DRAFT

MEMORANDUM

Date: September 6, 2000

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: Preliminary Riparian Protection, Management and Restoration Element

I. Introduction

It has been suggested that a fish story is never about a fish, but always about people and a place.[1] Arizona's fish story begins in 1904 with the publication of Morton Chamberlain's *Survey of Arizona Fishes* -- the first detailed study by an aquatic biologist of the area. In that day, Chamberlain was able to count sixteen native species in Arizona. Today, more than half are either extinct, or listed as threatened or endangered, and most of the rest are considered to be imperiled.[2] In Pima County, we can count more extirpated native fish than remaining residents. The fish potentially covered by the Sonoran Desert Conservation Plan are barely hanging on. The Gila topminnow and Desert pupfish are listed as endangered, and the Gila chub is a candidate for listing. With less than twenty known populations in 1997, delisting of the Gila topminnow was "not considered feasible in the foreseeable future" by the biologists who drafted its recovery plan. The Desert pupfish is considerably worse off: it has no natural populations in Pima County and exists only in ponds and aquariums. This story, absent a fairly dramatic change in circumstances, will end with the extirpation or extinction of all native fish in the region. The attached draft *Preliminary Riparian Protection, Management and Restoration Element* provides an opportunity to change the circumstances of aquatic and riparian systems in Eastern Pima County.

One of six elements developed as part of the Sonoran Desert Conservation Plan, the *Preliminary Riparian Element* details:

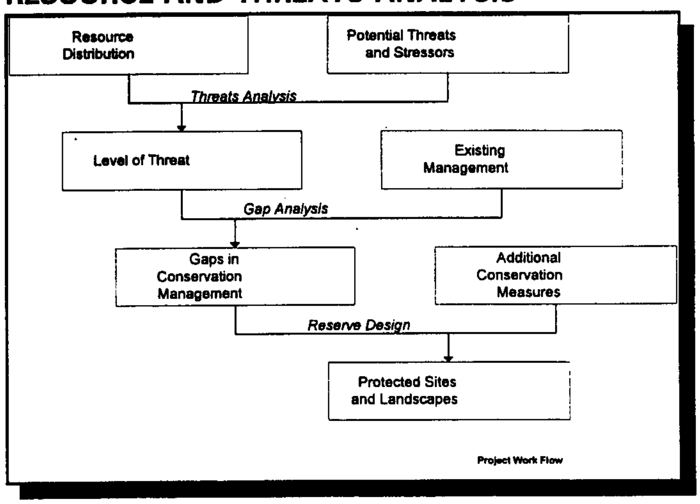
(1) the status of the resource base;

(2) threats to the resource base; and

(3) current management and existing gaps in protecting resources.

Specific conservation measures and riparian projects are recommended as a result of this information.

RESOURCE AND THREATS ANALYSIS



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[1] Shacochis, B.

[2] Minckley, W.L., Journal of the Southwest, *Chamberlain's 1904 Survey of Arizona Fishes*

II. The Status of the Resource Base

On an 1873 map of Arizona, the Gila River is connected by dotted line to a watercourse north of "Camp Lowell" and labeled the "Supposed course of the Santa Cruz River which sinks at Tucson." During the last one hundred and twenty-five years we have been able to map and measure aquatic and riparian resources with greater precision, but our technically improved map is of a much reduced system of watercourses. Former wetlands have been eliminated and many former perennial flows are reduced in their reach or exist only as ephemeral streams.

The loss of aquatic, semi-aquatic, and riparian areas is a significant dilemma given the resource protection mandates of the Endangered Species Act: while riparian areas are said to occupy less than one percent of the state's total land base, sixty to seventy-five percent of Arizona's resident wildlife species depend on riparian habitats to sustain their populations. Not surprisingly then, a high percent of extirpated and imperiled species are associated with this habitat type. To begin to address this problem, the Science Technical Advisory Team for the Sonoran Desert Conservation Plan has established biological goals in addition to riparian ecosystem function goals, guidelines for restoration, and guidelines for use of effluent use in riparian projects. This section briefly defines and describes the status of the riparian resource base in terms of its current state, and in terms of its processes.

A. State of Riparian Resource Base -- The native aquatic species in Pima County derive from the Gila River system. In Eastern Pima County, the major watersheds tend to slope northwest in the direction of this system, as reflected on the map below.

Components, Riparian Areas -- In general, the components of a riparian area include:

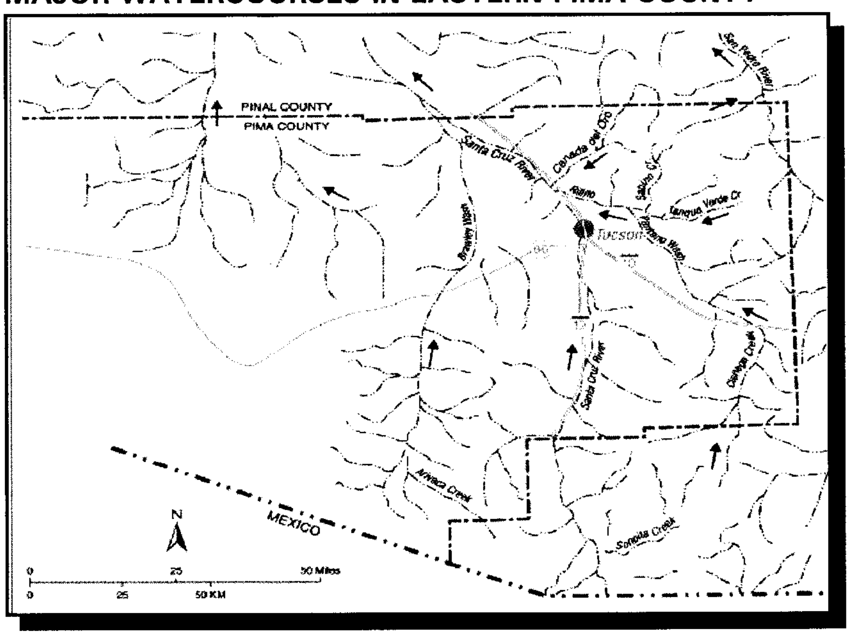
(1) the water availability;

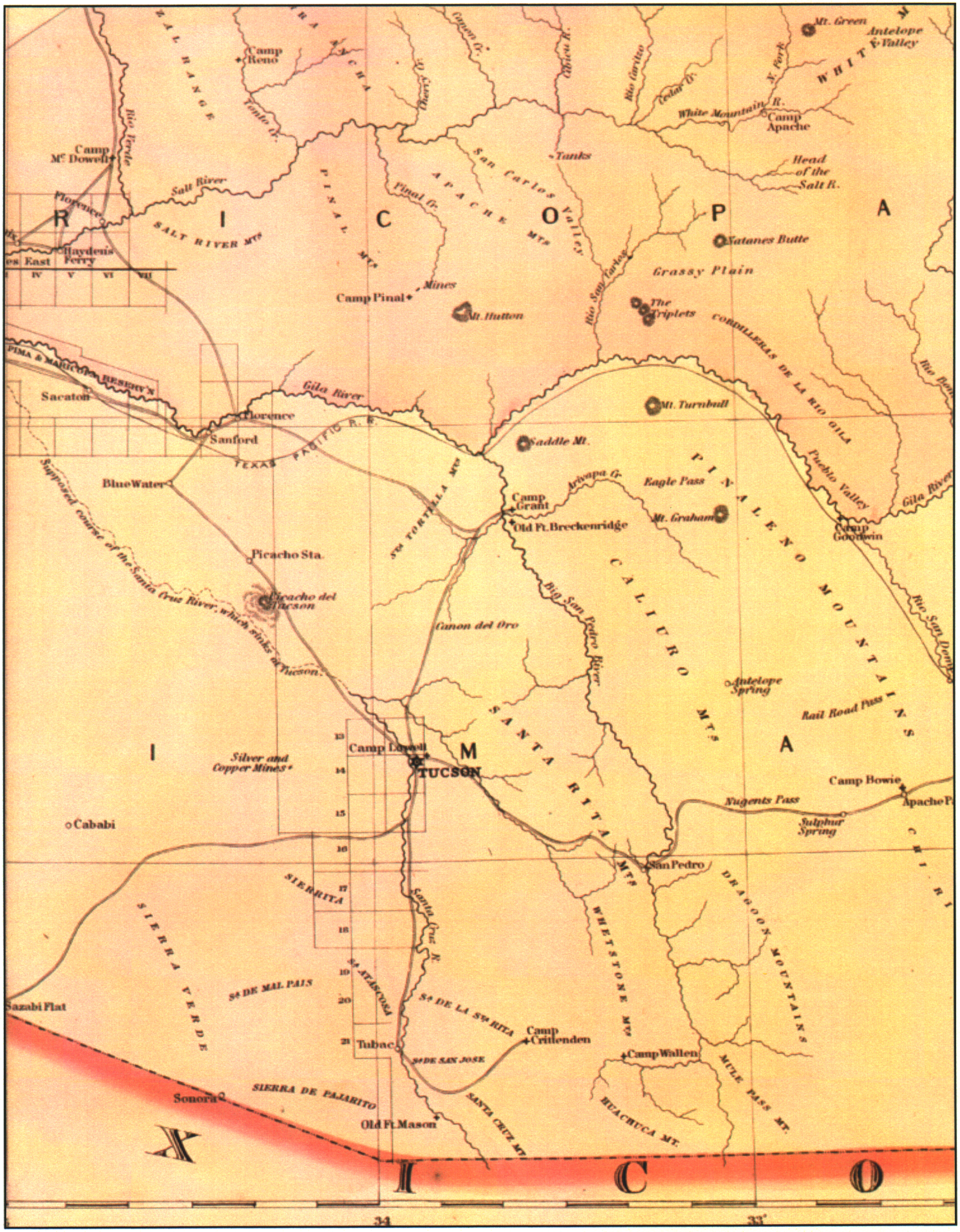
(2) the vegetation of the area; and

(3) the wildlife.

Each component is discussed below in relation to the Sonoran Desert Conservation Plan.

MAJOR WATERCOURSES IN EASTERN PIMA COUNTY





Detail of 1873 map of Arizona by Asher & Adams showing area surrounding Tucson.

1. **Riparian resources defined in part through water availability.** The four major water sources in Pima County are generally held to be surface water, groundwater, Central Arizona Project (CAP) water, and effluent. Surface water includes streams, which have been defined in prior reports to include springs, ponds, pools, wetlands, rivers and washes.

- A perennial stream has continuous flow;
- An intermittent stream has flow at certain times; and
- An ephemeral stream is not connected to the water table so flows only when it rains.

Counting Streams and Shallow Groundwater Sites: Fifty-five previously unmapped perennial stream reaches and eighty-two intermittent stream reaches were described in a report by Pima Association of Governments, carried out as part of the Sonoran Desert Conservation Plan. Almost one hundred shallow groundwater sites were also identified in the same report.

Counting Springs: A separate report identified over 250 springs in Pima County and identified known springs with these characteristics for conservation purposes: springs thought to have perennial flow; springs known to have native fish; or suitable habitat for native fish; and thermal springs.

- Springs thought to have perennial flow

Agua Caliente Spring	Nogales Spring
Aguajita Spring	Papago Spring
Bingham Cienega Spring	Pidgeon Spring
Box Spring	Quitobaquito Springs
Busch Spring	Scholefield Spring
Cold Spring	Silver Spring
Flicker Spring	Simpson Spring
Green Spring	Unnamed spring
Huntsman Spring	Unnamed spring
Kingler Spring	Unnamed spring
La Cebadilla Spring	Wakefield Spring
Little Nogales Spring	Wild Cow Spring (Whetstones)
Lower Wakefield Spring	Wild Cow Spring (Santa Catalinas)
Mountain Spring	

- Springs known to have native fish, or suitable habitat for native fish

Agua Caliente Spring
Little Nogales Spring
Mountain Spring
Nogales Spring
Quitobaquito Springs
Unnamed Spring in Davidson Canyon
Wakefield Spring

- Thermal Springs in Pima County, Arizona

Agua Caliente Spring
Mercer Spring
La Cebadilla Spring
Nogales Spring
Quitobaquito Spring

Prioritizing Streams: One hundred and fifty streams were compared. Streams that ranked in the top 20 by the following parameters are recommended for priority consideration for protection and restoration as part of the Sonoran Desert Conservation Plan:

- perennial stream length and intermittent stream length;
- area of hydro-mesoriparian vegetation and of xeroriparian Class A vegetation;
- area of shallow groundwater; and
- presence of native fish.

Almost 50 percent of the priority streams within the County are found within the Altar Valley and the Cienega Rincon area.

PRIORITY STREAMS

SDCP Planning Unit	Number of Priority Streams	Percentage of Total
1. Middle San Pedro	8	14
2. Cienega Rincon	17	29
3. Upper Santa Cruz	3	5
4. Middle Santa Cruz	9.5	16
5. Tortolita Fan	5.5	9
6A. Altar Valley	12	20
6B. Avra Valley	2	3
7. Tohono Nation	1	2
8. Western Pima Co.	1	2
Total	59	100

2. Riparian resources defined in part through vegetation: Water availability is one of the most significant factors in determining the distribution of riparian plant communities.

- Xeroriparian vegetation, such as mesquite and acacia, is found in areas with ephemeral stream channels.

- Mesoriparian vegetation, such as sycamore-ash trees, is found where there is intermittent surface flow, or shallow groundwater.

- Hydroriparian vegetation, such as cottonwood willow, is found in wetlands or along perennial watercourses.

Hydromesoriparian vegetation can be found in the Tanque Verde, Sabino and Agua Calliente areas.

Current Santa Cruz Subbasin Water Budget -- The table below allows water budgets to be determined by habitat type, and by the quality of the vegetation. A relatively low annual rate of evapotranspiration (2 AF of water/acre of land) is assumed in determining that the volume of water necessary to support 6,000 acres of vegetation in the Upper Santa Cruz subbasin is 12,000 acre-feet per year. The basis of the this assumption incudes factors such as: (1) the groundwater table decline in many places has already eliminated cottonwood-willow forest, and has caused canopy dieback of mature mesquite trees and decreased leaf volumes, and (2) the vegetation in many riparian areas is young and scrubby due to previous disturbance.

Water Needs for Vegetation (in Tucson area)	
Type of Vegetation	**Water Needs (acre-feet/acre)**
Desert Upland	
Saltbush, native grass	0.5 - 1
Creosotebush	0.8
Xeroroparian	
Less dense mesquite	1.6
Mesoriparian	
Mature, dense mesquite	3.0
Hydroriparian	
Mature cottonwoods	5.0 - 5.8
Young cottonwoods, willows	8.3
Wetlands	
Cattails	6.9
Other features	
Open water	5.4
Park with turf and trees	2.9 - 4.0
Pecan grove with ground cover	5.7
Golf course with water features	4.7

<u>Current Eastern Pima County Hydromesoriparian Vegetation Water Budget</u> -- A similar analysis based on the amount, type and quality of habitat can be performed for Eastern Pima County. Arizona Game and Fish Department estimated based on early 1990's mapping that there were 7402 acres of hydromesoriparian vegetation in eastern Pima County, primarily along Sabino Canyon and Cienega Creek. Of this amount, it was estimated there were 1049 acres of cottonwood-willow and 3430 acres of mesquite. Pima County mapped 8241 acres of hydromesoriparian vegetation in eastern Pima County in the early 1990's, but this mapping did not extend into the existing public reserves. A figure of approximately 10,000 acres of hydromesoriparian vegetation is not unreasonable for eastern Pima County, including those portions of the Santa Cruz and San Pedro watersheds. The water demand to support existing hydromesoriparian vegetation is probably around 3 feet per acre, considering that a) some riparian zones are at a higher elevation than Tucson and therefore require less water, and b) cottonwood-willow is a low percentage of the total area of hydromesoriparian vegetation. Therefore 30,000 af is an estimate of the total water needs of existing vegetation.

- Riparian Communities within watershed planning units

WATERSHED SUBAREA	Semi-desert grassland	Sonoran Desertscrub	Mixed Broadleaf	Cottonwood Willow	Mesquite Bosque	Cattail
Middle San Pedro			yes	yes	yes	yes
Cienega-Rincon	yes	yes	yes	yes	yes	yes
Upper Santa Cruz	yes	yes	yes	yes	yes	
Middle Santa Cruz		yes	yes	yes	yes	yes
Tortolita Fan		yes	yes	yes	yes	yes
Altar Valley	yes	yes	yes	yes	yes	yes
Avra Valley		yes			yes	
Western Pima County		yes		yes		yes

3. Riparian resources defined in part though species: A disproportionate number of Pima County's extirpated and imperiled species are associated with riparian habitat.

- Species that depended on riparian or aquatic habitats that no longer exist in Pima County

Muskrat	Desert Sucker	Desert Tryonia
Beaver*	Sonora Sucker	Blue Silverspot Butterfly
Tarahumara Frog	Gentry Indigobush	California Floater (clam)
Speckled Dace	Aravaipa Sage	Ribbonleaf Button Snakeroot
Desert Pupfish **	Malaxis Porphyrea (orchid)	

BEAVER

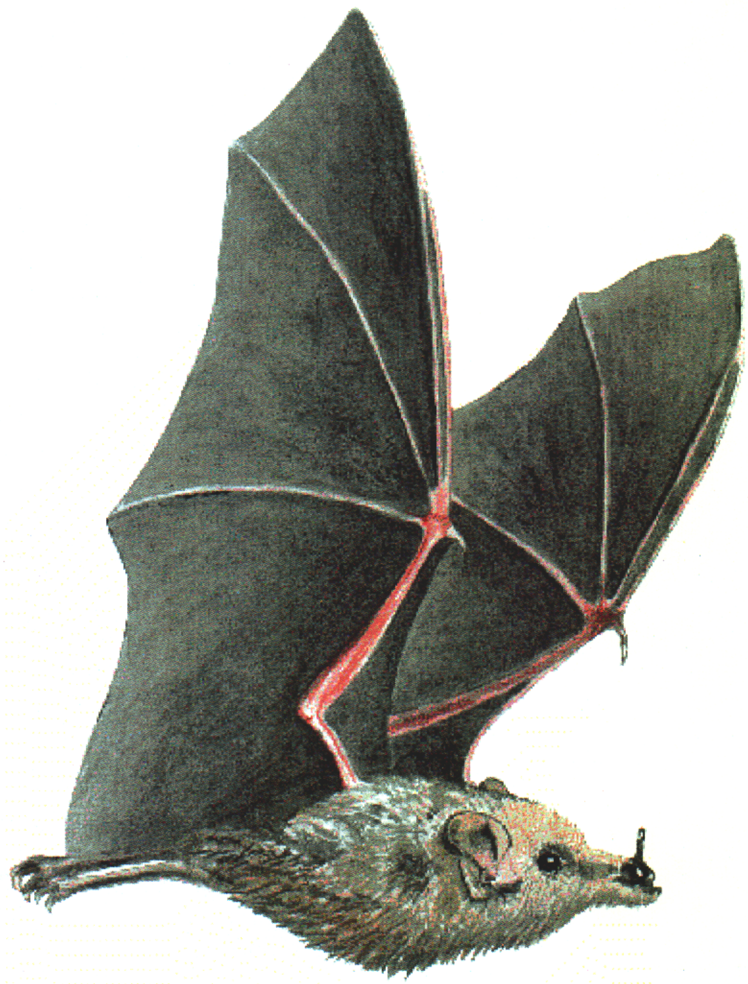
Notes

* Beaver may expand into Pima County from sites along the San Pedro river.

** Desert pupfish have no natural populations in Pima County but a few populations exist in private ponds and aquariums.

- Riparian associated species potentially covered by the Sonoran Desert Conservation Plan

Common Name	
Chiricahua Leopard Frog	Mexican Long-tongued Bat
Lowland Leopard Frog	Merriam's Mouse (Mesquite Mouse)
Mexican Garter Snake	Southern Yellow Bat
Red-backed Whiptail Lizard	Allen's Big-eared Bat
Giant Spotted Whiptail	Western Red Bat
Sonora Sucker	Arizona Shrew
Gila Chub	Southwestern Willow Flycatcher
Desert Pupfish	Western Yellow-billed Cuckoo
Longfin Dace	Cactus Ferruginous Pygmy-Owl
Gila Topminnow	Abert's Towhee
Desert Sucker	Bell's Vireo
Huachuca Water Umbel	Gentry Indigobush



MEXICAN LONG-TONGUED BAT

- Watercourses associated with existing or very recently extirpated native fish and frogs

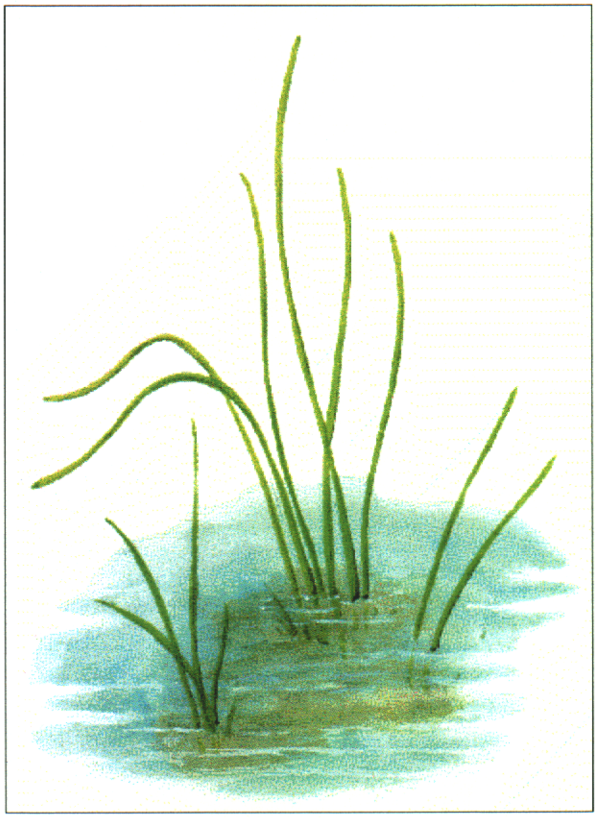
WATERSHED SUBAREA	NATIVE FISH -- NUMBER OF STREAMS	NATIVE FROGS -- NUMBER OF STREAMS
Middle San Pedro	4	8
Cienega-Rincon	9	20
Upper Santa Cruz	0	1
Middle Santa Cruz	3	9
Tortolita Fan	1	6
Altar Valley	0	8
Avra Valley	0	2
Western Pima County	1	1

B. Watercourse Functions and Processes

In addition to possessing a state made up of water, vegetation and wildlife, riparian areas have processes. They function to:

- transport water and dissipate energy during flood events through the floodplain;
- make shallow groundwater available to vegetation;
- flush accumulated salts down below root zones;
- store sediment between floods;
- store and recharge groundwater;
- serve as wildlife corridors;
- provide recreational value;
- improve water quality.

