ARIZONA GAME AND FISH DEPARTMENT

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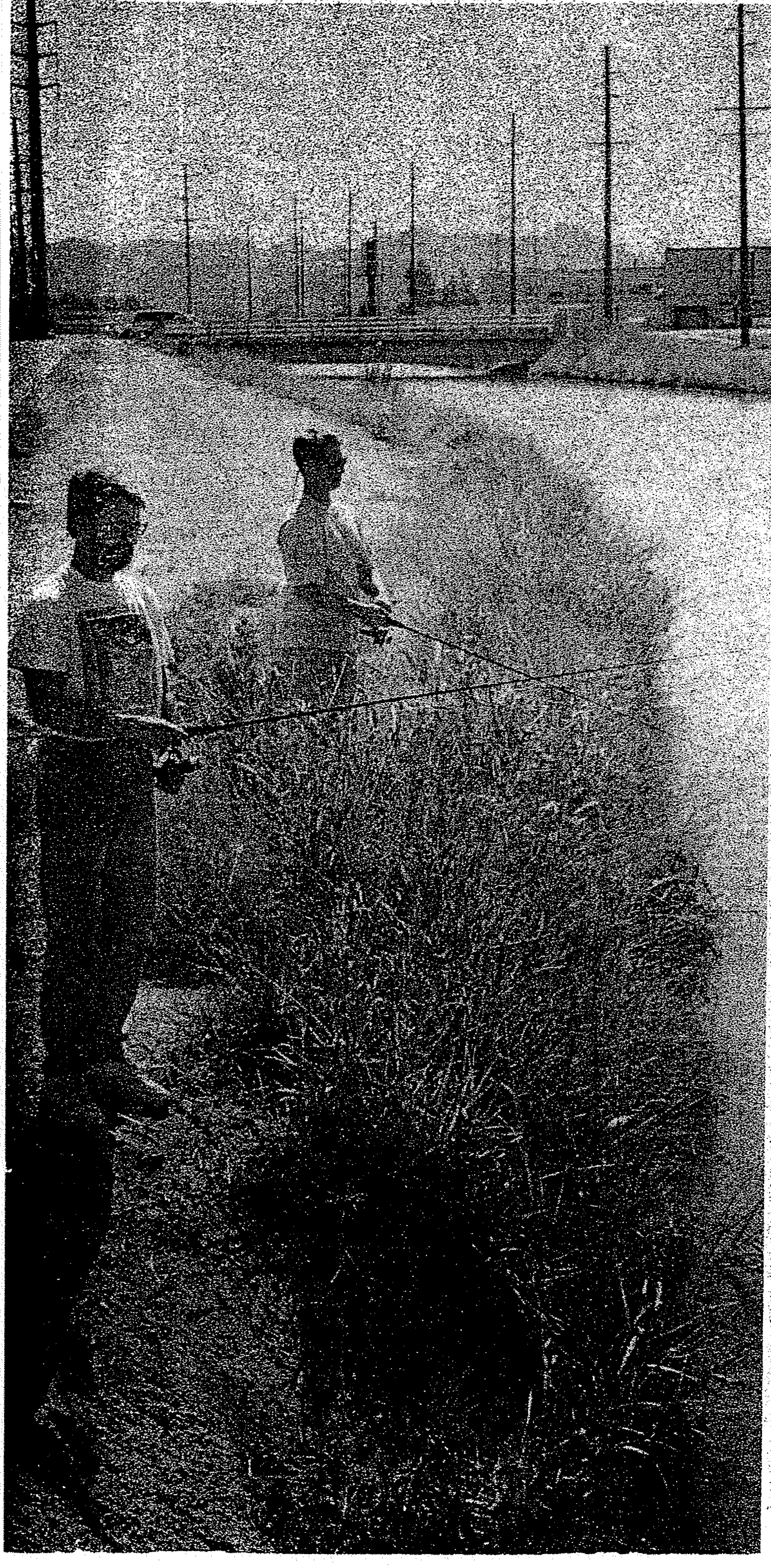

FEASIBILITY OF DEVELOPING AND MAINTAINING A SPORT FISHERY IN THE SALT RIVER PROJECT CANALS, PHOENIX, ARIZONA

A Final Report

BRIAN R. WRIGHT
JEFF A. SORENSEN
September 1995

FEDERAL AID IN SPORT FISH RESTORATION PROJECT
and
ARIZONA GAME AND FISH DEPARTMENT HERITAGE FUND

Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

Arizona Game and Fish Department
Research Branch

Technical Report No. 18

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Brian R. Wright
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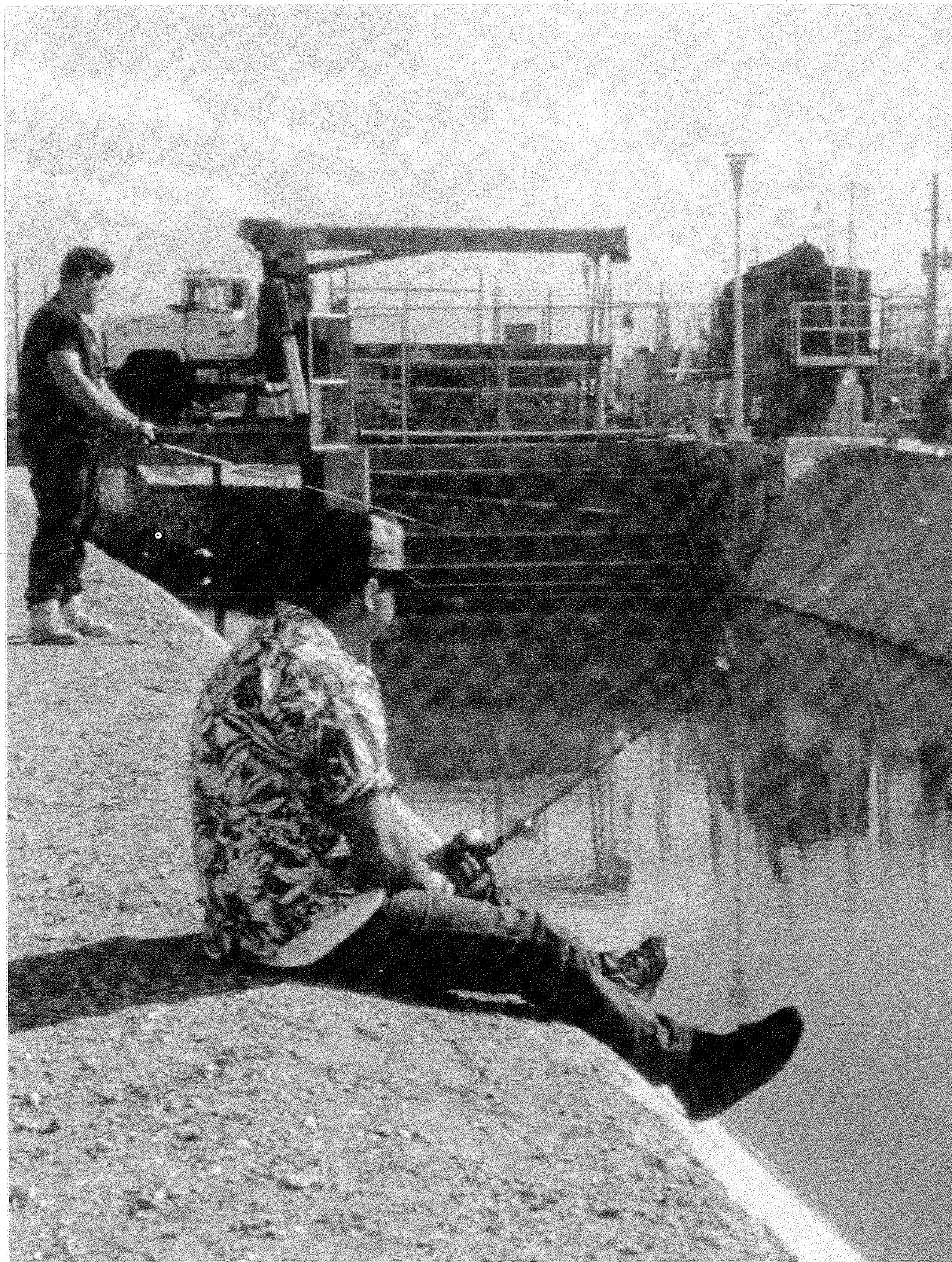

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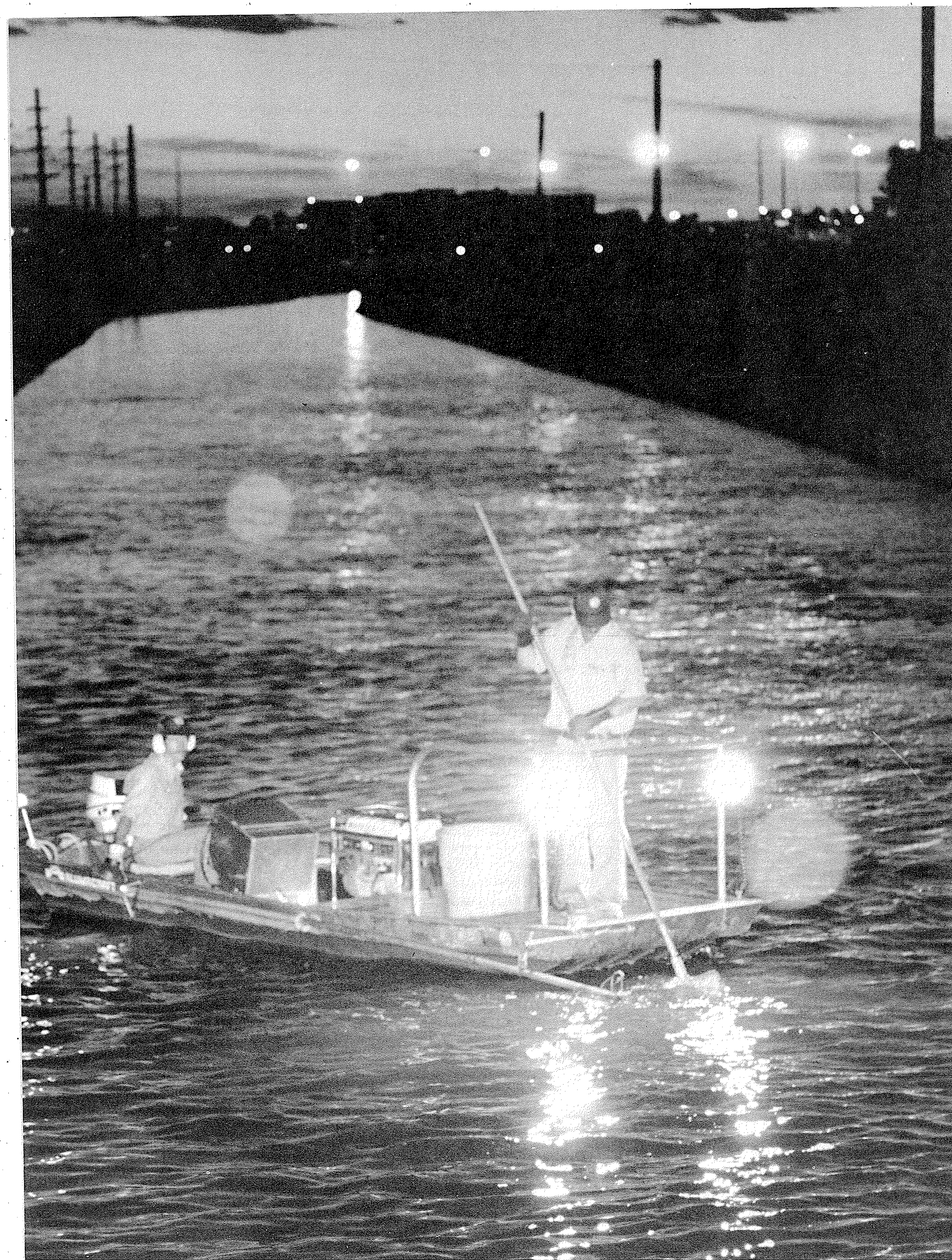
This project was also funded by a grant from the Arizona Game and Fish Department Heritage Fund. The Arizona Game and Fish Department Heritage Fund was designed to conserve, enhance, and establish wildlife habitats and populations in urban environments, and to increase public awareness of urban wildlife resources.



Feasibility of Developing and Maintaining a Sport Fishery in the Salt River Project Canals, Phoenix, Arizona

Brian R. Wright and Jeff A. Sorensen

Abstract: In the last decade, the increasing popularity of urban fishing has stimulated interest in using the Salt River Project (SRP) canals as a sport fishery. Currently, fishing occurs in these canals but is not encouraged by SRP due primarily to liability concerns. This project was initiated to study the biological and environmental potential of SRP canals to support increased angling opportunities. We investigated the aquatic resources of the 61.4 km Arizona Canal, a part of the SRP canal system, in the Phoenix metropolitan area from February 1992 through July 1994. Monthly electrofishing surveys showed a diverse assemblage of native and introduced fish species (species richness = 3 and 17, respectively). Relative abundance of fish among collection sites was highly variable and increased moving downstream (35% of all fish sampled were found at Site 3, while only 9.5% were at Site 7). Native suckers and forage fish sample numbers were high (n >1,500 each), while game fish were less abundant (n <200 each). Observed water quality values were adequate for sustaining warm-water fish species year-round. Primary production levels were moderate ($\bar{x}$ chlorophyll *a*:pheophytin *a* ratios ranged between 1.4 and 1.1). Benthic macroinvertebrate and zooplankton taxa were numerous (n = 18 and n = 38, respectively), but their standing stocks were low ($\bar{x}$ <20/m^2 and $\bar{x}$ <5/20 L, respectively). Recapture frequencies of experimentally stocked channel catfish (*Ictalurus punctatus*) and rainbow trout (*Oncorhynchus mykiss*) were highest within the first 6 weeks after stocking. After 5 to 12 months in the Arizona Canal, these fish showed no substantial growth or improvement in physiological condition. Most of the stocked fish (99.4% of the channel catfish and 95.5% of the rainbow trout) did not migrate from the area they were stocked. Based on limited samples, potential fish tissue contamination was low (priority compounds were below FDA Action Levels for safe human consumption). Our study revealed that a put-and-take fishery could be established in the Arizona Canal to provide increased angling opportunities. Channel catfish could be stocked in the summer and rainbow trout in the winter. A public opinion telephone survey showed a high level of interest and support for creating additional fishing opportunities in the SRP canals (68% of the respondents were in favor). A canal fishery program is estimated to add 750,000 angler-use days annually, and generate a potential $1.55 million in revenues from the sale of 129,500 new fishing licenses. Various management options are presented concerning program administration and licensing, physical and biological enhancements, stocking strategies, monitoring activities, public safety and liability, and future research.

Key Words: Arizona, canals, *Catostomus clarki*, *Catostomus insignis*, channel catfish, *Ctenopharyngodon idella*, desert sucker, *Ictalurus punctatus*, *Oncorhynchus mykiss*, rainbow trout, recreational fishing, Sonora sucker, urban fishing, white amur.

INTRODUCTION

Since 1900, large-scale surface water developments have been constructed in the western United States to store water for irrigation and to provide flood control (Calif. Dep. of Water Resour. 1957). Marsh and Fisher (1987) estimated that there are >11,000 km of canals in the desert southwest. These canals represent a considerable recreational resource for anglers. Interest in developing recreational fishing in canals of the western United States has grown in the last 30 years. By 1990, several western canal systems had public fisheries (U.S. Bur. of Reclam. 1990), such as California's Central Valley Project (CVP) and California State Water Project (CSWP).

The CVP had 328 km of canals with existing fisheries, with most angling occurring along rural sections of the Delta-Mendota and San Luis canals (U.S. Bur. of Reclam. 1990). An additional 256 km of the CVP offered fishing opportunities; specifically, portions of the Folsom South, Corning, and Tehama-Colusa canals (U.S. Bur. of Reclam. 1990). Both the Folsom South and Corning canals were limited to a put-and-take fishery due to the lack of year-round flows (U.S.

Bur. of Reclam. 1990). Currently, public fishing is allowed in the CVP canals but is not actively promoted. Most fishing occurs at major road crossings and established fishing access sites, while some sections of the CVP are fenced and posted "No Trespassing" (R. Edwards, U.S. Bur. of Reclam., pers. commun.).

The California Aqueduct, part of the CSWP, had 552 km of open canals for public fishing and 18 designated fishing access sites (Calif. Dep. of Fish and Game 1984). Construction costs for fishing access sites were approximately $25,000 each and included parking areas, sanitary facilities, trash containers, and fishing platforms (Calif. Dep. of Fish and Game 1984). In 1982, the California Department of Water Resources (CDWR) estimated that 99,000 anglers fished the California Aqueduct; 28,000 fished at designated access sites and 71,000 fished along other sections of the aqueduct (Calif. Dep. of Fish and Game 1984). For 1991 and 1992, the CDWR estimated that 61,000 and 53,000 anglers, respectively, fished along the aqueduct (Calif. Dep. of Water Resources 1992, 1994). It is unclear why the number of anglers fishing along the California Aqueduct declined between 1991 and 1992.

Other canal systems in California (e.g., All-American Canal, Coachella Canal, and Los Angeles Aqueduct) have potential fisheries, but are currently posted "No Trespassing" due to liability concerns. However, from November 1, 1985 to October 30, 1989, the Imperial Irrigation District estimated that 75,427 anglers fished a 38.6-km section of the All-American Canal and its 3 supply canals (Stocker et al. 1990). Numerous studies on the Coachella Canal have revealed a large, diverse fishery and considerable aquatic resources (Minckley 1980, Marsh 1981, McCarthy and Marsh 1982, Marsh and Stinemetz 1983, Minckley et al. 1983, Mueller et al. 1989, Mueller and Liston 1991). The U.S. Bureau of Reclamation (BOR) reported that all canals within the lower Colorado Region supported some degree of public angling, whether access was legal or not (U.S. Bur. of Reclam. 1990).

In 1989, the BOR and Arizona Game and Fish Department (AGFD) proposed a pilot project to examine the feasibility of establishing and maintaining a public fishing access facility on the Central Arizona Project (CAP; Mueller and Riley 1989). Investigations of the CAP (Mueller 1990, Mueller and Liston 1991) have documented the biological resources of this canal, but currently, no legal or authorized fishing is allowed within the CAP (L. Riley, Ariz. Game and Fish Dep., pers. commun.).

Although some canals described above are closed to fishing at this time due to safety and liability issues, canals can and do provide substantial recreational fishing opportunities. Due to an increased demand for urban fishing, numerous proposals have been made to utilize the Phoenix metropolitan Salt River Project (SRP) canals as an urban fishery (Fig. 1). This demand is illustrated by growth in urban fishing license sales from 2,500 sold in 1983 to 25,679 sold in 1994 (E. Swanson, Ariz. Game and Fish Dep., pers. commun.). Another indicator of the popularity of the Urban Fishing Program is based on the increased number of angler-days spent fishing. From 1987 to 1988, an estimated 250,000 angler-days were spent at the 8 urban lakes in the Phoenix and Tucson, Arizona, metropolitan areas (Watt and Persons 1990). By 1994, the number of angler-days increased to approximately 400,000, with most of this growth attributed to the addition of 4 new urban lakes to the Urban Fishing Program (E. Swanson, Ariz. Game and Fish Dep., pers. commun.).

The SRP canals could provide additional urban fishing opportunities, but more information was needed on the biology of this system. Limited studies have been conducted on fish species diversity and distribution in the canal system (Marsh and Minckley 1982). Primary productivity in the Arizona Canal and benthic fauna in a lateral canal were also studied (Marsh 1983, Marsh and Fisher 1987). These studies demonstrated that the SRP canals are an important aquatic resource, but little information exists from a sport fishery perspective.

Presently, the poor quality of the sport fishery and the public's lack of knowledge of the available angling opportunities limit the number of angler-days spent on the SRP canals. Maintenance operations by SRP also affect the quality of the fishery because many canal reaches are dewatered annually to remove vegetation, sediment, debris, and alum sludge, as well as for other maintenance purposes. Regardless, the SRP canal system, with 217 km of major canals, attracts substantial recreational interest from a population of over 2 million people within the Phoenix metropolitan area.

In 1964, an agreement between SRP and the BOR allowed public access for recreational

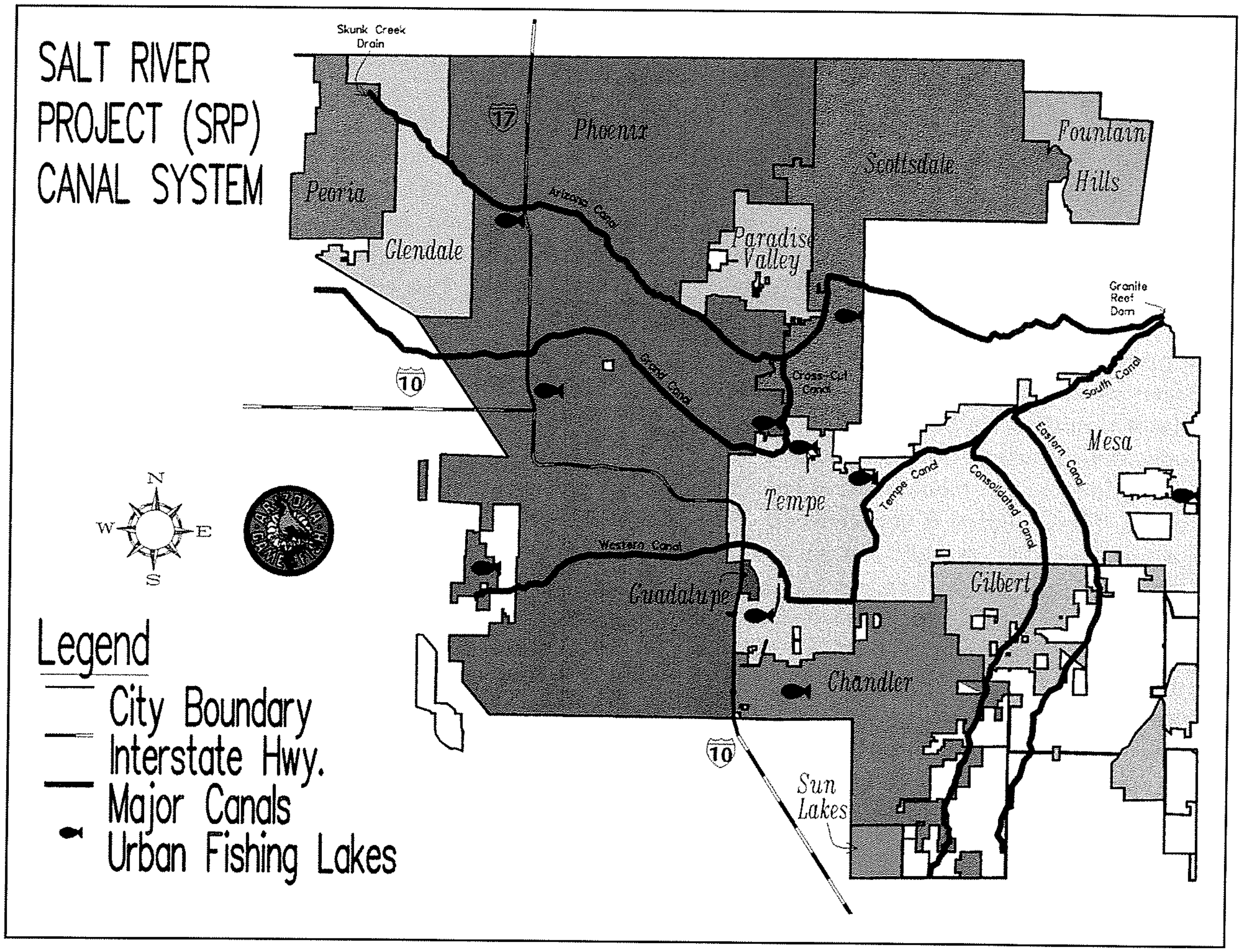


Figure 1. Major SRP canals and urban fishing lakes of the Phoenix metropolitan area.

activities along the SRP canal system. This agreement authorized issuance of permits to municipalities to allow development of right-of-ways along the canal banks for public recreational use. Scottsdale, Arizona, designated the bank area between Pima and Hayden roads as a multiple-use riverwalk (Salt River Proj. 1993). This area has become a popular path for walking, jogging, bicycling, and horseback riding. These activities are prevalent along much of the SRP canal system. In recent years, multiple-use of the canals has received greater interest as evidenced by community development projects in Scottsdale, Glendale, Sunnyslope, Chandler, Gilbert, and the formation of citizen advocacy groups.

Salt River Project has been reluctant to encourage fishing in the canals due to liability concerns. However before a canal sport fishery can be considered or promoted, public safety and liability issues must be resolved. Fishing in the SRP canals is widespread albeit at low levels. A statewide fishing license is required to fish the canals. These waters are not managed for sport fishery and, therefore, are not stocked with game fish (except for research purposes). Those resident game fish found in the SRP canals originate from the Salt and Verde rivers above the Granite Reef Diversion Dam.

For approximately 6 years, SRP has stocked sterile white amurs (*Ctenopharyngodon ideалla*) in some canal segments to control aquatic vegetation which impedes water flow. Annually, SRP stocks about 1,500 white amurs to maintain stable populations and by March 1994, had stocked about 18,000 white amurs in 118 km of canals. By using the amurs, SRP has reduced the amount of herbicides applied in the canals.

A steering committee composed of research and management personnel from AGFD and SRP was formed to identify the information needed to assess the feasibility of developing and maintaining a sport fishery in the SRP canals. Two goals of this research project were to determine if the SRP canals can support a harvestable sport fishery, and to determine if there is public demand for this fishery.

Initially, we needed to investigate the current fish communities within the canals to determine which fish species live in the canals and how abundant they are. Then, we needed to find out if the size and number of resident game fish would satisfy angler demands. Stocking catchable-sized game fish is expensive, so ideally resource managers would hope a canal fishery could be self-sustaining through immigration and natural reproduction. If fish stocking is necessary, we wanted to know if fish would survive and grow in the canals. This question is important in determining stocking strategies — a put-and-take fishery versus a put-grow-take fishery. If conditions in the canal allow fish to survive year-round, is there potential for managing a self-sustaining sport fish population?

Resource managers believe that stocked fish may leave the main canals through irrigation lateral deliveries, thus lowering the number of sport fish available for anglers (Sorensen 1990). In addition, heavy loss of fish to the lateral canals would not make a regular stocking program cost effective. If fish do remain in the main canals, do they continually move throughout the system or congregate in specific locations?

We were also concerned that stocked fish may accumulate pollutants in their tissues over time which may pose a public health risk. Contaminant analyses are necessary to establish a canal sport fishery with fish that are safe for human consumption.

Another important consideration was to determine whether the canals had environmental conditions that would limit fish survival. For example, we suspected that summer water temperatures and dissolved oxygen concentrations probably approach lethal levels for cold-water species, such as trout. Also, we wanted to ascertain what food items were available in the canals for fish.

If a canal sport fishery was established, who would take advantage of this new resource? Would the canals attract anglers from the general public? What is the estimated use and potential revenue from creating new fishing opportunities in the canals? In addition, managers want to know what types of game fish anglers would prefer having stocked.

The last step in planning a canal fishery is deciding where public fishing could occur along the canals. Established fishing sites with parking lots, restrooms, trash receptacles, safety railings, and good public access would attract anglers. These areas would be more convenient and safer for the public, especially children and the physically challenged, and would ease liability concerns. Law enforcement and creel survey personnel would benefit by having less total area to cover.

The objectives of this study were to:

- Determine the assemblage of fish in the canals – specifically species diversity, abundance, condition factors, and length frequencies.
- Estimate game fish abundance in the canals and determine if they are sufficient to meet angler demand.
- Investigate which fish species currently immigrate into the canals.
- Determine if 2 species of stocked game fish would survive and grow in the canal environment, as well as estimate how long stocked fish remain in the canals.
- Document stocked fish movement as well as possible escape into lateral canals.
- Analyze stocked fish for potential pollutants that may have accumulated in their tissues after several months in the canal.
- Investigate water quality parameters which may limit the potential for a sport fishery in the canal system.
- Identify what food items are available to fish in the canals.
- Survey licensed anglers and the general public to ascertain who would take advantage of a canal fishery.
- Estimate the potential increase in angler-use days and revenue from fishing licenses if a canal sport fishery were developed.
- Identify which fish species anglers want to catch in the canals.
- Identify and evaluate areas that offer the best potential for providing public fishing access.

STUDY AREA

The SRP canal system extends through 10 cities and the Salt River Indian Reservation within the Phoenix metropolitan area. It consists of 217 km of main canals and 1,487 km of smaller, lateral canals and ditches, which deliver water for irrigation and municipal use (Salt River Proj. 1993, 1994*a*). The SRP canal system begins below Granite Reef Diversion Dam and has 8 major canals: Arizona, Consolidated, Eastern, Grand, South, Tempe, Western, and Cross-Cut. Granite Reef Dam (Fig. 2) diverts water into the SRP canals, and is located about 6.5 km downstream of the confluence of the Salt and Verde rivers. The watersheds of the Salt and Verde rivers drain approximately 33,680 km^2 to the east and north, respectively, of the Phoenix metropolitan area. Four reservoirs (Saguaro, Canyon, Apache, and Roosevelt) are located within the Salt River watershed and 2 (Bartlett and Horseshoe) within the Verde River watershed. Annually, these watersheds receive an average of 53.3 cm of precipitation (Salt River Proj. 1990).

A raised, trapezoidal, concrete fish barrier is located immediately below Granite Reef Dam on the Arizona Canal (Fig. 3; Appendix A, Map 1). This barrier has a series of electrical fields across the canal, steep slopes, and high water velocities that permit downstream movement of fish. The primary purpose of this barrier is to prevent fish from moving from the Arizona Canal and the CAP into the Salt River through the Granite Reef headgates (E. Swanson, Ariz. Game and Fish Dep., pers. commun.). Another electrical fish barrier was constructed on the South Canal for similar reasons (Appendix A, Map 1).

The Arizona Canal (Fig. 4) was selected for intensive study because it is the longest continuous canal (61.4 km) in the SRP system and traverses an extensive residential area. From its source at Granite Reef Dam, this canal flows west through the Salt River Indian Reservation and the cities of Scottsdale, Phoenix, Glendale, and Peoria, where it drains into Skunk Creek.

We established 5 fish collection sites and 3 alternate collection sites along the Arizona Canal (Table 1). Sites were established at locations where SRP maintenance (concrete) ramps had been constructed. Physical barriers (i.e., bridges and water control structures; Fig. 5*a, b*) formed the boundaries of each collection site. Alternate sites were established specifically to monitor

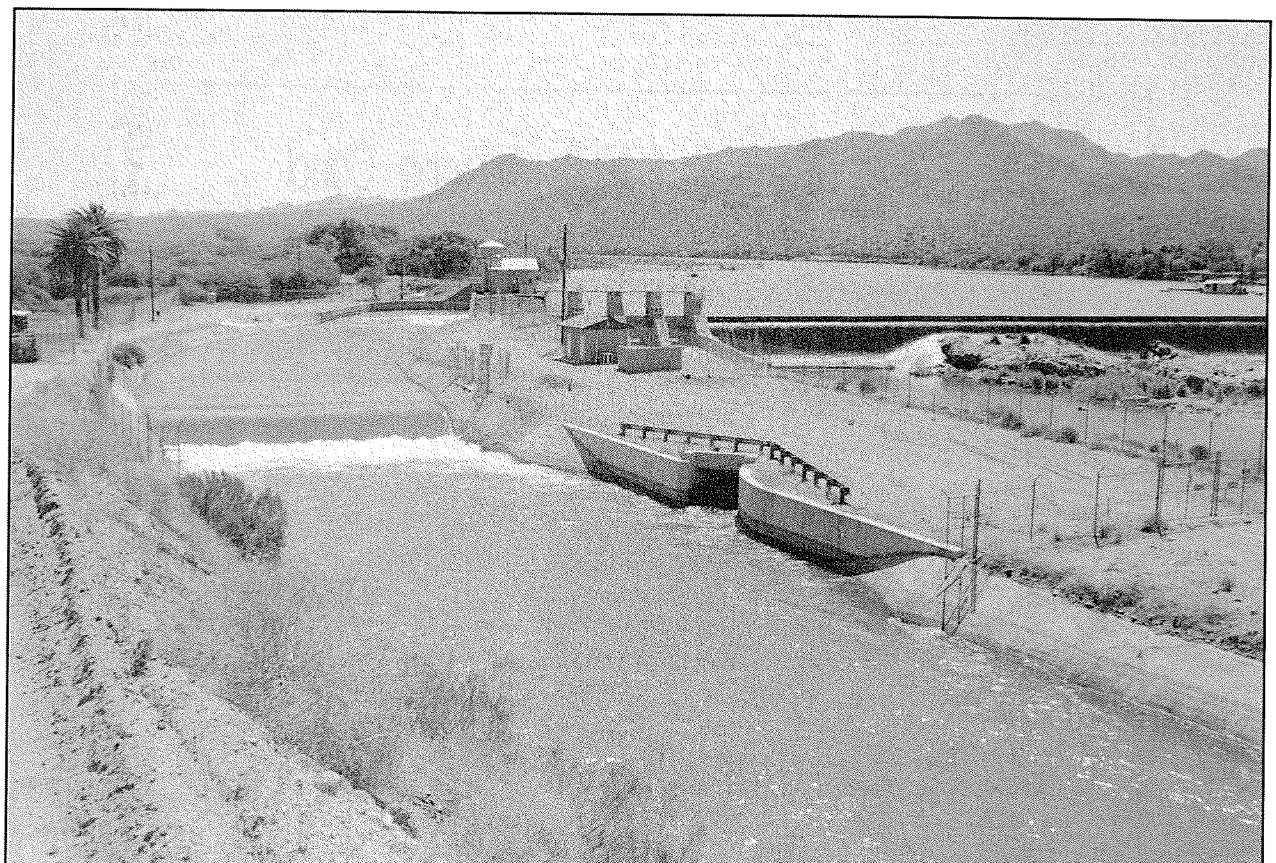


Figure 2. The origin of the Arizona Canal at Granite Reef Diversion Dam. The electric fish barrier is shown in the foreground.

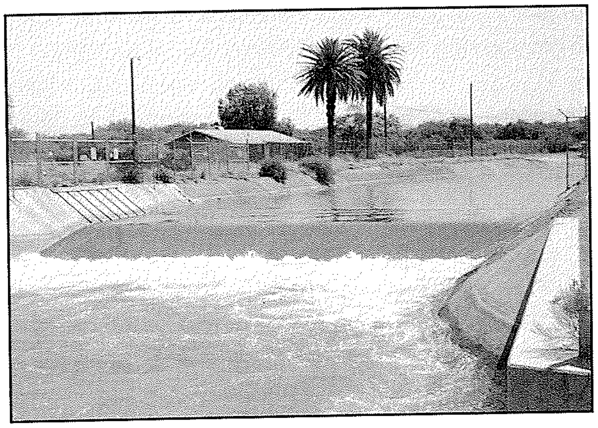


Figure 3. The electric fish barrier on the Arizona Canal prevents fish from moving upstream.

stocked fish movements and collect stocked fish for contaminant analysis. Water depth was approximated due to variations in seasonal water deliveries and gradient along the length of the canal.

Site 7 was a deep (2.5 m), free-flowing canal segment located about 20 km downstream from the Granite Reef Dam. This site was 1.6 km long with an average width of 26 m. The closest upstream water control structure was approximately 8 km above the Pima Road bridge at the Evergreen Drain Gates (Appendix A, Map 2). The nearest downstream water control structure was 0.5 km below the Hayden Road bridge (Appendix A, Map 3).

Site 5 was similar to Site 7 with free-flowing, deep water (2 m). This site was 2.4 km long and averaged 25 m across. The closest upstream water control structure was 0.6 km above the 68th Street bridge (Appendix A, Map 3). Located about 0.9 km downstream of the 68th Street bridge was the intake to the Cross-Cut Canal, which diverts large quantities of water to the Grand Canal. The lower boundary of this site was a water control structure (Arizona Falls) upstream of 56th Street.

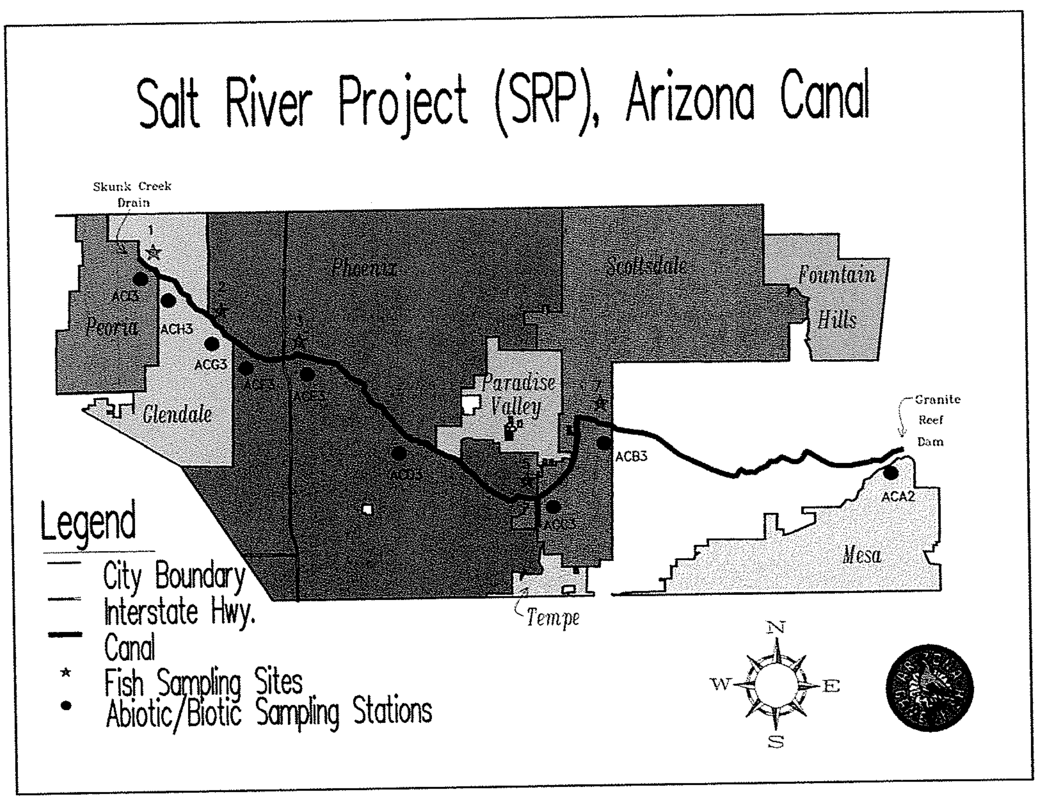


Figure 4. The Arizona Canal with AGFD sampling sites and stations.

