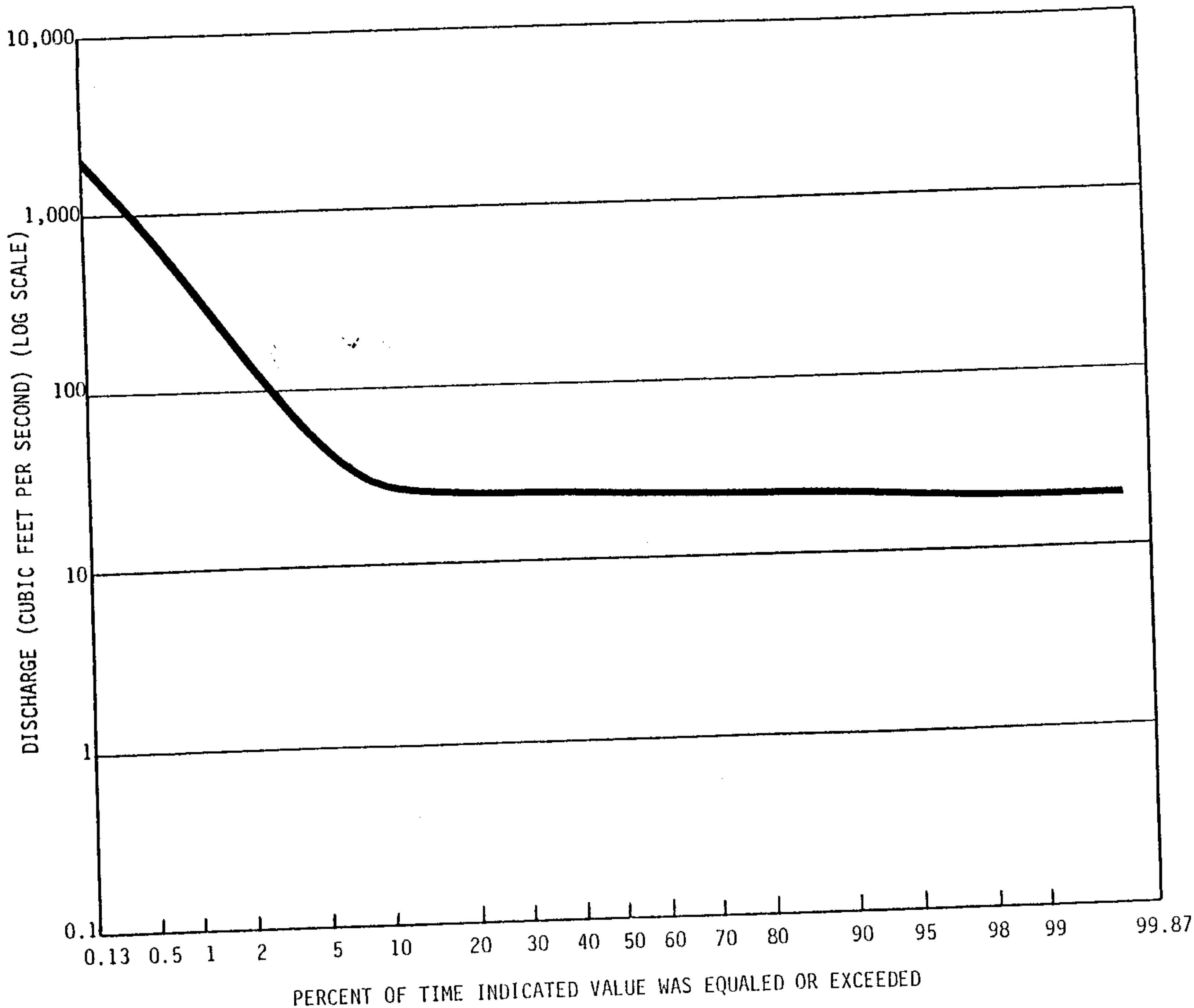

FIGURE 6. ANNUAL FLOW DURATION CURVE FOR VERDE RIVER AT PAULDEN GAGE

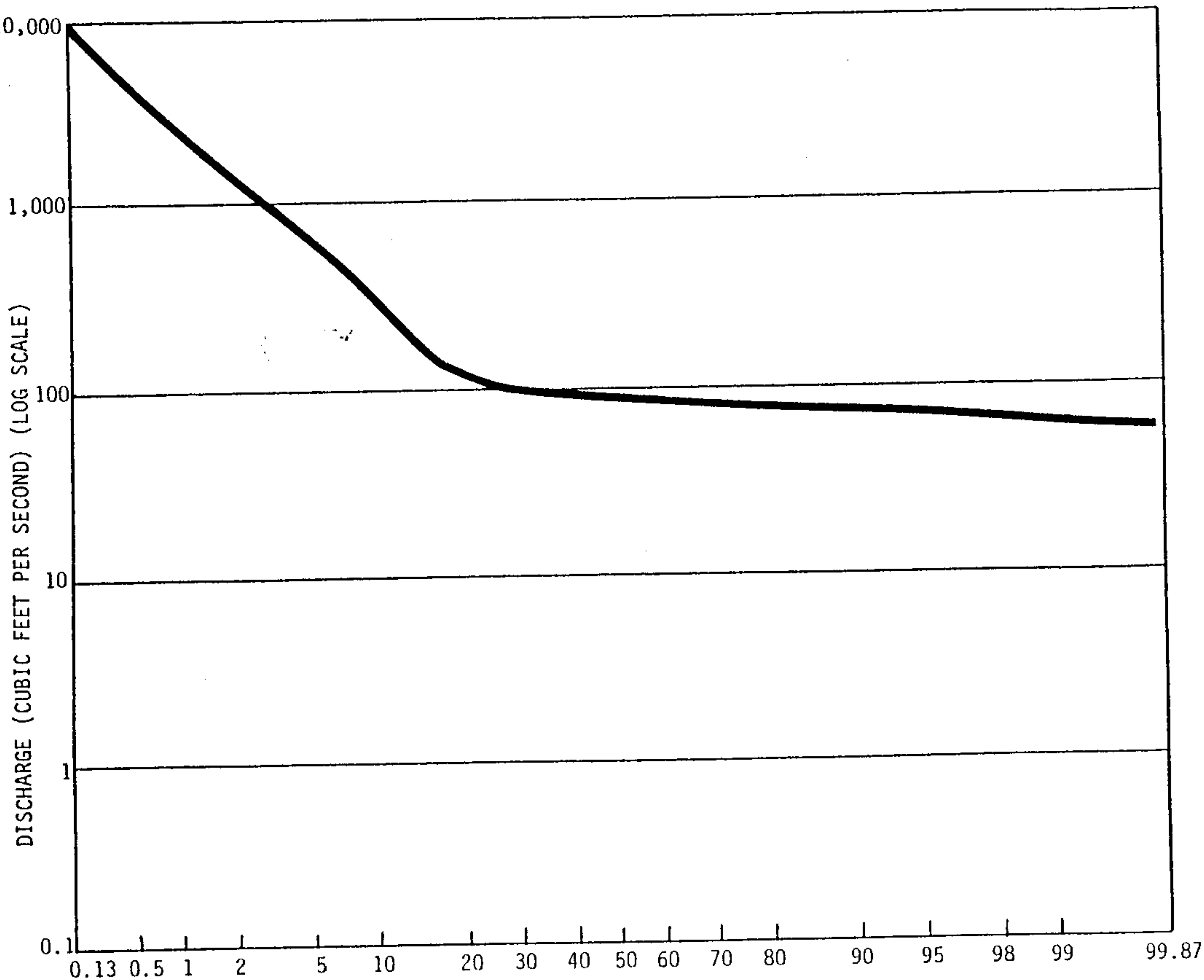

FIGURE 7. ANNUAL FLOW DURATION CURVE FOR VERDE RIVER AT CLARKDALE GAGE

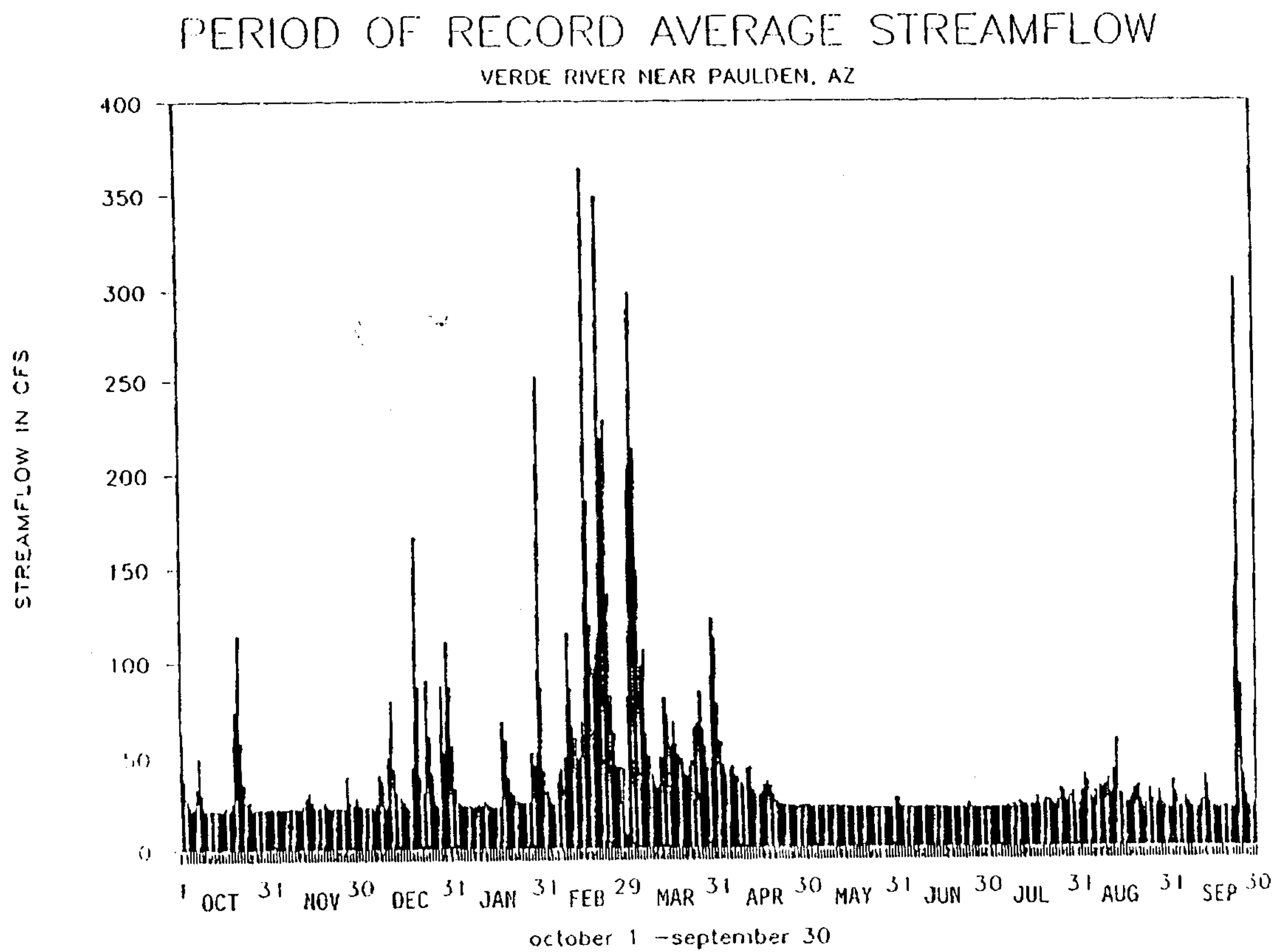

FIGURE 8. YEARLY HYDROGRAPH FOR VERDE RIVER AT PAULDEN GAGE. (Using average mean daily flow over period of record, 1964-86).

cfs). However, the yearly hydrograph continues to be relatively flat throughout the spikedace range.

Monthly median flows were used for most of the impact analyses of the proposed diversions. Medians are representative of the "normal" stream flow, as opposed to averages which, because of the large volume of flood events, are generally much higher than the flows present the majority of the time.

1. Changes in monthly median flows.

Alternative 1 - Actual percentage of the median or "normal" flow proposed to be diverted under alternative 1 would vary seasonally and the effects would vary along the stream length ranging from a high of 92 percent reduction of the monthly median flow at the alternative 1 diversion site in June, to a low of 12 percent at the mouth of Sycamore Creek in March (Figures 9, 10, and 11, Table 2). In general, flow reductions would be about one-half of the monthly median throughout the upper 29 miles of spikedace habitat. The impact of the diversion would rapidly diminish below Perkinsville to about an overall one-sixth of the monthly median in the lower seven miles of spikedace habitat. Flow reductions would be most severe during the dry months of the late spring and early summer.

Alternative 2 - The percentage of median flow proposed to be diverted under alternative 2 would also vary seasonally and along the stream length, although the pattern differs from that of alternative 1 with the largest flow reductions occurring in mid-winter. Monthly median flow reductions