HUACHUCA WATER UMBEL



III. Threats to the Riparian Resource Base

The major threats to the aquatic and riparian resource base include: groundwater pumping; surface water diversions; encroachment resulting in habitat modification and destruction; non-indigenous species; the potential introduction of non-native species through Central Arizona Project (CAP) water; and the loss of floodplain functions. More specifically:

A. Groundwater pumping -- On the issue of groundwater pumping, the streams and shallow groundwater with the highest annual reported pumping within one mile of the watercourse include:

- Santa Cruz River
- Tanque Verde Creek
- Sabino Canyon
- Ventana Canyon
- Agua Caliente Wash
- Rillito Creek

B. Surface water diversion -- Streams with surface water diversions include:

- Cienega Creek (entire base flow diverted)
- San Pedro River (entire base flow diverted)
- Arivaca Creek
- Santa Cruz River

C. Loss of floodplain function -- In the urban periphery, continued loss of floodplain function is an additional future threat. Examples of areas where future man-made structures may cause large losses of floodplain functions:

- Middle San Pedro Subarea (Subarea 1): Roadway improvements to the San Pedro River Road may require channelization of tributaries, construction of concrete fords, and localized bank protection on the San Pedro River.

- Cienega-Rincon Subarea (Subarea 2): Proposed levees along Rincon Creek will reduce overbank flood storage. Bank protection and channelization are proposed for portions of Pantano Wash adjacent to Vail Valley. Pantano Wash is the likely future source of aggregate for development in the area.

- Upper Santa Cruz Subarea (Subarea 3): Development along the Santa Cruz River could remove overbank storage. Consequent increases in peak discharge downstream to the urban area may be costly. If growth is directed to the distributary flow areas in the southeastern part of the Tucson Basin, flood peaks and erosion potential may increase. Advance planning and infrastructure commitments will be necessary to develop these areas without threatening Old Nogales Highway and increasing erosion of Lee Moore Wash.

- Middle Santa Cruz Subarea (Subarea 4): Encroachment and channelization of tributaries to the Santa Cruz River in the southeastern part of the Tucson Basin will decrease overbank storage and increase erosion potential. Extension of sewer interceptors along erodible stream banks will increase the need for bank protection. Continued channelization of Agua Caliente Wash and Tanque Verde Creek will increase peak flows downstream, and impair the natural development of cottonwood-willow and mesquite forest.

- Tortolita Fan (Subarea 5): The Marana levee construction will remove overbank flood potential and increase the energy directed by flooding upon the Santa Cruz River channel. To develop behind the levee will require advance planning and infrastructure commitments for tributary drainage structures. Development of distributary flow zones on the Tortolita piedmont will increase the need for structures to convey water and sediment to the Santa Cruz River. Encroachment of Big Wash may remove overbank storage.

- Altar Valley Subarea (Subarea 6A): Increasing storage volume at the Arivaca Lake would further reduce flooding as a natural disturbance and would increase the proportion of runoff that evaporates without production of biomass. Development of distributary flow zones on the Sierrita piedmont will increase the need for structures to convey water and sediment to the Black Wash, which has one of the few large remaining mesquite woodlands in the area.

- Avra Valley Subarea (Subarea 6B): Further floodplain development could cause the loss of overbank storage on Brawley Wash and increased peak discharge from the development of distributary flow zones.

ABERT'S TOWHEE

IV. Gaps in Protection of Resources and the Resulting Most Imperiled Systems

A. Local, State and Federal Management of Riparian Resources

In general, the gaps in regulatory protection are a lack of a nexus between wildlife programs and local compliance matters, and the lack of protection at the system level.

- The attached report points out that most local regulatory responses focus on retaining natural vegetation, not the other structures or functions of riparian and aquatic ecosystems. For example, in the late 1980's and early 1990's, City of Tucson and Pima County both adopted ordinances protecting or requiring mitigation of damage to certain streamside environments.

- In 1986 and 1997, voters approved bonds to purchase certain high-value riparian areas in Pima County. These measures will reduce but not halt or reverse the rate of loss of riparian vegetation.

- Not all communities have adopted ordinances identifying or protecting their riparian areas, nor do these ordinances address the attrition ongoing in rural areas.

- Measures to reduce the impacts of overbank flooding and sediment balance are primarily found in floodplain management ordinances of the various jurisdictions. For instance, Pima County requires some flood control projects to maintain some overbank storage for the 100-year flood event. In some areas, new in-channel aggregate mining is discouraged in favor of off-channel mining to reduce channel bed degradation.

- The report further emphasizes that local measures do not exist to protect groundwater-dependent aquatic and riparian ecosystems from drying up as groundwater pumping increases.

- The Safe Yield Task Force for the Tucson Active Management Area is considering recommending that Arizona Department of Water Resources be given authority to work with local communities to designate subareas where groundwater might be regulated to achieve additional goals other than safe-yield, such as subsidence mitigation and protection of groundwater-dependent streams.

- State and federal wildlife agencies neither manage nor conduct research consistently targeted to make a contribution to the protection of imperiled wildlife that is sufficient to resolve compliance issues under federal natural resource laws.

- Non-native species management is another area where new regulatory measures might be needed. Arizona Game and Fish Commission, for example, recently adopted more stringent regulations for crayfish, to reduce the likelihood that this organism will be transferred to aquatic sites where it does not yet occur.

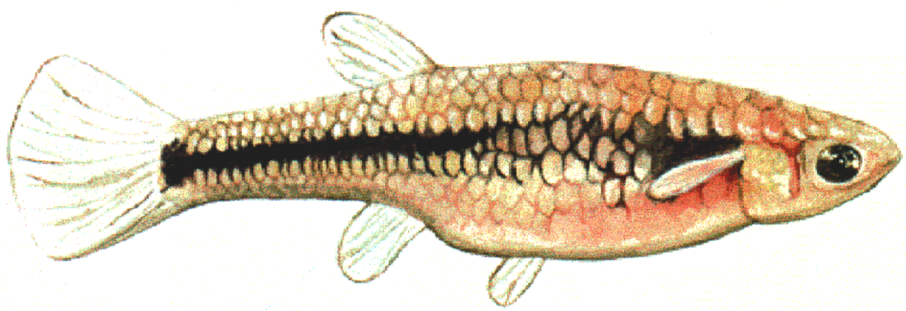
- RECON (2000) has urged Pima County to begin discussions with the Arizona Department of Agriculture (ADA) regarding problems associated with non-native and pest species.

- Rosen (2000) recommended legislation to prohibit purchase and release of bullfrogs.

B. Most imperiled river systems -- Comparing the watersheds to each other, the most imperiled river systems are:

- Tanque Verde, where habitat losses are high and where continued or increased groundwater pumping impairs streamflow and shallow groundwater conditions;
- Sabino Canyon, where groundwater pumping impairs streamflow, habitat losses are high, and exotic species are a problem;
- Rincon Creek, where groundwater pumping for development may deplete a local aquifer which supports streamflow, and gravel mining may increase channel downcutting;
- Arivaca Creek, where groundwater pumping, surface water diversion, water quality, and exotic species are impairing natural riparian functions;
- Cienega Creek, where future groundwater pumping may deplete streamflow, where derailments along the railroad could contaminate the aquifer, and where non-native species could imperil the largest remaining Gila topminnow population.
- Davidson Canyon, threatened principally by groundwater pumping and habitat loss. Future upstream mining could impair water quality.

GILA TOPMINNOW



V. Conservation Standards and Recommendations

A. Biological and Riparian Ecosystem Function Goals of the Science Technical Advisory Team

The biological goal of the Sonoran Desert Conservation Plan is to ensure the long-term survival of the full spectrum of plants and animals that are indigenous to Pima County through maintaining or improving the habitat conditions and ecosystem functions necessary for their survival. Inherent within this broad goal are several objectives:

1. Promote recovery of federally listed and candidate species to the point where their continued existence is no longer at risk.

2. Where feasible and appropriate, re-introduce and recover species that have been extirpated from this region.

3. Maintain or improve the status of unlisted species whose existence in Pima County is vulnerable.

4. Identify biological threats to the region's biodiversity posed by exotic and native species of plants and animals, and develop strategies to reduce these threats and avoid additional invasive exotics in the future.

5. Identify compromises to ecosystem functions within target plant communities selected for their biological significance and develop strategies to mitigate them.

6. Promote long-term viability for species, environments and biotic communities that have special significance to people in this region because of their aesthetic or cultural values, regional uniqueness, or economic significance.

The Science Team adopted specific riparian ecosystem function goals:

1. To the extent possible, maintain or restore the connection between interdependent components of river systems: channel, overbank floodplain, distributary flow zones, riparian vegetation and connected shallow groundwater. (A) maintain or restore natural flooding and sediment balance; (B) preserve or re-establish connections between channels and their floodplains, and channels and their distributary flow zones; and [C] maintain or re-establish hydrologic connections between riparian and aquatic ecosystems and shallow groundwater zones.

2. Manage uplands as appropriate to protect the functioning of riparian and aquatic ecosystems within the watershed;

3. Manage point-source and non-point source pollution to maintain water quality at a level needed to support SDCP biological goals;

4. Insure sufficient instream flows to achieve and protect natural functions of riparian and aquatic ecosystems.

B. Recommendations -- Protection; Restoration; Revegetation; Improved Riparian Conditions

1. Protection

Streams: The most important riparian areas to preserve are defined below in the context of preserving and augmenting the stability of native fish and frog populations. The priority streams have a high, natural availability of water and possess relatively unimpaired water quality. In order to focus on opportunities to improve land stewardship of the most threatened stream segments, only those streams which have part of their length outside core reserves are mentioned below as high priority for protection.

- Subarea 1-- The San Pedro River, Buehman, Edgar, Espiritu, Youtcy and Paige Canyons.
- Subarea 2 -- Agua Verde Creek, upper Rincon Creek, Davidson Canyon, Cienega Creek, Wakefield, Posta Quemada, Gardner, Chimney, and Distillery Canyons.
- Subarea 3 -- None.
- Subarea 4 -- Sabino Canyon, Bear Canyon, Ventana Wash, Tanque Verde and Agua Caliente Creeks.
- Subarea 5 -- Sutherland Wash.
- Subarea 6A -- Arivaca Creek, Las Moras, Pozo Hondo, Asolido, Thomas, Fraguita, Penitas.
- Subarea 6B -- None.
- Subarea 8 -- None.

Systems: Total riparian area is another fundamental biological parameter which is more relevant to terrestrial wildlife than to native fish and frogs. Larger areas are generally capable of sustaining more species and individuals. The streams listed above which possess the largest areas of unprotected riparian habitat include the:

- San Pedro River;
- Agua Verde Creek;
- Sabino Canyon;
- Agua Caliente Wash;
- Tanque Verde Wash; and
- Arivaca Creek.

The effluent-dominated Santa Cruz River downstream of Tucson also has a long, nearly continuous riparian area associated with year-long discharges of treated sewage. These discharges are significant for many migratory bird species.

Infrastructure planning in the metropolitan area could reduce water stress to:

- Tanque Verde Creek;
- Rincon Creek;
- Sabino Creek; and
- Cienega Creek.

Extension of reclaimed and potable water lines and substitution of renewable water for groundwater derived from these areas is needed.

Strategic purchases of land under Pima County's floodprone land acquisition and open space bond programs could reduce water demands and reduce fragmentation due to future development along high priority streams. Open space bonds have been approved for use along the

- Agua Caliente;
- Agua Verde;
- Tanque Verde
- Buehman;
- San Pedro;
- Sabino;
- Bear;
- Honey Bee; and
- Cienega watercourses.

There are a number of properties that are prone to flooding or bank erosion along:

- Sabino;
- Agua Caliente;
- Tanque Verde Creek; and
- Sutherland Wash.

2. Restoration

Need for restoration: "Restoration" is the effort to restore ecosystem structures and functions as they used to be at some point in the past. The need for riparian restoration was illustrated by the report entitled *Cocio Wash and the Gila Topminnow,* which chronicled how the intention to conserve a relic population of Gila Topminnow under current resource conditions was insufficient. As is true in most local riparian areas, and even in some upland areas, we have let the resource base degrade too far to expect project and site specific responses to stem losses, much less lead to recovery. The Gila Topminnow was considered to be among the most common of fishes in the Santa Cruz River system in the early 1940s. Three decades later it was considered endangered; and in another three decades time, its recovery is not foreseeable by the science community, given the piecemeal approach to protection efforts. Recovery efforts have been concentrated on federal land, but most perennial waters in the Southwest are controlled by private parties. Therefore, meaningful recovery will have to involve private parties, and will have to provide rewards for conservation efforts.

This theme was extended by the report entitled *Aquatic Vertebrate Conservation in Pima County* (Rosen, 2000). This report documents the tenuous position of native fish and frogs, which are primarily restricted to mountain headwater locations, due to the destruction of valley floor populations and incursion of non-native, predatory aquatic organisms. Without restoration of valley-floor source populations, the small, isolated populations in mountainous regions will be vulnerable to extinction.

Guidelines for restoration: To allow for full ecological restoration, biologists working toward recovery of riparian bird species have recommended these general guidelines:

1. Restore the diversity of fluvial processes, such as movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plains, that allow a diverse assemblage of native plants to co-exist.

2. Restore necessary hydrogeomorphic elements, notably shallow water tables and flows of water, sediments, and nutrients, consistent with the natural flow regime.

3. Restore biotic interactions, such as livestock herbivory, within evolved tolerance ranges of the native riparian plant species.

4. Re-introduce extirpated, keystone animal species, especially keystone species such as beaver, to appropriate sites within their historic range.

3. Revegetation

Guidelines for Use of Effluent for Riparian Benefits: Effluent derived from wastewater treatment plants will be an important source of water for restoration efforts. Water supplies that can be turned on or off, or at least re-routed to allow drying up of habitat, are ideal for elimination of various exotic fish species that may invade (or be illegally introduced into) re-establishment sites. Thus, effluent, reclaimed water, and highly managed waters in general, offer a key opportunity for multi-species recovery of our native wetland fauna. This opportunity is not readily available in natural water systems, because they are too difficult to regulate, divert, or turn on and off. The Science Team developed some guidelines intended to assist evaluation of the biological benefits of the use of effluent and reclaimed water for the Sonoran Desert Conservation Plan.

1. Protect systems that are self-sustaining over those that need continual inputs.

2. Restore or enhance native riparian and aquatic ecosystems by releasing water to restore local aquifer conditions.

3. If plantings are to be used: revegetation is favored in areas where perpetual irrigation will not be needed.

4. Enhance the ability of secondary effluent or reclaimed water to support aquatic life.

5. Manage riparian and aquatic ecosystems for native species.

4. Opportunities for Improved Riparian Conditions

Irrigated projects: The major opportunities for irrigated revegetation projects are where infrastructure exists to bring irrigation water and where undeveloped land is available. These areas are primarily along the:

- Santa Cruz River;
- lower Rillito Creek; and
- vicinity of the CAP aqueduct.

Discharge projects: The major opportunities for discharge or aquifer restoration projects are where renewable water infrastructure exists and where hydrogeologic conditions are favorable. Watercourses with favorable hydrogeologic conditions to restore localized aquifers are those reaches which possess an extensive low-permeability layer at a shallow depth:

- Pantano Wash;
- Ventana Wash;
- Sabino Canyon;
- Tanque Verde Creek;
- Agua Caliente Wash; and
- portions of the Santa Cruz River.

Removal of existing surface water diversions could restore flows to parts of:

- Cienega Creek;
- Sopori Wash;
- San Pedro River;
- Tanque Verde Creek; and
- Lemmon Creek and Arivaca Creek.

Reintroduction of species: In *Aquatic Vertebrate Conservation in Pima County* (Rosen 2000), development of various Tucson Basin core re-establishment sites is proposed so that (1) leopard frogs and other amphibians and reptiles may disperse from one site to another during especially good and wet years and thus maintain a metapopulation structure, (2) the metapopulation structure also permits occasional immigration-emigration exchange between the valley floor and surrounding mountain canyons, (3) fish are positioned in habitats in the landscape at which they can be expected to weather flooding and drying events. The Lower Santa Cruz River receives discharge of treated sewage from Tucson. Continued groundwater pumping and existing hydrogeologic conditions minimize the potential for the aquifer to rise to levels where the roots of riparian trees could reach. Allowing recharged effluent to mound to the surface would be a concern where landfills occur. For these reasons, the Lower Santa Cruz River is not deemed an opportunity for aquifer restoration. Nonetheless, the existing in-stream flows create valuable riparian habitat for many wildlife species, particularly migratory birds. Aquatic invertebrate communities in the effluent-dominated Santa Cruz River contain only organisms tolerant of poor water quality conditions (USGS, 1998). At present, native fish and frogs are not known to use the effluent-dependent reach of the Santa Cruz River. Water-quality and other habitat improvements could improve the usefulness of the flows to wildlife.

Removing non-natives: To restore natural biotic interactions, Rosen (2000) also recommends removing certain non-native vertebrates in:

- Canada del Oro;
- Youtcy;
- Espiritu;
- Paige;
- Romero;
- Sabino;
- Bear;
- Cienega;
- Agua Caliente; and
- Tanque Verde watersheds.

Reconstructing flow patterns -- The large spring at Agua Caliente Park presents a unique restoration opportunity. The spring flow is impounded to create three or more large ponds in a setting reminiscent of Quitobaquito Springs at Organ Pipe Cactus National Monument, where about 15,000 desert pupfish thrive in about 1/10th the water volume. The substantial spring flow could be used to create more stream-like conditions suitable for the support all of the most critically-declining or endangered wetland vertebrates of the Tucson Basin--pupfish, topminnow, chub, leopard frog, and garter snake--and all in potentially substantial numbers. The spring should be capable of providing a very great linear extent of the habitat type need by the most endangered species--pupfish and topminnows. Bullfrogs are not known to thrive in flow-dominated, small-channel habitat types (as opposed to deep pools, ponds, and lakes, where they do thrive), and thus native lowland leopard frogs, Sonoran mud turtles, and Mexican garter snakes could also exist.

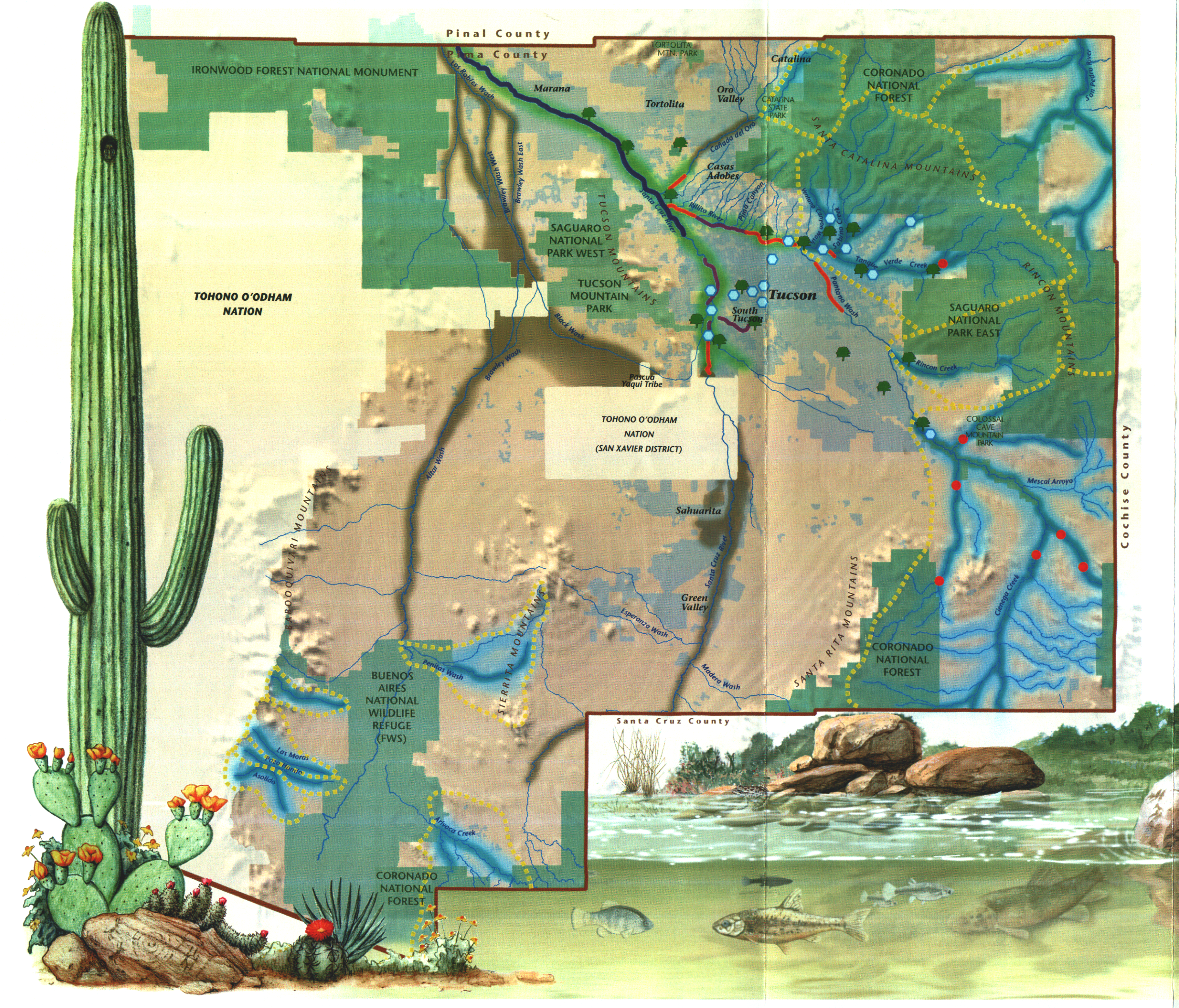
VI. Conclusion --Preliminary Reserve Alternatives

One century ago Morton Chamberlain concluded his landmark *Survey of Arizona Fishes* with a discussion and summary that stated: "The general causes of extinction of fish life now operative in this region may be outlined in this manner: (1) destruction of vegetation; (2) irrigating operations; and (3) mining operations." He also offered this prediction: "So long as the present climatic conditions remain, and the existing industries are prosecuted, I see no means of restocking these streams." "The only hope for fish in this region," said the very first fish biologist in Arizona, "lies in the pond culture."

