DRAFT

WATER RESOURCES IN PIMA COUNTY

A Report for the Sonoran Desert Conservation Plan and for Update of the Pima County Comprehensive Plan

Barbara Tellman
Water Resources Research Center
The University of Arizona
June 2001

Figures and Tables

Contents

Chapter 1
Introduction

Purpose of the Report

The purpose of this report is to summarize information relevant to water aspects of the Sonoran Desert Conservation Plan (SDCP) and the Pima County Comprehensive Plan. This report deals with water supply and human water demand, and water supplies and needs for riparian and wetland habitat. It also examines policy options for dealing with the challenge of meeting human water needs while protecting riparian areas and wetlands. It is intended to meet the requirements of the Growing Smarter Law which states that in updating the Comprehensive Plan, communities must take availability of water resources into account.

> "Planning for water resources that addresses:
> (a) The currently available surface water, groundwater and effluent supplies.
> (b) An analysis of how the future growth projected in the county plan will be adequately served by the legally and physically available water supply or a plan to obtain additional necessary water supplies. " (§ARS 11:821 C3)

This report is also intended to provide a base of information for the Sonoran Desert Conservation Plan and its Environmental Impact Statement.

While water quality is an important component of usable water supplies, these aspects are the subject of a separate study by the Pima Association of Governments.

This report ends with water resources options which the Pima County Board of Supervisors should consider when updating the Comprehensive Plan and finalizing the Sonoran Desert Conservation Plan.

Writing a report of this nature with the unincorporated areas as a focus is nearly impossible, since water knows no jurisdictional boundaries and water use within the City of Tucson, Marana and Oro Valley is a highly significant part of the regional water picture. The City of Tucson has a significant amount of control over the major renewable supplies- the Central Arizona Project (CAP) and wastewater. It is updating its own General Plan and will looking at water resources within city limits, yet almost half the customer base of Tucson Water lives in unincorporated Pima County. State agencies, including the Arizona Department of Water Resources (ADWR) , the Arizona Corporation Commission (ACC), and the Central Arizona Groundwater Replenishment District (CAGRD) also have significant authority over water resources in the county. The recommendations in this report will include calls for improved intergovernmental cooperation on water matters.

The Pima County Situation

Much of Pima County is in the Sonoran Desert where water is a limited and valuable resource. Less water comes into the area from rain or snow in the mountains than is used by people and plants and evaporated. This means that Tucsonans have been dependent on water stored underground. This supply is limited and is not being replenished as fast as it is being withdrawn.

People, wildlife, and vegetation all compete for a limited water supply. With few exceptions, human water use has taken priority over water use for preservation of riparian areas and wildlife throughout the region. Arizona's Groundwater Management Act (GMA), discussed below, was written to prolong groundwater supplies by using renewable supplies, which in many cases means that streamflow may be sacrificed to save groundwater.

The urban areas of Pima County now have the option of using water from the Colorado River to augment the amount of water that falls on the local area. Most of this water originates high in the Rocky Mountains of Colorado, Wyoming, and Utah. While the CAP canal that brings this water to Pima County adds a great deal of water to the area it, too, is a limited annual supply. If population growth continues as it has in the past fifty years, this supply will also be inadequate for all the water demands of the area even if conservation increases, although in the short term, there is a water surplus in the area.

Regional issues

Even if a region-wide balance can be achieved through use of CAP water, effluent, and conservation as discussed below, this does not mean that every part of the region will be in balance. A regional balance that ignores the impact of subsidence in the city would not benefit the area as a whole, for example.

CAP water can only reach places in and near the

urban area or along the canal route. It will only be provided to customers of Tucson Water and a few other water providers, to some agricultural and Indian users, and possibly to a mine near Green Valley. While it could be provided to other more remote regions, the cost of building a transmission system is liable to be prohibitive. Ajo, for example, has very limited water supplies and a low precipitation rate. It is not protected by the same groundwater laws that apply in the Tucson Active Management Area (TAMA). The CAP pipeline will never reach Ajo. The situation there is very different from the situation in Tucson and population growth there will be limited by available water supplies. There are no perennial or intermittent streams or springs in that area to damage.

Arivaca presents a very different situation. It too is an isolated basin but is within the TAMA, it has a high water table and an active cienega (marsh) and stream. Groundwater and surface water are still connected, even though there is some pumping for agricultural and domestic use. Residents there have shown that an increase of just a few thousand people could lower the water table to the point that there would not be enough water to support the cienega. CAP water could be brought to Arivaca, but it would be very expensive to build a pipeline to do so. Since Arizona water law does not protect the surface water in this area, other means will have to be used if the cienega is to be saved, such as purchase of land with water rights.

Water quality

This report does not deal with water quality issues, which are covered in another report. It is important to remember, however, that in order to be useful water must have a quality suited for the purpose for which it is intended, so water quality and water supply are closely related. Water that is not safe for drinking purposes may be treated, but this will involve added costs to make it safe..

Water resource perspectives

This report begins by providing general information about water supply, water use, and water law in the area. Since a large portion of the water used in the area is within city limits and/or provided by Tucson Water this will be covered only to the extent that its use impacts unincorporated areas, the focus of the report. It is assumed that City of Tucson water issues will be covered in more detail in the water element of the City's Comprehensive Plan update. Representatives of the major agencies that deal with water resources were asked to respond to the questions below. Their responses are summarized in Chapter 5. and provided verbatim in Appendix B.

The report looks at the water supply/demand situation in Pima County from four broad perspectives:

1. The legal perspective
Does the Tucson AMA have both adequate supplies and adequate legal and management tools to assure that the legal goal of safe yield can be achieved by 2025? If not, what is lacking and could/should be done?

2. The regional perspective
Are there adequate water supplies and water management tools within Pima County (including the Pima County parts of the AMA and parts of the county outside the AMA) to achieve a balance between supply and demand into the indefinite future? If not, what is lacking and could/should be done?

3. Local perspectives
Are there local areas within the county that might not be able to achieve a balance into the future even if the region as a whole is able to do so? (e.g. Arivaca, Ajo, or middle San Pedro). What could/should be done to deal with these areas?

4. Riparian habitat perspectives
Is adequate provision made in current law and practice to protect existing perennial streams, springs, and cienegas in the county? Should new water be made available to protect riparian areas and restore some that have lost their dependable water supply? What changes could/should be made?

5. Cooperation.
In what ways could/should Pima County improve its coordination and cooperation with the various water management entities (e.g. water providers, municipalities, tribes or ADWR).

Sonoran Desert Conservation Plan Studies

Sixteen previous SDCP studies dealt specifically with water resource matters. This report attempts to synthesize the information in those reports as well as provide new information from other sources.

Appendix F lists the reports that deal most directly with water matters.

The first report, *Water Resources and the Sonoran Desert Conservation Plan* discussed the problem of groundwater mining and damage to riparian areas and species dependent on them. *Focus on Riparian Areas, Environmental Restoration in Pima County.* and *Riparian Protection, Management and Restoration* went further into the needs of riparian area and the status of major riparian areas in the county.

GIS Coverages of Perennial and Intermittent Streams, and Areas of Shallow Groundwater. Pima County Riparian Vegetation Mapping Pilot Study, Riparian Vegetation Mapping and Classification and *Springs in Pima County* identified specific locations and vegetation types.

Overview of Pima County's Watersheds and Watercourses looked at the physical characteristics of watercourses with emphasis on the nature of the floodplains.

Historical Occurrence of Native Fish in Pima County examined loss of native fish in the area, largely because of loss of water supply and habitat. *Aquatic Vertebrate Conservation in Pima County* presented concepts for protection and reintroduction of native aquatic fauna, including streamflow needs for projects.

Water Usage along Selected Streams in Pima County looked generally at water usage near shallow groundwater areas while *Groundwater Level Changes in the Tanque Verde Valley* looked at how groundwater pumping has affected a specific area as did The Arivaca Water Education Taskforce has produced two reports on water issues in that area.

Water Conservation in Pima County looked at the past and present of water conservation efforts.

Finally, *Climate Variability In Pima County, Arizona And Its Significance To The Sonoran Desert Conservation Plan* looked at climate variability and its impact on riparian areas and restoration and protection projects.

Acknowledgments

Much of the general information is this report can be found in more detail in *Water in the Tucson Area: Seeking Sustainability*, published by the Water Resources Research Center in 1999. Information about riparian areas, shallow groundwater areas, and habitat issues can be found in more detail in the Sonoran Desert Conservation Plan reports mentioned above as well as other reports listed in the appendix.

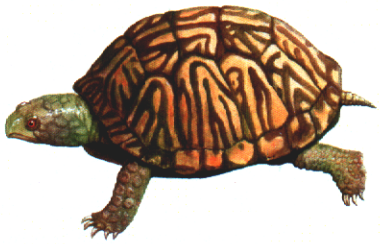
Thanks to Linda Stitzer, Austin Nuñez, David Modeer, Mark Stratton, Elaine Nathanson, Sharon Medgal, Nancy Laney, Charles Matthewson, and Julia Fonseca for providing helpful insights on the major water issues discussed in this report, as detailed in Appendix B.

Abert's towhee (*Pipilo aberti)*

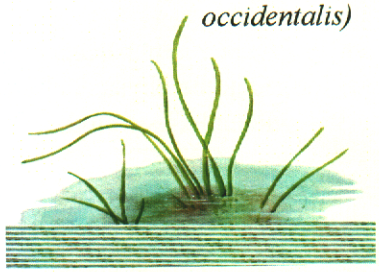
Cottonwood tree (*Populus fremontii)*

Western yellow-billed cuckoo (*Coccyzus americanus* ssp. *occidentalis)*

Sacaton grass (*Sporobulus wrightii*)

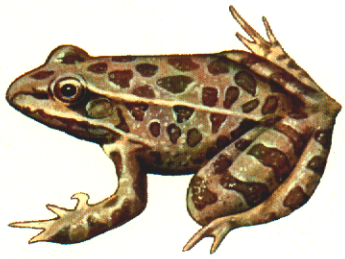


Desert box turtle *(Terrapene ornata luteola*)



Huachuca water umbel (*Lilaeopsis schaffneriana recurva*)

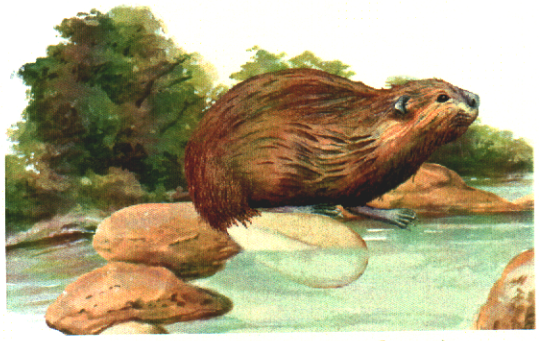
Arrowweed (*Pluchea purpurascens* var. *purpurescens*)



Lowland leopard frog *(Rana yavapaiensis)*

Muskrat (*Ondatra zibethicus*)

Longfin dace (*Agosia chrysogaster*)



Beaver (*Castor canadensis*)

Fig. 1. A few of the many species dependent on perennial or intermittent water supplies.
Drawings: Bill Singleton and George Malesky, Pima County Graphic Design

Chapter 2
Pima County Water Supply and Use in the Past

Prehistoric And Historic Uses

People have lived in Pima County for at least 12,000 years and have used irrigated agriculture along the Santa Cruz River and elsewhere since at least 500 B.C. The oldest known irrigation canal in North America is in Pima County. People have captured summer rainwater to grow crops for many years in a manner similar to the O'odham's "Ak Chin farming," a system by which summer rains are harvested for small plots. There were many more dependable springs than there are today in the valley and perennial surface water along parts of the Santa Cruz River and Rillito River which are normally dry today.

When the Spaniards arrived, they found plentiful water at San Xavier del bac where the natives were living and growing crops. Here they introduced new crops, including winter crops which the natives had not known, and expanded the agriculture, increasing the water use. When they introduced large numbers of cattle, the natives complained that there were so many cattle that their springs were drying up.

The arrival of Anglos starting in the mid nineteenth century brought more changes in water use. The Spaniards had an extensive system of canals used to water crops near the Presidio. By the 1880s, Anglos had farmed on many of those same fields and additional ones. They also built dams to create lakes for various purposes,. But these were washed out in floods in the 1890s and not rebuilt.

There was not enough water for the growing population so as Tucson grew people began to look farther and farther away for water. In the early days hand-dug wells were adequate, but many of these wells produced alkaline water that was not good to drink. Water was transported from a spring south of the current Tucson Community Center and delivered by donkey cart. The City Fathers offered a reward to anyone who could find local artesian water, but no one did. The water company installed pipelines to

Fig. 2 Getting water in the 1890s.

bring water from a location in the river near 29th Street and later from a source near San Xavier.

The demand for water for domestic and agricultural use expanded along with the technology to provide it through drilling deeper and deeper wells and pumping greater and greater amounts. By the 1930s so much water was being pumped that the water table dropped and was no longer connected to the rivers except for more remote areas. By the 1950s the water table had dropped so far near San Xavier that a giant mesquite bosque died when the roots could no longer reach water. Today a portion of Tucson's water comes from a large well field on the northern edge of the San Xavier District.

Other parts of the state were having similar problems during this period and people began to work towards solving the problem through new state laws and through importing water from the Colorado River. Locally, the City of Tucson began to buy farms to claim water rights so they could import water from the Avra Valley. At the state level, Arizona began its efforts to get federal financial support for importing water from the Colorado River. The first water law changes in the 1950s gave farmers protection against new farmers competing for their water. It did not affect urban use.

By 1980 the Central Arizona Project was becoming a reality and under pressure from the federal government (using the CAP as a incentive) Arizona passed its first comprehensive groundwater law, the Groundwater Management Act which is described below. Its intent is to prolong the groundwater supply in certain critical areas of the state through conservation and some restrictions on new pumping.

Modern Uses

Until recently, the vast majority of the water in the area was used for agriculture. Today, however, agriculture is much less significant and municipal users consume much more water. (Fig. 3) About ten percent of the municipal use is for golf courses and other turf.

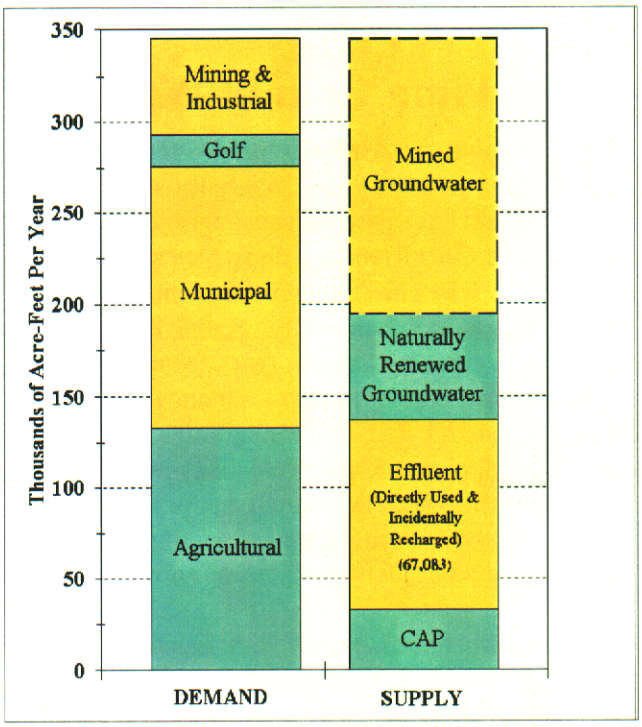


Fig. 3. Water Use and Supply in the Tucson AMA in 1998. Source: WRRC 1999.

Changes In the Water Table

Pumping has depleted the aquifer so that wells must be drilled deeper and deeper to reach dependable water. This level has changed unevenly in the region depending on where the pumping occurs, how close the area is to a natural or man-made recharge spot, and what the underlying geology is. The deep red areas on Fig. 5 indicate areas of greatest decline. The areas of greatest decline have the greatest potential for subsidence because as the

	1994 Population	1994 Use	Projected 2025 Use	Percent Change
Central	469,083	91,161	100,585	10
North	12,858	31,657	50,509	60
Marana	25,619	4,343	23,977	452
Southeast	9,631	2,081	11,235	440
Southwest	35,208	5,758	9,244	57
Green Valley	19,297	4,776	9,017	89
Oracle	3,627	361	643	78

Fig. 4. Present and Projected Municipal Water Use
Source: TAMA. Use in acre-feet.

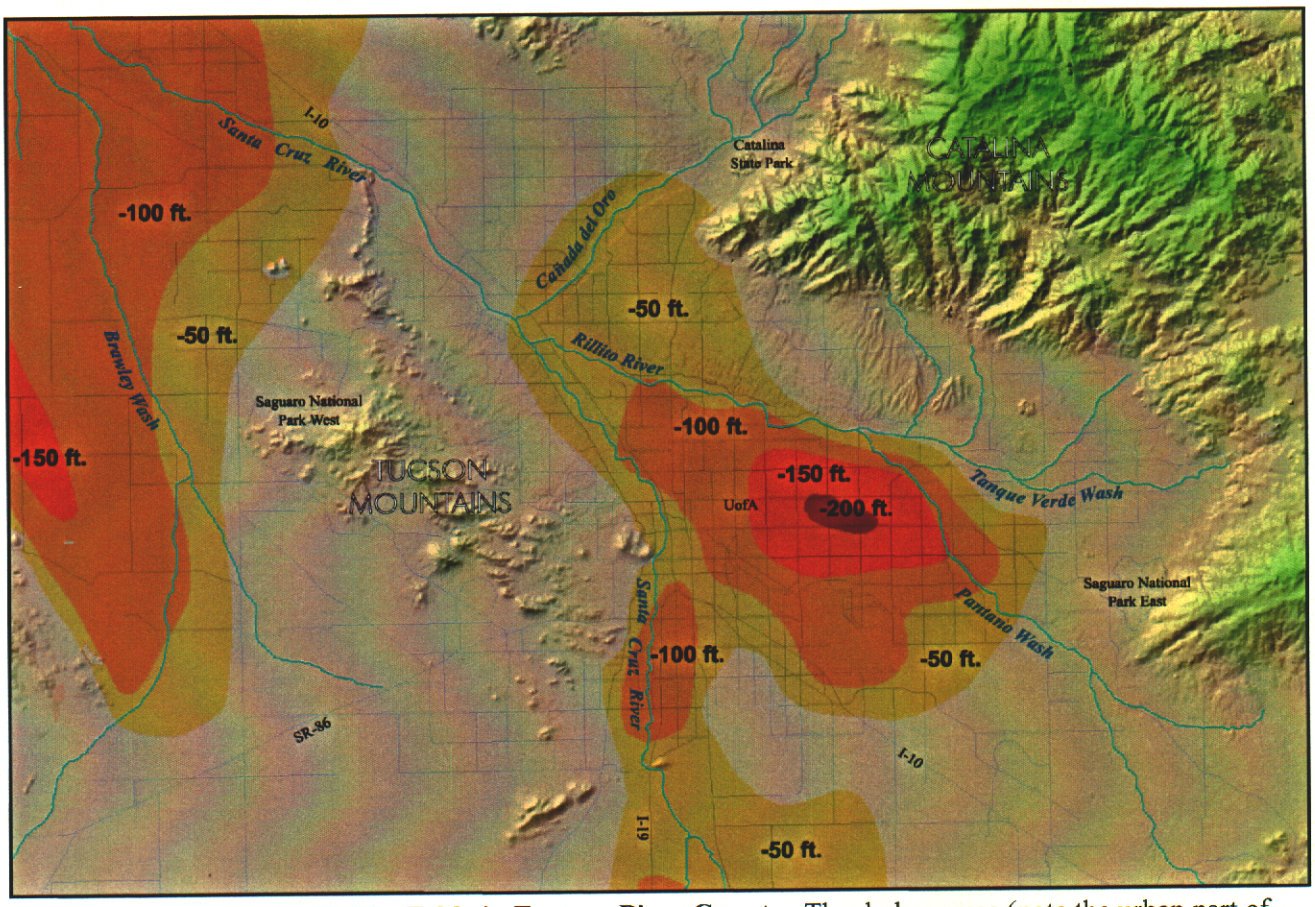


Fig. 5 Decline of the Water Table in Eastern Pima County. The darker areas (note the urban part of Tucson) are those with the greatest decline in addition to parts of the Avra Valley with extensive groundwater pumping. Another area of decline is just south of the area covered by this map where the city has many wells. Source: WRRC 1999.

water is pumped out, the areas between the grains of sand and rock tend to compact and the ground surface will eventually drop. (See the discussion of subsidence starting on page 27).

The areas of greatest decline, however, are not necessarily the areas of greatest biological significance. A small decline in some areas may have major impacts on a spring or stream while a large decline at some distance may not have significant biological effects. When the water table drops below the level of a flowing stream, that stream is likely to dry up except in the rainy season. Arizona water law does not recognize that there is a relationship between groundwater and surface water, so there is no protection for flowing streams when groundwater pumping affects the flow. This is the main reason why the Santa Cruz River, for example, is dry most of the time.

In May 2000 Governor Hull created the Water Management Commission whose purpose is to look at problems in the Active Management Areas (AMAs) and make recommendations to the Arizona Department of Water Resources and the Arizona Legislature about changes in the law. This commission has been deliberating for many months about such topics as whether conservation rules should be changed, whether there should be special rules for areas experiencing subsidence, whether isolated or remote areas within AMA should have special management, whether individual wells should continue to be exempt, whether riparian water supplies should be protected, and other topics. Recommendations will go to the legislature at the end of 2001. These issues will be discussed further in the final chapter.

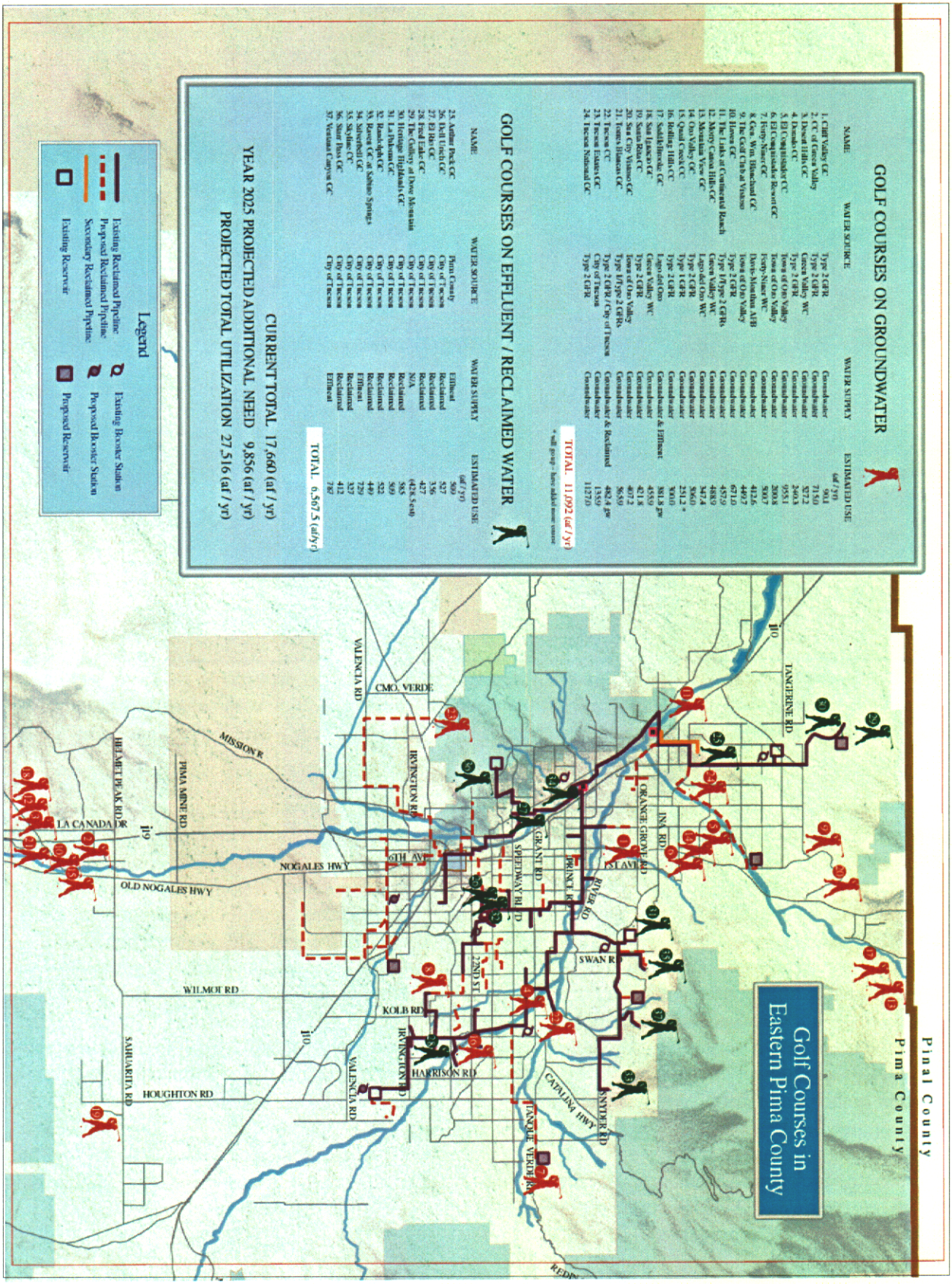


Fig. 6. Golf Courses and their water sources in metropolitan Pima County.
Source: Pima County graphics.

Chapter 3
Basic Water Information

Water Supplies

Pima County has two natural water sources as well as water imported from outside the basin. The water people have been using in the area for centuries comes into the area from rain or snow falling in the valley and the mountains. Much of the water stored underground is the result of rain that fell thousands of years ago when the climate was wetter than it is today. Much of the rain that falls is used by plants or evaporated, but when that water reaches a watercourse, it is liable to be recharged as it runs down the river. Some of that recharge, however, occurs downstream outside of Pima County. Long slow storms are more likely to result in a higher percentage of local recharge than are heavy storms that result in floods where some of the water may be recharged in Pinal County. The CAP depends on water that starts out as rain or snow throughout the Colorado River watershed, including the Colorado Rockies.

In the past much of the groundwater and surface water in the Santa Cruz watershed was a connected, system with the streams replenishing the groundwater supply and a high water table providing water for the streams. In most parts of the valley this connection has been broken through overpumping, although it remains in places like Arivaca and parts of the Tanque Verde area. Water that flows in the watercourses still replenishes the underground supply, but the water table is for the most part too low to keep the streams flowing. In some parts of the area, such as parts of the Rincon Mountains, the underground supplies are in isolated pockets and never were part of a regional aquifer. The next section makes a distinction between groundwater and surface water, which is the basis of Arizona water law, although this legal distinction is not scientifically accurate. The problems that arise from this dichotomy are discussed later in this report.

Surface Water

Surface water occurs on top of the ground or directly under it in a river. If a river has a constant flow of surface water, it is considered perennial. If it only flows right after a storm, it is considered ephemeral. Other flows are considered intermittent. Most of Pima County's surface water only flows ephemerally in desert washes and larger watercourses such as the Rillito. Sabino Creek at Sabino Canyon and Cienega Creek at the county preserve are examples of perennial streams.

Surface water also occurs in marshes, ponds, and lakes such as Arivaca Cienega. Some perennial and intermittent streams are fed by springs. Springs are less common than they were 150 years ago in this area. Fig 7 shows perennial and intermittent streams and springs, most of which are at the higher elevations or receive their water from flows starting at higher elevations. For perennial flow to occur at the lower elevations, a constant source of water is needed and this is ordinarily from a water table that is high enough to intersect the watercourse. In some cases, the underlying rock is very near the surface, forcing flow upwards. Once pumping has drawn the water level down below the river, it only flows in response to storms. For information on surface water law, see p. 31.

Groundwater

A myth prevails that there is an underground river or lake. This is not the case. If one could travel to the aquifer, one would find something more like very moist soil or a saturated sandy beach. Groundwater is water that fills spaces under the ground, between grains of sand or rock or in subterranean cracks. (See Fig. 14). The area where groundwater occurs is called the "aquifer" and the top level of the aquifer is called the "water table." The most productive aquifers consist of water stored in sand and gravel. These areas are typical of ancient floodplains (alluvium) where water, rocks and sand were laid down about the same time. Water and soils flowing off the mountains over a long period of time filled the aquifers.

The subterranean storage areas must be interconnected if water is to flow freely. Over the years, water moves slowly downward to reach the aquifer and it also spreads out moving in the Santa Cruz Valley generally northwest. At some point, the water will reach solid rock or a layer of clay that does not easily permit water to flow through. Sometimes aquifers are separated vertically by an impermeable layer and pumping from one aquifer will not affect the level in the other. When an impermeable layer is close to the surface, water may come to the surface as river flow or springs. If the water table overall is very close to the surface, rivers can flow. When

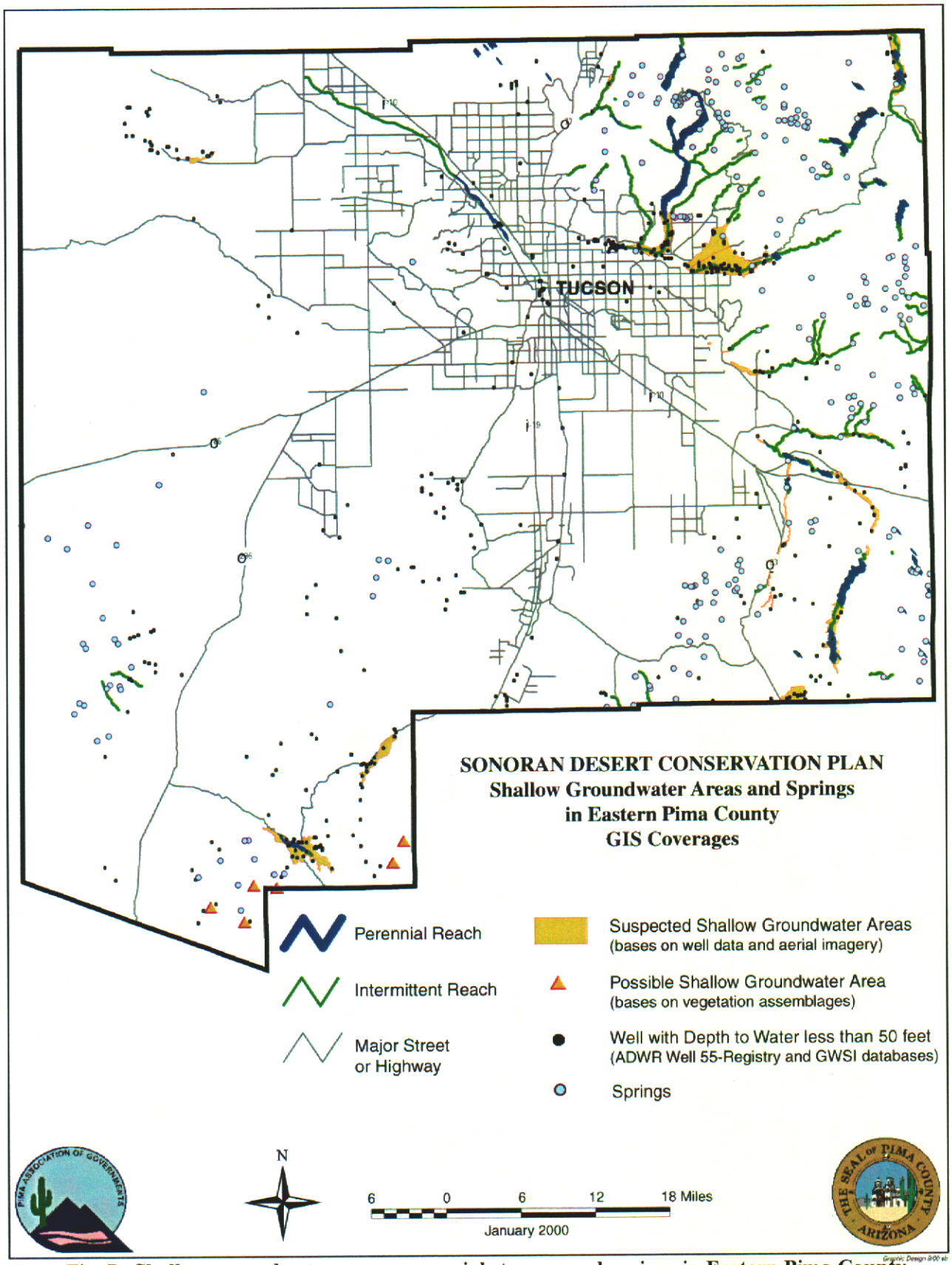


Fig. 7. Shallow groundwater areas, perennial streams and springs in Eastern Pima County

people pump water from the aquifer, the water table recedes, and surface flow is no longer possible except during rainy periods. Another impact of pumping is that the grains of sand or rock compact as the water is withdrawn. It may be difficult or impossible for percolating water to refill the spaces, especially at greater depths. Scientists believe that compaction is affecting the ability of the aquifer to refill in some areas so that recharge will be only moderately effective. (See Fig. 8 for locations of AMAs) and p. 35 for a discussion of groundwater law).

How much is an "Acre-foot?"

An acre-foot (abbreviated a.f.) is enough water to cover an acre of land to a depth of one foot. An acre-foot contains 325,851 gallons of water. One acre-foot of water is about enough for two average sized families for one year. Four to five acre-feet would irrigate an acre of cotton for a season or would water the turf around one golf course hole for a year.

Central Arizona Project

The CAP (Fig. 9) is a system of canals, pumping stations and storage facilities that brings water 320 miles from the Colorado River at Lake Havasu to the Phoenix area and eventually to the Tucson area. Fourteen pumping plants operate to lift water 2,400 feet in elevation to the terminus.

In the 1920s, the seven states along the Colorado River agreed on a plan to divide the river water, although Arizona did not go along with the agreement for more than twelve years. (See Fig. 11 for a map of the Colorado River watershed). Hoover Dam was built in the 1930s, and other dams were built that could store water in the Colorado River for later use. When a large aqueduct was built to take Colorado River to southern California in the 1930s, Arizonans took notice. Arizona began lobbying for its own project in the 1940s and gradually support began to develop. The federal government would build the project, and Arizona would repay a portion of the costs at a low interest rate. By 1960, all major Arizona politicians and political interests were on board and Congress approved the Central Arizona Project in 1968.

Fig. 8. Active Management Areas and Irrigation Nonexpansion Areas. Source: ADWR

The original project included dams on the upper Gila River in New Mexico, the middle Gila River in Arizona, the San Pedro River, and the Verde River at Fort McDowell. Ultimately none of the dams was built. Instead changes were made to some existing dams, and a new dam was built along the Agua Fria River to enlarge Lake Pleasant.

President Carter had doubts about the engineered, project-building approach to solving water problems, and required Arizona to change its water laws before the CAP was completed. In response, the Arizona Legislature passed the Groundwater Management Act of 1980 (See below). A three-county water district was formed to manage the project after completion and to develop water contracts with cities, farms, mines and other prospective users.

The project was completed to Tucson by 1990. But in the meantime problems had arisen. Few farming operations or mines signed CAP contracts, not even those that had been the most enthusiastic supporters of the concept. For the farmers, the cost was too high and the supply too unreliable. The mines were concerned that the fluctuating quality of the water would affect their mining processes. The cost of extending pipelines to individual farms and mines also was a significant factor. The City of Tucson was virtually the only commercial customer for the water in Pima County, although some water providers also have allocations (See Fig. 13). Water is also allocated to the Tohono O'odham through a legal settlement.

Those entities who actually contract for CAP water are the ones who pay the most to augment the water supply, while many others benefit from preserving the groundwater supply without paying more than a small amount through the property tax. In effect, since Tucson Water is by far the largest customer, Tucson Water customers pay the majority of the costs. Farms, mines and water companies could continue to pump groundwater at a relatively low cost while city water customers would pay the bills to keep the water table from dropping further.