underalternative 2 would range from a high of 62 percent at the Paulden gage in February, to a low of 20 percent at the mouth of Sycamore Creek in August (Figures 9, 10, and 11, Table 2). No reduction of flow would occur during the months of March through June and no reduction in flow would occur in the 10 miles of river above the alternative 2 diversion site (near the Paulden gage). In general, overall flow reductions from July through February would be about three-fifths of the monthly median throughout 19 miles of spikedace habitat. The impact of the diversion would rapidly diminish below Perkinsville to about one-fifth of the monthly median in the lower seven miles of spikedace habitat during July through February.

2. Changes in low flows.
The above discussion considers the impacts of the diversion on the monthly median flows; flows which are representative of "normal." However, in predicting impacts of flow reductions, the most critical flows are the extremes. The period of lowest flow in the river is generally the most critical period to the survival of fish species, including spikedace, and may serve as a limiting factor to the population. At extreme low flows, habitat space is severely reduced, water temperatures become extreme, water quality rapidly deteriorates, and major increases in predation occur. These conditions result in fish mortalities but tend to favor survival of non-native species over native species in southwestern streams.

Historic low flow records exist for two USGS gaging stations on the Verde River (Paulden and Clarkdale) in and near the spikedace habitat. In addition, estimated monthly median flows have been modeled for various other points

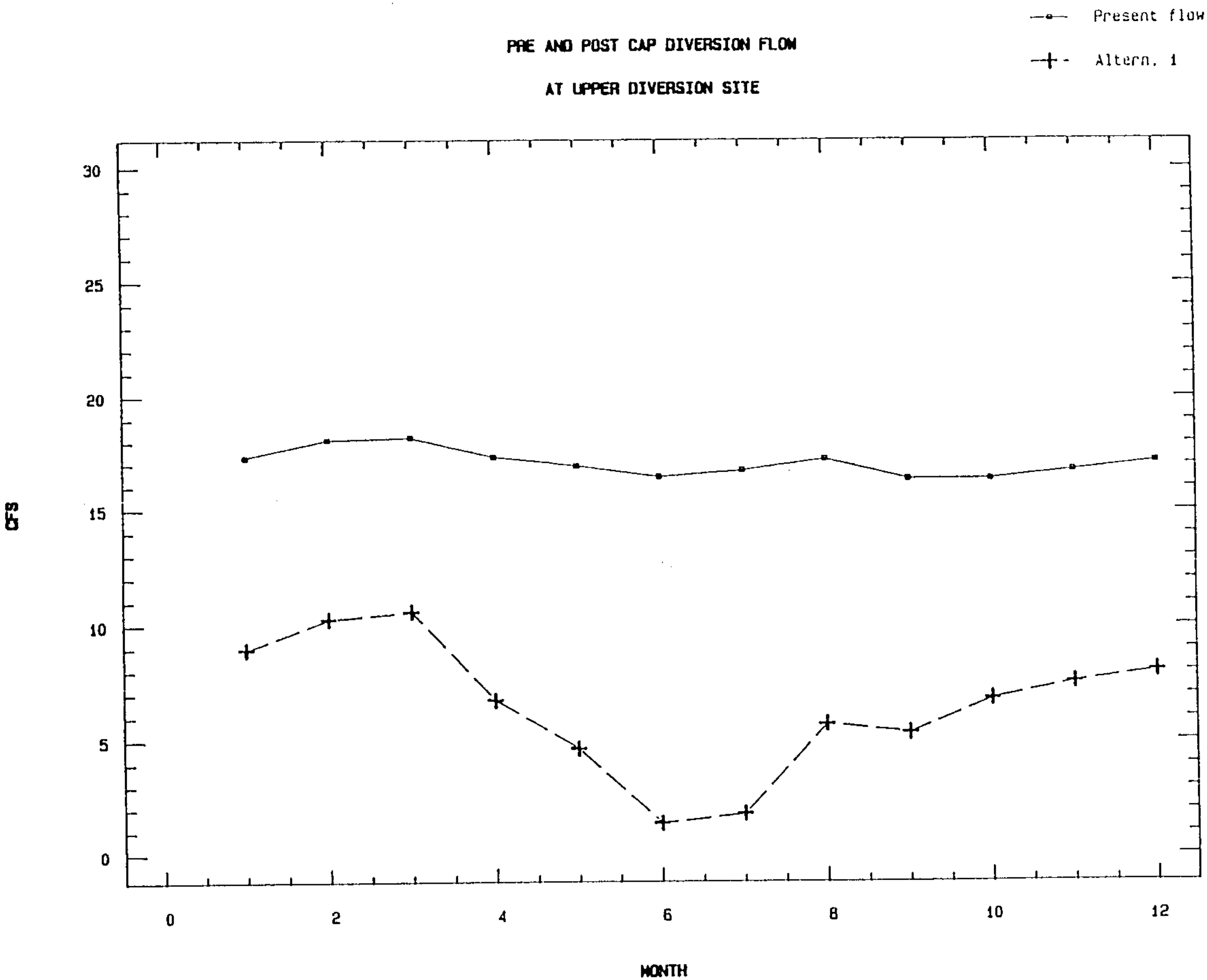

FIGURE 9. MONTHLY MEDIAN STREAM FLOWS AT THE ALTERNATIVE 1 DIVERSION SITE BEFORE AND AFTER PRESCOTT/YAVAPAI-PRESCOTT DIVERSION; UPPER VERDE RIVER, YAVAPAI COUNTY, ARIZONA