It will take at least as long to repair the riparian resource base as it has taken to bring it to its current state of disrepair. The attached *Preliminary Riparian Protection, Management and Restoration Element,* with its science based prescriptions for protection, restoration, revegetation and improvement measures, is a beginning. Certainly, one hundred years of ignoring the voice of science in this area of resource protection has been a century too long.

Sonoran Desert Conservation Plan

Riparian Conservation



- Effluent based Riparian Projects
- Stream based Potential Native Fish & Frog Projects
- Spring based Potential Native Fish & Frog Projects
- High Priority Riparian Protection Areas
- High Priority Watershed Boundaries
- Opportunities for Future Revegetation Projects
- Retain/Restore Natural Flood Plain
- Existing River Parks
- Future River Parks
- Effluent Dominated Reach
- Urban/Private Property
- Existing Reserves
- Indian Nation

Riparian Protection, Management and Restoration
An Element of the Sonoran Desert Conservation Plan

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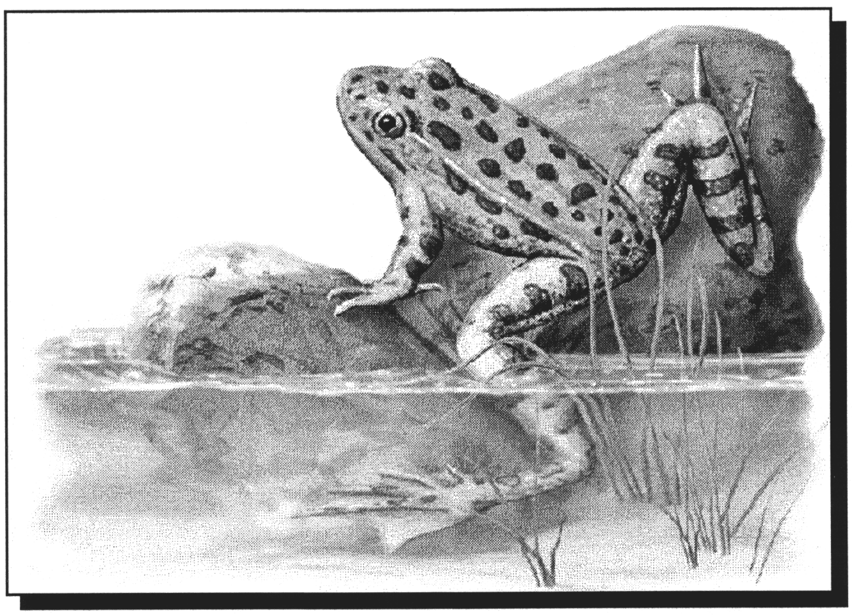
CHIRICAHUA LEOPARD FROG



Riparian Protection, Management and Restoration --An Element of the SDCP

1. The Lay of the Land

The major watersheds in Pima County generally slope northwest toward the Gila River (Figure 1) Exceptions occur in the Tohono O'odham Nation and in Western Pima County, where a few watercourses flow south toward the Gulf of California. Although our streams seldom actually flow into the Gila River, our native fish fauna was derived from the Gila River system.

For the purposes of the SDCP, Pima County has been divided into "subareas" (Figure 2). Subareas are not watersheds per se, however many subarea boundaries correspond to various watershed features.

The San Pedro subarea includes most portions of the San Pedro River watershed within Pima County.

The Cienega-Rincon subarea includes all of the Pantano watershed up to the Rincon Creek confluence, as it occurs within Pima County. It includes Cienega Creek and Rincon Creek, and a tiny watershed near the Whetstone Mountains which flows toward the San Pedro River.

The Upper Santa Cruz subarea, is the Santa Cruz watershed from the Santa Cruz county line to Martinez Hill, which is the prominent saguaro-studded volcanic hill along Interstate Highway 19.

The Middle Santa Cruz subarea is the Santa Cruz River watershed from Martinez Hill north to the confluence of the Canada del Oro Wash. The unit includes the foothills of the Tucson and Catalina Mountains, and the Tanque Verde Creek.

The Tortolita subarea includes all the watersheds that drain the Tortolitas, as well as a portion of the Canada del Oro watershed. The western boundary is the drainage divide between the Santa Cruz River and Los Robles Wash.

The Avra Valley subarea includes the Brawley Wash north of the Schuk Toak boundary, as well as portions of north-ward flowing watersheds near the Silverbell Mountains.

The Altar Valley subarea include the Arivaca watershed. It also includes a few southward-flowing watersheds near Sasabe.

The Tohono O'odham subarea includes the Aguirre and Santa Rosa watersheds and the San Simon watershed. Tribal lands in this subarea are excluded from the plan.

Western Pima County includes four separate watersheds: the Midway, Childs Valley, San

Cristobal and Rio Sonoyta. All but the Rio Sonoyta watersheds are tributary to the Gila River.

Because the characteristics of riparian areas can change dramatically from place to place within a subarea and even along a single stream, this document emphasizes analysis by watersheds based on individual streams.

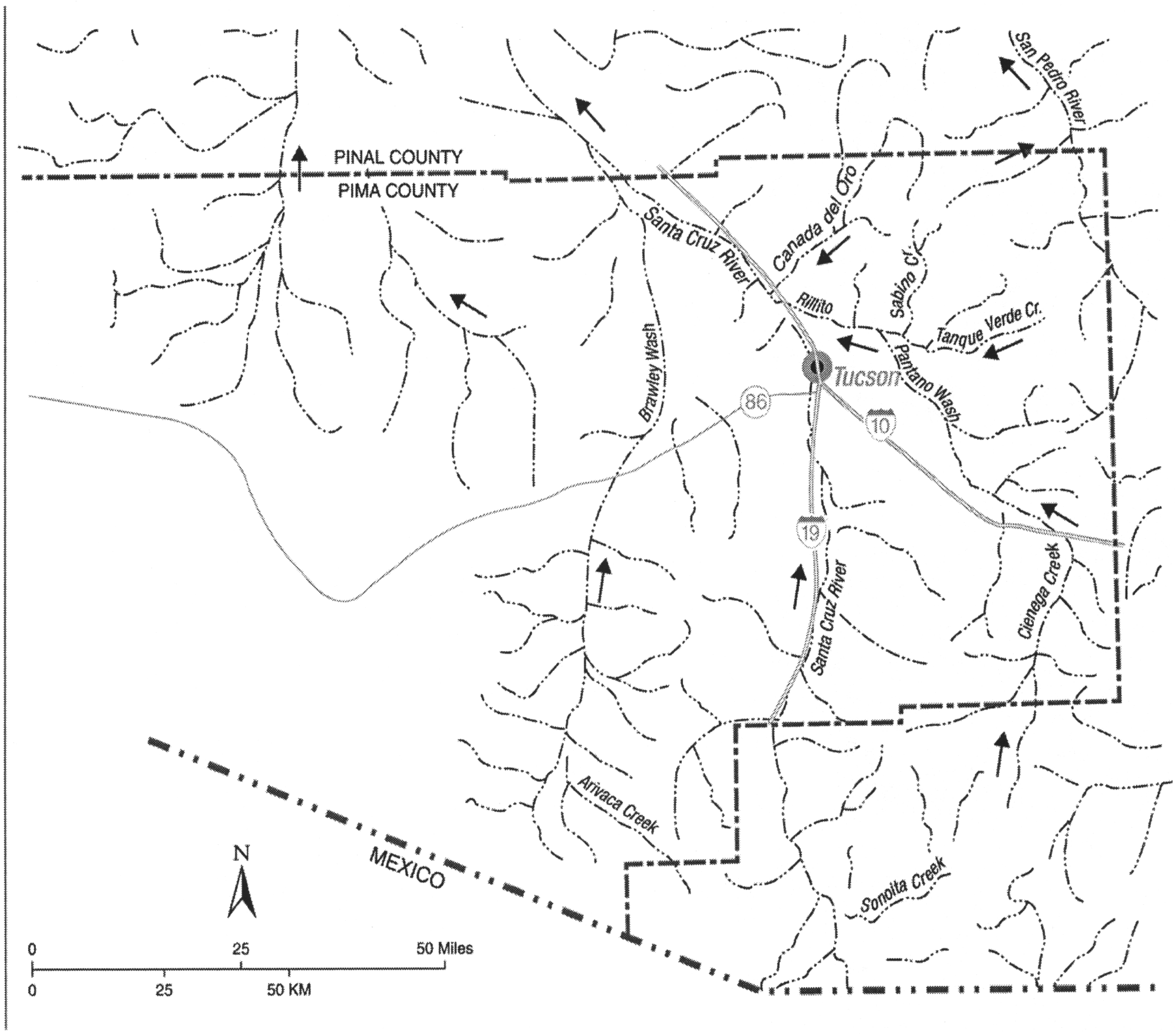


Figure 1. Major Watercourses in Eastern Pima County

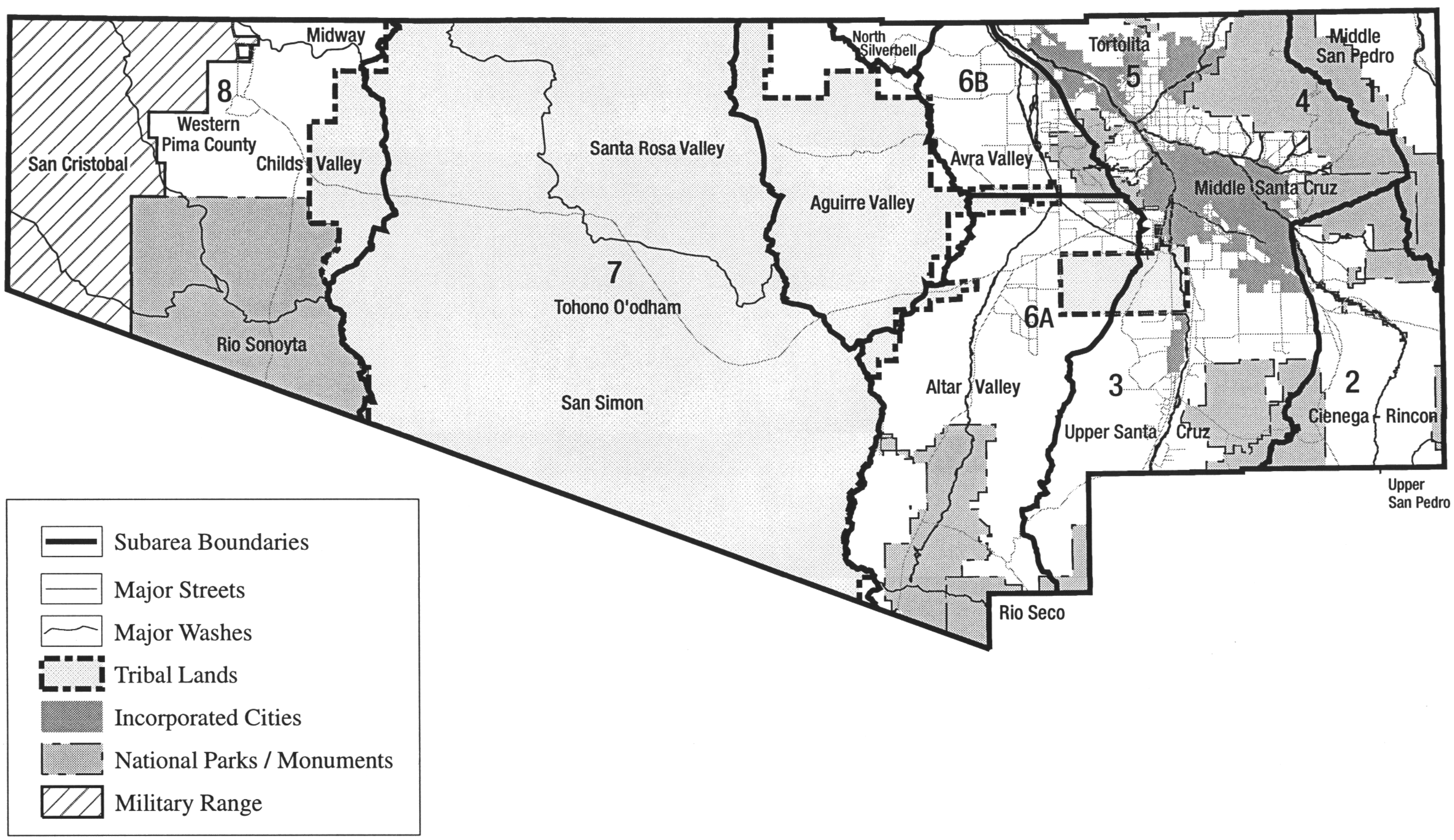


Figure 2

SUBAREAS OF PIMA COUNTY

1. Middle San Pedro
2. Cienega-Rincon
3. Upper Santa Cruz
4. Middle Santa Cruz
5. Tortolita
6. Avra-Altar
   A. Altar Valley
   B. Avra Valley
7. Tohono O'odham
8. Western Pima County

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2. Riparian Habitat Defined

The word "riparian" originates from a Latin word meaning "along the river". Here, in the semi-arid western United States, it means along a watercourse, arroyo, seep, pond, or other location where the availability of water is increased. The community of the watercourse, its vegetation and its wildlife are collectively referred to as a riparian area. Riparian vegetation is the vegetation that grows along streams, dry washes, seeps, ponds, and other places where the availability of water is higher than the uplands. The term as used herein includes areas with standing or flowing water, i.e. the aquatic ecosystem.

"Habitat" is not the same as vegetation. It refers to all of the things an organism needs to survive. So, it is specific to an animal's or plant's needs. Riparian habitats could include the barren sand bars where lizards run, the little holes along the banks where swallows nest, or the pools of water where toads breed after the summer rains. Habitat also includes the vegetation types and structure that provide food and shelter to an organism. So, for instance, cavities in large riparian trees are habitat for certain birds, but not others.

3. Watercourse Functions

Water and sediment transport roles

Watercourses serve as passageways for water to travel downhill. The channel carries most of the water, but when precipitation is too high, the channel is insufficient and the water spreads out over the floodplain (Figure 3). The natural function of floodplains is to dissipate energy during floods and to store sediment in between floods. If the flood's energy cannot be spread over the floodplain, it is concentrated in the channel and bank erosion or downcutting ensues. Channelization, bank protection and levees can diminish overbank flooding and cause the loss of riparian habitat. Watercourses and their floodplains are also important places for storage of sediment.

Watercourses are also the areas where the most natural storage and recharge of groundwater occurs. The beds of the watercourses tend to be sandy in the valley and the underlying soils are usually capable of allowing water to permeate. In general, when the flows are relatively slow and broad, infiltration occurs most effectively. Water that infiltrates is slowly released in the form of perennial or intermittent flow, or stays in the aquifer.

Biological roles

Riparian areas have been called "streams of life" and "lifeblood" of the desert. Approximately 60 to 75% of Arizona's resident wildlife species are dependent on riparian habitats to sustain their populations, yet these riparian areas occupy less than 0.5% of the state's total land (ARC, 1994). Riparian areas are among the most productive ecosystems in the world and they may be the highest, rivaling our best agricultural lands, in the production of living matter (ARC, 1994). In times of intense heat and drought, riparian areas are even more critical to providing food and shelter for wildlife. During low rainfall years, bottomlands along normally dry desert streams produce three to five times the amount of vegetation that uplands do (NRCS, n.d.).

It is only along watercourses with plenty of water that trees such as cottonwood, willow or bulrush can grow (Figure 3). Some of the vegetation, such as cattails and bulrushes, must be in water or moist soil all the time, while other vegetation such as willow can reach downward to get water through its roots.

Cottonwood trees have very particular needs in order to germinate. Established trees can reach downwards for water, but establishment of new trees requires floods that spread out onto the floodplain at a time when the seeds are viable in the spring, and then the water retreats leaving dry soil on the surface and water close to the surface. This happens only in years when the conditions are right. If the channel has become deeply incised and there is no floodplain to inundate, cottonwood seedlings have difficulty becoming established, although some may get started in the channel only to be eliminated in the next flood. Mesquite can grow in upland areas, but grows much larger along watercourses where its roots can reach down for water.

Saltcedar (tamarisk), a non-native tree, is not nearly as particular and can easily become established if there is flowing water at some time during the year, so is liable to competewith the cottonwoods for water and take over a watercourse that does not have a natural flow regime.

Watercourses may also provide relatively safe corridors for wildlife and since so many of the riparian areas and wetlands in eastern Pima County have been lost or degraded, the remaining ones have even greater importance. Even unvegetated watercourses provide better travel corridors than do city streets for some species.

<u>Water quality roles</u>

During flow events, nutrients are washed into the watercourses from the surrounding uplands. In the long periods between flows, the riparian zone slowly gives back nutrients to the less productive surrounding desert in the form of algae, insects, and plant growth.

Another role that vegetated washes serve is in improving water quality. Storm water runoff from urban areas often contains a mixture of petroleum products from vehicles and other kinds of pollution from materials dumped on the streets. Sewage effluent contains other pollutants. As the water runs off, much of that pollution will reach the main watercourses and some will reach the groundwater through recharge. If the runoff occurs relatively slowly along vegetated washes, the vegetation and sediment in the stream helps to capture and transform some of the pollution, minimizing the risk to groundwater quality.

Flood waters also flush accumulated salts downward below the root zone, thus preventing a long-term accumulation of salts which could inhibit plant growth.