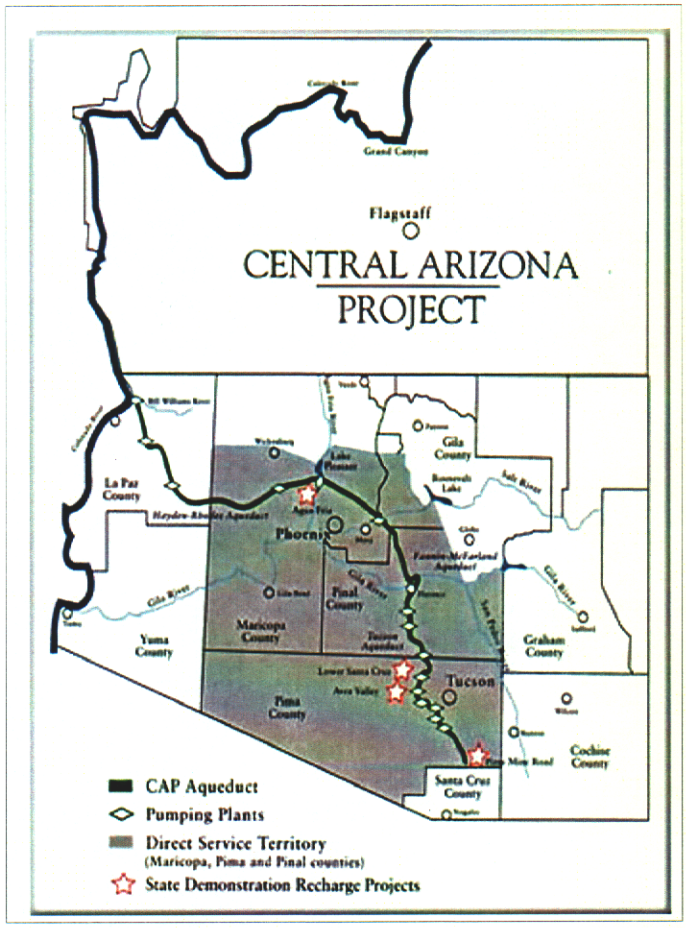


Fig. 9. Map of the Central Arizona Project

Some people believe that there should be some way to require the other water users in the basin to use CAP water and/or to share in the costs. Arizona law, however, has no provisions to enforce such a requirement.

How Reliable is CAP?

CAP advocates promise a reliable renewable water supply into the future. Yet problems are likely to arise. Short-term delivery problems may occur, or more serious problems might arise because of a long-term water shortage. Also, CAP managers anticipate that parts of the system will have to be closed down periodically for routine maintenance. They also anticipate that damage to the canal or lift stations will need to be repaired from time to time. Further, although the system was designed to withstand damage from subsidence, this still could be a problem. Pima County's location at the end of the system makes it vulnerable to problems throughout the entire system. The above situations would not likely affect the long-term water supply, although they could cause temporary problems.

Of greater concern is the long-term water supply. Studies by University of Arizona tree ring scientists show that over the centuries long periods of drought have occurred in the Colorado River watershed, lasting at times for decades. (Fig. 10) If such long-term drought should occur again, not enough water would be available to satisfy all water demands. University researchers also concluded that the long-term average flow of the river is considerably less than what was assumed when the Colorado River Compact was signed. They estimate an annual average flow of about 13 million acre-feet. Present river allocations, including the Mexican guarantee, account for more than 17 million acre-feet. This figure also includes estimates of water loss through evaporation.

In response to these concerns, CAP supporters argue that sufficient water is stored in Lake Mead and Lake Powell to enable us to survive long-term drought by drawing down the reservoirs. They also claim that the Upper Basin States are not likely ever to fully use their Colorado River allocations; Lower Basin States, therefore, will have this extra flow. Others counter that if the reservoirs are depleted, the power plants at Hoover Dam and Glen Canyon Dam will be unable to produce power effectively. They also point out that the reservoirs are expected to silt up over time, reducing reservoir capacity. Finally, they are concerned that the Upper Colorado River Basin States will use more water than is currently expected. For example, a proposed project called for St. George, Utah to pump water from Lake Powell to supply the water-hungry Las Vegas area. (This

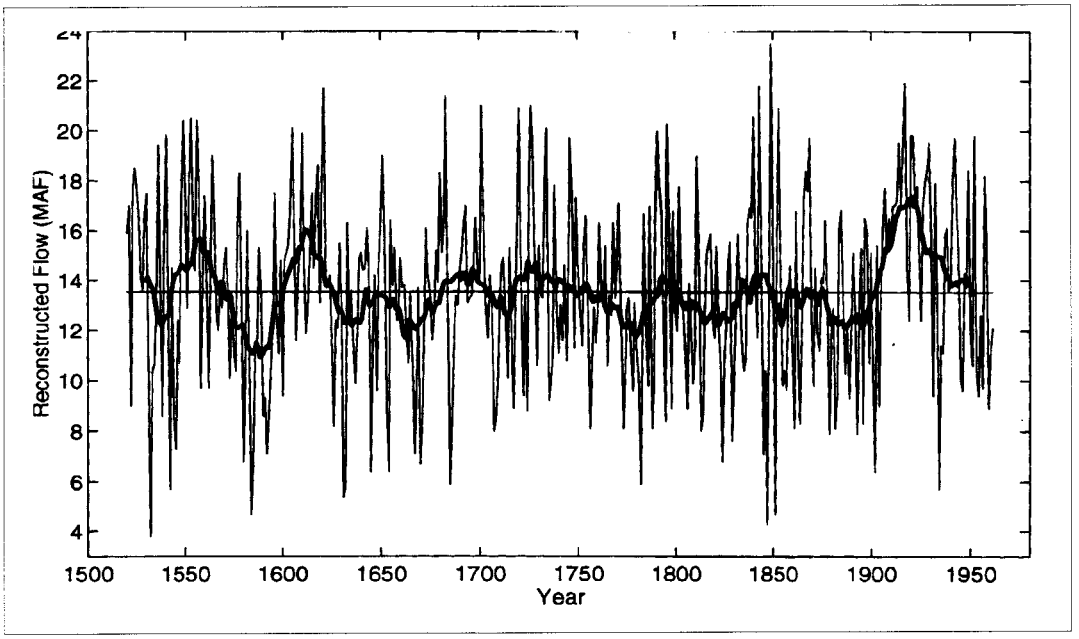


Fig. 10. Flow of the Colorado River at Lee's Ferry reconstructed from tree-ring records. The horizontal line represents the average flow of between 13 and 14 million acre feet (maf). The amount of water allocated to the states and Mexico is more than that (See text). Note several long drought periods where the flow was below average for years. Source: Meko et al. 1995.

peculiar long distance arrangement was preferable to bringing water from nearby Lake Mead because the water would come from the upper basin's share). This was not implemented. CAP supporters point out, however, that since cities have high priority for receiving CAP, urban users have no need for concern. As nonpriority uses diminish, however, there will be more competition for those with high priority.

Arizona's allocation of Colorado River water is determined by the "Law of the River," a collection of legislation, compacts, judicial decisions, international treaties and administrative rules that govern water allocation on the river. The Colorado River Compact of 1922 divided the river into two basins: the Upper and Lower Basins, with the river's average annual flow divided equally between the basins. Lees Ferry marks the boundary between the two basins. According to the compact each basin is to receive 7.5 million acre-feet per year. Arizona is a member of the Lower Basin, along with Nevada and California. A division of the waters of the Lower Basin was originally suggested by Congress in the Boulder Canyon Project Act and upheld in the Arizona vs. California Supreme Court decree in 1964. Arizona was allotted 2.8 million acre-feet of Colorado River water, while California was allotted 4.4 million acre-feet, with 300,000 acre-feet allocated to Nevada. Along with its Lower Basin allocation, Arizona also gets 50,000 acre-feet of Upper Basin water.

Approximately 1.3 million acre-feet of Arizona's

Fig. 11 The Colorado River Basin. The upper basin states are in green and the lower basin states in tan. Diversion systems are in red. Source: Adapted from

Some Cautions about CAP

While ADWR strongly supports the CAP, the ADWR web site includes some cautions which are excerpted here.

"Arizona has under-utilized its share of Colorado River water, the unused portion going to population centers in southern California. This under-utilization was expected to end when the Central Arizona Project (CAP) began delivering river water to the Phoenix and Tucson metropolitan areas and irrigation districts. However, many factors including a recent depression in the agricultural economy and the high price of CAP water relative to other sources, including groundwater, have resulted in continuing under-utilization of the CAP entitlement. Because of recent drought conditions in California and rapid population growth in California and Nevada, Arizona interests have expressed concern that pressure to reapportion the Colorado River's water may be growing..."

"The cost of CAP water is higher than most alternate supplies of water, which has resulted in a short-term reduction in water demand especially for agricultural purposes. The high cost of CAP water could make the water uneconomical as a source for future Indian water rights settlements and as a substitute water supply for municipal or industrial growth. The impact of under-utilization of CAP water may be continued groundwater overdraft which could negatively impact the ability to conjunctively manage water supplies. ..."

"As Arizona uses more of its Colorado River allotment, competition for available water within the State may increase. Rapid growth along the Colorado River in the Yuma, Lake Havasu City, Bullhead City and Parker areas will require increasingly larger diversions for local use. These increased diversions may lead to conflicts with CAP water users in central and southern Arizona during periods of limited surface water availability. ..."

allocation of Colorado River water is consumed along the mainstem of the river, leaving an average of 1.5 million acre-feet per year to be carried by the CAP canal. The canal has a design capacity for delivery of 2.1 million acre-feet per year, which is reduced to approximately 1.9 million acre-feet per year due to the need of routine maintenance. This extra capacity allows Arizona to take water above its annual allocation if a surplus is declared on the river.

CAP deliveries may be interrupted by drought shortages on the river or by the need to repair and maintain the canal. To gain the support of the California congressional delegation for Congressional approval of the CAP, Arizona was forced to agree that, in times of shortage, California's full 4.4 million acre-feet will be delivered before any water will be provided to the CAP. As a result, any shortages in the Lower Basin will be borne first by the CAP. The Bureau of Reclamation (BOR) projects that the risk of drought shortage will increase over time. After the year 2025, BOR anticipates that the probability of shortages affecting CAP water users

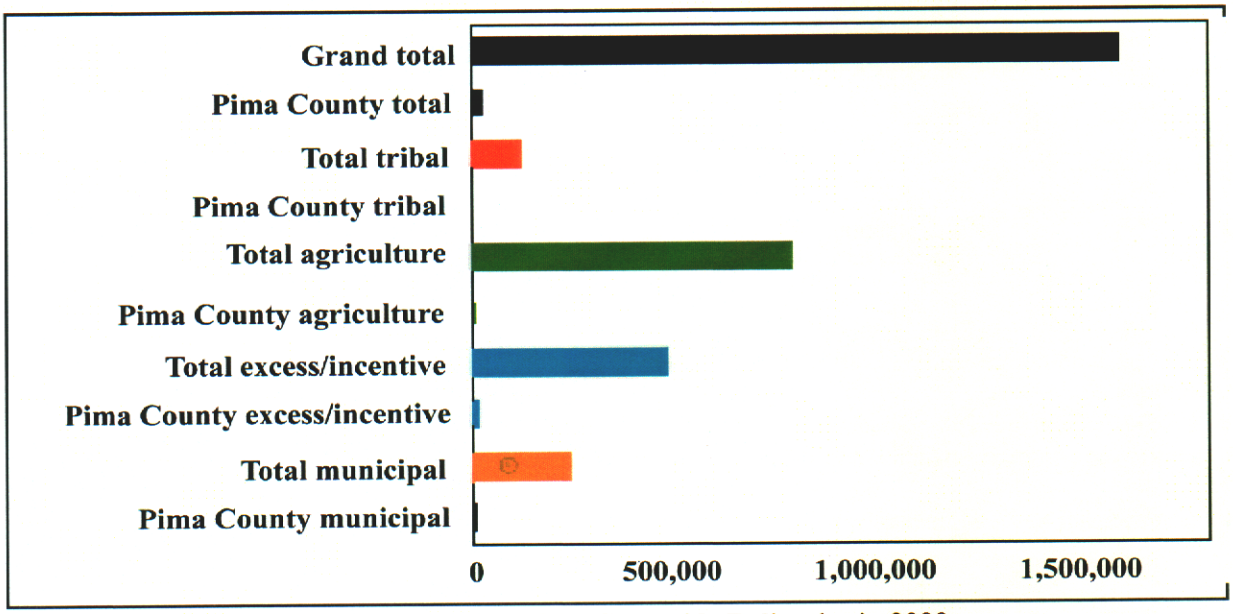


Fig. 12 CAP Statewide Deliveries in 2000.
Source: Central Arizona Project. Deliveries in acre-feet

will reach approximately 30 percent. The probability that municipal and industrial users will be affected is approximately 5 percent.

The law assigns the highest priorities for delivery of subcontracted CAP water to Indian and municipal and industrial (M&I) subcontractors. The lowest priority is assigned to non-Indian agriculture. This means if scheduled deliveries must be curtailed in any year, deliveries to non-Indian agricultural subcontractors will be cut first. It should be noted, however, that by 2025 water use for agriculture is expected to decrease significantly.

The amount of water delivered over the year is set, but the amount delivered each day varies greatly over the year, depending on demand. At times of high demand municipal users get first priority, but only for direct delivery, not for recharge projects which has a lower priority than agriculture. In March 1997, delivery to recharge sites was halted temporarily to meet demands for direct municipal use and agriculture. This is a reversal of the priority system that places agriculture last and that may require recharge systems to be designed to accept larger amounts of water at times when deliveries are high to compensate for the times when deliveries are cut. CAP officials are discussing possible changes to this policy.

Concerns about CAP outages from drought or maintenance point to the need for some mechanism to enhance delivery reliability. This could either be storage at the end of the aqueduct (terminal storage) or an operational plan that could involve keeping a certain number of groundwater pumps ready to provide water in case of an emergency.

Consideration of terminal storage has been delayed indefinitely and backup wells will provide reliability. Since Tucson Water plans to provide recharged CAP water blended with groundwater, reliability of CAP will not be a pressing issue for some time.

Subcontractor	Allocation	Recommended additional	Impediments
City of Tucson*	138,920	8,206	Full Infrastructure
AZ State Land Dept.	14,000		Infrastructure, Treatment, Legalities
Metro Water District*	8,858	4,602	Infrastructure, Treatment
Flowing Wells ID	4,354		Infrastructure, Treatment, Need
Spanish Trail Water Co.	3,037		Infrastructure, Treatment, Credits
Green Valley Water Co.*	1,900		Infrastructure, Treatment, Need
Town of Oro Valley*	2,294	3,557	Infrastructure, Treatment, Need
Midvale Farms	1,500		Infrastructure, Treatment, Need
Community Water/ Green Valley*	1,337	1,521	Infrastructure, Treatment, Need
Vail Water Co.	786	1,971	Infrastructure, Treatment, Need
Town of Marana*	47		Infrastructure, Treatment, Need
Avra Water Coop.	0	808	Infrastructure, Treatment, Need
Tohono O'odham San Xavier	27,000		
Tohono O'odham Shuk Toak	10,800		
Pascua Yaqui	500		Need
Total	215,333	19,765	

Agricultural and mining users declined subcontracts. Non-Indian agricultural use has been limited to groundwater savings facilities.
In 1999 ADWR recommended additional allocations (column 3) to the Department of Interior.
Amendments to the Southern Arizona Water Rights Settlement Act may increase Tohono O'odham allocation by 28,200 a.f.
* Indicates participation in CAP recharge projects.

Fig. 13. CAP Allocations in Pima County
Source: CAP. Allocations in acre-feet

BOR's draft Environmental Impact Statement relating to terminal storage estimated that Tucson would experience planned maintenance outages of five to 30 days per year. Emergency outages are projected zero to three times every 10 years. These emergency outages could last up to two months. An emergency outage lasting 48 to 365 days could happen zero to two times every 50 years. Terminal storage options identified included a 15,000 acre-foot above-ground reservoir, a 15,000 acre-foot per year underground storage and recovery facility, and installation of redundant features to minimize maintenance outages. Cost of the above-ground reservoir was estimated to be about $65 million and, if built as part of the CAP, the cost would be borne by CAP water users in Pima, Maricopa and Pinal counties, with the cost financed by the federal government at a 3.342 percent interest rate over a 50-year period.

Recharge

Recharge is the addition of water to groundwater already in the aquifer. In order to recharge the aquifer, water usually must first infiltrate the soil or ground surface and then percolate though the unsaturated zone of the aquifer (referred to as the vadose zone) to reach the water table. The water table defines the top of part of the aquifer which is saturated with groundwater. Infiltration is entry of water into the soil and the movement of water from the soil into the vadose zone. Recharge is addition of water to the part of the aquifer which is saturated with groundwater.

Recharge of the aquifer occurs in three ways: natural recharge resulting from precipitation; incidental recharge from water that seeps into the ground after various human uses, such as irrigation; and artificial recharge by constructed or managed projects designed to put water in the aquifer. Maintaining a balance of water use and supply can benefit from all three types of recharge.

Natural Recharge.

Natural recharge is the addition of precipitation and streamflows into the aquifer. Water from precipitation and runoff infiltrates along mountain fronts and in stream channels and also as direct underflow from joints and other openings in rocks of the mountains. Snow melt and mountain precipitation infiltrate at the foot of mountain ranges. Mountain-front recharge in the TAMA averages about 39,000 acre-feet annually. Stream channel recharge in the Tucson area occurs as a result of infrequent, but occasionally large stream- flow events. Some of the water that flows in streams after heavy rains infiltrates the streambed to recharge the aquifer. Total stream channel recharge in the TAMA averages approximately 38,000 acre-feet per year.

Underground flow of groundwater also is included

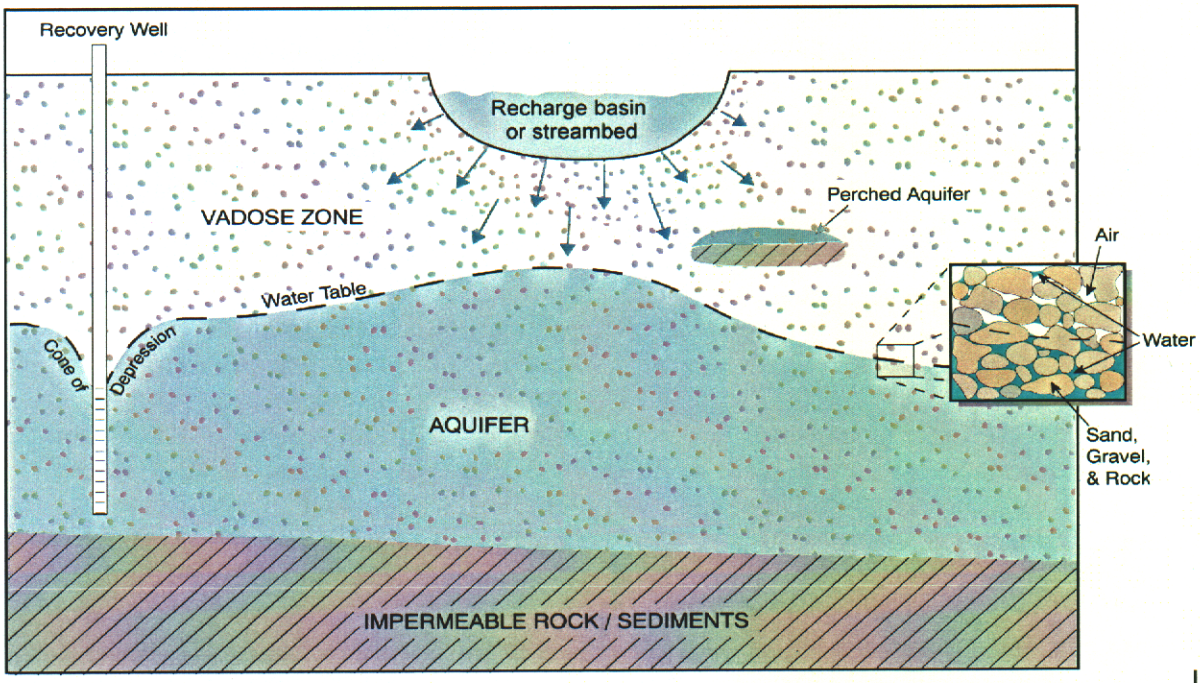


Fig. 14 The principles of natural or artificial recharge.
Source: Pima County Graphic Services

in calculating natural recharge to an area. Groundwater generally moves slowly (at a rate of a couple hundred feet per year) to the north and northwest in the Tucson area. On average approximately 9,000 acre-feet per year of groundwater flows underground into the TAMA from the south every year and about 25,000 acre-feet per year leaves the AMA by flowing underground to the north. The amount flowing into the TAMA is disputed by people from the Santa Cruz AMA who claim that more remains in that area and that they have the right to use it there. Some of the water is recharged in the Pinal County part of TAMA, not Pima County.

Incidental Recharge

Incidental recharge is water that reaches the water table after human use without the use of recharge structures. The amount of incidental recharge in the TAMA depends mostly on the level and water use efficiency of certain human activities, such as irrigated agriculture, mining and the discharge of effluent into stream channels. ADWR has estimated that annual incidental recharge in the TAMA totals about 81,000 acre-feet, based on water use levels projected for the year 2000, most of that from effluent discharged by the two large wastewater treatment plants. If that water is instead directly used for some purpose, the amount of incidental recharge will be reduced and the overall water balance is changed little. ADWR does not yet have a legally defensible method for calculating the actual amount of water that is recharged and is also recoverable.

Artificial Recharge

The artificial recharge of either CAP water or effluent is an important method of utilizing renewable supplies in the TAMA. Artificial groundwater recharge generally involves constructing facilities to control the movement and rate of infiltration. The following discusses artificial recharge as a way of replenishing the aquifer.

Little of the CAP water recharged in the TAMA so far has been pumped for use, although the City of Tucson has constructed a wellfield to allow recovery of water stored at Central Avra Valley Storage and Recovery Project (CAVSARP) and a pipeline to deliver a blend of recharged water and groundwater to the water treatment plant for ultimate delivery to the city. In May 2001 this delivery began.

Generally, recovery of recharged water is

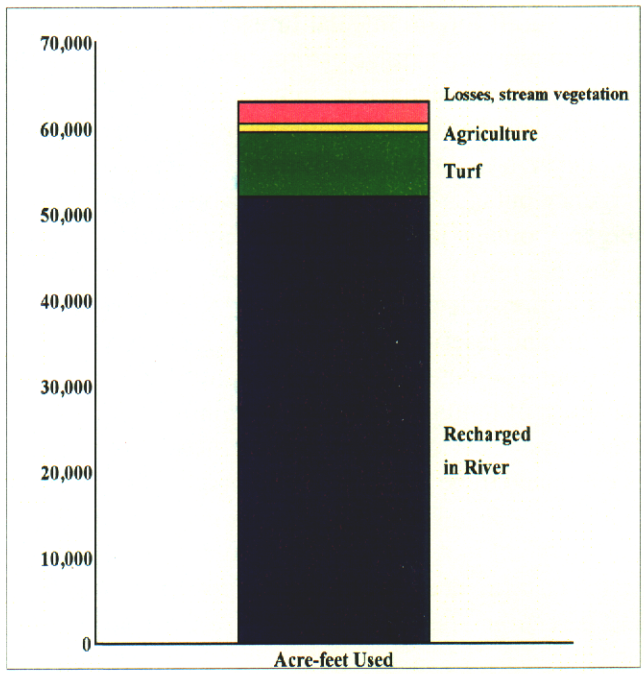


Fig. 15. Use (acre-feet) of the Effluent from Roger Road and Ina Road Wastewater Treatment Plants

permitted if it is recovered in the area where the water was originally stored, or in an area to which it migrated after storage. Recovery of water outside this "area of impact" is permitted under certain conditions to ensure that recovery of water does not occur in areas with substantially declining groundwater levels.

Fig. 17 shows existing and proposed direct recharge facilities in the TAMA. Four direct recharge facilities are currently operating in the TAMA. These include CAVSARP, Pima Mine Road Recharge Project, Avra Valley Recharge Project and Sweetwater Underground Storage and Recovery Project. All of these projects utilize off-channel spreading basins to recharge CAP water, except the Sweetwater facility, which uses basins to recharge reclaimed effluent.

Fig. 16 shows the amount of water stored at direct recharge facilities over time. The amount of water stored at Tucson area projects is small compared to the total renewable supplies available. Not including CAP water used at in lieu facilities, about 11,000 acre-feet were recharged in the TAMA in 1997, compared to approximately 215,000 acre-feet of CAP water under subcontract to entities in the TAMA.

New recharge projects are being developed. A facility permit has been issued for the Lower Santa Cruz Replenishment Project, which is projected to have a capacity of 12,000 to 13,000 acre-feet in its first phase. The facility is located along the Santa

Cruz River in northern Avra Valley. The proposed Cañada del Oro Recharge Project could add another 30,000 acre-feet of direct recharge capacity in northwest Tucson near the Town of Oro Valley. A study of the technical feasibility of the project is currently being conducted. Total direct recharge capacity on non-Indian land in the TAMA is projected to be 49,000 acre-feet in the year 2000, possibly rising to 131,000 by the year 2007 with the addition of a full-scale Lower Santa Cruz Replenishment Project, the Cañada del Oro Project and expansion of existing projects to full-scale. Proposed recharge projects on Indian land could add up to an additional 41,000 acre-feet of direct recharge capacity by 2007.

In-Channel Artificial Recharge

Artificial recharge facilities operate either in-channel or off-channel. In-channel constructed facilities are recharge facilities built into a river or stream bed to retain water while it infiltrates through the stream bed into the underlying aquifer. These structures include inflatable dams, gated structures, levees and basins, or other devices designed to impede water flow. Levees are the least expensive of these alternatives, but are the most subject to damage from flood flows. Also operating in-channel, managed facilities allow water to infiltrate the stream channel without the aid of structures to impede flow.

Off-Channel Artificial Recharge

Off-channel artificial recharge facilities include shallow spreading basins. These are basins up to 20 feet deep to reach more permeable layers and are usually constructed with earthen berm walls to hold water in place. During operation, the depth of water usually does not exceed five feet. Basins are operated on a wet/dry cycle to allow scraping or other techniques to maintain high infiltration rates.

Deep basins or pits also can be used for off-channel recharge. These facilities are usually converted from other uses, such as gravel pits. During operation, water levels up to about 10 feet are usually maintained. Operation costs are usually low, since basins are drained and maintained only once every year or two. Infiltration rates, however, are usually low due to build up of organic matter on the bottom and sides which clog up the pores.

Injection Wells

Also operating off-channel, injection wells are usually existing water extraction wells converted to allow injection of water directly into the aquifer. Water injected must normally meet drinking water standards (Maximum Contaminant Levels). The Water Consumer Protection Act effectively prohibited the City of Tucson from using injection wells unless the water injected is treated to the same standards as Avra Valley groundwater and was free of disinfection by-products. Voters repealed this law in 1999.

Direct injection is the most certain method of recharge because water can be directed to a location within an aquifer. For this reason, local recharge experts believe that direct injection may be the most effective tool in mitigating subsidence. With direct injection, water can be added as close as possible to the layers of the aquifer that are being compacted, however the extent to which subsidence can be limited with this method is uncertain, depending in part on the type of aquifer materials.

Programs to Promote Recharge

Administered by ADWR, the purpose of the Underground Water Storage, Savings, and Replenishment Program (UWS) is to encourage the use and/or

Recharge project	**1996**	**1997**	**1998**	**1999**
Avra Valley	2,794	5,555	4.939	5,781
CAVSARP	154	2,209	11,561	14,705
Pima Mine Road			7,382	10,480
Total	2,948	7,764	23,882	30,966

Fig. 16. Central Arizona Project Water Recharge Projects in Pima County
Amounts in acre-feet. Source: CAP

storage of renewable supplies, including CAP water. There are two types of facilities allowed under this program: Underground Storage Facilities and Groundwater Savings Facilities.

Underground Storage Facilities (USFs) involve physical recharge of water through injection wells, infiltration basins, or natural watercourses. Water stored at these facilities can be designated for one of several uses: recovery in the same calendar year (annual storage and recovery), long-term recovery using storage credits, or not to be recovered. If the water is recovered, it does not have to be recovered in the same place as it was stored. However, recovery rules are designed to prevent recovery of water in areas where groundwater levels are substantially declining.

Groundwater Savings Facilities (GSFs) are not really recharge projects, but are legally listed as recharge facilities because they substitute an alternate water source for groundwater, thus prolonging the groundwater supply. They involve farms where agreements are made to use CAP water rather than pumping ground-water. GSFs are referred to as "in-lieu" recharge facilities because CAP water is used in lieu of groundwater, but GSFs do not involve physical recharge. In a typical GSF arrangement, an entity such as a municipal water provider sells CAP water to a farm, usually at a price lower than what the farm would pay to pump groundwater. In return, the state grants credits to municipal providers for the amount of groundwater that is saved. The municipal provider can use these credits to offset pumping of ground-water in meeting ADWR conservation rules. Most of the activity under the UWS program to date in Pima County has been though GSFs. There has been some evidence that the availability of CAP water has prolonged the life of farms that would have stopped pumping and growing crops if it were not for this new supply.

Central Arizona Groundwater Replenishment District (CAGRD)

In 1993, the legislature created a groundwater replenishment authority to be operated by the Central Arizona Water Conservation District (CAWCD) throughout its three-county area (Maricopa, Pinal and

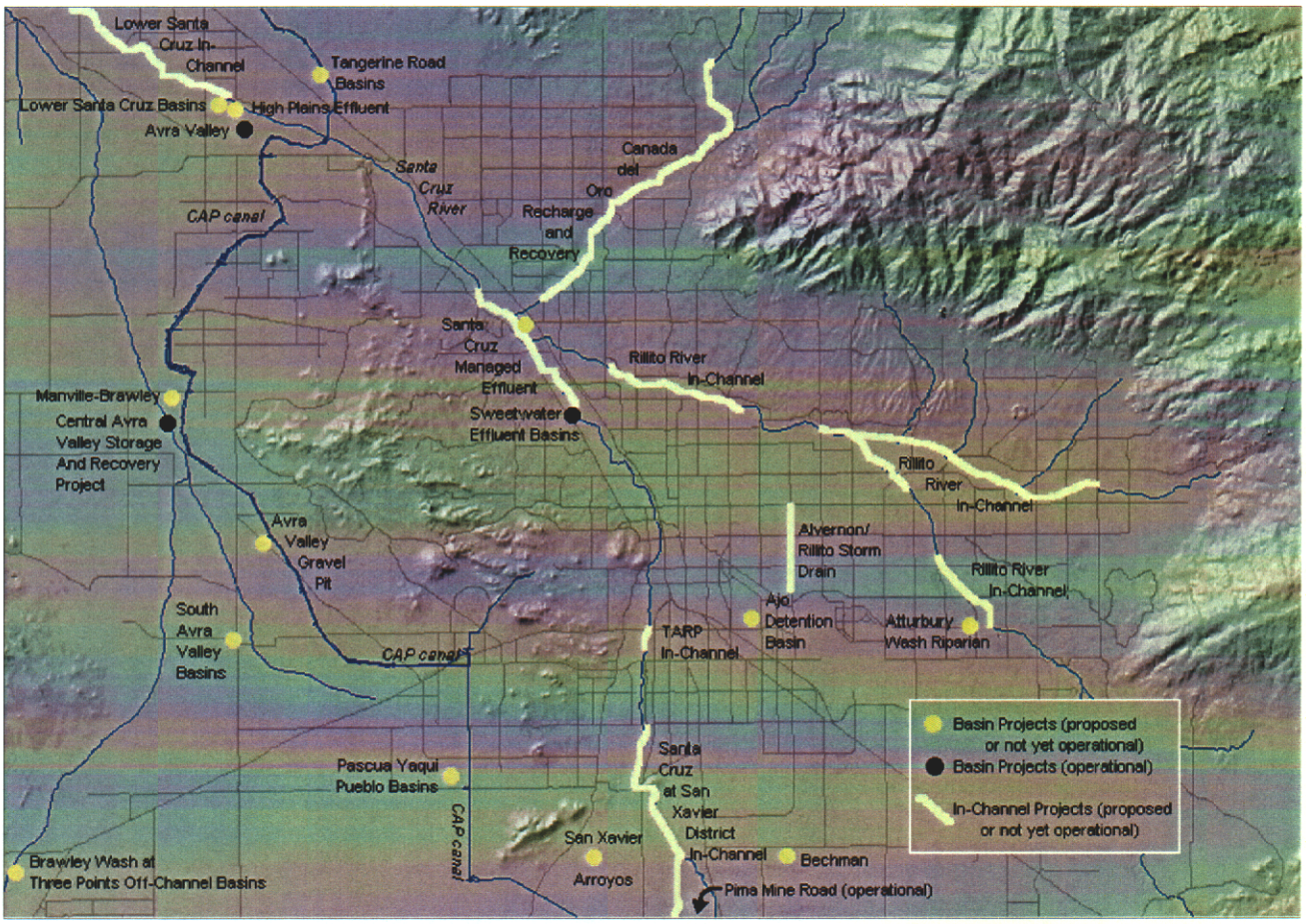


Fig. 17. Existing and Proposed Recharge Projects in Pima County.
Includes effluent and CAP Source: WRRC 1999.

Pima counties). The purpose of the CAGRD is to provide a mechanism for landowners, developers and water providers to demonstrate an assured water supply under the state's Assured Water Supply (AWS) Rules. One way to demonstrate AWS is to participate in recharge projects through the CAGRD.

The CAGRD must recharge in each AMA that amount of groundwater pumped by or delivered to its members which exceeds the pumping limitations imposed by the AWS Rules. This category of water is referred to as "excess groundwater".

Recharge may be accomplished through the operation of underground storage facilities or groundwater savings facilities. Water used for replenishment may be CAP water or water from any other lawfully available source, except groundwater withdrawn from within an AMA. For the foreseeable future, the water that the CAGRD will use for replenishment will be excess CAP water.

Membership in the CAGRD does not waive the requirement under the AWS Rules that an applicant must demonstrate the physical and legal availability of groundwater. Providers or subdivisions which rely on the CAGRD to meet the AWS requirements must still meet the depth to groundwater criteria established in the AWS Rules and have the legal right to withdraw groundwater from the point of withdrawal. Recharge projects are paid for through levies on the members, which may mean that homeowners in a subdivision may help pay for such projects through annual fees.

Arizona Water Banking Authority (AWBA)

The design of CAP originally envisioned that a large amount of CAP water would be used for agriculture in the early years and as the state's population grew the urban population would gradually begin to use that water as agriculture was phased out. There has been much less agricultural use than originally anticipated, and the mining companies have not switched from groundwater to CAP water as expected, so Arizona cannot currently directly use all its allotted CAP water and does not expect to use the full allotment directly until the year 2030. Since California claims a right to take unused Colorado River water, Arizona has devised a way of keeping as much of it as possible in the state. The Arizona Legislature created the AWBA to acquire unused portions of Arizona's allocation of Colorado River water and put it to use for storage underground (recharge) in central Arizona. AWBA is authorized to store water to meet one of four overall goals: to protect municipal uses from possible drought situations or CAP delivery interruptions; to meet Indian water rights claims; to meet local water management objectives; or to facilitate interstate water banking with California or Nevada. AWBA is funded using property taxes, groundwater withdrawal fees in counties with CAP water (Maricopa, Pinal and Pima counties). The main impact of AWBA on Pima County is helping to preserve Arizona's rights to Colorado River water in the future.

Water and Wastewater Infrastructure

An often neglected but simple fact is that in order for water to be used it must reach the consumer through a pipe or canal. Before the days of cheap power, people had to live near their water supply or carry it by hand or on the back of an animal. Today our water is often brought great distances through facilities that are largely invisible to the average user who turns on the faucet. A complex network of pipelines, pumping stations, and reservoirs makes up the Tucson Water system. (Fig. 20). CAP water is introduced into the system in the Avra Valley where it goes through the water treatment plant. For CAP water to reach portions of the metropolitan area, it must be piped there. As the system is now designed, only treated water will reach the urban area. Any CAP water used for purposes such as turf irrigation or riparian restoration in the metropolitan area would have gone through the treatment process unless it were piped in separately. .