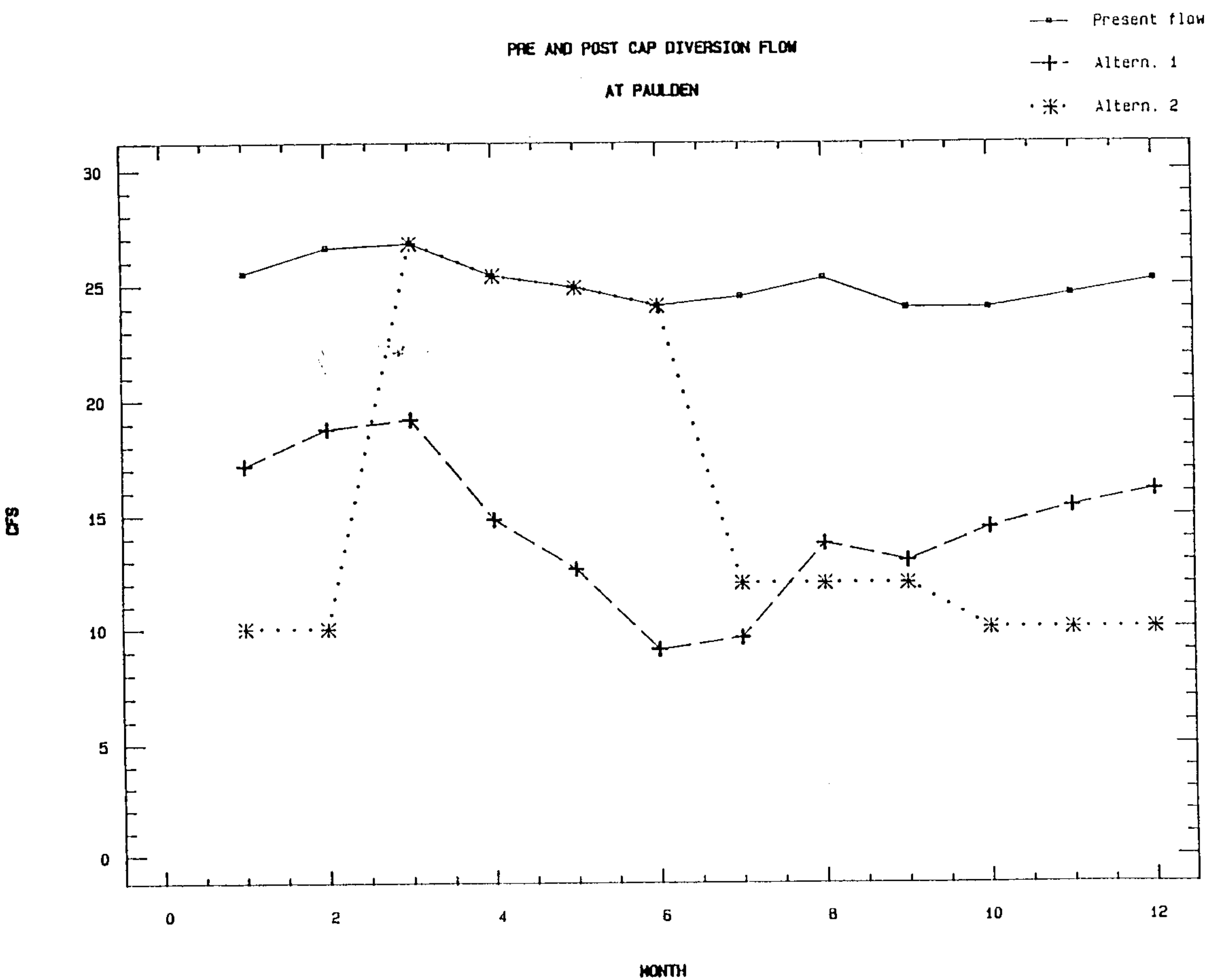

FIGURE 10. MONTHLY MEDIAN STREAM FLOWS AT PAULDEN GAGE BEFORE AND AFTER PRESCOTT/YAVAPAI-PRESCOTT DIVERSION; UPPER VERDE RIVER, YAVAPAI COUNTY, ARIZONA

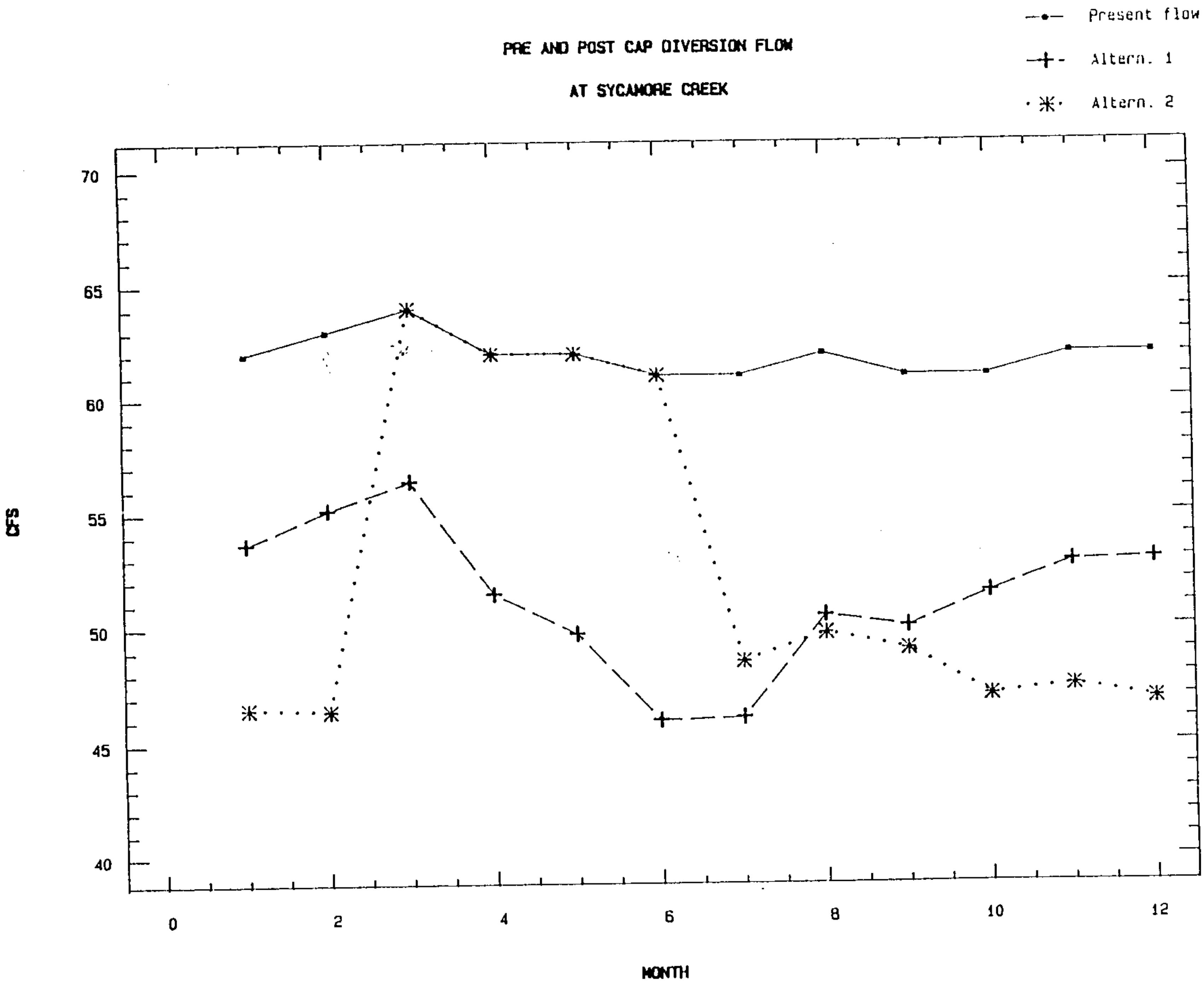

FIGURE 11. MONTHLY MEDIAN STREAM FLOWS AT THE MOUTH OF SYCAMORE CREEK BEFORE AND AFTER PRESCOTT/YAVAPAI-PRESCOTT DIVERSION; UPPER VERDE RIVER, YAVAPAI COUNTY, ARIZONA

TABLE 2. MONTHLY MEDIAN AND HISTORIC LOW FLOWS AT THREE LOCATIONS IN THE UPPER VERDE RIVER, ARIZONA AND THE RELATIONSHIP OF PROPOSED DIVERSION SCHEDULES FOR PRESCOTT/YAVAPAI-PRESCOTT INDIAN COMMUNITY CAP WATER DIVERSION