Table 1. Regular and alternate fish collection sites on the Arizona Canal.

Regular sites	Street/Physical Location
7	Pima Road footbridge to Hayden Road vehicle bridge. Scottsdale.
5	68th Street footbridge to the "Arizona Falls" water control structure, above 56th Street. Phoenix.
3	19th Avenue vehicle bridge to 25th Avenue vehicle bridge. Phoenix.
2	43rd Avenue/ Peoria Avenue vehicle bridge to 47th Avenue footbridge. Glendale.
1	Water control structure at 67th Avenue to the water control structure at Skunk Creek Drain. Peoria.
Alternate sites for repeated-effort electrofishing.	
Alt. Site 3	Downstream of the Interstate 17 frontage road to the water control structure adjacent to the Phoenix (Deer Valley) water treatment facility. Phoenix.
Alt. Site 2	35th Avenue vehicle bridge downstream to the water control structure at the intersection of 43rd Avenue and Peoria Avenue. Glendale.
Alt. Site 1	59th Avenue vehicle bridge to Thunderbird Road vehicle bridge. Glendale.

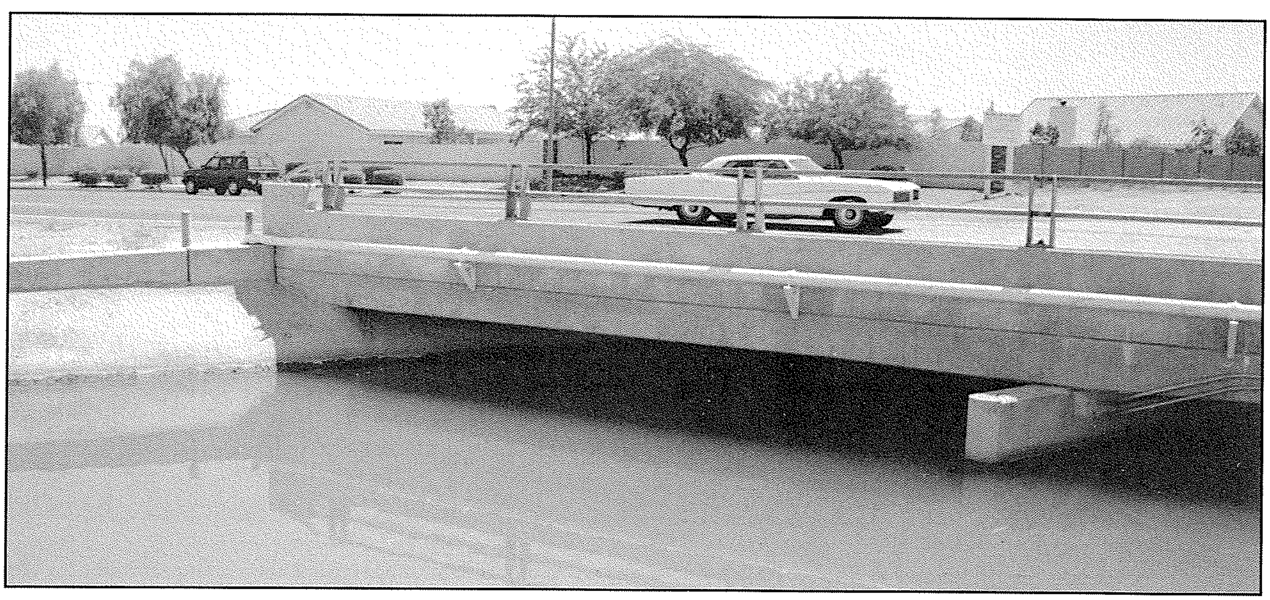


Figure 5a. Low bridges were physical barriers for our electrofishing boat and limited the area we could sample.

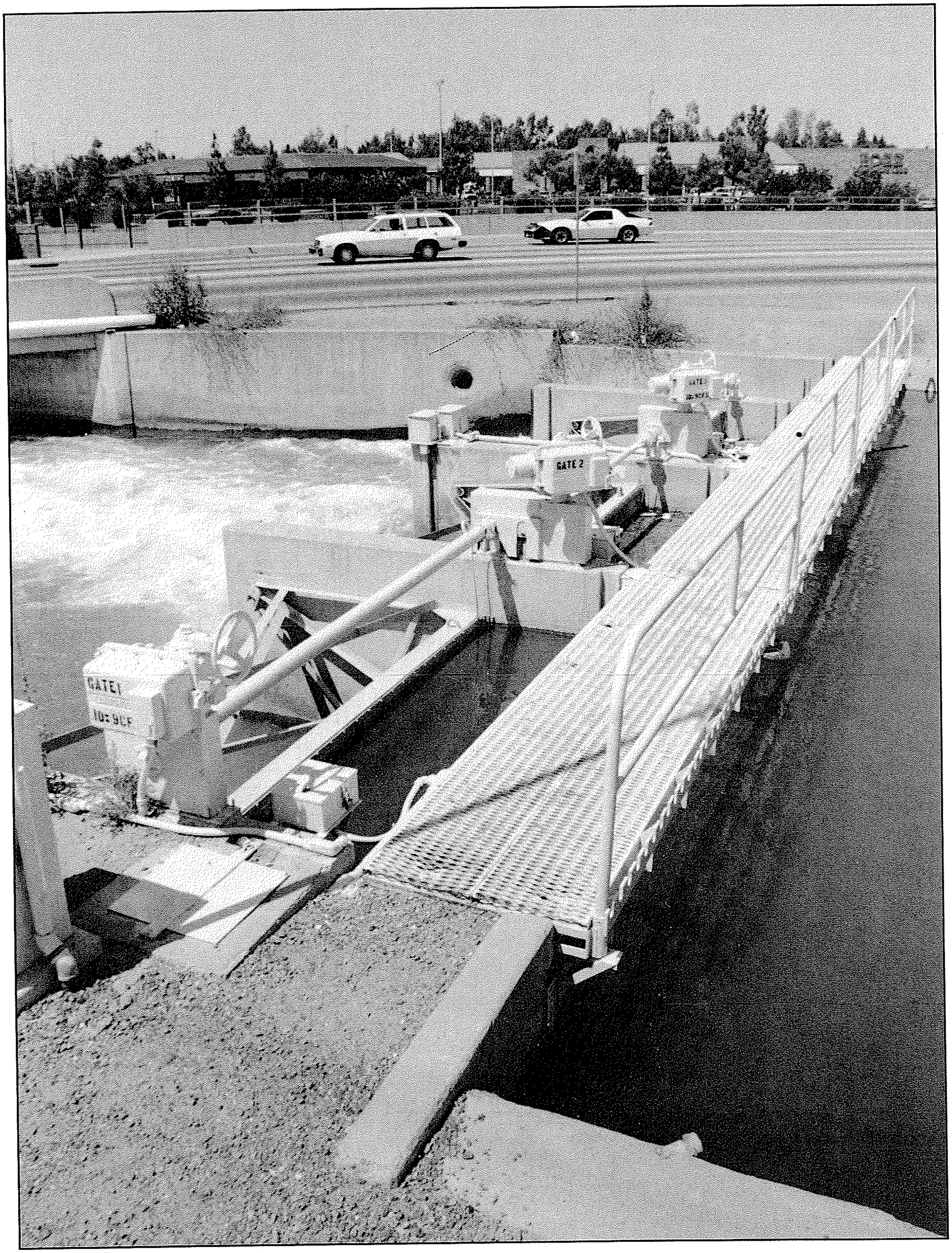


Figure 5b. A water control structure at Station ACF3, that uses a series of radial gates to regulate the volume of water flowing downstream.

Site 3 was a shallow site (1 m depth) with fast-moving water. It measured 1.1 km in length with an average width of 17 m. A water control structure was located at the upstream end of this site (19th Avenue; Appendix A, Map 5). Approximately 8.5 km upstream of Site 3, the Squaw Peak Water Treatment Plant discharged alum sludge into the Arizona Canal (Appendix A, Map 4). This discharge affected turbidity measurements at Site 3, as well as Sites 1 and 2. The lower sampling boundary for Site 3 was the 25th Avenue bridge.

Alternate Site 3 was located below Site 3 within the same canal segment (i.e., between 2 water control structures). This site was 0.6 km in length, averaged 17 m across, and was approximately 1-m deep. The upstream boundary was the frontage road immediately downstream of Interstate 17 (Black Canyon Highway; Appendix A, Map 5). The lower boundary was the water control structure adjacent to the Phoenix (Deer Valley) Water Treatment Plant. A vehicle bridge (29th Avenue) and a demossing bridge were located between Interstate 17 and the water control structure near the Phoenix (Deer Valley) Water Treatment Plant. Concrete-lined banks were found at the 29th Avenue bridge, the demossing bridge, and at the water control structure. The remaining canal segments within this site had earthen banks and an earthen bottom. Overhanging vegetation grew along the earthen banks. The Phoenix (Deer Valley) Water Treatment Plant regularly discharged alum sludge into the canal below the water control structure that formed the lower boundary of Alternate Site 3.

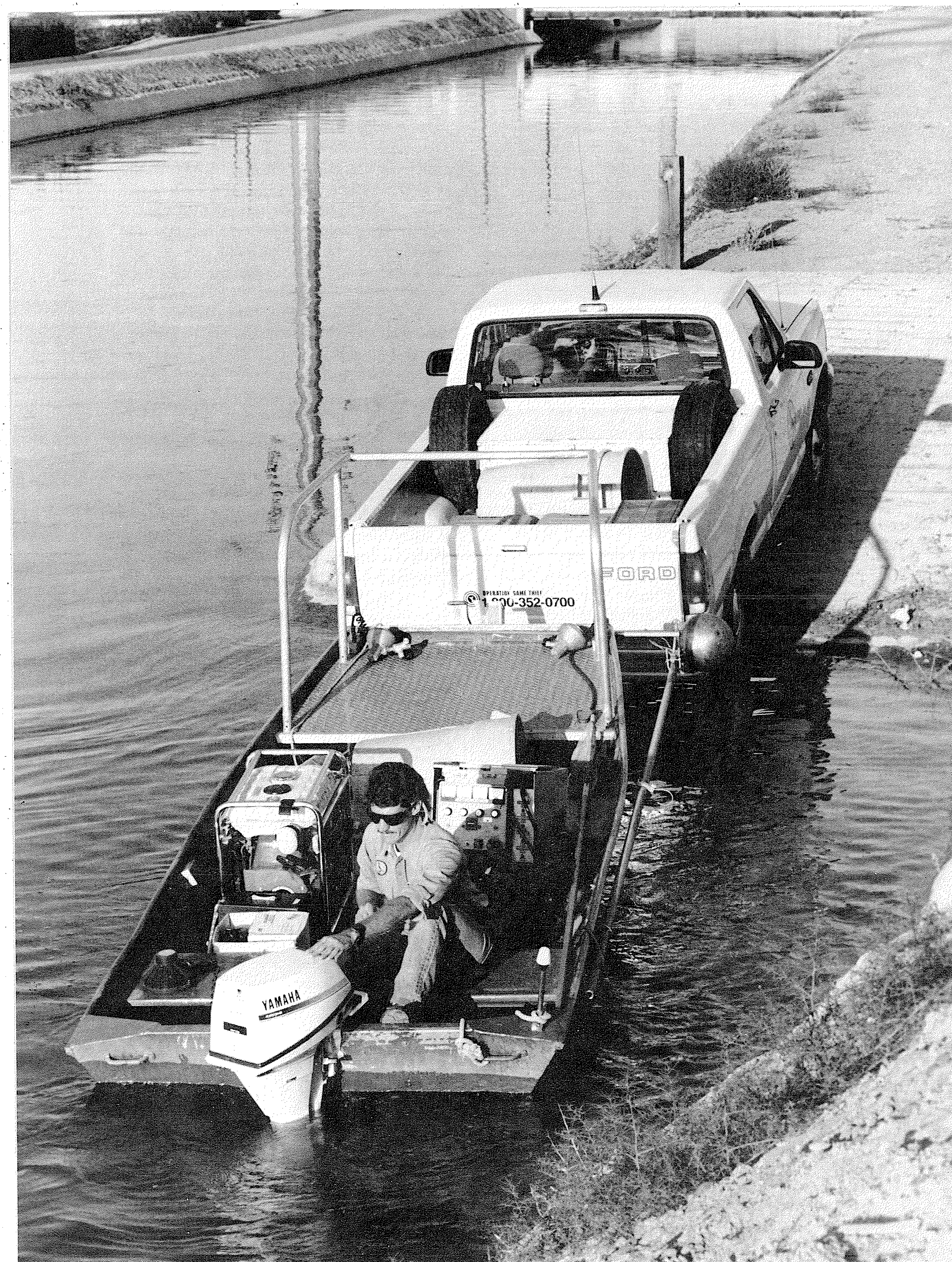
Alternate Sites 2 and 1 were established specifically to collect stocked fish for contaminant analysis; however, these sites were sampled sporadically. Therefore, these alternate sites will not be discussed further.

Site 2 was about 1.5 m deep and had slower-moving water than Site 3. This site measured 2.2 km in length and had an average width of 15 m. This site was divided into 2 segments (i.e., upper and lower). The upper segment was between the water control structure just upstream of the 43rd Avenue and Peoria Avenue intersection to the 47th Avenue footbridge just upstream of the Glendale (Cholla) Water Treatment Plant (Appendix A, Map 6). Approximately ⅓ of the northern side of the upper segment canal bank was earthen with overhanging vegetation, while the remaining banks of the upper segment was concrete-lined. The canal bottom of the upper segment of Site 2 was earthen, except near the intersection of 43rd Avenue and Peoria Avenue and 47th Avenue footbridge. The lower segment of Site 2 was between the 47th Avenue footbridge and the water control structure near the intersection of 51st Avenue and Cactus Road. Downstream of the footbridge, the banks and bottom were concrete-lined. The Glendale (Cholla) Water Treatment Plant regularly discharges alum sludge into the canal. Sludge accumulates upstream of the water control structure near the intersection of 51st Avenue and Cactus Road. Alum sludge can be as deep as 2 m in the lower segment of this site. We abandoned fish collections below the 47th Avenue footbridge because of the alum sludge.

Site 1 was located at the end of the Arizona Canal and was predominantly slack water. This site was 1.6 km long and averaged 10 m in width. A water control structure was located at the top of the site below the 67th Avenue bridge (Appendix A, Map 6). The lower boundary of this site was the Skunk Creek Drain Gate. The upper boundary of this site had an average water depth of 1-m while the lower boundary was approximately 2-m deep. Site 1 had concrete-lined banks and bottom.

Physical structures (i.e., bridges and water control structures), lateral canals, water treatment plants, and potential access sites (i.e., city streets, selected city parks, and concrete maintenance ramps) along the Arizona Canal are mapped in Appendix A. Habitat features (i.e., dirt-lined and concrete-lined banks), water control structures, and qualitative flow regimes (i.e., pools, runs, and riffles) in the Arizona Canal are mapped in Appendix B.

Locations for the water quality, chlorophyll *a*, benthos, and plankton sampling stations on the Arizona Canal are identified in Appendix C. Typically, these stations were found at bridges or water control structures.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METHODS

Fish Surveys

We used electrofishing to determine the number of resident fish species (species richness) in the canal. Resident fish were defined as those fish found in the canal either from natural reproduction or immigration. We used catch-per-unit-effort (CPUE; fish/hr) as an index of relative species abundance.

We electrofished the Arizona Canal monthly from October 1992 through July 1994 using a 4.3-m Alumacraft John-boat. This electrofishing platform was equipped with a Honda EMS-4000 generator, a variable voltage pulsator (VVP-15), and a spherical electrode. Typically, the electrofishing crew consisted of a netter and a boat/VVP-15 operator. Electrofishing was conducted at night using floodlights for better visibility and to attract some fish species (Minckley 1973). Typically, the range of VVP-15 settings used were: 100-150 V, 10-15 A, 30-40% DC pulse width, and 60-80 Hz frequency. The netter used an activating footpad to control electrical output. Effort was recorded in seconds using a chronometer activated by the footpad. The electrofishing boat was driven downstream within each site, covering both sides and the middle of the canal. Stunned fish were netted and placed in 121-L containers with fresh canal water. No anesthetics were used to sedate the fish.

We categorized fish into 4 general groups: natives, game fish, forage fish, and others. Native fish were: Sonora suckers (*Catostomus insignis*), desert suckers (*C. clarki*), and roundtail chubs (*Gila robusta*). Game fish were defined as: largemouth bass (*Micropterus salmoides*), yellow bass (*Morone mississippiensis*), channel catfish, and rainbow trout. Threadfin shad (*Dorosoma petenense*) and red shiners (*Cyprinella lutrensis*) were designated as forage fish or prey. We defined "other" species to be: white amurs, yellow bullheads (*Ameiurus natalis*), bluegill (*Lepomis macrochirus*), green sunfish (*L. cyanellus*), smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), flathead catfish (*Pylodictis olivaris*), oscar (*Astronotus ocellatus*), and walleye (*Stizostedion vitreum*). Species, total length (TL in mm), weight (g), and disposition (i.e., released alive, dead, preserved) were recorded. Each fish was examined for fin clips, tag scars, deformities, external parasites, and spinal injuries. White amurs and game fish with a TL $\geq$250 mm were tagged with a Floy® tag near the terminus of the dorsal fin. Floy® tags were used to identify individual fish, with known length, weight, and location, in subsequent sampling efforts. All fish were released back into the canal after processing, except selected individuals for contaminant analysis or reference collections.

Catch-per-unit-effort indices were also used to indicate changes in fish abundance across sites and over time. To determine differences in CPUE by site over time, each electrofishing effort was assigned to a specific season for each year. Each season covered a period of 3 months: September through November (Fall), December through February (Winter), March through May (Spring), and June through August (Summer). Two exceptions were Fall 1992 when sampling started in October, and Summer 1994 when sampling concluded in July.

To assess the canal's ability to sustain fish health and nutritional needs, estimates of fish physiological conditions were calculated from length-weight relationships. We calculated condition factors (K) using Fulton's equation (Anderson and Gutreuter 1983) for each species by site. Comparisons of K between different species cannot be calculated because of differences between body shapes and sizes; i.e., the size and shape characteristics of trout are different than those of sunfish. Additionally, K values tend to increase as fish length increases (Anderson and Gutreuter 1983). Our comparisons were limited to individuals of the same age group. Mean K factors were not calculated for fish weighing <10 g. The precision of our field scale (1-g units) was not effective in providing reliable weight measurements of fish <10 g. We considered K values of ≥ 1.00 to represent fish that were in good physiological condition, with the understanding that the range of optimum K varies with different species and age groups (Anderson and Gutreuter 1983). Our estimates of K were intended to provide a rough estimate of fish well-being in the Arizona Canal.

Seasonal length frequency distributions for the 6 most abundant species were plotted to estimate age classes and growth over time. Across-season length frequencies were plotted for yellow bass and roundtail chub. Age classes, or cohorts, were determined using the Peterson method (Jearld 1983), which identifies distinct peaks and ranges of length into separate age groups.

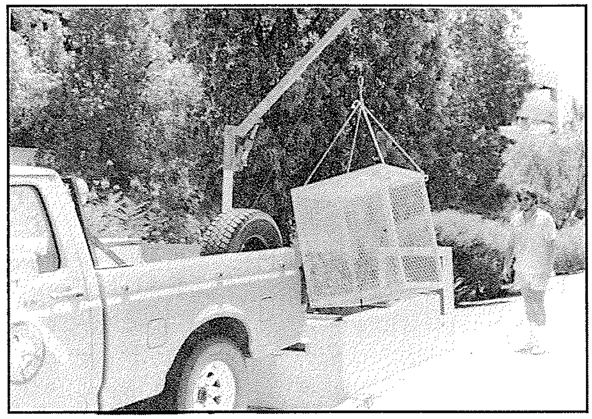
Granite Reef Electrical Barrier Monitoring

To determine the degree of fish immigration into the Arizona Canal, we looked at data from annual fish collections (Jakle and Riley, unpubl. data) at the head of the canal, between Granite Reef Dam and the electric fish barrier. Species richness and relative abundance of all fish collected were compiled for 5-yrs (1991 to 1995). These data represented an instantaneous estimate of fish that were immigrating into the canal because collections occurred on a single winter day each year when the canal was dewatered. Reduced water levels, multiple seine hauls, and backpack electrofishing were very effective in collecting most fish above the barrier. Surveys were a cooperative effort among BOR, SRP, AGFD, and U.S. Fish and Wildlife Service.

Experimental Fish Stockings

Catchable channel catfish and rainbow trout were experimentally stocked to: (1) estimate growth; (2) determine survival; (3) assess tissue contamination levels in fish; (4) monitor movements; and (5) assess losses to lateral canals. All fish were stocked at Site 3. On June 22, 1993, we stocked 1,500 channel catfish ($\bar{x}$ = 375-mm TL) marked with a right pectoral spine clip. On July 9, 1993, we stocked 500 additional channel catfish marked with numbered Floy® tags; we hoped to estimate growth and survival from recaptured fish. On November 3, 1993, 2,200 Floy®-tagged rainbow trout were stocked ($\bar{x}$ = 250-mm TL).

Before the June and November stockings, fish traps were placed in the first 5 lateral canals located downstream at Site 3 (Fig. 6). No traps were placed upstream of Site 3 because previous research indicated that fish did not move upstream through water control structures (Sorensen 1990). Each trap was constructed of 2-cm wide, steel diamond-mesh, and fit the inside dimensions of the lateral canal control structures (Fig. 7). These traps were designed to collect fish emigrating from the Arizona Canal. Based on previous studies (Sorensen 1990, Watt and Persons 1990), monitoring for a minimum of 40 days is sufficient to recover most stocked fish leaving the main canal. Traps were checked daily for a minimum of 40 days following initial stockings, to estimate the number of stocked fish lost to the lateral canals. We also checked the demossing structure (Fig. 8) at Skunk Creek Drain (Site 1) for stocked fish mortalities. The demossing structure at the canal's terminus collected most floating debris and organic material and deposited this refuse in a dump trailer. Fish traps were removed at the end of each monitoring period.



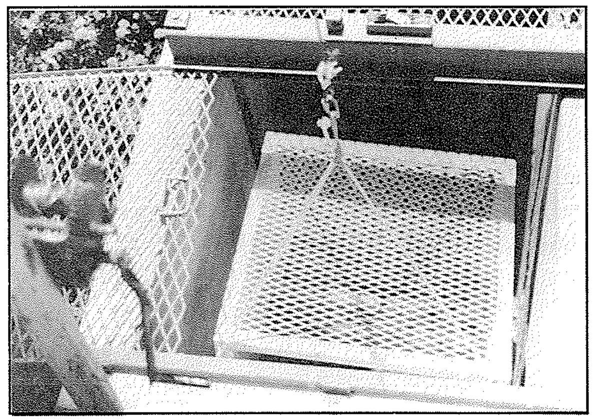


Figure 6. Placing a fish trap into a lateral canal near Site 3, prior to stocking game fish.

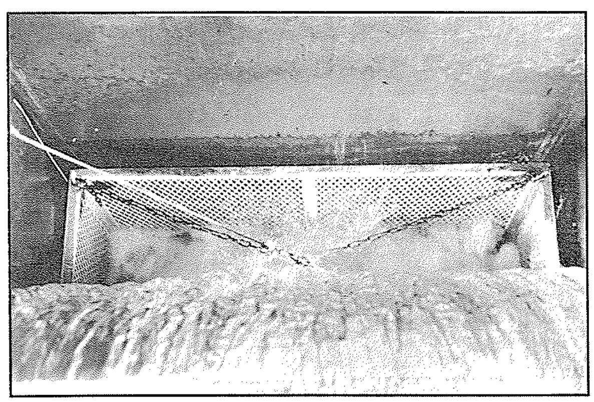


Figure 7. Water pouring into a lateral canal fish trap.

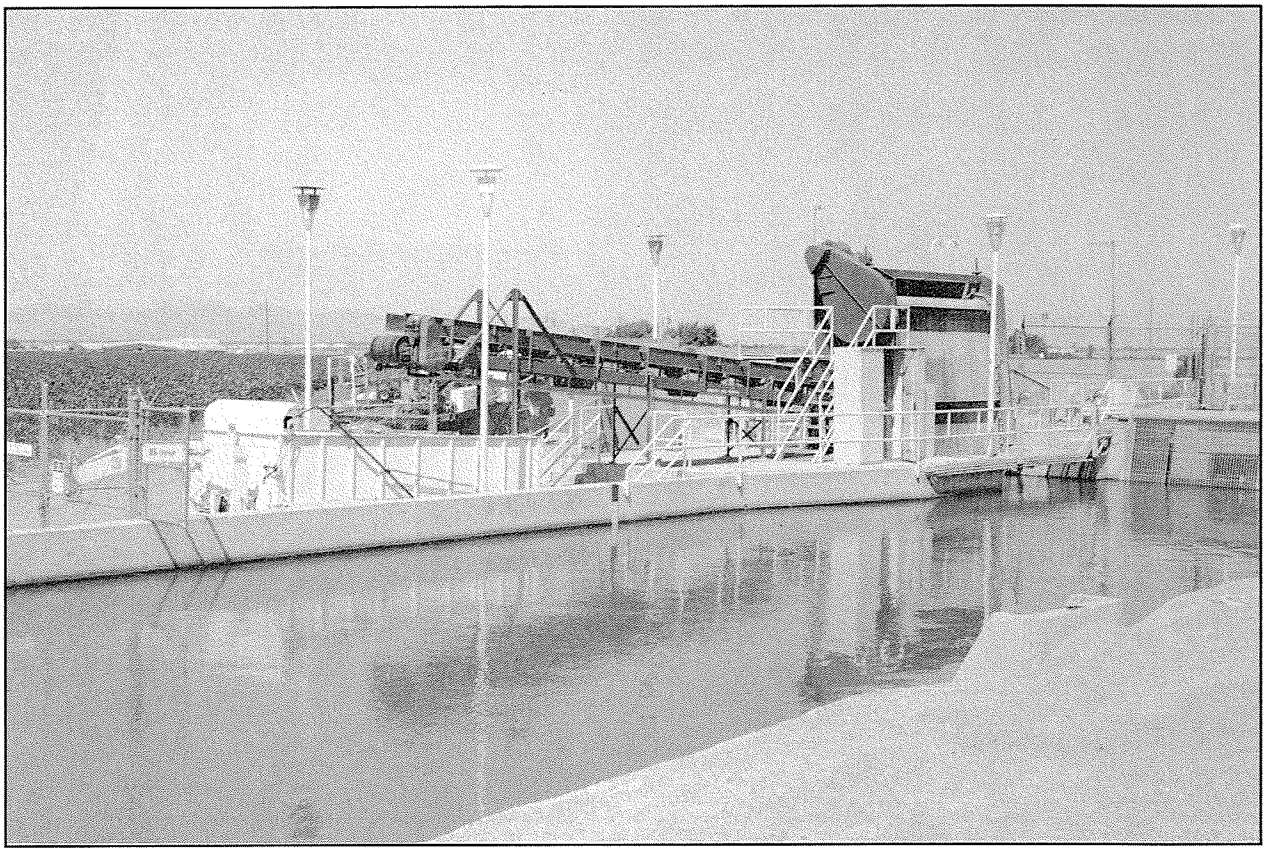


Figure 8. Skunk Creek Drain demossing structure and debris collection dump at Station ACl3 on the Arizona Canal.

During daily trap inspections, we conducted informal creel interviews with numerous anglers fishing along the canal banks. Originally, creel surveys were not part of the study plan; nevertheless, we took advantage of the opportunity to interview anglers. These creel interviews provided another source of information on the status of our stocked fish. We noted: creel date, location, species collected, TL, weight, Floy® tag number, and presence of fin clips.

In addition to our monthly electrofishing, we sampled 3 alternate sites (Table 1) to monitor stocked fish movement and later to collect specimens for tissue contaminant analyses. We used repeated-effort electrofishing, gill netting, and angling in these areas to increase the chance of recovering stocked fish. Prior to some of these electrofishing efforts, a 30-m experimental gill net was set across the canal and attached to a nearby bridge. The net was in place while the electrofishing boat herded the fish downstream.

We combined all sampling methods to determine the recapture frequency of stocked fish across weeks. Catch-per-unit-effort was calculated from repeated-effort electrofishing surveys, gill netting, and AGFD angling. Stocked fish movements and losses to the lateral canals were also recorded.

Potential growth of stocked rainbow trout and channel catfish was determined by subtracting the recaptured mean TL and weights from the initial stocking measurements. Of the 1,500 channel catfish stocked in June, a subsample of 300 were weighed and measured for baseline size data. June-stocked catfish with right pectoral fin clips were Floy® tagged when recaptured (Fig. 9). All July-stocked catfish and stocked rainbow trout were measured for TL and weight prior to release.

Estimates of physiological condition for both species were calculated using K and Wege-Anderson relative weight (Wr). Relative weight is another method of comparing physiological condition which is species-specific because of diverse body shapes and sizes (Anderson and Gutreuter 1983). A Wr value of 100 may be considered ideal for all species even of different age groups. However, Wr values are less reliable as fish reach full maturity and Wr values fall

Figure 9. A recaptured, June-stocked channel catfish being measured, weighed, and Floy® tagged.

below 100 (Anderson and Gutreuter 1983). Both K and Wr were presented in our results to evaluate the well-being of stocked and recaptured fish. Unfortunately, Wr is a new method, and species-specific standard weight (Ws) equations are only available for common game fish and a few nongame species. The most current standard weight (Ws) values for rainbow trout and channel catfish were used to calculate Wr (B. Murphy, Texas A and M., pers. commun., D. Willis, South Dakota State Univ., pers. commun.). Both stocking groups of channel catfish were combined to provide reliable comparisons of mean TL, weight, K, and Wr between the time they were stocked and recaptured.

Potential Fish Tissue Contaminants

Stocked and recaptured channel catfish and rainbow trout specimens were submitted to private laboratories for analysis of 129 priority pollutants listed by the U.S. Environmental Protection Agency (EPA) to assess public health risks. Fish from the original stocking groups were analyzed to determine baseline levels prior to stocking. After 5 months, recaptured channel catfish and rainbow trout were also analyzed for contaminant accumulation. Whole fish were wrapped in aluminum foil, sealed in plastic bags, labelled, and frozen (0 C) until laboratory testing (Environ. Prot. Agency 1979, 1993). Each composite (1 to 3 fish) was homogenized and then analyzed using established EPA methods (Environ. Prot. Agency 1979, 1993). The contaminants tested for included: pesticides, metals and inorganics, polychlorinated biphenyls (PCB) and related compounds, ethers, phenols and cresols, phthalate esters, halogenated aliphatics, polycyclic aromatic hydrocarbons, nitrosamines, and other nitrogen-containing compounds. Practical quantification limit (PQL) was used as the level of contaminant detection. This degree of detection provides a reliable reproduction of results by different laboratories using the same EPA analysis methods (Standard Methods 1989).

We obtained from SRP a list of herbicides and biocides used in and along the canals to control vegetation from January 1992 through July 1994. In addition, SRP provided application schedules, descriptions of chemical use, a map of locations where chemicals were applied, and white amur control sections. We obtained this information to supplement our contaminant analysis and to evaluate potentially adverse conditions to fish survival in the SRP canal system.

Abiotic Factors

Temperature and dissolved oxygen (DO) are water quality parameters that can affect fish survival (Piper et al. 1983). Levels of pH also influence fish survival when extremely acidic or basic water conditions persist for long periods (Piper et al. 1983). Specific conductivity is the ability of an aqueous solution to carry an electrical current (Standard Methods 1989) and directly affects electrofishing efficiency. Highly conductive water provides a greater area of effect for the shocking boat's electrode, thus affecting more fish and increasing sample sizes. Heavy turbidity in water is caused by fine, suspended sediment and organic matter. Turbidity impairs the visual-hunting ability of certain predatory fish as well as decreasing the levels of photosynthetic primary production of algae and phytoplankton (Piper et al. 1983, O'Brien 1990).

From February 1992 to July 1994, we collected monthly water quality measurements at 9 stations on the Arizona Canal (Appendix C) to study environmental conditions that might affect a sport fishery. Quarterly water quality measurements were also collected from 19 stations on the other SRP canals from March 1992 to July 1994 (Appendix C). Water quality stations were established at the beginning, middle, and end of each canal except for the Cross-Cut Canal, which had only 1 station. Water quality measurements were recorded during daylight hours. A Horiba U-10 Water Quality Checker was used to record water temperature (C), dissolved oxygen (mg/L), pH, specific conductivity (mS/cm), and turbidity. Turbidity values were represented by nephelometric turbidity units (NTU), the standard measurement of the intensity of light scattering by suspended particles in aqueous solution (Standard Methods 1989). Readings were taken at the surface and at depths of 0.5 m and 1.0 m. Secchi disk measurements of water transparency were also recorded.

Water quality values were compared among stations on the Arizona Canal to evaluate any spatial differences that might influence fish distribution. Monthly variations in mean temperature and DO across all stations were plotted to show seasonal extremes. Mean values of temperature, DO, pH, conductivity, turbidity, and Secchi depth measurements from the Arizona Canal (across all stations and months) were compared to the mean water quality aspects of the other 7 SRP canals. We averaged the 3 depth measurements for analysis.

Biotic Factors

Chlorophyll a. The ratio of chlorophyll *a* (CHLA) to pheophytin *a* (PHEA) can indicate the amount of primary production (i.e., the lowest trophic level of the food base) in an aquatic system because it is a measure of the photosynthetic activity of phytoplankton. A CHLA:PHEA ratio of ≥ 1.7 indicates high CHLA values and excellent physiological condition of phytoplankton. A ratio of 1.0 indicates pure PHEA, the degradation product of acidified CHLA, and reflects a poor condition. From January 1993 to July 1994, we collected and analyzed water samples to estimate concentrations of CHLA and PHEA in the 8 SRP canals. Nine stations were sampled monthly on the Arizona Canal, and 13 stations were sampled quarterly on the other SRP canals (Appendix C). All sampling occurred during daylight hours concurrent with other water quality sampling. Water samples were collected at 0.5 m below the surface using a 1-L, horizontal, van Dorn-type water bottle. We collected a 3 L composite sample of water from each station. Samples were stored in amber, polyethylene bottles and kept on ice in the field. Water samples were then refrigerated in the laboratory at 4 C until analysis.

We used analytical procedures outlined in Standard Methods (1989) for CHLA analyses. Samples were filtered through separate glass fiber filters (Whatman type 934-AH0, 45-μm porosity, 47-mm diameter). Sample volumes ranged from 400 to 3,000 ml of water depending on the amount of suspended sediment and organic matter. Filters were macerated and CHLA was extracted using 90% aqueous acetone for 24 hrs. Spectrophotometric analysis was conducted using a Perkin-Elmer Lambda-2 UV/Visible spectrophotometer. A test blank of 90% aqueous acetone was run prior to each sample series. Known calibration standards (1.7 ratio of CHLA:PHEA) were tested for quality control purposes.

Benthos. Benthic samples were collected from 8 stations on the Arizona Canal (Appendix C) to determine macroinvertebrate standing stocks and relative abundance. Benthic macroinvertebrates are animals that live in the bottom substrate, as well as on the substrate surface and on aquatic vegetation (Thorp and Covich 1991). Bimonthly samples were collected from September 1993 to July 1994, using a 0.04-m^3 (300-in^3) Petite Ponar Dredge. Dredge samples were collected from both sides and the middle of the canal at both the upper and lower ends of each station, for a total of 6 samples. If, after 3 attempts, no substrate or organisms were obtained in a dredge sample, no additional sampling was conducted at that station. A 500-μm sieve bucket was used to remove sediment fines (i.e., silt) from each sample. Each sample was preserved with 10% formalin or 70% ethanol.

We used Rose Bengal® powder to stain each sample. Then, each sample was rinsed with water using a 250-μm sieve and placed in a shallow specimen tray. Individuals from each taxon were identified, counted, and stored in vials with 70% ethanol. Taxonomic classifications were based on Barnes (1968) and Arnett (1985). Aquatic Consulting and Testing, Inc. processed ⅓ of our samples for quality control purposes.

Zooplankton. For the purposes of our study, zooplankton were defined as invertebrates found in the water column that float, drift, or weakly swim (Thorp and Covich 1991). Invertebrates found in the water column included true zooplankton, aquatic and terrestrial insects, and non-insect species. Quarterly zooplankton samples were collected from 8 stations on the Arizona Canal (Appendix C) between December 1992 and July 1994 to estimate seasonal zooplankton abundance and percent species composition. Using a portable water pump or a bucket, 3 samples were collected from each station from a depth of about 0.5 m. Twenty liters of water were filtered through an 80-μm, Wisconsin-type plankton net using a portable water pump or a bucket. Samples were rinsed with deionized water, stored in clear polyethylene bottles, and preserved in 70% ethanol. Samples were sent to Aquatic Consulting and Testing, Inc. for identification and enumeration using taxonomy based on Barnes (1968). To maintain decimal precision from low total counts, mean densities were recorded as numbers of organisms per 20 L, rather than numbers per liter.

Public Opinion Surveys

In May 1994, Behavioral Research Center, Inc. conducted 2 separate telephone surveys (Appendix D) to determine Maricopa County residents' attitudes toward the use of the SRP canals as an urban fishery. The first survey interviewed 300 licensed anglers, while the second survey targeted 600 individuals of the general public. Licensed anglers were chosen randomly from a list of current state or urban fishing license holders. The general public respondents from both urban and rural regions of Maricopa County were selected at random from a list of phone numbers by Behavior Research Center, Inc.'s automated system.

The surveys examined the following aspects: regional representation, current angling participation, respondent interest in an Urban Canal Fishing Program (UCFP), demographic status, fish species preference, willingness to pay, and level of use. Projected angler-use days, potential new anglers, and revenues were calculated.

Study Area Mapping

The study area was mapped using an ARC/INFO Geographic Information System (GIS), ground-truthed observations, Phoenix area maps, and Salt River Valley Water Users' Association's maps (1993*a*, *b*). A map of physical structures and potential public access sites along the Arizona Canal was created (Appendix A). Habitat features and qualitative flow regimes were also mapped (Appendix B). Velocity measurements were not available for our sampling sites on the Arizona Canal. Instead, we used terms from Orth (1983) to define flow regimes within the Arizona Canal: (1) *riffles* are high velocity, turbulent water; (2) *runs* or glides are steady, laminar flows; and (3) *pools* are low velocity or still water.