Similarly the wastewater system is a complex network of pipes and treatment facilities. (Fig. 21). For the most part, treatment plants are located at the

Groundwater Savings Facility	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
BKW Farms	250	2014	4325	7,080	8,648	7,457	7,644
Cortaro-Marana ID	2,650	0	5,902	9,581	9,746	7,612	7,751
Total	**2,900**	**2,014**	**10,137**	**16,661**	**19,394**	**15,096**	**15,359**

Fig. 18. Groundwater Savings Facilities in Pima County

downstream edge of the community, so sewage can flow downhill and not require pumping to get there. This means that for the most part if reclaimed water is to be used it must be pumped back uphill through pipes.

In both cases, questions arise as to who should pay the added costs of providing alternate supplies to customers who have cheaper groundwater available? Is this a community good in which the cost should be shared by all who benefit or should all the costs be borne by the user? To what extent is it worth building expensive systems to make use of alternate water supplies?

Who Provides Water?

A problem that complicates attempts at basin-wide water management is that there are so many different providers. One hundred and fifty-one municipal water providers operate in the Tucson area. Of this number 19 providers serve over 96 percent of total municipal demand. The service areas of the major water providers are shown on Fig. 22. Institutions in the urban area such as the University of Arizona, David-Monthan Airforce Base, and the state prison pump most of their own water.

Tucson Water is the largest municipal provider in the AMA, serving approximately 75 percent of total municipal demand in 1995. Approximately 40 percent of the population served by Tucson Water resides outside of the city limits, mostly in unincorporated areas of Pima County. Tucson Water's service area is projected to continue to grow, but the rate of growth has been slow. Metropolitan Domestic Water Improvement District (Metro Water District or MDWID) is the second larger municipal water provider. Smaller water providers on the edges of the Tucson metropolitan area, such as Oro Valley and Marana, tend to be the fastest growing. Rapidly growing service areas are likely to be areas with rapid population growth and newer homes, which are likely to have water saving fixtures and smaller yards, but are also more likely to have water consumptive facilities such as swimming pools and spas.

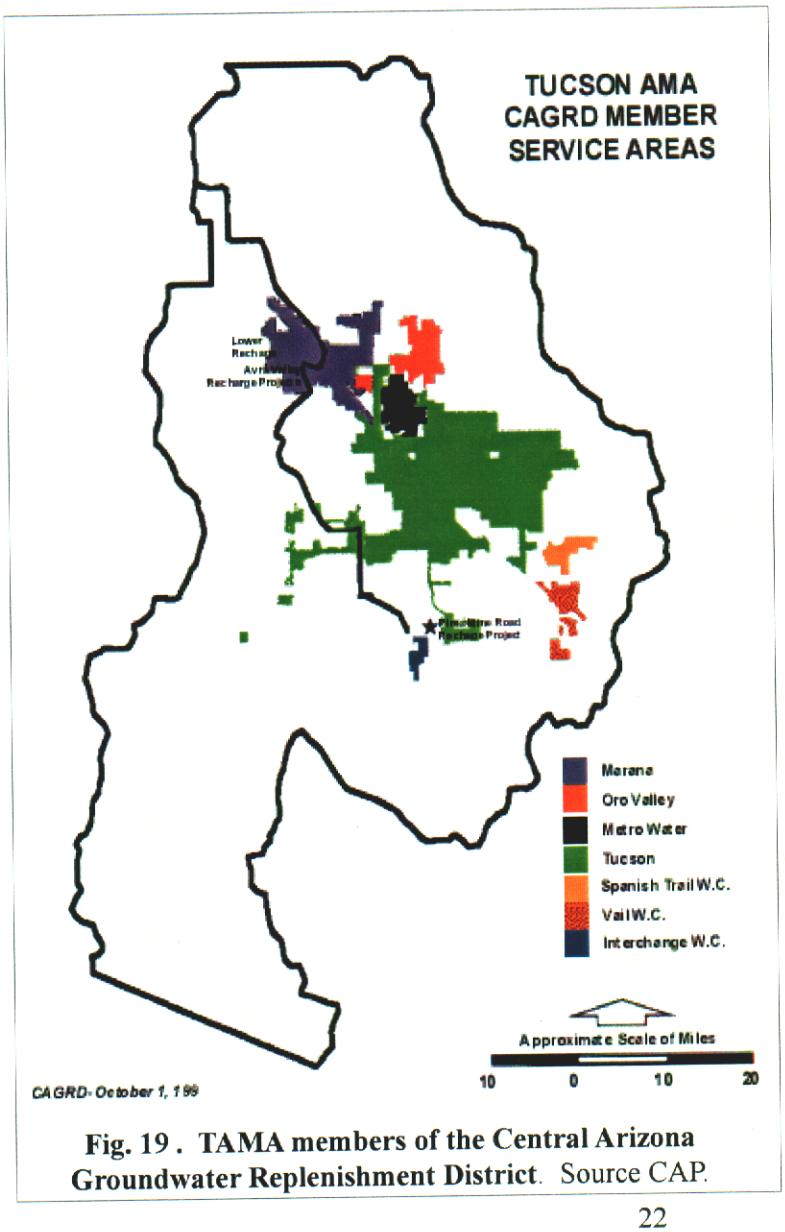


Fig. 19. TAMA members of the Central Arizona Groundwater Replenishment District. Source CAP.

In addition to the municipal providers, industries such as mines and agriculture pump their own water and many thousands of individuals in the county have their own wells.

While ADWR has some authority over water use in the AMA, especially for agricultural and industrial users, it does not have the authority to fully manage the water in the basin. It cannot, for example, require providers to use CAP water instead of pumping groundwater, although it can provide incentives. This means that Tucson Water customers and a few others as shown on the chart below shoulder most of the burden for paying to augment a dwindling water supply, while others may continue to pump groundwater at less cost.

Even if other users could be persuaded or required to use alternate supplies, it will be necessary to find a way to get that water to them. If, for example, the University of Arizona were to decide to use city water

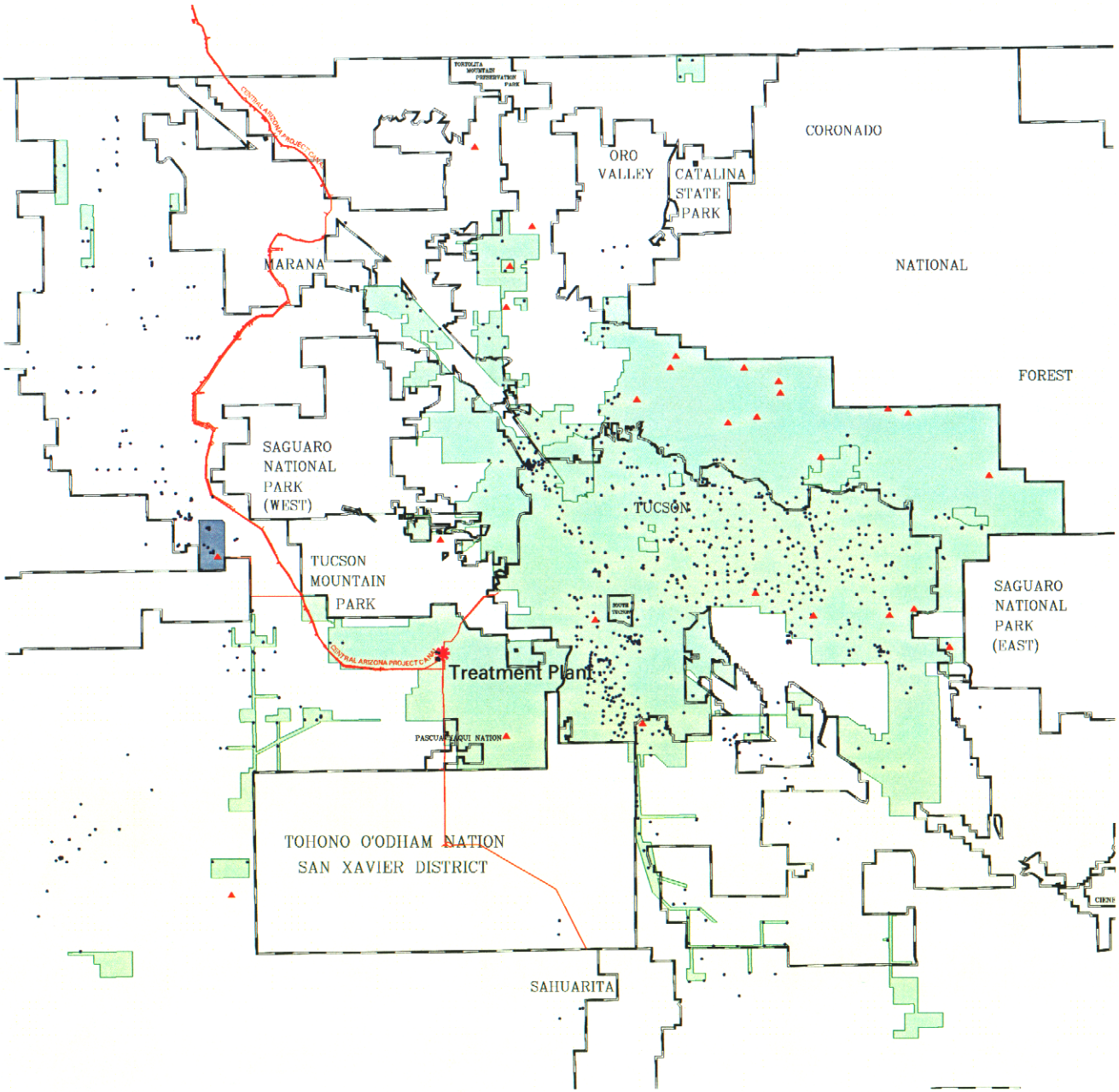


Fig. 20 Simplified map ot the Tucson Water System. We were unable to obtain information from Tucson Water to add the primary water mains to this map. the blended CAP water enters the city at the end of the red CAP line, near Starr Pass Blvd. Another major line brings Avra Valley water to the city to a reservoir near the airport. Most of the system is inter-connected with a series of pipes, reservoirs, and boosters that lift water to higher elevations. There are some isolated areas such as Saddlebrook and areas in the Altar Valley.

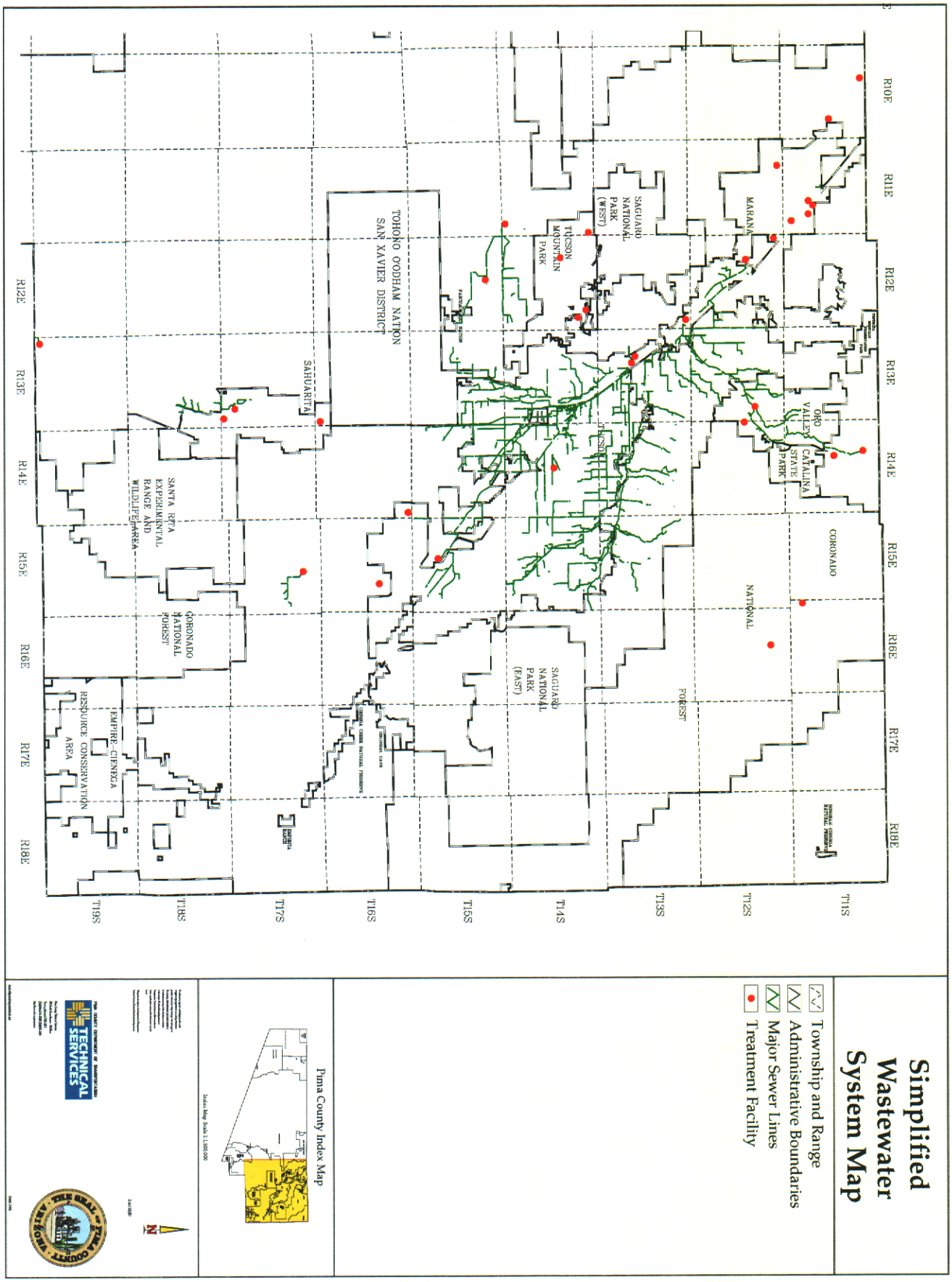


Fig. 21 Simplified map of the Pima County wastewater system

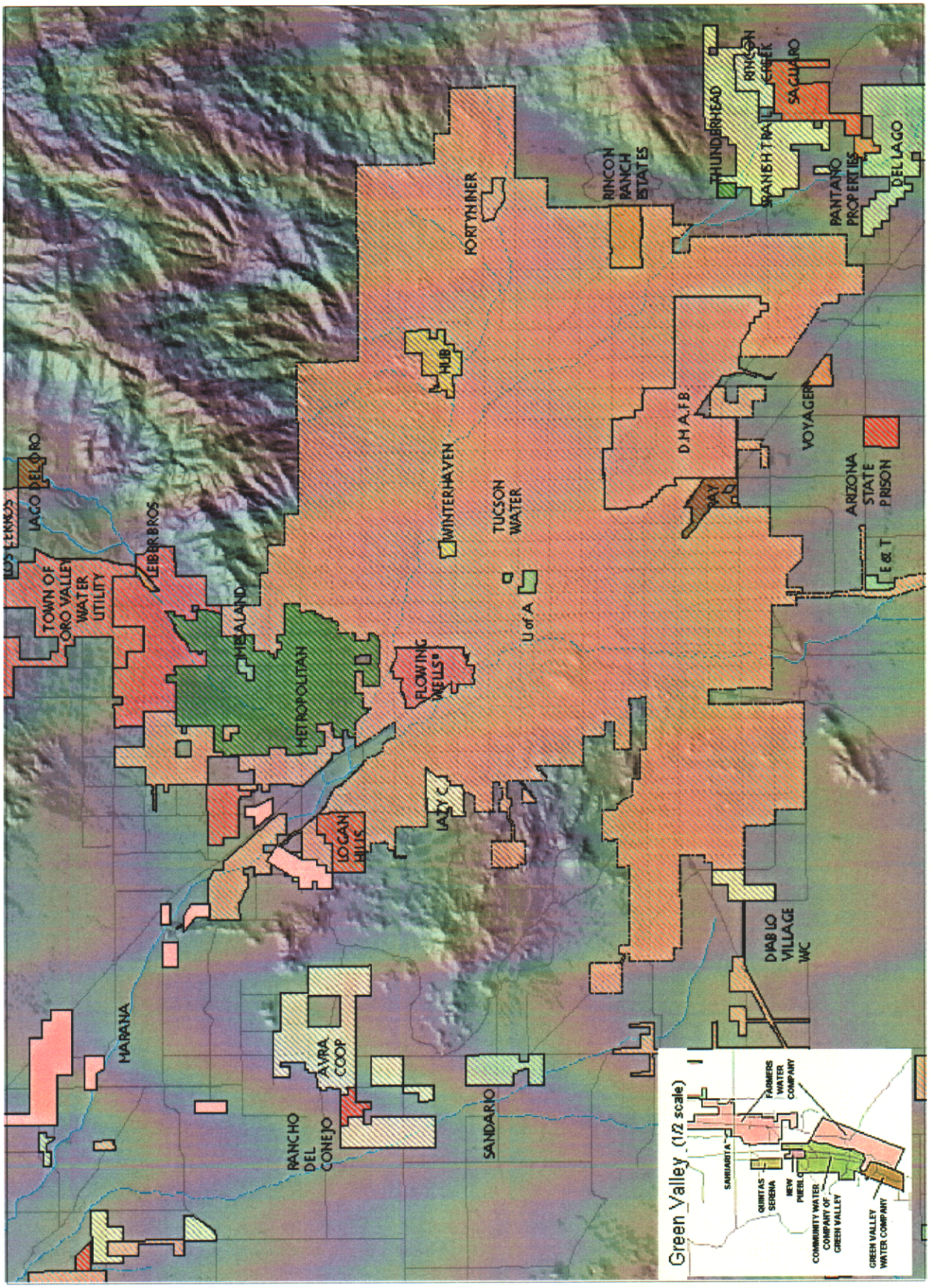


Fig. 22 Map of Major Municipal Water Providers in Pima County

instead of pumping its own wells, connecting it to the city system would be relatively simple as long as the existing pipe lines had adequate capacity in the area. If the existing capacity was inadequate, pipelines would have to be replaced, which involves tearing up pavement. Taking this alternative, however, is estimated to increase annual water costs for the university significantly. Reducing university pumping would benefit the community and help lower the risk of subsidence, but in this case the costs would be borne by the general taxpayer. In the case of a private user, the costs would be borne by the individual or shared among water users. To get CAP water to more remote users could be an even greater physical and economic challenge.

The theory and desirability of increasing use of renewable supplies is countered by these physical and economic issues.

Who Deals with Wastewater?

Until the mid 1960s, Tucson and Pima County both owned wastewater treatment plants. There was a short-lived attempt to have unified city-county management of water and wastewater under the Metropolitan Utilities Management Agency. Al-though city and county did work together for a few years, they parted company with an agreement that gave Pima County full responsibility for wastewater treatment while Tucson maintained full responsibility for water. In return for giving Pima County the wastewater treatment plants and sewer lines, Tucson maintained ownership of some ninety percent of all the effluent produced by the county plants. This agreement has been a source of tension ever since, but in 2000 the two entities reached a new agreement. As in the original 1979 City-County IGA, the City of Tucson retained control of the remaining 10 percent of the effluent. Unlike the original 1979 City-County IGA, the 2000 Supplemental City-County IGA transferred total control of the effluent produced at the Outlying Treatment Facilities to Pima County. The 2000 Supplemental City-County IGA also set aside a maximum of 10,000 acre-feet of effluent in future years into a Conservation Pool that is to be used for riparian restoration projects. (See Appendix E). Pima County, thus, treats the water but may not sign contracts to dispose of the effluent except for the portion to which it retains ownership.

Impacts of Using More Water than is Replaced

The most obvious impact of using too much water is that eventually the supply will run out. Arizona has many towns that became ghost towns after the resource on which the town depended was used up. Most often that resource was silver or gold. Reasons for the decline of Hohokam civilization appear to include long-term drought, salination of the soil from centuries of irrigation, and depletion of lumber and fuelwood resources. In *Pillar of Sand,* Sandra Postel attributes the fall of major civilizations from the Fertile Crescent of the Middle East to China and India to failures of the water supply in the face of long-term drought and damages to the soil and rivers from flooding, siltation, and water supply projects.

Increasing modern water technology makes such fates appear less likely today, but in fact Postel describes problems arising from overpumping of

Provider	Population	Water Use (acre-feet)
City of Tucson	621,290	115,860
Metropolitan DWID	44,153	9,161
Town of Oro Valley	23,416	6,503
Community Water Co.	14,261	2,249
Avra Water Coop	6,688	935
Lago del Oro Water Co.	6,461	1,787
Davis-Monthan AFB	6,191	1,969
University of Arizona	5,695	1,624
Ray Water Co.	4,617	658
Green Valley Water Co.	4,390	2,318
AZ State Prison	4,097	602
Hub Water Co.	4,078	1,118

Fig 23. Major municipal water providers in Pima County.
1997 figures. Note that some providers such as University of Arizona serve mostly a nonresidential population who also get water elsewhere for their residences. Source: WRRC 1999.

groundwater worldwide, especially in arid and semiarid regions such as Egypt and India. Deep wells that promised hope to an impoverished society now must be drilled deeper and deeper to reach a dwindling water supply. Water projects can prolong the water supply, but cannot provide infinite supplies into the future. This is a worldwide problem in arid and semiarid regions.

Pima County has a vast amount of water stored underground and could continue to pump groundwater for many years, although not forever, if it were not for three factors:

1. Water quality declines in many places as the depth to water increases.
2. The cost of pumping and of deepening wells increases with depth.
3. The surface of the land sinks. This factor is discussed in more detail below.

Subsidence

The Tucson Valley contains a large alluvial basin - a formation which has developed over a long period of time as sand, rock, and sediment flowed downhill from the surrounding mountain ranges along with water. This basin overlies bedrock far below. At the edges of the basin and in the mountains, the bedrock is very close to the surface and cannot hold water, except where there are fissures in the rock, as there are, for example, in the Rincon Mountains. In such places water may be trapped in pockets or flow along the fissure.

An important consequence of water level declines is land subsidence which happens when the surface of the ground sinks in the alluvial valley . In Arizona, subsidence is usually the result of excessive groundwater pumping. As water is pumped from an aquifer, the water occupying the spaces between the rock particles is removed, and the water table drops. Without the water, the particles then become more tightly packed together. With the continued pumping of groundwater without adequate recharge, the sediments become increasingly compressed causing the land to settle or subside.

In most cases, subsidence resulting from groundwater pumping occurs at about the same rate over large areas and can be difficult to detect. However, abrupt changes in conditions below the land surface such as changes in the types of sediments or faults below the earth's surface can cause the rate of subsidence to change quickly over a small area. This "differential subsidence" is more likely to cause damage to houses, office buildings, or infrastructure such as water and sewer lines or roads.

A related phenomenon, earth fissures, are a visible, and sometimes even spectacular manifestation of land subsidence. Fissures usually are noticed first as land cracks or crevices, a break in the earth's surface. They can then grow considerably as water erodes the fissured area. Gullies or trenches may be up to 50 feet deep and 10 feet wide, with the fissure extending hundreds of feet below the surface. The fissure may range in length from a few hundred feet to over eight miles. "El Grande" fissure system is ten miles long and is located in the Picacho Basin, northwest of Tucson. The average length of a fissure is measured in hundreds of feet. In the Tucson area fissuring has occurred west of the Tucson Mountains in Avra Valley.

More than 500 sinkholes have appeared in the San Xavier District. While experts do not fully agree on the reason for this, groundwater pumping by Tucson and for mining and agriculture outside the District appears to have played a major role.

Arizona ranks high nationally in land area affected by subsidence, ranking third after California and Texas. More than 3,000 square miles of the state have subsided, with hundreds of fissures occurring since the 1950s. The occurrence of subsidence in south-central Arizona is a major concern because it is a core area of the state, with major agricultural and urban centers. The Phoenix and Tucson metropolitan areas are located within this area, as well as the agricultural production areas within Pinal and Maricopa counties.

The Tucson urban area is especially vulnerable to the damaging effects of subsidence. It has dense areas of population, with large numbers of buildings, facilities, and structures – bridges, highways, electric power lines, underground pipes, etc. – that make up the urban infrastructure. Railroads, earthen dams, wastewater treatment facilities and canals also are prone to damage from subsidence. Sewer lines, laid at precise levels, can have their slopes reduced or even reversed, with serious consequences. This means that the sewage would flow sluggishly or in extreme cases flow backwards, away from the treatment plant. Any structure built across the path of a fissure likely will suffer serious damage. Careful and expensive construction procedures were worked out to protect the CAP canal from subsidence damage in certain areas. Despite these precautions, the canal was damaged by an earth fissures along its route to Pima County.

The U.S. Geological Survey (USGS) reports that

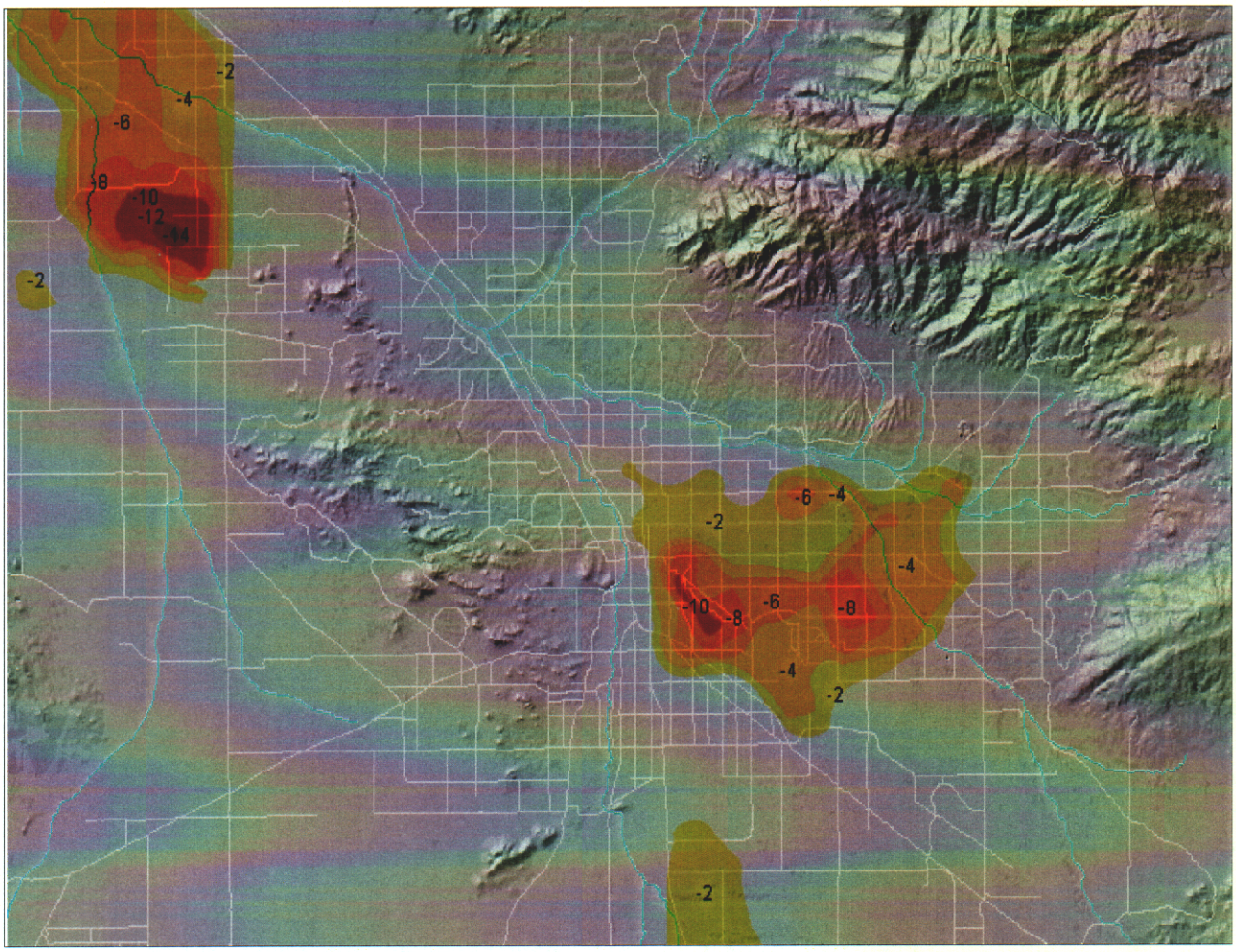


Fig. 24. Areas of Greatest Potential Subsidence. Darker areas indicate greater subsidence potential.. Source WRRC 1999.

since 1940 groundwater levels in Central Arizona have dropped over 220 feet, with Central Tucson subsiding at least one foot since 1950. Meanwhile the rate of subsidence in the area is increasing. Satellite images show that sections of central Tucson are sinking at the rate of 2 centimeters per year or 0.8 inches per year.

A European mapping company that uses satellite images taken over a period of years to plot subsidence, coupled with a technique called interferometry has identified a large subsidence area in central Tucson, centered at the intersection of East Speedway and Country Club Road. This marks the spot of the greatest subsidence activity in the Tucson area.

USGS models predict levels of subsidence likely to occur in Tucson wellfields. Assuming that groundwater pumping and natural recharge rates continue at 1986 levels through 2025, and based on other assumptions about the aquifer material being compacted, USGS models indicate that maximum subsidence could range from 1.2 to 12 feet in the Central Wellfield by the year 2025. Under the same assumptions, subsidence in the Santa Cruz Wellfield could reach up to 4 feet by the year 2025. For northern Avra Valley, maximum subsidence potential is estimated to range from 0.9 to 14.7 feet by the year 2025, assuming that pumping levels and natural recharge rates continue at 1970s levels. If subsidence approaches the maximum level projected for the year 2025 in the Central Wellfield, the risk of differential subsidence is significant, especially near downtown Tucson.

Subsidence can be halted either by ceasing or limiting groundwater withdrawal in an area. Also, under the right conditions, overdraft may be reduced through artificial recharge, thus slowly decreasing the danger of further subsidence. In most cases, subsidence is termed inelastic because the sinking of the ground is permanent, and recharge would not reverse the process. Well-injection recharge is likely to be more effective than other types of recharge at ensuring that water is recharged close to the

compacting layers. Surface water recharge projects may be effective at restoring the water table. In most cases, however, once subsidence occurs, the water storage capacity of the aquifer is permanently reduced. In some cases, recharge projects may even worsen subsidence, as the weight of the water applied at the surface acts to compact the underlying aquifer materials even more. In May 2001 Tucson Water announced that the arrival of CAP water in the city system would make it possible to shut down one well in the subsidence-prone area.

Ways of Resolving Water Problems

People in Pima County have been concerned about water problems for more than a century. There are three basic responses: Find more water, use less water, and settle disputes for limited supplies through legal means.

Augmenting the available supply has always been a popular solution to inadequate supplies, whether the augmentation came by way of longer pipelines and canals, storage facilities and dams, or deeper wells. Conservation has also had its advocates through the years. People have been urged to water only at certain hours or water rates have been changed to discourage waste. Arizona surface water law developed in response to arguments over water rights in the late nineteenth century. Ground-water law came much later when excessive agriculture pumping began to worry people in the mid twentieth century.

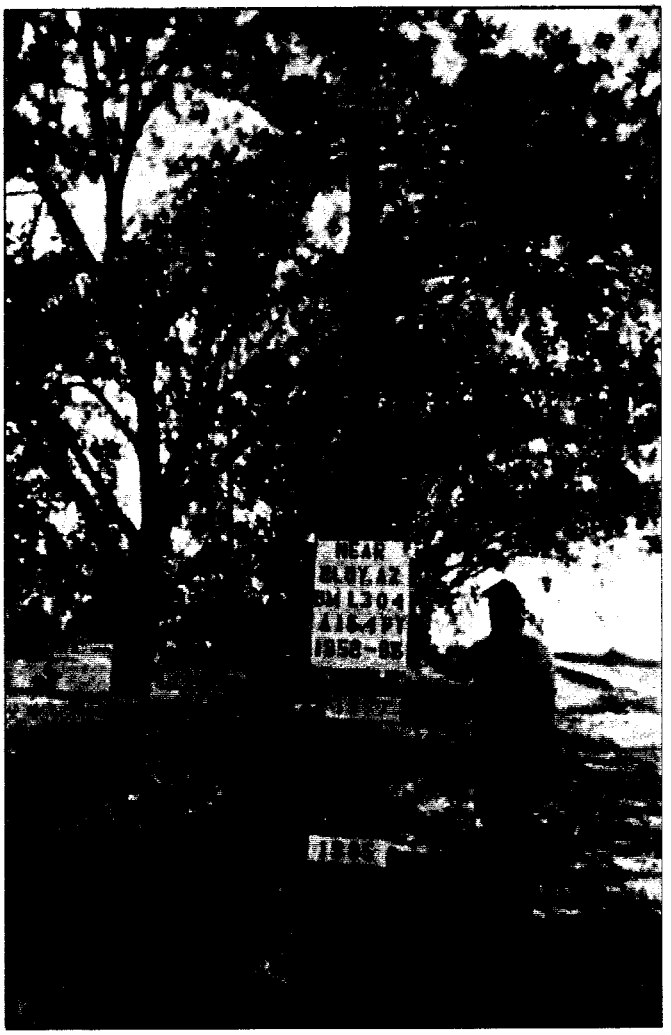


Fig. 25. Subsidence in the Eloy area. Signs on the pole show where ground level was at various times before subsidence caused it to drop. Source: USGS.

Augmenting the Supply

The CAP, discussed above, is the latest and probably the final attempt to augment the local water supply with water outside the area. The federal government has not authorized any new water projects in more than twenty years. More importantly there are really no new affordable sources of water to tap with current technology. Cloud seeding, importation of desalinized sea water, and imports from the Pacific Northwest or Canada have all been suggested and dismissed as either too costly, not politically feasible, or technologically unproven.

Another way to augment the supply is to capture more of the rainwater that falls in the valley. The Salt River has several excellent sites for dams and since construction of Roosevelt Dam in the early 1900s, the Phoenix area has depended on a series of dams to store excess water that comes down the river and then deliver it downstream at the dry times of year. These dams also serve a flood control purpose. The Santa Cruz basin does not have any comparable dam sites. During the past century people have envisioned building storage dams in Sabino Canyon and inflatable dams in the Santa Cruz or Rillito River, or flooding old gravel pits as ways to capture floodwaters for use in the metropolitan area. None of these ideas has proven to be a feasible way of increasing water supplies or recharge, since the rivers already do an efficient job of recharging the water that flows in it, although much is recharged downstream of where it is most needed.

On a much smaller scale, however, there are some recreational dams in Pima County as well as stock tanks that hold back water. The largest of these are on public lands in Rose Canyon, Sabino Canyon and near Arivaca. These dams have a localized impact, but do not significantly change the regional water picture. In the 1930s the Citizens Conservation

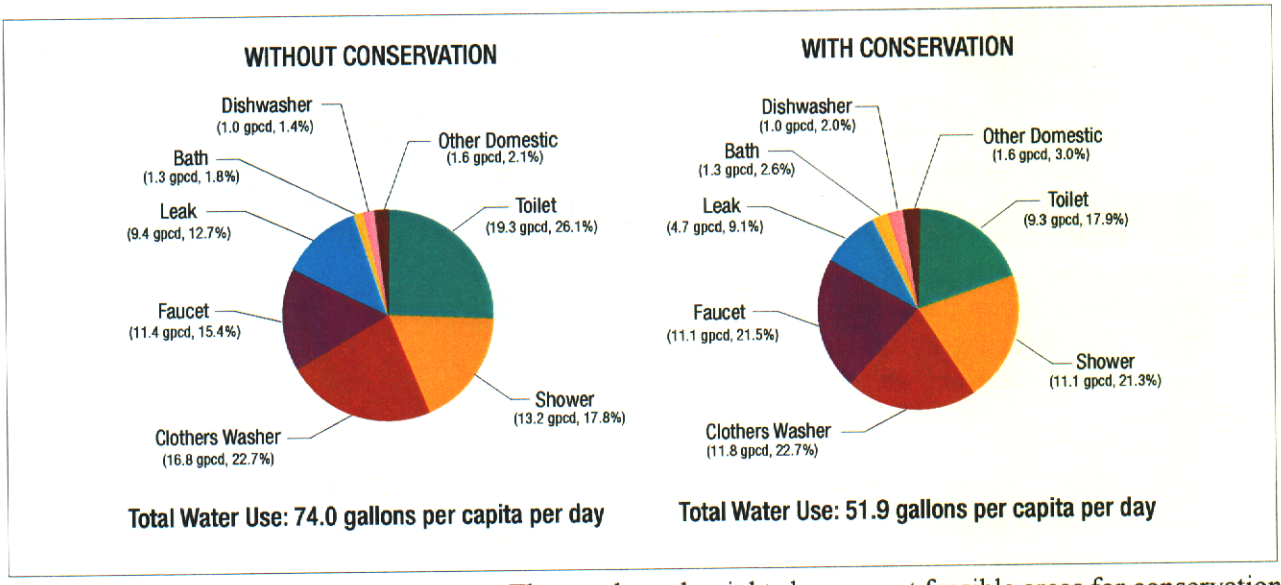


Fig. 26 How water is used in the home. The graph on the right shows most feasible areas for conservation. Source: WRRC 1999. From American Waterworks Association.