ALTERNATIVE 1

	AT UPPER DIVERSION SITE						AT PAULDEN GAGE						AT SYCAMORE CREEK					
MONTH	Monthly Median Flow[1] before Diversion (cfs)	Monthly Median Flow after Diversion (cfs)	% Median Removed by Diversion	Historic Low Flow[1] before Diversion (cfs)	Historic Low Flow after Diversion (cfs)	% of Low Flow Removed by Diversion	Monthly Median Flow[2] before Diversion (cfs)	Monthly Median Flow after Diversion (cfs)	% Median Removed by Diversion	Historic Low Flow[2] before Diversion (cfs)	Historic Low Flow after Diversion (cfs)	% of Low Flow Removed by Diversion	Monthly Median Flow[3] before Diversion (cfs)	Monthly Median Flow after Diversion (cfs)	% Median Removed by Diversion	Historic Low Flow[4] before Diversion (cfs)	Historic Low Flow after Diversion (cfs)	% of Low Flow Removed by Diversion
January	17.3	8.93	48%	13.6	5.23	62%	25.5	17.13	33%	20	11.63	42%	62	53.63	14%	49	40.63	17%
February	18.1	10.25	43%	12.2	4.35	64%	26.6	18.75	30%	18	10.15	44%	63	55.15	13%	43	35.15	18%
March	18.2	10.57	42%	10.9	3.27	70%	26.8	19.17	28%	16	8.37	48%	64	56.37	12%	38	30.37	20%
April	17.3	6.71	61%	12.9	2.31	82%	25.4	14.81	42%	19	8.41	56%	62	51.41	17%	46	35.41	23%
May	16.9	4.61	73%	10.2	0	100%	24.9	12.61	49%	15	2.71	82%	62	49.71	20%	37	24.71	33%
June	16.4	1.35	92%	12.2	0	100%	24.1	9.05	63%	18	2.95	84%	61	45.95	25%	46	30.95	33%
July	16.7	1.77	89%	13.6	0	100%	24.5	9.57	61%	20	5.07	75%	61	46.07	25%	50	35.07	30%
August	17.2	5.66	67%	11.6	0	100%	25.3	13.76	46%	17	5.46	68%	62	50.46	19%	42	30.46	28%
September	16.3	5.28	68%	12.9	1.88	85%	24.0	12.98	46%	19	7.98	58%	61	49.98	18%	48	36.98	23%
October	16.3	6.78	59%	12.2	2.66	78%	24.0	14.46	40%	18	8.46	53%	61	51.46	16%	46	36.46	21%
November	16.7	7.48	55%	13.6	4.38	68%	24.6	15.38	38%	20	10.78	46%	62	52.78	15%	50	40.78	18%
December	17.1	7.98	53%	13.6	4.48	67%	25.2	16.08	36%	20	10.88	46%	62	52.88	15%	49	39.88	19%
average	17.0	6.45	63%			81%	25.1	14.5	43%			59%	62	51.32	17%			24%
SD[5]	0.63	2.93					0.86	3.17					0.90	3.19				
CV[6]	3.7%	45%					3.4%	22%					1.5%	6.2%				

[1]USGS records for Paulden Gage (1964-1986) X 0.68 (0.68 = mean of monthly median flows at Upper Diversion Site (from Table 1, March 1988 Biological Assessment) / monthly median flows at Paulden gage (from Table 1, March 1988 Biological Assessment)

[2]From USGS records 1964-1986.

[3]From Carson 1986.

[4]Median flow at Sycamore Creek, from Carson 1986 / Median flow at Paulden gage, from USGS records 1964-86 X Historic low flow at Paulden gage, from USGS records 1964-86.

[5]Standard deviation of median monthly flows.

[6]Coefficient of variation of monthly median flows = standard deviation/average.

TABLE 2. Continued.

ALTERNATIVE 2

MONTH	AT PAULDEN GAGE: Monthly Median Flow[1] before Diversion (cfs)	Monthly Median Flow[2] after Diversion (cfs)	% Median Removed by Diversion	Historic Low Flow[1] before Diversion (cfs)	Historic Low Flow after Diversion (cfs)	% of Low Flow Removed by Diversion	AT SYCAMORE CREEK: Monthly Median Flow[3] before Diversion (cfs)	Monthly Median Flow after Diversion (cfs)	% Median Removed by Diversion	Historic Low Flow[4] before Diversion (cfs)	Historic Low Flow after Diversion (cfs)	% of Low Flow Removed by Diversion
January	25.5	10	61%	20	10	50%	62	46.5	25%	49	39	20%
February	26.6	10	62%	18	10	44%	63	46.4	26%	43	35	19%
March	26.8	26.8	0%	16	16	0%	64	64	0%	38	38	0%
April	25.4	25.4	0%	19	19	0%	62	62	0%	46	46	0%
May	24.9	24.9	0%	15	15	0%	62	62	0%	37	37	0%
June	24.1	24.1	0%	18	18	0%	61	61	0%	46	46	0%
July	24.5	12	51%	20	12	40%	61	48.5	21%	50	42	16%
August	25.3	12	53%	17	12	29%	62	49.7	20%	42	37	12%
September	24.0	12	50%	19	12	37%	61	49	20%	48	41	15%
October	24.0	10	58%	18	10	44%	61	47	23%	46	38	17%
November	24.6	10	59%	20	10	50%	62	47.4	24%	50	40	20%
December	25.2	10	60%	20	10	50%	62	46.8	25%	49	39	20%
average	25.1	15.6	38%			29%	62	52.5	15%			12%
SD[5]	0.86	7.23					0.90	7.28				
CV[6]	3.4%	46%					1.5%	14%				

[1]From USGS records 1964-1986.

[2]The proposed guaranteed minimum flow.

[3]From Carson 1986.

[4]Median flow at Sycamore Creek, from Carson 1986 X Historic low flow at Paulden gage, from USGS records 1964-86.
Median flow at Paulden gage, from USGS records 1964-86

[5]Standard deviation of median monthly flows.

[6]Coefficient of variation of monthly median flows = standard deviation/average.

on the Verde River (Carson, 1986). The ratio of monthly median flows between the gaging stations and ungaged points, such as the upper diversion site and the mouth of Sycamore Creek, can be applied to the recorded historic lows at the gaging stations to give an estimate of what the historic lows may have been at those points (Table 2). The minimum historic low for the Paulden gage (toward the upper end of the spikedace range) was 15 cfs recorded on May 13-23, 1964. The minimum historic low flow for the Clarkdale gage (located below the downstream end of known spikedace distribution) was 55 cfs recorded on August 31-September 1, 1920. Recorded monthly historic low flows for the Paulden gage and estimated monthly historic low flows for the upper diversion site and for near the mouth of Sycamore Creek are presented in Table 2.

The above information on recorded and estimated historic low flows must be used with caution. Both USGS gages in the upper Verde River have a relatively short period of record. Paulden gage records used include July 1963 to September 1986; a period of just over 23 years. Clarkdale gage records include June 1915 to October 1916, May 1917 to July 1921, and April 1965 to September 1986; a total of 27 years. Use of such a short period of record to predict future low flows leaves a high probability that drought flows lower than the recorded historic lows may occur during the life of the proposed diversion project. In addition, the period of record for both gages spans a time of relatively high rainfall. Earlier periods of lower rainfall, such as the severe drought of the 1940's and 50's, may have resulted in low flows in the Verde River that were significantly lower than recorded lows.

Alternative 1 - The proposed maximum instantaneous withdrawal rate for alternative 1 of the Prescott/Yavapai-Prescott diversion is 15.05 cfs during June, although that maximum could also be withdrawn at other times dependent upon need. As can be seen on Table 2, during drought conditions at or below the range of the historic low the diversion schedule proposed in alternative 1 has the potential to totally remove all summer flow at the point of diversion during four months of the year. This total loss of flow would extend for about 6 miles downstream. Flow would then be reduced to below 5 cfs for an additional 21 miles, but would rapidly increase in the next 7 miles to reach about 30 cfs at the mouth of Sycamore Creek. The preceding scenario assumes diversion at the proposed schedule rate. However, if Prescott water demand during such drought conditions resulted in diversion at the maximum instantaneous capacity planned, the dewatering would be even more severe, involving total loss of flow throughout about 16 miles of river (44 percent of spikedace habitat in Verde River).

Alternative 2 - The alternative 2 diversion schedule was designed to avoid some of the low flow impacts of alternative 1. No maximum instantaneous diversion capacity has yet been determined for this alternative; however, a guaranteed minimum streamflow, calculated on an instantaneous basis, has been proposed for each month. That minimum flow would be continuously maintained throughout the month as part of the proposed diversion schedule (Table 1). When natural river flow at the diversion fell below the minimum guaranteed, no diversion would occur and the flow downstream from the diversion would equal the natural flow. The diversion schedule assumes that all water over the minimum guaranteed flow would be diverted, except during flood events. Because the proposed alternative 2 diversion site is downstream from the alternative 1 diversion site, the low flow impacts would be avoided in eight miles of the area to be most severely impacted under alternative 1. In addition, the guaranteed minimum flows in alternative 2 would prevent the severe flow losses of alternative 1. Under alternative 2, no total loss of flow would occur. During drought conditions meeting or exceeding the historic low, the proposed alternative 2 diversion schedule would never allow the stream flow to drop below 10 cfs or the total natural flow, whichever was less.

3. Changes in flood flows.
Flood flows play an important part in the biology and habitat of fishes. Flooding occurs several times each year in the upper Verde River and flood flows are often of 2 or more orders of magnitude larger than the base flow. Flood flows peak and decline rapidly. Channel size and morphology, riparian vegetation composition and configuration, fish habitat distribution, and fish behavior and community composition are all directly related to the size, frequency, and timing of flood events.