1L Water Sample
ACG3


AZ 749
10·94

RESULTS

Fish Collection Site Habitats

At each fish collection site, we assigned qualitative flow regimes to indicate general aquatic habitats. We estimated that the Arizona Canal had approximately 44 km (72%) of runs, 13 km (21%) of pools, and 4.4 km (7%) of riffle habitat. Site 7 was a deep-water, run habitat. Approximately 1.9 km of Site 5 was also deep-water, run habitat, while the remaining section of this site was pool habitat. Site 3 was a shallow segment of canal with approximately ⅓ riffle and ⅔ run habitat. Riffle habitat in Site 3 was located immediately downstream of the water control structure at 19th Avenue. We classified Alternate Site 3 to be ⅓ run and ⅔ pool habitat. In addition, Alternate Site 3 had mostly earthen bottom and banks with overhanging vegetation. Both Site 3 and Alternate Site 3 were within the same reach between 2 water control structures. We classified Site 2 as pool habitat with some riffles occurring immediately below the water control structure upstream of the 43rd Avenue and Peoria Avenue intersection. Riffle habitat was found at the top of Site 1 immediately below the water control structure at 67th Avenue; however, most of Site 1 was pool habitat.

Fish Surveys

Species Diversity and Abundance. We collected 13,355 fish from our electrofishing surveys, representing 20 species and 10 families (Table 2). The most abundant species were: Sonora sucker, desert sucker, threadfin shad, red shiner, white amur, and largemouth bass, respectively (Table 3). Collectively, these 6 species accounted for about 98% of the total sample. To identify the resident assemblage of fish in the Arizona Canal, we excluded stocked channel catfish (n = 24) and stocked trout (n = 122) from the total electrofishing count. In addition, 38 larval fish were not identified and were excluded from our total. The 14 remaining species had relative abundances that were <1%. Four species were caught only once during our study: smallmouth bass, walleye, flathead catfish, and an oscar.

Species richness remained relatively constant throughout this study (Table 4). The highest number of species (n = 18) was collected at the downstream end of the canal (Skunk Creek Drain), and declined to 12 toward the head of the canal (Granite Reef Dam). The year-to-year difference in mean species richness was small (n = 4).

Table 2. Common names, scientific names, and species reporting codes of fish collected from 5 sites along the Arizona Canal, October 1992 through July 1994.

Family/Species*	Code
Catostomidae	
Desert sucker, *Catostomus clarki*	CACL
Sonora sucker, *Catostomus insignis*	CAIN
Centrarchidae	
Bluegill, *Lepomis macrochirus*	LEMA
Green sunfish, *Lepomis cyanellus*	LECY
Largemouth bass, *Micropterus salmoides*	MISA
Smallmouth bass, *Micropterus dolomieu*	MIDO
Cichlidae	
Oscar, *Astronotus ocellatus*	ASOC
Clupeidae	
Threadfin shad, *Dorosoma petenense*	DOPE
Cyprinidae	
Common carp, *Cyprinus carpio*	CYCA
Goldfish, *Carassius auratus*	CAAU
Red shiner, *Cyprinella lutrensis*	CYLU
Roundtail chub, *Gila robusta*	GIRO
White amur, *Ctenopharyngodon idella*	CTID
Ictaluridae	
Channel catfish, *Ictalurus punctatus*	ICPU
Flathead catfish, *Pylodictis olivaris*	PYOL
Yellow bullhead, *Ameiurus natalis*	AMNA
Percichthyidae	
Yellow bass, *Morone mississippiensis*	MOMI
Percidae	
Walleye, *Stizostedion vitreum*	STVI
Poeciliidae	
Western mosquitofish, *Gambusia affinis*	GAAF
Salmonidae	
Rainbow trout, *Oncorhynchus mykiss*	ONMY

* Source: Am. Fish. Soc. 1991.

Table 3. Total number (n) and relative abundance (%) of fishes collected from electrofishing sites along the Arizona Canal, October 1992 through July 1994. See Table 2 for fish species codes.

	Site 1		Site 2		Site 3		Site 5		Site 7		Total (n) All Sites	Overall % Abundance
Species*	n	%	n	%	n	%	n	%	n	%		
CAIN	307	9.20	353	22.24	1,847	39.18	1,219	49.67	750	59.33	4,476	33.52
CACL	54	1.62	144	9.07	2,038	43.23	858	34.96	171	13.53	3,265	24.45
DOPE	2,310	69.24	196	12.35	413	8.76	100	4.07	47	3.72	3,066	22.96
CYLU	363	10.88	764	48.14	222	4.71	201	8.19	237	18.75	1,787	13.38
CTID	180	5.40	16	1.01	28	0.59	21	0.86	6	0.47	251	1.88
MISA	42	1.26	21	1.32	82	1.74	30	1.22	1	0.08	176	1.32
MOMI	31	0.93	24	1.51	28	0.59	7	0.28	4	0.32	94	0.70
ICPU	3	0.09	46	2.90	10	0.21	3	0.12	26	2.06	88	0.66
GIRO	3	0.09	3	0.19	27	0.57	5	0.20	5	0.40	43	0.32
AMNA	6	0.18	14	0.88	4	0.08	0	0	0	0	24	0.18
GAAF	0	0	0	0	3	0.06	3	0.12	14	1.11	20	0.15
CYCA	4	0.12	2	0.13	7	0.15	4	0.16	2	0.16	19	0.14
LEMA	19	0.57	0	0	0	0	0	0	0	0	19	0.14
ONMY	7	0.21	1	0.06	0	0	2	0.08	1	0.08	11	0.08
CAAU	3	0.09	0	0	3	0.06	0	0	0	0	6	0.04
LECY	1	0.03	3	0.19	2	0.04	0	0	0	0	6	0.04
MIDO	1	0.03	0	0	0	0	0	0	0	0	1	0.01
ASOC	1	0.03	0	0	0	0	0	0	0	0	1	0.01
STVI	1	0.03	0	0	0	0	0	0	0	0	1	0.01
PYOL	0	0	0	0	0	0	1	0.04	0	0	1	0.01
Total	3,336	100%	1,587	100%	4,714	100%	2,454	100%	1,264	100%	13,355	100%

* Unidentified larval fish and stocked game fish (ICPU and ONMY) are not included.

Table 4. Number of fish species collected (species richness) by year, from 5 electrofishing sites along the Arizona Canal, October 1992 through July 1994.

Year	*n*	Site 1	Site 2	Site 3	Site 5	Site 7	Year Total	$\bar{x}$
1992	3	11	11	12	8	8	11	10.0
1993	12	17	12	15	13	11	17	13.6
1994	7	15	10	12	6	4	15	9.4
Overall Total		18	13	15	13	12		
$\bar{x}$		14.3	11.0	13.0	9.0	7.7		

Sixty percent of the fish sampled during our monthly electrofishing surveys were taken from Sites 1 and 3; 25% (n = 3,336) from Site 1 and 35% (n = 4,714) from Site 3. We collected the fewest fish (n = 1,264, or 9.5% of the total count) from Site 7. Electrofishing catch-per-unit-effort (CPUE) was summarized by site (Table 5) and by season (Table 6) for 8 species: Sonora and desert suckers, red shiners, threadfin shad, white amurs, largemouth bass, channel catfish, and rainbow trout.

Sonora and desert suckers were the most abundant fish collected during our electrofishing surveys. These fish were found at all sites, but were most abundant at Site 3 based on total number caught and CPUE. Native fish, including roundtail chubs, accounted for about 58% (n = 7,784) of all fish collected. We collected a total 43 roundtail chubs, or 0.3% of the total sample.

Forage fish (threadfin shad and red shiners) were taken from all our collection sites and comprised approximately 36% (n = 4,853) of our total electrofishing sample. The total number caught and CPUE for threadfin shad increased moving downstream (Site 7 to Site 1). Red shiners were also sampled at all sites, but CPUE was highest at Site 2. Collectively, forage fish were the second most abundant group of fish collected during our study.

White amurs were found at each site, but these fish were most abundant at the downstream end of the Arizona Canal. White amurs accounted for about 2% (n = 251) of the total electrofishing sample. Since white amurs have a tendency of moving downstream towards the Skunk Creek Drain (Site 1), SRP periodically moves many of these fish to upstream canal sections. Salt River Project relocation efforts influence the abundance of white amurs across sites.

Game fish (largemouth bass, resident channel catfish, yellow bass, and resident rainbow trout) represented 3% (n = 369) of the total electrofishing sample. Largemouth bass, resident channel catfish, and yellow bass were collected from all 5 fish collection sites along the Arizona Canal. Resident rainbow trout were collected from all sites except Site 3. Largemouth bass and channel catfish had the highest CPUE at Site 3. Overall, game fish numbers were very low when compared to the native suckers and forage fish.

Condition Factors. Most resident fish in the Arizona Canal were in good physiological condition based on overall mean condition factors (mean K; Table 7). All species sampled had mean K values >1.00, except threadfin shad, roundtail chub, channel catfish, and rainbow trout, which had mean K values >0.80. Due to missing TL and weight data, the number of fish used to calculate mean K factors differed from the total number of fish sampled (Table 3). Most threadfin shad (79.5%), red shiners (99.9%), and all western mosquitofish (*Gambusia affinis*) were below our weight criteria (i.e., <10 g) for calculating K factors.

Size and Age Structure. Mean lengths were calculated for all species collected (Table 8). Seasonal length frequency distributions were created for largemouth bass, threadfin shad, red shiners, Sonora suckers, desert suckers, and white amurs. Additionally, overall length frequency

Table 5. Mean catch-per-unit-effort (CPUE; fish/hr) by site for selected resident fish species electrofished from the Arizona Canal, October 1992 through July 1994. See Table 2 for fish species codes.

Species	Site	Mean CPUE	SD	n*	Species	Site	Mean CPUE	SD	n*
CAIN	1	13.56	8.76	23	CTID	1	6.28	4.71	23
	2	20.13	16.44	21		2	1.24	2.48	21
	3	101.64	97.22	29		3	1.10	1.57	30
	5	53.06	36.54	21		5	0.74	0.66	21
	7	40.07	44.23	18		7	0.32	0.77	18
CACL	1	2.10	2.61	23	MISA	1	1.55	1.67	23
	2	6.73	7.07	21		2	1.33	2.03	21
	3	111.27	144.38	30		3	2.83	4.61	29
	5	38.14	28.19	21		5	1.34	1.91	21
	7	11.69	20.61	18		7	0.06	0.26	18
CYLU	1	14.82	20.88	23	ICPU	1	0.50	0.89	23
	2	42.16	46.34	21		2	1.60	2.41	21
	3	9.46	21.91	30		3	2.49	4.35	29
	5	11.62	21.25	21		5	0.11	0.30	21
	7	15.63	27.39	18		7	1.24	1.99	18
DOPE	1	76.81	91.26	23	ONMY	1	0.30	1.42	23
	2	7.47	13.97	21		2	0.02	0.10	21
	3	21.56	76.26	30		3	0.00	0.00	29
	5	4.45	6.96	21		5	0.08	0.25	21
	7	2.26	3.46	18		7	0.08	0.34	18

* Number (n) of sample days for each site during this project

distributions were generated for roundtail chubs and yellow bass.

Throughout our study, largemouth bass total lengths were highly variable (Fig. 10). In Summer 1993 and Fall 1993, we identified 2 largemouth bass cohorts. During Spring 1994 and Summer 1994, we identified a single cohort; however, during these 2 seasons our sample size of largemouth bass with TL ≥240 mm was primarily the result of biased sampling due to repeated-effort electrofishing.

No gaps were found in the length frequency distribution to separate threadfin shad into separate cohorts (Fig. 11). Threadfin shad exhibited some degree of growth over time because TL measurements shifted upward. In Winter 1993-1994, threadfin shad (TL ≤90 mm) were absent from our collections. This trend continued in Spring 1994 (TL ≤100 mm) and Summer 1994 (TL ≤110 mm).

The number of red shiners declined dramatically during the last 3 seasons (i.e., Winter 1993-1994, Spring 1994, and Summer 1994) of this study. We found no distinct breaks in the length frequency distribution to separate red shiners into specific cohorts (Fig. 12).

Sonora suckers exhibited a bimodal length frequency distribution during most of our study (Fig. 13). To a lesser degree, a third cohort of young fish (TL ≤120 mm) appeared in Summer 1993 through Winter 1993-1994, and again in Summer 1994. However, by Summer 1994 a bimodal length distribution had returned.

Desert suckers exhibited a bimodal length frequency distribution throughout most of our study, except in Summer 1993 when a third cohort appeared (Fig. 14). The length ranges within the 2 cohorts remained stable during the first 3 seasons. The same 2 cohorts also remained stable during Fall 1993 through Spring 1994. By Summer 1994, the bimodal distribution shifted downward towards smaller fish.

Table 6. Mean catch-per-unit-effort (CPUE; fish/hr) by season for selected resident fish species electrofished from the Arizona Canal, October 1992 through July 1994. See Table 2 for fish species codes.

Species	Season	Mean CPUE	SD	n*	Species	Season	Mean CPUE	SD	n*
CAIN	Fall 1992	44.94	46.80	7	CTID	Fall 1992	3.21	4.74	7
	Winter 1992-93	73.81	62.57	11		Winter 1992-93	2.52	4.84	11
	Spring 1993	36.35	42.42	16		Spring 1993	1.95	2.05	16
	Summer 1993	38.61	32.44	17		Summer 1993	1.95	3.49	18
	Fall 1993	63.41	81.49	14		Fall 1993	2.70	3.84	14
	Winter 1993-94	62.83	86.39	12		Winter 1993-94	0.63	1.95	12
	Spring 1994	48.03	86.30	21		Spring 1994	2.01	3.26	21
	Summer 1994	35.91	46.28	14		Summer 1994	1.47	2.93	14
CACL	Fall 1992	18.68	24.27	7	MISA	Fall 1992	0.68	0.54	7
	Winter 1992-93	39.67	50.09	11		Winter 1992-93	1.02	1.59	11
	Spring 1993	26.86	30.81	16		Spring 1993	0.36	1.02	16
	Summer 1993	25.33	31.73	18		Summer 1993	1.60	2.15	17
	Fall 1993	57.48	123.36	14		Fall 1993	2.38	2.02	14
	Winter 1993-94	63.15	121.20	12		Winter 1993-94	0.71	1.08	12
	Spring 1994	53.52	136.17	21		Spring 1994	3.02	5.25	21
	Summer 1994	28.55	52.29	14		Summer 1994	1.47	2.39	14
CYLU	Fall 1992	10.40	14.72	7	ICPU	Fall 1992	2.37	3.64	7
	Winter 1992-93	25.77	49.20	11		Winter 1992-93	0.93	1.27	11
	Spring 1993	23.53	23.83	16		Spring 1993	0.72	1.03	16
	Summer 1993	25.14	35.30	18		Summer 1993	2.42	4.42	17
	Fall 1993	33.72	42.27	14		Fall 1993	2.45	3.96	14
	Winter 1993-94	18.76	31.27	12		Winter 1993-94	1.16	1.45	12
	Spring 1994	4.76	9.84	21		Spring 1994	0.22	0.59	21
	Summer 1994	3.77	4.74	14		Summer 1994	0.67	2.41	14
DOPE	Fall 1992	32.71	40.56	7	ONMY	Fall 1992	0.00	0.00	7
	Winter 1992-93	89.27	135.24	11		Winter 1992-93	0.10	0.24	11
	Spring 1993	41.69	100.39	16		Spring 1993	0.09	0.36	16
	Summer 1993	7.25	13.74	18		Summer 1993	0.40	1.65	17
	Fall 1993	22.91	29.01	14		Fall 1993	0.00	0.00	15
	Winter 1993-94	6.31	11.35	12		Winter 1993-94	0.00	0.00	12
	Spring 1994	9.15	21.79	21		Spring 1994	0.05	0.21	21
	Summer 1994	7.66	19.47	14		Summer 1994	0.00	0.00	14

* Number (n) of days sampled within each season during this study.

White amur TL measurements were highly variable over time but were all ≥360 mm TL (Fig. 15). To comply with AGFD white amur stocking permit conditions, SRP must stock sterile white amurs with a minimum head width of 57.2 mm. Due to low sample sizes and the wide range in TL, distinct cohorts were not apparent except for 1 in Spring 1994 (TL 440 to 560 mm). Over time, we found white amurs showed some degree of growth due to the upward shift of TL.

Due to low sample sizes, the yellow bass and roundtail chub length frequency distributions were plotted across seasons. We found 2 cohorts of yellow bass (Fig. 16) with peaks at 90 mm and 230 mm TL. We identified 2 separate cohorts of roundtail chubs with peaks at 170 mm and 250 mm TL (Fig. 17).

Table 7. Mean condition factors (K) and standard deviations (SD) for selected fish species collected from the Arizona Canal, October 1992 through July 1994. See Table 2 for fish species codes.

	Site 1		Site 2		Site 3		Site 5		Site 7		Overall	
Species*	n	$\bar{x}$ K (SD)	n	$\bar{x}$ K (SD)	n	$\bar{x}$ K (SD)	n	$\bar{x}$ K (SD)	n	$\bar{x}$ K (SD)	n	$\bar{x}$ K (SD)
CAIN	261	1.09 (0.12)	340	1.00 (0.11)	1,233	1.04 (0.23)	997	1.12 (0.26)	726	1.02 (0.09)	3,557	1.06 (0.21)
CACL	48	1.12 (0.10)	126	1.05 (0.10)	1,188	1.13 (0.20)	611	1.20 (0.19)	130	1.26 (0.12)	2,103	1.15 (0.19)
DOPE	405	0.96 (0.15)	81	0.97 (0.16)	94	0.94 (0.17)	38	1.04 (0.13)	11	0.93 (0.10)	629	0.96 (0.15)
CYLU	--	-- (--)	1	2.11 (0.00)	--	-- (--)	2	1.22 (0.04)	--	-- (--)	3	1.52 (0.51)
CTID	128	1.08 (0.13)	11	1.21 (0.19)	23	1.27 (0.17)	19	1.34 (0.20)	6	1.20 (0.17)	187	1.14 (0.18)
MISA	30	1.52 (0.21)	16	1.53 (0.26)	63	1.57 (0.27)	24	1.54 (0.25)	1	1.51 (0.00)	134	1.55 (0.25)
MOMI	18	1.25 (0.18)	12	1.17 (0.22)	11	1.14 (0.15)	5	1.37 (0.24)	3	1.43 (0.22)	49	1.23 (0.21)
ICPU	3	1.04 (0.18)	5	0.81 (0.08)	--	-- (--)	1	1.28 (0.00)	20	0.89 (0.13)	29	0.89 (0.13)
GIRO	2	0.90 (0.01)	3	0.89 (0.06)	26	0.97 (0.09)	3	1.01 (0.08)	5	0.96 (0.10)	39	0.96 (0.09)
AMNA	2	1.10 (0.21)	13	1.19 (0.15)	3	1.45 (0.04)	--	-- (--)	--	-- (--)	18	1.22 (0.17)
CYCA	4	1.56 (0.07)	1	1.46 (0.00)	4	1.66 (0.40)	3	1.25 (0.44)	2	1.44 (0.22)	14	1.50 (0.31)
LEMA	11	1.97 (0.34)	--	-- (--)	--	-- (--)	--	-- (--)	--	-- (--)	11	1.97 (0.34)
ONMY	3	0.83 (0.06)	--	-- (--)	--	-- (--)	--	-- (--)	--	-- (--)	3	0.83 (0.06)
CAAU	3	1.76 (0.23)	--	-- (--)	2	2.86 (1.53)	--	-- (--)	--	-- (--)	5	2.20 (0.99)
LECY	1	1.69 (0.00)	3	1.46 (0.09)	2	2.03 (0.21)	--	-- (--)	--	-- (--)	6	1.69 (0.30)
ASOC	1	2.81 (0.00)	--	-- (--)	--	-- (--)	--	-- (--)	--	-- (--)	1	2.81 (0.00)
PYOL	--	-- (--)	--	-- (--)	--	-- (--)	1	1.40 (0.00)	--	-- (--)	1	1.40 (0.00)

* Unidentified fish and stocked game fish (ICPU and ONMY) are not included.

Table 8. Mean total length (TL), standard deviation (SD), range, and number of resident fish (*n*) electrofished from the Arizona Canal, October 1992 through July 1994. See Table 2 for fish species codes.

Species*	*n***	$\bar{x}$ TL (mm)	SD	Range (mm)
CAIN	3,977	234.46	90.05	36-490
CACL	2,542	200.68	77.48	37-463
DOPE	1,301	106.32	13.64	61-147
CYLU	1,275	54.00	12.62	18-126
CTID	251	586.14	84.50	375-778
MISA	161	267.05	105.37	61-485
MOMI	94	138.12	62.10	42-286
ICPU	88	233.48	116.00	40-550
GIRO	41	219.68	87.73	106-430
AMNA	23	159.43	52.32	55-276
GAAF	20	39.85	8.88	26-55
CYCA	18	466.33	108.18	264-671
LEMA	19	166.32	26.68	99-215
ONMY	11	300.55	44.54	227-361
CAAU	5	225.60	78.03	140-296
LECY	6	106.33	9.27	94-119
MIDO	1	225.00	--	--
ASOC	1	248.00	--	--
STVI	1	341.00	--	--
PYOL	1	475.00	--	--

* Unidentified larval fish and stocked game fish (ICPU and ONMY) are not included.
** Sample numbers may differ from values on Table 3 due to missing TL data of sampled fish.

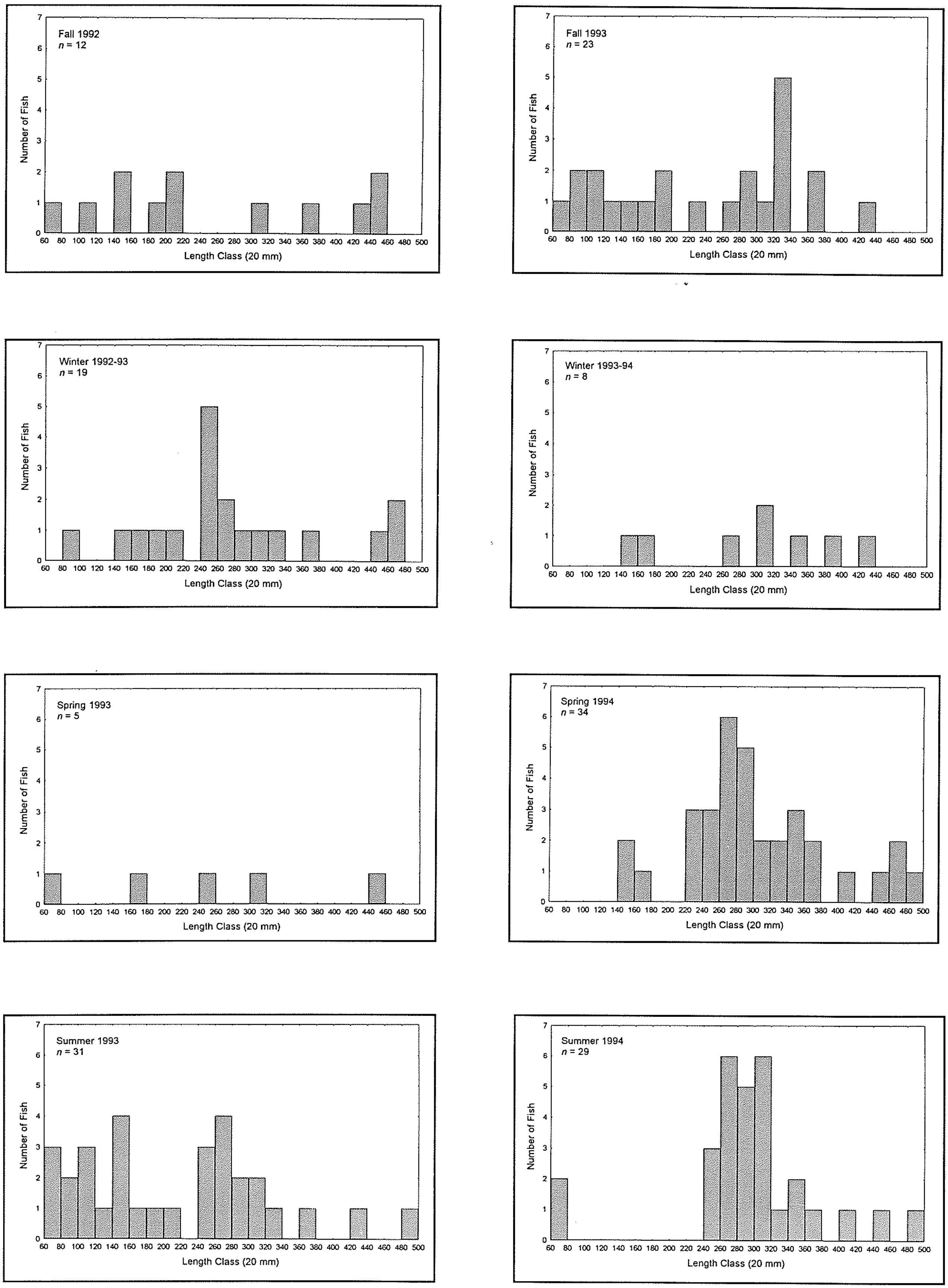


Figure 10. Seasonal length-frequency distributions of largemouth bass in the Arizona Canal.

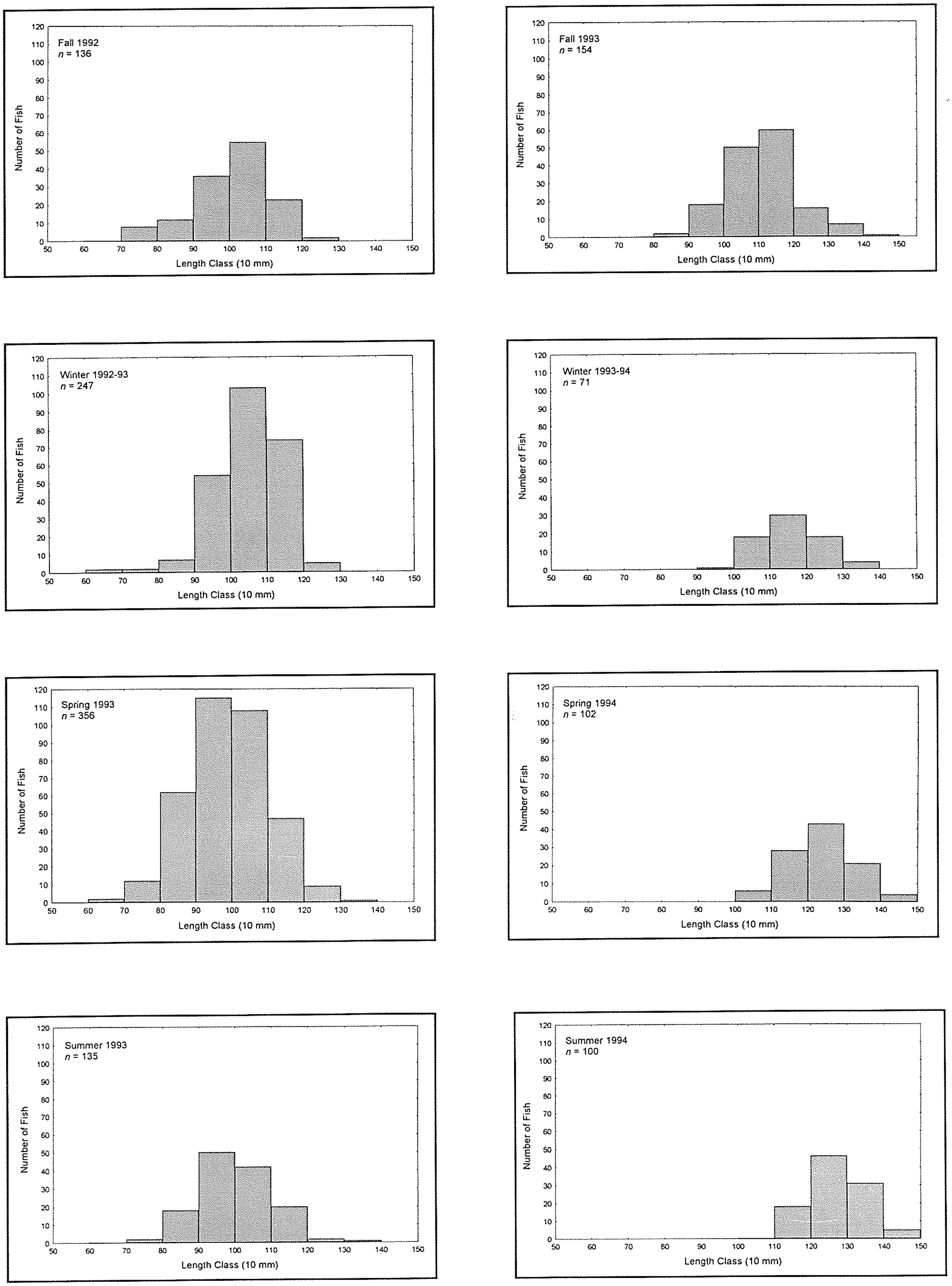


Figure 11. Seasonal length-frequency distributions of threadfin shad in the Arizona Canal.

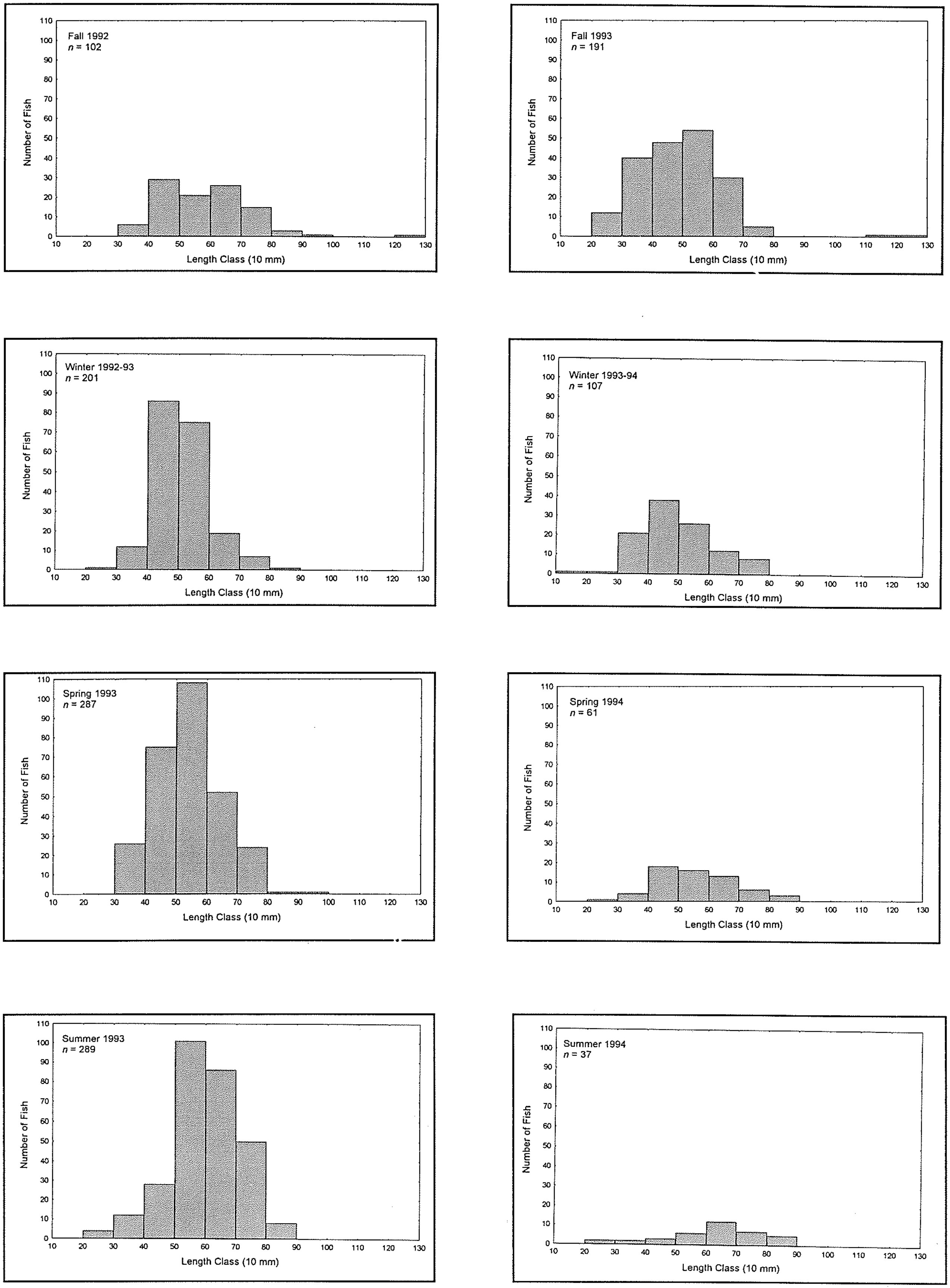


Figure 12. Seasonal length-frequency distributions of red shiner in the Arizona Canal.

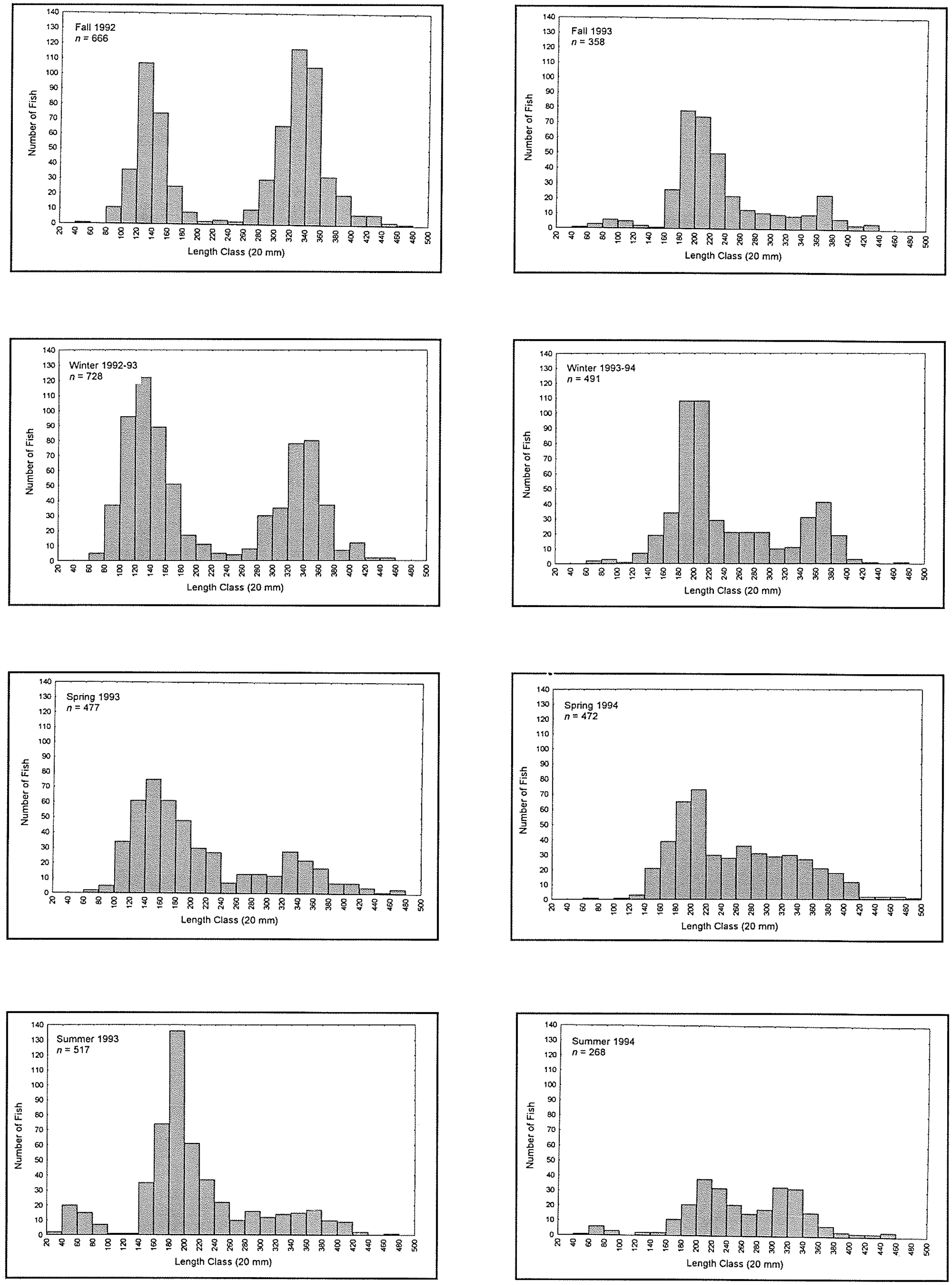


Figure 13. Seasonal length-frequency distributions of Sonora sucker in the Arizona Canal.

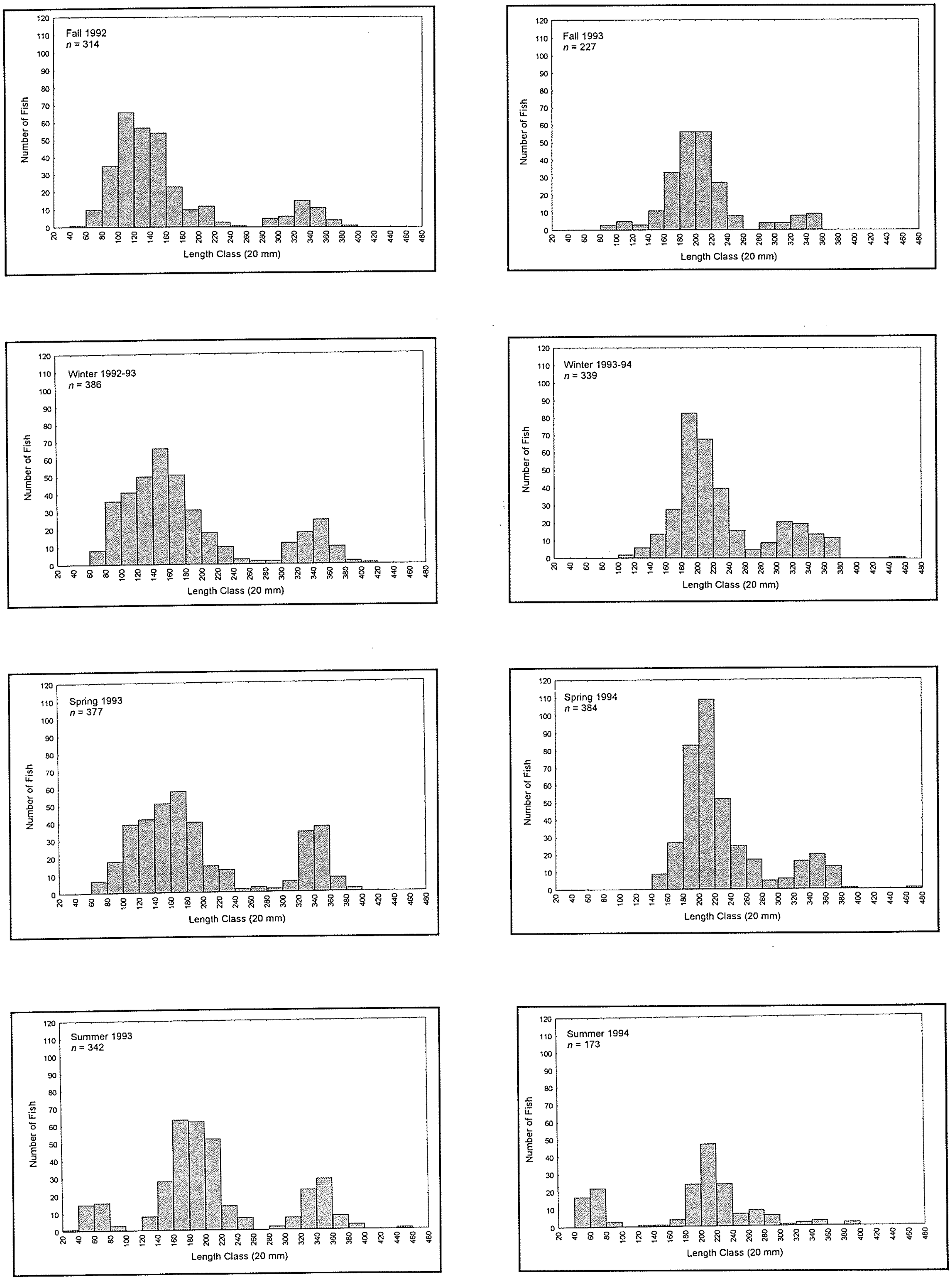


Figure 14. Seasonal length-frequency distributions of desert sucker in the Arizona Canal.