Corps (CCC) built hundreds of small check dams in the Tucson Mountains and other places in Pima County. Their purpose was to slow down the waters and increase percolation. Many of these dams can still be seen today. The cumulative effect of these dams has not been well analyzed.

Using less Water

Reduction of water use (or the rate of increase of water use) can be accomplished by reducing per capita water use and by limiting the number of people and businesses using the water.

Limiting per capita use is an important feature of the Groundwater Management Act, described below and has been practiced in Pima County for many years with varying success. Conservation efforts in Pima County are described in some detail in the SDCP report *Water Conservation in Pima County* and will not be repeated here.

Conversion of Uses

The increase in water use can also be reduced by switching from one water use to another. For example, when a farm is converted into a housing development, the water is not used for agriculture but for urban uses. This may result in an increase or a decrease in total water use, depending on the types of crops that were grown and type of irrigation on the one hand and the type of urban use, on the other hand. If the urban use is single family residential with landscaping and a golf course, net water use will probably increase, but if the new use is for apartments with low water use landscaping, there will be a net decrease. Population growth, therefore, does not always result in more water use.

Limiting Population Growth

Limiting population growth has not been seriously considered by elected officials in Pima County. Continued growth has generally been viewed as necessary to the economy or at least as inevitable. There are few mechanisms in the law to limit growth and the right of people to move wherever they choose within the country is considered a basic constitutional right. Some groups, most notably the Sierra Club in its 1988 study, *Saguaro We Going?*, questioned those assumptions and found many negative aspects to rapid population growth including availability of water for an indefinitely large population. This is one area that deserves more community discussion than it has yet received.

Regulating Use Through Legal Means

Surface Water Law

Arizona law considers surface water and groundwater to be distinct and regulates them quite differently. The surface water law developed in the late nineteenth century as a way to assure that miners and farmers could have a dependable supply of water. In order to use the water they generally had to remove it from the river. People could get an appropriation for water by filing for it with the government. The first permittees had priority over later ones and continue to do so to this day. That is, if someone has rights to a specific amount of water, and the right predates someone else's right to water, the first person can

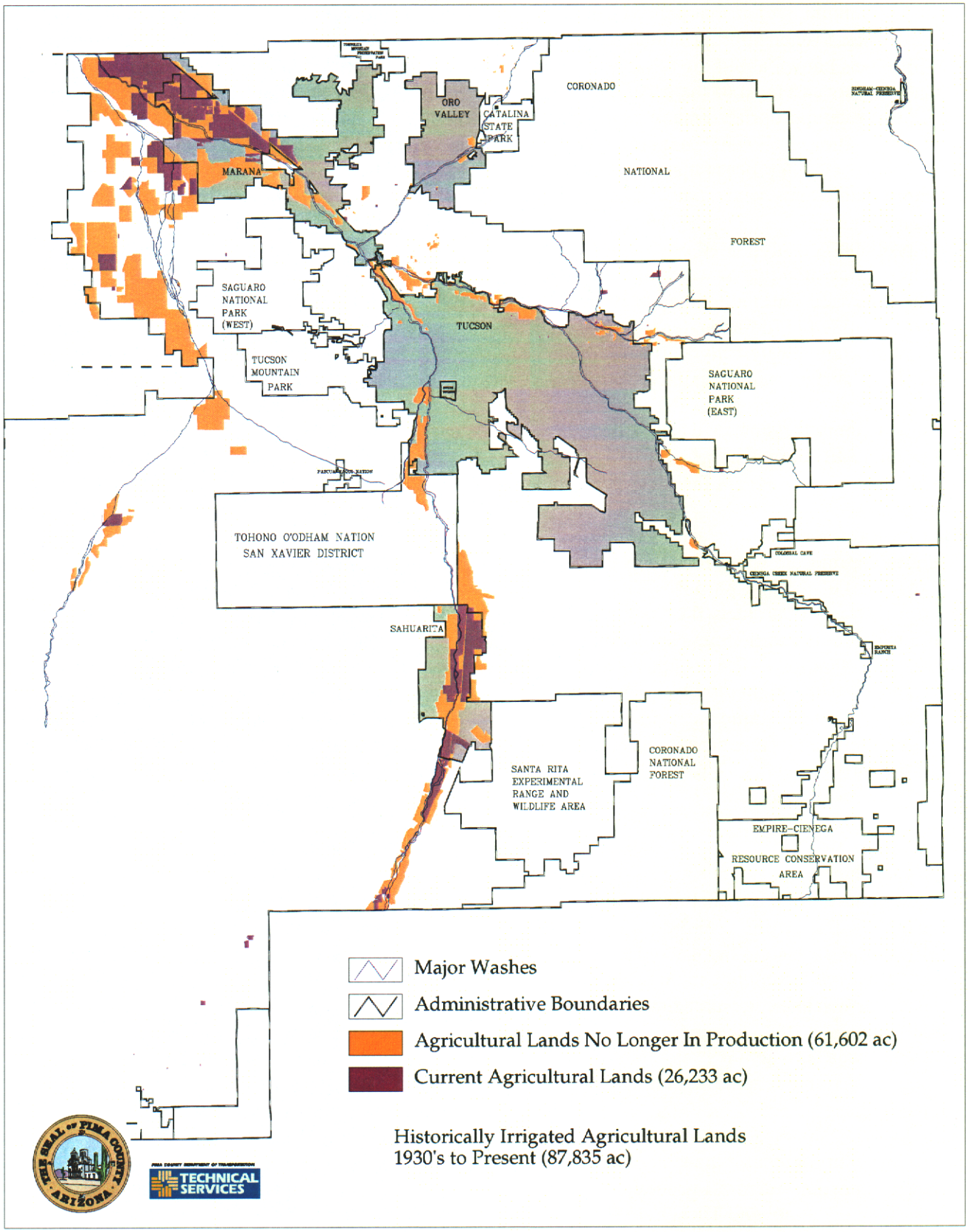


Fig. 27. Historic and current agricultural areas in Pima County. Much of the area hatched in purple was recently put into production by the O'odham and is irrigated with CAP water. Source: Pima County Technical Services

take his full amount even if that deprives the late comers of water. When appropriations were first made, little was known about the reliable amount of water in rivers and most of the surface water in the state was overappropriated many years ago and those appropriations still stand, but are being adjudicated in court, a process that has already taken more than twenty years and will be settled in the distant future.

This problem is complicated by the fact that tribes claim large amounts of water under federal law. The statewide water adjudication began as a way to deter-mine the Indian water rights, since if all the Indian claims were fully settled there would be little if any surface water available for others. This is a very complex process. (See below)

In Pima County the surface water is fully appro-priated and is not a significant source of water for human users except for some in more remote areas.

One special feature of the surface water law is the right to appropriate water for use in the stream for recreational or wildlife purposes. This "instream flow right" protects flow in a specific part of a watercourse so that new appropriators cannot deplete that flow. It does not, however, affect rights of senior rights holders, nor does it protect the flow from groundwater pumping. In Pima County instream flow permits have been granted for parts of Cienega Creek, and several higher elevation streams.

Groundwater Law

The Groundwater Management Act

In 1980, the Arizona Legislature passed the GMA which is designed to prolong the supply of ground-water and promote the use of renewable supplies. Renewable supplies include the CAP, reclaimed wastewater, and water flowing in streams - surface water. The basic goal of the GMA in this area is to achieve "safe yield" by balancing supply and demand with minimal use of ground-water.

The GMA established four Active Management Areas (AMAs) in regions of the state with the greatest groundwater overdraft problems: the Phoenix, Prescott, Pinal and Tucson AMAs. (Fig. 8). A fifth, the Santa Cruz AMA, was created in 1994 when it was split off from the Tucson AMA. The Tucson AMA basically includes the portion of the Santa Cruz River watershed downstream of Santa Cruz County and up to Picacho in Pinal County. It includes all the metropolitan area, but does not include the western parts of the county or the San Pedro River portions of the county. It also includes portions of Pinal County. Groundwater use is regulated more strictly in the AMA portion than in the outlying areas.

Some other areas were designated Irrigation Nonexpansion Areas (INAs). In these areas, new pumping for agriculture is limited, but other pumping is not. There are no INAs within Pima County.

Each AMA must develop five successive plans for reaching its goal over the period 1980 to 2025. The first four plans each cover a ten-year period, while the last plan covers the last five years. The AMAs are in the third management period, which covers the years 2000 to 2010. The Tucson AMA issued its Third Management Plan in the fall of 1998.

Safe Yield

The management goal designated for the Tucson AMA is to reach "safe yield" by the year 2025. Achieving safe yield involves reaching a balance between the annual amount of groundwater withdrawn and the annual amount of renewable water that reaches an AMA. Each AMA has its own criteria for satisfying the requirements. In the Draft Third Management Plan for the Tucson AMA, ADWR states that even with the use of CAP water and conservation measures, the safe yield goal will not be met.

The ADWR water budget is calculated by estimating water use based on projected population, probable per capita water use, agricultural and industrial use and Indian use. Supply is based on assumptions about CAP, recharge and effluent. Estimating up to 45 years into the future is obviously difficult, and projections are revised in succeeding management plans. For example, population estimates for the Tucson AMA in the year 2025 have been revised downward. For the Second Management Plan (SMP) the population estimate for the AMA in the year 2025 was set at 1,693,000 people, whereas the TMP estimate is only 1,266,500 by 2025. Population projections used are the official state projections. Several different approaches to predicting future supply and demand are discussed below.

Assured Water Supply (AWS)

New subdivisions are required to show an "assured water supply" before being built. What

counted as an "assured water supply" originally was very broad and included groundwater withdrawals that would lower the water table as much as 1,000 feet. Assured water supply rules have been revised and somewhat tightened to include the following criteria:

- A sufficient quantity of water is continuously available to satisfy the water demands of the development for 100 years;
- Water source meets water quality standards;
- Proposed use of water is consistent with conservation standards;
- Proposed use is consistent with water management goals;
- The applicant is financially capable of installing the necessary water distribution and treatment facilities.

The concept of assured water supply does not assure sustainability for more than 100 years, and the requirements can be met in some ways that do not assure sustainability. Participating in a recharge program or contracting for CAP water can be adequate to meet the requirement.

Municipal Conservation Programs

AMAs establish conservation goals for each municipal water provider and major agricultural and industrial water user. Large municipal water providers are allowed to choose among four programs to regulate their water use. The total gallons per capita per day (GPCD) program is the base program, under which GPCD goals are set for each provider. If goals are not met, a provider can be fined, although provisions allow use in very dry years to be balanced with use in wet years. There are alternate ways of complying with the requirements. This entire program is currently being reviewed because of a lawsuit brought by a water provider. The court ruled in 2000 that ADWR's conservation rules must be changed, so the details will not be discussed here.

Agricultural Conservation Requirements

The GMA regulates agricultural water use in several ways. First, no new agricultural land can be developed for non-Indian irrigation. Only lands which were legally irrigated with groundwater in the five years prior to implementation of the GMA may continue to be irrigated with groundwater. Such lands received an Irrigation Right. Only holders of the right may withdraw, receive and use groundwater for growing crops.

Connected Groundwater and Surface Water

Although surface water replenishes groundwater and groundwater may feed surface streams, the law treats groundwater and surface water very differently, in contrast to scientific reality. Surface water law based on a first-come-first -served basis while groundwater law outside AMAs favors the users with the greatest financial ability to pump water regardless of time of arrival. Within AMAs groundwater law recognizes grandfathered rights and attempts to work on a share-the-resource basis. Theoretically, groundwater law within AMAs attempts to ensure that the resource lasts as long as possible

Recent court decisions have not changed this basic dichotomy, but have expanded the definition of surface water to include some underground waters close to the river that were formerly treated as groundwater. How this will be interpreted is yet to be determined.

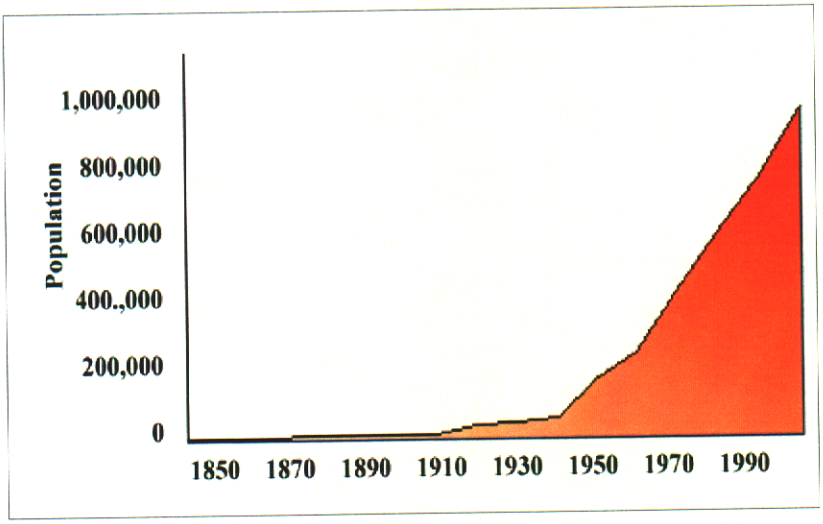


Fig. 28. Population growth in Pima County. In the past, population growth has not been correlated with increased water use because most of the water was used for agriculture. As non-indian agriculture declines, population growth will be an increasingly important factor.

	1995	2005	2015	2025
Population	768000	921000	1092200	1266500
Water Use				
Municipal	155,500	186,300	216,200	243,100
Agricultural	98,000	117,700	97,000	70,000
Industrial	60,200	72,100	73,000	75,400
Evapotranspiration	3,700	3,700	3,700	3,700
Total Use	317,400	379,800	389,900	392,200
Actual Overdraft	**163,900**	**92,600**	**71,500**	**49,000**

Fig. 29. Tucson Active Management Area Water Budget (acre-feet)
This scenario assumes water conservation goals are achieved by 2010 and continue through 2025.
Adapted from TAMA Third Management Plan

Water and Population Growth

A British film crew producing a video on water problems in the Southwest in 2001 repeatedly asked the question: "When will you run out of water?" It was difficult to persuade them that this question could be answered adequately, since the answer must be based on a large number of assumptions and projections about the future. These assumptions include the supplies available, amounts of recharged water that can be recovered, patterns of personal use, population levels, and amount used by other users such as mining companies and agricultural business and even assumptions about water supplies during a period of climate change. Any projection is only as good as the assumptions.

The Arizona Department of Economic Security is responsible for making population projections statewide and the Pima Association of Governments for distributing the projections to different areas within the county. Projections are made on the basis of past population growth which may not be repeated in the future. There may be some major new attractant that brings people to the area or some other area may be more attractive to migrants than Tucson at any particular time. The population of Pima County on April 1, 2000, according to the 2000 census was 843,746, a 26.5 percent increase since 1990.

There are many ways to look at this question of how much water we have for a growing population. Four approaches are briefly described below. The first by the Tucson Active Management Area, takes a legal viewpoint, assumes official population projections, and calculates a water budget to the year 2025, which is its legal mandate. The Southern Arizona Water Resources Association made certain assumptions in an attempt to answer the question "How much growth can be supported by our water supply?" The Water Resources Research Center offered a variety of scenarios based on various assumptions. The Sierra Club asked the question "How much would per capita consumption have to be reduced under different assumptions to avoid mining groundwater?" More information on the scenarios is in Appendix C.

Four Scenarios

Tucson AMA, Third Management Plan

Fig. 29 shows the water budget calculated under the assumption that water conservation goals are achieved by 2010. This shows that with a population of 1,266,500 it would still be necessary to mine groundwater. If agriculture were eliminated the water supply would be adequate for some years into the future. If municipal demand were to continue to increase at the same rate as it has in the past, groundwater overdraft would probably be needed at a population level of slightly more than 1.5 million even with elimination of agriculture. None of the scenarios factors in water for riparian protection or restoration.

Southern Arizona Water Resources Association

In autumn of 2000, SAWARA attempted to calculate how many people the area could support without further mining of groundwater. (Fig. 30) They looked at three scenarios: mining and agriculture at today's level, mining and agriculture at

Water use assumptions	Population that can be supported
Mining and agriculture at today's level	1,384,289
Half today's mining and agricultural use	1,833,249
No mining or agriculture	2,282,209

Fig. 30. SAWARA Calculations
Source: Waterwords, Autumn 2000.

half today's level, and both mining and agriculture cease. They assumed that net per capita water use would be about 107 gallons per capita per day, which assumes that some of the water used is reused or recharged. In all cases the official ADWR figures were used for supply, demand, and recharge. They assumed that the CAP supply would be 200,000 acre-feet per year.

Water Resources Research Center

Rather than ask about population levels, in 1999 WRRC developed scenarios based on various assumptions to determine how much groundwater would have to be mined under different supply and demand assumptions. (Fig. 31). The primary purpose was to illustrate how dependent projections are on the assumptions made about supply and demand. This is on the Web site www.ag.arizona.edu/azwater/ in an interactive format in which people may alter the assumptions to see the results. Of the fourteen scenarios shown on the table, only two resulted in no mining of groundwater. The full chart is in the appendix. Sample scenarios are shown here.

Sierra Club

In 1988 the Sierra Club did a similar analysis, also using official ADWR supply and demand figures from the Tucson AMA Second Management Plan. (Fig. 32). In this case, they used a range of projections from ADWR ranging from optimistic supply projections to pessimistic projections, and low to high population projection. In this scenario, the optimistic CAP supply assumption was 213,000 acre-feet per year and the pessimistic supply assumption 70,000. They asked the question - what would per capita consumption have to be in order to accommodate the projected population without mining groundwater?

Potential Impacts of Climate Change

In addition to adapting to the normal cycles of drought and plenty in the desert, planners now need to look at the possible impacts of long-term climate change.

In 2000, the Institute for the Study of Planet Earth issued a report called *Preparing for Climate Change* which included warnings about the impacts of climate change on water supplies in the southwest. Much of the report necessarily contains words like "might" and "probably." Some things are clear, however. Climate change will bring about much greater variability in weather, with more and longer extremes of drought and flood. El Niños will increase, bringing more winter rain which could add to the water supply, but summer temperatures will increase leading to higher evaporation and more water requirements for landscaping and other purposes. Flooding is likely to be more intense which would lead to less reliable local recharge., more soil erosion and property damage. Long term droughts

Scenarios	Pumping	CAP	Balance
1999 levels	325,000	0	-180,000
Double municipal use , others remain the same	300,000	175000	-98,000
Double municipal, decrease agricultural and industrial	193,800	193,800	-7,000

Fig. 31. Water Resources Research Center Sample Scenarios
Source: WRRC 1999. Amounts in acre-feet

throughout the Colorado Basin could increase evaporation from the large reservoirs and stress the capacity of the reservoirs to store large enough supplies to carry CAP users through long drought periods. ADWR is attempting to incorporate the uncertainties of climate change into its long-range calculations.

Dealing with Uncertainty

It is clear that no one knows that the future will bring in terms of either supply or demand. A long-term drought or major problems with the CAP canal could drastically reduce the supply of CAP water. New technologies could make it economically feasible to reuse wastewater for drinking purposes. Population growth could surge as California experiences shortages of water and power, or it could slow down if the area became less attractive than other areas for some reason. Mining could disappear from the area or a new mine could be opened. Climate change could drastically affect the supply picture if El Nino storms were to increase. It could affect the demand picture if higher summer temperatures led to more outdoor water use.

How should so much uncertainty be factored into planning for the SDCP? Most of the solutions are beyond control of the county acting alone, but land use planning in unincorporated areas is one factor over which the county has some control. Should planning be based on the most optimistic scenarios, the most pessimistic, or on a possible range with built in flexibility if assumptions prove to be wrong? While we cannot plan accurately for the indefinite future, planners will have to take into account the fact that barring some new technological advances, our annual supply will not increase beyond what we have today, including the full CAP allocation. If population and water use continue to increase indefinitely, there will be some point at which demand will again exceed supply, but no one knows when that will happen.

A major concern of the SDCP is assuring water supplies for habitat protection. So the county must be concerned both with the regional water supply picture and with the picture in specific parts of the county where riparian areas and springs may be threatened. These are discussed in the next section.

Supply assumptions	Population	Per capita use
A. Optimistic supply	1,000,000	181
	1,600,000	113
	2.000.000	90
B. Moderate supply	1,000,000	123
	1,600,000	77
	2,000,000	61
C. Pessimistic supply	1,000,000	78
	1,600,000	21
	2,000,000	17

Fig. 32 Sierra Club Scenarios Source: Sierra Club 1988. Use in gallons per day.

Chapter 4. Water Supplies In Specific Areas

Major Regional Water Issues

The different regions of Pima County have very different water supply conditions and some experience conflicts between water use for a growing population and water use for riparian areas. All of the metropolitan and agricultural parts of the county are in the Santa Cruz River Watershed, which gets its renewable water from a series of mountain ranges, most notably the Catalina Mountains and the Santa Rita Mountains.

Both Avra Valley and Altar Valley are in this watershed, but separate from it for the most part. The streams that drain these valleys enter into the Santa Cruz watershed downstream in the Marana area. Their aquifers are separate from the aquifers to the east of the Tucson Mountains, but groundwater is exported from Avra Valley to the Tucson valley.

The San Pedro River is completely outside the Santa Cruz watershed, but both are parts of the Gila River basin. It too gains some flows from the Catalina Mountains as water flows east.

Ajo is a completely separate basin both for surface water flow and for groundwater.

Seven different regions are briefly discussed below to illustrate the range of difference in terms of water supply and demand.

Tucson Urban Core

This area is bounded approximately by Silverbell Road, Pantano Road, the Rillito River and the Airport.

This area contains most of the population in the county and most of the urban water use. In this area the watercourses are dry most of the time, although some were perennial or intermittent in the nineteenth century. Pumping of groundwater has taken place here for more than one hundred years, with increasing amounts of pumping over time. In this area water demand far exceeds supply and demands cannot be satisfied through local renewable supplies. Since the 1960s water has been imported from the Avra Valley, but even this is inadequate and CAP water is now available for a new water supply in this area.

Because there has been so much pumping of groundwater, the water table here has dropped up to 200 feet (Fig. 5) and subsidence is occurring in the urban area. One major area of subsidence centers around El Con Shopping Center and radiates roughly in an irregular oval beyond the University to the west and beyond Wilmot Road to the east. Another area of subsidence centers around the city's wellfield north of San Xavier.

Most of the washes in the region have been radically altered, by being cemented, straightened, diverted into culverts, or by being paved over. Street flooding is common in some areas in storm season because natural drainageways have been altered and so much area is paved that a large amount of water runs off into the street instead of soaking into the ground. Runoff to the Santa Cruz and Rillito Rivers often occurs with rapid flows, changing the recharge patterns of the rivers as well as increasing flood and erosion damage.

The only perennial watercourse in this area is the Santa Cruz River downstream of the two wastewater treatment plants where the water originates. This treated wastewater flows through Marana and provides riparian habitat for many miles. Pima County is looking at the feasibility and design of a habitat restoration project (with some recharge benefits) where the Santa Cruz, Rillito and Canada del Oro meet near Orange Grove Road.

There is some talk of piping CAP water or wastewater to parts of the river upstream to create riparian habitat in connection with the city's Rio Nuevo Project. CAP water is being introduced upstream at San Xavier where the O'odham are working to restore some washes, a mesquite bosque and parts of the Santa Cruz River, using CAP water. (See page 43).

East Tucson Valley

This area includes the Rincon Mountains, Tanque Verde Wash, and Cienega Creek, where significant riparian resources can be found. In all of these areas new groundwater pumping could negatively impact the resources.

Water resources in Saguaro National Park were studied by a University of Arizona team in a report by K.J. Baird and others. Most of the water resources are protected within the park boundaries, but some of the downstream portions are highly vulnerable. The report identifies a number of isolated water pockets located in rock formations as well as some ephemeral or intermittent streams.

The riparian habitat adjacent to Rincon Creek

through the X9 Ranch is the best remaining cottonwood-willow riparian habitat in the park and threatened by urban development. The water supply for a mesquite bosque along a tributary of Tanque Verde Creek also is threatened by urban development and the pumping in the area both to serve local residents and for the city as a whole. Both areas offer high value wildlife habitat. Development of private wells for homes and resorts as well as City of Tucson municipal supply wells could increase pumping to levels detrimental to those riparian habitats. If groundwater depths fall below 3.5 meters in Rincon Creek or 5 meters in Tanque Verde Creek during a significant portion of the growing season, the riparian vegetation will have difficulty surviving and young trees will have problems getting established.

One SDCP report studied groundwater level changes in the Tanque Verde Valley downstream from the park. Parts of the Tanque Verde Wash still have excellent riparian vegetation, although this part of the stream is ephemeral. In the 1990s an Arizona State University team described the relationship between depth to groundwater and the health of the mesquite woodland habitat in the area. Mesquite trees in the reach from Wentworth Road to Sabino Creek became stressed when groundwater depths fell from 16 to 59 feet.

In addition to private wells in the area, (Fig. 33) Tucson Water has a series of wells in the area and agreed to use these wells only if other pumping was inadequate to meet urban demands. In 1984 Tucson Water pumped 8,161 acre-feet and by 1989 this had increased to 12,417 acre-feet. Since the amount of water recharged along the stream was only 4,800 acre-feet at the Agua Caliente Wash confluence with the Tanque Verde, the water table declined. In the early 1990s less water was pumped because of the temporary introduction of CAP water, making those wells less important. The water table rose at that time. Between 1994 and 1998, however, with temporary abandonment of CAP for urban uses, the pumping by all major users in the area increased, ranging from 5,910 to 7,826 acre-feet per year, again exceeding recharge. (Note: The precise numbers differ from those in some other studies because the area under consideration differed slightly, and some wells were included in one study but not another. Tucson Water also asserts that its groundwater pumping from a lower aquifer). The bottom line, however, is that pumping continues to affect the

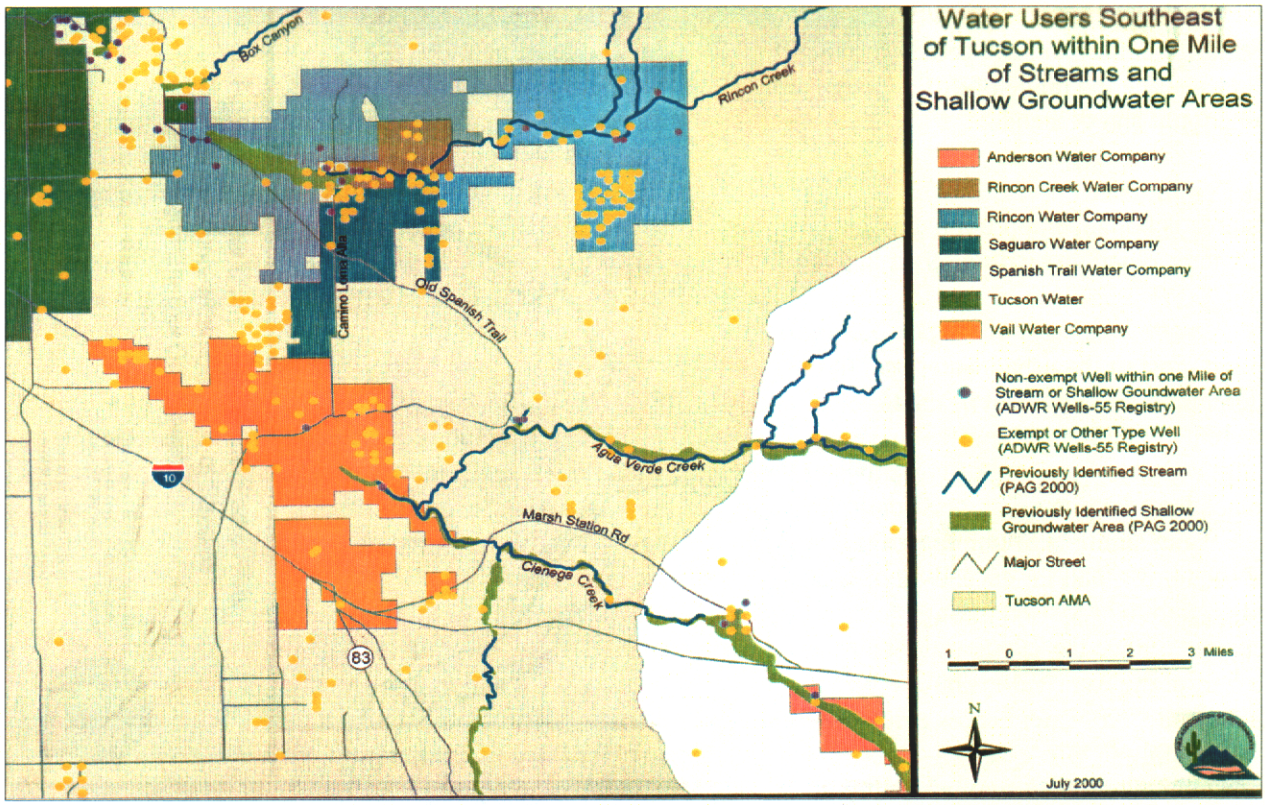


Fig. 33. Water users in the southeast in shallow groundwater areas. This is an example from the PAG study of pumping in shallow groundwater areas.

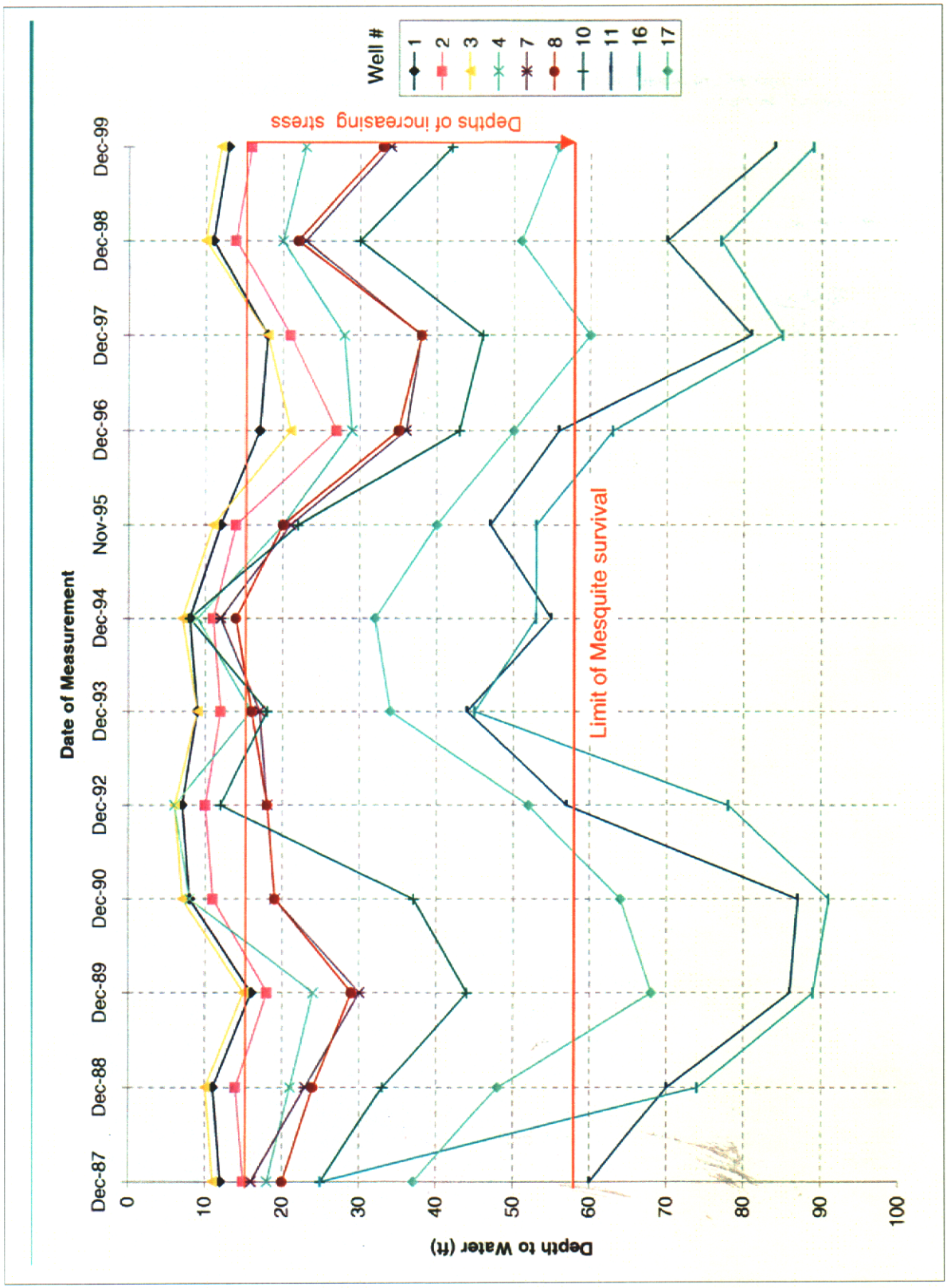


Fig. 34 Depth to water in selected wells near the Tanque Verde Wash. Note the fluctuations over time as pumping increases or surface flow brings water to the wells. Three wells are at the depth at which damage to the mesquite bosque is anticipated. Others are approaching that level, while others are still quite shallow. Source: SDCP Tanque Verde report.

bosque. One section of the bosque may be relying on a separate, perched, aquifer and be less affected than the rest.

Cienega Creek flows largely through public lands owned by the National Forest, Bureau of Land Management and Pima County. Most of the area is well protected against new groundwater pumping. Two areas, however, are vulnerable. Davidson Canyon is a major ephemeral tributary of the creek that runs partly through state trust land which may be sold in the future. If this land is sold, nothing is current state law would prohibit pumping in the area and this would affect Cienega Creek. In addition, at the downstream end of Pima County's Cienega Creek Preserve, a small surface water diversion removes water from the creek at a man-made underground dam. Development in the general area would threaten the water supply for the creek if wells were drilled in the area. The diversion is downstream of the preserve and does not threaten it, but pumping would. Again, state law does not protect the stream.

Another threat is possible at Empirita Ranch where developers are allowed to extract up to 1,600 a.f./year from the alluvial aquifer upstream of the perennial segments in the preserve. This arrangement was a condition of sale agreed to by the Pima County Board of Supervisors in the early 1990s. Damaris Chong-Dias showed in her 1995 UA master's thesis that if this pumping occurred, there were be less perennial flow in Cienega Creek and the length and duration of the flow would decline.

Northwest Valley

This area includes the Tortolita Mountains and the two towns that border them on the east and west - Marana and Oro Valley. The Marana area is the only part of Pima County where supply and demand have been relatively balanced. This is because a constant flow of wastewater down the Santa Cruz River has recharged the water table in the area, as have flood flows, since Marana is on the downstream end of the area. In spite of extensive farming the water table has not declined here in recent times as it has elsewhere. This constant flow, however, has affected water quality and nitrate levels in the water here are higher than in other parts of the valley.

If the effluent were to be removed from the river in favor of use in the Tucson urban area, the water supply picture could change radically, as could the riparian habitat. While this area does not have as high quality as the effluent dominated stretch downstream of Nogales, it does provide important

Fig. 35 Honeybee Canyon in the Northwest area

habitat for many species, especially birds.

CAP water can also easily be made available for urban uses in this area, although treatment will be needed for domestic use. It is already being used for agriculture through the in-lieu program described above.