Alternative 1 - Alternative 1 is not expected to significantly affect the flood flows of the upper Verde River. The maximum instantaneous diversion capacity of 15.05 cfs is a small amount compared to flood flows: USGS records show the 2-year peak flow event at the Paulden gage to be 1,638 cfs and the 100-year peak flow to be 29,102 cfs.

Alternative 2 - Because no maximum instantaneous diversion capacity has yet been specified for this alternative, it is not possible to determine the specific effects of the alternative on flood flows. However, it has been specified in this alternative that no major storage of water is necessary. We have, therefore, assumed that this alternative would not be constructed with a capacity to divert at an instantaneous rate larger than 25 cfs. That diversion rate would have no significant impact on flood flows. If this assumption becomes incorrect due to further development of proposed diversion plans, then additional analysis of impacts to spikedace and reinitiation of consultation would be necessary.

4. Changes in flow patterns.
In addition to analysis of project impacts to median, low, and flood flow events, potential changes to the timing and interrelation of those flows must also be analyzed. Those factors are very important to spikedace biology. The life history of a species is based upon cyclical patterns in its environment which act as stimuli for various biological responses in the species. To conserve the spikedace in the upper Verde River it is necessary to preserve the integrity of the flow regime, including the hourly, daily, weekly, monthly, and multi-year patterns of variation. The upper Verde River naturally has a relatively constant invariable flow punctuated by abrupt, short-lived floods; little variation occurs in the median flow over the course of the year or between years. The spikedace which inhabit the upper Verde River are likely adapted to that pattern.

Multi-year variability, which is primarily a function of the highs (floods) and lows (droughts), is not expected to be substantially affected by either proposed diversion schedule. Neither alternative would substantially affect the flood flows and under both alternatives the affect on low flows would be consistent from year to year. However, because of the disparity between diversion amounts proposed for different months, there would be a substantial change in the month to month variability of flows in the upper Verde River under both proposed diversion alternatives.

Alternative 1 - Water diversion from the upper Verde River in accordance with the schedule proposed in alternative 1 would result in substantial alteration of the monthly flow pattern from the existing condition. This can be readily seen in the hydrographs in Figures 9, 10, and 11. The coefficient of variation of the recorded monthly median flows of the upper Verde River would increase under alternative 1 from the present 3.7 percent at the upper diversion site to 45 percent; at Paulden gage from 3.4 percent to 22 percent; and at Sycamore Creek from 1.5 percent to 6.2 percent (Table 2). This measure of the variation of the monthly medians around their average is an indicator of the monthly or within-year variability of the streamflow. The existing upper Verde River values indicate that such variability is presently very low. Variability under alternative 1 would be substantially larger. The lessening impact of the diversion at the downstream sites is a function of the larger amount of median flow relative to the diverted amount. The increase in variability in streamflow under this alternative is due to the proposed diversion of a larger proportion of the median flow in the months of April through July to meet demand.

Under the naturally existing flows in the upper Verde River the only significant daily, hourly, or weekly fluctuations which occur are those caused by flood events. The diversion schedule for alternative 1 proposes one diversion rate per month and indicates no anticipated daily, hourly, or weekly fluctuations. We have, therefore, assumed that the diversion rate would be constant throughout the month and that all within-month variation would result from natural occurrences and reflect the pre-project hydrograph. A diversion schedule which would allow for large daily, hourly, or weekly fluctuations in flow could result in various adverse impacts to the spikedace.

Alternative 2 - Alteration of the streamflow pattern, through increased monthly flow variability, is even more striking under this alternative and can also be readily seen in Figures 9, 10, and 11. Diversion under the alternative 2 schedule would increase the coefficient of variation at Paulden gage from the existing 3.4 percent to 46 percent, and at Sycamore Creek from 1.5 percent to 14 percent (Table 2). The flow pattern at the upper diversion site (alternative 1) would not be affected under this alternative, which would divert at Paulden gage. The increased variability of streamflow under this alternative would primarily result from the proposed overall high rates of diversion contrasted with the complete cessation of diversion during the months of March through June.

Under the assumptions made regarding the inviolate nature of the guaranteed minimum flows and the maximum instantaneous diversion capacity under alternative 2, this alternative would slightly alter the daily, hourly, and weekly variation. At flow levels naturally falling below the guaranteed minimum, no change in natural pattern would occur. At flow levels between the guaranteed minimum and the total of the guaranteed minimum plus the maximum diversion capacity, the flow pattern would become invariable. And, at flow levels above maximum diversion capacity plus guaranteed minimum the natural pattern would be restored.

Impacts to Spikedace from Changes in Volume and Timing of River Flow

Available information on spikedace biology and habitat needs, particularly in the upper Verde River, is inadequate to make an accurate assessment of the impact of small incremental changes in median flow in the Verde River on the species and its proposed critical habitat. Little or no data are available on reproductive requirements, interspecific interactions, temperature tolerances, seasonal and diurnal habitat usage, genetics, population sizes for viability, and many other factors. Therefore, this assessment focuses primarily upon a worst case analysis.

1. Impacts of changes in low flows.
The most severe impacts of the proposed project to spikedace in the Verde River would result from diversion of water during periods of low flow. These impacts would be most damaging under alternative 1 due to the guaranteed minimum flow of alternative 2. However, at Paulden gage the guaranteed minimum flow is lower than the recorded historic low and many of the adverse impacts of low flows would occur. The spikedace needs flowing water with relatively high oxygen levels and cannot survive more than a few hours of severely depleted or total loss of flow even if isolated pools remain. Total loss of flow is a probable impact of the proposed alternative 1 diversion throughout at least 44 percent of the existing spikedace habitat during drought periods when flows drop to near or below the historic low. Such drought flows may extend over a many days; the recorded historic low at Paulden gage of 15 cfs lasted for 11 days. Complete loss of flow would most likely result in total elimination of the spikedace throughout the dewatered section of river. Spikedace would be killed by desiccation, decreased oxygen levels, increased water temperatures, and increased predation.

Long-term maintenance of the flows below the level of the historic low flow could also severely impact the spikedace. Under alternative 1 this would occur year-round in the upper 29 miles of river and under alternative 2 would occur in July through February in the upper 19 miles of river. These impacts are discussed further in the later analysis of changes in median flow.

Extreme low flow would have long-term effects on the spikedace population. In a natural system, populations which are extirpated or depleted due to a random event, such as extreme drought, are reestablished by immigration from adjoining populations. No such source of immigrants exists for the upper Verde River population of spikedace. Although spikedace in the lower 7 miles of existing habitat below Perkinsville would likely survive a project-amplified drought, their ability to repopulate the upper 29 miles would be severely limited. The 7-mile stretch does not appear to support a large proportion of the spikedace population (USFWS 1989) and spikedace do not move readily upstream for long distances (Propst et al. 1986).

Combined with the proposed alternative 1 diversion, even a moderate drought, especially one occurring in early summer when young fish are still in the larval stage, could potentially eliminate an entire year-class from the spikedace population, particularly if most reproduction occurs in the upper end of the range as may be indicated by the 1986 sampling data and AGFD observations (D. Hendrickson, AGFD, pers. com., February 9, 1989). Loss of a year class in itself would not likely be fatal to this population, but may reduce the population below minimum viable size. Spikedace are a short-lived fish and the bulk of the reproduction is from one-year old fish. Therefore, loss of an age-class would cause a significant loss in reproduction. A project-amplified drought for two consecutive summers could potentially eliminate two age-classes. Without a source of immigration, loss of two consecutive age-classes would result in extirpation of the population.

The adverse impacts of extremely low flows or total loss of flow would be intensified by the presence of non-native fish. As the riffles and other shallow waters dry, spikedace along with other fish would be crowded into the remaining pools where predation would become intense with little or no escape possible. Drought in combination with establishment of non-native predacious and competitive fish appears to have been responsible for the loss of spikedace and two other native species in the San Francisco River in eastern Arizona and western New Mexico (D. Propst, New Mexico Game and Fish Department, pers. com., February 12, 1990). Prior to the drought of the 1940's and 50's, spikedace, Gila topminnow (Poeciliopsis occidentalis), and roundtail chub (Gila robusta) were found in the San Francisco River. Roundtail chub were abundant enough to be a popular sport fish. Coincident with the drought was the establishment of several non-native fish and by the early 1950's the three native fish were no longer found in the river.

Many of the non-native fish present in the Verde River would survive total cessation of flow with only minor losses and some would actually benefit from the resulting depletion of the native species. Studies indicate (Marsh et al. 1989) that the presence of red shiner may result in displacement of spikedace into faster velocity water than they normally inhabit. Diversion of water from the Verde River would result in decreased average current velocities and may favor the survival of red shiner over spikedace. Red shiner can survive for long periods of time in isolated pools. Smallmouth bass, channel catfish, and other predatory non-natives could also survive periods of entrapment in isolated pools and would feed extensively on the smaller fish crowded into the increasingly limited water. As flows rise, the vacant habitat created by extensive losses of native fish would quickly be filled by non-natives. The surviving population of non-natives available to provide recruitment for the vacant habitat would be much larger than that of native species. While spikedace and many of the other native species are limited to spawning only in the spring, the red shiner has the ability to reproduce throughout much of the year. Following a mid-summer drought, red shiner could still produce large numbers of young to fill vacant habitat. When the small numbers of surviving spikedace spawned the following spring, the larvae would face intense competition for food and space along with heavy predation.