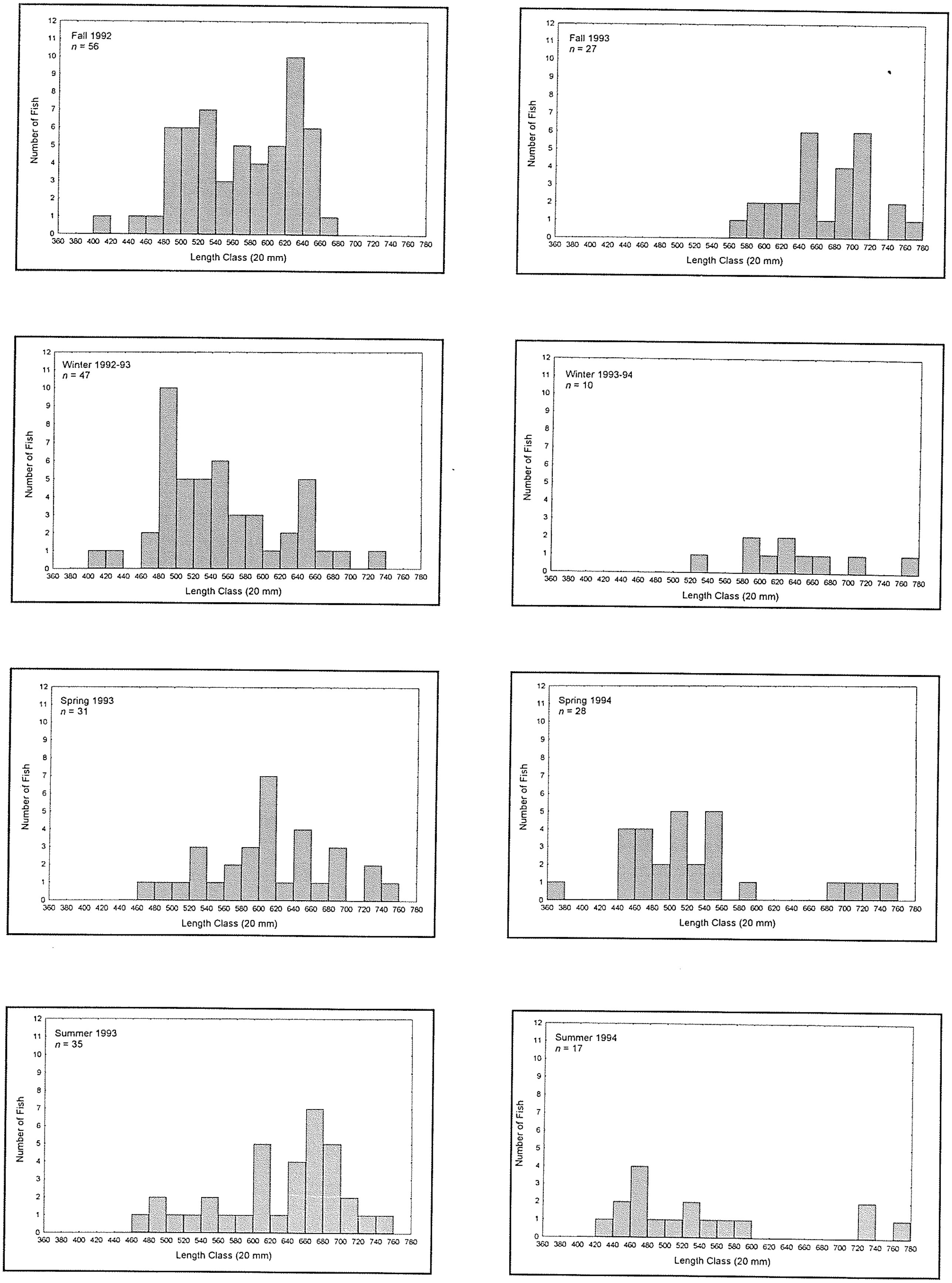


Figure 15. Seasonal length-frequency distributions of white amur in the Arizona Canal.

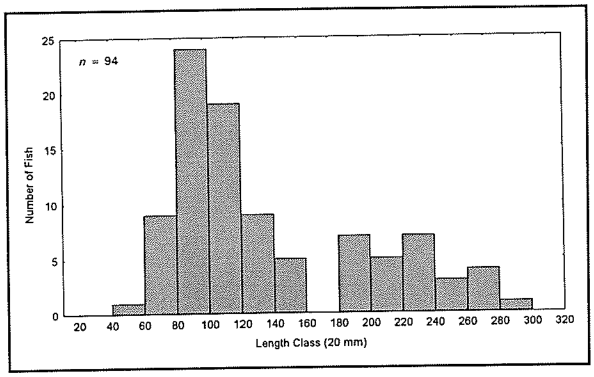


Figure 16. Overall length-frequency distributions of yellow bass in the Arizona Canal (October 1992-July 1994).

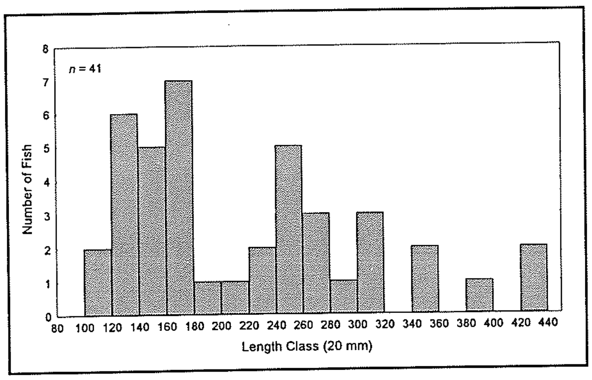


Figure 17. Overall length-frequency distributions (across seasons) of roundtail chub in the Arizona Canal (October 1992-July 1994).

Granite Reef Electrical Barrier Monitoring

To estimate fish immigration into the Arizona Canal, we looked at fish collection data from surveys (Jakle and Riley, unpubl. data) taken between Granite Reef Dam and the electric fish barrier. From 1991 to 1995, 17 fish species were collected above the barrier (Table 9). Species richness remained relatively stable, with a low of 9 species collected in 1991 and a high of 13 species in 1992 and 1995. Percent species composition varied across years. The most abundant species ($n \geq 700$) collected above the barrier for the 5-yr period were: desert sucker (29.7%), tilapia (*Tilapia* spp.; 16.5%), Sonora sucker (14.1%), channel catfish (13.0%), and common carp (12.4%). The least abundant species ($n < 50$) were: roundtail chub, walleye, threadfin shad, bluegill, yellow bullhead, white amur, and bigmouth buffalo (*Ictiobus cyprinellus*).

Percent species composition of tilapia and common carp were highly variable between years. In 1991, tilapia was the most common species collected (n = 748) but they were absent from the 1995 survey. However, tilapia still ranked second in overall relative abundance during this 5-yr period. Common carp above the barrier were rare to nonexistent between 1991 and 1993, but their numbers increased in 1994 (n = 526) ranking them highest in abundance. In the 1995 survey, carp numbers again declined, but they still ranked fifth in total abundance for the 5-yrs. The abundance of both species above the barrier was unusual when compared to our electrofishing sampling downstream where carp were rare (n = 19) and tilapia were absent.

Experimental Fish Stockings

Channel Catfish (June-Stocking). Most June-stocked catfish sampled were recovered within the first 5 weeks after stocking (Fig.18). We sampled 161 (10.7%) fish from June 1993 through July 1994. Monthly and repeated-effort electrofishing surveys captured 44 June-stocked channel catfish. Twenty of these fish were collected during our repeated-effort sampling (CPUE = 1.7 fish/hr). We sampled 69 June-stocked channel catfish by angling (CPUE = 1.1 fish/hr) and 1 fish by gill net (CPUE = 0.1 fish/hr). We documented an additional 41 fish harvested by public anglers, but were unable to estimate the catch rate due to

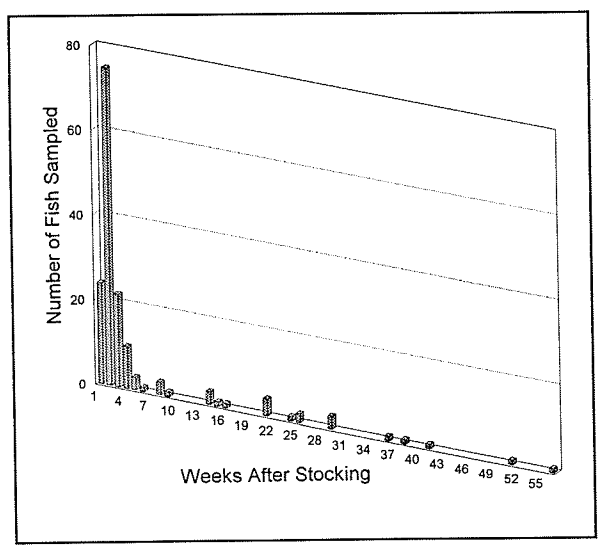


Figure 18. Recapture frequency of June-stocked channel catfish across weeks after stocking for all sampling methods (June 1993 - July 1994).

Table 9. Summary of annual fish collections between Granite Reef Dam and the electric fish barrier on the Arizona Canal for 1991-1995. Number of fish collected (*n*), percent species composition (%), overall mean ($\bar{x}$), and standard deviation (SD) given. See Table 2 for fish species codes.

	1991		1992		1993		1994		1995		Overall		Overall	
Species	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	$\bar{x}$	SD
CACL	51	5.62	459	41.20	97	15.18	470	34.06	601	37.31	1,678	29.69	355.60	245.79
Tilapia[1]	748	82.38	68	6.10	109	17.06	5	0.36	0	0	930	16.45	186.00	317.43
CAIN	21	2.31	163	14.63	218	34.12	105	7.61	288	17.88	795	14.07	159.00	102.59
ICPU	66	7.26	196	17.59	134	20.97	66	4.78	274	17.01	736	13.02	147.20	89.19
CYCA	2	0.22	17	1.53	0	0	526	38.12	155	9.62	700	12.38	140.00	225.27
ONMY	1	0.11	113	10.14	21	3.29	103	7.46	167	10.37	405	7.17	81.00	68.75
MISA	2	0.22	32	2.87	21	3.29	42	3.04	30	1.86	127	2.25	25.40	15.06
MOMI	0	0	0	0	9	1.41	39	2.83	37	2.30	85	1.50	17.00	19.53
PYOL	13	1.43	11	0.99	2	0.31	12	0.87	23	1.43	61	1.08	12.20	7.46
CYLU	4	0.44	33	2.96	5	0.78	0	0	15	0.93	57	1.01	11.40	13.28
GIRO	0	0	7	0.63	21	3.29	1	0.07	1	0.06	30	0.53	6.00	8.83
STVI	0	0	10	0.90	0	0	9	0.65	0	0	19	0.34	3.80	5.21
DOPE	0	0	1	0.09	1	0.16	0	0	17	1.05	19	0.34	3.80	7.40
LEMA	0	0	4	0.36	0	0	0	0	2	0.12	6	0.11	1.20	1.79
CTID	0	0	0	0	0	0	2	0.14	0	0	2	0.04	0.40	0.89
AMNA	0	0	0	0	1	0.16	0	0	0	0	1	0.02	0.20	0.45
ICCY[2]	0	0	0	0	0	0	0	0	1	0.06	1	0.02	0.20	0.45
Total	908	100%	1,114	100%	639	100%	1,380	100%	1,611	100%	5,652	100%	--	--

[1] Tilapia = indeterminate species (*Tilapia aurea, T. mossambica, T. zilli*)
[2] ICCY = *Ictiobus cyprinellus*, Bigmouth buffalo

Source: Jakle and Riley, unpubl. data.

missing data. Six June-stocked channel catfish were collected from lateral traps during the 42-day monitoring period. Lateral trap CPUE could not be estimated due to irregular SRP water delivery schedules.

Channel Catfish (July Stocking). The highest number of July-stocked channel catfish sampled were caught within the first 3 weeks after stocking (Fig. 19). A total of 26 July-stocked fish (5.2%) were collected between July 1993 and July 1994. After the second channel catfish stocking, we sampled both stocking groups concurrently. Public anglers reported harvesting 20 July-stocked fish, but we were unable to calculate CPUE. Four fish were sampled by our angling efforts (CPUE = 0.1 fish/hr). One July-stocked channel catfish was collected from monthly electrofishing surveys, and another was intercepted by the lateral traps. Repeated-effort electrofishing and gill netting yielded no July-stocked channel catfish.

Rainbow Trout. Recapture frequency of stocked rainbow trout was highest within the first 6 weeks after stocking (Fig. 20). Between November 1993 and July 1994, 347 (15.8%) stocked rainbow trout were caught. A total of 212 rainbow trout were sampled by electrofishing; 90 fish from repeated-effort collections (CPUE = 12.1 fish/hr). Public anglers reported harvesting 132 rainbow trout. During the 44-day monitoring period we collected 3 fish from the lateral traps. No stocked rainbow trout were collected using gill nets or during our angling efforts.

Stocked Fish Growth and Condition. Stocked channel catfish and rainbow trout had no substantial growth or improvement in well-being (K and Wr) from the day of stocking through July 1994. Recaptured channel catfish decreased in mean TL and weight, as well as physiological condition (Table 10). However, mean TL and weight of recaptured rainbow trout increased slightly, but K and Wr declined between November 1993 and June 1994 (Table 11).

Stocked Fish Movement. Most stocked fish remained within the same area they were stocked (channel catfish combined = 99.4% and rainbow trout = 95.5%). Stocked fish were never observed to move upstream, but a number of them gradually moved downstream over time. We recaptured 100 rainbow trout (4.5%) and 13 channel catfish (0.6%) downstream of the Site 3 stocking location. Movement occurred more slowly as the distance and number of physical barriers (water control structures) increased.

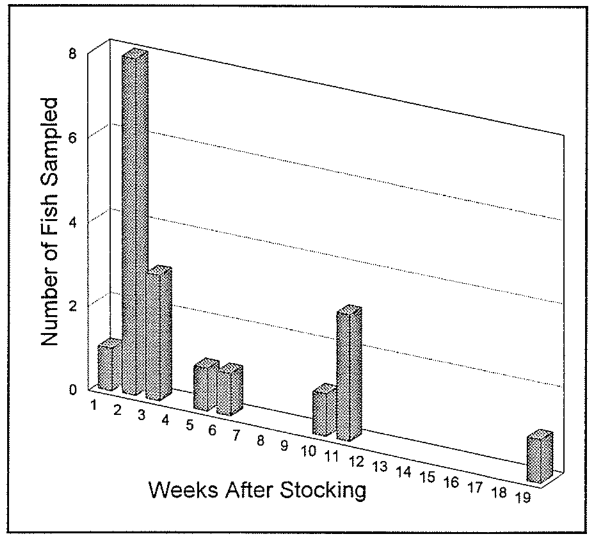


Figure 19. Recapture frequency of July-stocked channel catfish across weeks after stock for all sampling methods (July 1993 - July 1994).

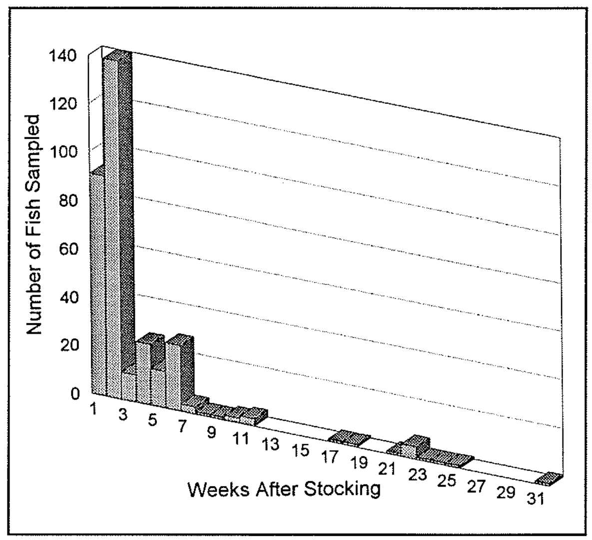


Figure 20. Recapture frequency of November-stocked rainbow trout across weeks after stocking for all sampling methods (November 1993 - July 1994).

Within the first 2 weeks after stocking, 85 of those rainbow trout had moved 2.4 km downstream to the first water control structure; the lower boundary of Alternate Site 3. After 4 weeks, 8 channel catfish were found at the same location. Stocked rainbow trout were first collected 5.6 km downstream at Site 2, after 7 weeks. Channel catfish were found at Site 2 after 12 weeks. Both species were collected from Site 1, 14.5 km downstream, after 17 weeks. No stocked

Table 10. Size and physiological condition data for stocked and recaptured channel catfish (June and July-stock combined) in the Arizona Canal, June 1993 to July 1994.

Stocked Fish	Mean	Standard Deviation	Minimum	Maximum	Sample Number*
Weight (g)	485.85	217.28	120.00	1,199.00	793
Total Length (mm)	377.56	47.84	232.00	547.00	794
K Factor	0.87	0.26	0.20	3.94	792
Relative Weight	96.34	30.81	19.69	493.55	792
Recaptured Fish	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Sample Number***
Weight (g)	445.69	271.62	117.00	1,614.00	121
Total Length (mm)	374.13	51.61	251.00	522.00	124
K Factor	0.77	0.13	0.52	1.24	121
Relative Weight	84.81	13.16	56.61	131.26	121

Table 11. Size and physiological condition data for stocked and recaptured rainbow trout in the Arizona Canal, November 1993 to July 1994.

Stocked Fish	Mean	Standard Deviation	Minimum	Maximum	Sample Number*
Weight (g)	193.98	43.05	82.00	465.00	2,189
Total Length (mm)	251.20	16.88	140.00	375.00	2,191
K Factor	1.21	0.13	0.50	2.09	2,182
Relative Weight	109.84	12.28	43.45	191.93	2,182
Recaptured Fish	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Sample Number***
Weight (g)	194.36	44.49	132.00	397.00	50
Total Length (mm)	267.70	20.59	227.00	340.00	56
K Factor	1.01	0.11	0.78	1.26	50
Relative Weight	91.79	10.09	69.81	113.57	50

* Sample numbers for size and physiological data are different from the total number of fish sampled due to missing TL and weight data.

rainbow trout or channel catfish were captured upstream of Site 3.

Fish Loss to Lateral Canals. A total of 122 fish representing 6 species were collected from the 5 fish traps during the 86 days of monitoring. Three rainbow trout (0.1% of total stocked) and 8 channel catfish (0.4% of total stocked) were lost to lateral canals (Fig. 21). Stocked fish made up 9.1% of the total percent species composition found in the traps. The remainder were yellow bullheads, bluegill, and green sunfish (collectively 25.4%) and native suckers (60.6%). Fish that could not be identified comprised 4.9% of the total. More fish were collected by the traps during the summer (n = 106) than during the winter (n = 16). No stocked fish were found in the Skunk Creek demossing dump.

Potential Fish Tissue Contaminants

Composites of control and recaptured fish tissues had low or no concentrations of the 129 EPA priority pollutants (Appendix E). Phenols and cresols, ethers, phthalate esters, polycyclic aromatic hydrocarbons, and nitrosamines were not detected in the fish. Pesticides such as aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, and heptachlor epoxide were found in minor quantities, but well below Food and Drug Administration (FDA) Action Levels (Peterson 1987). Mercury and PCB concentrations were also well below FDA Action Levels. Dioxin (TCDD) was not detected in any rainbow trout samples, and only at trace levels in the channel catfish samples. A few asbestos fibers were detected in the June samples of recaptured rainbow trout and channel catfish. Concentrations of metals and inorganics were also low in fish samples. Except for methylene chloride and chloroform, no halogenated aliphatics were detected.

Sample numbers of fish for contaminant analysis were very low. One channel catfish composite and 2 rainbow trout composites (3 fish each) were analyzed from the June and November stocking groups for baseline contaminant levels. These fish were taken directly from the hatchery and preserved immediately. Recaptured channel catfish with exposure intervals of 9, 12, and 13 months after stocking (1 fish each) were tested. All recaptured channel catfish for contaminant analysis were from the original June stock. Rainbow trout samples had exposure periods of 5 months (2 fish composite) and 7 months (1 fish) after stocking. Low recapture success over time prevented the submission of more fish in each composite. Sample numbers were also limited by the high costs of laboratory analysis.

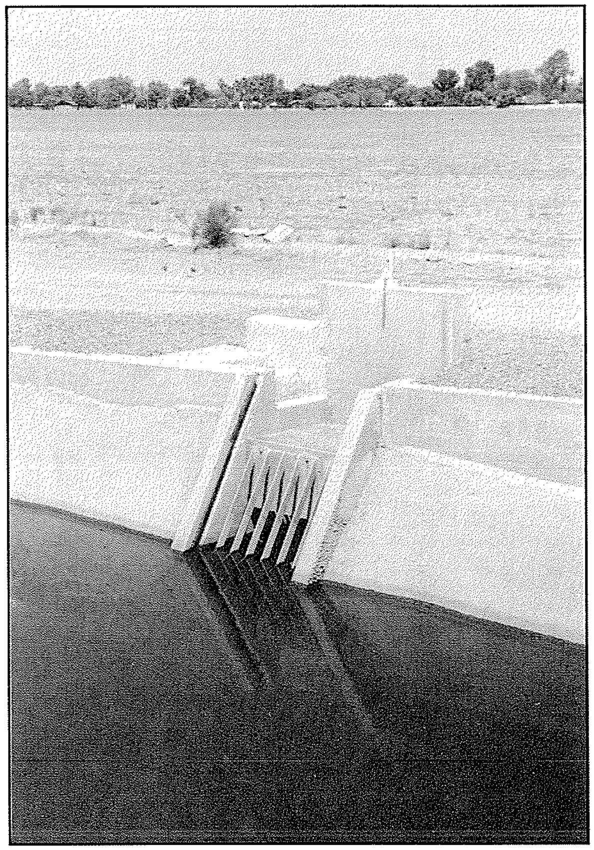


Figure 21. Lateral canal siphon used to transfer canal water for irrigation and municipal use.

Aquatic and Terrestrial Vegetation Control

Salt River Project uses a combination of biological, chemical, and mechanical methods to control aquatic and terrestrial vegetation in and along the canals (G. Elliott, Salt River Proj., pers. commun.). Locations of herbicide use and white amur stocking were identified in the SRP canal system (Fig. 22).

Since 1989, SRP has stocked sterile white amurs (Fig. 23) into the Arizona, Cross-Cut, South, Tempe, Consolidated, and Eastern canals to biologically control aquatic vegetation. These fish have been highly effective and have reduced or eliminated the need for chemical applications in stocked reaches. During annual dewaterings, SRP has committed substantial resources towards the salvage and upstream relocation of white amurs.

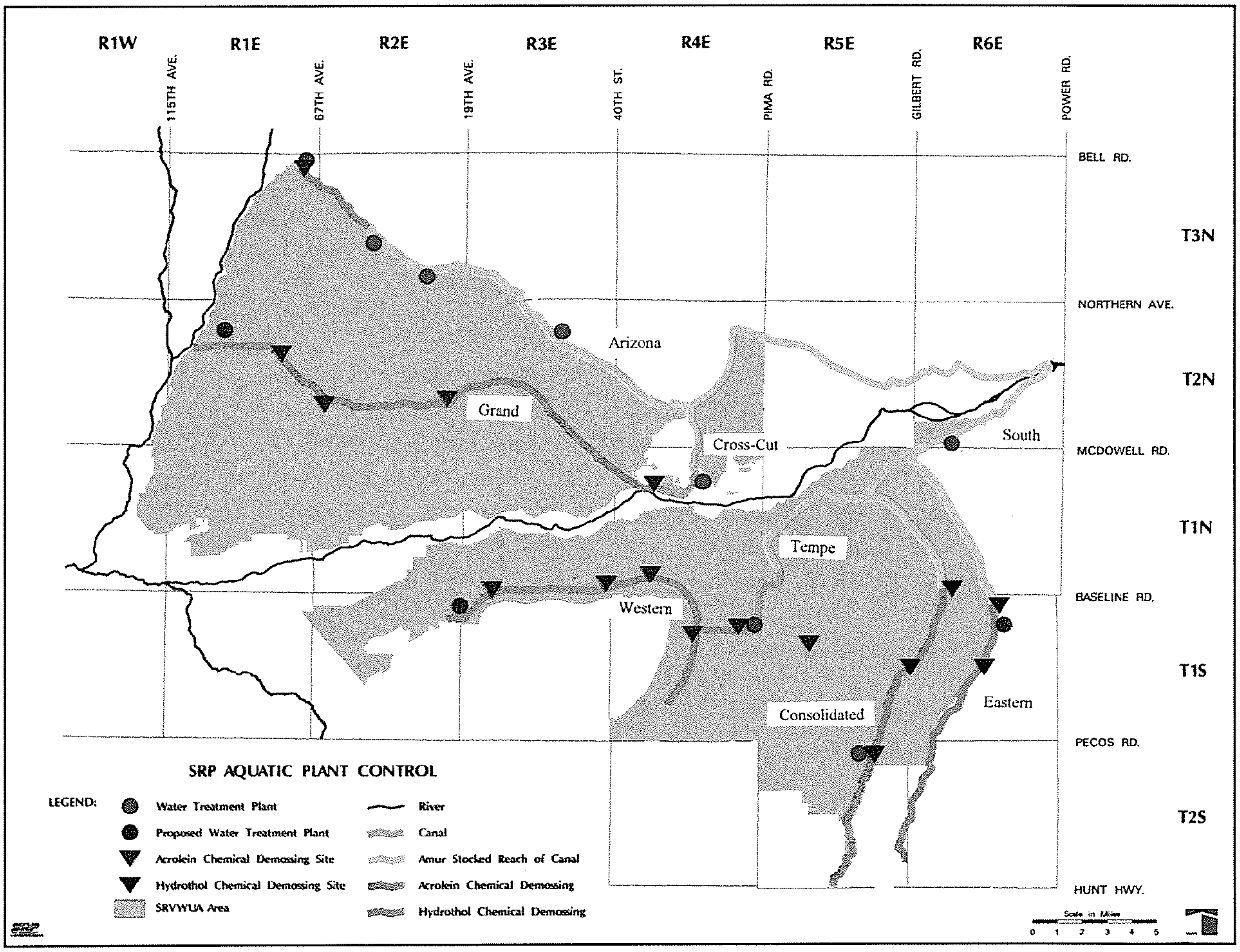


Figure 22. Locations of herbicide use and white amur stocking by SRP in the canal system (1993).

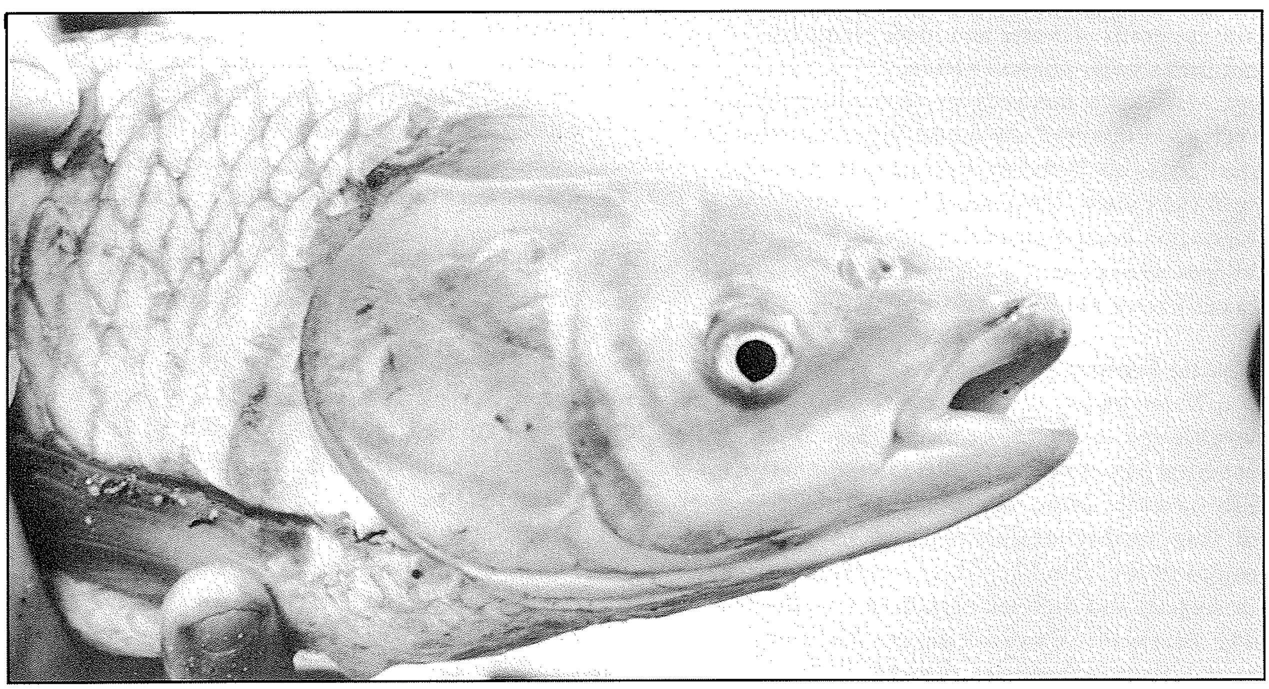


Figure 23. A white amur stocked by SRP to biologically control aquatic vegetation in the canals.

Management of white amur populations includes reducing the number of dewatered canal sections each year to increase carry-over of fish.

Chemical control of aquatic vegetation was accomplished using several herbicides: Hydrothol-191® (endothall), Magnacide H® (acrolein), copper sulfate, and Rodeo® (glyphosate). Endothall and acrolein are lethal to fish even in low concentrations, and these herbicides are not used in canal sections where white amurs are stocked (G. Elliott, Salt River Proj., pers. commun.).

On the Consolidated Canal, endothall was used from Baseline Road to Pecos Road, while acrolein was applied downstream of the Chandler Water Treatment Plant. Endothall was also used on the lower portion of the Eastern Canal (downstream of Baseline Road). On the Grand and Western canals, acrolein was applied to canal segments below water treatment plants. Both acrolein and endothall were applied biweekly, beginning in February and ending in November. Deviations from these established application schedules varied when seasonal growth patterns of vegetation warranted applications. On rare occasions, copper sulfate was used on the Consolidated Canal to control algal blooms that created taste and odor problems in drinking water. For the Arizona Canal, acrolein was applied only in a lateral canal near 73rd Avenue.

Canal bank vegetation was controlled using Rodeo®. Canal banks were treated in the spring, midsummer, and fall. Spraying was terminated just upstream of water treatment plants to minimize water contamination.

Mechanical methods for controlling aquatic vegetation involved the use of large, heavy-gauge steel grates anchored to demossing bridges that span the canals. Demossing bridges snag vegetation being transported downstream. These bridges were present along each of the major canals except the Cross-Cut Canal.

Abiotic Factors

Water quality of the Arizona Canal was investigated to determine if any physical or chemical parameters exceeded tolerance levels for fish survival. Mean values and standard deviations of water quality measurements by site are compiled in Table 12. Water temperatures peaked in August, and declined rapidly in October (Fig. 24). Seasonally, dissolved oxygen (DO) levels were highest in February through August, and then dropped during September through November (Fig. 24). During this study, the lowest recorded DO level was recorded in January from a portion of the Arizona Canal that was not fully dewatered.

The other 7 SRP canals had basic water quality and water transparency values comparable to the Arizona Canal. Mean values and standard deviations for these measurements are listed in Appendix F.

Biotic Factors

Chlorophyll a. The Arizona Canal had low-to-moderate concentrations of CHLA, indicating a fair amount of primary production by phytoplankton was occurring (Table 13). Primary production in the other SRP canals was similar to the Arizona Canal (Appendix F).

Benthos. Eighteen macroinvertebrate taxa were collected from the Arizona Canal (Table 14). The dominant taxonomic group was Pleuroceridae, followed by Oligochaeta, and *Corbicula* spp. Chironomids were the most abundant insects. Crayfish (*Procambarus clarki*) were not found in any of our benthic samples but were observed when electrofishing.

Stations ACH3 and ACI3 had the greatest abundance of benthic organisms (Table 15). By contrast, Station ACF3 and ACG3 had lower standing stocks of invertebrates.

Zooplankton. Eighteen taxa of true zooplankton were collected from the Arizona Canal (Table 16) and collectively were the most abundant (59.5%) group found in the water column. True zooplankton taxa included nematodes, rotifers, and microcrustaceans (e.g., copepods, cyclopods, amphipods, cladocerans, and ostracods). As a group, aquatic and terrestrial insects were second most abundant (38%) followed by non-insects (2.5%). No organisms from the phylum Annelida were collected from the water column. Zooplankton densities in the Arizona Canal were highest at stations ACC3, ACE3, and ACB3 (Table 17).

Public Opinion Survey

A random cross-section of licensed anglers and the general public was contacted from all regions of Maricopa County (Table 18). The estimated sampling error was ±5.8% for the Licensed Angler Survey and ±4.1% for the General Public Survey ($P = 0.05$).

Survey results indicated a high level of interest in a proposed canal fishery program. Sixty-eight

Table 12. Mean values (x̄) and standard deviations (SD) for water temperature (C), pH, dissolved oxygen (mg/L), specific conductivity (mS/cm), turbidity (NTU), and Secchi depth (m) measurements for each station on the Arizona Canal (n = 636), February 1992 to July 1994.