Oro Valley has a very different situation. Water supplies there are limited to inflow from the northwest side of the Catalina Mountains and groundwater. The area has a CAP allocation and a pipeline can be built from the main CAP canal to Oro Valley. The water would need to be treated if it were used for urban purposes, but not if the use were limited to purposes such as turf irrigation. Similarly, wastewater could be piped in from the Ina Road Wastewater Treatment Plan. In both cases, pipeline construction would be expensive and the water would have to be pumped uphill. If Oro Valley negotiates with the City for a share of the metropolitan effluent and if a facility were constructed in Oro Valley, the need to pump effluent a long distance would be avoided. Oro Valley could also construct its own wastewater treatment plant and use that effluent which would avoid the need to pump wastewater from Ina Road.

The prime riparian areas in the region are on public land and would probably not be adversely affected by groundwater pumping, because they are either not dependent on shallow groundwater or because they are in mountainous areas unlikely to be exploited for municipal use. Excessive pumping, however, would undoubtedly create subsidence problems.

Green Valley

Green Valley is located along the Santa Cruz River which is dry here except in the rainy season. This portion of the river was also ephemeral in historic times, although the region to the south in Santa Cruz County had perennial flow and cienegas. The geology changes near the county line where high bedrock gives way to a deep alluvium. Wastewater flow from the Nogales International Wastewater Treatment Plant nourishes prime riparian habitat in the Tubac region, but stops flowing upstream of Green Valley. Some flow enters this area from the Santa Rita Mountains but nowhere near enough to be a dependable water supply.

The major water uses in the area are for mining, agriculture (today, pecan groves), and urban pur-poses. At the time the GMA was conceived it was assumed that mining in this area would decline, but new technologies have extended the life of the mine and prolonged its water use. In some areas the pecan groves have been converted to urban use, but many acres of groves remain. Both of these uses tap the same underground supply as do the providers serving the urban area.

The raw CAP pipeline extends to a location north of Green Valley-Sahuarita and could become a water supply for the region. The City of Tucson has built a large CAP recharge facility near the river here and water could be made available for the mines, Green Valley or the pecan groves. The main barriers to use of this water are cost (which is higher than pumping groundwater) and water quality problems. Since the quality of the water varies it is difficult to adapt it for use in the mining process which requires water of a consistent quality. The mine and pecan grove owners declined to sign contracts for CAP water and do not currently have allocations, but urban water providers here do have small allocations. Water from the recharge project could be made available to users in this area. Water is piped from the end of the CAP system to the San Xavier District.

There are riparian areas which could be threatened by further water use but these are in the Santa Rita Mountains in the National Forest, but not on private land. Residents in the area are, however, concerned about threats to their water supply from large new

Scenario I	
Potential water use under existing zoning	1,026
Safe yield - Independent hydrologist	645
Safe yield AZ Water Commission	300-400
Potential overdraft - existing zoning	**381-726**
Scenario II	
Existing groundwater allocations	3,374
Safe yield AZ Water Commission	300-400
Safe yield - Independent hydrologist	645
Potential overdraft - existing water rights	**2,739-3,074**

Fig. 36. Overdraft calculations in the Arivaca area under two scenarios. Scenario I projects water use if existing zoning is built out. Scenario II projects water use with rezonings and full utilization of existing water rights. In both cases, both existing users and surface water flow are impacted. This is an example of a location where a small increase in pumping would have a major impact on surface water and habitat. Source: AWET 200

developments along the river. This is a special concern for people with their own wells.

Arivaca/Altar Valley

This region is relatively remote from the metropolitan area. Arivaca is in the Altar Valley watershed but has a relatively isolated water basin with a highly restricted water supply. It gets flows from the nearby mountain ranges which are, however, not high or extensive enough to provide a dependable plentiful water supply. Water use in the Arivaca region is barely delicately balanced today with the amount of water coming into the area. Residents of the region have studied the water supply picture and projected what impacts additional pumping would have on the cienega as well as on supply for existing residents. (Fig. 36). They came to the conclusion that the region cannot support much more groundwater pumping. Given the amount of land that can be developed without new zoning and the fact that new domestic wells can be drilled on that land, they came to the conclusion that the addition of a relatively small number of people pumping additional water would cause the cienega to dry up and the stream to flow much less often. This would also affect depth to water for existing residents.

A dam upstream from the town impounds water for sporting purposes which affects available water supplies downstream. The water in the lake is polluted with mercury and other contaminants from abandoned mines which present quite a different problem. Draining the lake would have water quality impacts downstream which might either be negative or positive. This needs further study before action is taken.

The remainder of the Altar Valley also has very limited water supplies and not enough renewable water to support dense development. A few intermittent streams provide habitat for a number of threatened and endangered species, including fish, birds and frogs. These streams are on or near private land which could be impacted by additional pumping.

San Pedro River

Only a small part of the San Pedro River flows within Pima County, but this short stretch has perennial water and prime riparian habitat. The San Pedro River originates in Mexico and gathers water from mountain ranges in Arizona, including the east side of the Catalina Mountains. Several perennial and intermittent streams flow from the mountains, including Buehman Creek. Pima County owns the Bingham Preserve on the west side of the river in this

Fig. 37 A view of the San Pedro River near Cascabel in the rainy season

region, a wetland which has multiple water sources. The Nature Conservancy also owns a riparian preserve in this region at a higher elevation than the river.

At this time water supply is adequate to meet demand. Only a few people live in the region. Cattle ranching is the main land use, along with some agriculture along the river. It is unlikely that enough land use change will occur in this area to threaten the water supply of the preserves. A new mine, however, could be developed in this area which would seriously affect water supplies. Pima County is proposing to acquire additional land to connect the two preserves and further protect the area. This would, however, not preclude mining. There is no feasible new water source for the area, so supplies would be overburdened by this or other new water use.

Because of the high quality of the riparian habitat here, this is a promising place to reintroduce some species such as beaver and native fish. A recent hydrologic study by the Arizona Nature Conservancy concluded that certain portions of the middle and lower San Pedro River would benefit greatly from purchase of farmland in specific locations to reduce water use, and the Conservancy recently bought land for that purpose.

Ajo

At the opposite end of the spectrum is the Ajo region, which is quite isolated from the metropolitan area. It has no surface water and only limited amounts of groundwater. There is one permanent spring in Organ Pipe National Monument to the south which is in the drainage of the Rio Sonoyta in Mexico. Rainfall is much less in Ajo than in the Tucson area, so natural recharge potential is very small. It is very clear in this region that water use must not exceed supply as there are no alternate water sources. Mining can be a major water use in the region although the mine has been closed for many years, but may reopen in the near future. There are no perennial or intermittent riparian areas here to protect, so water use decisions here can be made primarily on the basis of human demands. A major expansion of the town's population is unlikely for several reasons, of which a significant one is lack of easily available water.

Water Supplies for Perennial and Intermittent Streams And Springs

Water supplies for streams and springs come from seasonal rains as well as water stored underground. In a properly functioning system, the seasonal rains usually help replenish the underground supply and well as add to the surface flow. In a perennial stream, the base flow (the flow that continues all year) generally comes from the water table which lies close to the surface and additional flows come from the seasonal rain and snowmelt. This variability is important to the health of the streams and riparian areas. Each year is different. Some years experience heavy flows which rip out some of the old vegetation and allow seedlings to sprout and grow. Drought periods also contribute to the health of streams. Native desert fish, for example, are well adapted to wait out drought periods in isolated pools, then repopulate the stream when the flows arrive. Many nonnative species are not so well adapted to these cycles and do not thrive in either heavy flood or drought. Bullfrogs, for example, do well in stock

Riparian Restoration at San Xavier

In 1997 the San Xavier District of the Tohono O'odham Nation received a grant from the Arizona Water Protection Fund to implement a two-phase riparian restoration project within District boundaries. The first phase, a feasibility study, is complete and the community is now deciding how to proceed. In spring 2001 CAP water reached the District and is now available for several purposes, including riparian restoration.

The feasibility study indicated that full restoration of the Santa Cruz River and its mesquite bosque were not possible because the extent of degradation has been so great and the water table is now so far down. The report recommended concentrating on small areas where specific goals could be met.

The details of the proposal are beyond the scope of this report. The water-related elements, however, include using CAP water to reintroduce native plants. Three major sites are under consideration in addition to two arroyos. Water concerns studied included increased salinity from CAP water which is saltier than groundwater in the area, introduction of nonnative species, and mineral degradation from copper mining.

Once final decisions are made about sites and methods and phase two is approved by the Water Protection Fund, implementation can begin. This would be the first major riparian restoration project in Pima County using CAP water. See the reference is Appendix F for more information.

ponds or streams where the conditions have been altered so they contain more ponded areas. The nonnative saltcedar trees outcompete native trees in disturbed streams where the normal cycles no longer occur and the water supply is relatively steady throughout the year.

Springs, too, depend on water stored underground which comes to the surface where the geology favors it. Fissures in the rock may hold water which is discharged in springs. Places where bedrock comes close to the surface along watercourses may force the water to the surface. At the foot of "A" Mountain this type of formation once brought water to the surface as springs. Fig. 7. shows springs identified in Pima County. As might be expected, the majority are at higher elevations, but some springs still occur in the valley and vicinity, as they do at Agua Caliente.

Protecting riparian areas and springs, then, requires not only a supply of water, but protection of the conditions that allow the watercourse to function naturally. Watercourses naturally meander and change their course from time to time. When they are straightened out for flood control purposes, the energy of the water does not have a chance to dissipate and the water rushes downstream rapidly, often eroding the banks as it goes. Just as switch-backs on a trail make it easier for a hiker to go down hill, meanders in a stream allow the water to proceed downhill at a slower pace.

Flows usually bring along sediment which is important to a stream and helps form beaches and riffles. Rapid flows carry with them larger rocks while slower flows deposit finer materials. Too much sediment, however, can clog a stream. At places in Saguaro National Monument, for example, fire fed by the fuel of nonnative grasses, led to loss of soil and ash which accumulated in pools when it wash washed down the slope during heavy storms. Some of these pools filled up to the point that they are no longer able to support native fish and frogs. In the future another heavy storm may be able to wash out the materials and make the pools habitable once again.

Water sources are the most significant elements in the health of watercourses, but all these other factors must be considered when protecting or restoring them and that is the emphasis of this report.

Connected Groundwater and Surface Water

The physical connections between groundwater and surface water were discussed in brief above as well as the fact that Arizona law does not conform to scientific reality. Whether pumping will affect any specific riparian area needs to be determined on a site analysis. In many cases the geological and hydro-logic conditions are well known, but not always. There may be two separate aquifers, for example, separated by rock or an impermeable clay layer. Pumping from the lower aquifer may have no effect on the upper aquifer which supports the riparian area.

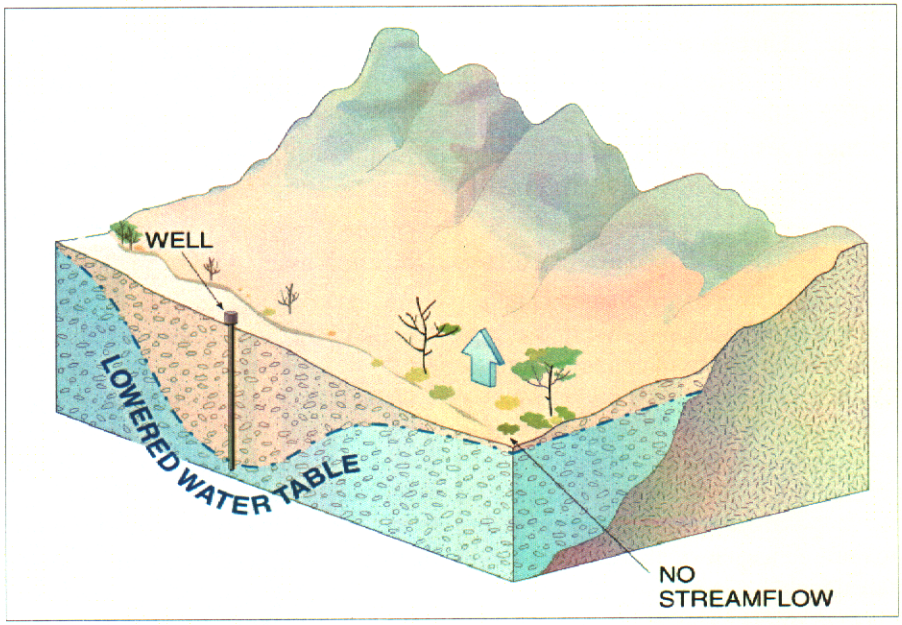


Fig. 38. Diagram of a cone of depression. As pumping increases, the water table near the pump lowers, pulling other groundwater toward the hole by gravity. This may eventually deplete the streamflow.
Source: Pima County Graphics

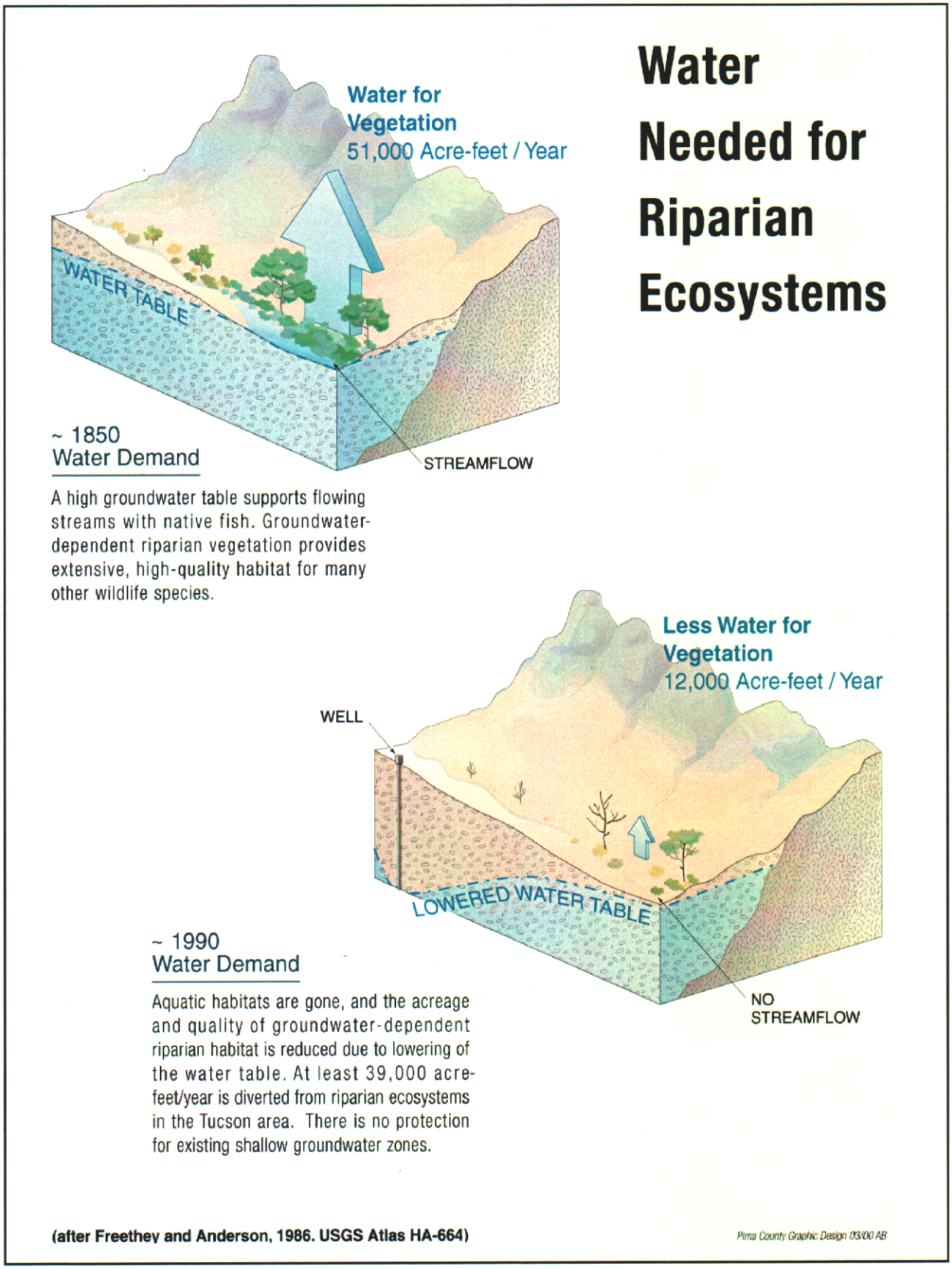


Fig. 39. The importance of a high water table for maintaining surface flow and riparian vegetation. Source: Pima County Graphics.

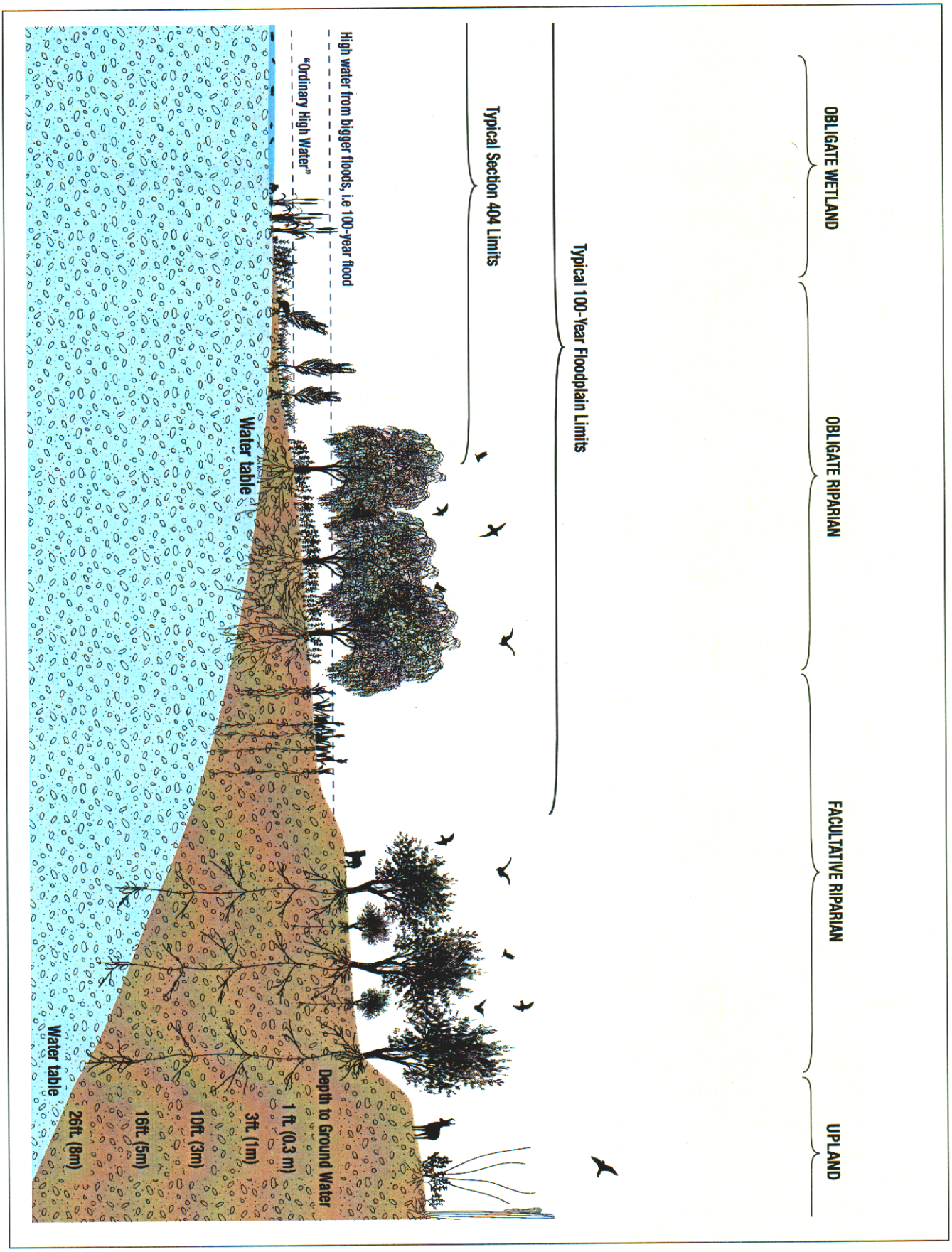


Fig. 40. Water Needs of Riparian Vegetation
Source: Pima County Graphics

In most cases, however, pumping near a watercourse will affect its flow. Pumping at a distance from the watercourse can also affect the flow when it generally lowers the water, when it intercepts water that would have reached the watercourse from the mountains or when there is so much pumping that a cone of depression is formed. (See Fig. 38)

The Pima Association of Governments followed up its 2000 study of Perennial and Intermittent Streams and Shallow Groundwater (See Fig. 7) with an analysis of pumping along the areas with shallow groundwater. The study identified both exempt (small domestic wells) and nonexempt wells (usually higher volume wells) within one mile of these streams and found a total of 493 nonexempt and 1,242 exempt wells. Figures are not available for how much water those wells pumped.

Nearly one-fourth of the wells along perennial and intermittent streams are along the effluent-dependent portion of the Santa Cruz River. A third are along Tanque Verde Creek and its tributaries. Nearly half of those same wells are located within one mile of shallow groundwater near the Tanque Verde and its tributaries.

These latter areas are highly vulnerable to the effects of additional pumping, as are the Arivaca area, some areas near the Rincon Mountains, and Cienega Creek.

Needs of Riparian-dependent Species

Biologists have studied the water needs of different riparian plant species and have concluded that some plants need to have water right at the surface while others can reach down more than fifty feet for water. Along some watercourses the aquifer is shallow and responds readily to changes in flow coming down the watercourse or to pumping taking water away from it. Riparian species are adapted to these changes, but not to long-term changes that result from excessive pumping. Cottonwood trees, for example, produce their seed in the spring about the time that heavy flows of water may arrive. In those years when winter precipitation has been heavy, the seeds will germinate in the moist earth and begin to grow. To survive the water must recede enough so that they do not drown, but not so far that they cannot get the water they need. In drought years there will be few young trees. The seeds are only viable for a month or so. Cottonwoods, willows, and other natives are well adapted to a drought-flood cycle. Saltcedar trees, on the other hand, produce seed for many months and the seed remains viable and can germinate most of the year. This gives them an advantage in human-altered streams. Similarly native fish and frogs are well adapted to conditions of the natural rivers, while bullfrogs do well in human-altered conditions such as ponds. In many cases, natural flows favor the native species of plants and animals while artificial conditions favor those that have evolved in places with similar conditions, although there are exceptions. Restoring natural stream function is necessary for a healthy community of native riparian species. This must be considered when planning restoration projects.

One SDCP proposal is to reintroduce native fish and frogs to selected streams. Fig. 42 shows a scheme developed by Dr. Phil Rosen in 2000 for native frog reintroduction. This depends on appropriate water supplies. The SDCP Science team developed criteria for reintroduction projects. These include having a dependable supply of water distributed in relatively natural annual rhythm. They recommended enhancing natural healthy riparian situations rather than creating artificial situations without appropriate long-term water supplies.

Many of the sensitive species have more specific needs. These are some examples. More information is available in the biological SDCP reports. The Southwest willow flycatcher requires healthy riparian habitat in situations that have occasional floods. They require dense riparian habitat of medium size shrubs and trees with a few larger trees and moist soil beneath the canopy. The Gila topminnow can survive in a variety of stream and spring habitats with pools where the fish can take refuge in dry years. Storms often move the fish to new locations where they have thrive. The Huachuca water umbel requires perennial flow that provides a wet substrate and a stream channel that is stable but prone to occasional flooding.

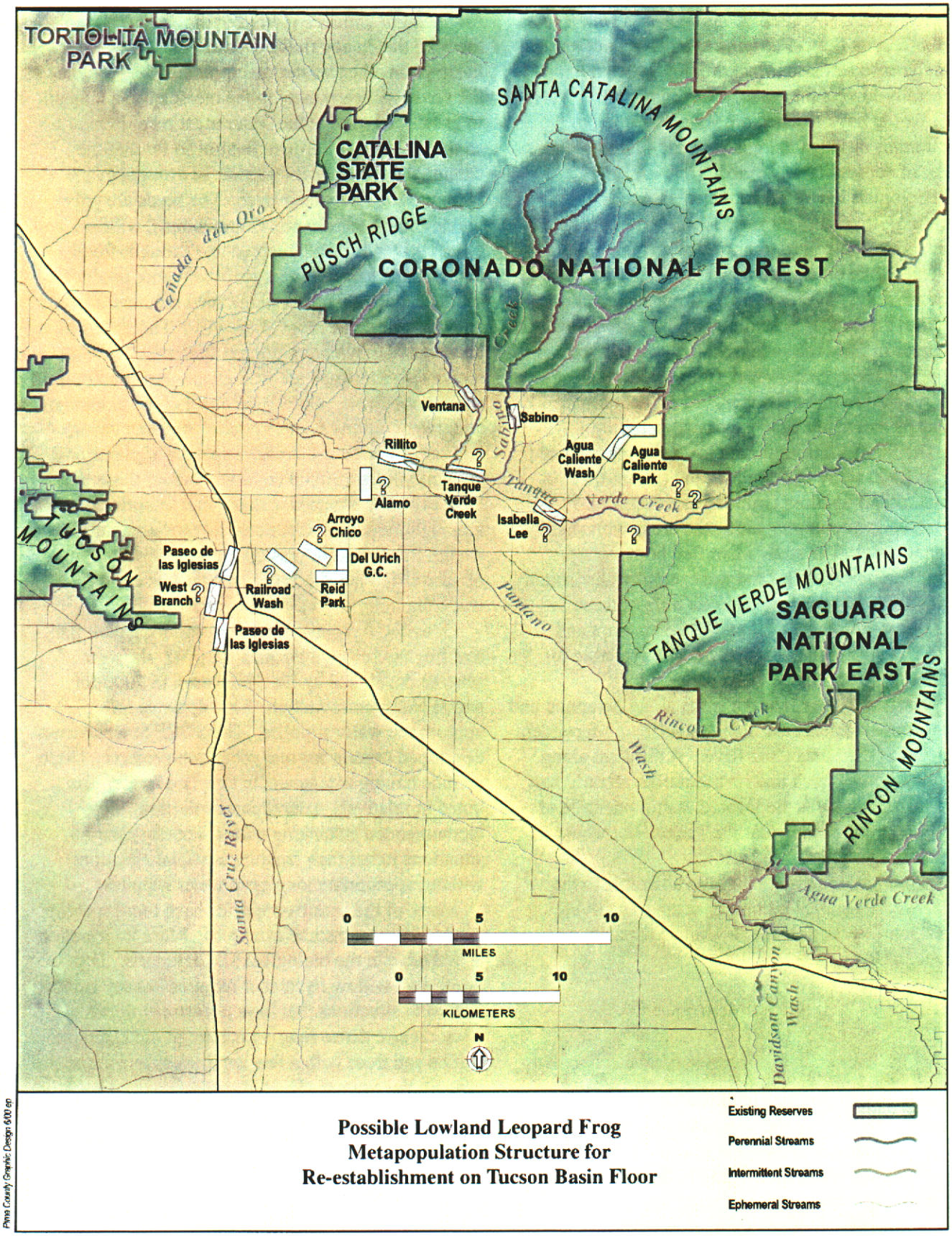


Fig. 41. One possible option for native frog reintroduction
The yellow rectangles are possible sites. Source: Rosen 2000.

Chapter 5. Options for the Future

There were two major goals for this report. One was to satisfy the requirement in state law for including an analysis of water resources in the Comprehensive Plan:

> "Planning for water resources that addresses:
> (a) The currently available surface water, groundwater and effluent supplies.
> (b) An analysis of how the future growth projected in the county plan will be adequately served by the legally and physically available water supply or a plan to obtain additional necessary water supplies. " (§ARS 11:821 C3)

The second goal was to assess the availability of water resources to meet the goals of the SDCP. Five basic questions address these issues.

Some Expert Viewpoints

In preparation for this report, twelve people active in the water community in Pima County were asked their opinions about the basic questions raised in Chapter 1. TAMA, Pima County, San Xavier, Tucson Water, Pima Association of Governments, and Metro Water District responded. Water Commission members Sharon Megdal and Nancy Laney responded, representing themselves. Three others did not respond. The answers are summarized below under each question. Note that some respondents chose not to answer one or more questions. See Appendix B. for the full responses.

1. The legal perspective

Does the Tucson AMA have both adequate supplies and adequate legal and management tools to assure that the legal goal of safe yield can be achieved by 2025? If not, what is lacking and could/should be done?

While some respondents were more pessimistic than others, they generally agreed that reaching safe yield within TAMA by 2025 depends on using all possible renewable supplies, increased conservation, limiting or even eliminating non urban uses, and achieving at least some of the changes in law and regulation under consideration by the Governor's Water Management commission. Some respondents expressed doubt that safe yield could be attained or maintained in the face of continued population growth, while one was optimistic about achieving it.

2. The regional perspective

Are there adequate water supplies and water management tools within Pima County (including the Pima County parts of the AMA and parts of the county outside the AMA) to achieve a balance between supply and demand into the indefinite future? If not, what is lacking and could/should be done?

There was less agreement about availability of supplies for the county as whole (both inside and outside the AMA). Some pointed out that most of the projected future water use within TAMA (which extends into Pinal County and does not include large parts of Pima County outside the metropolitan areas). Several respondents suggested that where long-term supplies are in doubt, Pima County's authority extends primarily to land use controls rather than water use regulation. One recipient expressed concern over dependence on use of municipal wastewater because of potential water quality problems. Several respondents pointed out problems to be anticipated from continued unregulated development outside the metropolitan area where water supplies are much more tenuous. Two respondents pointed out that while there may be adequate water supplies, there is no infrastructure to get the water (e.g., reclaimed wastewater or CAP water) to where it can be used. One recipient expressed great confidence that water providers would be able to keep up with increased demand even in the nonmetropolitan areas.

3. Local perspectives

Are there local areas within the county that might not be able to achieve a balance into the future even if the region as a whole is able to do so? (e.g. Arivaca, Ajo, or middle San Pedro). What could/should be done to deal with these areas?

All respondents agreed that there are some areas both within and outside TAMA where continued increase in water use would mean the local area would not be in balance. Areas specifically mentioned were Arivaca, Tanque Verde Valley, lower Sabino Creek, Rincon Creek, Cienega Creek, Davidson Canyon, middle San Pedro River, Sopori Wash, parts of the Tortolita Mountains, Santa Cruz River south of Green Valley, Silverbell Mountains, and Canada del Oro. They did not agree on solutions, but several indicated that land use controls were

generally more likely to be effective in the long term than water regulation.

4. Riparian habitat perspectives

Is adequate provision made in current law and practice to protect existing perennial streams, springs, and cienegas in the county? Should new water be made available to protect riparian areas and restore some that have lost their dependable water supply? What changes could/should be made?

Most respondents felt that Arizona law and regulation is not adequate to protect riparian areas, but not all agreed that changes were needed. Some felt that human needs should and will take priority. Others felt that measures need to be taken to protect areas and provide water for preservation and restoration. The city-county agreement (See Appendix E.) was cited as a place where water is and should be provided for riparian uses. Again some respondents believe that land use controls and land purchase will be more effective tools than mechanisms such as changes in water law. Several stressed the need for the law to recognize the physical relationship between groundwater and surface water.

5. Intergovernmental perspectives

In what ways could/should Pima County improve its coordination and cooperation with the various water management entities (e.g. water providers, municipalities, tribes or ADWR).

Respondents suggested ways in which cooperation could be improved. Ideas included working with local water committees and water providers on such projects as water conservation ordinances, coordinating through PAG, joint studies, regional reuse system, improved scientific understanding of SDCP issues, partnering with nonprofit groups as well as other government agencies, county support on issues that impact water providers, cooperation on implementation of SAWRSA, implementation of the city-county agreement on effluent, regional watershed management, and joint funding of needed infrastructure.

Options for Meeting the Goals

Having adequate resources for the human aspects of the Comprehensive Plan and the biological aspects of the SDCP depends on a variety of factors, most of which are not within the jurisdiction of Pima County working alone. Water budgets have traditionally focussed on human demand rather than water use for riparian preservation or restoration. The long-term success of some of the SDCP draft proposals depends on water being set aside for these purposes.

Some of the proposed changes must be implemented at the State level. Some of the changes will involve other local jurisdictions, including municipalities, water providers, and major water users. Some can be accomplished by mutual agreements and incentives programs. Adequate water resources cannot be assured at the present time unless changes are made. Even if all the proposals are implemented, success depends on such nebulous factors as impacts of climate change and long-term viability of CAP.

Potential solutions are summarized in Fig. 42. This table illustrates several points.

1) The fact of a multiplicity of jurisdictions can offer problems or it can be treated as an opportunity for cooperation among jurisdictions. There are few solutions which the county can implement by itself.

2) State law does not always allow use of some of the most effective means of protection. Column 4 indicates whether or not changes in state law are required for implementation.

3) Column 5 briefly mentions some cautions. These are not insurmountable barriers, but things that need to be considered. Several occur over and over. "Who pays?" is important in encouraging alternate water supply use and in various protection options. Construction of infrastructure may be necessary to bring in alternate supplies and such infrastructure can be expensive to build and operate. Impacts on property rights and on state trust lands is also a recurring caution. Dealing with vested rights in private property requires care to assure that constitutional rights are not abridged in the name of protection. Similarly, the state has responsibilities for maximizing revenue from state lands. It does not have a legal mandate to protect sensitive areas. Some of the proposals such as limiting pumping rights could affect the value of state lands. Cooperation between the county and the state is essential as each serves to meet its goals. Land use management is outside the scope of this report, but must be coordinated with water use management.

Potential Changes in State Water Management and Law

Most of the regional water supply options are outside Pima County's jurisdiction and depend on

decisions made at the state level. State water law prevails and does not offer counties the option of regulating water use. At the time of writing, the Governor's Water Management Commission was discussing a variety of measures to ensure long-term water supplies for Active Management Areas which are to be presented to the Arizona Legislature in 2002. The major relevant potential changes under discussion include:

Exempt wells

The exempt wells are the small domestic wells that do not fall under ADWR's strict permit requirements within AMAs. While the effect of one such well may be insignificant, the cumulative effect of many such wells can be highly significant. This is especially true in isolated shallow groundwater areas. Arivaca is a good example of this problem, where the addition of just a few hundred new exempt wells would seriously affect the supply of water for the cienega as well as for existing residents. Changes under consideration include putting all wells under the same rules, regardless of size, doing this just for specific subbasins of the AMA, and having new stricter rules for exempt wells, but different from the rules for larger wells.

The Commission is not considering any changes outside the AMAs. Well drillers in the San Pedro River and Ajo portions of the county may currently drill for water outside AMAs without regulation, other than the need to register the well with ADWR. Extending additional protection to non-AMA areas is one need that the state could address in the near future. This need is much more pressing in the Upper San Pedro River in Cochise County than in the Pima County portion.

Subbasin management

AMAs cover large areas with very different hydrological conditions, water supplies, and water demands. One proposal is to identify subbasins where the water needs to be managed in a manner different from that of the AMA as a whole. These subbasins might be different because of a limited water supply, lack of alternate water sources, shallow groundwater areas, areas where subsidence is occurring, or other criteria.

Arivaca is an example of an area in Pima County that would benefit from being managed as a separate basin.

Restrictions on New Wells in Sensitive Areas

Another way to protect areas with special conditions is to place restrictions on new wells in areas in the kinds of areas listed above. Specific areas would not be designated, but criteria would be set for kinds of areas where restrictions would apply.

Assured Water Supply (AWS) Rules

AWS rules currently allow some mining of groundwater while demonstrating AWS. They also allow demonstration of AWS by buying into recharge projects through the Central Arizona Groundwater Replenishment District. Under current rules, the physical recharge does not actually have to benefit the area in which the water is being used, so one basin can be filled to excess while another is depleted. Applying AWS within designated subbasins in which the recharge must benefit the subbasin is one solution. Another solution would apply this concept generally to all recharge credits.

Subsidence

Because of the severe problems caused by subsidence, one proposal would limit new groundwater pumping in areas experiencing or expected to experience subsidence. Existing pumping in such areas could also be controlled in such hazard areas. Although the intent might be to encourage the use of renewable supplies, one impact of such rules might be to drive pumping to areas where natural recharge is greatest - along watercourses. Subsidence would most seriously impact the urban core with its dense population and many structures, while pumping in more remote areas could impact some riparian areas.