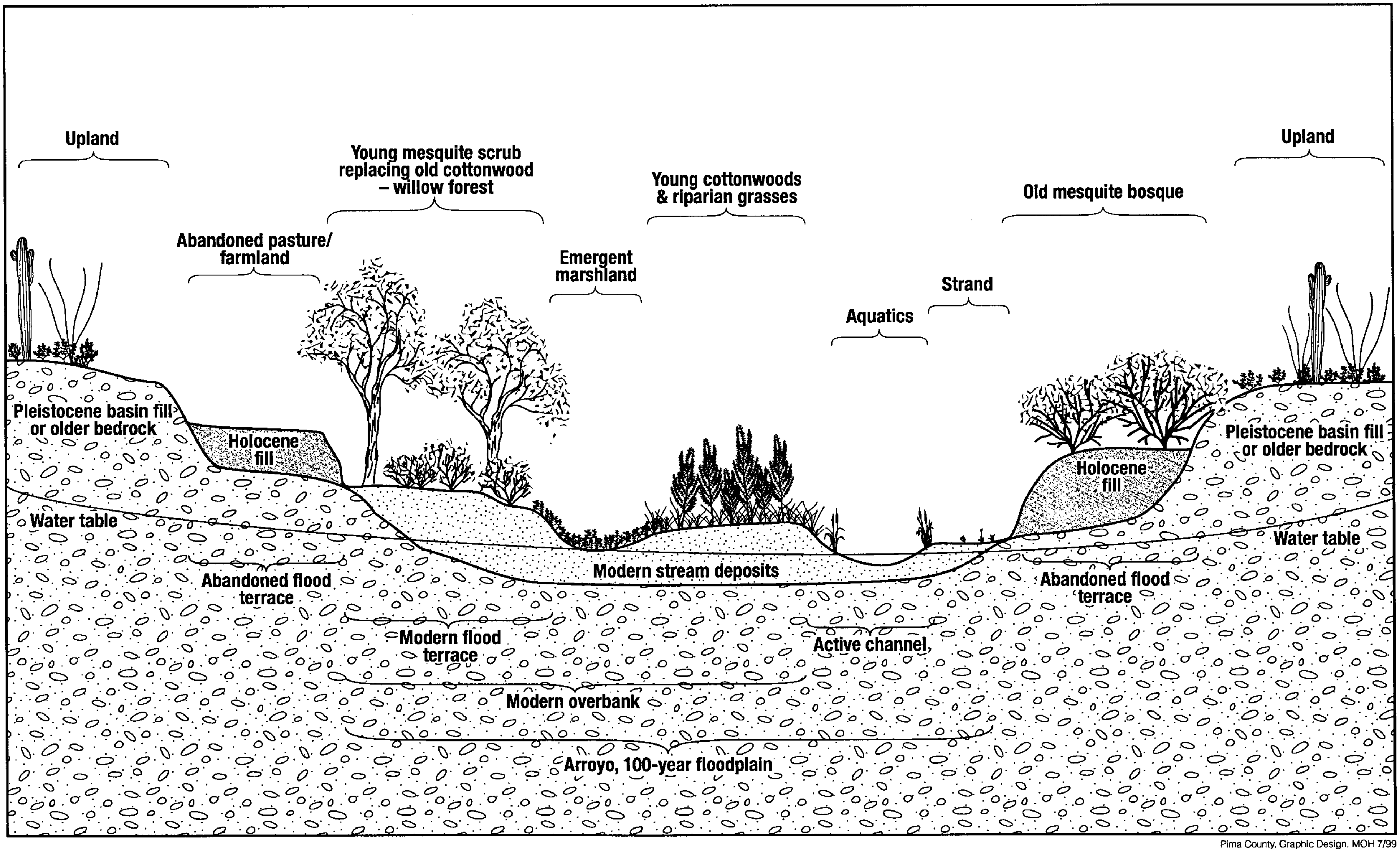


Figure 3

Riparian plant communities along a gaining reach, point-bar setting. (modified after Brown 1982)

Recreational and social roles

Watercourses can play important values for humans. The linear trails along the Santa Cruz and Rillito River are popular biking and jogging routes for people, away from the city streets. Some of these trails have been landscaped to increase their appeal. The watercourses with riparian areas provide another kind of recreational value, especially popular with bird watchers and hikers. Pima County's Cienega Creek Preserve, for example, offers a very pleasant environment for humans as well as for many kinds of wildlife. Sabino Canyon is one of Tucson's most popular retreats because of its beauty, serenity, coolness, and wildlife viewing. The dry washes offer another kind of recreational opportunity which many people enjoy, especially when such a wash is preserved within a neighborhood. Sometimes watercourses can serve to unite a community which appreciates and enjoys them. The value of these opportunities cannot be given in economic terms, but they may benefit the human community enormously.

4. Biological Goals

Technical teams of experts in the areas of science, law, economics, cultural resources and ranch issues were formed in 1999 to provide guidance to Pima County in their respective areas of expertise, and to produce and evaluate technical information. Each team has produced goal statements to guide its activities. The Science Technical Advisory Team (STAT) has adopted the following goal for the Sonoran Desert Conservation Plan:

The biological goal of the Sonoran Desert Conservation Plan is to ensure the long-term survival of the full spectrum of plants and animals that are indigenous to Pima County through maintaining or improving the habitat conditions and ecosystem functions necessary for their survival. Inherent within this broad goal are several objectives:

1. Promote recovery of federally listed and candidate species to the point where their continued existence is no longer at risk.

2. Where feasible and appropriate, re-introduce and recover species that have been extirpated from this region.

3. Maintain or improve the status of unlisted species whose existence in Pima County is vulnerable.

4. Identify biological threats to the region's biodiversity posed by exotic and native species of plants and animals, and develop strategies to reduce these threats and avoid additional invasive exotics in the future.

5. Identify compromises to ecosystem functions within target plant communities selected for their biological significance and develop strategies to mitigate them.

6. Promote long-term viability for species, environments and biotic communities that have special significance to people in this region because of their aesthetic or cultural values, regional uniqueness, or economic significance.

To further these overarching biological goals, the STAT has adopted these specific riparian ecosystem function goals:

1. To the extent possible, maintain or restore the connection between interdependent components of river systems: channel, overbank floodplain, distributary flow zones, riparian vegetation and connected shallow groundwater.
   a. maintain or restore natural flooding and sediment balance;
   b. preserve or re-establish connections between channels and their floodplains, and channels and their distributary flow zones;
   c. maintain or re-establish hydrologic connections between riparian and aquatic ecosystems and shallow groundwater zones.

2. Manage uplands as appropriate to protect the functioning of riparian and aquatic ecosystems within the watershed;

3. Manage point-source and non-point source pollution to maintain water quality at a level needed to support SDCP biological goals;

4. Insure sufficient instream flows to achieve and protect natural functions of riparian and aquatic ecosystems.

The STAT early on determined that riparian areas would be an important component of the Sonoran Desert Conservation Plan. Ongoing investigations by the consultants and County staff continue to explore the relationship between river conditions and the degree of biological impacts in forthcoming reports, and improve the base of our knowledge of the location and significance of these areas.

5. <u>Availability of Water</u>

The report entitled *GIS Coverages of Perennial Streams, Intermittent Streams, and Areas of Shallow Groundwater* was prepared by the Pima Association of Governments (PAG) as part of the Sonoran Desert Conservation Plan. This work was undertaken to fill a data gap which would otherwise affect the quality of biological evaluations. PAG's work identifies springs and streams in Pima County and classifies surface flow according to the United States Geological Survey definitions. As a result of the PAG study, fifty-five perennial stream reaches and eighty-two intermittent stream reaches were identified for 74 different streams (Figure 4). The identifications were based on literature research, aerial photographic interpretation, previous mapping, field notes of experts, and limited field investigation by PAG staff.

The report defined streams to include springs, ponds, pools, wetlands, rivers, and washes. United States Geological Survey distinctions apply so that:

- a perennial stream is one that has continuous flow;
- an intermittent stream is one that has flow at certain times of the year; and

- an ephemeral stream has a channel above the water table, and flows only in direct response to precipitation.

Shallow groundwater (Figure 5) was defined for purposes of the report as being within 50 feet of the land surface. This definition is based on the assumption that groundwater at this depth can sustain existing mesquite bosques. Nearly one hundred potential shallow groundwater sites are listed within the report. A technical advisory team prioritized which of the potential shallow groundwater sites would be mapped. Many of the larger, more threatened zones were mapped using a combination of aerial photographic and topographic interpretation, and review and mapping of groundwater level information from various agencies, including Tucson Water and the Arizona Department of Water Resources.

The report entitled *Springs in Pima County* (May 2000) continued this line of investigation and followed up on a recommendation in the March 2000 *Land Cover Data Assessment* by defining, discussing, and documenting the current information about springs in Pima County. The report identifies over 250 springs in Pima County (Figure 6).

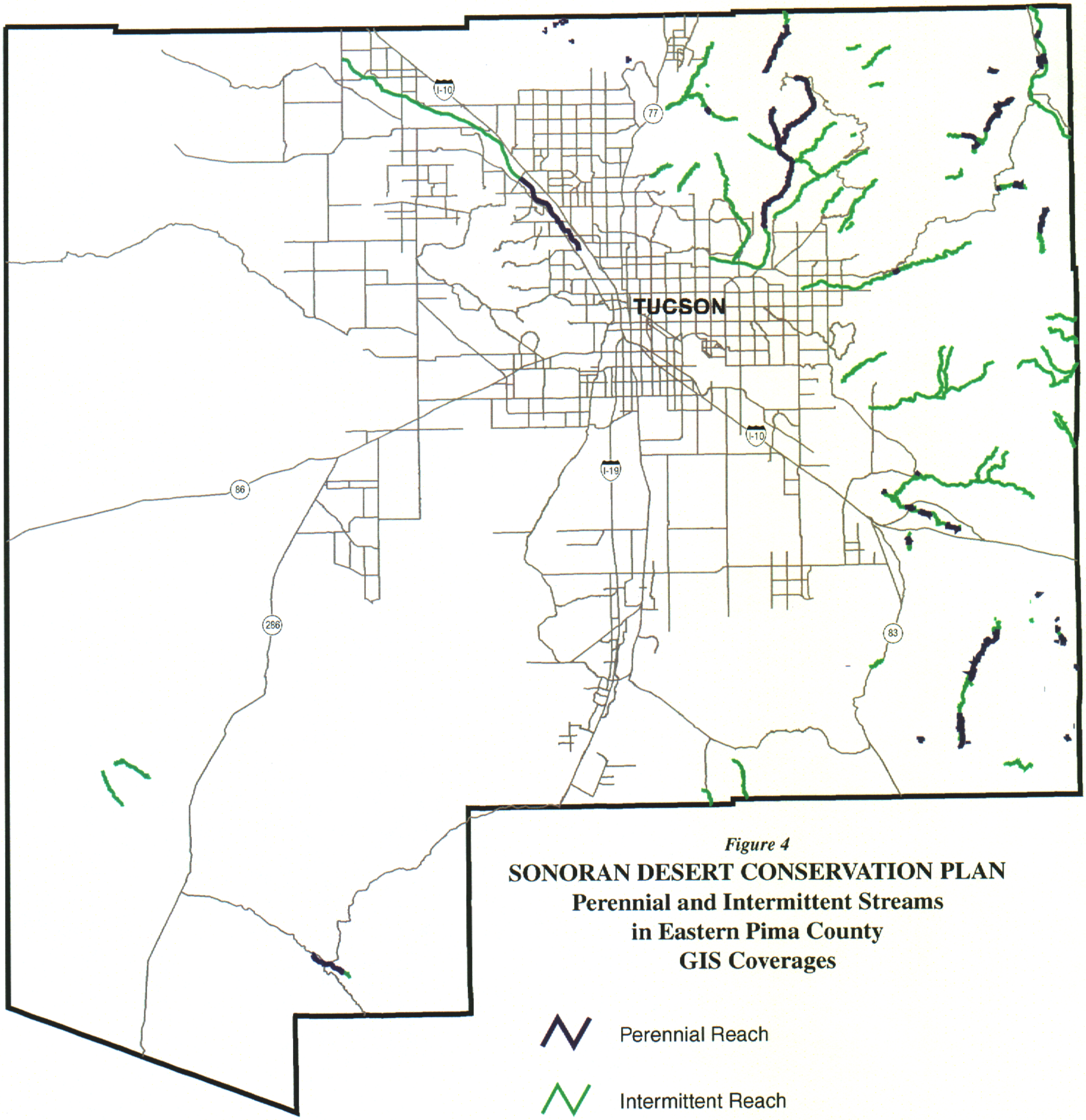


Figure 4

SONORAN DESERT CONSERVATION PLAN
Perennial and Intermittent Streams in Eastern Pima County GIS Coverages

Perennial Reach

Intermittent Reach

Major Street or Highway

N

6 0 6 12 18 Miles

January 2000

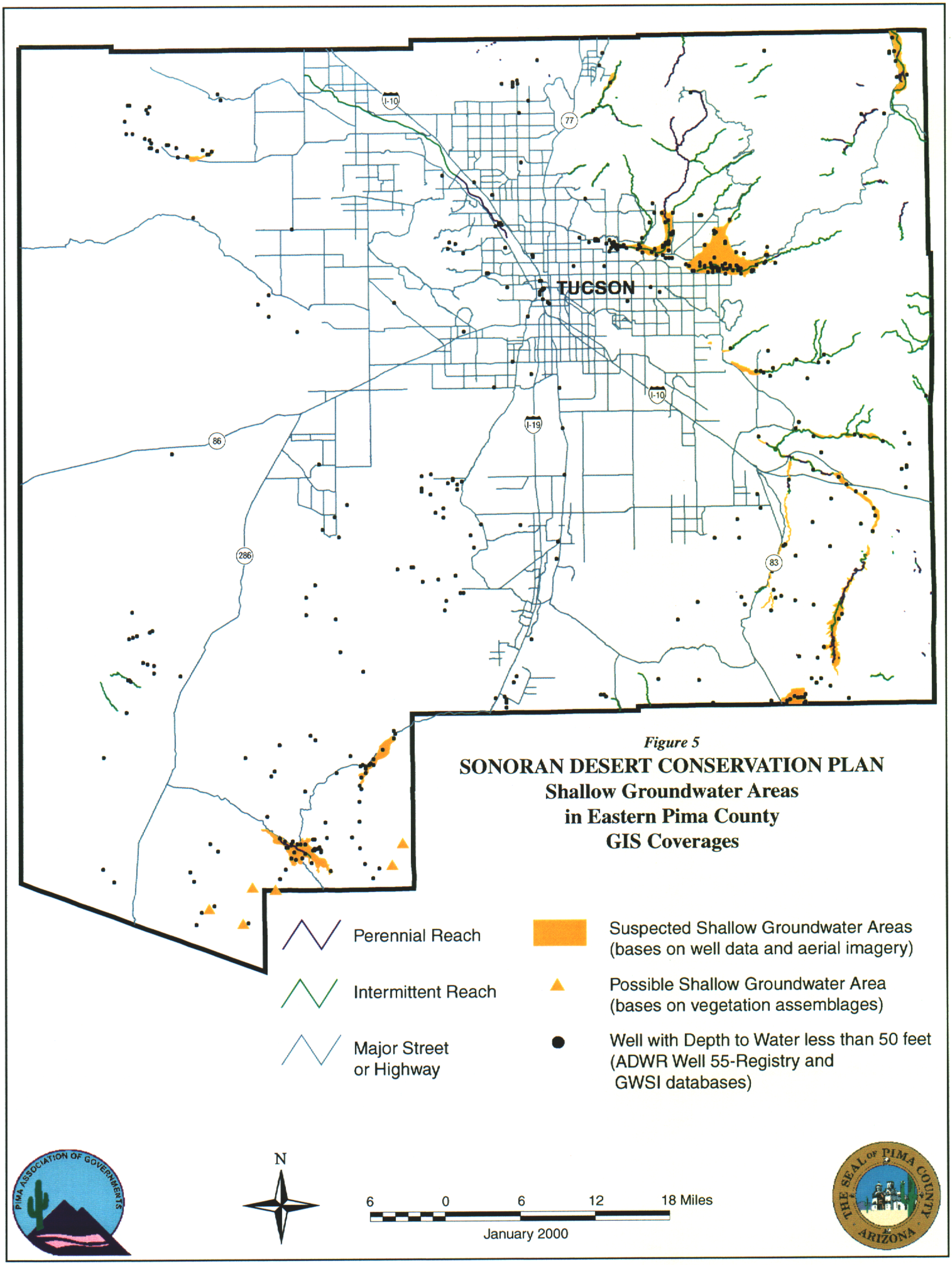
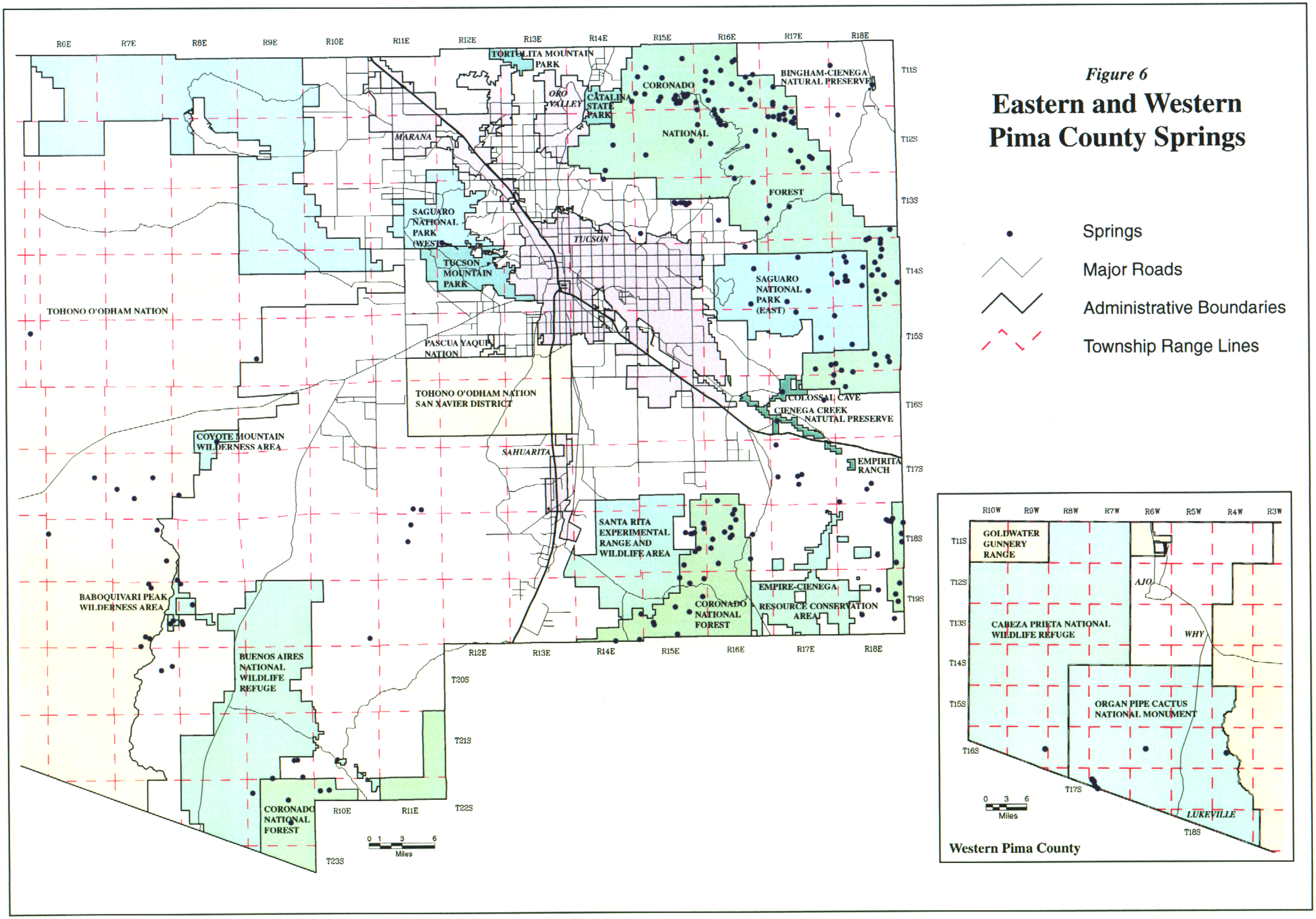


Figure 5

SONORAN DESERT CONSERVATION PLAN
Shallow Groundwater Areas
in Eastern Pima County
GIS Coverages



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6. Riparian Vegetation Communities

Xeroriparian vegetation grows in areas where stormwater flows provide additional moisture, such as in ephemeral stream channels (PCFCD, 1994). Mesquite and acacia are typical xeroriparian trees or shrubs.

Mesoriparian vegetation is generally found along intermittent watercourses or where groundwater is close to the surface. Mesquite and sycamore-ash trees are examples of this type of vegetation.

Hydroriparian vegetation is generally found along perennial watercourses or wetlands. The vegetation is dominated by wetland plants and trees such as willow or cottonwood that need large amounts of water supplied for long amounts of time. While this is the least common riparian community type, it is vitally important for the life cycles of many specialized forms of wildlife. Mature and immature stands of these trees provide different functions for wildlife, and both are important.

In the Tucson area, most hydromesoriparian vegetation occurs in the Tanque Verde, Sabino and Agua Caliente valleys. Meso- and hydroriparian plants use water stored underground for their life cycles. Many of these plants die if the water table declines below their root zones (ADWR, 1994).

Availability of water and elevation are among the most significant factors affecting the distribution of different riparian plant communities. A cross-section of the relationship of different riparian plants and geomorphic settings to the water table is shown on Figure 3.

The types of riparian vegetation found in various subareas is shown on Table 1. Table 1 was compiled based on the author's field knowledge. Not all of the series in Table 1 are represented in the composite land cover map developed for the SDCP. The riparian maps under development for the SDCP will classify riparian vegetation to the biome level, which is grosser than the list in Table 1.

Table 1
CHARACTERISTICS OF RIPARIAN COMMUNITIES PATCH SIZE, GLOBAL RANGE, MATRIX AND DISTRIBUTION

GAP Vegetation Biome	Vegetation Series or Association	Patch Size	Global Range	Matrix Community	Subareas (SDCP)								
					1	2	3	4	5	6A	6B	7	8
143.1 Semi-desert grassland	Tobosa-scrub	Linear, width varies	Limited: shared with few ecoregions	Grassland-scrub			X	?				X	
	Sacaton-scrub	Broad, linear	Restricted to Chihuahuan ecoregion	Grassland-scrub		X				X			
154.1 Sonoran Desertscrub	Blue palo verde-Ironwood	Linear, width varies	Restricted to Sonoran ecoregion	Desertscrub			X		X	X	X	X	X
	Saltbush	Broad	Limited, shared with few regions	Desertscrub				X	X			?	X
	Burrobush	Linear, width varies	Limited: shared with few regions	Desertscrub		X	X	X	X	?	X	?	
223.2 Interior Riparian Deciduous Forest and Woodland	Mixed broadleaf	Narrow, linear	Restricted to Chihuahuan ecoregion	Encinal, pine-oak woodland, conifer forest	X	X	X	X	X	X		?	
224.5 Sonoran Riparian and Oasis Forest	Cottonwood-willow	Linear, width varies	Limited: shared with several other ecoregions	Desertscrub, grassland-scrub	X	X	X	X	X	X			X
234.7 Sonoran Deciduous Swamp and Riparian Scrub	Mesquite bosque	Linear, width varies	Mesquite bosque is restricted to Sonoran ecoregion	Desertscrub	X	X	X	X	X	X	X	?	
243.5 Madrean Marshland	Cattail	Small, extremely localized	Limited: shared with few regions	Encinal, grassland-scrub		X		X					
244.7 Sonoran Marshland	Cattail	Small, extremely localized	Widespread	Desertscrub	X	X		X	X	X			X

Source: J. Fonseca, field observations

Blue palo verde / ironwood riparian vegetation can be found in most subareas. The biological significance of the shade, thermal refuge and high productivity provided by xeroriparian trees such as mesquite, ironwood, catclaw acacia, and blue palo verde may be highest in the hottest, most arid subareas.