	Water Temperature		pH		Dissolved Oxygen		Specific Conductivity		Turbidity		Secchi Depth	
Station	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD
ACA2	17.1	(4.7)	8.14	(0.29)	9.52	(1.62)	395.23	(111.70)	17	(15.5)	0.9	(0.3)
ACB3	18.5	(4.2)	8.27	(0.39)	10.90	(2.63)	523.89	(192.85)	20	(38.4)	1.1	(0.2)
ACC3	18.4	(4.2)	8.12	(0.39)	9.79	(1.97)	507.13	(186.77)	15	(13.2)	1.0	(0.4)
ACD3	19.4	(4.7)	8.29	(0.42)	10.90	(2.90)	490.81	(213.40)	38	(56.8)	0.7	(0.3)
ACE3	19.6	(4.9)	8.09	(0.35)	10.04	(1.81)	502.42	(203.51)	27	(49.1)	0.7	(0.3)
ACF3	20.5	(5.2)	8.17	(0.69)	9.64	(2.00)	516.44	(205.30)	21	(33.9)	0.8	(0.4)
ACG3	19.8	(5.4)	8.05	(0.62)	9.59	(1.86)	506.97	(212.42)	18	(20.0)	0.9	(0.5)
ACH3	19.9	(5.6)	7.97	(0.49)	9.34	(1.94)	561.37	(242.56)	21	(38.5)	1.1	(0.4)
ACI3	20.0	(5.5)	7.99	(0.54)	8.96	(1.83)	522.79	(215.64)	15	(30.8)	1.2	(0.4)

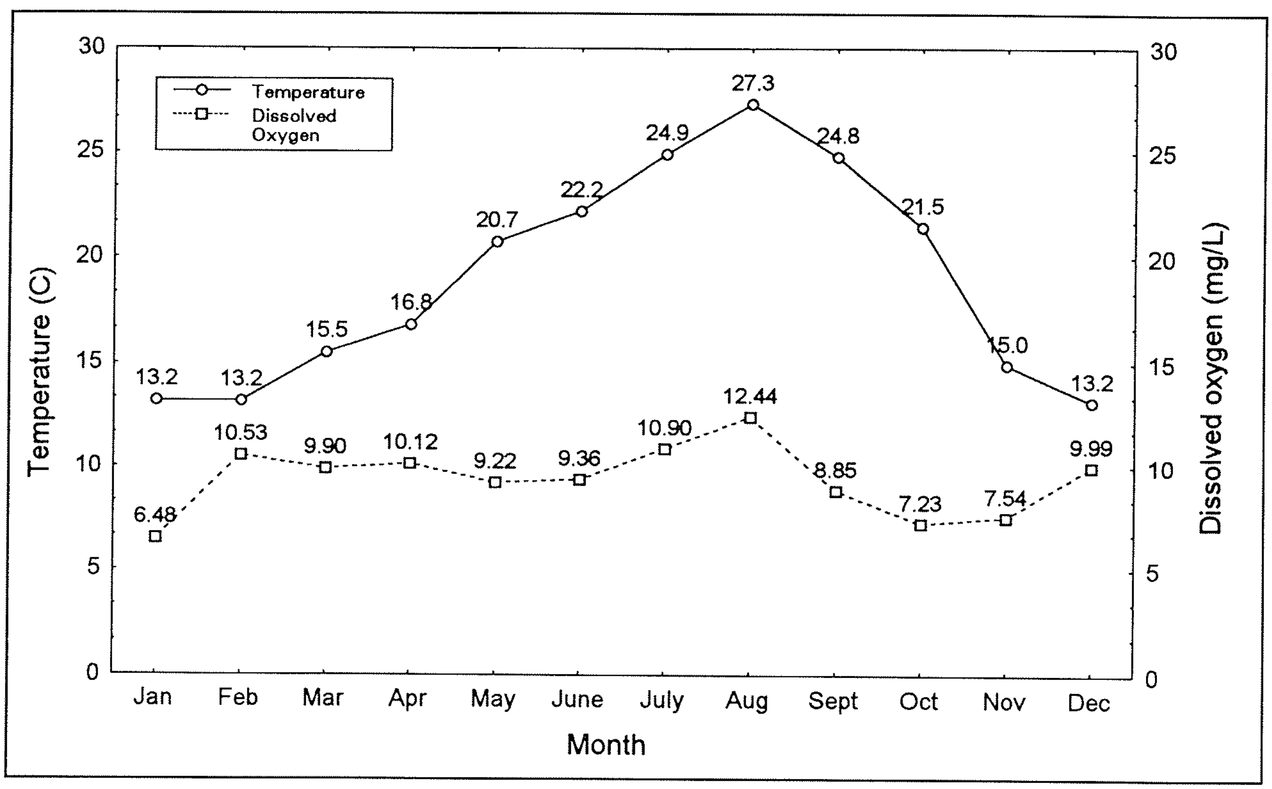
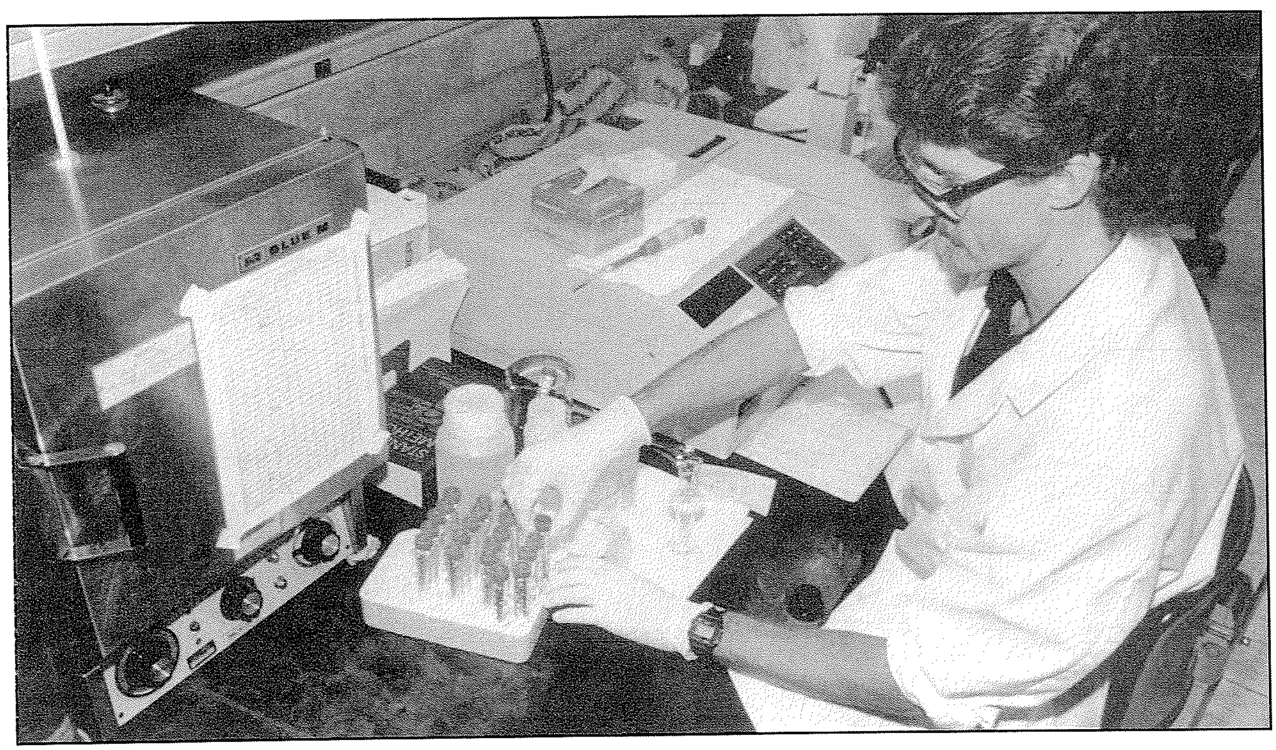


Figure 24. Seasonal mean water temperature and dissolved oxygen (across stations) for the Arizona Canal (1993-1994).

Table 13. Mean CHLA values (mg/m^3), CHLA:PHEA ratio values, standard deviations, and sample number for each station on the Arizona Canal, January 1993 to July 1994.

Station	Habitat Type	Mean CHLA	Standard Deviation CHLA	Mean Ratio	Standard Deviation Ratio	Sample Number
ACA2	Run	1.24	0.97	1.3	0.15	16
ACB3	Run	1.17	0.91	1.2	0.14	16
ACC3	Run	1.82	1.20	1.3	0.15	15
ACD3	Run	1.43	1.26	1.3	0.15	13
ACE3	Run	1.38	1.50	1.3	0.18	16
ACF3	Run	0.65	0.42	1.3	0.24	7
ACG3	Pool	1.16	1.25	1.3	0.18	10
ACH3	Pool	1.23	2.34	1.4	0.20	12
ACI3	Pool	0.48	0.86	1.1	0.15	8



Processing chlorophyll *a* samples using a spectrophotometer.

Table 14. Benthic macroinvertebrate mean standing stock ($\bar{x}$), standard deviation (SD), total count, and relative abundance from the Arizona Canal, all stations combined (n = 190), September 1993 to July 1994.

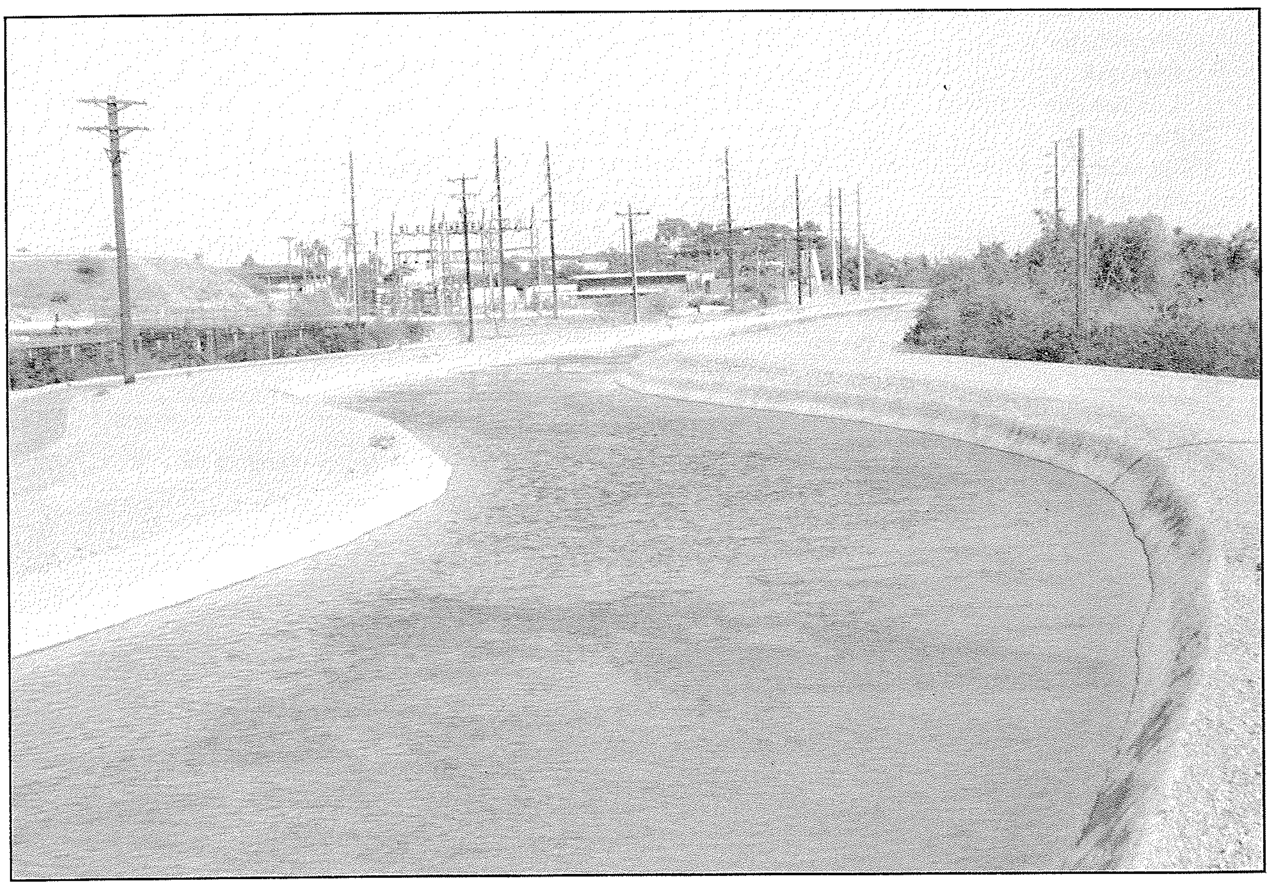
	Standing stock (no/m^2)			
Taxonomic Group	$\bar{x}$	SD	Total Count	Percent Total
Insecta				
Diptera (undetermined)	2.82	7.46	263	5.3
Chironomidae	5.46	17.49	510	10.2
Hemiptera	0.01	0.07	1	<0.1
Trichoptera	0.64	1.95	60	1.2
Ephemeroptera	1.38	8.08	129	2.6
Lepidoptera	0.03	0.12	3	0.1
Coleoptera (Carabidae)	0.01	0.07	1	<0.1
Non-Insecta				
Bivalvia (undetermined)	0.01	0.07	1	<0.1
Corbicula spp.	6.98	14.08	652	13.1
Gastropoda (undetermined)	3.24	12.81	303	6.1
Pleuroceridae	16.4	30.61	1,532	30.7
Planorbidae	1.00	3.28	93	1.9
Physidae	0.50	1.21	47	0.9
Lymnaeidae	0.13	0.34	12	0.2
Hirudinea	0.02	0.10	2	<0.1
Oligochaeta	14.2	30.54	1,328	26.6
Nematoda	0.01	0.07	1	<0.1
Ostracoda	0.50	3.19	47	0.9
Hydracarina	0.02	0.10	2	<0.1
Unidentified Organisms	0.08	0.31	7	0.1
Overall Count			4,994	100%

* Incomplete or deteriorated samples were identified to lowest possible taxonomic level and classified as "undetermined."

Table 15. Benthic macroinvertebrate mean standing stock ($\bar{x}$), standard deviation (SD), and relative abundance for each station on the Arizona Canal (n = 190), September 1993 to July 1994.

Station	Habitat Type	Standing stock (no/m^2)			
		$\bar{x}$	SD	n	Abundance (%)
ACB3	Run	39.17	42.72	39	8.0
ACC3	Run	59.74	70.80	30	12.2
ACD3	Run	47.23	4.97	23	9.7
ACE3	Run	36.30	9.46	26	7.4
ACF3	Run	6.75	1.18	22	1.4
ACG3	Pool	25.16	4.66	19	5.2
ACH3	Pool	117.74	8.45	17	24.1
ACI3	Pool	155.76	4.14	14	31.9

Standard deviations are those of the mean density before conversion to numbers of organisms per square meter.



The Arizona Canal near Station ACD3 and Phoenix's Squaw Peak Water Treatment Plant.

Table 16. Mean density of zooplankton (x̄) per 20 L, standard deviation (SD), total count, and relative abundance from the Arizona Canal, all stations combined (n = 178), December 1992 to July 1994.

Taxonomic Group	Number per 20 L x̄	SD	Total Count	Percent Total
True Zooplankton				
Nematoda	0.02	0.13	3	0.2
Rotifera *Asplanchna, Enteroplea,* and *Euchlanis*	0.47	5.40	83	5.1
Crustacea				
Copepoda (undetermined)	0.02	0.13	3	0.2
Calanoida *Leptodiaptomus siciliodes*	0.15	0.88	26	1.6
Cyclopoida *Nauplius, Diacyclops thomasi,* and *Paracyclops*	2.03	4.42	362	22.2
Amphipoda	0.09	0.66	16	1.0
Anostraca	0.01	0.07	1	0.1
Conchostraca	0.06	0.57	10	0.6
Cladocera *Chydorus, Bosmina coregoni, Diaphnasoma, Daphnia galeata mendotae,* and *Ceriodaphnia*	2.08	5.69	372	22.8
Ostracoda	0.52	2.04	92	5.6
Aquatic and Terrestrial Insects				
Diptera (Chironomidae and Tripulidae)	2.20	4.50	392	24.0
Coleoptera	0.11	0.38	19	1.2
Ephemeroptera	0.29	1.50	51	3.1
Odonata (Anisoptera and Zygoptera)	0.42	1.31	74	4.5
Plecoptera	0.21	0.72	38	2.3
Trichoptera	0.02	0.13	3	0.2
Collembola	0.19	0.63	34	2.1
Hemiptera (Corixidae and Belostomatidae)	0.05	0.22	9	0.5
Megaloptera (Corydalidae)	0.01	0.11	2	0.1
Non-Insects				
Tardigrada	0.05	0.29	9	0.5
Mollusca				
Gastropoda *Campeloma* and *Limnaea*	0.01	0.11	2	0.1
Bivalvia Pelecypoda				
Miscellaneous	0.01	0.07	1	0.1
Arachnida				
Hydracarina	0.03	0.21	6	0.4
Hydra	0.12	0.58	22	1.3
	0.01	0.07	1	0.1
Total Count			1,631	100%

* Incomplete or deteriorated samples were identified to lowest possible taxonomic level and classified as "undetermined."

Table 17. Mean zooplankton density ($\bar{x}$), standard deviation (SD), sample number, and relative abundance for each station on the Arizona Canal (n = 178), December 1993 to July 1994.

	Number per 20 L			
Station	$\bar{x}$	SD	n	Abundance (%)
ACB3	10.22	13.43	23	15.4
ACC3	15.78	17.13	27	23.8
ACD3	8.75	17.51	24	13.2
ACE3	10.67	13.71	30	16.1
ACF3	2.40	1.78	10	3.6
ACG3	7.04	6.76	25	10.6
ACH3	4.38	3.71	13	6.6
ACI3	7.04	8.06	26	10.6

Table 18. Regional representation of survey respondents in Maricopa County, May 1994.

Region Surveyed	General Public Survey (%)	Licensed Angler Survey (%)
Phoenix	42	47
Southeast Valley (Tempe, Mesa, Chandler, etc.)	30	23
West Valley (Glendale, Peoria, Goodyear, etc.)	17	19
Northeast Valley (Scottsdale, Carefree, etc.)	11	11
Percent Total	100	100

percent of the licensed anglers and 51% of the non-angling public indicated that they would be somewhat or very likely to utilize the canals if a fishery program were developed (Table 19). Demographically, the highest interest was among males and younger residents (Table 20). A conservative estimate of 750,000 annual angler-use days was calculated (Appendix D). This number was calculated from the number of licensed anglers and non-anglers, percent of interested respondents, and average number of days "very likely" users would fish the canals. Percentages and number of angler-use days were adjusted downward (based on interest level) to attain conservative estimates.

In 1993, the estimated number of licensed anglers in Maricopa County was 178,000. Based on conservative estimates, 45,000 licensed anglers (25.3%) would fish the canals — the number of "very likely" respondents was adjusted downward 50% and "somewhat likely" respondents adjusted downward 75%. The estimated number of non-anglers, over age 14, in Maricopa County was 1,617,200 in 1993 (Dep. Economic Security 1993). "Very likely" (adjusted downward 75%) and "somewhat likely" (adjusted downward 90%) respondents made up 8.0% of the total, or potentially 129,500 new anglers, showed an interest in fishing the SRP canals (Appendix D).

Additionally, 80% of both interested anglers and non-anglers indicated they would be willing to purchase a special license to support an urban canal fishery (Table 21). Median angler-use days for a canal fishery were estimated to be 12 days annually based on licensed anglers and general public responses (Table 22).

Respondents were asked what fish (species unspecified) they would prefer, if the program were developed (multiple choices were given — percentages are not cumulative). Bass was the top choice among licensed anglers (75%), followed by catfish (39%) and trout (28%). General public anglers showed similar preferences in species: bass (62%), catfish (39%), and trout (39%). The interested non-angling public favored catfish (45%), bass (36%), and trout (20%). Other fish species, such as crappie and bluegill/sunfish were listed but less often.

Respondents that showed no interest in a proposed canal fishery were asked to state their main reasons for no interest. Of the licensed anglers, 52% preferred to fish in rural areas, while 20% said they could not use their boat in the canal system. Fifty-eight percent of the combined general public indicated they didn't like to fish. Eleven percent said they preferred to fish in rural areas, and 10% indicated they were too old or ill to utilize the canals for sport fishing.

Most non-interested respondents reported they still would support the development of a proposed canal fishery program (Angler Survey 66% and General Public Survey 57%). Eighteen percent of the licensed anglers and 21% of the general public were opposed to the program. Respondents that were "not sure" were closely matched to those opposed; i.e., Angler Survey 16% and General Public Survey 22%.

Table 19. Interest of survey respondents in proposed SRP Canal Fishery Program, May 1994.

Level of Interest	General Public Survey (%)			Licensed Angler Survey (%)
	Angler	Non-angler	Combined	
Very likely	49	20	26	33
Somewhat likely	31	31	31	35
Not very likely	9	16	14	11
Not at all likely	11	32	28	19
Not sure	0	1	1	2
Percent Total	100	100	100	100

Table 20. Demographical detail of interested (% very/somewhat likely) survey respondents, May 1994.

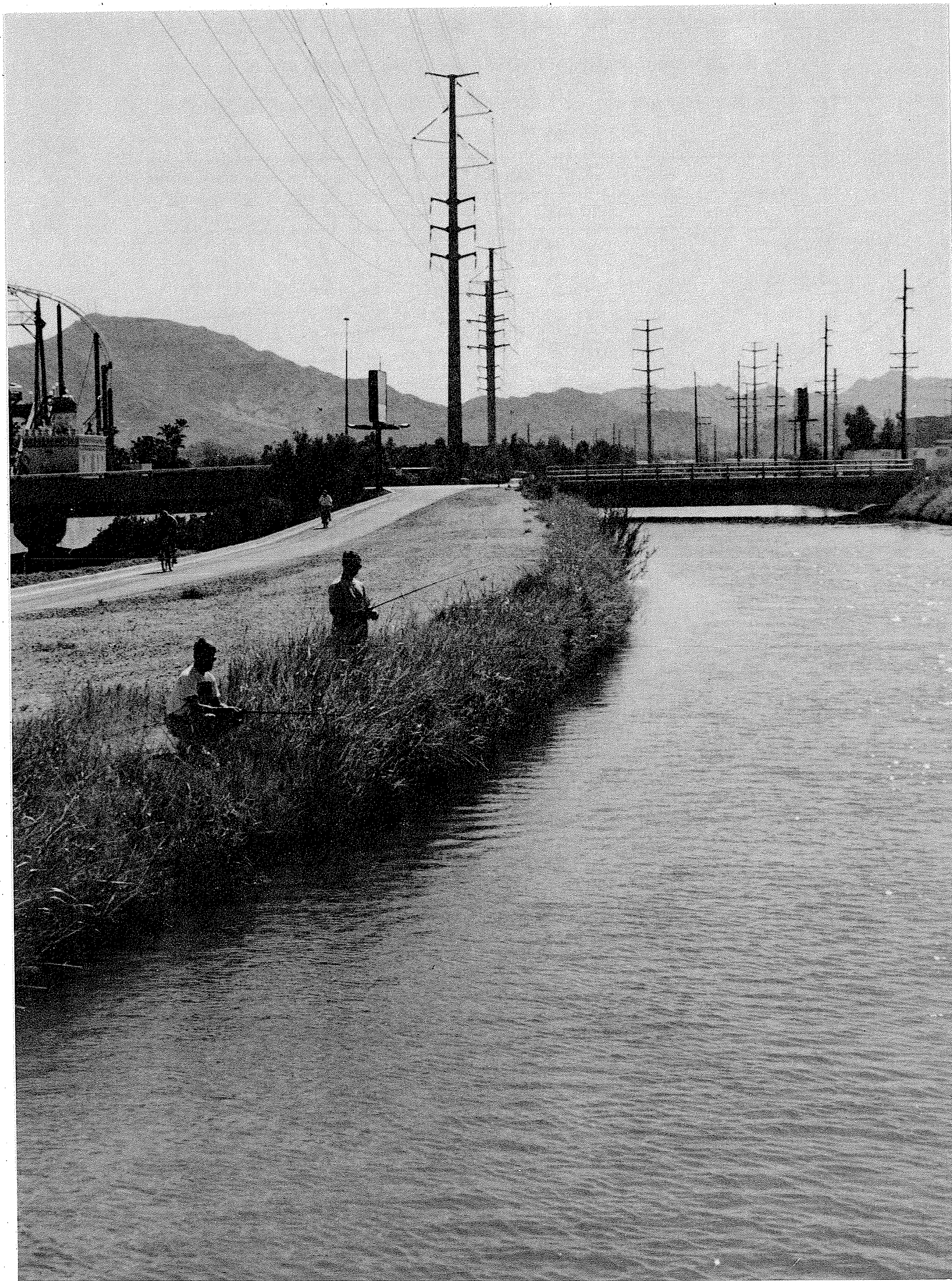
	General Public Survey (%)			Licensed Angler Survey (%)
	Angler	Non-angler	Combined	
Percent total	80	51	57	68
Gender				
Male	78	56	62	70
Female	82	46	52	57
Age				
Under 35 years	79	61	66	72
35 to 54 years	82	56	63	70
55 years & over	75	32	37	65

Table 21. Responses to "willing to pay" for an annual special license fee to fish in the SRP canals, May 1994.

Proposed Fee Cost	General Public Survey (%)			Licensed Angler Survey (%)
	Angler	Non-angler	Combined	
Nothing	13	4	7	17
Under $5.00	14	10	11	17
$5.00 to $9.99	22	23	23	24
$10.00 to $14.99	31	28	29	31
$15.00 or over	14	22	20	8
Not sure	6	13	10	3
Percent total	100	100	100	100
Median Cost for those willing to pay special fee to fish in the SRP canals.	$10.71	$11.55	$11.25	$9.90

Table 22. Frequency of canal fishery program use by survey respondents, May 1994.

Days per year use	General Public Survey (%)			Licensed Angler Survey (%)
	Angler	Non-angler	Combined	
1 to 5	26	26	26	22
6 to 10	9	22	18	24
11 to 20	21	15	17	26
21 or over	37	31	33	23
Not sure	7	6	6	5
Percent Total	100	100	100	100
Median Number of Days	16.5	10.8	12.7	11.7



DISCUSSION

Fish Surveys

Large canal systems are difficult to sample due to high water velocities, steep banks, poor access, and deep water (Mueller 1990). We believe that Sites 5 and 7 were too deep to effectively sample bottom-dwelling fish using electrofishing techniques. As a result, the number of fish collected at these sites may be underestimated. In addition, some species (e.g., Sonora and desert suckers, largemouth bass, and rainbow trout) were more effectively sampled using electrofishing than other species (e.g., channel catfish). Electrofishing is also biased towards larger fish; therefore, forage fish and young-of-year fish may be underestimated. More effective sampling methods, such as block netting and dewatering the canal, were not options available to us.

Species Diversity and Abundance. We found that species richness in the Arizona Canal (20 species of fish - 17 introduced and 3 native) was comparable to a previous study of fish in the SRP canals. Marsh and Minckley (1982) surveyed most of the SRP canal system in 1981 and found 23 species of fish (19 introduced and 4 native). These researchers found the greatest numbers and diversity of fish within the first few kilometers downstream of the Granite Reef Dam. Furthermore, beyond 25 km downstream only a few red shiners and western mosquitofish were found, but most collecting sites yielded no fish at all (Marsh and Minckley 1982). Marsh and Minckley (1982) also noted that the fish fauna in the canals were unstable and undergoing numerous changes in species composition and diversity. In contrast, we found species richness and relative abundance on the Arizona Canal were higher at our lower sites compared to our upper sites. We attribute these differences to: (1) the area of the canal system sampled; (2) sampling gear; (3) duration of sampling; (4) seasons; and (5) changes in canal management where only portions of the canals have been dewatered since the late 1980s.

We expected that CPUE of native suckers at Site 7 would have been higher than our downstream sites due to its distance downstream of Granite Reef Dam, habitat, and lack of water control structures. Site 7 was the closest fish collection site to the Granite Reef Dam and closely resembled habitat found in the Salt River. While we found that Site 7 had a higher number of native suckers than our farthest downstream sites (Sites 1 and 2), our data showed that natives were most abundant at Site 3. We believe this finding was due to the combination of fast-moving water and shallow depth. Also in recent years, reduced dewatering in this canal segment for white amur management may explain a higher abundance of fish due to carryover from year to year.

Forage fish numbers and CPUE were highest at our 3 lowest sites. The distribution of threadfin shad at our lower sites may result from high water velocities flushing fish downstream, especially during summer when water demands and flow volumes are high. Overhanging vegetation on the earthen banks at Alternate Site 3 and Site 2 may have provided protection for shad from large predators and high water velocities. Metal grates used to prevent amurs from escaping Skunk Creek Drain and other laterals (Fig. 25), may also offer protection for forage fish. We believe that the increase in CPUE for threadfin shad during Fall 1993 was the result of natural reproduction in the canal, since shad spawn during the spring and early summer (Minckley 1973). Red shiners were most abundant at Site 2. We believe the aquatic habitat at this site was stressed from alum sludge discharges and storm runoff along dirt banks. Red shiners tend to thrive in stressed or degraded habitat (Minckley 1973).

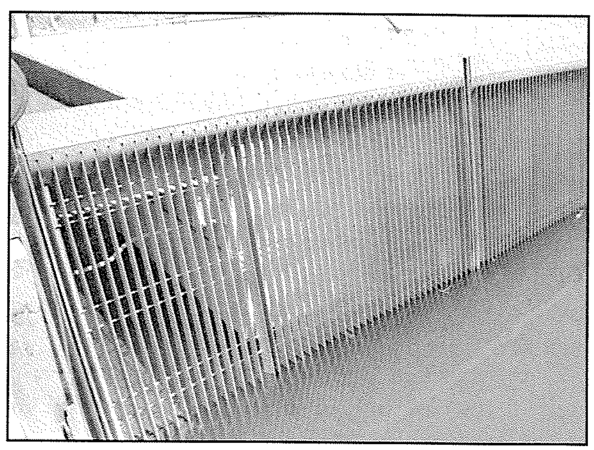


Figure 25. Metal grates at the end of the Arizona Canal, Skunk Creek Drain.

White amurs were collected from all fish collection sites along the Arizona Canal; however, the highest number were sampled at the farthest downstream site (Site 1). A decline in CPUE in Spring and Summer 1993 may be attributed to a large fish kill in the lower half of the Arizona Canal. Over 400 amurs were found dead following a suspected chlorine discharge on May 15, 1993 by a water treatment plant. It is also possible that our electrofishing efforts may have contributed to some spinal injury or mortality.

Resident game fish were collected from all sites along the Arizona Canal, with the exception of rainbow trout at Site 3. Game fish populations tended to be highly variable depending on the site. Largemouth bass CPUE was highest at Site 3, probably due to abundant prey and quality habitat at the end of the reach, Alternate Site 3. There were no physical barriers to limit fish movement between these 2 sites. Preferred habitat for largemouth bass includes earthen banks and overhanging vegetative cover (Minckley 1973); conditions that were found at Alternate Site 3.

Excluding our experimentally stocked fish, the number of rainbow trout collected during this study was small (n = 11). Further, few resident rainbow trout (n = 3) were collected from our farthest upstream sites (5 and 7) over the course of this study. Therefore based on our data, we could conclude that few rainbow trout are emigrating from the Salt River into the Arizona Canal. However, the results from 5-yrs of fish barrier surveys (Jakle and Riley, unpubl. data) found that rainbow trout comprised over 7% of total number of fish sampled. Over that same period, AGFD has stocked the lower Salt River on a frequent year-round basis with catchable rainbow trout (E. Swanson, Ariz Game and Fish Dep., pers. commun.). Furthermore, rainbow trout are stocked in winter months on the lower Verde River by the Fort McDowell Indian Tribe (E. Swanson, Ariz Game and Fish Dep., pers. commun.). Therefore, it is apparent that moderate numbers of these river-stocked rainbow trout were emigrating to the Arizona Canal (E. Swanson, Ariz Game and Fish Dep., pers. commun.). Therefore, the status of resident rainbow trout in the Arizona Canal is unclear.

Size and Age Structure. We believe that natural reproduction of largemouth bass occurs in the Arizona Canal. Seasonal length frequency graphs showed 16 fish with TL ≤120 mm, which may have represented young-of-year fish. Largemouth bass spawn from April through June (Minckley 1973). Also, young bass can grow to around 125 mm TL by the end of their first summer (Minckley 1973). Length measurements of largemouth bass were highly variable and indicated several age classes were present throughout our study. We observed pairs of mature fish guarding nests as well as numerous juvenile fish that were not collected during repeated-effort electrofishing in the last 2 sampling seasons. It is uncertain to what extent bass reproduction in the canal contributes to a catchable-size largemouth bass fishery.

The threadfin shad population in the Arizona Canal was most likely maintained by natural reproduction, but this was not apparent in seasonal length frequency graphs. Age classes of young and mature fish may have overlapped in these graphs due to fast growth rates. Threadfin shad mature within a few weeks and may begin spawning in their first year (Kimsey 1958, Minckley 1973). Electrofishing bias towards larger fish may have been another reason why young shad were not encountered.

Red shiners appeared to have a single cohort during each season in the Arizona Canal, but they may have an overlap of age classes similar to threadfin shad. Red shiners spawn from March through June (Minckley 1973). Natural propagation of shiners was observed in the canal, but very young fish were not collected because they escaped through the mesh of our dipnet. On many occasions we observed various sizes of fry and juveniles together, often hiding in the shelter of steps or other microhabitats along the canal bank waterline.

Seasonal length frequency graphs of Sonora suckers revealed a small cohort of juvenile fish (TL ≤120 mm) that indicated a reproducing resident population. Sonora suckers generally spawn between January and early July (Minckley 1973). A distinct cohort of mature fish was also present in the canal. During our fish sampling, we noticed many suckers were tuberculate (e.g., small bumps along the anal and tailfins) and had deformed anal fins which may be the result of building redds.

Desert suckers appeared to have reproduced successfully in the canal. We observed similar tubercles and deformed fins on this sucker species as well. According to Minckley (1973), desert suckers spawn in late winter and early spring. Length frequency graphs show distinct cohorts of juveniles in both summer seasons. An overlap of age classes may have occurred in the first 3 seasons as TL ranges reached a minimum of 40 mm in the first groups.

We did not find any evidence of reproduction by white amurs in the Arizona Canal, which SRP introduced as a sterile population. No juvenile amurs were collected, but growth of mature individuals appears to have occurred based on our seasonal length frequency graphs. The largest amurs collected during this study had TL >700 mm and weighed over 4 kg. In October 1994, a Glendale angler caught a state record white amur with a TL of 838 mm and a weight of 7.2 kg from Alternate Site 3 on the Arizona Canal (E. Swanson, Ariz. Game and Fish Dep., pers. commun.). A distinct cohort in Spring 1994 was probably a result of annual SRP amur stockings. All the amurs appeared to meet the minimum head width requirement of the AGFD stocking permit.

Yellow bass in the Arizona Canal may be reproducing based on several juveniles with lengths ≤80 mm that were collected during our study. Roundtail chubs, however, were all ≥100 mm TL, and therefore, probably did not result from reproduction in the canal. Sample numbers for both species were too low for reliable evaluations. Other resident fish, including channel catfish and rainbow trout, had insufficient sample sizes to be evaluated.

Granite Reef Electrical Barrier Monitoring

Fish species from the Salt River watershed immigrate into the canal system according to surveys (Jakle and Riley, unpubl. data) below Granite Reef Dam. Desert and Sonora suckers were well represented in these surveys and their relative abundance was similar to that in the canal below the fish barrier. Forage fish were poorly represented in the barrier surveys, while large numbers of these fish were found at downstream sites. Only 19 threadfin shad were sampled above the barrier, indicating either that few shad were immigrating into the canals or they suffered heavy predation by game fish above the barrier during the dewatering period. Regardless, based on our electrofishing data we believe threadfin shad were successfully reproducing at our downstream sites.

Common carp and tilapia were abundant above the barrier during certain years, but they were rare or nonexistent, respectively, in our electrofishing sampling downstream. It has been speculated that these 2 species are highly sensitive to electrical fields and avoid moving downstream past the barrier (E. Swanson, Ariz. Game and Fish Dep., pers. commun.). Tilapia absence in the Arizona Canal may also be a result of winter kills when water temperatures drop to 10 C (M. Jakle, U.S. Bur. of Reclam., pers. commun.).

While the electric fish barrier was designed to prevent fish from moving upstream, 2 SRP-stocked white amurs, nevertheless, were captured above the barrier in 1994. An investigation revealed that the Arizona Canal barrier lost power due to a brief power outage on December 23, 1993 (Salt River Proj. 1994*b*). Based on our observations, white amurs are strong swimmers and capable of jumping several feet out of the water. Evidently, these 2 fish were able to get past the steep incline and high water velocity of the barrier while the power was out. Fortunately, most amurs tend to migrate downstream, based on the numbers of fish that SRP regularly collects and relocates from the end of the Arizona Canal (B. Moorhead, Salt River Proj. pers. commun.).

Barrier fish data represented only 1 sampling day per year, which may account for the high variability in species composition and abundance. Yet, previous studies have shown a similar disparity in types and numbers of fish present in the canal system (Marsh and Minckley 1982).

In January 1994 and 1995, the annual SRP drawdown allowed AGFD an opportunity to relocate largemouth bass, channel catfish, and rainbow trout from the Arizona Canal into 2 Urban Fishing Program lakes. In the future, both game and nongame species captured above the electric fish barrier and from dewatered areas could also be relocated to partially dewatered canal segments, or at designated fishing areas along the Arizona Canal. Managing canal fish populations through salvage and relocation should improve angler success in these fishing areas.

Experimental Fish Stockings

Stocked Fish Survival. Stocked game fish remained within canal reaches for long enough periods to support a put-and-take sport fishery. Most stocked game fish were not present for more than 2 months; however, some rainbow trout persisted for at least 7 months and channel catfish for as long as 13 months. It is unknown whether these fish were harvested by anglers (unreported), suffered other forms of mortality, or immigrated out of the system. If a stocking program is established, we anticipate that the best catch rates would occur in the first 6 weeks after stocking. This trend is consistent with previous studies (Edwards and Okamoto 1980, Landye and Watt 1985) where stocked game fish in urban lakes had the highest harvest within the first 10 days after release.

While unannounced, news of each experimental stocking spread quickly and numerous anglers were observed during our daily activities. Not all the anglers observed were interviewed. Some anglers may have been fishing illegally and immediately departed the area when we stopped to interview others. We believe actual public harvest of stocked fish was higher than reported. Angling effort was not estimated. Several anglers left phone messages, providing tag numbers of fish caught, but little else. Most anglers reported good catches and were highly supportive of the fish stockings.

We compared our results to a previous AGFD experimental stocking on the Arizona Canal (Sorensen 1990) that also revealed a large percentage of unaccounted fish. During Winter 1989-1990, 1,200 albino rainbow trout were stocked at Site 2 near Glendale (Cholla) Water Treatment Plant, 2 weeks prior to the annual canal drawdown. The objectives of this test stocking were to monitor fish movement and survival. At the end of the study, only 51 albino rainbow trout were recaptured. The remaining 95% of the stocked fish were not present when that section of the canal was dewatered, nor were any observed above the stocking site (Sorensen 1990). Only 1 public angler with a single recapture was reported. Salt River Project workers did not report seeing any trout in the lateral canals. Six fish were found in the precipitation basin of the Glendale (Cholla) Water Treatment Plant (Sorensen 1990). What happened to most of the stocked albino rainbow trout is unknown.

No rainbow trout were found in the Arizona Canal after July because water temperatures increased beyond tolerance limits. As a cold-water species, they experience physiological stress at sustained temperatures above 20 C (Piper et al. 1983, Armour 1991).

Stocked Fish Growth and Condition. Presently, the biotic conditions and relatively uniform habitat of the Arizona Canal may restrict channel catfish growth and prevent a successful put-grow-take stocking program for this species. The lack of growth and decreased physiological condition of channel catfish may have resulted from a limited food base and lack of suitable shelter. Catfish shelter was scarce in the canal due to annual dredging and removal of debris by SRP. Other contributing factors for poor catfish growth could result from intraspecific or interspecific competition for food, disease, internal parasites, or unreported angler take of larger fish from catch-and-release practices. Few external parasites were observed on recaptured channel catfish. Water quality does not appear to be a limiting factor in channel catfish survival because we recaptured channel catfish a year after stocking, and numerous juvenile channel catfish were observed as well. It should be noted that most of the length and weight data on recaptured channel catfish was obtained within the first few weeks after stocking. This aspect coupled with low sample numbers of older stocked fish may impart a sampling bias to growth data.

Our estimated K and Wr values on recaptured channel catfish from the Arizona Canal were comparable to the results of other studies of southwest fisheries. McCarthy and Marsh (1982) reported mean K values of 0.72 from channel catfish in the Coachella Canal, while Lake Pleasant, Arizona, had mean K values of 0.81 in 1988 and 0.82 in 1989 (Morgensen 1990). Relative weight of Lake Pleasant channel catfish was estimated at 94. A Wr value of 100 is considered ideal, but as a fish reaches full maturity Wr values tend to decrease (Anderson and Gutreuter 1983).

A put-grow-take stocking program for rainbow trout would not be feasible. High water temperatures during the late spring months would likely prevent growth, and reach lethal limits during the summer (Piper et al. 1983, Armour 1991). While rainbow trout growth was fair during the winter season, average well-being did not improve in the Arizona Canal. The same conditions that limit growth in stocked channel catfish probably apply to rainbow trout.

Stocked Fish Movement. Fish movement downstream should not be a problem in designating public fishing areas along the Arizona Canal. Within 1-yr, most stocked game fish (channel catfish = 99% and rainbow trout = 95%) remained within the same reach (between upper and lower water control structures) in which they were stocked. The fish that did migrate downstream moved approximately 0.8 to 4.0 km per week poststock. Fish movement is a relatively unimportant factor in comparison to angler harvest; most of the stocked fish were caught within the first 6 weeks. After this period, catch rates (all methods) for stocked fish dropped greatly. Stocked fish that moved through water control structures were never recaptured above those barriers. Likewise, no stocked fish were collected above the Site 3 stocking location. We believe that the design of these radial gates prevents fish from traveling upstream due to high velocity, bottom-released water.