2. Impacts of changes in flood flows.
Loss of flood flows would result in changes to the stream channel and substrate (Bovee 1982) and would likely exacerbate the proliferation of exotic fish (Minckley and Meffe 1987). Although the project, under either proposed alternative, is not expected to affect existing flood flows; other possible methods for obtaining the needed water from the river may have the potential to reduce or eliminate those flows. Reduced flood flows, particularly loss of the bankfull or approximately 2-year flood event, would result in an aggrading stream with a narrower, shallower channel, a higher width to depth ratio and a smaller substrate size. These changes would most likely result in large losses of available spikedace habitat and could result in the extirpation of the population. Non-native fishes, on the other hand, would benefit from the loss of flood flows. Large floods, such as those at and above the 10-year event, are important in keeping non-native fish populations in check. While native fish are adapted to surviving the large volume, short duration floods which are typical of southwestern streams, non-native fish in general suffer heavy mortality during such floods. In addition, changes in channel morphology would likely create habitat that is more suitable to habitat generalistic non-native species than to habitat specific native species. Flooding is considered to be important in the rejuvenation of spikedace habitat (Propst et al. 1986). Maintenance of flood events is therefore essential in preserving native fish species and their habitat.

3. Impacts of changes in median flows.
The Service believes that overall reduction of median flows under either the proposed alternative 1 or 2 withdrawal schedules would have adverse impacts to the spikedace resulting in substantial habitat alterations, population reductions, and/or extirpation. Expected results of reduction of median flows, as proposed, would include a reduction in wetted area; direct reduction in spikedace habitat availability; more extreme water temperatures; increased numbers of non-native predacious and competitive fish species; reduction in water quality through changes in water chemistry; alteration of nutrient levels; reduction in food availability; and reduced sediment transport capability resulting in increased substrate embeddedness and a tendency toward a braided channel. The specific mechanisms and levels of impact cannot be quantified at this time due to the lack of adequate life history, population, genetic, habitat, hydrologic, hydraulic, and water quality data.

Under alternative 1, median flow reductions would average 53 percent of the monthly median flow in the upper 27 miles of spikedace habitat and 17 percent in the lower 7 miles; no reduction would occur in the 2 miles of river above the diversion site. Alternative 2 would cause no flow reduction in the uppermost 10 miles of river and no reductions at all during the months of March through June. During July through February, alternative 2 would average 57 percent reduction of median flow for 19 miles below Paulden gage and 23 percent reduction in the lower 7 miles of spikedace habitat. Such major reductions in the median flow would create a significant risk to the survival of the spikedace population and to its proposed critical habitat. Although losses cannot be quantified at this time due to lack of adequate biological and hydrologic information, comparison of portions of the historic spikedace range where the species is now extirpated, with portions of the range where the species has persisted, shows that the extirpated portions have all undergone extensive reduction and/or alteration of the river flow while extant portions have experienced only minor or no reduction/alteration in flow. It is also known that spikedace do not occupy small tributary streams (e.g. Mogollon, Mangas, and Sapillo Creeks on the upper Gila River, and Sycamore and Wet Beaver Creeks on the upper Verde River), indicating that there may be a lower limit on the size of stream necessary to support spikedace. The upper Verde River is naturally a rather small stream and the size threshold below which it would no longer sustain spikedace may be rather close to the existing median.

Because each life stage of spikedace has differing habitat needs, the impact of a given flow reduction would vary depending upon the life stages present in the river at the time of the diversion. Little data exist on the needs of spawning spikedace, and no information is available to indicate what environmental factor or factors cause initiation of spikedace spawning. Rising water temperature and declining flows have been suggested as probable causes of spawning initiation in Aravaipa Creek and the upper Gila River (Barber et al. 1970, Propst et al. 1986). Although no long-term temperature data are available, it appears that due to the spring origin of its headwater base flow the upper Verde River has a smaller variation in temperature and flow than other streams where the spikedace exist. Although flood flows are likely in February and March in the upper Verde River, years without a significantly higher flow in those months are not uncommon. Therefore, if temperature and/or change in amount of flow are initiators of spikedace spawning here, the cue is likely to be a change of relatively small magnitude vulnerable to disruption by human-caused changes of relatively small magnitude. Alternative 1 would divert relatively large amounts of water during the spring when spawning is occurring. Spawning may be disrupted due to the altered flow patterns, reduction in available habitat, altered water temperatures, and increased sedimentation. Alternative 2 would not divert water during the spawning months of March, April, and May but would divert 62 percent of the median flow in February. The low flow in February may result in spawning disruption by raising water temperatures and lowering flows prematurely or otherwise disrupting spawning stimuli.

The greatest impacts of alternative 1 are expected to larval spikedace. Larval spikedace have a much more limited thermal range than do adults and exhibit subtle habitat use shifts to accomplish thermal regulation. The larvae generally use the warm, shallow, slow velocity stream edges. Several possible scenarios resulting from water diversion could potentially have heavy impacts to larval spikedace. The shallow edges warm and cool rapidly on a diurnal basis and in response to certain outside factors. The cooling of these shallows edges causes larval spikedace to move outward seeking the relatively warmer water of the slower-cooling main channel. However, if larval fish move too far out into the current, they become entrained and are swept downstream. Narrowing of the shallow edges due to diversion could result in a larger proportion of the larvae becoming entrained in the current. This drift of larval fish downstream is a natural phenomena that contributes to migration and colonization, however, if the proportion of larvae entering the drift becomes too large, it is detrimental to the local population. In the upper Verde River where downstream habitat is unsuitable, larvae which drift below the suitable habitat die and the population is depleted. When the need for thermal regulation or the drying up or silting in of the shallows force larval spikedace to move out into faster, deeper water they also more vulnerable to thermal shock, predation, and other problems.

Spikedace feed primarily upon aquatic insects and are known to consume mayflies, caddisflies, flies, stoneflies, dragonflies, beetles, true bugs, and wasps (Barber and Minckley 1983, Propst et al. 1986, Marsh et al. 1989). The breadth of this food supply should buffer the spikedace against shortages of food due to changes in the stream caused by the proposed diversion. However, the primary food groups, such as mayflies, caddisflies, and stoneflies, in general are relatively intolerant of habitat alterations. Severe flow reductions, total loss of flow, sedimentation, channel narrowing, warmer water temperatures, and various other potential changes may result in decreased availability of food for spikedace.

The diversions proposed in both alternatives 1 and 2 would be expected to create major changes in the existing balance of habitat partitioning between red shiner and spikedace. Red shiner are habitat generalists; they can live in a large variety of currents, substrates, depths, water temperatures, and water chemistries (Deacon et al. 1987, Matthews and Hill 1979). They can survive in non-flowing pools for long periods of time. Red shiner spawn from early spring through fall (Farringer et al. 1979), allowing them to exploit short periods of favorable conditions to rapidly expand their populations throughout most of the year. Alteration of natural conditions usually causes changes in habitat that are unfavorable to the spikedace, which is a habitat specialist and is, therefore, tied to a narrow set of specific habitat needs. On the other hand, alteration of the natural conditions usually results in habitat changes that are quite acceptable to the red shiner, a habitat generalist. For example, reduction of flows would disrupt the present stable nature of the river channel and may result in an aggrading stream with a shifting bottom of fine sediments. This disturbance of the system would be favorable to red shiner which is a pioneer species and is often one of the first fish species to recolonize disturbed channels. The warmer summer water temperatures, which are a potential result of reduced summer flows, would probably increase red shiner spawning. As a result, the red shiner proliferates and either replaces spikedace in habitats that can no longer support spikedace, or displaces the spikedace through increased competition in habitat which has become marginal for spikedace and more favorable for red shiner (Bestgen and Propst 1986, Marsh et al. 1989).

4. Impacts of changes in flow patterns.
Because of the inherent steadiness of the base flow, the upper Verde River and its fish community are particularly vulnerable to impacts from activities which would alter the flow regime. Both alternatives 1 and 2 of the proposed diversion would result in substantial changes in the variability of flow and in the pattern of flow within the yearly cycle. Too little is known about the life history and ecology of the spikedace to make precise predictions of the effects of small changes in the flow pattern on the population, and the unusual nature of the flow regime of the upper Verde River precludes the use of data from other populations of spikedace to predict the impact

of altering the flow regime. However, because of the low variability of the base flow, even small alterations in the regime would be expected to have greater consequences than small alterations would in a highly fluctuating environment.