Madrean mixed broadleaf riparian vegetation, such as sycamore or alder forest, does not occur in Western Pima County or the Avra Valley subarea, due to climatic factors. These last two subareas are hotter and drier than the others.

Sacaton grassland is a vegetation type that occurs in floodplains at higher elevations. Much of the sacaton grassland that once existed in Pima County has been lost. Today it is restricted to the Altar and Cienega-Rincon subareas. Tobosa grassland is another vegetation community that occurs in floodplains, but at lower elevations. It occurs on the Tohono O'odham Nation and in swales in the vicinity of the State Prison, but it is not mapped.

Cienega wetlands are another land cover type that were formerly more numerous. They were located along axial streams with perennial to intermittent flow. Today they are primarily restricted to headwaters of major streams, where flow persists. These are called the "cattail" series in Table 1, but they may consist of many other species of plants.

Wet meadows also occurred at high elevations in the mountain, fed by springs. No montane wetlands are mapped in the SDCP's composite land cover map. Although clearly there are many springs at high elevations (Figure 6), most of them are developed with tanks and pipelines. The degree to which any support wetlands is unknown.

The saltbush vegetation community occurs preferentially in the fine-grained bottomland soils of the low desert. These areas have been preferentially developed for agriculture, so that today, there is very little remaining saltbush community occurring outside protected areas. An remnant example of this community occurs inside Christopher Columbus Park in Tucson.

On the basis of a June 1999 review of existing information, the Science Technical Advisory Team (STAT) determined that a special effort would be needed to improve the accuracy of riparian vegetation classification and delineation. Existing sources of information are out of date, have significant mapping and classification errors, do not depict plant species and plant structure or overlook riparian areas.

Harris Environmental Group was selected to improve the quality of available riparian mapping. They are mapping vegetation communities at the biome level. The draft maps will be completed in September 2000. Field reconnaissance will be used to determine the locations of cottonwood-willow stands and mesquite bosques.

Keeping in mind inadequacies in the knowledge of riparian community distribution, there is probably sufficient information to suggest that the cottonwood-willow, mixed broadleaf, and the sacaton communities are found mainly outside of reserves managed primarily for biodiversity (Connolly et al, 2000). Cattail marshlands and saltbush areas , on the other hand, are probably well-represented in reserves managed primarily for biodiversity, such as Organ Pipe Cactus National Monument, Buenos Aires National Wildlife Refuge and Bingham Cienega Natural Preserve.

7. Sources of Loss--Past and Future

In the last 100 years, most of Arizona's low-elevation riparian areas have been altered or destroyed by human activities (ARC, 1994). Little more than a century ago, portions of the Santa Cruz River, Tanque Verde Creek, Pantano Wash, Rillito Creek, and San Pedro River flowed year round in Pima County (Hendrickson and Minckley, 1986). As previously documented in Pima County's *Water Resources and the Sonoran Desert Conservation Plan,* many plant and wildlife species that use riparian areas, and more particularly, groundwater-dependent riparian zones, are threatened with extinction or regional elimination.

Watershed deterioration (soil loss, sedimentation, vegetation changes) due to overgrazing, direct loss (encroachment) of wildlife habitat and surface water diversions have been the primary biological stresses to riparian ecosystems in the past. Watershed deterioration has affected virtually all subareas. Encroachment of low desert riparian areas by urban and agricultural use is more common than encroachment of mid to high elevation zones. Surface water diversions are more localized, and affect primarily aquatic and hydromesoriparian systems. Surface water diversions currently deplete base flows of the San Pedro River and Cienega Creek, as well as many small springs.

Aquatic and riparian systems which have suffered from habitat loss and surface water diversions can be restored over time, if the hydrologic processes are left intact. Hydrologic processes include overbank flooding, sediment erosion and deposition, and availability of shallow groundwater to the root systems of native plants. The rate of restoration is somewhat dependent on the availability of water, with wetlands responding more quickly than infrequently flooded areas.

Major future threats to riparian system functions are groundwater pumping and non-indigenous species. Groundwater pumping is continuing to eliminate a wide range of dependent aquatic and riparian habitats. Non-native species are severely impairing the ability of native species to use aquatic and riparian habitats. Both of these impairments are difficult to reverse.

<u>Non-indigenous species</u>

Non-indigenous species were brought into riparian areas for food (catfish, bullfrogs), bait (scuds, crayfishes, shad, shiners and other minnows, tiger salamanders), and for biological control of aquatic weeds and insect pests (tilapia, mosquitofish). They appeared as unintentional contaminants with other organisms (bullfrogs), or when presumably discarded from home aquaria (a perpetual problem at Agua Caliente Park) or as unused bait and escapees from aquaculture (some shiners). Many non-native plants were introduced for erosion control or livestock forage (tamarisk, Johnson grass).

Sabino Canyon and Arivaca Creek are examples of sites impaired by non-native animal species, but virtually all aquatic ecosystems are threatened by invasive non-native species such as bullfrogs, sunfish and crayfish. Tamarisk is a common woody riparian species along the effluent-dominated Santa Cruz River and the San Pedro River.

One species from an unknown source is the Asiatic clam which clogs irrigation canals and conduits--it is in CAP water and is unknown in the Tucson Basin, except at Kennedy Park, which it was probably introduced with non-native fish brought in to provide urban fishing opportunities. African clawed frogs occur in golf course ponds at Arthur Pack Park.

Some non-indigenous animals, such as the zebra mussel and the aquatic plant called Salvinia, now spreading rapidly in eastern and central United States, can be transported nearly anywhere. These and other organisms stocked in adjacent states have ready access through interstate waters such as the Colorado or Gila rivers mainstreams. From there, they can disperse statewide through artificial interbasin connections like the CAP.

Whatever the case, second to habitat loss and disruption, NIS have been deemed by some as the most important current danger to what remains of Arizona's indigenous aquatic biota (Minckley 1991). Unlike physical/chemical ecosystem changes induces by humans, which can often be corrected or at least ameliorated, naturalized non-indigenous species are difficult to control and some may be impossible to eradicate.

The potential for the Central Arizona Water Project (CAP) to introduce non-native species to the Santa Cruz watershed has prompted a consultation with U.S. Fish and Wildlife Service. Non-native fish could threaten the continued existence and recovery of endangered species such as the Gila topminnow. The Gila topminnow occurs in the Santa Cruz River near Tubac and the Cienega Creek at the Empire Ranch.

The Endangered Species Act requires that the U.S. Fish and Wildlife Service (FWS) be consulted when a project involving federal government action is to be taken. The construction of the Central Arizona Project (CAP) by the U.S. Bureau of Reclamation (USBR) is one such action.

The status of the CAP with respect to endangered species is still unresolved. In 1994, USBR and FWS worked out a set of measures to protect endangered and threatened native fish species in the Gila River watershed, excluding the Santa Cruz watershed.

These measures included: 1) construction of fish barriers, basically concrete structures on channels that would impede the upstream movement of fish; 2) maintenance of existing electrical fish barriers; 3) monitoring fish populations in the CAP aqueduct; 4) funding control of non-native fishes; and 5) an education program regarding the impacts of non-native aquatic species. Similar measures will probably be required in the Santa Cruz watershed, however U. S. Fish and Wildlife Service has not yet rendered its opinion.

The USBR has not proposed fish barriers to protect the Cienega Creek because of the grade-control structure at Pantano Wash and Broadway and the diversion dam on the Cienega Creek. These structures would impede the upstream movement of fish during the times when flows might connect Cienega Creek with other streams in the Tucson Basin. Similar structures do not protect the Tanque Verde watershed, where native fish still occur.

Active control of selected species and community education are sorely needed. With management of bullfrogs and exotic fish, it may be possible to expand the range of native fish and frogs. Development of policies for water body construction and management and dissemination to the government and private sectors would help to reduce the extent of new problems. Careful consideration needs to be given to the location and use of raw (untreated) CAP water. If native fish and frogs are to be reintroduced to the Tucson Basin, design and operational measures are needed to minimize the potential for non-native organisms in raw (untreated) CAP water to become established in our stream. Physical barriers to prevent the spread of water-borne pests will be needed in some instances. CAP discharges off-channel could raise the water table to the point where certain stream reaches begin to flow, while minimizing the chance of introducing non-indigenous species.

Groundwater pumping and surface -water diversions

Pima Association of Governments (2000b) compiled information on groundwater withdrawals and surface water diversions near perennial streams, intermittent streams, and shallow groundwater areas previously identified by PAG for the SDCP. The Arizona Department of Water Resources (ADWR) well registry and reported annual groundwater withdrawals were the primary data sources for this project. ADWR also provided ArcView GIS shapefiles for water companies and other potential water users, and water pumpage data for small water providers and large municipal water providers. Detailed findings are summarized in the report entitled *Water Usage Along Selected Streams in Pima County, Arizona.*

Most of the perennial and intermittent streams and shallow groundwater areas had at least one well located within one mile. Twenty-four streams had no wells within a mile. These were primarily in remote areas outside the Tucson AMA and along rugged mountain slopes. Sites with no registered wells within one mile are upper Bear Canyon, Bear Creek, Bootlegger Spring, Bullock Canyon, Canada del Oro, Deer Creek, East and West Forks Sabino Creek, Edgar Canyon, upper Espiritu Canyon, Honey Bee Canyon, Lemmon Creek, Palisade Canyon, Peck Basin, Quitobaquito Spring and Pond, Romero Canyon, Smitty Spring, Sycamore Canyon, Unnamed Spring, and Youtcy Canyon. These areas are presumably associated with little or no groundwater pumpage.

The streams and shallow groundwater areas with the highest annual reported pumpage within one mile are the Santa Cruz River, Tanque Verde Creek, Sabino Canyon, Ventana Canyon, Agua Caliente Wash, and Rillito Creek. Streams with relatively moderate annual reported pumpage within one mile are Arivaca Creek, Rincon Creek, Chiminea Creek, Madrona Creek, Pantano Wash, and Box Canyon. Annual reported pumpage does not include "exempt" wells, which are wells that pumps that extract water at a rate less than 35 gallons per minute.

Several areas outside the Tucson AMA have no reported groundwater pumpage, but a comparatively high number of registered wells. These areas are San Pedro River, Barrel Canyon, Mud Spring, portions of Davidson Canyon, Gardner Canyon, upper Cienega Creek, portions of lower Cienega Creek, and Sopori Wash. Groundwater usage in these areas is presumably relatively high, because of the large number of wells. There are no requirements for measuring and reporting groundwater pumping outside Active Management Areas. There are also several areas within the Tucson AMA which have little or no reported pumpage, but have a relatively high number of registered wells within one mile. These areas are Canada Agua, portions of Agua Verde Creek, portions of Davidson Canyon, portions of lower Cienega Creek, and Box Canyon.

Companies with the highest annual pumpage within one mile of a stream or shallow groundwater area are Tucson Water, Metropolitan Domestic Water Improvement District, Forty-Niner Water Company, and Cortaro-Marana Irrigation District. Figure 7 shows the distribution of non-exempt wells in northeast Tucson relative to stream channels and water company boundaries. Access to CAP water or reclaimed water might help some of these water companies reduce groundwater withdrawals or limit future increases. Tucson Water, Vail Water Company, Town of Marana, Metro

Water, Flowing Wells Irrigation District, Oro Valley Water Company and Spanish Trail Water Company have CAP allocations. Reclaimed water lines are located in or comparatively close (less than 2 miles) to the majority of the water users identified in this project.

Table 2 compares pumping from exempt wells versus non-exempt wells along some of the more biologically sensitive streams. Because groundwater pumping is not reported for exempt wells, an annual rate of 1 acre-foot per year was assumed. Along streams in the northeast Tucson Basin, non-exempt wells probably remove more water from the aquifer than do exempt wells. Along Arivaca Creek, pumping by exempt wells probably has a proportionally greater effect on the local groundwater budget.

Table 2. Pumping within one mile of perennial or intermittent stream reaches or shallow groundwater zones

Area Name	Avg. ann. reported pumping from non-exempt wells (acre-feet)	Number of exempt wells (no pumping data)	Potential pumping from exempt (1 acre-feet/yr assumed)	Total estimated pumping within one mile (acre-feet)
Agua Caliente shallow groundwater area	3069	156	156	3225
Arivaca Creek	98	88	88	186
Lower Sabino Creek	3603	111	111	3716
Lower Tanque Verde	3479	120	120	3599
Ventana Canyon	1054	46	46	1100

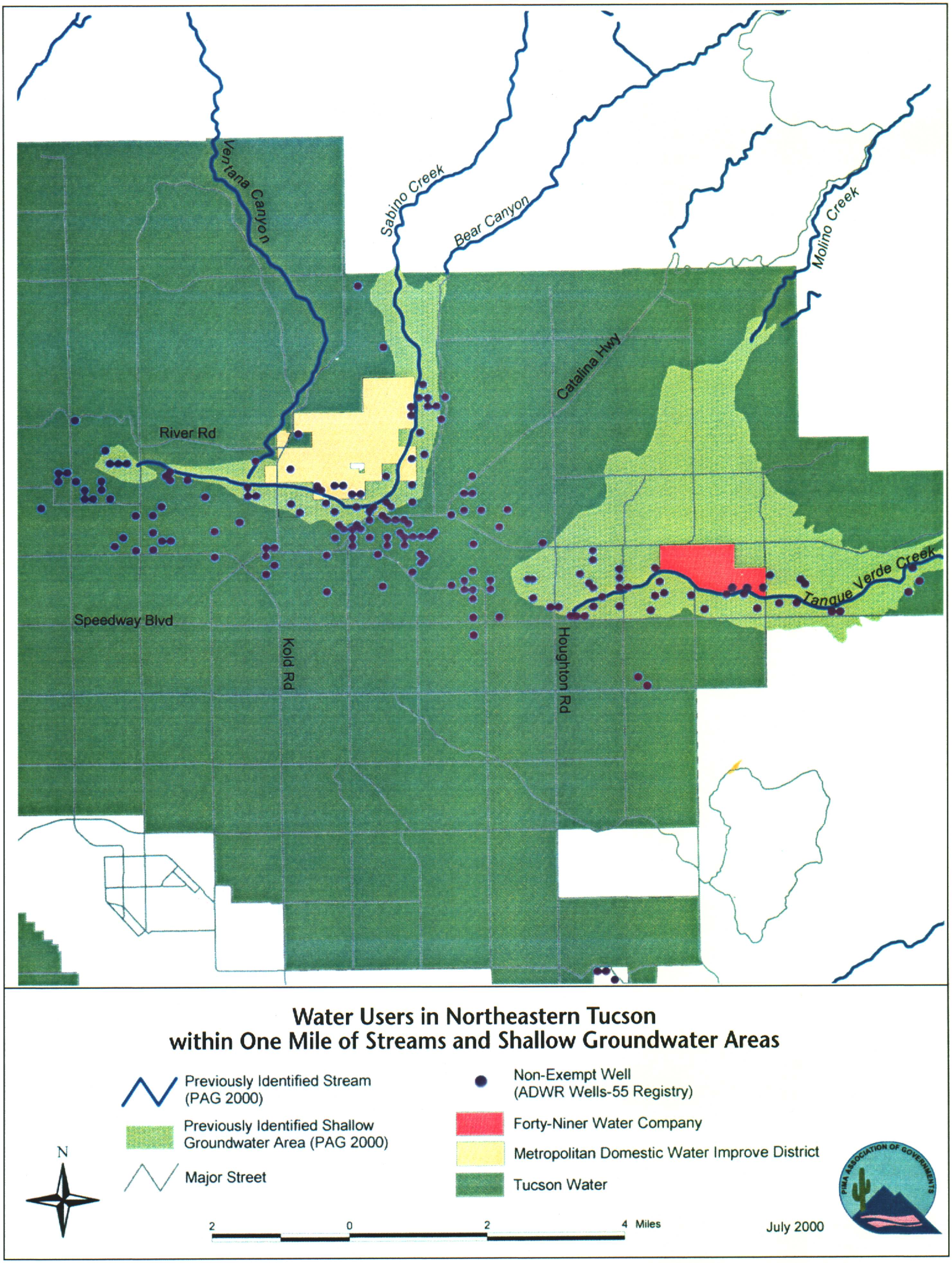
Ventana Canyon
Sabino Creek
Bear Canyon
Molino Creek
Catalina Hwy
River Rd
Speedway Blvd
Kolb Rd
Houghton Rd
Tanque Verde Creek
Water Users in Northeastern Tucson
within One Mile of Streams and Shallow Groundwater Areas
Previously Identified Stream
(PAG 2000)
Previously Identified Shallow
Groundwater Area (PAG 2000)
Major Street
Non-Exempt Well
(ADWR Wells-55 Registry)
Forty-Niner Water Company
Metropolitan Domestic Water Improve District
Tucson Water
N
2
0
2
4 Miles
July 2000
PIMA ASSOCIATION OF GOVERNMENTS

Figure 7

Continuation of the current development pattern in the Arivaca area could cause dramatic increases in pumping from exempt wells. A local citizen's group has projected the maximum potential build-out allowable under existing zoning in the Arivaca area (AWET, 2000). Under current zoning, an additional 2177 residences could be built in the Arivaca Valley, resulting in an estimated usage of 1026 acre-feet of groundwater annually (An acre-foot of water is enough to cover one acre with one foot of water. This estimate was based on assuming an annual rate of 0.42 acre-feet/well per family). Most of this use would occur in a portion of the Tucson Active Management Area where CAP water is not available.

Streams with known surface water diversions are Cienega Creek, the San Pedro River, Arivaca Creek and the Santa Cruz River. The entire perennial base flows of Cienega Creek and San Pedro River are diverted for golf course and pasture use, respectively. A small portion of the effluent flows of the Santa Cruz River are diverted for pasture use. Arivaca Lake impounds 1037 acre-feet of runoff in the Arivaca Creek watershed for recreation purposes. One study suggested the lake decreases downstream recharge by 1500 acre-feet annually (Heller, J., 1999). In addition, springs that feed the headwaters of Sabino Creek on Mount Lemmon are diverted for domestic water use in Summerhaven. City of Tucson has water rights to 9 million gallons a year from the springs; the U. S. Forest Service has rights to 10 million gallons a year (RECON, 2000).

<u>Loss of floodplain function</u>

In the urban periphery, continued loss of floodplain function is an additional future threat. Examples of areas where future man-made structures may cause large losses of floodplain functions:

Subarea 1: Roadway improvements to the San Pedro River Road may require channelization of tributaries, construction of concrete fords, and localized bank protection on the San Pedro River.

Subarea 2: Proposed levees along Rincon Creek will reduce overbank flood storage. Bank protection and channelization are proposed for portions of Pantano Wash adjacent to Vail Valley. Pantano Wash is the likely future source of aggregate for development in the area.

Subarea 3: Proposed development along the Santa Cruz River threatens to remove overbank storage. Consequent increases in peak discharge downstream to the urban area may be costly. If growth is directed to the distributary flow areas in the southeastern part of the Tucson Basin, flood peaks and erosion potential may increase. Advance planning and infrastructure commitments will be necessary to develop these areas without threatening Old Nogales Highway and increasing erosion of Lee Moore Wash.

Subarea 4: Encroachment and channelization of tributaries to the Santa Cruz River in the southeastern part of the Tucson Basin will decrease overbank storage and increase erosion potential. Extension of sewer interceptors along erodible stream banks will increase the need for bank protection. Continued channelization of Agua Caliente Wash and Tanque Verde Creek will increase peak flows downstream, and impair the natural development of cottonwood-willow and mesquite forest. Development of River Road may require elimination of the last remaining distributary flow zone in the Rillito Valley, at Finger Rock Wash.

Subarea 5: The Marana levee construction will remove overbank flood potential and increase the energy directed by flooding upon the Santa Cruz River channel. To develop behind the levee will require advance planning and infrastructure commitments for tributary drainage structures. Development of distributary flow zones on the Tortolita piedmont will increase the need for structures to convey water and sediment to the Santa Cruz River. Encroachment of Big Wash may remove overbank storage.

Subarea 6A: Increasing storage volume at the Arivaca Lake would further reduce flooding as a natural disturbance and would increase the proportion of runoff that evaporates without production of biomass. Development of distributary flow zones on the Sierrita piedmont will increase the need for structures to convey water and sediment to the Black Wash, which has one of the few large remaining mesquite woodlands in the area.

Subarea 6B: Further floodplain development could cause the loss of overbank storage on Brawley Wash and increased peak discharge from the development of distributary flow zones.

Subarea 7: Not evaluated.

Subarea 8: Expansion of Ajo to the east could cause the loss of distributary flow zones associated with Ten mile Wash and overbank storage along the Rio Cornez.

8. Wildlife and Riparian Areas

Species which formerly depended on riparian or aquatic habitats, but which no longer exist in Pima County include:

Scientific Name	Common Name
Ondatra zibethicus	Muskrat
Castor canadensis	Beaver[1]
Rana tarahumarae	Tarahumara Frog
Rhinichthys osculus	Speckled Dace
Catostomus clarkii	Desert Sucker
Catostomus insignus	Sonora Sucker
Cyprinodon macularius macularius	Desert Pupfish[2]
Tryonia protea	Desert Tryonia
Speyeria nokomis caerulescens	Blue Silverspot Butterfly

Anodonta californensis	California Floater (clam)
Eryngium sparganophyllum	Ribbonleaf Button Snakeroot
Dalea tentaculoides	Gentry Indigobush
Salvia amissa	Aravaipa Sage
Malaxis porphyrea	Malaxis Porphyrea (orchid)

1 This species may eventually expand into Pima County from other sites along the San Pedro River.
2 There are no longer natural populations of this species in Pima County. However, there are several populations in private ponds and aquariums, but no natural populations.