Fish movements were similar to a previous test stocking between 1989-1990 at Site 2 (Sorensen 1990). Within 2 weeks poststock, several rainbow trout had travelled downstream 8.0 km to Site 1, Skunk Creek Drain. No stocked fish had been sampled upstream of the water control structure at Station ACF3 — the upper end of Site 2 (Sorensen 1990).

Fish Loss to Lateral Canals. Fish loss to the lateral canals should not be a major concern for a proposed sport fish stocking program. For up to 6 weeks poststock, low numbers of fish were lost to the lateral canals around the stocking area. Three rainbow trout and 8 channel catfish were collected from the fish traps. No stocked fish were found at the demossing dump at Site 1. Most of the stocked fish sampled remained in the main canal.

Vertical steel grates that cover openings to all lateral canals and siphons were designed to prevent stocked white amurs from escaping. The space between grates was typically 50.8 mm wide. In addition, all stocked amurs have head diameters >57.2 mm wide (B. Moorhead, Salt River Proj., pers. commun.). These grates may also preclude larger game fish from leaving the main canal and provide habitat and protection for small fish as well as forage fish. Some species may select these openings as preferred habitat. Based on our fish trap data, narrow-bodied fish moved freely between the grates, and we observed numerous bluegill and green sunfish within and around these lateral canal openings.

Seasonal flows, flooding effects, and heavy water siphoning may influence the number of fish leaving the main canal through the laterals. High main canal velocities during summer flows may force some lentic-adapted species to seek the shelter of lateral canal openings. Opened siphons can have water velocities strong enough to draw small fish out of the system. Larger fish, such as stocked rainbow trout and channel catfish, would be able to overcome strong currents.

Potential Fish Tissue Contaminants

We were unable to conclude if consumption of stocked fish from the Arizona Canal would pose a serious public health risk. Recaptured fish composites from the Arizona Canal were found to contain little or no amounts of the 129 priority pollutants tested. Some metals and inorganics were expected to be found; copper, selenium, zinc, and possibly arsenic, which are essential for fish survival (Peterson 1987). Quantities of certain halogenated aliphatics were also expected. Methylene chloride was used as an extraction solvent for gas chromatography/mass spectrophotometry in semivolative analysis, and may be present in control and recapture composites from possible laboratory contamination. In addition, both methylene chloride and chloroform are byproducts of the chlorination process for drinking water. The water treatment plants along the Arizona Canal discharge alum sludge, which may contain both compounds, into the canals.

Concentrations of aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, mercury, and PCBs were well below FDA Action Levels (Peterson 1987). The FDA established maximum concentration levels for these substances in human foods for safe consumption. However, FDA Action Levels for the other 120 EPA priority pollutants have not been set, and safe concentration limits vary according to different regulatory agencies.

We must emphasize that AGFD is not a regulatory agency for classifying limits of toxic substances in human foods. Therefore, AGFD cannot declare fish from the SRP canals as safe or not for consumption. Our results were for analytical purposes only, and were intended to provide a rough estimate of contaminant levels found in fish tissues. Our low sample number (3 control composites and 5 recapture composites) may be inadequate to properly determine contaminant levels, but high costs of laboratory analyses prohibited testing additional samples. Extensive contaminant testing of native and resident game fish in the Arizona Canal were beyond our budget constraints. Based on the small sample number, interpretation of these results should be made with caution.

Abiotic Factors

Water quality values in the Arizona Canal were within normal ranges for an aquatic system of this design, and would not impair the success of a canal sport fishery for warm-water species. Temperature, dissolved oxygen, pH, and conductivity in the Arizona Canal were similar to results of a 1986-1989 study of the CAP Aqueduct (Mueller 1990). Mueller (1990) reported ranges for water temperature between 9.1 and 29.9 C, DO from 6.0 to 12 mg/L, pH between 7.3 and 10, and conductivity between 820 and 946 mS/cm.

Seasonal water temperature extremes would not seriously impact year-round survival of channel catfish and largemouth bass, but it would affect rainbow trout. The range of optimum water temperature varies by species (Piper et al. 1983). As cold-water species, trout require optimal temperatures between 10.0 and 15.5 C, but they can survive temperatures up to 25.5 C (Piper et al. 1983). Conversely, channel catfish are a warm-water species and require optimal temperatures between 21.1 and 29.4 C, but they can survive temperatures up to 35.0 C (Piper et al. 1983). As water temperatures rise, fish metabolic rates increase. Prolonged periods of high water temperature cause stress or even mortality (Armour 1991). High summer temperatures in the Arizona Canal were beyond upper survival limits for rainbow trout.

Recorded DO and pH levels in the Arizona Canal are satisfactory for fish survival. Fish become stressed when levels of DO are <5.00 mg/L, and death may occur when DO is <1.00 mg/L (Piper et al. 1983). The optimum range of pH for cold-water species is 6.5 to 8.0, while warm-water species prefer pH of 7.5 to 9.0 (Piper et al. 1983). Dissolved oxygen levels were stable throughout most of the year, except during the Fall when mean levels dropped to 7.23 mg/L. We do not know what caused this decrease in DO. High water temperatures, which negatively affect DO saturation levels, also dropped in the Fall. Stable DO levels are probably maintained by regular water releases through water control structures along the length of the canal. The low DO level in January (6.48 mg/L) was the result of sampling stagnant, shallow water at a few stations during the annual canal dewatering. Our December and February measurements of DO are more representative of winter conditions in the canal.

Biotic Factors

Chlorophyll a. Waters of the Arizona Canal yielded levels of primary productivity sufficient to provide a moderate food base to support a canal put-and-take sport fishery. Quantitative estimates of lotic and lentic primary production have used CHLA:PHEA as a standard estimator of phytoplankton physiological condition (Standard Methods 1989). Marsh and Fisher (1987) found that the Arizona Canal was autotrophic and exported organic matter. Comparative information regarding primary production within urban canals, specifically CHLA values and ratios, is scarce. A study of mean CHLA values of Lake Pleasant between 1987 and 1989, ranged from 1.7 to 19.5 mg/m^3 and ratios of 1.4 to 1.7 (Morgensen 1990). The Arizona Canal had a mean CHLA:PHEA ratio of 1.3, which was equal to or slightly lower than the other major SRP canals. Individually, the Consolidated, Eastern, and Cross-Cut canals had slightly better primary productivity (ratio of 1.4). However, greater applications of biocides or herbicides by SRP in these canals would make them less desirable for a potential sport fishery.

Benthos. The Arizona Canal supported a substantial diversity of benthic fauna but in low abundance. The number of benthic macroinvertebrate taxa found in our study (18 taxa) closely compares with other studies on canal benthic fauna. A study on California's Delta-Mendota Canal (Eng 1974) reported 21 invertebrate species collected from sediment deposits, and an additional 10 species found in earthen portions of the canal. Marsh (1983) found 15 different taxa in a large lateral channel of the SRP Consolidated Canal. A similar study was conducted on southern California's Coachella Canal where 19 different invertebrate taxa were identified (Marsh and Stinemetz 1983).

Gastropods were more abundant (60% species composition) in the Arizona Canal than documented in other studies. In comparison to the Delta-Mendota Canal, Eng (1974, 1975) reported the Asiatic clam *(Corbicula fluminea = C. manilensis)* had the highest abundance. Asiatic clam was also the most dominant taxon found in the Coachella Canal study (Marsh and Stinemetz 1983). The Coachella also contained high densities of oligochaetes, chironomids, and trichopterans. In Lateral 9.5 of the Consolidated Canal, oligochaetes were most abundant, followed by *C. fluminea*, chironomids, and ephemeropterans (Marsh 1983).

In other studies, Asiatic clams were an important food source for channel catfish (Turner 1966, Minckley 1982). Minckley (1982) found *Corbicula* was eaten by common carp, channel catfish, yellow bullhead, and largemouth bass in the lower Colorado River. He also reported that carp had the highest consumption of clams. Prokopovich (1968) noted that young *Corbicula* were preferred fish food and were often sold in bait shops. Crayfish were a major food source for trout, bass, carp, and especially catfish (Minckley 1982). Additional research is required to evaluate fish foraging and dietary needs in the canals.

In the Arizona Canal, the preference and foraging on gastropods and oligochaetes by fish is unknown. Invertebrate species abundance may not be comparable to the food requirements of canal fish. Aquatic insects, especially dipterans, are a regular source of food for many fish species. Marsh (1981) reported that channel catfish in the Coachella Canal fed primarily on aquatic insects (i.e., Trichoptera, Odonata, Lepidoptera, and Chironomidae). However, Marsh (1981) also noted that threadfin shad and *Corbicula*, while abundant in the Coachella Canal, were not used as primary food items for channel catfish.

Based on our collections, the Arizona Canal supports a relatively low density of benthic fauna compared to other canals. Marsh (1983) reported a total benthos density of 14,802 individuals/m^2 from Lateral 9.5 of the Consolidated Canal. The Coachella Canal supported mean densities of 158 to 3,678 individuals/m^2 (Marsh and Stinemetz 1983). In both of these studies, sampling areas on the Coachella Canal and Lateral 9.5 of the Consolidated Canal had earthen banks and bottom.

Concrete-lined areas of the Arizona Canal had a higher abundance of benthic fauna than areas with earthen banks and bottom. In our study, approximately 90.3% of the Arizona Canal was concrete-lined. Alternate Site 3, half of Alternate Site 2, and Site 2 (including Stations ACF3 and ACG3) had earthen banks and bottom. Both ACF3 and ACG3 had the lowest mean density of benthic invertebrates. Salt River Project eventually plans to line the entire Arizona Canal with concrete to increase water transport efficiency and reduce water loss by seepage. Sediment deposits are common within the Arizona Canal, regardless of concrete-lined or earthen substrate. High water velocities and fluctuating flows in the canal scour loose bottom sediments in areas of runs and riffles. Sediments settle out in pool areas, typically upstream of water control structures.

Sediment deposits in the Arizona Canal were mostly the result of alum discharges (a very fine, inert filtrate) from the 3 municipal water treatment plants (Fig. 26). These facilities were located at ACD3, at Alternate Site 3, and between Stations ACF3 and ACG3. A fourth water treatment plant is planned to be constructed near Site 1 (ACH3), by the City of Peoria. Additional sources of sediment result from surface runoff on the upper banks, floodwater drainages during heavy rains, and airborne deposits of soil and dust. This runoff material was more heterogenous in quality (fine and coarse particulates). It is unknown if benthic species prefer either heterogenous sediment deposits to those mostly of alum composition.

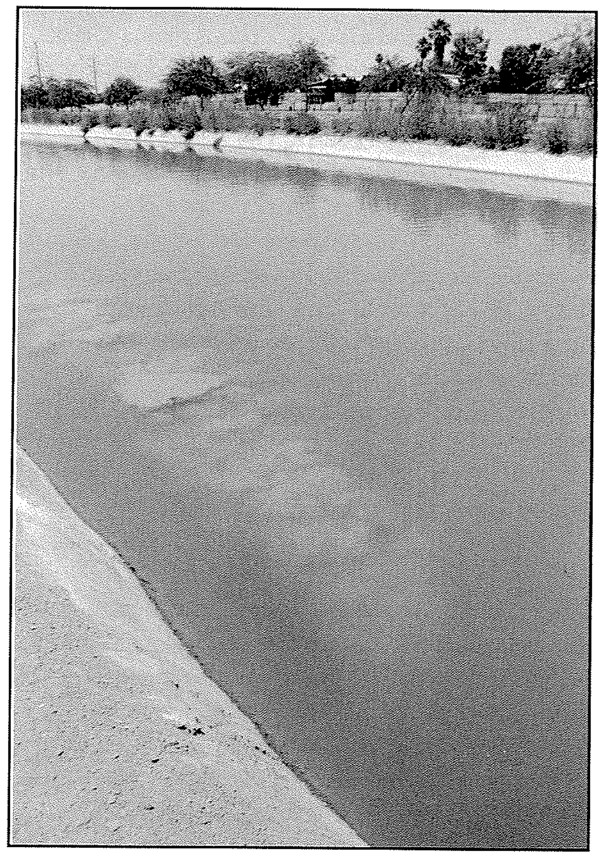


Figure 26. Alum sludge from Glendale's Cholla Water Treatment Plant, downstream of Site 2, was pumped into the Arizona Canal creating heavy turbidity.

During the annual drawdowns, SRP maintenance crews dredge the dewatered portions of the Arizona Canal and remove most of the sediment deposits containing benthic fauna, thus greatly impacting benthic biomass available to fish. Those species better adapted for concrete-lined banks/bottom and fast population recoveries would be favored. Currently, the quantity of sediment being dredged appears to be adequate to support a fair number of invertebrates. It is anticipated that sediments will decrease in the future due to recent actions by the Environmental Protection Agency that would require the water treatment plants to reduce or eliminate their alum and filter backwash discharges into the SRP canals.

Zooplankton. We found a high number (n = 38) of zooplankton taxa in the Arizona Canal, but at low total densities ($\bar{x}$ <5/20 L) which might hinder a canal put-grow-take sport fishery. A similar study on the Delta-Mendota Canal, California, by Eng (1974) collected only 14 genera of zooplankton. Eng (1974) reported a high abundance of rotifers, cladocerans, and copepods from 3 sampling locations in the large, concrete-lined Delta-Mendota Canal. The Arizona Canal zooplankton population was comprised mostly of true zooplankton (cladocerans and copepods) and aquatic insects (dipterans). The relative caloric value of each zooplankton species to foraging fish is unknown. However, previous studies (Minckley 1982) have shown cladocerans and copepods are consumed by threadfin shad, red shiner, rainbow trout, and largemouth bass. Bass have also been found to feed on ostracods. Dipteran larvae, especially chironomids, are a popular food source for most species (Minckley 1982).

Public Opinion Survey

Results from the public opinion survey show strong public support for establishing a sport fishery in the SRP canal system. Most anglers and non-anglers reported they would be interested in fishing in the canals. Based on respondents' interest, nearly 130,000 new anglers would participate in this canal fishery program resulting in the sale of additional licenses and tackle. A canal fishery would supplement AGFD's popular Urban Fishing Program, which stocks rainbow trout and channel catfish in selected urban lakes in the Phoenix and Tucson metropolitan areas. A canal stocking program would add approximately 750,000 annual angler-use days and additional revenues from special use fees. Currently, the AGFD Urban Fishing Program generates an estimated 400,000 annual angler-use days from 12 lakes within Phoenix and Tucson (E. Swanson, Ariz. Game and Fish Dep., pers. commun.). Urban fishing licenses cost $12/yr for both residents and nonresidents. Based on our survey, the canal fishing program is projected to add $1.55 million in revenues from an estimated sale of 129,500 new licenses. Realistically, it is unlikely that this sum would be generated, but even a fraction would be a sizeable source of revenue to support a canal sport fishing program.

A stocking program would be necessary in the Arizona Canal to meet angler preferences and demand. Respondents showed a high preference for bass, followed by catfish and trout (species unspecified). Largemouth bass, channel catfish, and rainbow trout are found within the Arizona Canal, but their immigration from the upstream watershed appears to be low. Stocking game fish would boost the number of fish available to anglers. Arizona Game and Fish Department fish hatcheries raise trout species for statewide stocking efforts, and a limited production of warm-water species. The Urban Fishing Program utilizes private hatcheries for all rainbow trout and channel catfish stockings. Catchable-sized rainbow trout and channel catfish are regularly stocked in the urban lakes, on a biweekly schedule; channel catfish in the summer and rainbow trout in the winter (E. Swanson, Ariz. Game and Fish Dep., pers. commun.).

Evaluation of Fishing Access Sites

There are multiple locations along the Arizona Canal that can be used as public fishing areas. Most sites are near city parks, established parking lots, and near residential areas (Appendix A). The addition of safety railings, toilets, and trash receptacles would improve several of these locations at low expense. A few potential sites may require new parking lots or use-agreements with local businesses owning nearby lots. We have identified the 5 best locations for fishing access sites. These areas were regular sampling sites during our study or near those sites.

Site 7. Scottsdale has created a recreational nature park along the canal banks between Pima and Hayden roads. This riverwalk is used for jogging, biking, equestrian riding, and fishing. A small parking lot, drinking fountain, and restroom facility are located on the north side of the canal next to Pima Road (Fig. 27). Several trails lead through the desert landscaping and the nearby flood-control corridor that runs parallel to the canal. Residential neighborhoods surround this area and public access is very good. No major modifications would be required to upgrade this fishing area. Adding safety railings and more trash receptacles should be sufficient.

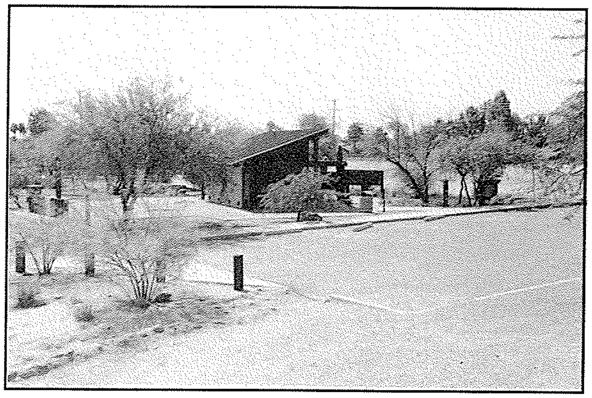


Figure 27. Nature park along the Arizona Canal at Hayden Road in Scottsdale.

Site 5. In Phoenix, the G.R. Herberger Park is adjacent to the Arizona Canal and makes an ideal fishing access site (Fig. 28). Located between 56th Street and 60th Street on Indian School Road, this park has a fair-sized parking lot and drinking fountains, but no restrooms. Residents use the canal banks for jogging, biking, and fishing. Public access is good, but could be improved by creating a pathway from the parking lot to the canal bank. Additional trash receptacles, safety railings, and restrooms would upgrade this potential fishing site.

Site 3 and Alternate Site 3. Between 35th Avenue and 19th Avenue in Phoenix, the Arizona Canal has good access for fishing. This reach runs adjacent to Cortez Park, Metrocenter Mall, and the Cave Creek Sports Complex. A popular bike path runs along the north side of the canal. Cortez Park, at 35th Avenue, has sufficient parking, restrooms, water fountains, and the only urban fishing lake in the northwest metropolitan area. This small lake attracts numerous anglers from the surrounding neighborhoods. Most of the anglers we interviewed along the canal regularly fish Cortez Lake and utilize this canal reach as an additional fishing site (Fig. 29). Metrocenter and the Cave Creek Sports Complex have extensive parking on the north side of the canal that could be used by urban anglers. Safety railings, restrooms, and trash receptacles would be improvements to this canal stretch.

Below Site 2. Glendale's Paseo Racquet Park at 63rd Avenue and Thunderbird Road is an ideal location for an established fishing site. The Arizona Canal runs adjacent to the park's extensive parking lot (Fig. 30). Restrooms, trash containers, and drinking fountains are already in place. To improve this fishing site the only modifications necessary would be the addition of safety railings and a walkway for physically-challenged individuals from the parking lot to the upper canal bank.

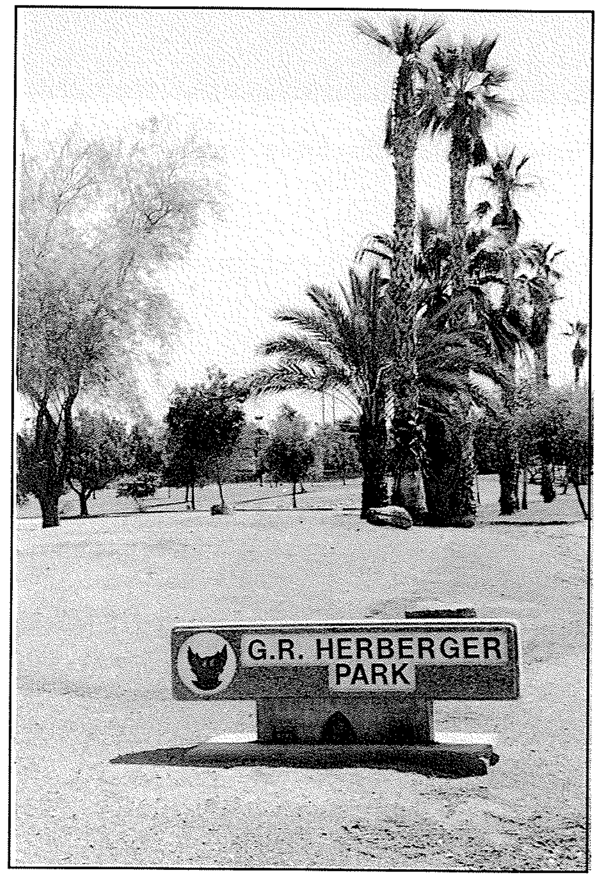


Figure 28. G.R. Herberger Park next to the Arizona Canal on Indian School Road east of 56th Street, Phoenix.

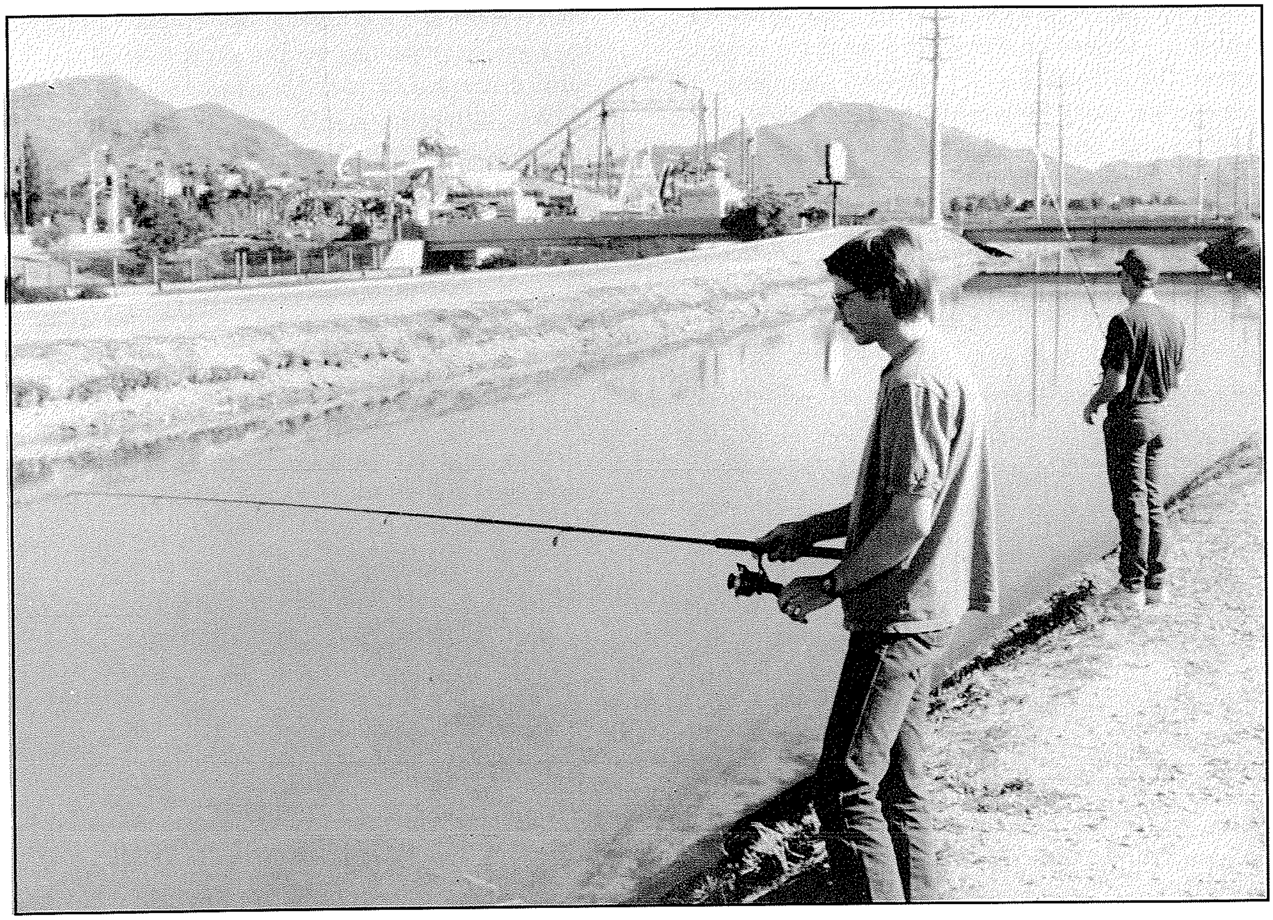


Figure 29. Public anglers fishing the Arizona Canal at Alternate Site 3, near Metrocenter Mall, Phoenix.

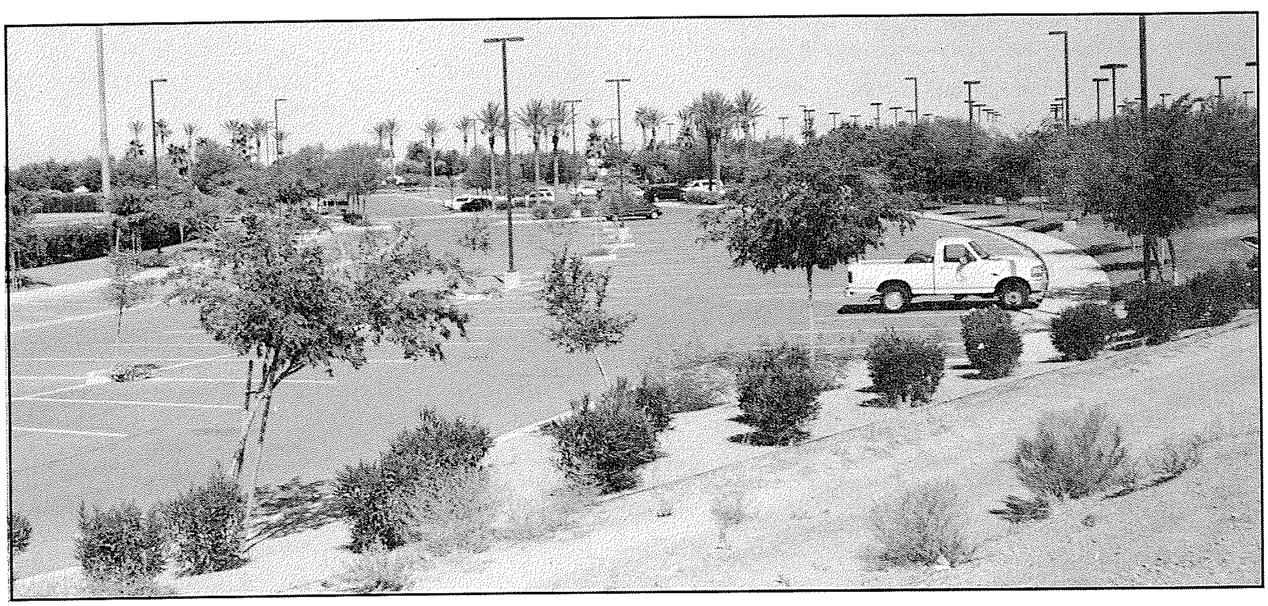
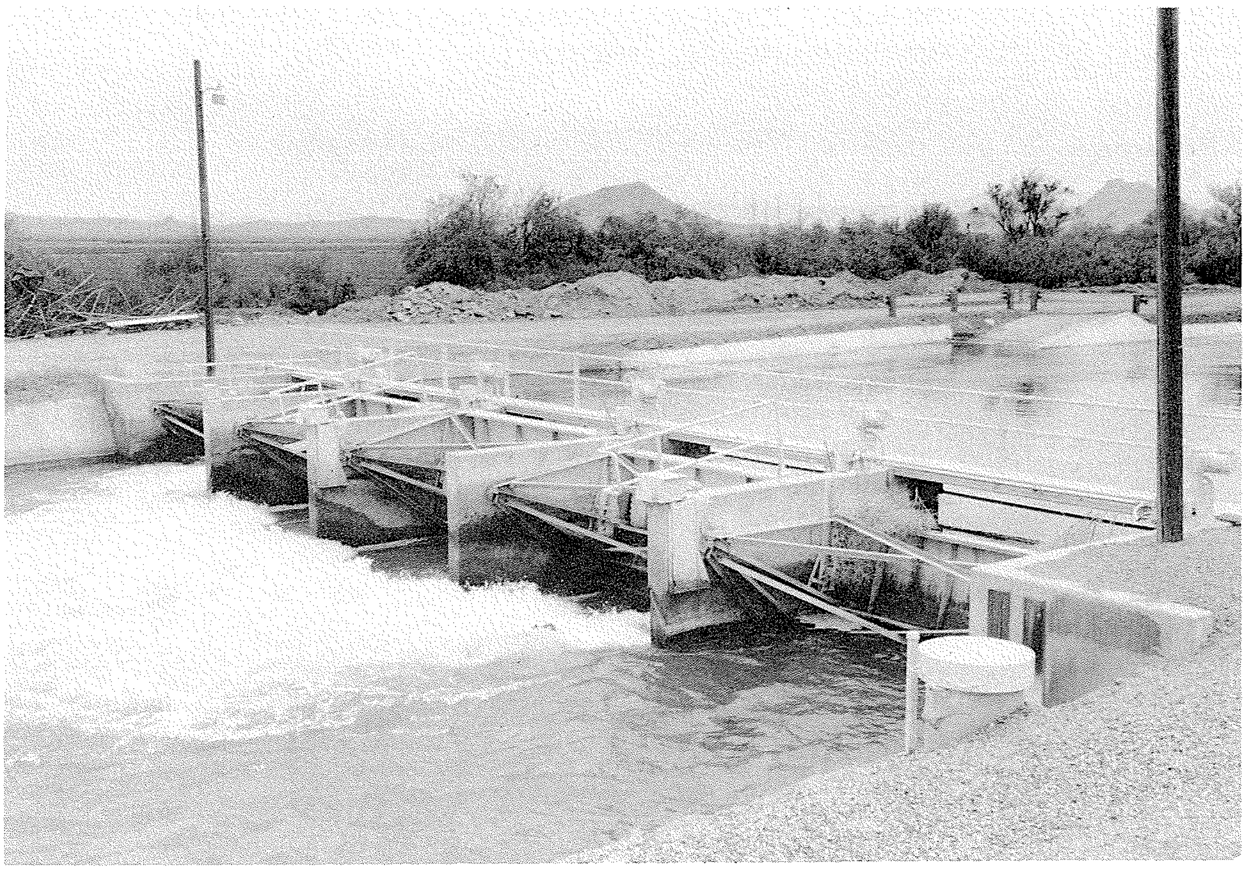


Figure 30. Glendale's Paseo Racquet Park at 63rd Avenue and Thunderbird Road is adjacent to the Arizona Canal.



A water control structure at the Evergreen Drain on the Arizona Canal.

MANAGEMENT OPTIONS

Currently, fisheries management activities by AGFD and SRP are limited to selectively salvaging and relocating fish, particularly white amurs, during annual dewatering of the Arizona Canal. Under a "no action" option, AGFD and SRP would continue these management activities. Other SRP canal and water operations and management activities would continue unaffected. No physical changes either in the canals or along canal banks would be included.

The Arizona Canal currently supports at least 20 different fish species, including largemouth bass, yellow bass, channel catfish, and rainbow trout; however, game fish numbers are small (5.1% of the total catch). Without active fisheries management, game fish numbers will probably remain at current low levels. Recreational fishing opportunities will remain poor, and will probably be limited to the occasional angler that currently fishes the canal.

The active fisheries management actions that follow are directed specifically to the Arizona Canal, and we caution the reader that these options may not be suitable on the other SRP canals whose biological resources were not examined during this study. We separated management options into 6 categories: program administration and licensing, physical and biological enhancements, fish stocking, monitoring activities, public safety and liability, and future research. These options should be viewed as management components, that would be most effective if conducted concurrently as opposed to independently. We define an "Urban Canal Fishing Program" as a managed urban fishery restricted to the Arizona Canal.

Program Administration and License Funding Base

An Urban Canal Fishing Program (UCFP) could be administered using 1 of 3 different strategies: 1) keep the UCFP under the existing Statewide Fishing Program; 2) expand the Urban Fishing Program to include the UCFP; and 3) establish the UCFP as an entirely new and independent program.

Statewide Fishing Program. Managing the UCFP under the statewide fishing program would be advantageous because it would maintain the existing license structure and regulations. Currently, a statewide license is required to fish in the SRP canals. Also, public confusion over regulation changes would be minimized. However, drawbacks to this option are: (1) inadequate new revenues to cover program costs; (2) additional administrative and law enforcement personnel; and (3) additional responsibilities for regional personnel. Revenues generated through the current licensing structure may be inadequate to cover the costs of the UCFP, particularly costs of providing a put-and-take sport fishery.

Urban Fishing Program. The UCFP could be incorporated into the existing Urban Fishing Program. The UCFP could be modeled after the Urban Fishing Program with revenues generated from the sale of urban fishing licenses. The current Urban Fish Biologist or a new administrator could oversee this new program. Advantages and disadvantages of this option would be identical to those mentioned above under the Statewide Fishing Program. Revenues generated through new license sales may be inadequate to cover the costs of the UCFP; primarily, those costs of purchasing fish.

Urban Canal Fishing Program. This option could create an independent UCFP requiring a special canal fishing license or a special-use stamp, similar to that used on the Colorado River. Special-use stamps would still require anglers to purchase a regular statewide or urban license. Funding for this program would be generated from new license or stamp sales. The cost of a new license or stamp could be set at $12.00 based on the willingness to pay results of our public opinion survey as well as the current cost of a regular state or urban fishing license. The UCFP could be a separate program administered within the AGFD Fisheries Branch or Field Operations, Mesa Region.

Physical and Biological Enhancements

Physical and biological enhancements would improve the quality of the canal fishery. Physical enhancements include development of fishing access sites (e.g., fencing, fishing platforms, and safety railings), parking, physically-challenged access, restrooms, and trash receptacles. Development costs for fishing access sites could be partially or wholly funded by tax monies from the Sport Fish Restoration Act. Parking, physically-challenged access, restrooms, trash receptacles, operation and maintenance costs could be funded through the cooperative efforts of AGFD, SRP, Maricopa County, local cities, and fishing clubs. After the physical enhancements have been created, revenues from license sales could be used to administer the program as well as make improvements to the program.

Biological enhancements include the use of artificial fish habitats, such as tire-reefs. Tire-reefs were tested on the Hayden-Rhodes Aqueduct of the CAP and the Coachella Canal in California (Mueller and Liston 1991). These tire-reefs were highly successful in increasing fish abundance. They found that species diversity increased by 140% (i.e., from 5 to 12 species). Artificial reefs provided resting and feeding sites, spawning habitat, escape cover, and additional food organisms by increasing habitat diversity for sessile invertebrates (Mueller and Liston 1991). Both predator and forage fish species are attracted to these structures. Mueller and Liston (1991) believed these tire-reefs could be used to concentrate and hold fish in specific areas. Habitat structures could increase the density of aquatic organisms in the canal as well as concentrate anglers at specific locations. These areas might be safer and more accessible to the public, thereby reducing overall liability.

Catfish houses, constructed of bound sections of corrugated pipe, would enhance reproduction of catfish. These structures would also serve as habitat and refugia for other species. Any artificial habitat must be able to remain in place and intact while not affecting SRP canal operation and maintenance functions.

Salt River Project canal operations and management greatly affect fish populations. Incorporating canal operation and maintenance opportunities to benefit fish populations is encouraged. Dewatering plans could take into account long-term fish population management. Fish salvage and relocation efforts tied to dewatering could be increased. Reduction of chemical inputs, including alum sludge and herbicides, would benefit fish populations.

Fish Stocking

To meet angler demand for preferred fish of catchable size, an UCFP would require regular stockings of catchable channel catfish and rainbow trout. Our research showed that resident channel catfish and rainbow trout numbers in the Arizona Canal were small. Therefore, additional angler pressure on these populations could eliminate them from the canal. A fish stocking schedule could be modeled after the Urban Fish Program. For example, a winter put-and-take rainbow trout fishery could be established, while channel catfish could be stocked during the summer. Due to high water temperatures, rainbow trout would not be expected to survive over the summer months. Based on our public opinion survey, respondents also wanted to catch bass (species unspecified) from the canals. Largemouth bass are difficult and expensive to produce, therefore precluding a regular stocking program. Instead, bass populations (species unspecified) may be enhanced by the addition of artificial habitat.

Periodic Monitoring Activities

An UCFP would require periodic monitoring using creel surveys, water quality sampling, and fish collections. In addition to basic fisheries data, creel surveys should be conducted to assess angler satisfaction, fish harvest, and program success. Water quality should be measured seasonally or prior to fish stockings. Electrofishing and other fish sampling should be conducted to monitor changes in species composition and abundance in response to stocking and angling pressure.

Public Safety and Liability

Public safety and liability issues have prevented SRP from encouraging the establishment of any kind of fishery within their canal system. Salt River Project is reluctant to promote fishing because of past litigation involving canal-based recreation. To develop an UCFP, the liability issue is the first and perhaps most important step to resolve before any further planning occurs. Liability agreements will need to be made between SRP, AGFD, and the cities (e.g., parks and recreation departments). The AGFD would assume law enforcement duties related to fishing activities. Local police departments would continue to patrol the canals as needed for public safety.

Future Research

Little biological information exists on the 7 other SRP canals. Beginning in 1990, yearly monitoring at electrical barrier sites has been conducted at the heads of both the Arizona and South Canals. Data from the South Canal could provide some insight into the assemblage of fishes in the remaining canals. We believe that additional research is needed to assess the biological resources of these canals including fish populations, primary production, benthos, and zooplankton. Other aspects need to be studied such as canal operations, agricultural returns, fishing access sites, habitats, and fish losses to lateral canals.

In addition, comprehensive contaminant studies on fish and sediments in all the SRP canals should be examined. We include the Arizona Canal because contaminant data from this study was based on a small number of samples and did not include sediment studies. The effects of alum sludge on fish and invertebrate numbers, distribution, survival, reproduction, and growth need to be studied. Further investigation is needed to quantify the amount and composition of sediments in the Arizona Canal and how it affects species use.

While lateral traps only intercepted a few stocked fish, we suspect fish might be escaping the main canal through lateral siphons farther downstream from the stocking area. We believe that to fully assess fish losses to the lateral canals the number of traps should be increased and be placed along the entire length of the Arizona Canal. In addition, a longer monitoring period for traps may be advisable.

This study has shown that the biological conditions in the Arizona Canal can support a fishery. Now the focus is on issues such as public safety, liability, and conflicts between an urban fishery and SRP's operations and maintenance functions.