Alternative 1 would result in a yearly base flow in the Verde River with much greater variability than existing conditions. The existing flow regime has the highest flows in late winter, followed by slightly lower flows in late spring and early summer that are broken by a slightly higher late summer flow and then resumed in an equally low autumn flow (Figures 9, 10, and 11). Post-diversion flows would be characterized by a winter flow that is the highest of the year followed by a rapid drop in late spring and summer flows to a substantially lower level with a relatively strong rise to late summer and an additional rise in autumn. Predictable potential adverse impacts from this altered regime are primarily associated with the strong reductions in spring and summer flow and their affect on spawning and larval spikedace. However, it is likely that other impacts may occur, particularly in the relationship between spikedace and non-native fish. Sufficient data are not available to predict the type and mechanism of such impacts.

Under alternative 2 the flow regime of the upper Verde River would have much more variability on a monthly basis and the yearly cycle would essentially be reversed from the existing pattern (Figures 10 and 11). The naturally declining hydrograph from winter through spring would be replaced by a low winter flow that would increase by a factor of 2.5 in a matter of days to a high spring and early summer flow. A subsequent rapid drop in flow would occur in late June to summer flows that are slightly higher than winter flows. While this regime was designed to protect flows during spring spawning and larval periods and reduce the impact of diversions during the dry summer period, the magnitude of difference between diversion and non-diversion periods and the total disruption of normal flow patterns is expected to have adverse impacts that are almost as large as those they were designed to mitigate. If spawning is initiated by any factor related to flow, water temperature, or other instream factor (as opposed to photoperiod or other external factor not affected by streamflow) this reversed regime is likely to disrupt the initiation of spawning. Spikedace that may be cued to spawn by small but consistent changes in water temperature and declining flow level would likely react inappropriately to the substitution of a dramatically higher sustained flow and the consequent colder water temperatures. The subsequent rapid drop in late June would likely result in death to a large number of larval and juvenile spikedace as their habitat shrinks rapidly to a substantially smaller size. It is also likely that this substantial change in flow regime would disrupt the balance between spikedace and the non-native fish species.

5. Indirect effects.

Changes in flow regime, low flows, median flows, and loss of flood events all have the potential to cause loss of or alteration to the riparian vegetation. Riparian vegetation provides sediment control, bank stabilization, instream cover, nutrient input, thermal regulation, and various other factors to the stream ecosystem. Loss or alteration of any of those factors may be detrimental to spikedace survival. Changes in density or species composition of riparian vegetation have the potential to create changes in stream channel morphology and spikedace habitat. Reduction of median flows and severe dewatering from diversion of low flows may result in death of riparian plants and long-term narrowing of the riparian zone. Changes in the flow regime may disrupt reproduction of riparian species which are dependent upon established flow cycles to distribute seeds, initiate germination, or support seedling survival. The alternative 2 diversion schedule may result in a strip of unvegetated lower bank due to the inundation of riparian during the high spring and early summer flows followed by the abnormally lowered late summer flows. On the other hand, the alternative 1 schedule may allow excessive silt accumulation in the channel and resulting vegetation encroachment due to the abnormally lowered spring and summer flows. These impacts to the riparian vegetation and stream channel would occur over a long-term and would be cumulative among themselves and with other more direct effects to the spikedace. Accumulative and synergistic effects of project-related riparian vegetation and channel changes may be the ultimate cause of the extirpation of the spikedace, if more direct effects do not result in proximate extirpation.

Impact of Loss of Verde River Spikedace Population to Species as a Whole

Loss of the upper Verde River spikedace population would severely compromise the survival of the species as a whole. Loss of this population, which comprises one-third of the existing range, would reduce the species to a very precarious status. Threats exist to all of the remaining four other populations which may result in eventual extirpation of one or all of those populations. The upper Verde River population is the only remaining representative of the northern portion of the spikedace historic range. As such, that population may contain variations in habitat adaptation or genetic structure that may be vital to ensuring the survival of the species in the face of continuing inevitable alteration of its habitat. Although no genetic work has been conducted on spikedace, substantial genetic differences between populations at extreme ends of a species range have been documented for other species (Vrijenhoek et al. 1985). The draft spikedace recovery plan calls for reintroduction of spikedace into former historic range and specifies that reintroduction stocks should come from local stocks with genetic and adaptive affinities to those formerly occupying the streams identified for reintroduction (Marsh 1988). The Verde River spikedace are the only existing stock, under those guidelines, appropriate as a source for reintroductions in the northern portion of the spikedace range.

Instream Flow Incremental Methodology (IFIM) Analysis of Flow Reduction Impacts to the Upper Verde River Spikedace Population

A joint study was conducted by AGFD, the Service, and Reclamation in 1985-87 using the IFIM (Bovee 1982) to assist in defining the impacts of the proposed and various alternative flow reductions on habitat availability for the spikedace and several other fish species. This methodology attempts to predict the carrying capacity of a stream at various flows using measurements of four habitat variables: velocity, substrate, depth, and cover. It was developed primarily for coldwater, high gradient streams and salmonid fish. Its use in lower gradient, warmwater, and desert streams and for cyprinid fish, such as spikedace, is recent, experimental, and has been questioned by many biologists, conservationists, and water developers (Granholm et al. 1985, Mathur et al. 1985, Moyle and Baltz 1985, Orth and Maughan 1982).

Field data gathered on the distribution and status of the upper Verde spikedace population and its habitat during the 1985-87 upper Verde River IFIM study were used in the development of this biological opinion. However, the final output of the IFIM modeling, which estimates available habitat for spikedace at various levels of flow, was analyzed by a team of agency biologists and species experts who concluded that the model does not accurately assess the impacts of water depletion on the spikedace in the upper Verde River. This conclusion was based on the failure of the spikedace population and habitat of the Verde River to meet many of the assumptions inherent in the IFIM model; the inability of the IFIM to consider many important factors of spikedace biology, such as interspecific interactions, interdependent use of various habitat variables, and seasonal habitat use changes; and on the collective professional judgement of the team which would result in conclusions that are substantially different than those of the IFIM. Detailed rationale for the decision can be found in Appendix A.

Cumulative Effects of the Proposed Action

Cumulative effects are those impacts on threatened and endangered species of future state or private actions that are reasonably certain to occur within the action area. Future Federal actions would be subject to the consultation requirements established in Section 7 and, therefore, are not considered cumulative to the proposed action.

The proposed water diversions would have several indirect effects upon the Verde River, its spikedace population, and the proposed critical habitat. The human population of the Big and Little Chino Valleys at the upper end of the Verde River watershed is growing rapidly. Projected population estimates for the water service area of the City of Prescott predict an increase of 46 percent between 1990 and 2010 (Gookin and Assoc. 1983). Development of the CAP allocated water would facilitate this growth. The additional population would result in increased land disturbance in the upper watershed of the Verde River and consequent increases in sediment and pollutant problems in the river.

Increased population in the area would result in more intensive use of the upper Verde River for recreation. Increased recreational use is also expected to occur independent of the Prescott area population. Although most recreational impacts to spikedace and its habitat are expected to be localized, uses such as off-road vehicles may have severe negative impacts to spikedace and their habitat through bank destabilization, sedimentation, substrate destruction, and pollution.

The proposed diversion would reduce the spikedace population and alter its proposed critical habitat thereby making it more vulnerable to damage or extirpation by other actions. This increased vulnerability, in conjunction with increased human activity at the diversion site, increased recreation along the river, and increased human occupancy of the upstream watershed would result in a significantly higher risk of severe losses to or extirpation of the spikedace due to a major pollution event or other human or natural stochastic occurrence. Unpredictable catastrophic occurrences such as disease (black-footed ferret), dam failure (woundfin), intense storms (Attwater's prairie chicken), floods (desert slender salamander), and chemical spills (Gila topminnow) have been known to cause population extirpation or near extinction in other species which were already reduced to minimum acceptable levels by human development.

REASONABLE AND PRUDENT ALTERNATIVES

The Section 7 regulations have defined reasonable and prudent alternatives as alternate actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that the Service believes would avoid the likelihood of jeopardizing the continued existence of listed species or of destroying or adversely modifying its critical habitat.

Reasonable and prudent alternatives set forth below include several alternatives which alone or in combination with one or more others would allow the City of Prescott and the Yavapai-Prescott Indian Community to fulfill the project objectives of obtaining water supplies through exchange of CAP allocations without jeopardizing the survival of the spikedace and/or destroying or adversely modifying its proposed critical habitat. Alternatives include:

1. Acquisition of existing water rights.
There are numerous existing wells and state permitted water rights in areas nearby the Prescott/Yavapai-Prescott point of use (Gookin and Assoc. 1983, Arizona Department of Water Resources [ADWR] water rights records). Acquisition of some of those water sources and conversion, if necessary, from agricultural or other uses to municipal and industrial use is a viable alternative for providing all or part of the needed water supply. The Service is aware of recent acquisitions by Prescott of groundwater which may partially fulfill the need. Exchange of allocated CAP water could be accomplished with other water development entities in return for water rights and/or other considerations in water development.