These locally extinct species indicate that losses of habitat occurred not just in the low desert perennial streams (Pupfish, Beaver), but also in mid and high elevation canyons (Speckled Dace, Gentry Indigobush), and in high elevation wetlands (Blue Silverspot Butterfly).

"Potentially covered" species are those for which an incidental take permit might be sought under the Endangered Species Act. Incidental take allows for some types of habitat destruction, direct mortality or other forms of harm to occur in the process of otherwise lawful activities when the effects of the taking are mitigated and minimized by agreed-upon conservation measures. The SDCP would allow permit holders to "take" individual endangered or threatened species incidental to otherwise lawful activities. The potentially covered species thought to need riparian areas are summarized by subarea in Table 3.

Table 3.

Scientific Name	Common Name
Choeronycteris mexicana	Mexican Long-tongued Bat
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)
Lasiurus ega	Southern Yellow Bat
Idionycteris phyllotis	Allen's Big-eared Bat
Lasiuris borealis	Western Red Bat
Sorex arizonae	Arizona Shrew
Empidonax traillii extimus	Southwestern Willow Flycatcher
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl
Pipilo aberti	Abert's Towhee
Vireo bellii	Bell's Vireo
Rana chiricahuensis	Chiricahua Leopard Frog
Rana yavapaiensis	Lowland Leopard Frog
Thamnophis eques megalops	Mexican Garter Snake
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail
Catostomus insignus	Sonora Sucker
Gila intermedia	Gila Chub
Cyprinodon macularius macularius	Desert Pupfish
Agosia chrysogaster	Longfin Dace
Poeciliopsis occidentalis occidentalis	Gila Topminnow

Catostomus clarkii	Desert Sucker
Lilaeopsis schaffneriana ssp recurva	Huachuca Water Umbel

Critical habitat for certain riparian-dependent species has been designated by U. S. Fish and Wildlife under the Endangered Species Act. Critical habitat for spikedaceand loach minnow has been designated in the San Pedro River Valley. Critical habitat for the ferruginous pygmy-owl also includes many riparian areas, the largest riparian corridor being the San Pedro River corridor.

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Watercourses associated with existing or very recently extirpated populations of native fish and frogs are listed on Table 4. This information was developed by Pima County by consulting expert knowledge, literature review and HDMS records, and will continue to be improved.

Table 4

Subarea	Stream Name	Native Fish	Leopard Frogs
1	Bullock Canyon	✔	✔
	Redfield Canyon	X	✔
	Edgar Canyon	✔	✔
	Youtcy Canyon	?	✔
	San Pedro River	✔	✔
	Buehman Canyon	✔	✔
	Espiritu Canyon	?	✔
	Bingham Cienega	?	✔
2	Chiminea Canyon	?	✔
	Box Canyon	?	✔
	Gardner Canyon	?	✔
	Rincon Creek	✔	✔
	Agua Verde Creek	?	✔
	Paige Creek	?	✔
	Madrona Canyon	?	✔
	Empire Gulch	?	✔
	Wakefield Canyon	✔	✔
	Mattie Canyon	✔	✔
	West Sawmill Canyon	X	✔
	Fish Canyon	X	✔
	Unnamed Spring (#173)	?	X
	Cinco Canyon	?	✔
	Posta Quemada Canyon	✔	✔
	Nogales Spring	✔	✔
	Cienega Creek (lower)	✔	✔
	Little Nogales Spring	✔	✔
	Cienega Creek (upper)	✔	✔
	Box Canyon (Santa Ritas)	X	✔
	Davidson Canyon	✔	✔

Subarea	Stream Name	Native Fish	Leopard Frogs
3	Florida Canyon	?	✔
4	Bear Canyon	?	✔
	Tanque Verde Creek	✔	✔
	Sabino Canyon	✔	✔
	Molino Canyon	?	✔
	Railroad Wash	X	✔
	Ventana Canyon	?	✔
	Rillito Creek	X	✔
	Pantano Wash	X	✔
	Santa Cruz River	?	✔
	Agua Caliente Canyon	✔	✔
5	Alamo Canyon (Catalinas)	X	✔
	Romero Canyon	X	✔
	Cargodera Canyon	?	✔
	La Milagrosa Canyon	?	X
	Montrose Canyon	X	✔
	Lemmon Creek	X	X
	Canada del Oro	✔	✔
	Santa Cruz River	?	✔
6A	Fresnal Wash	X	✔
	Puertocito Wash	X	✔
	Oak Tree (Altar Valley)	X	✔
	Altar Wash	X	✔
	Canoa Wash	X	✔
	Arivaca Creek	?	✔
	Presumido Canyon	X	✔
	San Luis Wash	X	✔
6B	Cocio Wash	?	✔
	Brawley Wash	X	✔
8	Quitobaquito Pond	✔	X
	Alamo Canyon	X	✔

Legend

✓ Yes X No ? Unknown

Springs occupy a tiny portion of the landscape but can support a disproportionate amount of the region's species. In Pima County, springs provide habitat for vulnerable species, such as the Quitobaquito Pupfish and a rare grass known as Box Canyon Muhly. Springs also serve as the remaining refugia for some species that were widespread at one time, such as the Chiricahua and Lowland Leopard Frogs. In the absence of other information or criteria, the*Springs* report identified known springs with these characteristics for conservation purposes:

- springs thought to have perennial flow
- springs known to have native fish, or suitable habitat for native fish

- thermal springs

Springs thought to have perennial flow

Agua Caliente Spring
Aguajita Spring
Bingham Cienega Spring
Box Spring
Busch Spring
Cold Spring
Flicker Spring
Green Spring
Huntsman Spring
Kingler Spring
La Cebadilla Spring
Little Nogales Spring
Lower Wakefield Spring
Mountain Spring
Nogales Spring
Papago Spring
Pidgeon Spring
Quitobaquito Springs
Scholefield Spring
Silver Spring
Simpson Spring
Unnamed spring
Unnamed spring
Unnamed spring
Wakefield Spring
Wild Cow Spring (Whetstones)
Wild Cow Spring (Santa Catalinas)

Springs known to have native fish, or suitable habitat for native fish

Agua Caliente Spring
Little Nogales Spring
Mountain Spring
Nogales Spring
Quitobaquito Springs
Unnamed Spring in Davidson Canyon
Wakefield Spring

Thermal Springs in Pima County, Arizona

Agua Caliente Spring
Mercer Spring
La Cebadilla Spring
Nogales Spring

The *Springs* report identifies a number of conservation actions that could be taken to protect springs, including the most obvious measure of ceasing spring water depletion or diversion where that is occurring. An improved database of spring information is needed. Management of non-native species is identified as a conservation need, as well as for biologic inventory of plants, aquatic invertebrates (especially snails) and vertebrates of springs, and flow monitoring.

9. Riparian Protection

Appendix A.1 displays the characteristics of streams which are proposed for protection or restoration by Pima County based on their physical or biological characteristics. A draft of this list was published in April 2000 in a report entitled *Prioritization of Streams for Conservation in Pima County*. The revised list in Appendix A.1 compares 150 streams based on new information that has been obtained since that time.

Comparing the watersheds to each other, the most imperiled river systems are:

Tanque Verde, where habitat losses are high and where continued or increased groundwater pumping impairs streamflow and shallow groundwater conditions;

Sabino Canyon, where groundwater pumping impairs streamflow, habitat losses are high, and exotic species are a problem;

Rincon Creek, where groundwater pumping for development may deplete a local aquifer which supports streamflow, and gravel mining may increase channel downcutting;

Arivaca Creek, where groundwater pumping, surface water diversion, water quality, and exotic species are impairing natural riparian functions;

Cienega Creek, where future groundwater pumping may deplete streamflow, where derailments along the railroad could contaminate the aquifer, and where non-native species could imperil the largest remaining Gila topminnow population.

Davidson Canyon, threatened principally by groundwater pumping and habitat loss. Future upstream mining could impair water quality.

Major opportunities for protection

The most important riparian areas to preserve are defined below in the context of preserving and augmenting the stability of native fish and frog populations. The priority streams have a high, natural availability of water and possess relatively unimpaired water quality. Only those streams which have part of their length outside core reserves are mentioned below as high priority for protection. To exclude core reserves is not to say that existing management is adequate to maintain or reintroduce native fish and frog populations. The point of this list is to focus on opportunities to improve land stewardship of the most threatened stream segments.

Subarea 1: The San Pedro River, Buehman, Edgar, Espiritu, Youtcy and Paige Canyons.

Subarea 2: Agua Verde Creek, upper Rincon Creek, Davidson Canyon, Cienega Creek, Wakefield, Posta Quemada, Gardner, Chimney, and Distillery Canyons.

Subarea 3: Sabino Canyon, Bear Canyon, Ventana Wash, Tanque Verde and Agua Caliente Creeks.

Subarea 4. None.

Subarea 5. Sutherland Wash.

Subarea 6A: Arivaca Creek, Las Moras, Pozo Hondo, Asolido, Thomas, Fraguita, Penitas.

Subarea 6B: None.

Subarea 7: Excluded.

Subarea 8: None.

Total riparian area is another fundamental biological parameter which is more relevant to terrestrial wildlife than to native fish and frogs. Larger areas are generally capable of sustaining more species and individuals. The streams listed above which possess the largest areas of unprotected riparian habitat include the San Pedro River, Agua Verde Creek, Sabino Canyon, Agua Caliente Wash, Tanque Verde Wash, and Arivaca Creek. The effluent-dominated Santa Cruz River downstream of Tucson also has a long, nearly continuous riparian area associated with year-long discharges of treated sewage. These discharges are significant for many migratory bird species. If not for the poor water quality and lack of connection to the groundwater table, the effluent-dependent Santa Cruz River downstream of the treatment sewage treatment plants would rate higher for protection. The STAT has emphasized protection of natural ecosystems over artificially sustained ones.

Infrastructure planning in the metropolitan area could reduce water stress to Tanque Verde Creek, Rincon Creek, Sabino Creek and Cienega Creek. Extension of reclaimed and potable water lines and substitution of renewable water for groundwater derived from these areas is needed. Without extensions of infrastructure, existing golf courses on Tanque Verde Creek will continue to utilize groundwater. The Rincon Creek restoration project and future golf courses associated with the Rocking K development may impose an additional 2000 acre-feet (af) of groundwater pumping in the Rincon Valley. Golf courses under construction for the Vail Valley development will use up to 1100 af surface water from Cienega Creek. Potable water needs and hence groundwater pumping will increase in these areas as developments approved by Pima County are built out, unless strategic decisions are made regarding the location and construction of new wells and pipelines.

The recovery of CAP water in Avra Valley by Tucson Water creates the opportunity to reduce the amount of water derived from high-priority streams. Tucson Water could shut off wells in the Tanque Verde Valley when CAP recovery begins. Tucson Water has already adopted a "last on, first off" policy for certain wells in the Tanque Verde Valley, in response to scientific information (Stromberg, et al., 1992) demonstrating the effects of groundwater pumping on the riparian plant communities there. Interties between the water delivery system of Tucson Water and Metropolitan Water Improvement District and Forty-Niner's Water Company could facilitate using CAP and groundwater derived from areas outside these more sensitive biological systems. The need of water companies to replenish groundwater or store reclaimed water could also create opportunities to store reclaimed water in the floodplain aquifers.

Pima County should consider whether further extensions of sewers along the priority streams listed above, especially Tanque Verde Creek, Rincon Creek, and Sabino Creek, are warranted. When sewers are placed next to erodible banks, bank protection is needed to protect this costly infrastructure. Unlike reclaimed and potable water lines, sewers flow by gravity and therefore have traditionally been placed next to stream channels. Sewer extensions also can facilitate increased water usage along streams because higher residential densities are permitted in sewered subdivisions than those with septic tanks. Conversion of septic tanks to sewers also directly reduces the availability of water to riparian vegetation, because septic tank leach fields return pumped groundwater to the soil near where the pumping occurs. Most of the water in sewers is discharged to the Santa Cruz River following treatment, rather than being returned to the watershed from which it was pumped.

Strategic purchases of land under Pima County's floodprone land acquisition and open space bond programs could reduce water demands and reduce fragmentation due to future development along high priority streams. Open space bonds have already approved for use along the Agua Caliente, Agua Verde, Tanque Verde, Buehman, San Pedro and Sabino, Bear, Honey Bee, and Cienega watercourses. There are a number of properties along Sabino, Agua Caliente, and Tanque Verde Creeks and Sutherland Wash which are prone to flooding or bank erosion. Acquiring certain properties along these watercourses with Flood Control District revenue could reduce the need for future flood and erosion hazard structures, and have biological benefits. Land and Water Conservation Funds might also be pursued for land acquisition.

10. Riparian Restoration

Definition

"Restoration" is the effort to restore ecosystem structures and functions as they used to be at some point in the past. Other terms such as "replacement" or "rehabilitation" should be used when there is no attempt to create an ecosystem similar to what was present prior to the activities that degraded the resources. For instance, the creation of artificially supported wetlands where none ever existed is not restoration. However, one could speak of restoring vegetation structure through artificial plantings, say, for certain riparian bird species along a watercourse, without restoring all of the other components of the riparian ecosystem (such as the aquifer and the flooding and erosion which used to create the vegetation structure).

Restoration efforts depend on establishing a "reference condition" that represents a place in time or space against which one can measure success (Falk et al, 1998). If the degree or range of variability in ecological processes and functions has been achieved to a level consistent with the reference condition, then we can say the area has been restored. A reference condition can be established using a description of ecological parameters at a location that exists today, or through study of past ecological conditions for a given parameter in the study watershed itself.

Need for Restoration

The need for riparian restoration was illustrated by the report entitled *Cocio Wash and the Gila Topminnow,* which chronicled how the intention to conserve a relic population of Gila Topminnow under current resource conditions was insufficient. As is true in most local riparian areas, and even in some upland areas, we have let the resource base degrade too far to expect project and site specific responses to stem losses, much less lead to recovery.

The Gila Topminnow was considered to be among the most common of fishes in the Santa Cruz River system in the early 1940s. Three decades later it was considered endangered; and in another three decades time, its recovery is not foreseeable by the science community, given the piecemeal approach to protection efforts. Recovery efforts have been concentrated on federal land, but most perennial waters in the Southwest are controlled by private parties. Therefore, meaningful recovery will have to involve private parties, and will have to provide rewards for conservation efforts.

This theme was extended by the report entitled *Aquatic Vertebrate Conservation in Pima County* (Rosen, 2000). This report documents the tenuous position of native fish and frogs, which are primarily restricted to mountain headwater locations, due to the destruction of valley floor populations and incursion of non-native, predatory aquatic organisms. Without restoration of valley-floor source populations, the small, isolated populations in mountainous regions will be vulnerable to extinction.

Guidelines for Restoration

To allow for full ecological restoration, biologists working toward recovery of riparian bird species have recommended these general guidelines:

(1) Restore the diversity of fluvial processes, such as movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plains, that allow a diverse assemblage of native plants to co-exist.

(2) Restore necessary hydrogeomorphic elements, notably shallow water tables and flows of water, sediments, and nutrients, consistent with the natural flow regime.

(3) Restore biotic interactions, such as livestock herbivory, within evolved tolerance ranges of the native riparian plant species. (Appropriate levels of livestock utilization will need to be determined on a site-by-site basis; in certain cases the utilization may be zero.)

(4) Re-introduce extirpated, keystone animal species, especially keystone species such as beaver, to appropriate sites within their historic range.

Biologists recognize that the potential for restoration success varies among sites with many physical, biological, and societal factors. Where possible:

(1) Fully restore these natural processes and elements by removing management stressors.

(2) Where full restoration by removal of stressors is not possible, modify the management stressors, by naturalizing flow regimes, modifying grazing regimes, removing exotic species, or removing barriers between channels and flood plains, for example, to allow for natural recovery.

(3) Take over processes such as plant establishment (e.g., nursery stock plantings) only if the above options are not available.

Some additional general recommendations:

(1) Focus restoration efforts at sites with the conditions necessary to

support self-sustaining ecosystems, and at sites that are connected or near to existing high quality riparian sites.

(2) Develop restoration plans that encompass goals, models, performance criteria, and monitoring.

(3) If mitigation is required, call for "up-front" mitigation (mitigation achieved prior to destruction/degradation of habitat)

Some specific recommendations dealing with water and channel management:

(1) Conduct regional planning to identify sites most suitable for riparian restoration upon the release of reclaimed water (effluent), ground water recharge, or agricultural return flows.

(2) Conduct regional assessments to determine the merits of dam removal as a riparian ecosystem restoration strategy.

(3) Secure operating agreements for dams that incorporate environmental flows, for example to allow for tree and shrub regeneration flows during wet years and maintenance (survivorship) flows at other times.

(4) Pursue options for restoring sediment flows to below dam reaches.

(5) Secure operating agreements to manage reservoir drawdowns in such a way as to allow for regeneration of desired plant species.

(6) Develop water use management plans for river basins that will sustain or restore shallow ground water tables and perennial stream flows.

(7) At appropriate sites, remove barriers that reduce the connectivity between channels and floodplains.

Some specific recommendations dealing with land management:

(1) Within grazed watersheds, coordinate and communicate to establish goal-consensus among land managers and to achieve grazing levels compatible with riparian restoration.

(2) Establish a series of livestock exclosures that encompass riparian lands and/or watersheds, to provide benchmarks against which sites managed for livestock production can be compared.

(3) Monitor reference sites and grazed sites for a wide variety of measures of ecosystem integrity, including stream channel morphology and plant cover, composition, and structure, in addition to direct measures of plant utilization.

Guidelines for Use of Effluent for Riparian Benefits

Effluent derived from wastewater treatment plants will be an important source of water for restoration efforts. For this reason, the STAT has developed some guidelines (see Appendix A.2) intended to assist evaluation of the biological benefits of the use of effluent and reclaimed water for the Sonoran Desert Conservation Plan. The STAT recognizes that on a site basis, decision-makers will need to weigh biological benefits of a project against such constraints such as presence of landfills and lack of infrastructure, as well as a diverse range of other economic and land use issues.

Overall, the STAT prioritizes protecting existing self-sustaining riparian and aquatic ecosystems over the creation of new or enhanced areas of riparian and aquatic life which depend on continuing inputs of water, energy and materials. This principle is embodied in the guidelines above, in Appendix A.2, and in the subcommittee evaluations provided of individual effluent-based projects in Appendix A.3.

Water supplies that can be turned on or off, or at least re-routed to allow drying up of habitat, are ideal for elimination of various exotic fish species that may invade (or be illegally introduced into) re-establishment sites. Thus, effluent, reclaimed water, and highly managed waters in general, offer a key opportunity for multi-species recovery of our native wetland fauna. This opportunity is not readily available in natural water systems, because they are too difficult to regulate, divert, or turn on and off.

Opportunities for improved riparian conditions

The major opportunities for irrigated revegetation projects are where infrastructure exists to bring irrigation water and where undeveloped land is available. These areas are primarily along the Santa Cruz River and lower Rillito Creek, or in the vicinity of the CAP aqueduct, and several local entities are considering constructing such projects (Figure 8). Because untreated CAP water can import new non-native organisms to our riparian areas, treated (chlorinated or filtered) CAP water is recommended for irrigation and recharge along watercourses where there are potential interconnections with flood flows.

The major opportunities for discharge or aquifer restoration projects are where renewable water infrastructure exists and where hydrogeologic conditions are favorable (Figure 9). Untreated CAP water has the potential to introduce non-native aquatic organisms. CAP discharges off-channel along the Santa Cruz River upstream of downtown Tucson could raise the water table to the point where certain reaches begin to flow, while minimizing the chance of introducing non-indigenous species.

Watercourses with favorable hydrogeologic conditions to restore localized aquifers are those reaches which possess an extensive low-permeability layer at a shallow depth: Pantano Wash, Ventana Wash, Sabino Canyon, Tanque Verde Creek, Agua Caliente Wash, and portions of the Santa Cruz River. Removal of existing surface water diversions could restore flows to parts of Cienega Creek, Sopori Wash, San Pedro River, Tanque Verde Creek, Lemmon Creek and Arivaca Creek.

In *Aquatic Vertebrate Conservation in Pima County* (Rosen 2000), development of various Tucson

Basin core re-establishment sites is proposed so that (1) leopard frogs and other amphibians and reptiles may disperse from one site to another during especially good and wet years and thus maintain a metapopulation structure. (a metapopulation is a group of subpopulations that support one another by exchanging immigrants and emigrants), (2) the metapopulation structure also permits occasional immigration-emigration exchange between the valley floor and surrounding mountain canyons, (3) fish are positioned in habitats in the landscape at which they can be expected to weather flooding and drying events. Figure 9 illustrates these ideas.

The Lower Santa Cruz River receives discharge of treated sewage from Tucson. Continued groundwater pumping and existing hydrogeologic conditions minimize the potential for the aquifer to rise to levels where the roots of riparian trees could reach. Allowing recharged effluent to mound to the surface would be a concern where landfills occur.