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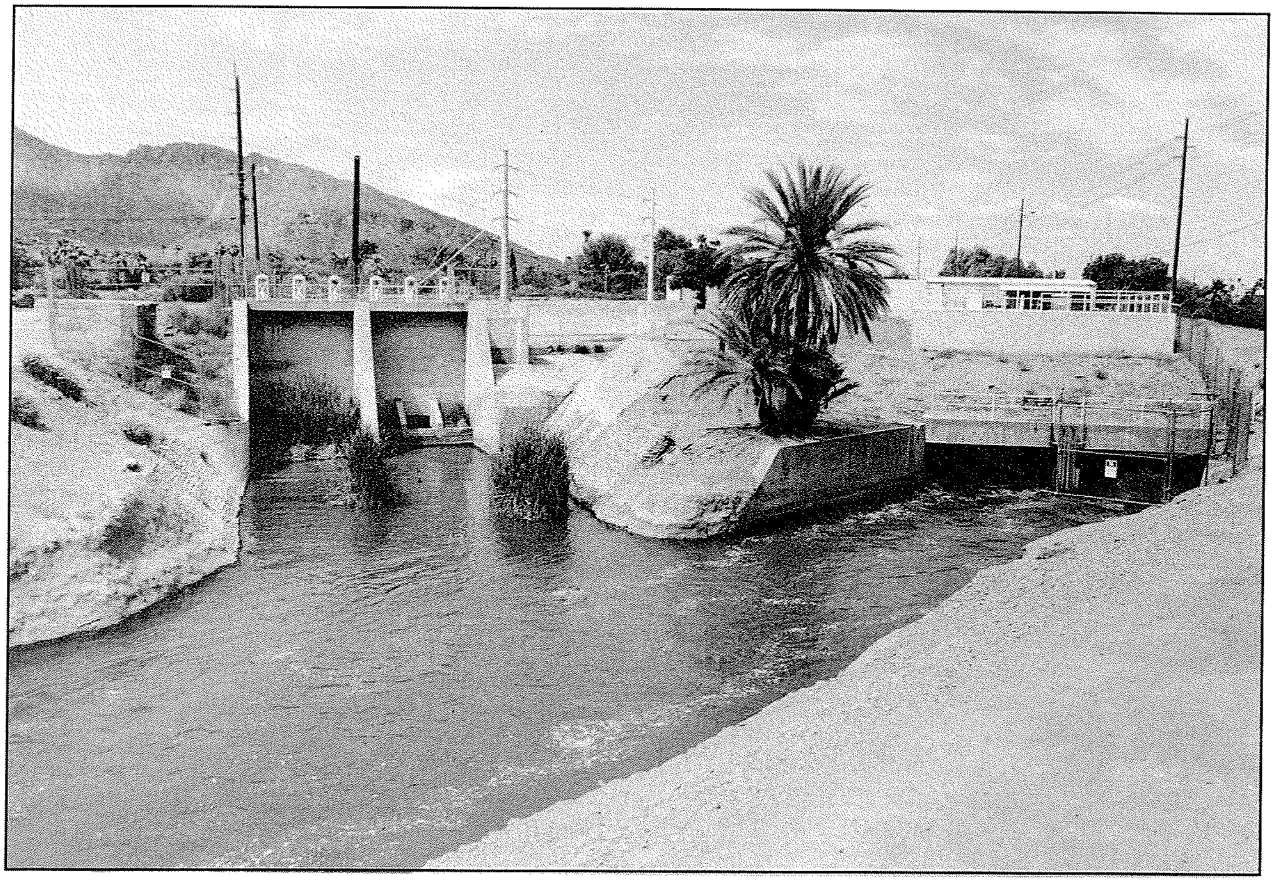


The "Arizona Falls" water control structure below Site 5.

APPENDICES

Appendix A: Potential fishing access sites on the Arizona Canal, listed geographically (upstream to downstream). Letters correspond to locations on the Structure Maps.

A. The riverwalk between Pima and Hayden Roads (Site 7). Scottsdale.

B. G.R. Herberger Park between 56th and 60th Street on Indian School Road (Site 5). Phoenix.

C. Granada Park on Maryland Avenue and 20th Street (Site 4). Phoenix.

D. Sunnyslope Park/Herberger Park next to Sunnyslope High School at Dunlap Avenue and Central Avenue. Phoenix.

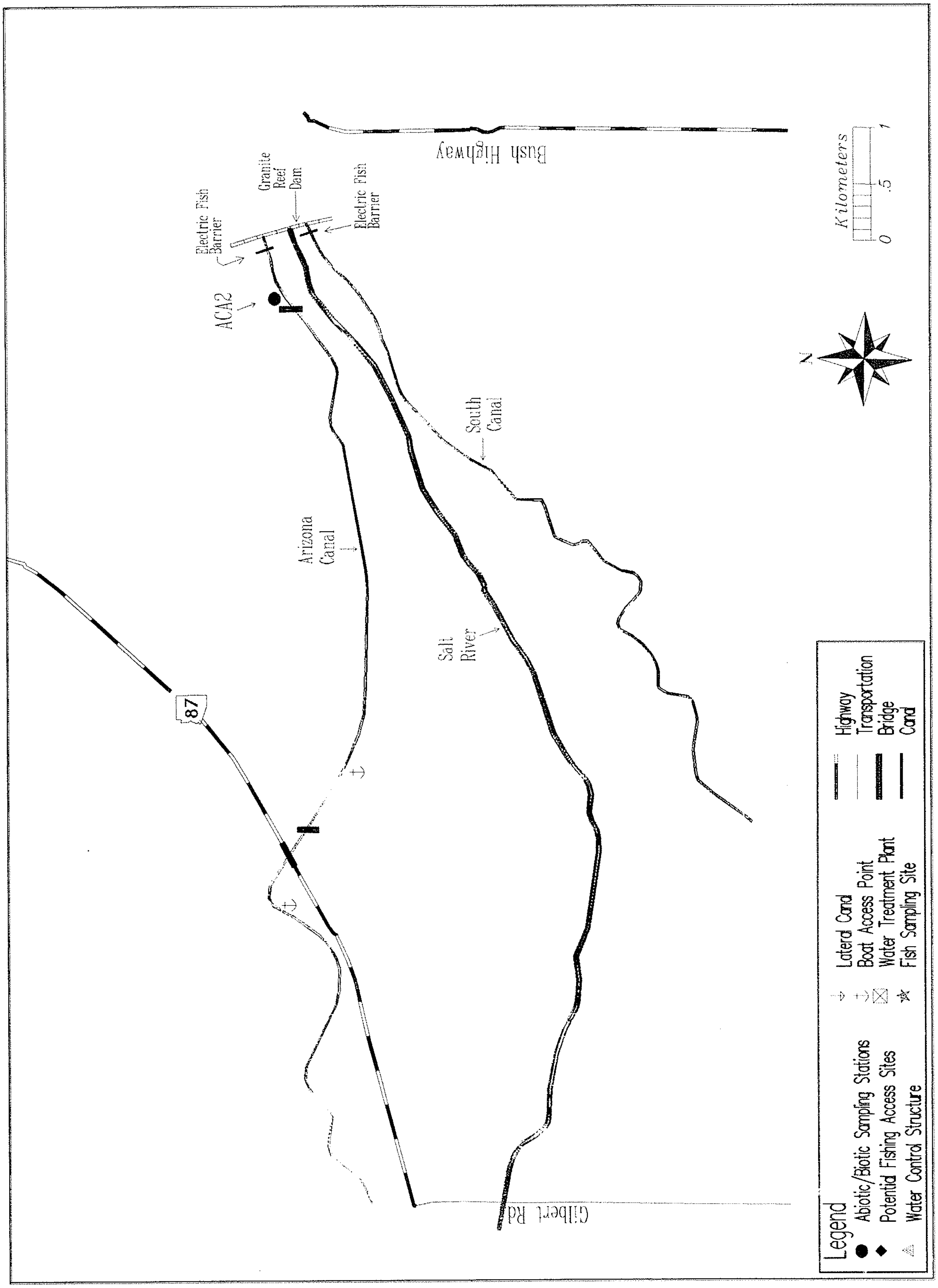
E. Between the Black Canyon Freeway and 19th Avenue, next to the Cave Creek Sports Complex (Site 3). Phoenix.

F. Between 35th Avenue and the Black Canyon Freeway, next to Cortez Park and Metrocenter Mall (Alternate Site 3). Phoenix.

G. Cholla Park next to the Cholla Water Treatment Plant (Site 2). Glendale.

H. Paseo Racquet Park at 63rd Avenue and Thunderbird Road. Glendale.

I. Thunderbird Paseo Recreation Area (flood-control channel park) at 67th Avenue (Site 1). Peoria/Glendale border.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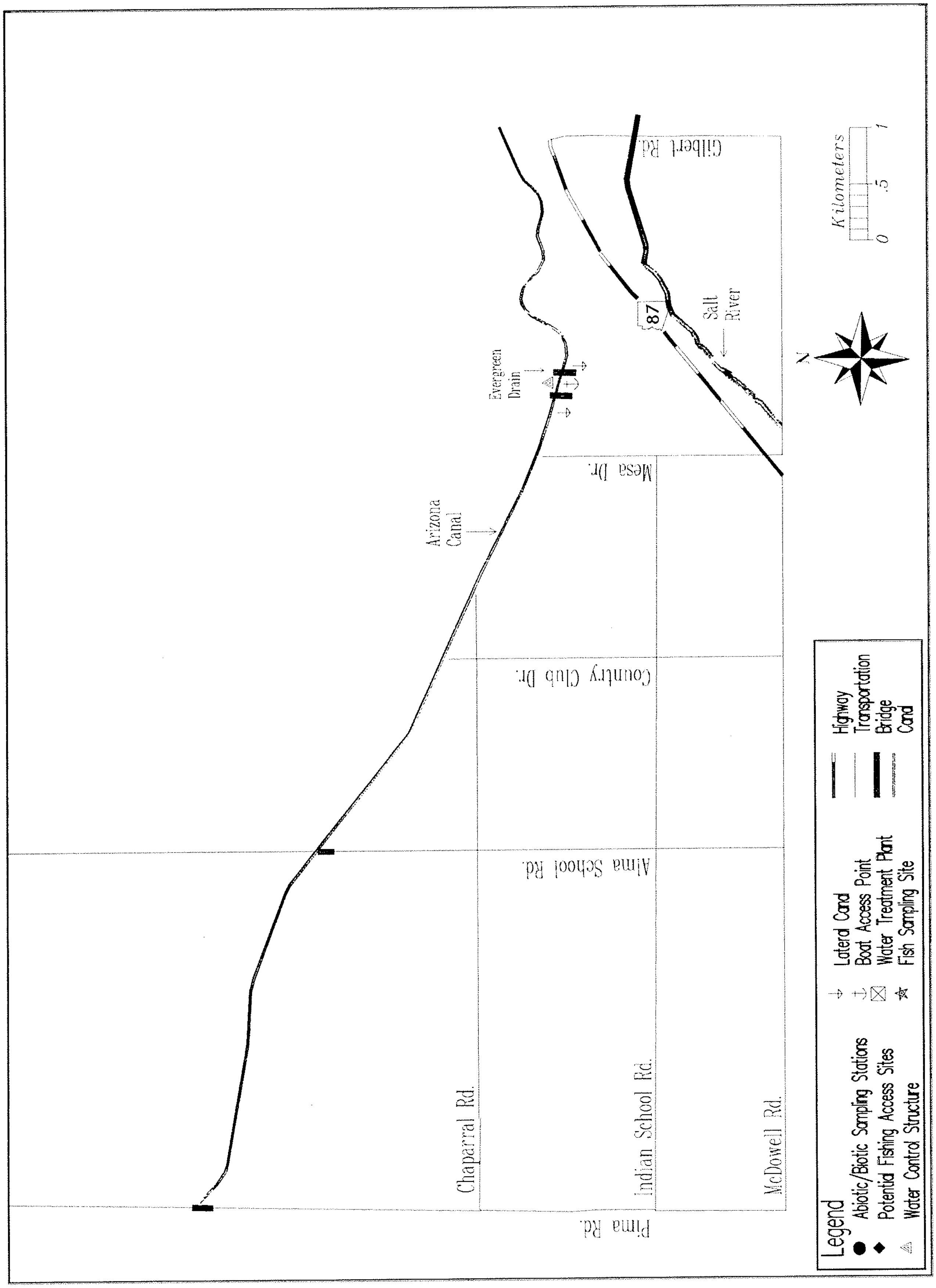

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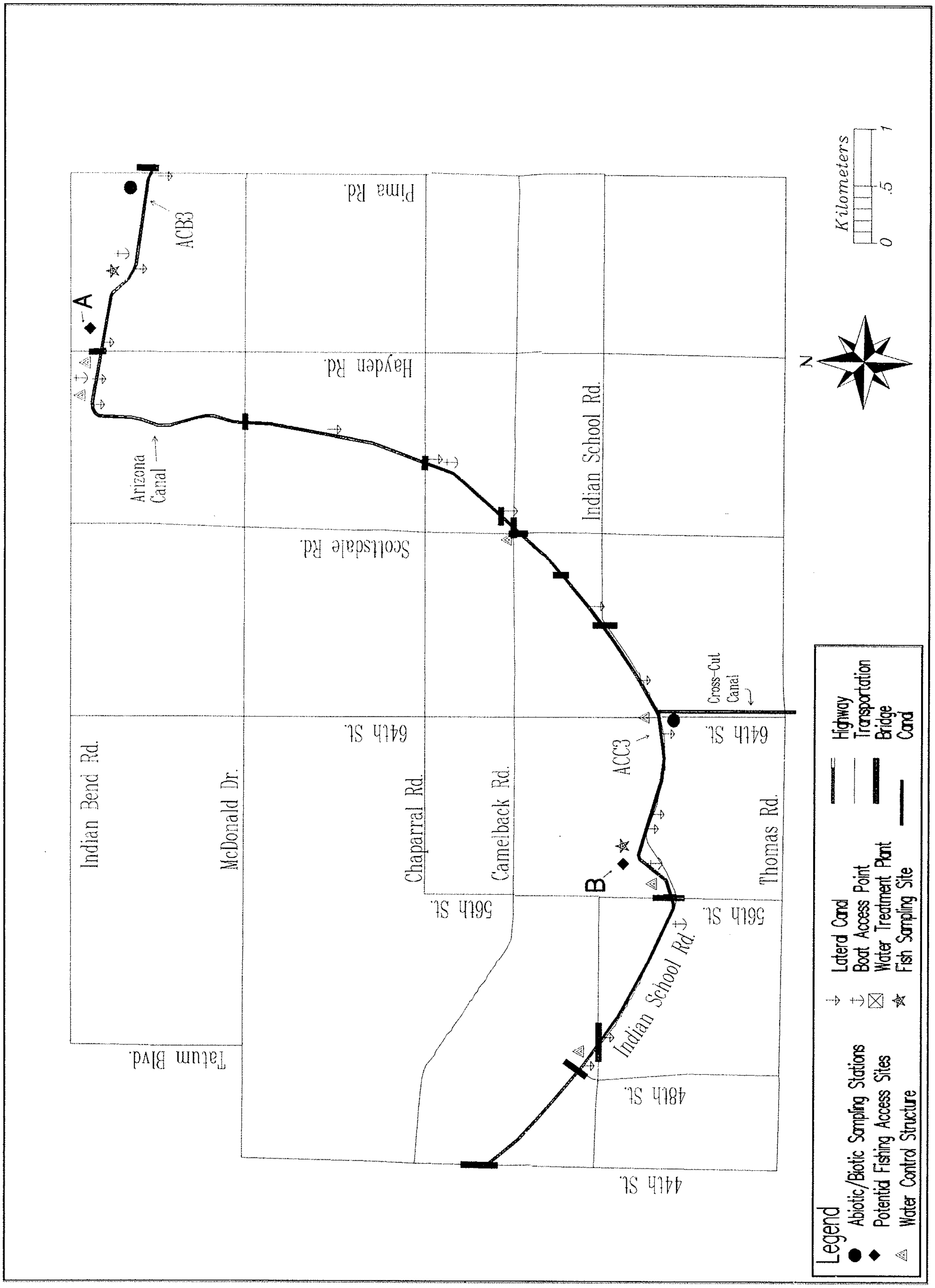
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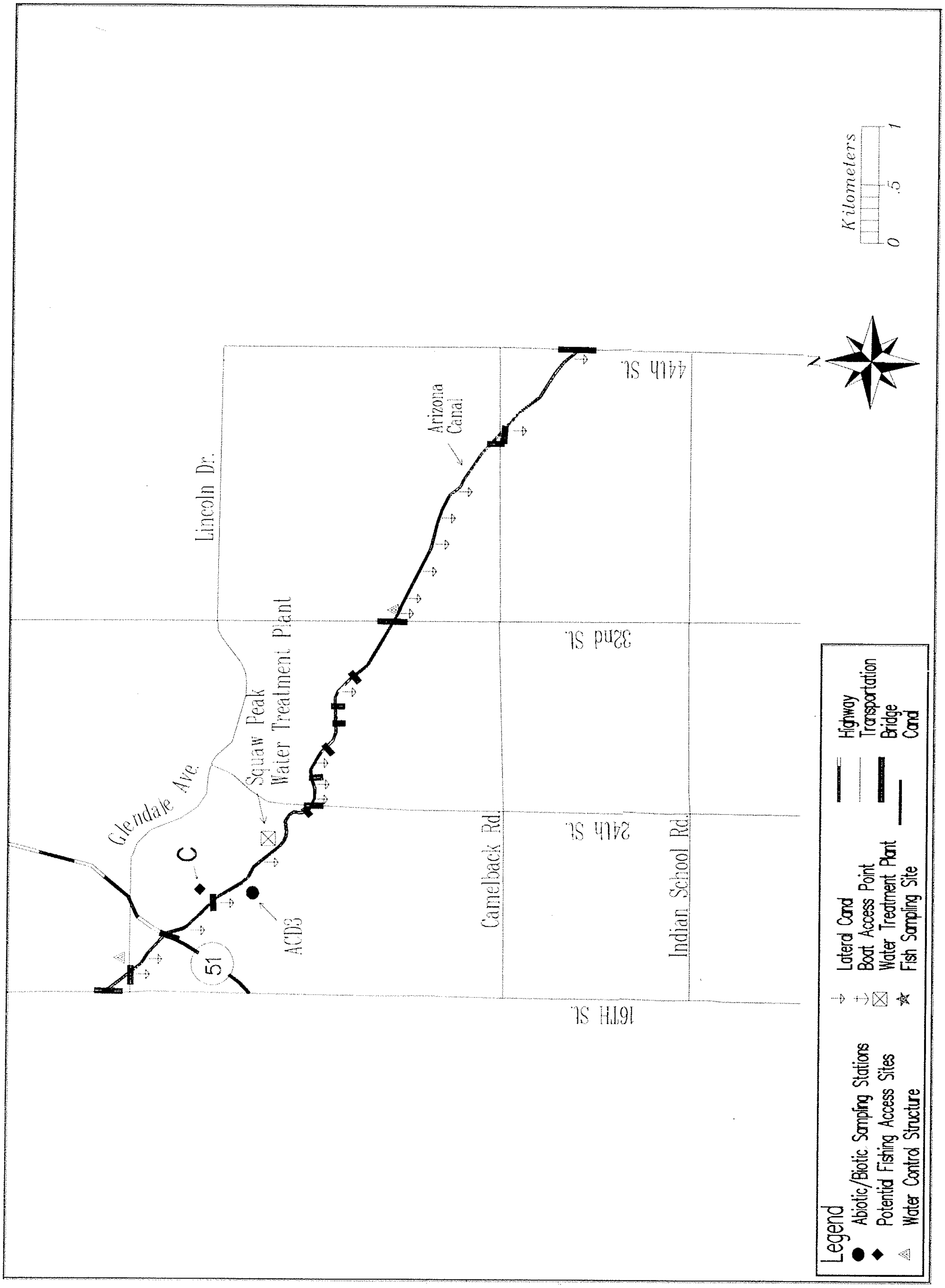
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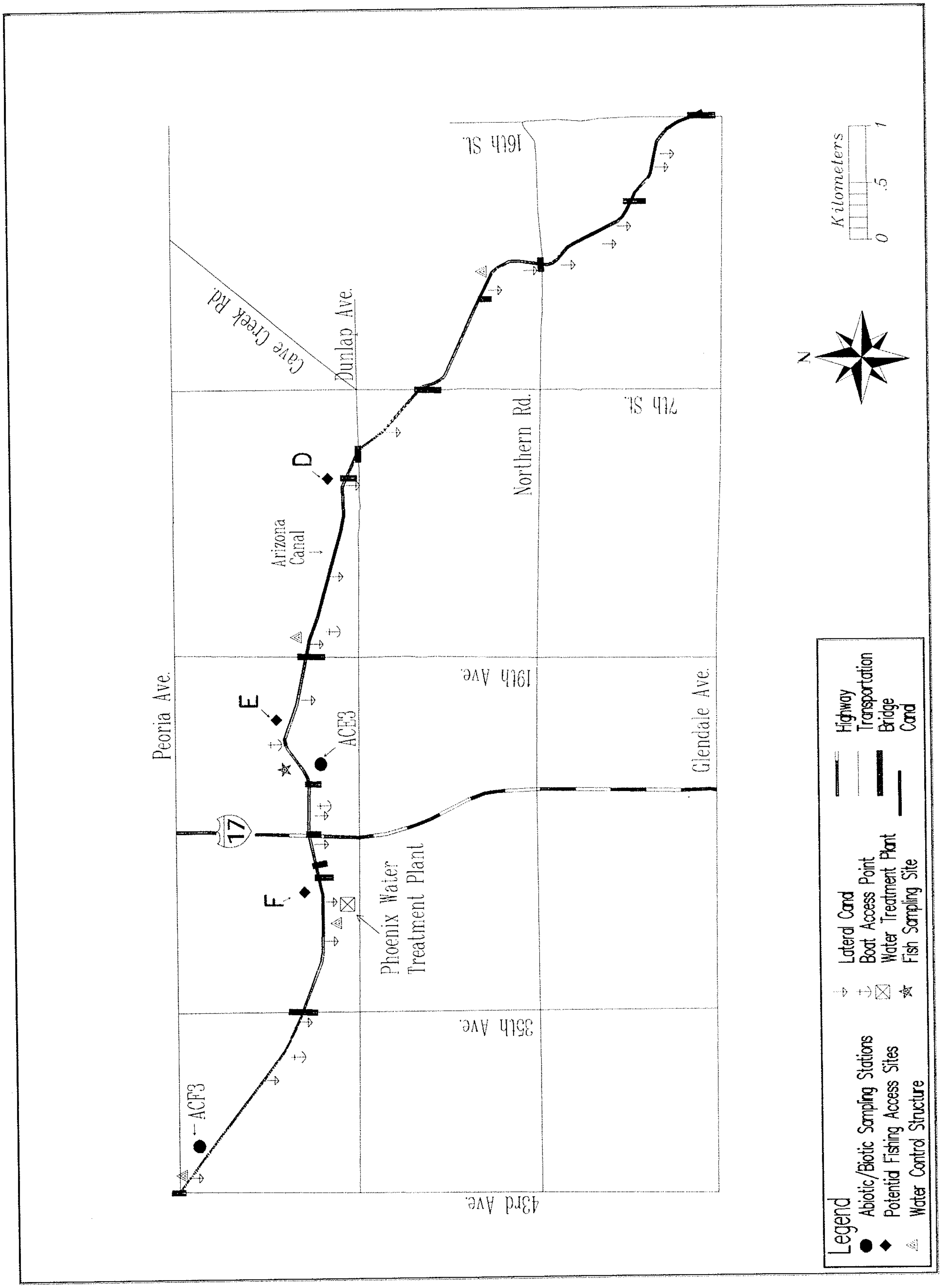
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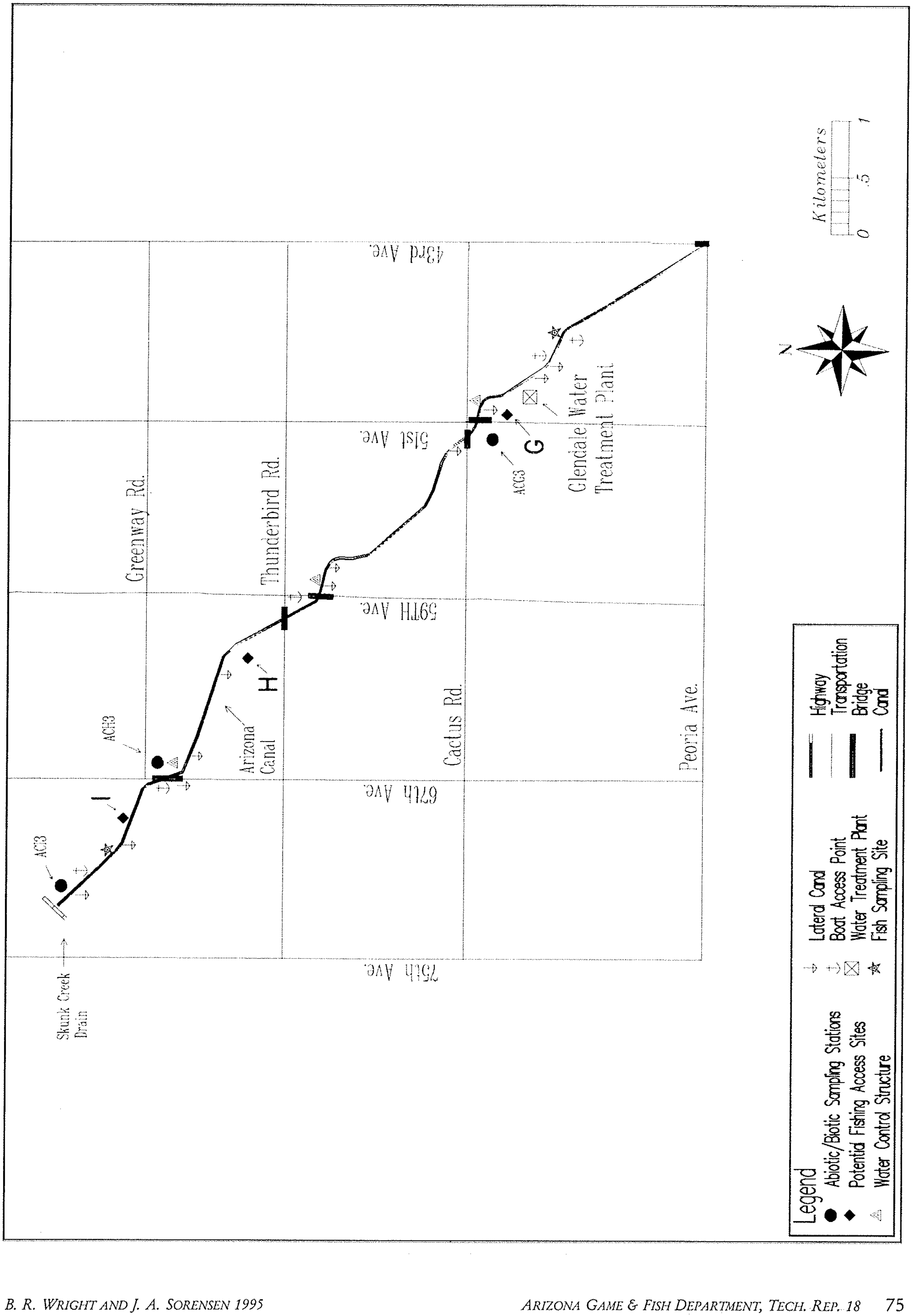
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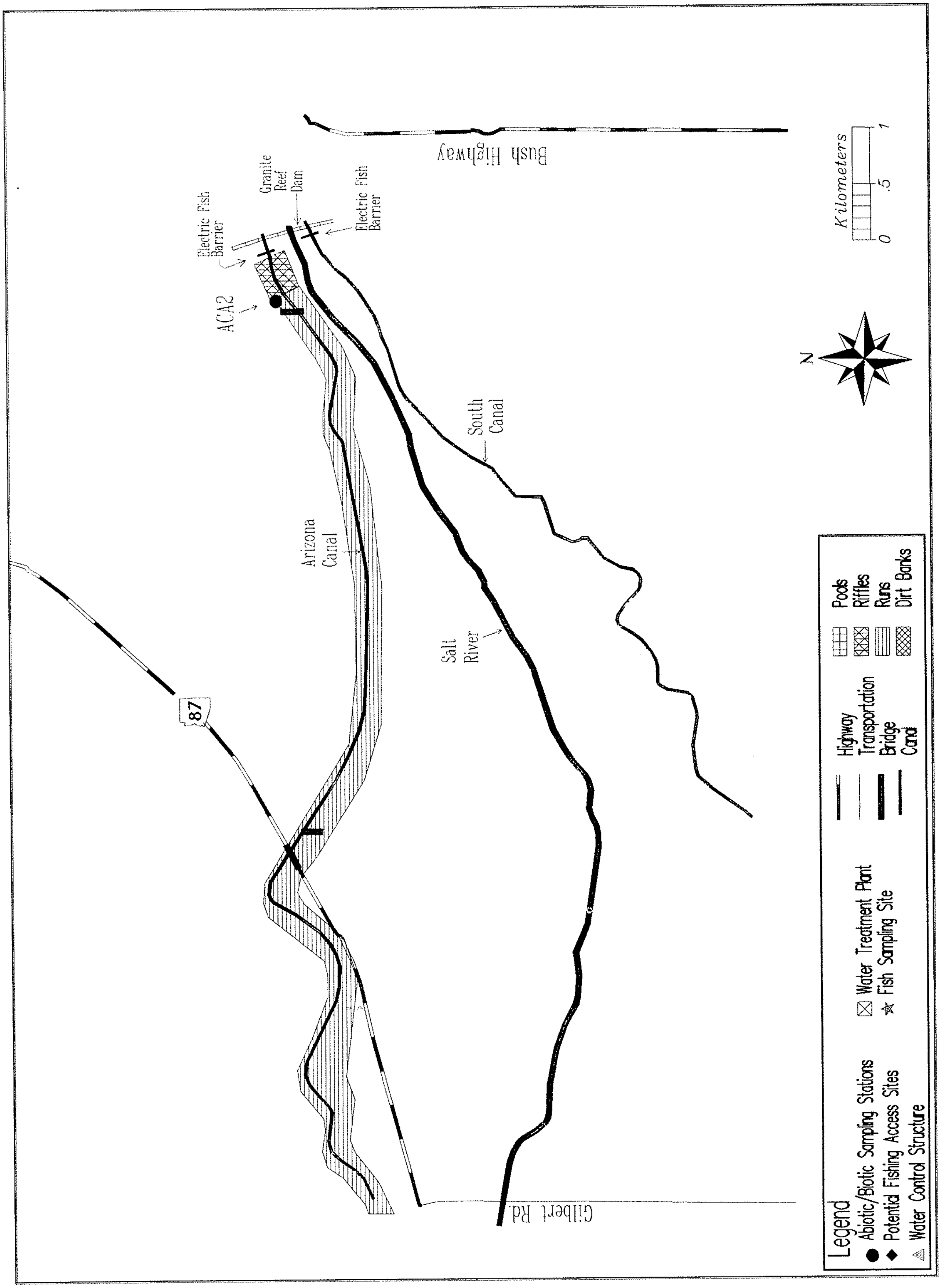
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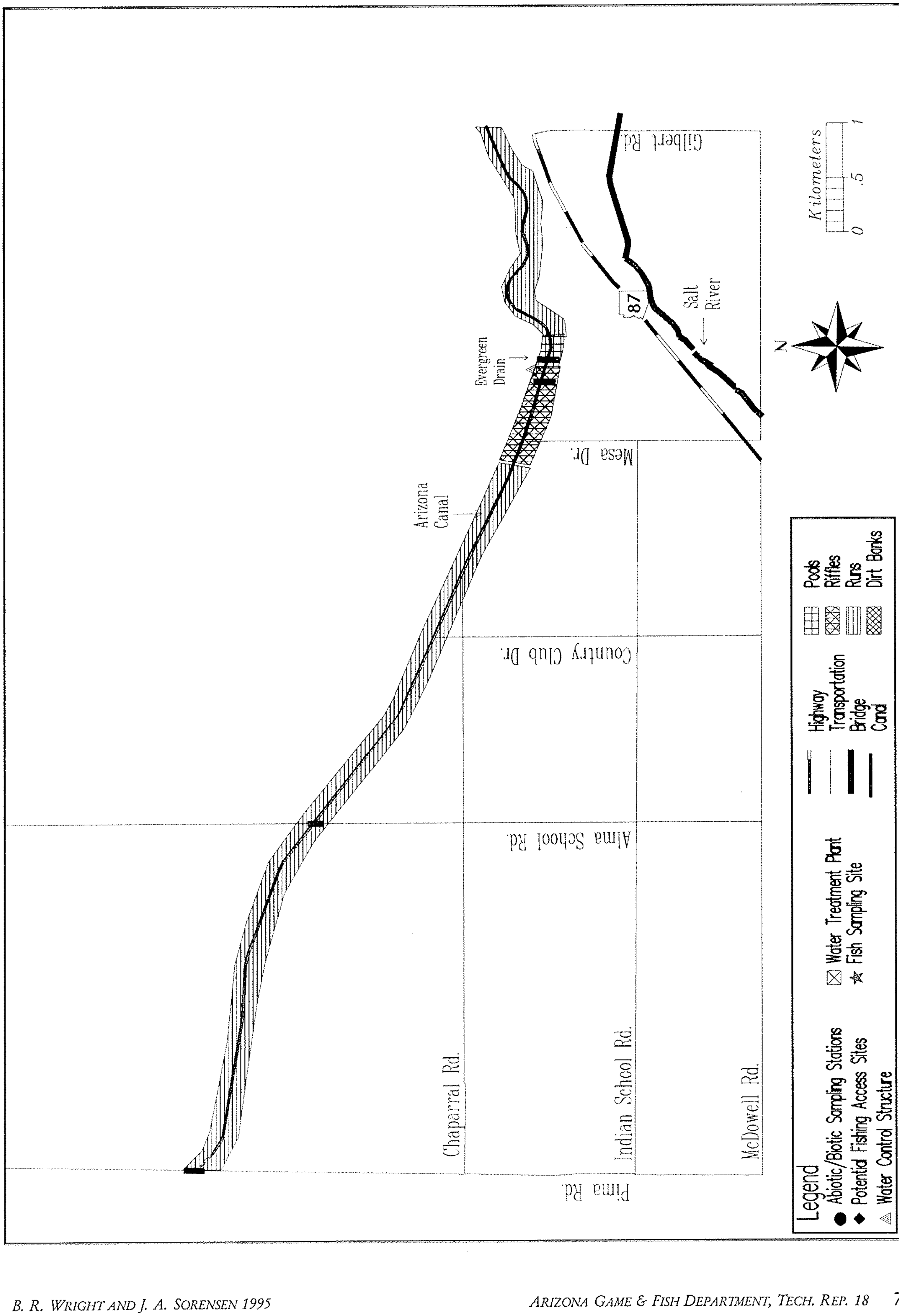
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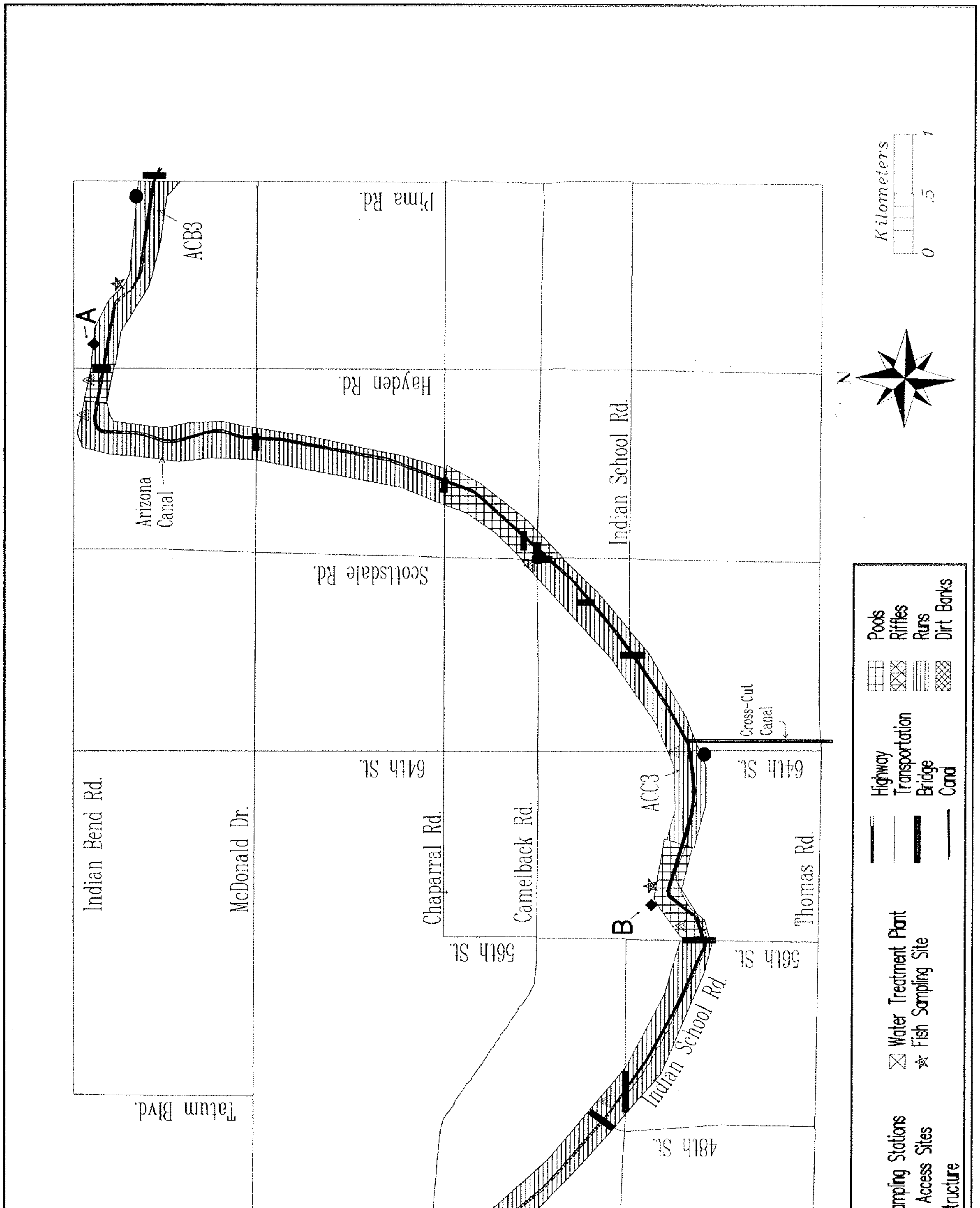
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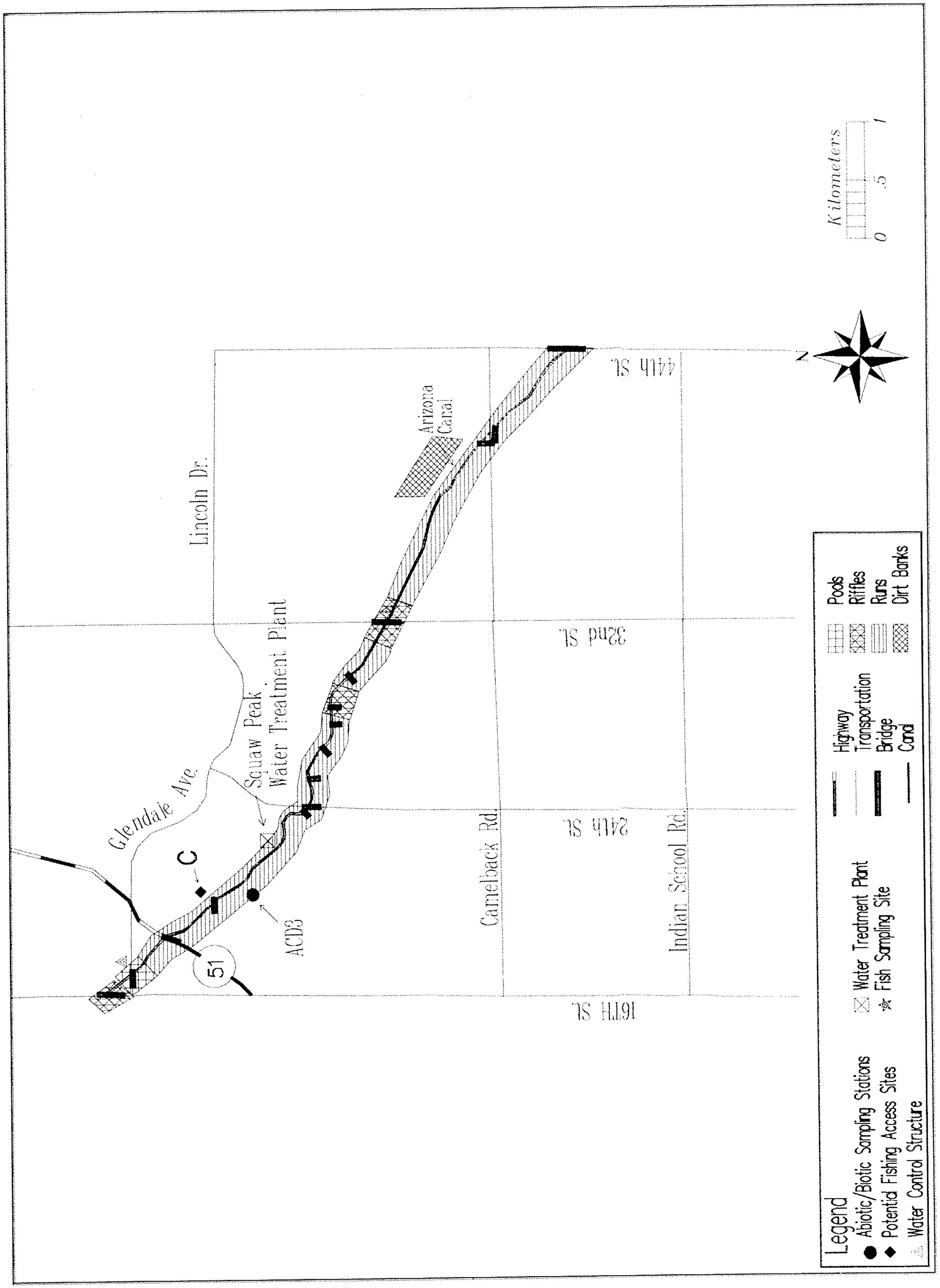
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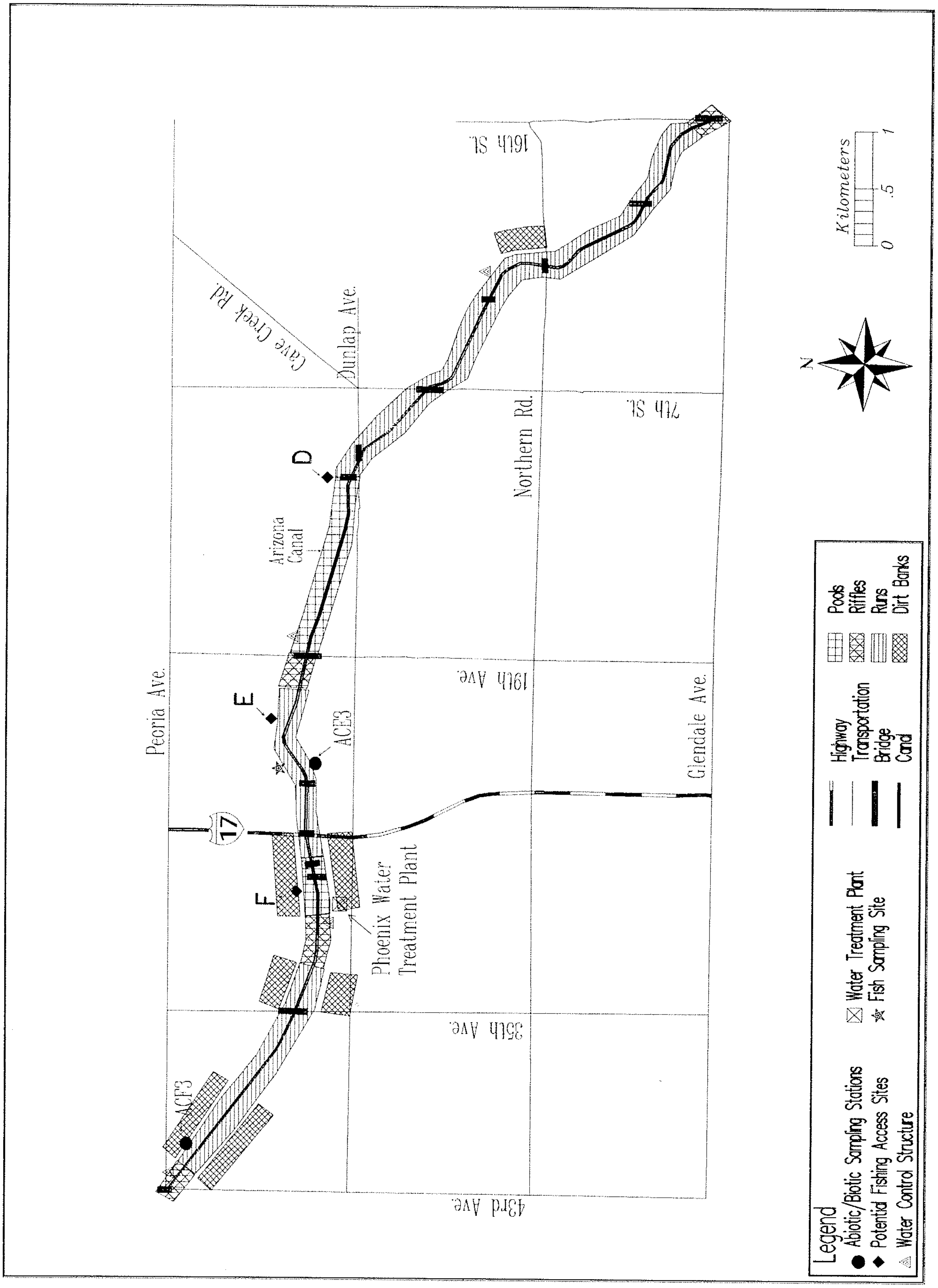
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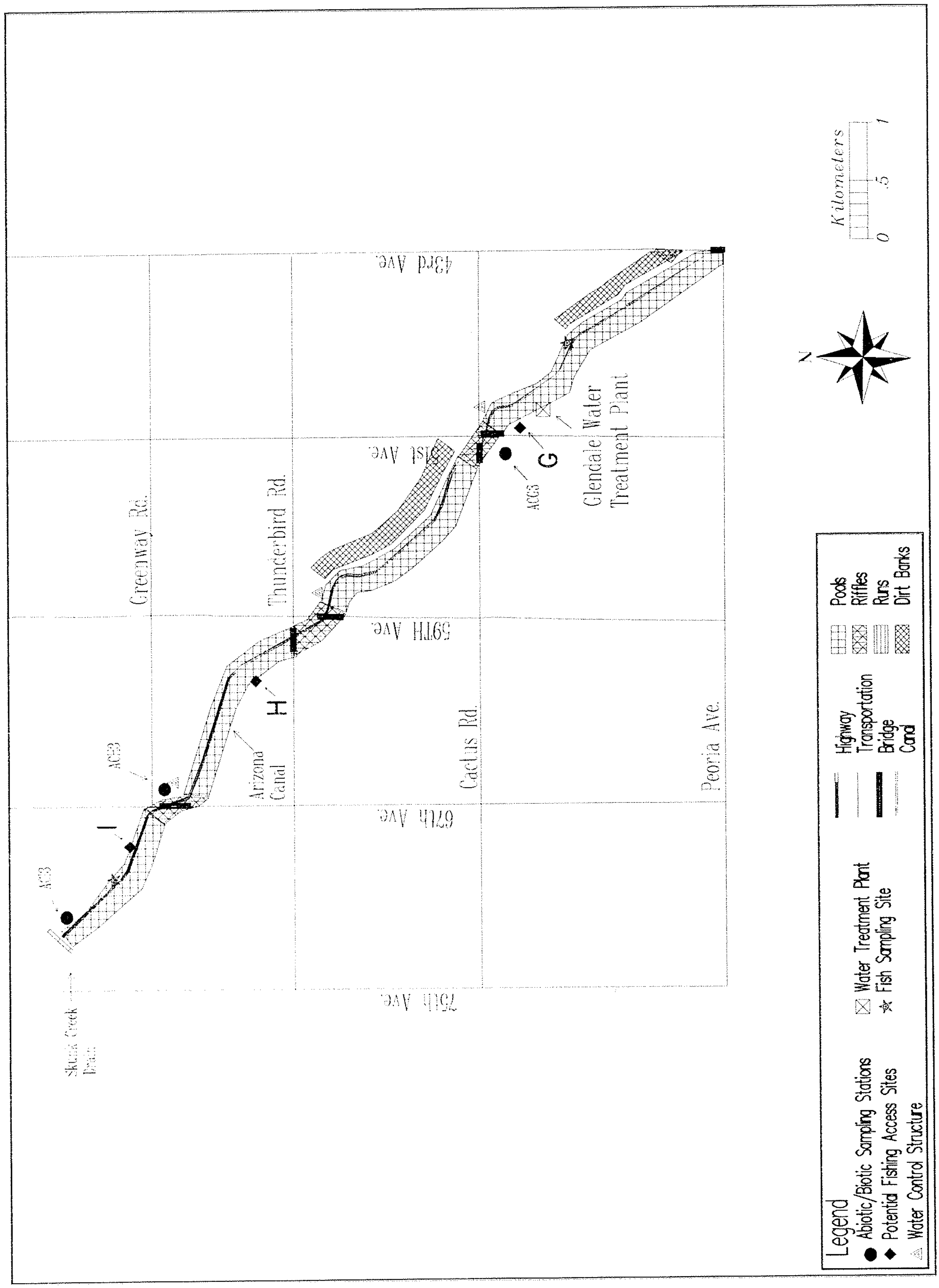
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Appendix C.