2. Development of additional groundwater supplies.
Both Prescott and the Yavapai-Prescott are located in the Prescott Active Management Area (AMA) which is subject to stringent restrictions on water development and exploitation of groundwater supplies. However, the Big Chino Valley, just to the north, is not located in an AMA. The Service is aware that Prescott is already pursuing future development of groundwater supplies in the Big Chino Valley and believes that the full amount of the CAP allocation for the City may be obtainable from that source (Gookin and Assoc. 1983; K. Kane Graves, City of Prescott, pers. com., January 27, 1989; William Swan, Office of the Field Solicitor, DOI, pers. com., February 20, 1990). Allocated CAP water could be exchanged with other water development

entities in return for other water rights and/or assistance in development of groundwater facilities. Development of this alternative must be accompanied by extensive studies to determine the extent of connection between groundwater of the Big Chino Valley and the surface flow of the Verde River. Those studies are already being conducted by Prescott (K. Kane Graves, City of Prescott, pers. com., January 27, 1989). However, if any aspect of the Big Chino Valley groundwater pumping, transport, etc., may affect the flow volume or regime of the Verde River or the spikedace, then additional consultation under Section 7 of the Endangered Species Act will be required if Federal monies, actions, or authorities are involved.

3. Separate development of Yavapai-Prescott allocation.
If Prescott pursues an option for water acquisition separate from that of the Yavapai-Prescott, then additional alternatives need to be developed for supplying the Yavapai-Prescott allocation. Alternatives exist for development of the Yavapai-Prescott allocation in ground or surface waters of other river basins or in headwater tributaries of the Verde River. Although those alternatives are expected to have little to no adverse effects on the spikedace, any alternatives developed may be subject to further Section 7 consultation regarding the potential for affecting spikedace and other listed species.

4. Water conservation and recycling.
Daily per capita water usage of Prescott was 141 gallons in 1980, which is low compared to the 267 gallons per capita per day (gpcd) used in Phoenix, the 160 gpcd used in Tucson (ADWR undated), and the average of 237 gpcd used in the southwestern United States (USGS 1976). Additional information furnished in Reclamation's April 13, 1990 comments on the draft of this biological opinion indicate that Prescott water consumption has been reduced to 129 gpcd with a recharge program in place to recycle water. Detailed information was not furnished on those items. While Prescott's efforts are commendable, the Service believes additional water conservation and recycling are still a feasible alternative for furnishing some portion of the water which would otherwise be obtained via diversion of the CAP allocation from the Verde River. Water recycling is one of the alternatives which the ADWR requires Active Management Areas, such as Prescott, to consider in their development of future water supplies (ADWR undated). CAP exchange could be accomplished by exchange of allocated water to another entity in return for assistance in development of conservation and/or recycling programs and facilities.

Two additional alternatives for water development were considered and rejected as not feasible. The first concerned the potential for capture of flood flows for transmittal to offstream storage. That alternative was rejected because of the importance of the flood flows to channel maintenance and non-native fish control, because of the limited occurrence and short duration of flood events in the Verde River headwaters, and because no feasible site for offstream storage could be identified (A. Gookin, Gookin and Assoc., pers. com., January 25, 1989). The second would have involved diversion of water from the Verde River below the confluence with Sycamore Creek and the downstream end of the spikedace range. This alternative was rejected due to the high biological value of the aquatic and riparian ecosystem in that portion of the Verde River basin. The endangered bald eagle and several candidate species inhabit that area and additional water diversion may adversely affect one or more of those species. For those reasons, the Fish and Wildlife Coordination Act Report (USFWS 1989) on the CAP Water Exchange Project in the Upper Verde River recommended that no water be diverted from the Verde River.

INCIDENTAL TAKE

Section 9 of the Endangered Species Act, as amended, prohibits any taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species without a special exemption. Under the terms of 7(b)(4) and 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered taking within the bounds of the Act provided that such taking is in compliance with the incidental take statement. The Service does not anticipate that the proposed action would result in any incidental take of the spikedace. Accordingly, no incidental take is authorized and no incidental take statement is provided. If during the course of the action any incidental take should occur, Reclamation must reinitiate formal consultation with the Service and provide an explanation of the causes of the taking.

Because this is a jeopardy biological opinion, Reclamation is required to notify the Service of its final decision on the reasonable and prudent alternatives.

This concludes formal consultation on this action. Reinitiation of formal consultation is required if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, if the action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion, and/or if a new species is listed or critical habitat designated that may be affected by this action. This formal consultation does not include other endangered or threatened species for which Reclamation has indicated consultation would be requested at a later date.

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APPENDIX A

USE OF INSTREAM FLOW INCREMENTAL METHODOLOGY IN ANALYSIS OF IMPACTS TO SPIKEDACE FROM CENTRAL ARIZONA PROJECT UPPER VERDE WATER EXCHANGE PROJECT

An Instream Flow Incremental Methodology (IFIM) study was conducted on the upper Verde River in 1985-87 by the Arizona Game and Fish Department (AGFD), the Fish and Wildlife Service (Service), and the Bureau of Reclamation (Reclamation). The purpose of this study was to analyze the potential impacts to target fish species of various alternative levels of diversion from the Verde River as proposed under the Bureau of Reclamation's Central Arizona Project (CAP) Upper Verde River Water Exchange Project. IFIM is a modeling tool which attempts to predict the carrying capacity of a stream for target species at various flows using measurements of four habitat variables: velocity, substrate, depth, and cover.

The IFIM study and its predictions for spikedace habitat availability at the flow levels proposed under the joint City of Prescott/Yavapai-Prescott Indian Community CAP Water Exchange diversion were reviewed by a team of agency and university biologists. The findings of that group and of the Service is that the IFIM does not accurately assess the impacts of water depletion on the spikedace in the upper Verde River and that the predictive results are not valid for this species in this case.

Too little is known of spikedace biology and habitat needs to accurately apply IFIM to the upper Verde River population. Several of the basic assumptions on which IFIM is based may not apply to spikedace in general or to the upper Verde River population in specific. IFIM assumes a linear correlation between the basic measure of habitat availability (Weighted Usable Area [WUA]) and biomass of fish. There are no data available to indicate if this is true for spikedace in the upper Verde River. Such linearity has been shown to exist for some species and to be nonexistent in other species (Orth and Maughan 1982).

To predict habitat availability, and thereby population size, IFIM uses measurements of only four habitat parameters; stream depth, velocity, substrate, and cover, and assumes equal value for each variable. In addition, water temperature and chemistry may be addressed using IFIM, although this was not done in the upper Verde River study. This approach ignores the concept of limiting factors and assumes that the population is always at the carrying capacity of the habitat. No data are available to indicate if this assumption is true for spikedace in the upper Verde River. However, spikedace abundances at any one point in the upper Verde River are known to undergo large fluctuations apparently independently from any obvious changes in the four IFIM habitat parameters. This indicates that the population is probably not limited by any simple function of one of the IFIM parameters, but rather by some other abiotic or biotic factor or combination of factors. These fluctuations may also indicate seasonal shifts in habitat use or in limiting factor, in which case the IFIM study may substantially underestimate the amount of habitat needed to support a population of spikedace.

IFIM also assumes that a species use of each habitat variable is independent from its use of each other variable. This again has not been shown to be the case for the spikedace in the upper Verde River. Studies on spikedace elsewhere (Propst et al. 1986) indicate that there are intricate interrelationships between spikedace use of velocities and substrates under various channel configurations and in differing temperature regimes.

Use in the IFIM of only four measures of general habitat, each assumed to act upon the population independently, may give an inaccurate assessment of habitat availability for an intensely microhabitat specific species such as spikedace. The areas of primary adult spikedace use are at the slow/fast water interface or shear zone, at the upper end of mid-channel, sand/gravel bars where the flow divides and becomes shallow, sheet flow, and in eddy pools at the downstream end of cross-channel riffles. The IFIM model does not allow for incorporation of such conditional habitat needs. Therefore, the WUA estimates produced by the IFIM model may be highly inaccurate for spikedace.

WUA estimates depend heavily on the use of transects at "representative" sites to gather hydrologic and hydraulic data. If the stream being modeled has a high degree of variability in hydraulic and hydrologic characteristics along its length, or if the sites are not carefully selected, then they may not accurately represent the available habitat and the WUA estimates would be erroneous.

IFIM does not allow for incorporation of data on the role of interspecific interactions among fish species. Such interspecific interactions may be a major factor in habitat use by spikedace in the upper Verde River. In particular, the interaction between spikedace and the red shiner may plan an important role in actual habitat availability for spikedace in the presence of red shiner (Marsh et al. 1989).

Many aspects of spikedace biology are poorly understood. No eggs of spikedace have yet been found and nothing is known of incubation or hatching needs for the species. The data gathered to define spikedace spawning habitat preferences in the upper Verde River IFIM study are based upon a small sample size (n=50) of spikedace with observed secondary spawning characteristics. Because of lack of data, the IFIM study does not address incubation or hatching needs and may not accurately assess spawning needs.

Analysis of seasonal and diurnal habitat use changes using IFIM is difficult and was, therefore, not addressed during the upper Verde River IFIM study. Although the biological data collected from the upper Verde River did not indicate occurrence of any such seasonal or diurnal habitat shifts in the spikedace population, seasonal shifts have been shown to occur in the spikedace population in the Gila River (Propst et al. 1986). Data from the upper Verde River study appropriate for such an analysis was very limited and was inadequate to support an assumption that no such seasonal shifts occur there. Any use of WUA estimates must be modified by such considerations. Subtle shifts in seasonal spikedace habitat use in areas of different habitat availability make the applicability of generalized IFIM species habitat preference curves problematic.