For these reasons, the Lower Santa Cruz River is not deemed an opportunity for aquifer restoration. Nonetheless, the existing in-stream flows create valuable riparian habitat for many wildlife species, particularly migratory birds. Aquatic invertebrate communities in the effluent-dominated Santa Cruz River contain only organisms tolerant of poorwater quality conditions (USGS, 1998). At present, native fish and frogs are not known to use the effluent-dependent reach of the Santa Cruz River. Water-quality and other habitat improvements could improve the usefulness of the flows to wildlife.

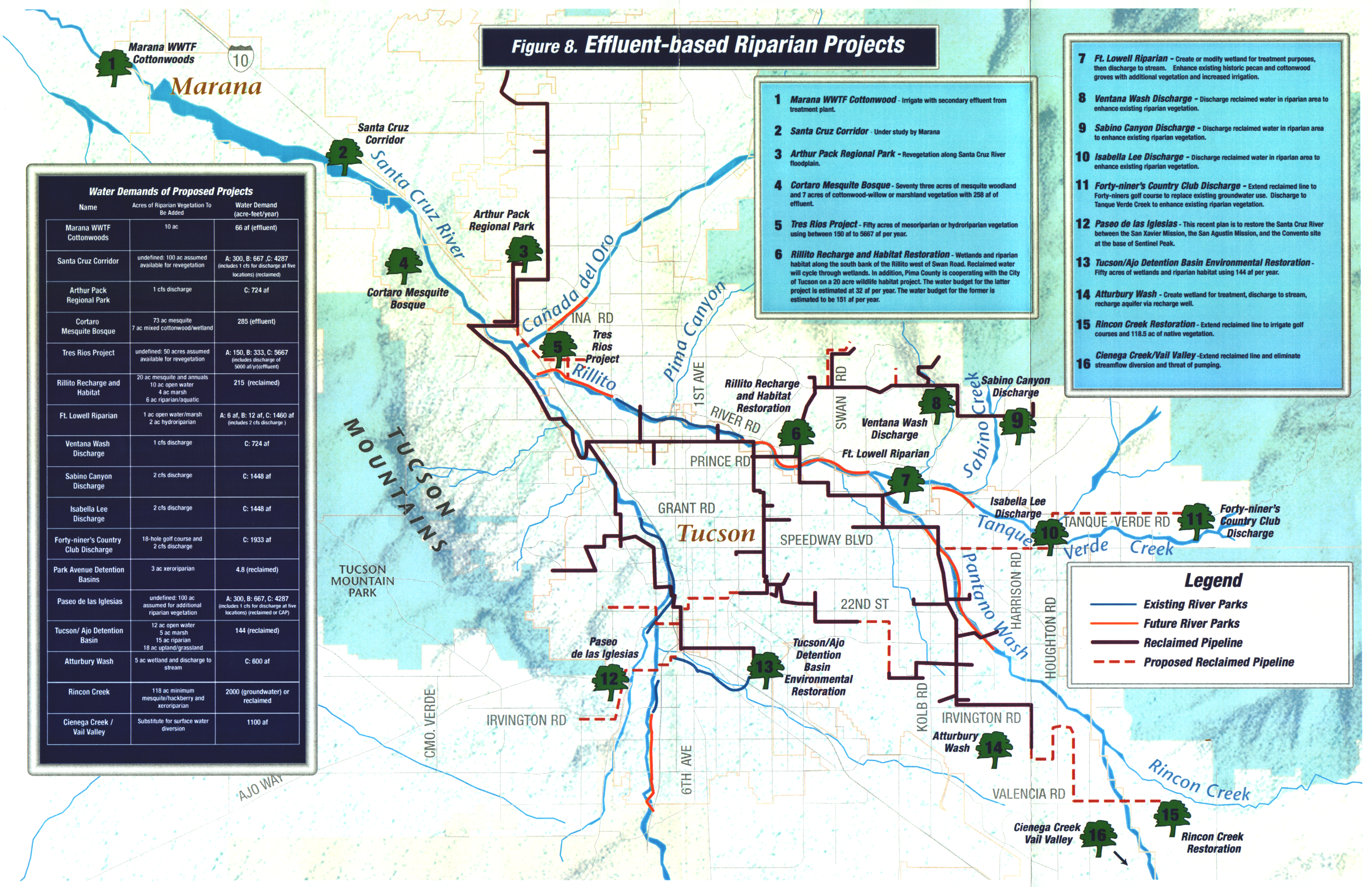
To restore natural biotic interactions, Rosen (2000) also recommends removing certain non-native vertebrates in Canada del Oro, Youtcy, Espiritu, Paige, Romero, Sabino, Bear, Cienega, Agua Caliente and the Tanque Verde watersheds.

The large spring at Agua Caliente Park presents a unique restoration opportunity. The spring flow is impounded to create three or more large ponds in a setting reminiscent of Quitobaquito Springs at Organ Pipe Cactus National Monument, where about 15,000 desert pupfish thrive in about 1/10th the water volume. The substantial spring flow could be used to create more stream-like conditions suitable for the support all of the most critically-declining or endangered wetland vertebrates of the Tucson Basin--pupfish, topminnow, chub, leopard frog, and garter snake--and all in potentially substantial numbers. The spring should be capable of providing a very great linear extent of the habitat type need by the most endangered species--pupfish and topminnows. Bullfrogs are not known to thrive in flow-dominated, small-channel habitat types (as opposed to deep pools, ponds, and lakes, where they do thrive), and thus native lowland leopard frogs, Sonoran mud turtles, and Mexican garter snakes could also exist.

In the uplands, damaged soils will take decades and even centuries to repair; however, this work must be undertaken to reverse watershed impairment. Gains in flood control can be made through proper grazing management in the watersheds upstream of urban areas, especially through implementing grazing plans that anticipate the natural occurrence of droughts. For instance, under the Emergency Watershed Program of the Natural Resources Conservation Service, livestock operators can be paid to move livestock out of land affected by drought declarations. In the future, use of the Emergency Watershed Program funds will require support from taxing entities, either Pima County or Pima County Flood Control District. This program is particularly needed in the Tanque Verde and Agua Caliente watersheds. These watersheds are upstream of various urban structures, have thin upland soils, and lie entirely in Pima County.

Grass banks are another tool which can be used to improve upland watersheds. Ranchers in the

Figure 8. Effluent-based Riparian Projects



1 ***Marana WWTF Cottonwood*** - Irrigate with secondary effluent from treatment plant.

2 ***Santa Cruz Corridor*** - Under study by Marana

3 ***Arthur Pack Regional Park*** - Revegetation along Santa Cruz River floodplain.

4 ***Cortaro Mesquite Bosque*** - Seventy three acres of mesquite woodland and 7 acres of cottonwood-willow or marshland vegetation with 258 af of effluent.

5 ***Tres Rios Project*** - Fifty acres of mesoriparian or hydroriparian vegetation using between 150 af to 5667 af per year.

6 ***Rillito Recharge and Habitat Restoration*** - Wetlands and riparian habitat along the south bank of the Rillito west of Swan Road. Reclaimed water will cycle through wetlands. In addition, Pima County is cooperating with the City of Tucson on a 20 acre wildlife habitat project. The water budget for the latter project is estimated at 32 af per year. The water budget for the former is estimated to be 151 af per year.

7 ***Ft. Lowell Riparian*** - Create or modify wetland for treatment purposes, then discharge to stream. Enhance existing historic pecan and cottonwood groves with additional vegetation and increased irrigation.

8 ***Ventana Wash Discharge*** - Discharge reclaimed water in riparian area to enhance existing riparian vegetation.

9 ***Sabino Canyon Discharge*** - Discharge reclaimed water in riparian area to enhance existing riparian vegetation.

10 ***Isabella Lee Discharge*** - Discharge reclaimed water in riparian area to enhance existing riparian vegetation.

11 ***Forty-niner's Country Club Discharge*** - Extend reclaimed line to Forty-niners golf course to replace existing groundwater use. Discharge to Tanque Verde Creek to enhance existing riparian vegetation.

12 ***Paseo de las Iglesias*** - This recent plan is to restore the Santa Cruz River between the San Xavier Mission, the San Agustín Mission, and the Convento site at the base of Sentinel Peak.

13 ***Tucson/Ajo Detention Basin Environmental Restoration*** - Fifty acres of wetlands and riparian habitat using 144 af per year.

14 ***Atturbury Wash*** - Create wetland for treatment, discharge to stream, recharge aquifer via recharge well.

15 ***Rincon Creek Restoration*** - Extend reclaimed line to irrigate golf courses and 118.5 ac of native vegetation.

16 ***Cienega Creek/Vail Valley*** - Extend reclaimed line and eliminate streamflow diversion and threat of pumping.

Water Demands of Proposed Projects

Name	Acres of Riparian Vegetation To Be Added	Water Demand (acre-feet/year)
Marana WWTF Cottonwoods	10 ac	66 af (effluent)
Santa Cruz Corridor	undefined: 100 ac assumed available for revegetation	A: 300, B: 667 ,C: 4287 (includes 1 cfs for discharge at five locations) (reclaimed)
Arthur Pack Regional Park	1 cfs discharge	C: 724 af
Cortaro Mesquite Bosque	73 ac mesquite 7 ac mixed cottonwood/wetland	285 (effluent)
Tres Rios Project	undefined: 50 acres assumed available for revegetation	A: 150, B: 333, C: 5667 (includes discharge of 5000 af/yr)(effluent)
Rillito Recharge and Habitat	20 ac mesquite and annuals 10 ac open water 4 ac marsh 6 ac riparian/aquatic	215 (reclaimed)
Ft. Lowell Riparian	1 ac open water/marsh 2 ac hydroriparian	A: 6 af, B: 12 af, C: 1460 af (includes 2 cfs discharge)
Ventana Wash Discharge	1 cfs discharge	C: 724 af
Sabino Canyon Discharge	2 cfs discharge	C: 1448 af
Isabella Lee Discharge	2 cfs discharge	C: 1448 af
Forty-niner's Country Club Discharge	18-hole golf course and 2 cfs discharge	C: 1933 af
Park Avenue Detention Basins	3 ac xeroriparian	4.8 (reclaimed)
Paseo de las Iglesias	undefined: 100 ac assumed for additional riparian vegetation	A: 300, B: 667, C: 4287 (includes 1 cfs for discharge at five locations) (reclaimed or CAP)
Tucson/ Ajo Detention Basin	12 ac open water 5 ac marsh 15 ac riparian 18 ac upland/grassland	144 (reclaimed)
Atturbury Wash	5 ac wetland and discharge to stream	C: 600 af
Rincon Creek	118 ac minimum mesquite/hackberry and xeroriparian	2000 (groundwater) or reclaimed
Cienega Creek / Vail Valley	Substitute for surface water diversion	1100 af

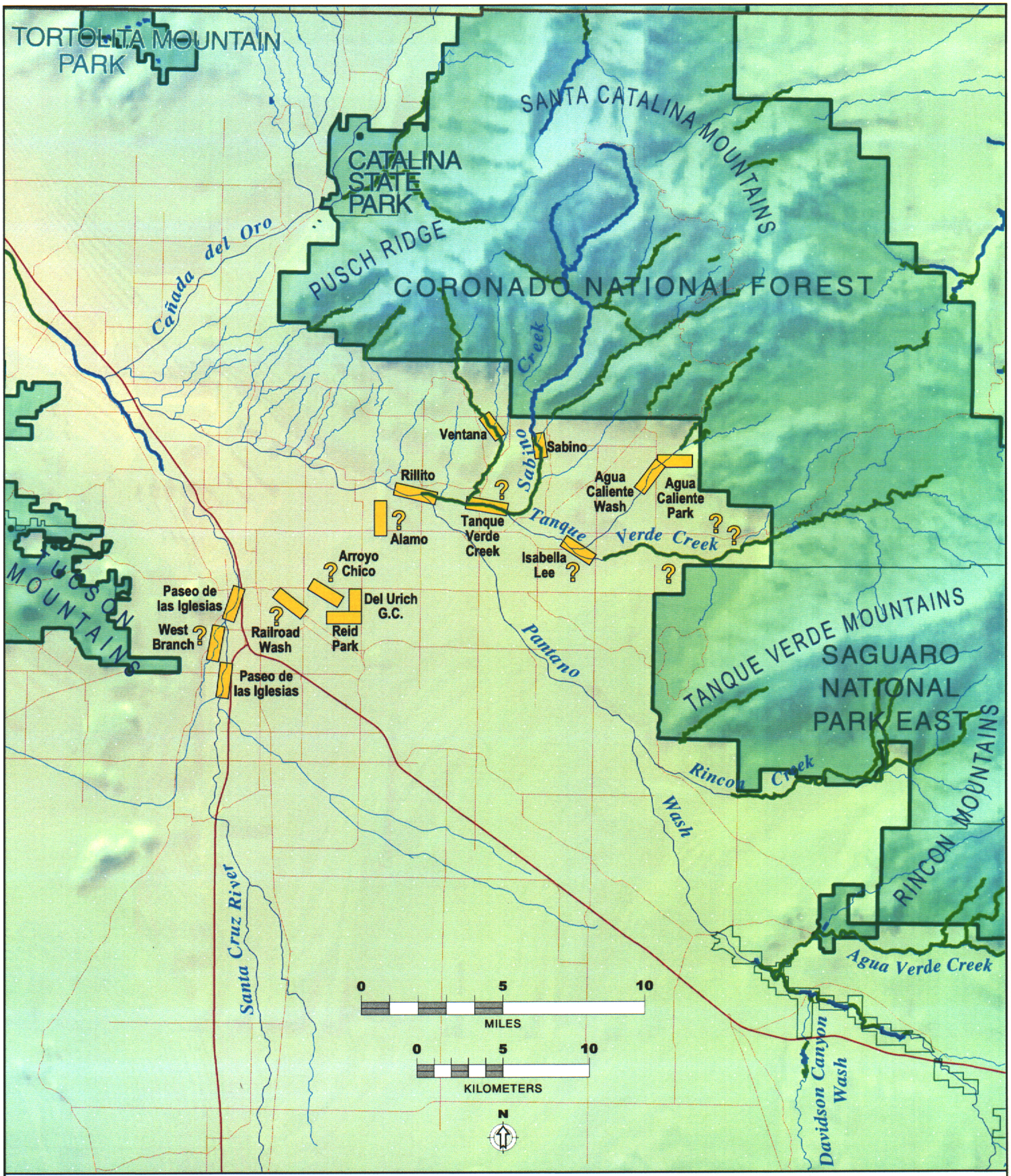


Figure 9

Possible Lowland Leopard Frog Metapopulation Structure for Re-establishment on Tucson Basin Floor

City of Tucson's A7 Ranch, for instance, are considering setting aside portions of land for "grass banks", which are only grazed during droughts, to provide relief for other parts of the landscape during critical times of drought. The A7 Ranch is in the San Pedro watershed.

Regulatory Response

To reverse the centuries-old decline in riparian functions will require new methods of protecting both urban and rural riparian areas.

Until recently, communities in Pima County neither identified nor protected riparian vegetation as an important resource. In the mid-1980's, scientists and citizens began to educate the public about the value of streamline vegetation as urban wildlife habitat, flood and erosion control and water quality improvement. They quickly realized that new policies and even ordinances would be needed to protect riparian areas during urban development.

Most of the regulatory responses focus on retaining natural vegetation, not the other structures or functions of riparian and aquatic ecosystems. For example, in the late 1980's and early 1990's, City of Tucson and Pima County both adopted ordinances protecting or requiring mitigation of damage to certain streamside environments. In 1986 and 1997, voters approved bonds to purchase certain high-value riparian areas in Pima County. These measures will reduce but not halt or reverse the rate of loss of riparian vegetation. Also, not all communities have adopted ordinances identifying or protecting their riparian areas, nor do these ordinances address the attrition ongoing in rural areas.

Measures to reduce the impacts of overbank flooding and sediment balance are primarily found in floodplain management ordinances of the various jurisdictions. For instance, Pima County requires some flood control projects to maintain some overbank storage for the 100-year flood event. In some areas, new in-channel aggregate mining is discouraged in favor of off-channel mining to reduce channel bed degradation. As new cities form and existing ones expand, more efforts to coordinate floodplain management will be needed.

No measures, other than lawsuits, exist to protect groundwater-dependent aquatic and riparian ecosystems from drying up as groundwater pumping increases. However, the Safe Yield Task Force for the Tucson Active Management Area is considering recommending that Arizona Department of Water Resources be given authority to work with local communities to designate subareas where groundwater might be regulated to achieve additional goals other than safe-yield, such as subsidence mitigation and protection of groundwater-dependent streams.

Non-native species management is another area where new regulatory measures might be needed. Arizona Game and Fish Commission, for example, recently adopted more stringent regulations for crayfish, to reduce the likelihood that this organism will be transferred to aquatic sites where it does not yet occur. RECON (2000) has urged Pima County to begin discussions with the Arizona Department of Agriculture (ADA) regarding problems associated with non-native and pest species. Rosen (2000) recommended legislation to prohibit purchase and release of bullfrogs.

11. Effects of Missing Information on the Riparian Protection Element

Distributional information

Distribution information is one of the most important types of information used in habitat conservation plans under the Endangered Species Act. Known or potential distributions of conservation targets (species, communities, or landscape features) will be used to base conclusions about the degree to which habitat is conserved under the SDCP. Each conservation target will have a different degree of uncertainty in distribution information. The level of protection offered by potential land acquisitions or management could be overstated because of missing information about distribution of conservation targets.

One of the most important data sets of such information for use by biologists and land managers in Arizona is the Heritage Data Management System (HDMS), managed by Arizona Game and Fish Department (AGFD).The HDMS data set is driven by information that isavailable from areas that have been heavily surveyed, such as federal lands. The HDMS also includes historical information that is often incomplete with regards to specific location.

Many areas lack distribution information because of access difficulties, particularly land ownership jurisdictions associated with private, State Trust, and Native American lands. Distribution information within these non-federal lands is more likely to be available along roads and utility corridors, and where there has been a high rate of federally sponsored development. The distribution of non-native species is not generally tracked.

Distribution information is generally improved upon after a species has been federally listed under the Endangered Species Act. Recently, information has improved for some species not under jurisdiction of the U.S. Fish and Wildlife Service as a result of Arizona's Heritage Fund and other programs like the Arizona Breeding Bird Atlas program, both managed by AGFD.

Another problem with species distribution information is that point locations do not necessarily represent the distribution of species with low population densities or species with large home ranges. The distribution of species is also dynamic over time and space. Some animal species are quite mobile. The absence of a species at a particular point in time does not mean that the habitat is not capable of supporting that particular species.

In the short term, staff engaged in the SDCP have augmented distributional information with literature review and expert opinion for selected species such as native and exotic fish, leopard frogs, and certain riparian trees. Habitat factors such as elevation, hydrology or vegetation community information are also being used to try to map where potential or unoccupied habitat for riparian or aquatic species might be. A third method that is being considered is the use of conservation targets that encompass landscape variability, an approach that may eventually provide a safety net for mistakes we make in our assumptions of where species area.

Some specific recommendations for surveys of aquatic vertebrates in Pima County are contained in Rosen (2000). High priority sites for surveys include Cerro Colorado, the Sierrita and Baboquivari Mountains, and stock tanks in the northern Santa Rita, Agua Caliente and Tanque Verde watersheds.

Hydrologic information

Basic hydrologic data are needed if judgments are to be made about the amount or variability of aquatic habitat available, trends of aquatic resources, and vulnerability to drought and invasion by non-native species. The watershed boundaries presently available in the Pima County GIS are too general and incomplete for use in the Sonoran Desert Conservation Plan. GIS-based analysis of stream gradients is not possible because of deficient topographic mapping.

PAG (2000a) found that few landowners or agencies monitor the length, extent, or persistence of base flows over time. This data gap is important because base flows are what sustain aquatic habitats. In general, the stream gauging programs of the U.S.Geological Survey (USGS) and Pima County Flood Control District have focused on measuring the frequency, magnitude, and in some cases, volume, of storm flows rather than base flows. Few agencies monitor the persistence of spring flows or stock tank waters at all, although ranchers generally have some idea of water availability at sites used by cattle or for domestic purposes.

Groundwater level and well-construction information for integrated hydrogeologic and ecological modeling of some stream reaches is needed. Modeling would help predict or understand the benefits that might accrue due to cessation of pumping and recharge of renewable water supplies, but models should be built upon geologic data and recent water-level information that is of sufficient quality to understand flow gradients and the degree to which perched or confined aquifers may be present.

Well-construction data are needed to help interpret water level information from existing wells. Annual groundwater pumping measurements would be helpful to have; they are not currently required outside the Active Management Area and for wells which pump less than 35 gpm inside the Active Management Area.

Absent these key data, we need to take a conservative approach to protect riparian and aquatic areas from new demands, while better information is sought.

Additional water quality information (especially temperature, pH, turbidity, ammonia, dissolved oxygen, dissolved metals) for natural streams will probably be needed to support native fish and frog reintroduction efforts. Water quality information is completely lacking for many of the smaller streams and springs. The degree to which natural variability in water quality parameters has been measured by existing monitoring efforts varies among sites.

The SDCP's riparian and aquatic restoration effort is also dependent upon effluent and reclaimed water. More information on quality of water needed to support native biota is needed. Aquatic invertebrate communities from effluent-dependent streams such as the Santa Cruz River are characterized by organisms tolerant of poor water quality conditions. Along the Santa Cruz River in Santa Cruz County, excessive ammonia may be diminishing the abundance and diversity of fish. Ongoing research by USGS is finding that antibiotics, hormones, and other drugs and chemicals pass into treated sewage at typical metropolitan treatment plants. The effect of pharmaceuticals on wildlife along effluent-dependent streams is unknown. The extent to which these chemicals are removed by recharge and tertiary filtration used in the reclaimed water process is not known.