Table 1. Stations for abiotic/biotic sampling on the Arizona Canal.

ACA2 Water quality (WQ) readings were taken at the first vehicle bridge below Granite Reef Dam. Water samples for chlorophyll *a* (CHLA) were collected at this bridge and the vehicle bridge upstream of Highway 87.

ACB3 WQ readings and benthos (BN) samples were taken from the footbridge downstream of Pima Road vehicle bridge. CHLA and plankton (PKN) samples were collected at the footbridge, the maintenance vehicle ramp, and Hayden Road vehicle bridge. Additional BN samples were collected at the Hayden Road vehicle bridge.

ACC3 WQ readings were taken from above the water control structure at 64th Street--the beginning of the Cross-Cut Canal. CHLA and PKN samples were collected at the footbridge downstream of 68th Street, at the 64th Street water control structure, and the maintenance vehicle ramp upstream of "Arizona Falls" water control structure, near 56th Street. BN samples were taken at both the footbridge and the vehicle ramp.

ACD3 WQ readings were taken on the upstream side of Maryland Avenue vehicle bridge. CHLA and PKN samples were collected at this bridge, the downstream bend across from the Phoenix (Squaw Peak) water treatment plant, and from the footbridge downstream of 24th Street. BN samples were taken at both bridges.

ACE3 WQ readings were taken from the upstream side of 25th Avenue vehicle bridge. CHLA and PKN samples were collected at this bridge, at the first upstream bend, and at the footbridge downstream of 19th Avenue. BN samples were taken at both bridges.

ACF3 WQ readings, 1 CHLA, and 1 PKN sample was taken from the upstream side of the water control structure above the 43rd Avenue/Peoria Avenue intersection.

ACG3 WQ readings, 1 CHLA, and 1 PKN sample was taken from the upstream side of the water control structure above the 51st Avenue/Cactus Road intersection. An additional CHLA and PKN sample was collected at the footbridge at 47th Avenue. BN samples were taken downstream of the 43rd Avenue/Peoria Avenue vehicle bridge and at the footbridge.

ACH3 WQ readings, 1 CHLA, and 1 PKN sample was taken from the upstream side of the water control structure below the 67th Avenue vehicle bridge. BN samples were taken below the 67th Avenue vehicle bridge.

ACI3 WQ readings, 1 CHLA, and 1 PKN sample was taken above the water control structure at Skunk Creek drain. An additional CHLA and PKN sample was collected at the first upstream bend. BN samples were taken above the Skunk Creek drain water control structure.

Appendix C.

Table 2. Other SRP canal quarterly monitoring stations for sampling water quality and chlorophyll *a*.

Station	Canal	Street/Physical Location
CCA2	Consolidated	From the South/Tempe/Consolidated Canal conjunction downstream (east) to Stapely Drive vehicle bridge. Mesa.
CCC2	Consolidated	Above the Frye Road vehicle bridge, upstream to Cooper Road vehicle bridge. Chandler.
ECA2	Eastern	Below the water control structure south of Rambo Road. Mesa.
ECC2	Eastern	Below Pecos Road vehicle bridge east of Lindsay Road. Nortons Corner (south of Gilbert).
GCA2	Grand	From the Washington Street vehicle bridge, downstream to 40th Street and Van Buren Street vehicle bridge. Phoenix.
GCC2	Grand	From 99th Avenue vehicle bridge, upstream to 91st Avenue vehicle bridge. Unincorporated area.
SCA2	South	Vehicle bridge below Granite Reef Dam. Salt River Indian Reservation.
SCC2	South	Below Horne Street vehicle bridge to the water control structure above the South/Tempe/Consolidated Canal conjunction. Mesa.
TCA2	Tempe	From the South/Tempe/Consolidated Canal conjunction downstream (west) to Brown Road vehicle bridge. Mesa.
TCC2	Tempe	Above the water control structure at Baseline Road and Price Road, upstream to Southern Avenue. This station was dry during the study and no samples were collected. Mesa.
WCA2	Western	Below the water control structure/filtration facility at Price Road, and downstream to the footbridge at Country Club Drive. Tempe.
WCC2	Western	Above the water control structure near 19th Avenue and Dobbins Road, upstream to South Mountain Avenue vehicle bridge. Phoenix.
XCA2	Cross-Cut	Below McDowell Road vehicle bridge, downstream to the water control structure east of the Phoenix Zoo. Tempe.

Appendix C.

Table 3. Other SRP canal quarterly monitoring stations for sampling water quality.

Station	Canal	Street/Physical Location
CCB1	Consolidated	At the Baseline Road vehicle bridge east of Lindsay Road. Mesa.
ECB1	Eastern	At the Baseline Road vehicle bridge east of Greenfield Road. Mesa.
GCB1	Grand	At the 27th Avenue vehicle bridge south of Indian School Road. Phoenix.
SCB1	South	At the Rambo Road vehicle bridge. North Mesa.
TCB1	Tempe	At the Dobson Road vehicle bridge north of University Drive. Tempe.
WCB1	Western	At the 40th Street vehicle bridge north of Baseline Road. Phoenix.

Appendix D. Canal Fishery Program Questionnaire.

BEHAVIOR RESEARCH CENTER, INC. JOB ID 93184 (1-5)

Phoenix, AZ URBAN FISHING SURVEY May, 1994 RESP ID (6-8)

Hello, may I speak to {LISTED NAME}, please?

{IF DESIGNATED RESPONDENT NOT HOME, ARRANGE CALLBACK}

CALLBACK INFO:

{WHEN DESIGNATED RESPONDENT ON LINE}:

Hello {LISTED NAME}, my name is _________ and I'm with the Behavior Research Center of Arizona. We are conducting a brief survey on fishing for the Arizona Game & Fish Department and I'd like to speak with you for a few minutes.

A. According to my records, in 1993 you had a (regular/urban) Arizona fishing license. Is that correct?

Regular...1 (9)
Urban...2

IF YES: CONTINUE IF NO: THANK AND TERMINATE

---

1. To begin, during the past 12 months, how may days, if any, did you do the following in Arizona? {READ EACH; RECORD BELOW}

		No. Days
A.	Fish for warm water fish such as bass, crappie, or catfish	(10-11)
B.	Fish for cold water fish such as trout, walleye, or pike	(12-13)

TOTAL DAYS (14-15)

2. Next, have you ever fished at any of the following locations in the metropolitan Phoenix areas? {READ EACH}

2a. {FOR EACH DONE, ASK}: And how many days in the past 12 months, if any, did you fish at {SPECIFIC LOCATION}?

	Q2	Yes	No	Not Sure	Q2a No. Days
A.	Any urban lake in a local city park	1	2	3 (16)	(17-18)
B.	Any of the Valley's major canals	1	2	3 (19)	(20-21)
C.	Any of the Valley's small irrigation canals	1	2	3 (22)	(23-24)
D.	The Central Arizona Project Canal	1	2	3 (25)	(26-27)

(BLANK COLS. 28 - 30)

IF ANY OF ABOVE DONE PAST 12 MONTHS, GO TO Q3
IF NONE OF ABOVE DONE PAST 12 MONTHS, GO TO Q4

Appendix D. Canal Fishery Program Questionnaire continued

3. What fish species have you fished for when you've fished at metro Phoenix urban lakes or canals?
(CIRCLE ALL MENTIONED)

Bass...1 (31)
Catfish...2 (32)
Trout...3 (33)
Whatever bites...4
__________ Other (SPECIFY)

4. Next, the Arizona Game & Fish Department is studying the possibility of developing the Salt River Project canal system into an urban fishing facility for the use of local anglers. This program would provide fishing areas with safety railings, parking lots, toilets and garbage containers at selected locations throughout the Valley and the canals would be stocked with several varieties of sport fish popular with anglers. If such a program were developed, would you be very likely, somewhat likely, not too likely, or not at all likely to make use of it?

(GO TO Q5) Very likely...1 (34)
Somewhat likely...2
Not very likely...3
(GO TO Q4a) Not at all likely...4
Not sure...5

4a. Why wouldn't you have any interest in such a program? (35-36)

(37-38)

4b. Even though you may not personally be interested in this program, would you support or oppose its development?

Support...1 (39)
Oppose...2
Not sure...3

(GO TO Q8)

5. How may days per year do you think you would spend fishing in the canals if this program were developed?
(CODE NOT SURE 99) NUMBER ______(40-41)

6. If this program were established, what species of fish would you like to catch?
(CIRCLE ALL MENTIONED)

Bass...1 (42)
Catfish...2 (43)
Trout...3 (44)
__________Other (SPECIFY)
Not sure...9

7. If a special fishing license were required to fish in Valley canals under this program, what would you be willing to pay annually for such an adult license?

Nothing...1 (45)
Under $5.00...2
$5.00 to $9.99...3
$10.00 to $14.99...4
$15.00 to $19.99...5
$20.00 or over...6
Not sure...7

8. Now, before we finish, I need to ask you a few questions for classification purposes. First, how many years have you lived in the metro Phoenix area? YEARS ______ (46-47)

Appendix D. Canal Fishery Program Questionnaire continued

9. And finally, which one of the following categories best describes your age? (READ EACH EXCEPT REFUSED)

Under 35...1 (48)
35 to 54...2
55 or over...3
(DO NOT READ) Refused...4

OBSERVED DATA:

Male...1 (49)
Female...2

(FROM SAMPLE) Zip Code: 8 5 ___ ___ ___ (50-52)

Thank you very much, that completes this interview. We very much appreciate your help on this project.
(VERIFY PHONE NUMBER)

NAME: PHONE #: ________(53-59)

ADMINISTRATIVE DATA:

INTERVIEWER NAME: #: ________(60-62)

VALIDATED BY: #: ________(63-65)

CODED BY: #: ________(66-68)

Appendix D. Canal Fishery Program Questionnaire continued

GENERAL PUBLIC SURVEY

(FROM QUARTERLY BRC METROTRACK™ SURVEY)

16. Next, do you or does any other member of your household have a current Arizona fishing license? (CIRCLE ALL THAT APPLY)

Yes - self...1
(GO TO Q17) Yes - other...2
(GO TO Q19) No/Not sure...3

17. During the past 12 months, how many days did you or any other members of your household fish in Arizona?

NUMBER ______

18. Have you or any other members of your household ever fished at any of the following locations in the metropolitan Phoenix area? (READ EACH)

	Yes	No	Not Sure
A. Any urban lake in a local city park	1	2	3
B. Any of the Valley's major canals	1	2	3
C. Any of the Valley's small irrigation canals	1	2	3
D. The Central Arizona Project Canal	1	2	3

19. Next, the Arizona Game & Fish Department is studying the possibility of developing the Salt River Project canal system into an urban fishing facility for the use of local anglers. This program would provide fishing areas with safety railings, parking lots, toilets and garbage containers at selected locations throughout the Valley and the canals would be stocked with several varieties of sport fish popular with anglers. If such a program were developed, would you or other members of your household be very likely, somewhat likely, not too likely, or not at all likely to make use of it?

(GO TO Q20) Very likely...1
Somewhat likely...2
Not very likely...3
(GO TO Q19a & b) Not at all likely...4
Not sure...5

19a. Why wouldn't you have any interest in such a program? (PROBE)

19b. Even though you may not personally be interested in this program, would you support or oppose its development?

Support...1
Oppose...2
Not sure...3

(GO TO Q23)

20. How may days per year do you think you or other members of your household would spend fishing in the canals if this program were developed?

NUMBER ______
Not sure ☐

21. If this program were established, what species of fish would you like to catch? (CIRCLE ALL MENTIONED)

Bass...1
Catfish...2
Trout...3
______________ Other (SPECIFY)...
Not sure...9

22. If a special fishing license were required to fish in Valley canals under this program, what would you be willing to pay annually for such an adult license?

Nothing...1
Under $5.00...2
$5.00 to $9.99...3
$10.00 to $14.99...4
$15.00 to $19.99...5
$20.00 or over...6
Not sure...7

Appendix D. Canal Fishery Program utilization summary.

PROJECTED USE BY LICENSED MARICOPA COUNTY ANGLERS

A_1	Estimated number of licensed anglers in Maricopa County - 1993	178,000
A_2	Percent of A_1 who indicate "very" likely use of program if developed (33.2%) adjusted downward (-50.0%)	16.60%
A_3	Average number of days "very" likely users estimate they would fish canal (18.5 median) adjusted downward (-50.0%)	9.25 days
	Sum A (A_1 X A_2 X A_3) = 273,300 person-use days	
B_1	Percent of A_1 who indicate "somewhat" likely use of program if developed (34.6%) adjusted downward (-75.0%)	8.65%
B_2	Average number of days "somewhat" likely users estimate they would fish canal (8.0 median) adjusted downward (-75.0%)	2.00 days
	Sum B (A_1 X B_1 X B_2) = 30,800 person-use days	

PROJECTED USE BY NON-LICENSED MARICOPA COUNTY RESIDENTS

C_1	Estimated number of persons in Maricopa County 14 years of age or over without a fishing license - 1993	1,617,200
C_2	Percent of C_1 who indicate "very" likely use of program if developed (19.7%) adjusted downward (-75.0%)	4.93%
C_3	Average number of days "very" likely users estimate they would fish canal (21.0 median) adjusted downward (-75.0%)	5.25 days
	Sum C (C_1 X C_2 X C_3) = 418,600 person-use days	
D_1	Percent of C_1 who indicate "somewhat" likely use of program if developed (30.8%) adjusted downward (-90.0%)	3.08%
D_2	Average number of days "somewhat" likely users estimate they would fish canal (6.1 median) adjusted downward (-90.0%)	0.61 days
	Sum D (C_1 X D X D_2) = 30,400 person-use days	

TOTAL PERSON-USE DAYS (SUM A + B + C + D) = 753,100 person-use days	753,100 person-use days
TOTAL NEW ANGLERS (SUM {%C_2 X C_1} + {%D_1 X C_1} = 129,538 new anglers	129,538 new anglers
ESTIMATED TOTAL REVENUE FROM NEW LICENSE SALES ($12.00 X TOTAL NEW ANGLERS)	$ 1,554,456.00

Appendix E.

Table 1. Analysis of fish tissue composites for PCB's and related compounds. ND = Not detected. Analyzed by PACE, Inc.

PCB's*	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94	Baseline[1]	3/31/94	6/9/94	7/14/94
A	301(n)/8080	2.0	ND	ND	ND	ND	ND	ND	ND	ND
B	301(n)/8080	2.0	ND	ND	ND	ND	ND	ND	ND	ND
C	301(n)/8080	2.0	ND	ND	ND	ND	ND	ND	ND	ND
D	301(n)/8080	2.0	ND	ND	ND	ND	ND	ND	ND	ND
E	301(n)/8080	2.0	ND	ND	ND	ND	ND	ND	ND	ND
F	301(n)/8080	2.0	ND	ND	15.0	ND	ND	250.0	61.0	130.0
G	301(n)/8080	2.0	ND	64.0	ND	ND	ND	ND	ND	ND
H	8270	0.2 mg/Kg	ND	ND	ND	ND	ND	ND	ND	ND

*A PCB-1016 (Aroclor 1016)
B PCB-1221 (Aroclor 1221)
C PCB-1232 (Aroclor 1232)
D PCB-1242 (Aroclor 1242)
E PCB-1248 (Aroclor 1248)
F PCB-1254 (Aroclor 1254)
G PCB-1260 (Aroclor 1260)
H 2-Chloronaphthalene

[1] Analyzed by HES, Inc. (used a PQL of 50.0 µg/Kg for A-G; 660.0 µg/Kg for H)

Practical Quantification Limit (PQL) or level of detection equivalents:
mg/Kg = parts per million
µg/Kg = parts per billion
ng/Kg = parts per trillion

Appendix E.

Table 2. Analysis of fish tissue composites for phenols and cresols. ND = Not detected. Analyzed by PACE, Inc.

Phenols / Cresols*	EPA Methods	PQL mg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94	6/9/94	7/14/94
A	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
B	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
C	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
D	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
E	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
F	8270	0.2	ND	ND	ND	ND	ND	250.0	ND	ND
G	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
H	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
I	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
J	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
K	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND

*A Phenol
B Phenol, 2-Chloro-
C Phenol, 2, 4-Dichloro-
D Phenol, 2,4,6-Trichloro-
E Phenol, Pentachloro-
F Phenol, 2-Nitro-
G Phenol, 4-Nitro-
H Phenol, 2,4-Dinitro-
I Phenol, 2,4-Dimethyl-
J 4-Chloro-3-Methylphenol
K 2-Methyl-4,6-Dinitrophenol

[1] Analyzed by HES, Inc. (Used PQL of 660.0 μg/Kg for A-D, F, I, J; 3200.0 μg/Kg for E, G. H, K)
[2] PQL doubled (A, B, F, J = 0.4 mg/Kg; C-E, G-I, K = 1.0 mg/Kg)

Appendix E.

Table 3. Analysis of fish tissue composites for ethers. ND = Not detected. Analyzed by PACE, Inc.

Ethers*	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94[3]	6/9/94	7/14/94
A	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
B	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
C	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
D	8240	4000.0	ND	ND	ND	ND	ND	ND	ND	ND
E	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
F	8270	0.2**	ND	ND	ND	ND	ND	250.0	ND	ND
G	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
H	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
I	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
J	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
K	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
L	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
M	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
N	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
O	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
P	8270	0.2**	ND	ND	ND	ND	ND	ND	ND	ND
Q	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
R	8270	0.5**	ND	ND	ND	ND	ND	ND	ND	ND
S	8270	0.5**	ND	ND	ND	ND	ND	ND	ND	ND

*A Ether, Bis (Chloromethane)
B Ether, Bis (2-Chloroethyl)
C Ether, Bis (2-Chloroiso-)
D Ether, 2 (Chloroethyl Vinyl)
E Ether, 4-Bromophenyl phenyl
F Ether, 4-Chlrophenyl phenyl
G Bis (2-Chloroethoxy) Methane
H Benzene
I Benzene, Chloro-
J Benzene, 1, 2-Dichloro-
K Benzene, 1,3-Dichloro-
L Benzene, 1,4-Dichloro-
M Benzene, 1,2,4-Trichloro-
N Benzene, Hexachloro
O Benzene, Ethyl-
P Benzene, Nitro-
Q Toluene
R Toluene, 2,4-Dinitro-
S Toluene, 2,6-Dinitro-

** PQL in mg/Kg
[1] Analyzed by HES, Inc. (Used PQL of 10.0 for A, H, I, O, Q; 660.0 for B-G, J-N, P, R.S)
[2] PQL doubled (A, H-L, O, Q = 40.0; B, C, E-G, M, N, P = 0.4; D = 8,000.0; R, S = 1.0)
[3] PQL increase tenfold (A, H-L, O, Q = 200.0; D = 40,000)

Appendix E.

Table 4. Analysis of fish tissue composites for phthalate esters. ND = Not detected. Analyzed by PACE, Inc.

Phthalate Esters**	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94	6/9/94	7/14/94
A	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
B	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
C	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
D	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
E	8270	3.0	ND	**	ND	ND	ND	ND	ND	ND
F	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND

*A Phthalate, Dimethyl-
B Phthalate, Diethyl-
C Phthalate, Di-n-octyl-
D Phthalate, Di-n-octyl-
E Phthalate, Bis (2-Ethyl-hexyl)
F Phthalate, Butyl Benzyl-

** Detected, but below quantification level·
[1]Analyzed by HES, Inc. (Used PQL of 660.0 µg/Kg for A-F)
[2] PQL doubled (A, C,F = 0.4; B = 1.0; D, E = 6.0)

Appendix E.

Table 5. Analysis of fish tissue composites for polycylic aromatic hydrocarbons. ND = Not detected. Analyzed by PACE, Inc.

Polycyclic Aromatic Hydro-carbons*	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94	6/9/94	7/14/94
A	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
B	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
C	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
D	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
E	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
F	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
G	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
H	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
I	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
J	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
K	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
L	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
M	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
N	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
O	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
P	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND

*A Acenaphthene
B Acenaphthylene
C Anthracene
D Benzo (a) Anthracene
E Benzo (b) Fluoranthene
F Benzo (k) Fluoranthene
G Benzo (g,h,i) Perylene
H Benzo (a) Pyrene
I Chrysene
J Dibenzo (a,h) Anthracene
K Fluoranthene
L Fluorene
M Indero (1,2,3-cd) Pyrene
N Naphthalene
O Phenanthrene
P Pyrene

[1]Analyzed by HES, Inc. (Used PQL of 660.0 µg/Kg for A-P)
[2] PQL doubled (A-F, I, , M-P = 0.4; G, H, J, L = 1.0)

Appendix E.

Table 6. Analysis of fish tissue composites for halogenated aliphatics. ND = Not detected. Analyzed by PACE, Inc.

Halogenated Aliphatics*	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94	6/9/94	7/14/94
A	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
B	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
C	8240	40.0	7200.0	170.0**	170.0	1100.0	140.0	2500.0	710.0	ND
D	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
E	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
F	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
G	8240	20.0	ND	ND	280.0	170.0	ND	420.0	ND	ND
H	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
I	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
J	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
K	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
L	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
M	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
N	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
O	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
P	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
Q	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
R	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
S	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
T	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
U	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
V	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
W	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
X	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
Y	8240	20.0	ND	ND	ND	ND	ND	ND	ND	ND
Z	8270	0.5 mg/Kg	ND	ND	ND	ND	ND	ND	ND	ND

Appendix E.

Table 6. (continued) Halogenated aliphatics

*A	Methane, Bromo-(methyl bromide)	N	Ethane, 1,1,1-Trichloro-
B	Methane, Chloro- (methyl chloride)	O	Ethane, 1,1,2-Trichloro-
C	Methane, Dichloro-(methylene chloride)	P	Ethane, 1,1,2,2-Tetrachloro-
D	Methane, Chlorodibromo-	Q	Ethane, Hexachloro-
E	Methane, Dichlorobromo-	R	Ethene, Chloro- (vinyl chloride)
F	Methane, Tribromo- (bromoform)	S	Ethene, 1,1-Dichloro-
G	Methane, Trichloro- (chloroform)	T	Ethene, Trans-Dichloro-
H	Methane, Tetrachloro- (carbon tetrachloride)	U	Ethene, Trichlor
		V	Ethene, Tetrachloro-
I	Methane, Trichlorofluoro-	W	Propane, 1,2-Dichloro-
J	Methane, Dichlorodifluoro-	X	Propane, 1,3-Dichloro-
K	Ethane, Chloro-	Y	Butadiene, Hexachloro-
L	Ethane, 1,1-Dichloro-	Z	Cyclopentadiene, Hexachloro-
M	Ethane, 1,2-Dichloro-		

** Initially exceeded calibration levels & diluted to quantify.
[1]Analyzed by HES, Inc. (Used PQL of 10.0 for A-P, R-X; 660.0 for Q, Y, Z)
[2] PQL doubled (Z = 1.0)
Note: Methylene chloride is used as an extraction solvent for gas chromatography/mass spectraphotometry (GCMS) semivolative analysis. Methylene chloride and chloroform are by-products of the chlorination process of drinking water.

Appendix E.

Table 7. Analysis of fish tissue composites for nitrosamines. ND = Not detected. Analyzed by PACE, Inc.

Nitro-samines*	EPA Methods	PQL µg/Kg	Results							
			Rainbow Trout				Channel Catfish			
			Baseline	Baseline[1]	3/31/94	6/2/94[2]	Baseline[1]	3/31/94	6/9/94	7/14/94
A	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
B	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
C	8270	0.2	ND	ND	ND	ND	ND	ND	ND	ND
D	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
E	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
F	8270	0.5	ND	ND	ND	ND	ND	ND	ND	ND
G	8270	20.0	ND	ND	ND	ND	ND	ND	ND	ND

*A Nitrosamine, Dimethyl-(DMN)
B Nitrosamine, Diphenyl-
C Nitrosamine, Di-n-propl-
D Benzidine
E Benzidine, 3, 3-Dichloro-
F Hydrazine, 1, 2-Diphenyl-
G Acrylonitrile

[1] Analyzed by HES, Inc. (Used PQL of 20.0 for A-C; 3200.0 for D; 660.0 for E, F; 50.0 for G)
[2] PQL doubled (0.4 A-C; 1.0 D-F)

Table 10. FDA Action Levels for maximum concentrations (μg/Kg) of mercury and selected synthetic organic compounds in human foods.

Substance	FDA Action Level
Mercury	1,000 μg/Kg
Aldrin	3000
Dieldren	300
Endrin	300
Heptachlor	300[1]
Heptachlor epoxide	300[1]
Chlordane	300
Toxaphene	5,000
Total DDT	5,000
Total PCB	2,000[2]

[1] Individually or in combination

[2] Tolerances not action level. Source: U.S. FDA, Peterson 1987.

Appendix F.

Table 1. Mean values ($\bar{x}$) and standard deviations (SD) for water temperature (C), pH, dissolved oxygen (mg/L), specific conductivity (mS/cm), turbidity (NTU), and Secchi depth (m) measurements for each SRP canal (n = 1,296), February 1992 to July 1994.

	Water Temperature		pH		Dissolved Oxygen		Specific Conductivity		Turbidity		Secchi Depth	
Canal	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Arizona	19.4	(5.0)	8.11	(0.51)	9.81	(2.16)	511.31	(207.50)	48	(104)	1.0	(0.4)
Consolidated	18.8	(4.6)	8.06	(0.45)	10.15	(2.22)	651.53	(256.95)	25	(36)	0.8	(0.4)
Eastern	19.0	(4.5)	8.01	(0.39)	10.00	(2.21)	726.89	(323.87)	22	(43)	1.0	(0.4)
Grand	19.7	(5.2)	8.18	(0.39)	9.87	(1.64)	603.36	(247.11)	51	(71)	0.7	(0.2)
South	17.2	(4.3)	7.87	(0.42)	10.23	(1.53)	642.24	(246.95)	87	(83)	0.8	(0.4)
Tempe	18.0	(4.4)	7.87	(0.46)	9.99	(1.70)	707.61	(245.77)	50	(72)	0.9	(0.3)
Western	20.0	(5.4)	8.03	(0.38)	9.22	(1.68)	759.27	(275.28)	11	(17)	0.9	(0.5)
Cross-Cut	18.6	(4.9)	8.05	(0.47)	10.08	(2.04)	559.22	(220.35)	39	(669)	0.9	(0.3)

Appendix F.

Table 2. Mean CHLA values (mg/m^3), CHLA:PHEA ratio values, standard deviations, and sample number for all SRP canals, January 1993 to July 1994.

Canal	Mean CHLA	Standard Deviation CHLA	Mean Ratio	Standard Deviation Ratio	Sample Number
Arizona	1.25	1.31	1.3	0.17	113
Consolidated	2.87	3.19	1.4	0.21	13
Eastern	2.79	2.37	1.4	0.17	10
Grand	1.12	0.81	1.3	0.16	9
South	2.24	2.39	1.3	0.19	12
Tempe	2.76	3.32	1.3	0.21	5
Western	1.00	0.95	1.3	0.20	8
Cross-Cut	2.06	1.59	1.4	0.26	6

NOTES

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Key Words: Arizona, canals, *Catostomus clarki*, *Catostomus insignis*, channel catfish, *Ctenopharyngodon idella*, desert sucker, *Ictalurus punctatus*, *Oncorhynchus mykiss*, rainbow trout, recreational fishing, Sonora sucker, urban fishing, white amur.

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