Recharge Credits

Currently there are different rules for giving credit towards reaching Safe Yield if the recharge project is incidental recharge in a river rather than within an artificial recharge structure. Artificial recharge basins are assumed to recharge most of the water in a way that can be recovered, while incidental recharge is assumed to recharge much less recover-able water. Developing a system for determining how much water should be credited as recoverable could lead to providing greater credit and thus greater incentive for using streambeds as recharge areas. This could benefit some watercourses within the SDCP program.

Fig. 42. Summary of Options

Strategy/Goal	Method	Jurisdiction	State law?	Caution
Limit pumping near shallow groundwater	Use alternate supply for human use in SGA	Water providers	Yes	Who pays?
	Prohibit new wells that would impact SGA	ADWR	Yes	Property rights issues?
	Land use controls near SGA	County, municipalities	No	Property rights issues? State land issues?
	Recharge near SGA	Water providers	No	Future withdrawals?
	Purchase land/water rights in SGA	County, municipalities	No	Who pays? Willing sellers?
Maximize human CAP use/ Reclaimed water use	Require use where feasible	Water providers	Yes/No	Who pays? Infrastructure?
	Incentives to providers	ADWR, County, Municipalities, providers	No	Who pays? Infrastructure?
	Incentives to landowners	County, municipalities, providers	No	Who pays? Infrastructure?
	Limit rezonings outside CAP area	County, municipalities	No	Property rights issues? State land issues?
Limit human use in certain areas	Require use where feasible	ADWR, County municipalities, providers	No	Who pays? Infrastructure?
	Incentives to providers	ADWR, County, municipalities, providers	No	Who pays? Infrastructure?
	Incentives to landowners	County, municipalities, providers	No	Who pays? Infrastructure?
	Limit rezonings outside CAP area	County, municipalities	No	Property rights issues? State land issues?
CAP for riparian areas	Allocate amount for riparian Exotic species issues Long-term commitment?	Those with CAP allocation	No	Who pays? Infrastructure?
Reclaimed for riparian off-stream riparian	Allocate amount for	County, Tucson	No	Who pays? Infrastructure? Exotic species? Long-term commitment?
	Preserve part/all of current discharge	County, Tucson	No	Water quality? Exotic species? Long-term commitment?
Reduce per capita consumption	Education	Water providers	No	Effective?
	Pricing	Water providers, ACC	Yes/No	Effective? ACC rules?
	Landscape requirements	County, municipalities	No	Enforcement?
	In-home requirements - new homes	County, municipalities	No	Further reduction feasible?
	In-home requirements - older homes	County, municipalities	No	Who pays?
Limit turf water use	New golf courses on CAP/reclaimed	County, municipalities	No	Who pays? Infrastructure?
	Existing golf courses on CAP/reclaimed	County, municipalities	No	Who pays? Infrastructure?
	No new golf courses	County, municipalities	No	Property rights issues? State land issues?
	Further limit water use	ADWR, providers	No	Impact values?

Strategy/Goal	Method	Jurisdiction	State law?	Caution
Prevent subsidence	No new pumping in subsidence prone areas	ADWR	Yes	Alternate pumping area impact riparian?
	Reduce current pumping in subsidence areas	ADWR	Yes	Alternate pumping impact riparian?
	Recharge subsidence prone areas with CAP	CAP allocatees	No	Feasible? Who pays?
	Recharge subsidence prone areas with reclaimed	County, Tucson	No	Feasible? Who pays?
Restore/preserve natural areas	Floodplain acquisition	County, municipalities	No	Who pays? Willing sellers?
	Purchase land/water rights private, federal	County, municipalities,	No	Who pays? Willing sellers?
	Alternate supplies	See above	No	Who pays? Infrastructure?
	Limit rezonings	County, municipalities	No	Property rights issues? State land issues?
Construct wetlands, riparian areas	CAP, reclaimed water	County, municipalities	No	Who pays? Infrastructure? Exotic species? Long-term commitment?
	Recharge projects	County, providers	No	Who pays? Infrastructure? Exotic species? Long-term commitment?
Protect remote basins	Limit new wells to carrying capacity	ADWR	Yes	Property rights, state land issues?
	Purchase land/water rights	County, federal, private	No	Who pays? Willing sellers?
	Limit rezonings to carrying capacity	County	Yes/No	Property rights, state land issues?
	Reuse water	Water provider, county	No	Infrastructure? Who pays?
	Conservation	Water provider, county	No	Effective?
	No golf courses	County	No	Property rights, state land issues?

Use of CAP Water

Currently, there is no requirement that everyone in a basin share in the costs of importing CAP water to prolong the water supply. It is still legal to pump groundwater if the user has the right to do so. The existing small pump tax could be greatly increased to help pay the costs of replenishing the supply either through CAP use or recharge.

Use of Reclaimed Water

The use of reclaimed water is largely optional for water users, except for golf courses covered under local ordinances. ADWR grants credit for turf users who take reclaimed water which gives them a greater water allowance under conservation rules. Changes in the law could increase the incentives or provide penalties for not using reclaimed water.

Water Conservation

The validity of the approach ADWR has taken to conservation was successfully challenged in the courts. One proposal puts conservation programs on an incentives basis with ADWR providing assistance to water providers and flexible approaches to achieving a conservation goal, rather than specific prescriptions for methods of conservation. Flexibility would also be increased for goals under different climatic conditions. TAMA's water budget assumes that the possibilities for very much additional conservation are quite limited.

Riparian Area Protection

Riparian areas receive virtually no protection under current water law. The GMA favors the use of renewable supplies over groundwater and in some cases this can lead to use of surface water on which riparian areas depend. The Santa Cruz AMA has the authority to consider surface and groundwater as one water body and regulate groundwater use to protect the Santa Cruz River. Similar authority could be granted in other AMAs, or riparian areas could receive other protection from pumping. The Santa Cruz AMA is very different from the Tucson AMA in terms of aquifer width and depth. Groundwater and surface water are more clearly connected there, so the rules have to be drafted differently. The goal of the TAMA could be changed to include protection of surface flow in shallow groundwater areas, for example.

Groundwater-Surface Water Law

One change not under serious consideration by the commission is a basic change in the state law to recognize the physical link between groundwater and surface water. The courts have urged to state to deal with this issue, but at the present time, it is the courts that are attempting to address the issue in part.

Local Programs

While it will be necessary to change Arizona law in many cases if riparian areas are to be protected, there are some things local governments can do without additional authority.

Location of Infrastructure

The location of water and wastewater infrastructure can affect where new development can go. Since Pima County operates the countywide wastewater program, location of main sewer lines could be used as a tool to direct when and if growth extends into undeveloped areas. Currently the Wastewater Management Department provides sewer service in a manner that follows growth. Location of water lines is much more complex because of the many water providers in the area and ACC rules that direct that water companies provide water within their assigned service areas unless it is quite infeasible to do so.

Infrastructure for Renewable Supplies

In order to fully utilize CAP water and reclaimed wastewater, additional infrastructure will be required. This infrastructure can only be provided through coordinated regional construction and funding programs. While it will not be physically possible to connect all water using entities in the county, some people believe that all water users in the Tucson basin should participate financially in prolonging the water supply because all benefit from doing so. Those who will continue to pump groundwater benefit from the fact that the decline of the water is slowed or even stopped. The infrastructure would have to be built by local entities, but authority to develop the funding mechanisms would have to come from the legislature.

Septic system rules

The county operates the permit system for septic systems under ADEQ rules. The rules allow location of structures in places that cannot be reached by sewer lines because of remoteness or difficult terrain. Septic systems must meet minimum requirements for drainage potential. In some places it might be desirable to encourage the use of septic systems to avoid the

Water Demands of Proposed RiparianProjects

Name	Acres of Riparian Vegetation To Be Added	Water Demand (acre-feet/year)
Ajo Detention Basin	12 ac open water 5 ac marsh 15 ac riparian 18 ac upland/grassland	144 (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)
Park Avenue Detention Basins	3 ac xeroriparian	4.8 (reclaimed)
Rillito Creek at Bosque Farm	20 ac mesquite and annual crops	32 (reclaimed)
Rillito/Swan Wetlands	10 ac open water 4 ac marsh 6 ac riparian/aquatic (10 ac enhanced riparian)	151 (reclaimed)
Cortaro Mesquite Bosque	73 ac mesquite 7 ac mixed cottonwood/wetland	285 (effluent)
Santa Cruz Effluent Riparian	undefined: 100 ac assumed available for revegetation	A: 300, B: 667 ,C: 4287 (includes 1 cfs for discharge at five locations) (reclaimed)
Canada del Oro Recharge	undefined: 100 ac assumed available for revegetation	A: 300, B: 667, C: 16,667 (includes one discharge of 16,000 af/yr) (CAP)
Three Rivers Project	undefined: 50 acres assumed available for revegetation	A: 150, B: 333, C: 5667 (includes discharge of 5000 af/yr)(CAP)
Bingham Cienega Riparian Restoration	23 ac sacaton grassland 16 ac mesquite woodland 11 ac deciduous broadleaf riparian forest	0 (no supplemental water after establishment)
Pantano Jungle Project	17 ac xeroriparian and grassland	0 (no supplemental water after establishment)
San Xavier Riparian	undefined: 50 ac assumed available for revegetation	A: 150, B: 333, C: 5667 (includes discharge of 5000 af/yr)(CAP)
Rincon Creek	118 ac minimum mesquite/hackberry and xeroriparian	190 (groundwater)
Total	758 ac minimum (alternatives A or B)	A: 2007, B: 3474, C: 37,382

Fig. 43. Estimated amounts of water needed to implement specific riparian projects. In some cases a range of amounts is shown reflecting a series of project options. These figures are to be viewed as examples, not precise requests. It is clear from these estimates that water amounts needed are very site specific and must be evaluated for each project. Source: Pima County Flood Control District.

damage to riparian areas from construction and maintenance of sewer lines in and across watercourses. In other places it might be desirable to discourage the use of septic systems to protect fragile areas. There have been recent changes in Wastewater Department policies to require that new sewer conveyance facilities be constructed in dedicated paved roadways and easements to minimize damage to natural areas and to facilitate maintenance.

Purchase of Land with Water Rights

In some cases the only way to preserve a riparian area is to purchase it for flood control purposes and/or purchase nearby land where additional pumping could impact the riparian area.

Conservation Easements with Water Rights

A similar approach could be used by acquiring conservation easements to property with a goal of preserving water supplies for riparian areas. The conservation easement process is described in several SDCP reports.

Use of zoning powers

The county can use its zoning powers to limit increased density in sensitive areas without alternate water sources. While it cannot deny all use of the land, it can keep the land at the existing zoning density, thus reducing the demand for increased water use. Similarly, it can use the zoning powers to deny rezonings that include water-intensive uses such as golf courses in areas without renewable supplies.

Restrictions could be placed on wildcat development. These could include a requirement to hook up to a water provider rather than drilling a well.

Use of CAP or reclaimed water to protect riparian areas

Finally, the county can either use CAP or reclaimed water directly to maintain riparian areas or create new ones, or it can provide incentives for neighbors of the area to use these alternate supplies, thus reducing the impacts of pumping. This is especially useful in areas near Tucson Water's reclaimed water system and in places within Tucson Water's service area. This will require close cooperation between city and county.

Water Conservation

Pima County already has rules governing the use of low water use toilets and shower heads in new construction. This could be extended to older housing, possibly with the help of a fee levied on new connections or existing users. Pima County already requires new golf courses to use reclaimed water if feasible, this could be strengthened to prohibit new golf courses in areas where it is not feasible to provide reclaimed water. Xeriscape requirements could be strengthened especially for new commercial structures. Other recommendations were made in the report *Water Conservation in Pima County*.

Options for Regions with Special Water Supply Problems

Tucson Core

Most of this area is within city limits of Tucson and South Tucson, and thus outside the jurisdiction of Pima County. Cooperative arrangements, however, with the city could benefit riparian areas both inside and outside the city.

The primary water-related problem in this area is subsidence which would have the greatest economic effect in the densely populated and business areas. Since the water currently provided to city customers only contains an average of 30 percent CAP water, there will still be a need for extensive pumping somewhere in the area. Tucson Water announced in 2000 that it was closing one well because it was not needed with CAP water.

If new state legislation were to regulate either new or existing pumping in this subsidence-prone area, this could have a major impact on the outlying areas. While CAP water will replace some pumping in the region, for the immediate future, Tucson Water might choose to make up the difference in well capacity by pumping more in outlying areas such as along Tanque Verde Creek where there are existing wells.

Some of the areas that are proposed for riparian restoration or reintroduction of native species are in this area. Developing a secure water supply for these projects will involve cooperation between city and county. Reclaimed water, for example, would be an option for riparian restoration as it is for turf irrigation. One issue that needs resolution is deciding how to pay for the water. One drawback to this option is that delivery of the water is liable to be variable depending on other demands, and not related to riparian needs.

East Valley

Pumping by Tucson Water has adversely affected shallow groundwater areas along Tanque Verde Creek and tributaries in the Rincon Valley. Additional pumping would have increasingly adverse effects. Pumping by other water providers could

affect Cienega Creek as well as some tributaries coming from the Rincon Mountains. While many of these waterbodies are already protected by being within the Saguaro National Park, Cienega Creek Preserve, or Empire-Cienega Conservation Area, critical portions of some of these streams are on private property or close enough to private land that pumping would affect the surface water supply. As state law now stands Pima County would have no authority to forbid such pumping, but could work out cooperative agreements and incentives programs.

This area does or could have the option of using supplies other than groundwater. Much of the area is within the Tucson Water service area and could receive CAP water as a substitute for groundwater. The reclaimed water line reaches parts of the area and could be extended to provide an alternate water supply for new or existing golf courses and other turf facilities.

Since both CAP water and reclaimed water will be more costly than groundwater, current water users will need incentives to make the change. The County could, for example, pay for the connection to the water system. New users could have their permits conditional upon use of alternate water supplies, but since much of this area is within the City of Tucson, cooperative efforts with the city will be needed for implementation.

Northwest Valley

Much of this area is under the jurisdiction of Marana and Oro Valley. Pima County, however, does have a role to play, especially along the Santa Cruz River. Most of the significant watercourses in the Oro Valley area occur on public lands, but Honeybee Wash is an intermittent stream that occurs within Rancho Vistoso, part of Oro Valley. This watercourse has been the subject of much contention with some people urging its protection from development and groundwater pumping, and developers wishing to build along the banks. This is within the jurisdiction of Oro Valley not Pima County.

Also in the area is the Canada del Oro which is partially protected within Catalina State Park and Coronado National Forest. A portion of the wash upstream of the State Park is vulnerable and Pima County proposes purchase of the section to preserve a wildlife corridor.

On the west side of the area, the Santa Cruz River is an effluent dominated stream with a constant flow of wastewater from Pima County's Roger Road Wastewater Treatment Plant through Marana. This stream offers wildlife habitat along parts of the stream where it has been left relatively natural.

Both Marana and Pima County have jurisdiction in this area. In addition, the City of Tucson has rights to most of the wastewater from both the Roger Road and Ina Road wastewater treatment plants and could decide to use it elsewhere. Pima County has, however, reserved a portion of that effluent for riparian purposes through an intergovernmental agreement, but may decide to use that water either within the river or elsewhere. A major U.S. Army Corps of Engineers recharge project is underway in the Marana area.

Another project is in the planning stage near Orange Grove Road. This project will use effluent either within the river bed or off-channel to develop wildlife habitat and reintroduce species that have become rare in Pima County and the project may have recharge value.

The long-term fate of this area is made more complex by the fact that the Tohono O'odham have rights to a significant amount of the wastewater, so long-term decisions are on hold until decisions are made on how to implement the wastewater allocation.

Arivaca/Altar Valley

The Altar Valley is a part of the Santa Cruz River watershed that flows toward the river and meets it near Marana. Many of the significant riparian areas are on public land. Brown Canyon, for example, in the Baboquivaris is owned by the U.S. Fish and Wildlife Service. Some prime riparian areas occur on ranchland in this area on both private and public land. One SDCP proposal is to assist ranchers who protect riparian and other sensitive areas to discourage proliferation of subdivisions and wildcat housing that could threaten the area.

Arivaca is in a relatively isolated basin which flows toward Brawley Wash. The USFWS owns the Arivaca Cienega adjacent to the town and portions of Arivaca Creek. The major threat to this area is from new groundwater pumping that would lower the water table below the level needed to maintain the cienega.

Alternatives for preserving the water supply include changes in the state law that would

- Treat this region as a separate basin within TAMA, requiring a local water balance - safe yield for the Arivaca basin.
- Set new requirements for exempt domestic wells that would consider the cumulative effects of multiple small wells when granting drilling permits.

Other options for the water supply in this area include purchase of land with water rights. USFWS has funds to begin the process. Zoning restrictions could be placed in this area, not allowing increased density which would lead to higher water use. Some of the area is already zoned beyond the carrying capacity, however. Arivaca residents issued a report in May 2001 that recommends that the major emphasis in dealing with water problems should be on cooperative agreements, rather than relying on changes in state law.

San Pedro River

This area is entirely within unincorporated Pima County, but it is strongly influenced by what happens upstream in Cochise County. Water supply and demand are relatively balanced in this area, including water for Bingham Cienega, Buehman Preserve, and riparian vegetation along the river. If the population were to increase significantly or if new mining operations were to be developed, water supplies for habitat would be threatened. SDCP includes plans to connect the two preserves by acquiring land along the river, which would help protect the water supply. Since Pima County has no jurisdiction over pumping in the area which is all from individual wells, land use controls are the best option for this area.

Downstream, The Nature Conservancy has acquired a farm and retired the agriculture near Mammoth in order to increase flow to its preserve at Winkleman. This was done after extensive study of the hydrology of the river. Similar land purchases in the Pima County or Cochise County portions could possibly increase flows in the Pima County section of the river.

Ajo

The private land in this area is entirely in Pima County jurisdiction but is served by water companies that are not under county jurisdiction. There are no major riparian areas or wetlands, except for Quitobaquito which is within Organ Pipe National Monuent. The major water supply issue in this area is providing water for the population and for mining operations when and if they resume. The only controls that Pima County currently has here are land use controls to match the population levels to the reliable water supply. At the present time this is not an issue.

Final Thoughts

Water is crucial to the success of parts of the SDCP as it is to a Comprehensive Plan that meets the needs of residents into the future.

Comprehensive Plan

The Growing Smarter legislation calls for an analysis of existing and future water supplies, as quoted at the start of this chapter.

It is clear that there is adequate water for the near future, probably at least to 2025, especially if at least some of the proposals described above are accepted by the Governor's Water Commission and the Legislature. Renewable water supplies for the area consist of a relatively small amount of annual supplies entering the area from precipitation, Colorado River water, and water reuse. Any other water must come from tapping a limited underground supply. The main barriers to full utilization of CAP and treated wastewater are the infrastructure needed to get the supplies to where they are needed, the lack of incentives for users to switch from groundwater to renewable supplies, and a funding structure to share the costs equitably.

Change in water demand patterns can help prolong the supply. These include conservation by homeowners and businesses and reduction or elimination of some uses such as agriculture and mining.

There appear to be no new sources of water in addition to CAP, although technology may find ways to develop them in the future. There are uncertainties about the long-term viability of CAP. For long-range planning purposes it should be assumed that at some unknown point in the future the county plan will not be "adequately served by the legally and physically available water supply," although in the short range there not only is not a problem, but water is in surplus because the CAP allocation is not being fully utilized. Water supplies for continued growth in some currently rural areas are more in question than those within the urban area.

SDCP

Some of the priority conservation areas are threatened by increased water use nearby. The only authority the county currently has to protect these areas is its ability to regulate land use through methods or provide incentives, such as dening rezonings and permits, purchasing vulnerable land with water rights, and working out cooperative agreements with landowners, water providers and others.

Water will be needed for projects involving reintroduction of native fish and frogs or restoration of riparian areas. Water features have also been proposed for the city's Rio Nuevo project, including having a constant flow in the river at some points. If such projects are succeed more than briefly, there will have to be some assurance that the water supply will be dedicated into the future, not withdrawn if human demands prevail. Pima County does not have enough water to satisfy the demands of a population which grows continually into the indefinite future and to provide adequate water for habitat and riparian needs unless changes are made. The intergovernmental agreement between Tucson and Pima County is a start in that direction. Infrastructure, legal authority, and jurisdiction to make these changes will require action by the state, other local jurisdictions, water providers, and individuals. It will be useful to establish priorities to optimize use of limited water supplies for maximum wildlife and riparian vegetation benefit.

Intergovernmental Cooperation

Intergovernmental cooperation as well as cooperation with nonmunicipal water providers will be essential not only for success of SDCP but also for long-term viability of the human community under the Comprehensive Plan. A regional water management agency would be useful in order to fully utilize all the region's water supplies. This will take more than voluntary cooperation, however, as state legislation will be necessary for such an agency to have funding authority.

In Summary

In the short-term (25 years) water supplies will probably keep up with human demand in the urban area if there is maximum utilization of CAP and treated wastewater, if conservation is accelerated, and if the legislature approves some of the proposed changes in law. Control of subsidence in the most problematic areas will depend on limiting pumping especially in the urban area. There may, however, be water supply problems in areas not within actual reach of CAP or reclaimed wastewater if water use increases there. Availability of water for protection of riparian areas and construction of water-based projects is more questionable and depends on dedicating adequate water for this purpose and on restricting pumping in the most sensitive areas such as Arivaca.

In the long-term (beyond 25 years), the prognosis is more in doubt, especially if total water use continues to increase. Questions about long-term future of CAP, impacts of climate change, and availability of new alternate supplies make this time period much more difficult to predict than the near future. Whether water will continue to be dedicated for environmental needs is doubtful if human competition for water increases in all or parts of the region.

A regional approach to water management will help in making potential problems more manageable.

Fig. 44. The screwbean mesquite This tree used to be relatively common along the Santa Cruz River. One SDCP proposal is to grow seed in the new Pima County plant nursery and reintroduce the tree along the Santa Cruz River. This is a low water use restoration project

Appendix A. Glossary and Acronyms

ACC - Arizona Corporation Commission

Acre-foot - An acre-foot (abbreviated a.f or a.f..) is enough water to cover an acre of land to a depth of one foot. It contains 325,851 gallons of water.

Active Management Area - A regional division of the Arizona Department of Water Resources. There are five AMAs in Arizona. See page 11.

ADWR - Arizona Department of Water Resources

Alluvium - Deposit formed of sediment and other materials brought down watercourses over time.

AMA - Active Management Area

Aquifer - An underground area from which stored water may be recovered. Water is stored between grains of sand and rock, or in fissures in the rock.

AWBA - Arizona Water Banking Authority

AWS - Assured Water Supply. A legal term in the GMA. Developers in TAMA must demonstrate that they have enough water to last at least 100 years. See Chapter 3 for more information.

BOR - Bureau of Reclamation, the federal agency that built CAP, builds and manages dams, and has other duties.

CAGRD - Central Arizona Groundwater Replenishment District

CAP - Central Arizona Project

CAP allocation - The amount of CAP water that is legally available to a water provider or other user. Changes in allocations must be approved by the Department of Interior.

CAWCD - Central Arizona Water Conservation District, the agency that manages CAP.

Central Arizona Project - A system of canals, pumping stations, pipelines, and storage facilities that brings water from the Colorado River to Central Arizona and Pima County.

Cienega - See Wetland

Cone of depression - A portion of the water table in which the water table is lower than in surrounding areas, due to intense pumping.

Effluent - Water discharged from a wastewater treatment plant

Effluent-dominated stream - A stream in which the flow of water is primarily made up of treated effluent discharged to it.

Ephemeral stream - A watercourse that is normally dry and flows only in direct response to rain or snow.

Exotic species - A species that did not evolve in a specific area or in a nearby area, usually imported by humans from another continent or distant part of the same continent.

Floodplain - The area alongside a watercourse on which water may flow during major storm events.

GMA - Groundwater Management Act

Grandfathered rights - Water rights that continued after passages of GMA once demonstrated.

Graywater - Water from showers, bathtubs, bathroom sinks or washing machines that has a very low level of pollutants. Graywater may be reused legally.

Groundwater - Water beneath the surface of the land in a aquifer.

Groundwater Management Act - The basic law governing the use of groundwater in Arizona.

GSF - Groundwater Savings Facility - A facility in which the agricultural user agrees to use CAP water instead of groundwater, also known as "in-lieu recharge."

IGFR - Irrigation grandfathered water rights. These are rights that continued after passage of GMA.

INA - Irrigation Nonexpansion Area

Infrastructure - For water related functions, infrastructure includes pipelines, canals, pumping stations, and treatment facilities needed to take water to users and wastewater from users.

Intermittent stream - A stream that flows perennially in some places but not in others.

Invasive species - A species, usually nonnative, that invades an area crowding out native species. Examples include bullfrogs and buffelgrass.

Perennial stream - A stream that flows continually, usually because it is connected to groundwater.

Potable water - Water that is safe to drink.

Recharge - Replenishment of the aquifer by water. Natural recharge occurs when precipitation reaches the aquifer. Artificial recharge occurs through a constructed project. Incidental recharge occurs when releases of water used by humans returns to the aquifer, but not through constructed facilities.

Reclaimed water - Wastewater that has received more than standard treatment making it usable for uses such as turf irrigation.

Riparian area - An area including and adjacent to a watercourse including riparian vegetation and usually providing wildlife habitat.

Septic system - A system for domestic use that treats sewage on site, most often found in rural areas without wastewater treatment systems.

Sewage - Water from an urban area that is piped to a treatment plant.

Shallow groundwater area - An area where the groundwater is close enough to the surface to support riparian vegetation.

SDCP - Sonoran Desert Conservation Plan

Subsidence - Lowering of the surface of the land, in this area usually due to dewatering of the aquifer beneath. Subsidence may be uniform throughout a region, or may be differential resulting in cracks and abrupt changes in ground surface level.

Surface water - Water that flows on the surface of the ground or directly underneath or immediately adjacent to a watercourse.

TAMA - Tucson Active Management Area.

TMP - Third Management Plan. See Chapter 3.

USF - Underground Storage Facility. A mechanism for recharging water for later recovery.

Vadose zone - The unsaturated area between the earth's surface and the water table. Water infiltrates through the vadose zone on its way to the aquifer. Water in the vadose zone generally cannot be economically recovered by pumping. Pollution in the vadose zone may be transported to the aquifer during the infiltration process.

Wastewater - Water from an urban area treated in a wastewater treatment plant.

Water harvesting - The procedure of salvaging rainwater from rooftops or land to store for later use or to direct the water to landscaping.

Water table - The top level of the aquifer, the highest point from which water can be pumped from the aquifer.

Wetland - A pond-like area with a permanent water supply that supports vegetation and wildlife that require a dependable water supply. A natural wetland receives its water from a high water table. An artificial wetland usually receives its water from a man-made source, such as a wastewater treatment facility. An artificial wetland may be an important part of the treatment process. Also known as "cienega" or "marsh."

Wildcat development - Housing that is built on such a small scale that rules that apply to subdivisions do not apply.

Xeriscape - Low water use landscaping which may include small higher water use areas.

Appendix B. Viewpoints of Water Experts

Questionnaires were sent to the following agencies and individuals in Pima County with water-related responsibilities. Each was asked to be concise in providing answers. In some cases the responses came from individual staff and do not reflect the official view of the agency, as noted. People were not to feel obligated to answer those questions which were not in their areas of expertise or the agency's responsibility. All the answers to each question are grouped together, with the respondent indicated by an abbreviation. It is interesting to note the variety of responses, which in many cases reflect the mandate of the agency. TAMA, example, does not have jurisdiction outside the boundaries of the Active Management Area, although ADWR has statewide responsibility. Metro's legal jurisdiction is even more limited, being restricted to its service area in northwest Tucson, although it has a regional interest and belongs to regional organizations such as Water CASA and the Southern Arizona Water Users Association.

TAMA - Tucson Active Management Area, part of the Arizona Department of Water Resources (ADWR). The questionnaire was answered by Linda Stitzer, Acting Director.
SAN XAVIER – Austin Nuñez, San Xavier District Chair, responded on behalf of the San Xavier District of the Tohono O'odham Nation.
PAG-WQ – The Water Quality staff of the Pima Association of Governments responded based on their expertise. Their responses are not to be considered official responses by PAG or its member governments.
PC-FONSECA - Julia Fonseca, Program Manager for the Pima County Flood Control District, responded for Pima County.
TUCSON WATER - David Modeer, Director, responded on behalf of Tucson Water, the city's water utility.
METRO – Mark Stratton, Director, responded on behalf of the Metropolitan Domestic Water Improvement District, located in northwest Tucson, the area's second largest water provider.
TRWC – Elaine Nathanson, Director, responded on behalf of the Tucson Regional Water Council.
LANEY – Nancy Laney responded as one member of the Governor's Water Management Commission. Nancy is Associate Director of the Arizona-Sonora Desert Museum, but the views expressed are her own, not those of the Museum or the Commission.
Sharon Megdal is also a member of the Governor's Water Management Commission and operates a private consulting firm which deals with water issues, among other matters. She provided comments which have been incorporated into the summary but did not wish her remarks to be quoted verbatim.
The following people were invited to participate, but declined:

Steve Weatherspoon, water attorney
Victor Baker, Chair of the UA Department of Hydrology and Water Resources
Robert Glennon, Regents Professor, UA College of Law.

1. *Does the Tucson AMA have both adequate supplies and adequate legal and management tools to assure that the legal goal of safe yield can be achieved by 2025? If not, what is lacking and could/should be done?*

TAMA

The Third Management Plan (TMP) water budget, which assumed that TMP conservation goals are achieved, shows an actual overdraft of 50,400 acre-feet in 2025. This budget scenario does not assume full utilization of all available renewable supplies.

The TMP budget assumes utilization of 162,200 acre-feet of CAP water and 45,400 acre-feet of effluent in 2025 (207,600 acre-feet total). Total effluent production in 2025 is estimated at 117,400 acre-feet and there are AMA CAP M&I subcontracts that total 177,03 3 acre-feet. There are also Indian subcontracts totaling 38,300 acre-feet. This supply will be used to meet Indian agricultural demands but some portion may be available for lease to meet M&I demands. In addition, the Central Arizona Groundwater Replenishment District has contracts with seven designated water providers and with certificated subdivisions to replenish mined groundwater with renewable supplies to meet the Assured Water Supply requirement of consistency with the management goal (safe-yield).

If all available supplies are utilized, safe-yield is achievable by 2025, However, there are several reasons why renewable supplies are not fully utilized now and may not be in the future. Reasons include the higher cost of renewable supplies, lack of infrastructure (distribution systems, water treatment facilities), lack of legal or physical access to supplies by potential users, water quality concerns, inadequate capacity at recharge facilities, supply reliability and environmental regulations. A regional financing authority to finance water infrastructure for multiple entities has been suggested to promote renewable supply utilization.

The Governor's Water Management Commission is evaluating a number of additional management tools that, if implemented, will enhance the prospects for achieving safe-yield.

SAN XAVIER

It doesn't appear that safe yield can be achieved in the Tucson AMA by 2025 from a hydrologic point of view. Reduced and wise use of groundwater, and increased reliance on renewable water resources such as CAP water will help off-set groundwater depletion in the Tucson area.

PAG-

We are not nearly as well qualified as ADWR staff, members of the TAMA Safe Yield Task Force, or the Governor's Water Management Commission to answer these questions; and we urge consultation with those authorities on this subject. Our sense, however, is that supplies will probably be adequate to achieve safe yield as long as CAP water and treated effluent are used to their full capacity and as long as adequate conservation and water-harvesting measures are in place. We do have concerns about this, though, due to the increasing demands from continuing population growth. We are also concerned about the adequacy of legal and management tools available to deal with such demands. Consideration of the following issues could help assess the need for possible future actions:

- Whether recharge credit should be given for future pumping of groundwater when effluent is recharged or used at a "groundwater savings facility." (This effluent would be discharged and augment the aquifer, anyway. Under this approach, the groundwater to be withdrawn in the future will be unregulated in its use because it is regarded as effluent for accounting purposes.)
- Whether exempt wells should be allowed to pump without regulation.
- Whether irrigation rights should continue to be grandfathered.
- Whether the water-table decline rates under the well-impact rules for new wells are sound as established.
- Whether the qualifications for 100-year assured water supply designation are sound as established.
- Whether developments should remain able to connect to an existing water provider without making a full assessment of impact on water resources.
- Whether the general practice of giving recharge credits within an entire AMA (allowing "paper" water trading) is consistent with a hydrologically sound definition of "safe yield."

PC – FONSECA

It seems unlikely that safe yield will be achieved in the Tucson AMA by 2025. This is why new measures to increase the likelihood of reaching a balance by 2025 are being debated in the Governor's Water Management Commission.

TRWC

The Tucson AMA has adequate water supplies. What it is lacking is a way to move the water to where it is needed. There is no legal way for multiple water providers to jointly build and payback the costs of water infrastructure. For example, in the northwest area, Marana, Oro Valley and Metropolitan Water District all hold CAP contracts but have no physical way to get the water from the canal to their service areas. They can not individually afford to build the necessary canals, pumping, storage and treatment facilities and there is no law that enables them to combine their resources. The same situation exists for an effluent distribution system. While it makes sense to have a joint effluent distribution system, some type of legal entity would have to be created to accept federal funds and manage the financial obligations of an effluent distribution

system. Hopefully, necessary legislation for some type of water infrastructure financing and management will be addressed through the Governor's Water Management Commission and be accepted in the 2002 Arizona Legislative Session.

TUCSON WATER

There is no question that safe yield can be achieved in the Tucson AMA by 2025. Water demands of the mining and agricultural sectors are projected to decline over the next 25 years; only the municipal sector is projected to have increased water demands. However, these increasing municipal demands will not be met by groundwater. All of the major municipal water providers in the AMA have been designated by the State as having a 100-year assured supply of renewable water. ADWR's Assured Water Supply program ensures that the overwhelming majority of existing municipal water demands and ALL future growth in municipal demands will be met through the use of renewable water supplies imported into the basin. Mined groundwater will not be the basis of future municipal growth. In fact, long term reductions in groundwater pumping, combined with incidental recharge of return flows from renewable water supplies imported into the region, will reverse the current basin deficit.
The return flows generated by municipal use of renewable water supplies imported to meet future demands in the basin will be a significant addition to available water supplies. Approximately 55% of these renewable supplies will not be consumptively used and will be available for reuse through the City's or others' reclaimed water systems, will be stored underground for future use, or will be discharged and will incidentally recharge the regional aquifer. Over time, this incidental recharge will exceed the total amount of groundwater withdrawn from the basin and the amount of groundwater in storage will actually increase.

The only unrestricted, long-term municipal use of mined groundwater is approximately 22,000 ac-ft/yr of pumping by existing, undesignated providers (i.e., Flowing Wells, Winterhaven, Community Water Co., etc.). However, there is considerable interest in and support for modifying existing water law to make this pumpage subject to full or partial replenishment (see discussion below regarding the Governor's Water Management Commission). It is possible, perhaps likely, that even this relatively small amount of mined groundwater use by the municipal sector will be reduced or eliminated by 2025. The Third Management Plan for the Tucson AMA projects the amount of groundwater overdraft in the year 2025 to be 6,900 ac-ft, assuming no additional water conservation requirements during future management periods and after accounting for the allowable groundwater use under the assured water supply rules. This is a very small of overdraft in comparison to the total amount of groundwater resource in the AMA, representing only 0.01% of the 60,000,000 ac-ft in storage to a depth of 1,200 feet. In addition, as required by law, future management periods WILL require additional conservation efforts from all water users. Therefore, the elimination of this projected overdraft before 2025 is quite achievable with only minor adjustments to current conditions.

All of these factors combined demonstrate that safe yield is achievable in the Tucson AMA by 2025. Increases in water demand after 2025 are projected to occur only in the municipal sector and, since these increases must be met by use of renewable supplies, safe yield also can be maintained beyond 2025.