Pima County Wastewater Management Department has been funded by the U.S. Environmental

Protection Agency (EPA) to conduct the Arid West Water Quality Research Project. The objective of the project is to improve the scientific base for regulation of water quality, protection of species, habitats, and uses of watercourses, and designation of appropriate treated wastewater effluent controls for effluent-dominated reaches of streams of the arid and semi-arid western states. This program may provide an opportunity to investigate these issues.

Vegetation and geomorphologic data

As previously discussed, the SDCP is directing much effort is being toward improved classification and mapping of riparian plant communities. Missing information about the location of small, isolated wetland plant communities might remain after these efforts are completed; utilization of the GIS coverage of springs as a proxy for these isolated wetlands in reserve design will help fill the gap. Some riparian areas might be dominated by tamarisk rather than native riparian species, a distinction that will not be apparent with the classification system used for the SDCP. This problem is avoided by relying on the field knowledge of experts and mapping of the larger cottonwood-willow stands and mesquite bosques in the contract with Harris Environmental Group.

At this time, there is little information on the condition of riparian areas. Riparian condition usually includes observations of the species and structure of woody riparian trees, evaluation of channel bank stability, pebble counts, or channel width-depth measurements. Riparian condition is being evaluated at some locations by various governmental entities, but exactly where these efforts are or what is being measured to evaluate riparian condition is not known. Riparian condition information would be useful baseline information. Trends in riparian condition could be used as a monitoring tool for the adaptive management phase of the SDCP.

Conclusion

In the long-term adaptive management plan phase, the SDCP will need to seek out better distribution and hydrologic information and use that information to increase its effectiveness. In addition, focused floral and faunal inventories of certain areas will be needed to determine the presence or absence of vulnerable and non-native species. Finally, because distribution information tells us nothing about the health of a population or long-terms trends, long-term monitoring of specific populations of certain species or riparian conditions may be necessary.

12. Effects of Natural Variability on the Riparian Element

A science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism.

--Aldo Leopold, 1941

An understanding of natural variability is needed if we are to going to achieve the biological goals stated earlier in this document.

Riparian areas will change over time. We can be sure that the habitat structure, vegetation volume, and distribution of riparian plant species will change over time and the term of the SDCP, as floods and droughts occur, vegetation matures, development proceeds, upland watershed conditions changes, and the groundwater table fluctuates.

The southwestern U. S. is an area of great variability in climate. The warm, wet winters of the 1980's and early 1990's locally helped to establish germinating conditions favoring cottonwoods and other riparian species and maintain aquatic habitats through augmenting natural recharge. The short, severe drought of 1989 and longer drought of the late 1990's reduced aquatic habitats for wildlife. For instance, within the Cienega Creek Natural Preserve, drought has reduced the available surface water that the fishes and tadpoles of native frog species use. Severe frost also has the potential for limiting the distribution or changing the abundance of some organisms with tropical affinities.

What the next several decades will bring in the way of precipitation and temperatures is unknown. However, environmental histories of change within riparian ecosystems can help us understand how changes in climate and flood frequency may affect these areas. Because riparian areas have been disproportionately affected by humans, studies of the range and variability of ecological processes and structures during times when they were less affected may be useful. Long-term studies of natural variation in specific parameters at modern "reference areas" will also help understand how riparian areas respond to change. Continuation of measurements of basic climatic factors (precipitation, flood peaks, temperature) will also be needed.

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Appendix A1.
Stream Prioritization for Pima County, Arizona
Revised July 13, 2000

Table 1 displays streams which are proposed for protection or restoration by Pima County based on their physical characteristics. These characteristics include the length of perennial and intermittent reaches, the acreage of both Hydro-mesoriparian and Class A Riparian habitats, the acreage of shallow groundwater and the number of fish species recorded along each stream. The original list was produced by comparing 112 streams with one or more of these characteristics and determining streams with the 20 highest numbers for each. Streams which did not rank among the top 20 for any of the characteristics were removed from the list. That list was published in April 2000. The revised list (Table 1) compares 150 streams based on new information that has been obtained since then.

Perennial and intermittent stream lengths were determined using the data obtained by the Pima Association of Governments (PAG) during their study of perennial streams, intermittent streams and areas of shallow groundwater for Pima County (PAG, 2000). This data was obtained by PAG using literature searches, field notes, field observations and information obtained from the people who called in or sent information by E-mail. Data from the latter was used only when field verified by PAG staff. All other data has not been field verified to the limited budget and time constraints of this study. In total, PAG listed 55 perennial reaches and 82 intermittent streams along 74 different streams in Pima County. Additional stream reaches and updates to existing stream reaches have been added to this total based on information provided by the Arizona Game and Fish Department, Julia Fonseca (Pima County Flood Control District), and others with knowledge of the region. The current total of streams with perennial and/or intermittent reaches is 79. The priority perennial streams had flow lengths at or above 0.7 miles, while the top intermittent streams at flow lengths greater than 3.3 miles.

Acreage of Hydro-mesoriparian and Class A Riparian habitats were determined using Pima County's Riparian Habitat Classification Maps (scale: 1" = 1000"). Hydroriparian habitats are defined as habitats generally associated with perennial watercourses, with plant communities dominated by obligate or preferential wetland species such as cottonwood and willow. Mesoriparian habitats are generally associated with perennial or intermittent streams or shallow groundwater. Plant communities may be dominated by species found in drier habitats (e.g. mesquite) but also contain some preferential species such as ash or netleaf hackberry. Class A Riparian, or Xeroriparian A, habitats are associated with ephemeral streams where the total vegetative volume is greater than 0.85 cubic meters per square meter as specified in the Floodplain and Erosion Hazard Management Ordinance No. 1994-FC2. Xeroriparian habitats typically contain

plant species found in upland habitats, however, the plants are typically larger or occur at higher densities than adjacent uplands.

The riparian maps produced by Pima County only include areas outside of designated preserves (i.e., Coronado National Forest, Saguaro National Park) and incorporated jurisdictions (i.e., City of Tucson). Habitat information for streams located within these areas is displayed as N/A (not available). In addition, some streams may have a portion of their reach located within a preserve or incorporated area, in which case the acreage of riparian habitat along the stream may be greater than what is displayed. This analysis added a total of 38 streams to the list developed by PAG.

As with perennial and intermittent streams, areas of shallow groundwater were determined using the data available from PAG (PAG, 2000). The technical advisory team convened by PAG for their study prioritized areas of shallow groundwater on the basis of size and threats. Priority areas were delineated with polygons by PAG. In many cases the polygons were not delineated for shallow groundwater areas if these areas had already been represented in the perennial or intermittent stream covers. For some other streams, groundwater areas were suspected to occur based on the presence of hydro-mesoriparian vegetation provided by the U. S. Forest Service Riparian Area Survey and Evaluation System or other source. These areas were recorded as points by PAG and no acreage was available. An "S" is displayed in the column for these streams and others listed in Table 6 of the PAG report. None of the streams with suspected groundwater were included in the revised streams prioritization table, because so many are unmapped. The term "N/A" in this column is used for all the other streams to indicate the lack of information.

The number of fish species recorded along each stream was determined using three sources. The first source was data obtained by PAG (PAG, 2000). This source provides information on the presence of fish and, in many cases, included specific names of fish species present. A couple of streams contained non-native species and are indicated by endnotes in the table. The second source of information was the "Arizona Rivers Assessment" produced by Arizona State Parks and the National Park Service (AZ State Parks, 1995). This report includes a series of tables which show the number of native fish species present along various streams in Arizona, including Pima County. The final source of information was provided by Julia Fonseca and others with knowledge on particular stream resources in Pima County.

Four other physical characteristics are displayed in the table, but were not a part of the analysis to prioritize streams. A brief description of each of these is provided below:

- Pygmy-Owl Critical Habitat - Geographic Information Systems maps obtained by Pima County from PAG (streams and groundwater) and the U. S. Fish and Wildlife Service (Pygmy-Owl habitat) were used to determine if the stream exists within the designated critical habitat for the Cactus Ferruginous Pygmy-Owl.
- Leopard frogs - Data was initially obtained using the PAG study and updated through discussions with Dr. Phil Rosen from the University of Arizona to determine streams with existing and historic populations of leopard frogs in Pima County. Occurrence is represented by either an "E" for existing or extant populations or an "H" representing historical locations (N = no occurrence).
- Deciduous Riparian Forest and Mesquite Bosque - Occurrence of these two habitat types was determined using information presented in the "Wildlife Habitats in Tucson" report by Dr. William Shaw and others (1986). A map inventory was created during this study which used aerial photographs, low level flights, on-site inventories and existing data from other sources to map the distributions of critical and sensitive habitats in Eastern Pima County. Limitations to the maps include the oldness of the data (1986) and the fact that no attempt was made to distinguish between sycamore versus cottonwood or willow dominated riparian forests.

Planning Units for the Sonoran Desert Conservation Plan are also included to show which sub-areas are well represented by high priority streams in Pima County.

The attached table represents a continuing attempt to prioritize streams in Pima County. Despite the limitations to the data, it should be a useful tool to help target areas where conservation and/or restoration efforts may be needed. Future research is required to help verify this information and possibly provide new data which may be useful to further prioritize the streams.

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Table 1

PRIORITY STREAMS IN PIMA COUNTY, ARIZONA

ARRANGED BY SDCP SUB-AREA

SDCP Planning Unit	Stream Name	Length		Habitat					GW	Animals	
		Perennial (mi.)	Intermittent (mi.)	Pygmy-Owl Critical Habitat	Hydro-Mesoriparian Habitat (acres)	Class A Riparian Habitat (acres)	Deciduous Riparian Forest	Mesquite Bosque	Shallow Groundwater (acres)	Fish Species (# recorded)	Leopard Frogs
1	Buehman Canyon	5.2	2.5	N	0	228.4			N/A	3[a]	E
	Espiritu Canyon	2.2	2.4	N	0	0			N/A	N/A	E
	Bingham Cienega	1.9	0.0	Y	0	0			N/A	N/A	E
	San Pedro River	1.3	10.6	Y	2306	0	X	X	2102	6[a]	E
	Youtcy Canyon	1.2	1.6	N	0	0			N/A	N/A	E
	Edgar Canyon	0.7	0.0	N	93.4	70.9			N/A	1	E
	Bullock Canyon	0.7	3.1	N	N/A	N/A			N/A	1	E
	Miller Creek	0.0	4.1	N	N/A	N/A			N/A	N/A	N
2	Cienega Creek (upper)	7.7	4.6	N	897	159.8		X	2911	3	E
	Cienega Creek (lower)	2.7	4.8	N	577	55.5	X	X	1651	1	E
	Empire Gulch	1.4	0.0	N	N/A	N/A			N/A	N/A	E
	Wakefield Canyon	1.4	0.3	N	0	37.1			N/A	1	E
	Mattie Canyon	1.3	0.4	N	N/A	N/A			N/A	3[a]	H
	Cinco Canyon	0.7	0.0	N	N/A	N/A			N/A	N/A	H
	Davidson Canyon	0.7	1.3	N	0	26.6		X	907	2	E
	Posta Quemada Canyon	0.3	0.0	N	N/A	N/A	X		21	1	H
	Nogales Spring	0.3	0.0	N	0	0			N/A	1	E
	Little Nogales Spring	0.2	0.0	N	0	0			N/A	1	E
	Agua Verde Creek	0.0	15.0	N	N/A	291.3		X	1057	N/A	E
	Gardner Canyon	0.0	0.5	N	N/A	N/A			1210	N/A	E
	Rincon Creek	0.0	11.3	N	563	0	X	X	568	1	E
	Mescal Arroyo	0.0	0.0	N	0	218.3			N/A	0	N
	Box Canyon (Rincons)	0.0	4.1	N	N/A	N/A			62	N/A	E
	Chiminea Canyon	0.0	4.1	N	N/A	N/A			N/A	N/A	E
	Madrona Canyon	0.0	3.4	N	N/A	N/A			N/A	N/A	E
3	Florida Canyon	0.0	3.4	N	N/A	N/A			N/A	N/A	E
	Franco Wash	0.0	0.0	N	0	67			N/A	0	N
	Madera Canyon	0.0	1.5	N	N/A	105.1			N/A	N/A	N
4	Sabino Canyon	15.0	3.4	N	839	N/A	X	X	1753	3[a]	H
	Tanque Verde Creek	0.5	17.2	N	1115	N/A	X	X	5528	1	E
	Romero Canyon	0.4	4.8	N	186	N/A			N/A	1[c]	H
	Bear Canyon	0.0	12.3	N	N/A	N/A			N/A	N/A	H
	Agua Caliente Canyon	0.0	0.0	N	1011	N/A	X	X	2863	1	H
	Ventana Canyon	0.0	9.3	N	N/A	N/A			N/A	N/A	H
	Pantano Wash	0.0	0.0	N	N/A	N/A	X	X	30	0	H
	Rillito Creek	0.0	0.0	N	177	0	X	X	177	0	H
	Molino Canyon	0.0	5.2	N	N/A	N/A			N/A	N/A	H

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Table 1

PRIORITY STREAMS IN PIMA COUNTY, ARIZONA

ARRANGED BY SDCP SUB-AREA

SDCP Planning Unit	Stream Name	Length		Habitat					GW	Animals	
		Perennial (mi.)	Intermittent (mi.)	Pygmy-Owl Critical Habitat	Hydro-Mesoriparian Habitat (acres)	Class A Riparian Habitat (acres)	Deciduous Riparian Forest	Mesquite Bosque	Shallow Groundwater (acres)	Fish Species (# recorded)	Leopard Frogs
4,5	Santa Cruz River	6.8	15.7	Y	3499	N/A	X	X	N/A	N/A	H
5	Canada del Oro	4.2	1.2	N	303	N/A		X	N/A	2[a]	H
	Lemmon Creek	2.7	0.0	N	N/A	N/A			N/A	1[b]	N
	Wild Burro Canyon	0.7	0.0	N	N/A	N/A			N/A	N/A	N
	Palisade Canyon Creek	0.0	4.5	N	N/A	N/A			N/A	N/A	N
	Sutherland Wash	0.0	6.5	N	N/A	121			483	N/A	N
6A	Arivaca Creek	2.7	0.7	N	1051	22.8	X		3311	N/A	H
	Asolido Wash	0.0	0.0	Y	0	85.9			N/A	0	N
	Las Moras Wash	0.0	0.0	Y	0	121.2			N/A	0	N
	McCafferty Canyon	0.0	0.0	N	0	80.1			N/A	N/A	N
	Penitas	0.0	0.0	N	0	230			N/A	0	N
	Pozo Hondo Wash	0.0	0.0	Y	0	85.3			N/A	0	N
	Sabino Wash	0.0	0.0	Y	0	353.2			N/A	0	N
	Brown Canyon	0.0	3.4	Y	N/A	123.5			N/A	N/A	N
	Sopori Wash	0.0	0.0	N	970	0			1551	0	N
	Thomas Canyon	0.0	3.0	Y	0	194.8			N/A	N/A	N
	Saucito Wash	0.0	0.0	Y	0	92.2			N/A	0	N
	Unnamed tib. to Arivaca Creek	0.0	0.0	N	0	81.9			N/A	0	N
6B	Blanco Wash	0.0	0.0	N	0	69.5			N/A	0	N
	Cocio Wash	0.0	0.0	N	0	22.9			369	0	H
7	Aguirre Wash	0.0	0.0	N	0	79.4			N/A	0	N
8	Quitobaquito Pond	0.1	0.0	N	N/A	N/A			N/A	1	N

Legend

Habitat

Y = Yes

N = No

N/A = Not available

X = Occurrence (Shaw, 1986)

Blank = No occurrence or unknown

GW

N/A = Not available

Animals

#[a] = Number of native species listed in the Arizona Rivers Assessment (AZ State Parks, 1995)

#[b] = Introduced non-native brown trout

#[c] = Introduced non-native green sunfish

N/A = Information is not available

E = Existing or Extant

H = Historic

N = No occurrence

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Appendix A2.
Proposed Guidelines for Use of Effluent and Reclaimed Water
Adopted by STAT on June 23, 2000

The guidelines below are intended to assist evaluation of the biological benefits of the use of effluent and reclaimed water for the Sonoran Desert Conservation Plan. The STAT recognizes that on a site basis, decision-makers will need to weigh biological benefits with constraints such as presence of landfills and lack of infrastructure, as well as a diverse range of other economic and land use issues. Overall, the STAT prioritizes protecting existing self-sustaining riparian and aquatic ecosystems over the creation of new or enhanced areas of riparian and aquatic life which depend on continuing inputs of water, energy and materials. This principle is embodied in the guidelines below:

1. **Protect systems that are self-sustaining over those that need continual inputs.** Based on this belief, the STAT prioritizes substitution of renewable water supplies for groundwater and surface water diversions in areas where high-quality aquatic and riparian ecosystems still exist and where diversion of water is a primary stressor of those systems. For example, previous work has identified the Tanque Verde Valley as an example of an important riparian resource that has been degraded by groundwater pumping. Substitution of reclaimed water for land uses which are diverting water from the aquatic and riparian ecosystems will help relieve this source of biologic stress.

2. **Restore or enhance native riparian and aquatic ecosystems by releasing water to restore local aquifer conditions.** Where ground water pumping is limited and favorable hydrogeologic conditions exist, reclaimed water and secondary effluent can be released to in an area in a manner that restores local aquifer conditions. The STAT believes that where hydrogeologic conditions are suitable, restoring localized shallow groundwater systems and floodplain dynamics will have a greater likelihood of success in creating a sustainable system than construction of artificial wetlands and container plantings or seedings of riparian vegetation.

3. **If plantings are to be used: a) revegetation is favored in areas where perpetual irrigation will not be needed;** Ideally, these projects will be designed to avoid disturbance of existing vegetation and minimize the need for perpetual irrigation and maintenance. Placement in areas where hydrologic conditions are suitable can provide the necessary water. **b) conflicts with other social objectives should be minimized** Revegetation sites should be chosen to minimize future conflicts with aesthetic, recreation, or public safety considerations. These other social demands can reduce the value of the plantings for self-perpetuation and for wildlife use. For instance, pruning and eradication of the understory reduces the utility of areas for most forms of wildlife. **c) native species appropriate to the site must be used;** Using native species that are adapted to the specific soil, aspect and elevation of the site will assist in establishment and **d) sites which augment existing high-quality riparian habitats are favored.**

4. **Enhance the ability of secondary effluent or reclaimed water to support aquatic life.** In some cases, improvement of water quality may be necessary to support aquatic species such as fish or other aquatic organisms in the food chain.

5. **Manage riparian and aquatic ecosystems for native species.** In many cases, sites using reclaimed water or secondary effluent will require active management against non-native species and public education about why control efforts are needed. This is particularly true where open water bodies exist. Where open water bodies are proposed, the potential consequences on native species should be considered.

Appendix A3.
Prioritization of Biologic Benefits of Specific Projects that Utilize Effluent or Reclaimed Water

On May 31, 2000, the riparian subcommittee met to prioritize the effluent projects that claim riparian benefits. Most, but not all of the projects we discussed are summarized on the graphic entitled " Proposed effluent-based riparian revegetation projects". All committee members (Julia Fonseca, Sherry Ruther, Doug Duncan, Russell Duncan) contributed to the following list of priorities. The subcommittee chose not to rank projects already under design or construction, such as the Ajo Detention Basin project.

The purpose of the meeting was to prioritize projects based on biological merits, not other social values. In general, projects that were adjacent to existing natural hydromesoriparian areas and projects that involved reducing groundwater uses in these areas were ranked highest. The subcommittee stated that as more information becomes available about the projects, rankings could change.

First Priority: Ft Lowell, Ventana Discharge, Sabino Discharge, Isabella Lee Discharge, 49'ers Groundwater Replacement and Discharge, Rincon Creek Groundwater Replacement and Restoration, Vail Valley Surface Water Replacement.

The Ft. Lowell discharge concept could be extended into the Rillito Creek area upstream of Craycroft Road where the cottonwoods are still trying to hang on. With landowner cooperation, flows to the historic acequia could be augmented seasonally.

Second Priority: Rillito Recharge/Habitat Restoration, Arthur Pack Wetland/Discharge

If the Arthur Park Project would involve disturbing previously undisturbed desert to bring in new reclaimed water lines or create wetlands, the project would be lower priority. Eliminating some of the unnatural golf course features in favor of native plants and landscapes would be desirable, as would eliminating the exotic African clawed frog population.

Third Priority: River parks, Santa Cruz Effluent, Tres Rios, Paseo de las Iglesias, Marana Treatment Facility Cottonwood-Willow Forest

The Tres Rios project area includes the historic 9-mile waterhole near the Rillito and Santa Cruz confluence. This water feature could possibly be resurrected and approached as an historic park and wildlife area. The pecan orchard along the Santa Cruz River could be purchased and used for a shaded picnic area, particularly if interplanted with dense understory plants to screen off the views of the adjacent gravel pit mine. Project concepts for many of the above projects are not well developed. The biologic benefits will ultimately depending on particulars.

Few or no apparent biologic benefits: Tanque Verde Creek Bank Stabilization near Tucson County Club Estates and Park Avenue Detention Basins. These projects have merit as responses to protecting infrastructures, however they provide few if any biologic benefits. The team does not see biologic value in using soil-cement embankments to protect mesquite bosques. The team suggests that other solutions be examined to protect sewer lines from erosion, such as buried soil-crete caps placed on top of the sewer lines themselves, sewer relocation, or other measures. Soil cement bank protection severs the connection between the channel and floodplain, and eliminates bankside habitats used by various wildlife.