The State of Arizona is the political entity responsible for developing management plans for the AMAs and for ensuring the achievement of safe yield in the Tucson AMA. It should be acknowledged that the Governor's Water Management Commission has spent the last year evaluating how the management goal for each AMA will be achieved or not achieved and, concurrently, evaluating needed changes to existing law in order to advance these management goals. The GWMC specifically has retained safe yield as the management goal for the Tucson, Phoenix and Prescott AMAs. At this time, the Commission is advancing several proposals for legislative amendments to "plug the holes in the bucket" and make the attainment of safe yield even more achievable. Many of these potential changes in water law are important to ensure equity among water users (i.e., everyone contributes their "fair share"), as well as to achieve safe yield.

METRO

Safe-yield is a goal or objective to attempt to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area. Based on the Third Management Plan, the Tucson AMA will be near that goal if all projections hold true. Future circumstance may make it harder to reach the goal or make it so the goal is reached earlier than 2025. The Assured Water Supply rules help to ensure adequate supplies and management for reaching safe yield. Predictions show that municipal providers will use more water; however, new municipal water uses after 1995 are required to use renewable supplies.

LANEY

No - There is no connection between growth and development and water supplies except through inadequate Assured Water Supply rules. Growth can continue well beyond sustainable levels without the means to control it.

2. *Are there adequate water supplies and water management tools within Pima County (including the Pima County parts of the AMA and parts of the county outside the AMA) to achieve a balance between supply and demand into the indefinite future? If not, what is lacking and could/should be done?*

TAMA

Most of the population and water use in Pima County is within the Tucson Active Management Area boundaries and is subject to the management plan conservation requirements and assured water supply rules (See #1). Pima County has limited water management authority, however it can adopt ordinances and land use policies that reduce water use or increase use of renewable water supplies. Coordinated efforts by jurisdictions within the Tucson AMA can be helpful in achieving water management goals.

SAN XAVIER

There are adequate water supplies for the Tucson Area for the next 50 years providing that CAP water is utilized & reliance on groundwater diminishes. However, it appears that groundwater usage will increase again at some future date if present growth rates and water use practices continue, even if CAP water is utilized.

PAG-WQ

Again, we defer to the views of ADWR, the task force, and the commission. It appears to us, though, that neither the supplies nor tools available to providers and jurisdictions within Pima County are adequate. Outside the AMA there is no water management beyond the assured water supply program for new developments. These areas have little incentive to reuse or conserve water. Without the ability to control population growth or individual water usage, the county lacks the tools for assuring a balance between supply and demand. Furthermore, it is especially difficult to predict anything into the "indefinite future." Likewise, there is no guarantee that the quality and quantity of the Colorado River water supply will persist indefinitely. Possible areas for future action might include the following:

- Whether exempt private wells and small water systems should be regulated (to prevent imbalance due to "wildcat" water companies and wells). Increasing the accuracy of reporting for exempt wells could help establish water use in outlying areas. Currently, there is incomplete information about pumpage for many private wells.
- Whether enhancement of planning and zoning authorities over outlying areas is warranted to control growth, to limit wildcat pumping, or to require the use of reclaimed water. It may be prudent to direct growth toward locations where there are existing water-distribution infrastructure and water-recharge facilities.
- Whether the practice of balancing "up stream" groundwater withdrawal against "down stream" recharge should be reassessed in light of the incomplete knowledge on natural recharge.

PC-FONSECA

No. Under present conditions we will always overshoot our resource base. What is lacking are negative feedback loops that are compelling enough to either change social expectations or decease population. Urban communities are too good at short-term fixes and obtaining resources from economically disadvantaged areas to allow for a balance to be maintained.

Recharged municipal effluent is a growing component of our potable supply. I am concerned about recent research in the U.S. and Europe showing health effects from chemical constituents that are passing into the potable supply from sewage. Many of these constituents are unregulated and hardly detectable. Some of these chemicals are not toxins or carcinogens, but have hormone-like effects at minute quantities, affecting animal (including human) development and behavior. This may not be a big concern if these constituents are removed by recharge, but there is very little research to show that they are. The bottom line is that we will have poorer water quality and more expensive water in the future, but we will accept it as a tradeoff for supporting more people and avoiding more unpleasant consequences. In addition, I think that it is more likely that the benefits of technology fixes will not be felt evenly across the human population, but instead be focused on economically advantaged groups. It is the job of public agencies to think about how public health and welfare can be protected across the entire population - in a sense this is a part of constructing negative feedback loops. This was tried before by the City Council (which considered energy costs of transporting water) in the 1970s; there was a tremendous backlash.

TUCSON WATER

There should not be any areas within the urbanized portions of the county that are not able to achieve a long-term water balance. The water providers for the municipal populations of the basin are responsible for ensuring that sufficient water supplies exist to meet the long-term needs of their service areas. The vast majority of the county's residents are served by water providers that have demonstrated a 100-year supply of renewable water

In other portions of the county, this long-term balance may be threatened by dry-lot subdivisions where residents drill their own exempt wells or, as in the case of Arivaca, low-density residential development may threaten riparian habitat dependent upon perennial streams. Pima County, as the jurisdiction responsible for zoning decisions in these areas, can address many of these issues through appropriate land use planning.

From a water management perspective, the GWMC is

supporting a proposal to modify ADWR's well permitting process to allow the State to deny well permits in areas such as Arivaca, where a proliferation of exempt or non-exempt wells near a perennial stream may threaten riparian habitat. This proposal would give the State the water management tools necessary to solve this problem.

3. Are there local areas within the county that might not be able to achieve a balance into the future even if the region as a whole was able to do so? (e.g. Arivaca, Ajo, or middle San Pedro). What could/should be done to deal with these areas?

TAMA

Safe-yield is defined as a basin-wide balance and, when achieved, there could still be sub-areas that will not be in balance. Sub-area issues have been discussed by the Tucson Safe-yield Task Force and by the Governor's Water Management Commission. These discussions have focused on subsidence and protecting environmentally sensitive areas. Ideas for special tools for these areas could include either incentives or new restrictions. Incentives could include conservation or augmentation grants or tax credits or incentives to recharge water. New restrictions could include: 1) limitations on conversions of irrigation grandfathered rights; 2) limitations on new exempt wells; 3) higher pump taxes; 4) required replenishment within the sub-area; 5) more stringent conservation requirements; or 6) more stringent recovery well criteria. Another approach could be a more rigorous well permitting system requiring hydrologic review. The review could include an analysis of impacts on ecosystems, contribution to subsidence, impacts on municipal service areas, impact on plumes of contamination, etc. If wells were found to have an adverse impact, a permit would not be issued. Implementing these restrictions would require changes to rules, statute or ADWR management plan requirements.

PAG-WQ

Although we are not fully qualified to assess this issue, we believe there is a likelihood of localized imbalances in the future. Areas with development pressure can be expected to have the most difficulties. Arivaca, Mount Lemmon, Oro Valley, Tanque Verde Creek, and eventually the Vail area will likely experience groundwater decline/shortage issues. Balance may never be reached in heavy withdrawal areas, such as those centered on a large mine, a municipal well field, a large farm, or a concentration of productive exempt or wildcat wells. Without access to CAP water and reclaimed wastewater, locations of high water usage (or high growth potential) and limited natural recharge will probably not achieve a balance locally. Given the rate of known pumping and the sensitivity of watersheds in Pima County, it is conceivable that local areas remote from water infrastructure (e.g., artificial recharge basins) will be unable to achieve an indefinite balance. Some of these areas would probably include the Northeast Tucson Basin, Rincon Creek, upper and lower Cienega Creek, Davidson Canyon, upper and lower Sabino Creek, Arivaca, Tortolita Mountains including foothills, Silverbell Mountains, middle San Pedro River, Santa Cruz River south of Green Valley, Sopori Wash, and Canada del Oro. Achieving a balance would be made more difficult if it was also a priority to maintain the health of a particular riparian zone, particularly if it is a critical riparian habitat that depends on surface flow or near-surface subflow. Insofar as the reference to Ajo is concerned, we believe the area is serviced by deep, drinking-water wells located a significant distance from the developed area.

This is a difficult problem, because each area has an individual set of problems. Some local imbalances might be considered acceptable where there is minimal risk of subsidence or damage to riparian areas or other areas of habitat relying on shallow groundwater. The use of reclaimed water will become more important in some of these areas over time, especially if they are outside the CAP delivery range. Infrastructure could be built to transfer CAP water or reclaimed water to priority areas, if needed. Moving water around the area by pumps is expensive, though, and water may be lost in the system. Certain agriculture could be shifted to crops that have lower water demands. A county-wide conservation program could be adopted, with conservation regulations being implemented and enforced in order for these areas to achieve balance. Water conservation could be pursued more vigorously in the region, with more public outreach and more data-based reporting in this area. Municipal water providers could charge higher rates for water to encourage conservation. Local jurisdictions could place limits on growth, target areas for preservation, or convert irrigated farmland to other uses. They should comprehensively evaluate and prioritize the available resources, with a view toward eliminating or decreasing groundwater pumping in priority areas. These areas would be particularly affected by the safe-yield definition that credits recharge even though it occurs remotely from pumping. Water harvesting could be used effectively on a local level because no basin-wide infrastructure is needed; rural homeowners could be educated on and assisted with building appropriate berm and drain features. Keeping water on site could help by irrigating the property without pumping groundwater; plus, it would alleviate strain on any stormwater infrastructure and would probably improve stormwater quality. Maximizing graywater usage would also be a good strategy for these more localized areas.

PC-FONSECA

Tanque Verde Valley and lower Sabino Creek are examples of riparian areas which might remain out-of-balance, or even be subject to additional pumping in the future. Human growth has already been directed into these areas through past zoning decisions, and several water companies collectively pump as much or more water than is provided naturally. This prevents the recovery of the aquifer, which historically provided habitat conditions suitable for fish. In this area, Tucson Water could reduce groundwater pumping further, and Metropolitan Water and 49er's Water Company could construct pipe connections to take advantage of the CAP blend now available through Tucson Water. Pima County's Board of Supervisors could help by not approving zoning changes which would rely on groundwater from these areas, and by not extending the regional sewer system into this area. The Pima County Flood Control District could help by not constructing soil-cement bank stabilization and channelizing the streams.

Residents of the Arivaca Watershed fear that new water uses could deplete the aquifer underlying Arivaca Cienega. A major developer could deplete their aquifer, yet comply with AMA restrictions by recharging elsewhere in the TAMA. Pima County could reduce this threat through land use planning, but cannot regulate the "wildcat" subdividing that is presently occurring. Existing laws would have to be changed to give Pima County authority over this type of development. A third source of risk is the accumulated grand-fathered irrigation rights, which could be used to pump more groundwater. Land acquisition or conservation easements would be needed to reduce this threat.

TUCSON WATER

As noted above, within the Tucson AMA there are adequate water supplies and management tools in place. In addition to the designated water providers that have access to renewable water supplies through CAP subcontracts, the CAGRD provides a mechanism for other water providers to access renewable water supplies in compliance with the Assured Water Supply program. In order to receive an assured water supply designation based on CAGRD membership, potential members must demonstrate physical availability of sufficient groundwater to meet their projected demands for 100 years. These requirements of the AWS program ensure that development will occur only where there is sufficient water supply, either through direct delivery or through pumping and replenishment, to meet the long-term needs of the development.

Outside the Tucson AMA, there may be areas within Pima County where there are not adequate groundwater supplies to meet significant amounts of new development and where renewable supplies cannot be imported due to physical or economic constraints. Development in these areas should be limited to that which is sustainable under existing water supply availability.

METRO

Some parts of Pima County will probably not have renewable supplies available to them and continued groundwater pumpage will lead to persistent depletion. This will be difficult to alter unless great resources are expended to bring in renewable supplies or options to reduce or limit groundwater pumping is pursued. Those concerns are best addressed when the citizens and water providers in those local areas develop possible solutions.

4. Is adequate provision made in current law and practice to protect existing perennial streams, springs, and cienegas in the county? Should new water be made available to protect riparian areas and restore some that have lost their dependable water supply? What changes could/should be made?

TAMA

Because of the bifurcation of surface water law and groundwater law, there is no current way to protect streams, springs and cienegas from the effects of groundwater pumping, However, the 2000 Arizona Supreme Court decision on subflow may offer new protection. This issue is currently before the Governor's Water Management Commission. (See attached recommendations of the Environmental and Economics Sub-committee. Note that these recommendations may or may not move forward as final recommendations by the Commission).

Instream flow rights provide some protection to keep water in a stream for preservation purposes. The Arizona Water Protection Fund, provides funds for protection and restoration of riparian habitat. Existing streams, cienegas and springs could be protected through land purchases, zoning practices, restrictions on new wells and existing rights, limits on exempt wells, or retiring existing pumping in riparian areas. Use of renewable water supplies for riparian area restoration has been suggested. However, restoration of historic stream flow would require a long-term commitment of water supplies, which could affect the ability to achieve and maintain safe-yield. Effluent supplies will increase with population growth but there will be increasing competition for the supply to irrigate golf courses, parks and potential potable use.

SAN XAVIER

Current practices & laws allow for the depletion of groundwater which negatively impacts perennial streams in the county. Whatever suitable water that is available could be used to protect and/or restore riparian areas that have been or are in danger of being degraded. CAP water could be used for this purpose providing that the projects are well planned and conditions are well controlled.

PAG-WQ

Legal and technical issues related to water rights, the protection of surface water, and the relationship between surface water and groundwater are highly complex, and PAG staff has limited expertise in this area. Qualified experts should be asked to comment on the legal aspects of this question, particularly. From a general standpoint, however, it would appear that these water-resource areas are not protected adequately by current law or practice. While there are regulations that provide some protection for flora and fauna (under the Endangered Species Act), there is very little that protects surface water or groundwater beyond provisions for instream flow rights. While the unique-waters designation is currently used to protect surface waters on the basis of water quality, legal tools are probably needed to protect surface water on the basis of availability alone.

While we believe riparian areas should be protected, the availability of new water for riparian systems could be limited if there were stronger concerns about reaching safe yield. In this regard, it's important to remember that water being pumped into a riparian area is coming from somewhere and that there may be consequences to the source region. We should understand that any supplementation of our perennial surface water may be at the expense of another region's surface water. There would likely be a serious public-policy dilemma brought about by a proposal to de-water downstream areas by removing surface water from one source and pumping it upstream to restore areas de-watered by groundwater withdrawal. This will be an issue requiring consideration, through broad public participation, of many factors including community values and regional economics. In areas where there are existing riparian systems and where pumping is a problem that cannot be mitigated, then new water supplies may be appropriate for protecting these areas. But an area that is restored and needs constant application of imported water will likely not endure, because people needing the water for human use will be able to pull it from the riparian area. Other problems that may occur from new-water importation would be the potential for invasive species.

The connection between surface water and ground water in the Arizona legal system probably needs to be recognized. ADWR presently can only use surface water adjudication to manage groundwater withdrawal impacts on surface water. One approach could be to designate (after extensive scientific review and public input) certain streams for water resources protection in a way that is analogous to the unique-waters program for water quality. Such an approach would require a technically and legally defensible hydrogeologic assessment and water balance study for these streams. Any water resources development significantly impacting the water balance for these streams could then require review by a regulatory agency. The protection and restoration of certain riparian areas using renewable sources and recharge strategies should be a planning priority. While consideration would likely be given to using CAP water for restoration (with recharge), consideration could also be given to constructing some treatment wetlands that would provide desired habitat. However, we should probably expect most of the effluent produced to be reserved for uses that will supplant groundwater pumping.

PC-FONSECA

No. Existing law does not adequately protect perennial streams and springs. In my opinion, the recent court decision on sub-flow will also prove to be inadequate protection for perennial flows. I am not sure there is such a thing as new water, but I think re-allocations of water are needed to protect and restore riparian areas.

Acquisition of water rights to restore water supplies diverted from streams is one method. For instance, at Cienega Creek, 1100 a.f./year is diverted to irrigate the Vail Valley (Del Lago) golf course. This is a historic water right for which the owners must be compensated.

In general, acquiring property rights from willing sellers is probably a more expedient means of protecting and restoring the highest priority riparian areas than is amending existing water and land use law, with the exception of amendments which create funding sources for acquisitions.

The Science Technical Advisory Team for the Sonoran Desert Conservation Plan prefers to see self-sustaining riparian systems protected over those dependent on effluent. If reclaimed water is available, they would prefer that the water be used to restore or enhance localized aquifers, rather than to perpetually irrigate plantings.

TUCSON WATER

In February 2000, the City and the County agreed to set aside up to 10,000 ac-ft/yr of effluent for regional habitat conservation programs. In addition, the county has rights to 10% of the effluent that it may choose to dedicate to restoration of riparian areas. Managed properly, this volume of water should be sufficient to address reasonable habitat restoration in the urbanized core.

Outside the urban area, the GWMC proposal on well permitting would be the major mechanism to protect riparian habitat protection. ADWR, the state agency responsible for managing both surface water and groundwater, currently does not have the authority to deny well permits on the basis of impact to riparian habitat; the GWMC well permitting proposal would grant the agency that authority. Additionally, however, zoning restrictions and ordinances administered by the county are needed to prevent other impacts to these areas, such as clearing of vegetation for development.

METRO

To protect perennial streams and riparian areas, first questions need to be asked who has ownership of the streams, who owns the supplies to protect or restore riparian areas, and who is to fund this effort. Caution should be given to protecting or especially to restoring riparian areas with new water. While the concept appears admirable, there are far reaching implications that need to be considered. Excessive corrections for unfortunate past misuses of our environment do have the potential to result in unfortunate consequences for our future environment and water.

LANEY

There is definitely not adequate protection for streams, etc. There is a need to safeguard existing flows and make provisions for supplemental water during times of drought. We should encourage recharge in natural stream channels, limit all groundwater pumping in riparian areas, and reserve water for future riparian needs.

5. In what ways could/should Pima County improve its coordination and cooperation with the various water management entities (e.g. water providers, municipalities, tribes or ADWR).

TAMA

The County should continue to participate in local water committees, provide GIS products (maps) and contribute funding for water-related studies such as the ongoing subsidence monitoring study. The Department urges the County to continue to strengthen these efforts including working cooperatively with the City of Tucson and other municipalities and water users to promote a regional approach to water management. This could include working collaboratively on water conservation ordinances and water supply utilization. There is no question that coordination and cooperation between jurisdictions and agencies in Pima County could be improved.

SAN XAVIER

The various water management entities in the Tucson Area should cooperate with ADWR to achieve its water management goals, especially the goal of safe yield. Coordination and cooperation between the San Xavier District and Pima County are good at this time and it is hoped that this relationship will continue in the future.

PAG-WQ

Good multi-lateral cooperation among all water-management entities is essential to solving the region's long-term supply problems. All entities should constantly strive to overcome barriers to well-coordinated water-management decisions. On a general level, allowing for peer review on studies that might involve other entities in some way would be helpful. Also, good cooperation is enhanced through regionally facilitated communication and coordination mechanisms, such as PAG's Environmental Planning Advisory Committee and Water Quality Subcommittee (of which the County and water-management entities have typically been key supporters and participants). On a more specific level, wastewater managers will have to be leaders in effluent reuse and strive to provide the highest quality reclaimed water possible. Entities could work together to build a reuse distribution system throughout the region that creates incentives for reuse, and satellite treatment plants could be built higher up in the basin to capture wastewater for reuse at various additional points.

PC-FONSECA

Pima County Wastewater can best respond as far as coordination on effluent. I will respond based on my involvement with the riparian aspects of the Sonoran Desert Conservation Plan. I think Pima County can cooperate with others to improve the scientific understanding of the relationship between water resources and biological resources. We also need to work with others to identify opportunities to protect and restore water supplies for riparian areas. I see the need to work with private individuals, corporations, and reserve managers, in addition to water agencies.

TUCSON WATER

Since the signing of the Supplemental Effluent IGA in February 2000, Tucson Water staff and Pima County Wastewater Management staff have met regularly to discuss and plan matters of mutual interest. This regular meeting and coordination effort has facilitated inter-agency coordination and cooperation between the water department and the wastewater department.

There are two significant areas in which continued coordination and cooperation are of primary importance. First, Pima County can provide political support on state and federal regulatory or legislative issues that impact water providers in the region. For example, final implementation of the SAWRSA settlement needs to be ensured to avoid further litigation over Native American water rights in the basin. Pima County could support a legislative change to allow the 28,200 ac-ft/yr of effluent controlled by the Secretary of the Interior to accrue 100% credits through managed in-channel recharge. This legislative change would ensure the physical and financial resources necessary for the full implementation of the federal obligations under the settlement and would help stabilize the groundwater rights of non-Indian parties in the basin. In addition, this legislative change would help ensure that a significant amount of effluent remains in the Santa Cruz River channel to maintain the riparian habitat that has been established by historical flows.

Second, Pima County can continue its program of process improvements at the existing Roger Road and Ina Road treatment plants to improve the quality of effluent produced from these plants. Lower turbidity levels and reduced nitrate content both facilitate beneficial reuse by reducing the cost of additional treatment to meet reuse standards and by making greater volumes of water available for reuse. The additional use of reclaimed water to serve non-potable uses helps preserve higher quality groundwater for potable uses.

METRO

Pima County, through Pima County Wastewater Management, is a member of the Southern Arizona Water Users Association (SAWUA), which comprises of the major municipal and agriculture water providers in Pima County to work together on water issues in common. By being an active member of SAWUA, Pima County has an opportunity to coordinate and cooperate on water management issues of the region. More importantly, by speaking with one voice on issues of common ground, Pima County as a whole will be more productive in dealing with the Legislature, regulators, and other water entities.

LANEY

We should be coordinating demands with appropriate supplies of water - effluent, CAP, groundwater, harvested rainwater, etc. across different jurisdictions. Joint funding and management of infrastructure is needed.

6. *Other brief comments relevant to your agency's mandate or your expertise.*

TAMA

ADWR is committed to working with all jurisdictions within the AMA to maximize the likelihood of achieving safe yield and ensuring sustainable water supplies for the future.

PAG-WQ

Promoting a regional watershed management approach would be beneficial. If water-management authority is going to remain multi-jurisdictional, there should probably be an effort to establish a more effective coordination mechanism for water providers, regulators, managers, users, polluters, protectors, remediators, educators, advocates, etc., to make decisions and resolve conflicts. Furthermore, we should keep in mind that some areas within Pima County are connected watersheds that are partially outside of the county (e.g., Santa Cruz River, Arivaca Creek, Cienega Creek, San Pedro River, and Canada del Oro). Therefore, coordination is needed with entities involved with managing the areas outside Pima County and the Tucson AMA. This would even include consideration of surface flows in the Colorado River and their ultimate impact downstream of withdrawal in support of our region. Insofar as water use in the desert is concerned, especially recognizing our region's record of and potential for growth, conservation has to be more than a virtue; and water-use requirements have to be a more significant factor in setting land-use policies.

PC-FONSECA

One of the things I have learned from biologists involved in the Sonoran Desert Conservation Plan is how important the Tucson Basin is biologically. It is not just the pygmy-owl which is at risk, but many other species. What we do in the basin affects many species in the mountains. A number of species which we think of as mountain species used to depend on riparian areas in the Tucson Basin, and some still do. So although we know urban development will continue, how we develop is still important.

We had an inter-agency symposium several months ago on aquatic species. At that meeting, we talked about the threats posed by non-native aquatic plants, insects, and animals on our native species. It is clear that protecting water quantity is not enough. Collectively, we need to manage existing and future water bodies to minimize the threats posed by some of these non-native organisms. Agencies, individuals or companies constructing new ponds on the periphery of the Catalina and Rincon Mountains need to be particularly careful because they are so close to vulnerable populations of native fish and frogs.

TUCSON WATER

On May 3, 2001, the City of Tucson dedicated the Clearwater Renewable Resource Facility, a facility that will initially bring 20,000 ac-ft/yr of renewable water supply into the basin. Over the next three years, the renewable supply from this project will increase to 60,000 ac-ft/yr and will allow Tucson Water to dramatically reduce groundwater pumping in the Central well field. This single project will do more to protect the water resources and the environment in the Tucson area than all other actions combined. With the successful re-introduction of CAP water as a potable supply in this community, the long-standing concerns regarding groundwater overdraft, land subsidence and destruction of vulnerable riparian habitat will be eliminated within the metropolitan area served by Tucson Water. As the other municipal water providers in the region move forward with their own plans for using renewable supplies, these concerns will be eliminated for their service areas as well. The water resource issues remaining for Pima County to address through its Comprehensive Plan are those associated with protection of vulnerable riparian habitat outside the urbanized area.

METRO

Water resource management is a complicated matrix to ensure you meet future needs to coincide with the balance of environmental considerations, water quality and quantity, and overall cost to the public. It is important to understand the perspective of all interests, especially those who deal on a day-today effort to ensure that the public has safe drinking water.

LANEY

It is vital that we regulate exempt wells.

Appendix C. Water Budgets in More Detail

Tucson Active Management Area

This section of the appendix contains three tables from the Draft Third Management Plan 2000-2010, of TAMA, printed in 1998. The goal of these calculations is to predict whether the TAMA will reach the goal of safe yield as required by law. The tables are numbered as they are in the Plan, located in Chapter 11. The tables deal only with TAMA, not the whole of Pima County. Note also, that part of TAMA is within Pinal County.

The first table shows projected supply and demand in TAMA assuming that present baseline conditions remain in effect through the period. That is, for example, there are no significant new water conservation efforts. It makes numerous other assumptions. It assumes, for example that non-Indian agriculture will decrease while Indian agriculture increases, taking advantage of its CAP water.

The second table shows projected conditions assuming conservation goals are achieved by 2010 and remain in effect.

The third table shows the cumulative overdraft under the conditions assumed in both the first two tables.

The notes below apply to the first two tables which can be found on the following two pages.

Notes for Tables 11-11 and 11-12

All units are acre-feet unless otherwise noted.

AMA = Active Management Area; IGFRs = Irrigation Grandfathered Rights;

Non-Indian demand indicates demand for uses off Indian Reservation lands. For the municipal sector, acre-foot demand includes exempt well use.

For the agricultural sector, this demand includes canal losses and irrigation use by exempt small rights

Indian demand includes San Xavier and Schuk Toak Districts of the Tohono O'odham Reservation within AMA boundaries

100 acre-feet of CAP water used for treatment plant maintenance

Renewable supply use by Tucson Water commences in 2001

Includes secondary effluent, reclaimed system effluent, and effluent credits purchased from the Secretary of the interior

Net Natural Recharge is composed of mountain front recharge, stream channel recharge, and groundwater inflow less outflow,

Incidental recharge decreases between 2000 and 2005 when managed in the channel effluent , recharge increases substantially

Extinguishment of Arizona Water Banking Authority CAP recharge credits is assumed to take place only in the TMP Scenario

Industrial demand is projected to continue to grow slightly during this period with effluent use replacing some groundwater use. Groundwater use is projected to be 71,200 acre-feet in 2025 for the industrial sector, an increase from 59,400 acre-feet in 1995. Total demand by 2025 is projected to be 75,900 acre-feet for the industrial sector, an increase from 60,200 acre-feet in 1995.

In the Base Scenario, groundwater accounts for 193,400 acre-feet of water use in 2025 for all sectors combined. This total volume is offset by a combined total of 140, 100 acre-feet of net natural recharge, incidental recharge, and cuts to the aquifer from recharge projects to yield an actual overdraft of 53,300 acre-feet. The subtraction of allowable mined remediation water and allowable mined groundwater through the AWS Program reduces the actual groundwater overdraft to 5,700 acre-feet. For accounting purposes, the use of allowable mined groundwater is considered acceptable in the context of meeting the AMA's goal. However, in actuality groundwater overdraft continues and this issue may need to be revisited.

TABLE 11-11
BASE SCENARIO: PROJECTED FUTURE CONDITIONS ASSUMING 1995 CONDITIONS CONTINUE THROUGH 2025, TUCSON ACTIVE MANAGEMENT AREA

Year								
Projected AMA Population	655,000	768,000	838,300	920,900	1,005,300	1,092,200	1,179,200	1,266,500
Projected Irrigation Acres	40,000	36,100	35,320	35,750	33,900	30,400	26,400	21,400
IGFRs	40,000	36,100	35,100	33,600	30,600	27,100	23,100	18,100
Indian Irrigation	01	0	220	2,1501	3,300	3,300	3,3001	3,300
Municipal Sector								
Total Demand	130,100	155,500	172,900	193,500	212,100	231,900	249,800	267,100
Non-Indian'	130,000	155,400	172,800	193,400	212,000	231,800	249,600	266,900
Indian	100	100	100	100	100	100	200	200
Total Supply	130,100	155,500	172,900	193,500	212,100	231,900	249,800	267,100
CAP	0	1003	8,500	111,9004	117,100	131,300	146,600	162,100
Effluent	6300	7,700	11600	23,4001	32,900	36,000	37,100	37,700
Groundwater	123,800	147,700	152:800	58,200	62,100	64,600	66,100	67,300
Agricultural Sector								
Total Demand	93,800	98,000	104,700	117,700	107,500	97,000	85,000	70,000
Non-Indian	93,800	98,000	103,600	107,400	91,700	81,200	69,200	54,200
Indian	0	0	1,100	10,300	15,800	15,800	15,800	15,800
Total Supply	93,800	98,000	104,700	117,700	107,500	97,000	85,000	70,000
CAP	0	0	0	10,400	15,800	15,800	15,800	15,800
Effluent	4,000	1,800	3,000	3,000	3,000	3,000	3,000	3,000
Groundwater	89,800	96,200	101,700	104,300	88,700	78,200	66,200	51,200
Industrial Sector								
Total Demand	48,800	60,200	71,000	72,100	73,800	73,500	74,700	75,900
Total Supply	48,800	60,200	71,000	72,100	73,800	73,500	74,700	75,900
CAP	0	0	0	0	0	0	0	0
Effluent	0	800	1,300	1,700	2,900	3,600	4,200	4,700
Groundwater	48,00	59,400	69,700	70,400	70,900	69,900	70,500	71,200
Other Demands								
Demand: Evapotranspiration	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700
Supply- Groundwater	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700
Total Demand	276,400	317,400	352,300	387,000	397,100	406,100	413,200	416,700
Total Groundwater Use	265,3001,	307,000	327,900	236,6001	225,400	216,400	206,500	293,400
(Less) Net natural recharge	60,800	66,800	60,800	60,800	60,800	60,800	60,800	60,800
(Less) Incidental recharge	70,300	82,300	80,800	39,900	35,600	35,200	34)400	33,300
(Less) Cuts to aquifer	0	0	5,100	33,200	36,300	38,200	42,100	46,000
(Less) Extinguished credits	0	0	0	0	0	0	0	0
Actual Overdraft	134,2001	163,900	181,200	102,7001	92,700	82,200	69,200	53,300
(Less) Remediation water	0	0	8,400	7,000	6,500	6,500	6,500	6,500
(Less) Allowable groundwater	0	0	10,000	33,400	37,000 1	39,200	40,300	41,100
Accounting Overdraft	134,200	163,9001	162,800	62,300	49,2001	36,500	22,400	5,700

TABLE 11-12
THIRD MANAGEMENT PLAN SCENARIO: PROJECTED FUTURE CONDITIONS ASSUMING THIRD MANAGEMENT PLAN CONSERVATION GOALS ARE ACHIEVED BY 2010 AND CONTINUE THROUGH 2025, TUCSON ACTIVE MANAGEMENT AREA

Year								
Projected AMA Population	655,000	768,000	838,300	920,900	1,005,300	1,092,200	1,179,200	1,266,500
Projected Irrigation Acres	40,000	36,100	35,320	35,750	33,900	30,400	26,400	21,400
IGFRs	40,000	36,100	35,100	33,600	30,600	27,100	23,100	18,100
Indian Irrigation	0	0	2201	2,150	3,300	3,300	3,3001	3,300
Municipal Sector								
Total Demand	130,100	155,500	172,900	188,300	199,800	218,500	234,000	247,300
Non-Indian'	130,000	155,400	172,800	188,200	199,700	218,400	233,800	247,100
Indian	100	100	100	100	100	100	200	200
Total Supply	130,100	155,500	172,900	188,300	199,800	218,500	234,000	247,300
CAP	0	100	8,5004	107,800	107,300	120,6001	134,000	146,400
Effluent	6,300	7,700	11,600	23,400	32,900	36,000	37,100	37,700
Groundwater	123,800	147,7001	152,800	57,100	59,600	61,900	62,900	63,200
Agricultural Sector								
Total Demand	93,800	98,000	104,700	117,700	107,500	97,000	85,000	70,000
Non-Indian'	,800	98,000	103,600	107,400	91,700	81,200	69,200	54,200
Indian'	0	0	1,100	10,300	15,800	15,800	15,800	15,800
Total Supply	93,800	98,000	104,700	117,700	107,500	97,000	85,000	70,000
CAP	0	0	0	10,400	15,11	15,800	15,800	15,800
Effluent	4,000	1,800	3,000	3,000	"000	3,000	3,000	3,000
Groundwater	89,800	96,200	101,700	104,300	88,700	78,200	66,200	51,200
Industrial Sector								
Total Demand	48,800	60,200	71,000	72,100	73,300	73,000	74,200	75,400
Total Supply	48,800	60,200	71,000	72,100	73,300	73,000	74,200	75,400
CAP	0	0	0	0	0	0	0	0
Effluent	500	800	1,300	1,700	2,900	3,600	4,200	4,700
Groundwater	48,000	59,400	69,700	70,400	70,400	69,400	70,000	70,700
Other Demands								
Demand: Evapotranspiration	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700
Supply: Groundwater	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700
Total Demand	276,400	317,400	352,3001	381,800	384,300	392,200	396,900	396,400
Total Groundwater Use	265,300	307,000	327,900	235,500	222,400	213,200	202,800	188,800
(Less) Net natural recharge	60,800	60,800	60,800	60,800	60,800	60,800	60,800	60,800
(Less) Incidental recharge	70,300	82,300	80,800	39,700	35,000	34,500	33,700	32,400
(Less) Cuts to aquifer	0	0	5,100	33,000	35,800	377001	41,500	45,200
(Less) Extinguished credits'	0	0	11,700,	8,400	7,900	7:600	0	0
Actual Overdraft	134,200	163,900	169,500	93,600	82,900	72,600	66,800	50,400
(Less) Remediation water	0	0	8,400	7,000	6,500	6,500	6,500	6,500
(Less) Allowable groundwater	0	0	10,000	32,400	34,500	36,500	37,000	37,000
Accounting Overdraft	134,200	163,900	151,1001	54,200	41,900	29,6001	23,300	6,900

TABLE 11-13
BASE AND TMP SCENARIOS CUMULATIVE WATER BUDGET FACTORS
TUCSON ACTIVE MANAGEMENT AREA

Base Scenario	
Cumulative Municipal Groundwater use 1995 to 202	52,704,200 acre-feet
Cumulative Agricultural Groundwater use 1995 to 2025	2,660,200 acre-feet
Cumulative Industrial Groundwater use 1995 to 2025	2,142,900 acre-feet
Cumulative Municipal Remedial Groundwater Use 2000 to 2025	178,150 acre-feet
Cumulative Municipal Allowable Groundwater Use 2000 to 2025	887,250 acre-feet
Cumulative Arizona, Water Banking Authority Extinguished Credits 2000 to 2017	0 acre-feet
Cumulative Actual Overdraft 1995 to 2025	**3,346,900 acre-feet**
Cumulative Accounting Overdraft 1995 to 2025	**2,253,900 acre-feet**
TMP Scenario	
Cumulative Municipal Groundwater use 1995 to 2025	2,646,450 acre-feet
Cumulative Agricultural Groundwater use 1995 to 2025	2,660,200 acre-feet
Cumulative Industrial Groundwater use 1995 to 2025	2,134,150 acre-feet
Cumulative Municipal Remedial Groundwater Use 2000 to 2025	178,150 acre-feet
Cumulative Municipal Allowable Groundwater Use 2000 to 2025	829,500 acre-feet
Cumulative Arizona Water Banking Authority Extinguished Credits 2000 to 2017	156,650 acre-feet
Cumulative Actual Overdraft 1995 to 2025	**3,126,650 acre-feet**
Cumulative Accounting Overdraft 1995 to 2025	**2,091,400 acre-feet**

Tucson Regional Water Council
Water Scenarios from Water Words, Autumn 2000

TRWC's goal was to determine how many people could be supported with renewable water supplies in the TAMA under different assumptions.

Limitations of Projections

The scenarios presented in this article do not account for several important factors, including water quality, economics, and recharge/recovery limitations. Water quality degrades as water is reused; recycled water is generally of poorer quality than CAP water or groundwater This important factor is very difficult to quantify but must be considered in evaluating future water use.

Economic factors, including the price of water and value of water are also difficult to quantify, but will play a role in future water use. Groundwater can be pumped for generally less than $100 per a.f. The estimated cost for an a.f. of City of Tucson potable water is $668 based on current rates. City of Tucson reclaimed water costs $4 75 per acre foot, a price that is subsidized by potable water rates.

Incidental recharge is an important part of the water budget. However, most incidental recharge occurs downstream from the Roger Road and Ina Road wastewater treatment plants and, therefore, downstream from most of the Active Management Area. This fact of geography creates difficulties in realizing the full benefit of incidental recharge

Water Budgets - Current and Future Supply and Demand

To determine future water use, two crucial figures must be projected: 1). water demand and 2) water supply. Water budgets are used to evaluate the current total water supply and demand picture and to project future potential water supply and demand scenarios. In a surface water system, if demand exceeds supply, and there are no storage reservoirs, there is a water shortage. In the Tucson Active Management Area (AMA), we have very little surface water, but we have a large volume of groundwater in storage, known as the Tucson Basin and Avra Valley aquifers.

The groundwater in the aquifers underlying the Tucson area has provided water for growth since the early part of the 20th century. This groundwater accumulated over many thousands of years, including wetter climatic regimes. Since 1940, we have been overdrafting our groundwater supply, which means that we have been pumping more groundwater than is being replaced through natural and artificial recharge. Overdraft has resulted in a decline in groundwater level of up to 200 feet. The negative consequences of 11 mining" our groundwater include land subsidence (up to 4 inches in central Tucson), increased pumping costs, decreased groundwater yields from wells, decreased water quality, and the loss of riparian areas. In 1980, through the enactment of the Groundwater Management Act, the decision was made to reduce groundwater pumping in the AMAs and to utilize "renewable" supplies, which in the Tucson AMA means CAP water and effluent.

ADWR uses water budgets, supply versus demand, to assess and project the impact to the aquifer of different water management strategies. "Safe yield" is the management goal for the AMA and means that groundwater use does not exceed recharge. Net natural recharge in the Tucson AMA is estimated to be 60,800 acre-feet per year a.f./yr. This is the amount of groundwater that can be pumped in a safe-yield situation. Components of water supply and water demand for 1998 are shown on Figures 1 and 2 and on Table I.

Per Person Water Demand

As population increases, residential, commercial, and non-mining industrial water demand also increase. For this analysis, the municipal (residential plus commercial) demand is assumed to be 175 gallons per capita per day (gpcd); nonmetal mining plus industrial demand is 10 gpcd. * Thus each new resident increases the demand by 185 gpcd. However, some of that water percolates back to the aquifer as incidental recharge (estimated as 4% of the municipal and 12% of the industrial demand), and some flows into the sewers where it is available for reuse or recharge (40% of municipal demand). When calculating a water budget, these "return flows" are subtracted from the demand. Therefore the net impact of an additional resident is 107 gpcd, or roughly eight people per acre-foot per year

Water Supply and Use Scenarios

Because of the number of assumptions that are required to develop a water budget and to project future supply and demand, it is impossible to state unequivocally when our population will outstrip our water supply. However, it is possible to project water use under particular scenarios based on a given set of assumptions. Three scenarios and the number of people that the water supply could support based on the given assumptions are provide here. All three scenarios assume that renewable supplies are fully utilized and that groundwater pumping does not exceed recharge. These assumptions are made to comply with ADWR management plan goals.

Table 1 Components of Water Supply

Components of Water Supply used in 1998 (a.f.)	
Renewable	
CAP Water	46,800
Effluent	11,100
Natural Recharge	60,800
Incidental Recharge	86,500
Non-Renewable	
Groundwater Overdraft	105,600
TOTAL	**310,800**

Components of Water Demand Volume used in 1998 (a.f.)	
Municipal	160,500
Agriculture	93,000
Mining	43,000
Other Industrial	14,300
TOTAL	**310,800**

Scenario I - Mining and agriculture water use stay at today's level.

STEP I - Determine net agriculture and mining demand:

- 93,000 a.f.	agriculture demand
- 43,000 a.f.	mining demand
-136,000 a.f.	mining and agricultural demand
+23,760 a.f.	agricultural and mining incidental recharge*
-112,240 a.f.	agricultural and mining impact
+60,800 a.f.	net natural recharge
- 51,440 a.f.	net agricultural and mining demand (overdraft)

Note: Demand is shown as a negative number and supply is shown as a positive number Thus, 51,440 a.f. is the annual overdraft by agriculture and mining under these conditions. To maintain safe yield, that overdraft amount must be subtracted from the CAP water supply. Incidental recharge factor is 20% for agricultural and 12% for mining.

STEP 2 - CAP supply minus agriculture, mining and municipal demand

+200,000 a.f.	CAP supply
- 51,440 a.f.	net agricultural and mining demand (overdraft)
+148,560 a.f.	water for municipal and industrial use
- 15 1,000 a.f.	1998 municipal use
+ 66,440 a.f.	municipal incidental recharge factor + 64,000 a.f. water available for growth

STEP 3 - Calculate population that can be supported by the available water:

64,000 a.f. x 8 persons per a.f. =	512,000 additional population
	872,289 existing population
Population	**1,384,289**

Arizona Department of Economic Security (DES) projections indicate that the population of Pima County will be 1,372,325 in 2030. DES projections do not extend beyond 2050.
It is important to note that in 1998, CAP water use was only 46,806 a.f. . Because of our limited use of CAP water, we are "mining" groundwater to make up for the supply deficit.

Scenario 2 - Mining and agriculture water use decrease by half from today's levels.

STEP I

- 56,120 a.f.	agricultural and mining impact
+ 60,800 a.f.	net natural recharge
+ 4,680 a.f.	net agricultural and mining demand (surplus)

STEP 2

+ 200,000 a.f.	CAP supply
+ 4,680 a.f.	net agricultural and mining demand
+ 204,680 a.f.	water for municipal and industrial use
- 151,000 a.f.	1998 municipal use
+ 66,440 a.f.	municipal incidental recharge factor
+ 120,120 a.f.	water available for growth

STEP 3

120,120 a.f. x 8 persons per a.f. = 960,960 additional population
872,289 existing population
Population 1,833,249

DES projections indicate that the population of Pima County will be 1,671,175 in 2050.

Scenario 3 - Mining and agriculture water use cease.

STEP 1 is eliminated.

STEP 2

+ 200,000 a.f.	CAP supply
+60,800 a.f.	net natural recharge
-151,000 a.f.	1998 municipal use
+66,440 a.f.	municipal incidental recharge factor
+176,240 a.f.	water available for growth

STEP 3

176,240 a.f. x 8 persons per a.f. = 1,409,920 additional population
872,289 existing population
Possible Population 2,282,209

Water Resources Research Center, University of Arizona
From Water in the Tucson Area: Seeking Sustainability, 1999.

The purpose of this calculation was first to develop a water budget based on water actually available and secondly to demonstrate how calculations of water balance depend on the assumptions made. The WRRC web site www.ag.arizona.edu/AZWATER/ has an interactive budget in which the user can input other assumptions to develop other water budgets.

"Wet Water" Budget*

For Tucson Active Management Area, 1997 data (in acre-feet)

GAINS TO AQUIFER		
GROUNDWATER INFLOW FROM SANTA CRUZ AMA		**8,700**
RECHARGE		
Natural	Mountain	38,900
	Streambed	37,700
	subtotal	76,600
Incidental	Municipal	56,900
	Industrial	5,300
	Agricultural	26,500
	subtotal	88,700
Direct	CAP	7,800
	Effluent	3,200
	subtotal	11,000
Total recharge		**176,300**
Total of all gains to aquifer		**185,000**
LOSSES FROM AQUIFER		
GROUNDWATER OUTFLOW TO PINAL AMA		**-24,500**
GROUNDWATER PUMPING		
Municipal		-145,300
Industrial		-57,700
Agricultural		-104,700
Total groundwater pumping		**-307,700**
EVAPOTRANSPIRATION (from shallow groundwater)		**-3,700**
Total of all losses from aquifer		**-335,900**
AQUIFER BALANCE		
Total of gains and losses (overdraft)		**-150,900**

DIRECT USE OF RENEWABLE SUPPLIES**	
EFFLUENT (Direct Use)	
Municipal	8,700
Industrial	800
Agricultural	2,900
Total direct effluent use	**12,400**
CAP (Direct Use)	
Municipal	200
Agricultural	25,100
Total direct CAP water use	**25,300**
Total of direct use of CAP water & effluent	**37,700**

** These uses may indirectly benefit the aquifer by serving as a substitute for groundwater that would have been pumped. Incidental recharge from these uses is already included in the "Gains to the Aquifer" section.

NOTES ON WATER BUDGET CALCULATIONS

* This budget uses data from ADWR, but differs from ADWR's "paper water" budgets by considering only the physical use and movement of water. Direct recharge is counted as a gain to the aquifer in the year recharge occurs, not when recharge credits are used. Irrigation with CAP is counted as direct CAP use, not groundwater or *in lieu* "recharge."

Supply & Demand Scenarios*

Based upon Approximate Current Levels of Demand by Sector, in Acre-Feet

	Demand (% of current)				Groundwater Pumping					
	Muni.	Indus.	Ag.	Supply	Muni.	Indus.	Ag.	Total	CAP	Balance†
Current levels	100	100	100	Groundwater for all sectors	150,000	50,000	125,000	325,000	0	-180,000
	100	100	100	Groundwater for municipal, CAP for others	150,000	0	0	150,000	175,000	-5,000
	100	100	100	CAP for municipal, groundwater for others	0	50,000	125,000	175,000	150,000	-30,000
2X Municipal	200	100	100	Groundwater for all sectors	300,000	50,000	125,000	475,000	0	-273,000
	200	100	100	Groundwater for municipal, CAP for others	300,000	0	0	300,000	175,000	-98,000
	200	100	100	CAP for municipal, groundwater for others	0	50,000	125,000	175,000	300,000	+27,000
2 Mun. ½ Ag. & Ind.	200	50	50	Groundwater for all sectors	300,000	25,000	62,500	387,500	0	-201,000
	200	50	50	Groundwater for municipal, CAP for others	300,000	0	0	300,000	87,500	-113,000
	200	50	50	CAP for municipal, groundwater for others	0	25,000	62,500	87,500	300,000	+99,000
	200	50	50	Half groundwater, half CAP for all sectors	150,000	12,500	31,300	193,800	193,800	-7,000
2 Mun., Ag. & Ind.	200	200	200	Groundwater for all sectors	300,000	100,000	250,000	650,000	0	-417,000
	200	200	200	Groundwater for municipal, CAP for others	300,000	0	0	300,000	350,000	-67,000
	200	200	200	CAP for municipal, groundwater for others	0	100,000	250,000	350,000	300,000	-117,000
	200	200	200	Half groundwater, half CAP for all sectors	150,000	50,000	125,000	325,000	325,000	-92,000

* This table represents a range of supply and demand scenarios for general illustration; it should not be used to make specific future projections. Simplified assumptions (e.g. all groundwater or all CAP for a sector) have been made to clarify the relationships between supply, demand and the aquifer balance.

† This number represents the approximate "wet water" loss or gain to the regional aquifer. The value is calculated as: (net natural recharge [76,600]) - (groundwater outflow [24,500]) - (evapotranspiration [3,700]) - (groundwater pumping) + (incidental recharge) + (groundwater inflow [8,700]). Incidental recharge is itself calculated as 38% of municipal demand (multi-year average), 20% of agricultural demand, and 12% of industrial demand. This balance does not consider factors such as long-term storage through recharge, or changes in incidental recharge rates.

Sierra Club
From Saguaro We Going, 1988

The purpose of this water budget was to determine what per capita water use would have to be under different assumptions if groundwater mining were to cease. Note that the supply and demand figures in these calculations were taken from the TAMA Second Management Plan. It is interesting to see how the basic assumptions changed in the ten years between the second and third management plans.

APPENDIX B 2 WATER SUPPLY SCENARIOS

Water demands (acre-feet)	I	I I	I I I	IV	V
Municipal	125,000	310,000	328,000	347,000	365,000
Industrial	56,000	42,000	65,000	90,000	113,000
Irrigation	123,000	39,000	90,000	173,000	300,000
Other	5,000	5,000	5,000	5,000	5,000
Total	309,000	396,000	488,000	615,000	783,000
Water supplies (acre-feet)					
Incidental recharge	60,000	42,000	70,000	105,000	154,000
Net natural recharge	62,000	62,000	62,000	62,000	62,000
CAP	0	213,000	140,000	70,000	0.
Other surface water	0	0	0	0	0
Effluent use	7,000	100,000	71,000	41,000	13,000
Augmentation	0	20,000	14,000	5,000	0
Total	129,000	437,000	357,OOO	284,000	229,000
Overdraft	**180,000**	**(41,000)**	**131,000**	**331,000**	**554,000**
Population	634,836	1,600,000	1,600,000	1,600,000	1,600,000
Gal/Person/Day	104	95	105	115	125
Industrial Demand Factors					
Mining	33,551	20,000	33,000	47,000	60,000
Turf	6,333	6,000	-10,000	14,000	18,000
Power	2,598	2,500	5,000	7,500	10,000
S&G	4,575	4,500	6,300	8,200	10,000
Other	8,858	9,000	11,000	13,000	19,000
Irrigation Demand Factors					
Non-Indian irrigation	53,000	20,000	31,000	42,000	53, 000
Indian Irrigation	1,000	1,000	4,000	8,100	12,000

Scenario I is the base supply/demand situation in 1986. Scenario II is the most optimistic supply scenario Scenarios III through V represent increasingly pessimistic supply scenarios. These calculations were supplied by the Department of Water Resources (Tucson Active Management Area) in March 1987. Water use in in acre-feet.

SUPPLY AND DEMAND CALCULATIONS UNDER DIFFERENT SCENARIOS

	A	B	C	D
Supply	437,000	372,000	272,000	129,000
CAP	213,000	170,000	70,000	0
Effluent Use	100,000	50,000	30,000	7,000
Incidental Recharge	42,000	90,000	110,000	60,000
Augmentation	20,000	0	0	0
Natural Recharge	62,000	62,000	62,000	62,000
Demand	437,000	372,000	272,000	309,000
Agriculture	39,000	39,000	39,000	123,000
Industry	90,000	90,000	90,000	56,000
Turf	50,000	50,000	50,000	12,500
Other Municipal	203,000	138,000	38,000	112,000
Other	5,000	5,000	5,000	5,000

A through C represent increasingly pessimistic supply scenarios. D represents the 1986 supply/demand situation. .

PER CAPITA RESIDENTIAL WATER USE UNDER DIFFERENT SCENARIOS

	Population	Per capita use
A Optimistic Supply	1,000,000	181 gallons per person per day
	1,600,000	113 gallons per person per day
	2,000,000	90 gallons per person per day
B. Moderate supply	1,000,000	123 gallons per person per day
	1,600,000	77 gallons per person per day
	2,000,000	61 'gallons per person per day
C. Pessimistic supply	1,000,000	78 gallons per person per day
	1,600,000	21 gallons per person per day
	2,000,000	17 gallons per person per day
D. 1986 conditions	650,000	158 gallons per person per day

These calculations were made by the Sierra Club, using ADWR data from the Second Management Plan and assume "Safe Yield" conditions.

Appendix D. Water Element of the City of Tucson's Draft General Plan Update

The following are excerpts from the water element of the City's General Plan. For the full text, see the City's web site: www..ci.tucson.az.us/planning/grosmart/grosmart.htm.

Water Element

"One of the most important water goals of the community is attainment of safe yield, when no more water is withdrawn from the aquifer than is replenished. New water supplies and a community-wide emphasis on conservation are needed to achieve this goal...."

Policies

1. Support efforts to improve regional cooperation and communication among appropriate agencies and communities..

2. Expand processes to communicate current and planned water programs to the public, and expand opportunities for interested citizens to participate meaningfully in long-term planning decisions.

3. Continue to promote water conservation.

4. Continue to develop and implement programs for the reuse of water.

5. Continue to develop and implement programs for new sources of water.

6. Maintain a 100-year Assured Water Supply Designation from the Arizona Department of Water Resources.

7. Promote and expand conservation programs, reuse, and acquisition of new water supplies through water rates.

8. Continue to review and adopt guidelines, incorporating community input, for managing the Tucson Water utility.

9. Word cooperatively with State of Arizona agencies to refine existing water legislation and achieve the adoption of plans, policies, and regulations.

10. Continue to work with the Federal and State agencies and water interest associations to develop policies programs, and facilities for water management.

11. Document ongoing water programs and analyses and make this information easily accessible to agency personnel and the public.

12. Continue to research the relationship between water supplies and service, land use, and growth of the region.

13. Continue to pursue appropriate land uses for City-owned retired farmland in the Avra Valley.

14. Pursue water plans and policies that protect and benefit natural ecological systems.

15. Protect and enhance the quality of Tucson's water sources.

Appendix E. Excerpts: City of Tucson - Pima County Supplemental Intergovernmental Agreement Relating to Effluent

This is an Intergovernmental Agreement dated this day of February, 2000, by and between the City of Tucson, Arizona, a municipal corporation, hereinafter sometimes referred to as the "City", Pima County, a body politic and corporate, a political subdivision of the State of Arizona, hereinafter sometimes referred to as the "County", and the Pima County Flood Control District, ("District") a special taxing district organized pursuant to Article 1, Chapter 2 1, Title 48 of the Arizona Revised Statutes. ...

NOW, THEREFORE, in consideration of the mutual promises and covenants contained Herein, the parties covenant and agree as follows: ...

SECTION II. STATEMENT OF PURPOSE.

The purpose of this Supplemental IGA is to supplement the terms and provisions of the 979 IGA; in the event of a conflict between the terms and provisions of this Supplemental IGA and the terms and provisions of the 1979 IGA, the terms and provisions of this Supplemental IGA will govern. Capitalized terms are defined in Section III below. It is the intent of the parties that the interpretation and implementation of this Supplemental IGA be guided by the following principles. The parties agree that the provisions of the 1979 IGA and of this Supplemental IGA are consistent with these principles:

2.1 Effluent is an important long term renewable source of water in the Tucson Active Management Area; every reasonable effort should be made to:

2.1.1Use Effluent to replace current groundwater uses within the service area of the Water Provider which provides the water from which the effluent is derived;

2.1.2Encourage the use of Effluent in place of groundwater for future uses within such service area where feasible; and

2.1.3 Preserve Effluent for use by Water Providers in meeting long term potable water demands.

2.2 The uses of Effluent are limited unless the Effluent is treated to Reclaimed Water standards. The costs of treating Effluent to Reclaimed Water standards and the costs of distributing Reclaimed Water should, as a general rule, be paid by the users of the Reclaimed Water. The parties will cooperate in efforts to lower those costs where feasible.

2. 3 Reasonable quantities of Effluent should be reserved for use in Riparian Projects. Beneficiaries or operators of these Projects should pay the costs of distributing the Effluent and the costs of treating the Effluent to Reclaimed Water standards and distributing the Reclaimed Water. To the extent that the use of the Reclaimed Water in a Riparian Project is interruptible, recoverable costs should be limited to the operating expenses of producing and distributing the Reclaimed Water.

2.4 Reasonable efforts should be made, consistent With the principles and purposes of this Supplemental IGA, to give other Water Providers reasonable access to Effluent derived from the water they supply, so long as they pay all costs associated with the use of said Effluent. ...

SECTION IV. PROVISIONS RELATING TO NON-METROPOLITAN EFFLUENT.

4. 1. City Control Waiver. The City waives its right of unilateral control over the use and disposition of effluent discharged from County treatment plants in Nonmetropolitan areas, provided, however, if any Effluent is put to a use other than Public Use, the following conditions will apply to such Effluent:

4.1.1 None of the Costs of distributing such Effluent from the point of production to the point(s) of use are charged to sewer ratepayers within the City of Tucson or to County taxpayers within the City of Tucson; and

4.1.2 None of the Costs of treating such Effluent to meet reuse plans, in excess of federal and state standards for discharge into the waters of the United States, are charged to sewer rate payers within the City of Tucson or to County taxpayers within the City of Tucson; and

4. 1.3 County agrees that it will charge each user of such Effluent from a treatment plant located in a Nonmetropolitan Area a fee per acre foot which contains a production component which is not less than the City's actual average per acre foot operating Costs of the production/treatment of Reclaimed Water during the previous fiscal year; the City's operating Costs per acre foot of Reclaimed Water produced during the previous fiscal year shall be determined in accordance with the methodology described in Exhibit A hereto and the example of the application of that methodology in Exhibit A-1. The results of the application of the methodology for FY 1999 ar.- stated in Exhibit B hereto. This provision will not apply to any existing contractual obligations of the County. This provision may be waived by mutual written agreement between the City and County.

4.1.4 If the disposal of Effluent from a treatment plant located in a NonMetropolitan Area will reduce treatment costs, including capital, maintenance and operating expense, the projected savings per acre foot can be applied by the County to reduce the per acre foot fee required by the provisions of subparagraph 4.1.3 of this Agreement. In the event of such reduction, the County shall provide to the City substantiation of the projected savings from such disposal.

4.2. City Net Profit Waiver. The City waives its right to 50% of the net profit from the disposition of Effluent

discharged from County treatment plants in Nonmetropolitan Areas provided that the conditions stated in Subsections 4.1.1, 4.1.2 and 4.1.3 are met with regard to such Effluent.

SECTION V: PROVISIONS RELATING TO EFFLUENT FOR RIPARIAN PROJECTS

5.1 Conservation Effluent Pool.

City and County agree that a pool of Effluent (the "Conservation Effluent Pool") shall be made available to Riparian Projects each year on the following terms and conditions:

5.1.1 The quantity of Effluent contributed per annum to the Conservation Effluent Pool shall be 5,000 acre feet during the five year period commencing on the effective date of this Supplemental IGA. After the five year period, a sufficient quantity of Effluent shall be contributed annually to the Conservation Effluent Pool to meet the demand for such Effluent by operators of Riparian Projects up to a maximum of 10,000 acre feet of total Effluent per annum. In the event that the total annual demand for Effluent by operators of Riparian Projects exceeds 10,000 acre feet, the City and County will meet and determine whether the quantity of Effluent contributed per annum to the Conservation Effluent Pool should be increased. In the event that he parties cannot agree on whether and how much to increase the Conservation Effluent Pool, e quantity of Effluent contributed to the Conservation Effluent Pool will not be increased.

5.1.2 Effluent in the Conservation Effluent Pool shall be contributed from Metropolitan effluent on the following basis:

5.1.2.1 Effluent Will be contributed to the Conservation Effluent Pool after the United States has taken the SAWRSA effluent

5.1.2.2 From the Effluent remaining after the contribution to the Conservation Effluent Pool, the County will be entitled to take its 10%;

5.1.2.3 Any Effluent assigned to a Water Provider will bear its pro-rata share of the contribution to the Conservation Effluent Pool.

5. 1.3 Effluent in the Conservation Effluent Pool shall be available to any entity (an operator') that operates a Riparian Project. In the event that the quantity of Effluent in the conservation Effluent Pool is insufficient to meet the demand, the Effluent shall be apportioned among the Riparian Projects. Effluent in the Effluent Conservation Pool not used in the year that he Effluent is contributed to the Pool shall not be carried over to the next year.

5.1.4 The terms and conditions by which Effluent will be made available to operators of he Riparian Projects shall be established in a Conservation Effluent Pool Agreement to be negotiated by the City and County not inconsistent With the terms and conditions of this supplemental IGA.

5.2 Charges for Effluent for Riparian Projects

5.2.1 With regard to Riparian Projects not requiring Reclaimed Water, Effluent shall be made available from the Conservation Effluent Pool at no charge to the operator by the City. The operator requiring Effluent shall take delivery of the Effluent at the secondary treatment facility and shall be solely responsible at the operator's sole cost and expense for transporting the Effluent to the Riparian Project.

5.2.2 With regard to Riparian Projects requiring Reclaimed Water, the City shall produce and deliver Reclaimed Water from the Conservation Effluent Pool to Riparian Projects on the following terms and conditions:

5.2.2.1 The City shall produce and deliver the Reclaimed Water on an interruptible basis to Riparian Projects and shall charge an Environmental Rate to be paid by operators or beneficiaries of the Riparian Projects. The Environmental Rate shall be based on recovery of the average operational expenses per acre foot of the production and delivery of Reclaimed Water in the Reclaimed Water System. Exhibit A describes the methodology to be used in determining these operational expenses; Exhibit A-I illustrates the application of this methodology; and Exhibit B contains the rates that result from the application of this methodology.

5.2.2.2 Notwithstanding the City's obligation to deliver Reclaimed Water on an interruptible basis at an Environmental Rate, the City shall not be obligated to deliver Reclaimed Water if specific capital improvements are needed for the production or delivery of Reclaimed Water to a particular Riparian Project and the operator falls to finance the costs of the capital improvements.

5.2.3 Non-interruptible service of Reclaimed Water for Riparian Projects will be provided at the same price and on the same terms as retail service to users of Reclaimed Water.

SECTION VI. COUNTY AND FLOOD CONTROL DISTRICT COOPERATION IN EFFLUENT MANAGED RECHARGE PROJECTS IN SANTA CRUZ RIVER BED.

6. 1. County agrees to execute the Consent in the form attached hereto as Exhibit C, to allow the City and the United States to use the County's land in the Santa Cruz River bed, between Roger Road and Ina Road, for the sole purposes of percolating and transporting effluent in County lands in the Santa Cruz stream bed for an effluent managed recharge facility.

6.2. Flood Control District agrees to execute the Consent in the form attached hereto as Exhibit D, to allow the City and the United States to use the Flood Control District's land in the Santa Cruz River bed, between Roger Road and Ina Road, for the sole purposes of percolating and transporting effluent in District lands in the Santa Cruz stream bed for an effluent managed recharge facility, subject to the Districts right to construct and maintain bank- protection and grade control structures.

6.3. County and Flood Control District hereby withdraw their protests of ADWR Permits Nos. 71-

545944.001, 733-545943.0 100 and 73-545943.0200 and stipulate to the dismissal of their appeals in Matter No. 99A-USWS001-DWR before the Office of Administrative Hearings. County and District agree to execute additional documents consistent' with their withdrawal and stipulation for dismissal.

6.4. The City intends, with the United States, to file a joint application for an effluent managed recharge facility in the Santa Cruz River bed from Ina Road north to the northerly boundary of the Tucson Active Management Area. The City agrees to formally consult with the County and District in developing the joint application and agrees to provide the County and District with copies of all documents, submitted to ADWR as part of the joint application.

6.4.1 County agrees that it will support the application and will execute and deliver to the City a Consent, in the form attached as Exhibit E, to allow the City to use the County's land in the Santa Cruz River bed north of Ina Road, for the sole purposes of percolating and transporting effluent in County lands in the Santa Cruz stream bed for an effluent managed recharge facility. County may, at its option, elect to join in the application set forth in Subsection 6.4.

6.4.2 Flood Control District agrees that it will support the application and will execute and deliver to the City a Consent, in the form attached as Exhibit F, to allow the City to use the Flood Control District's land in the Santa Cruz River bed north of Ina Road, for the sole purposes of percolating and transporting effluent in District lands in the Santa Cruz stream bed for an effluent managed recharge facility, subject to the District's right to construct and maintain bank protection and grade control structures.

6.5. City agrees that County may store Effluent in the managed recharge facilities of the City pursuant to an effluent storage permit issued by ADWR to the County. City agrees that, as part of the City program to recover its stored Effluent, it will recover, on an interruptible basis, Effluent stored by the County. The City will be responsible for operating such managed recharge facility and may charge a fee for the use of each such facility which allocates the operating costs among- the users of the facility pro-rata to the quantity of Effluent stored in the facility. For County stored Effluent recovered by the City, the County agrees to pay the City's average operating costs per acre foot of producing Reclaimed Water. Exhibit A describes the methodology to be used in determining these average operational expenses; exhibit A-1 illustrates the application of this methodology; and exhibit B contains the rates that result from the application of this methodology. In the event that the County is paying a storage fee pursuant to Subsection 6.7 based upon pre-storage treatment costs. pre- storage treatment costs will be excluded from the average operational expenses charged to the County for recovery of stored Effluent.

6.6. The City shall not undertake any managed or constructed recharge project, or recovery plan associated with same, which proximately results in groundwater pollution, associated with any landfill, which violates state or federal water quality standards. In the event that the City's activities in this regard cause actual pollution to the groundwater from an existing landfill, in violation of state or federal water quality standards, the City shall responsible for any remediation required as a proximate result of the City's activities. City agrees to regularly consult with County with regard to managed and constructed recharge facilities and recovery plans associated with same in order to protect the groundwater from pollution from any landfill and promote remediation programs. City agrees to consult with County to determine whether recovery wells can be placed in locations that assist the County in its remediation of pollution from County landfills.

6.7. The County has federal National Pollution Discharge Elimination Permits for the discharge of effluent to the Santa Cruz River for the Ina Road Regional Wastewater Treatment Facility (No. AZ0020001) and the Roger Road Regional Wastewater Treatment Facility (No. AZ0020923). The County is obtaining a State Aquifer Protection Permit for discharging effluent to the Santa Cruz River for both the Ina and Roger Road Regional Wastewater Treatment Facilities. The County will continue to be responsible for meeting the requirements of these permits or future permits if effluent is discharged from either facility into the Santa Cruz River, a water of the United States. If additional treatment is legally required because of the existence of a City managed recharge facility, the City will be responsible for the additional treatment costs and may establish a storage fee for use of the facility to recover these pre-storage treatment costs pro-rata, among the storage permittees, to the amount of Effluent stored.

SECTION VII CONSTRUCTED EFFLUENT RECHARGE PROJECTS

7.1. City, County and Flood Control District agree to cooperate in planning and establishing Effluent constructed recharge projects for City and/or County operation in the Metropolitan Area. The constructed recharge facilities will be available for storage of SAWRSA Effluent and Effluent of the City, the County and Water Providers. The County has federal National Pollution Discharge Elimination Permits for the discharge of effluent to the Santa Cruz River for the Ina Road Regional Wastewater Treatment Facility (No. AZ0020001) and the Roger Road Regional Wastewater Treatment Facility (No. AZ0020923). The County is obtaining a State Aquifer Protection Permit for discharging effluent to the Santa Cruz River for both the Ina and Roger Road Regional Wastewater Treatment Facilities. The County will continue to be responsible for meeting the requirements of these permits or future permits if effluent is discharged from either facility into the Santa Cruz River, a water of the United States.

7.2. The City will be responsible for constructing any

constructed recharge facility that the City operates and may charge a storage fee for the use of each such facility which allocates the amortized construction costs among the users of the facility pro-rata to the quantity of Effluent stored in the facility. In the event that the Federal and/or State standards for discharge into a constructed recharge project are higher than the standards for discharge into the stream bed, the City, if it decides to establish a constructed recharge facility, will be responsible for additional treatment costs and will include these as a pre-storage treatment cost element in the storage fee for the use of each such facility.

7.2.1 The City may choose to require each user of the facility to finance the construction costs pro-rata to the quantity of Effluent stored by that user in the facility, in lieu of the average operating costs per acre foot of production/treatment of Reclaimed Water. Exhibit A describes the methodology to be used in determining these average operational expenses; exhibit A-1 illustrates the application of this methodology; and' exhibit B contains the rates that result from the application of this methodology. In the event that the County is paying a storage fee which includes a pre-storage treatment cost element pursuant to Subsection 7.2. this cost element will be excluded from the average operational expenses charged to the County for recovery of stored Effluent.

SECTION VIII. COUNTY COOPERATION IN CITY ESTABLISHMENT OF RECLAIMED WATER PRODUCTION FACILITY AT INA ROAD TREATMENT PLANT AND COUNTY EXPANSION OF ROGER ROAD TREATMENT PLANT.

8.1. County agrees to provide to the City approximately 10 acres of land on which the City can establish a Reclaimed Water production facility for Effluent from the Ina Road Treatment Plant. City and County will jointly select an appropriate, cost efficient parcel of land reasonably proximate to the Ina Road Treatment Plant. In the event that the City and County are unable to reach agreement on the parcel to be provided to the City within 3)65 days after the effective date of this Supplemental IGA, either the City or the County may submit the unresolved issues to alternative dispute resolution pursuant to Section XIV of this Supplemental IGA.

8.2. City agrees to provide to the County land for expansion or modification of the Roger Road Treatment Plant. City and County will jointly select an appropriate, cost efficient parcel of land reasonably proximate to the Roger Road Treatment Plant. In the event that the City and County are unable to reach agreement on the parcel to be provided to the County within 365 days after the effective date of this Supplemental IGA, either the City or the County may submit the unresolved issues to alternative dispute resolution pursuant to Section MV of this Supplemental IGA.

SECTION IX. DIVISION OF EFFLUENT PRODUCED FROM THE NEW TREATMENT FACILITY AT INA ROAD.

9. 1. County is constructing a new treatment facility at Ina Road, the product of which will be Effluent treated to a standard beyond secondary. Prior to completion of the new facility, City and County Will attempt to reach agreement on protocols for access by the City and County to Effluent from the new facility. In the event that City and County are unable to reach agreement on such protocols, the following Will govern access to Effluent from the new Ina Road facility:

9.1.1 County shall be entitled to take, from Available Effluent, up to its full daily entitlement of Effluent from the two Ina Road treatment plants. Effluent taken by the County from the Ina Road treatment plants shall be divided between the old treatment plant and the new treatment plant in the proportion which the average daily output of Available Effluent from each plant bore during the previous calendar year to the average daily output of Available Effluent from the two plants. The County may choose to take a portion of its 10% share from the Roger Road plant, provided that Effluent taken from the Roger Road plant shall be excess to the needs of the City.

9.1.2 The Conservation Effluent Pool will be divided among the Roger Road plant Effluent, the old Ina Road plant Effluent, and the new Ina Road plant Effluent in the proportion which the average daily Effluent output of each plant bore in the previous calendar year to the total average daily Effluent output of the three plants.

9.1.3 The City shall be entitled to take up to its full 9001/0 of the Effluent divided among the Roger Road plant Effluent, the old Ina Road plant Effluent, and the new Ina Road plant Effluent in the proportion which the average daily output of Available Effluent from each plant bore in the previous calendar year to the total average daily output of Available Effluent from the three plants, and subject to the availability of Effluent from the Ina Road plants after the County has taken its 10% share. The City may choose to take a larger than proportionate share from the Roger Road plant, in which case the remainder of the Effluent to which the City is entitled from each of the Ina Road plants shall be in the proportion which the average daily output of Available Effluent from each of the Ina Road plants bore in the previous calendar year to the total average daily output of Available Effluent from the Ina Road plants.

9.2. The United States may take its Effluent from the three treatment plants in accordance with a protocol to be agreed between the City and the United States. Thai protocol will provide that the United States share of Effluent from the new Ina Road,' facility shall; be no greater than the proportion to which the average daily output of Effluent from the new Ina Road facility bore in the previous calendar year to the total average daily output of Effluent from the Roger Road plant and the two Ina Road plants.

9.3. Each Water Provider to which the City assigns Effluent shall be entitled to take its Effluent on the basis of the protocol in the agreement between the assignee and the City. That protocol will provide that the Water Providers share of Effluent from the new Ina Road facility shall be no greater than the proportion which the average daily output of Available Effluent from the new Ina Road facility bore in the previous calendar year to the total average daily output of Available Effluent from the Roger Road plant and the two Ina Road plants. Each assignment agreement between the City and a Water Provider shall provide that the Water Provider takes the effluent subject to the obligations of the City to the County with regard to that Effluent.

...

Appendix F. References

Sonoran Desert Conservation Plan Reports

Water Resources and the Sonoran Desert Conservation Plan. July 1999.

Focus on Riparian Areas. July 1999.

Environmental Restoration in Pima County. December 1999.

GIS Coverages of Perennial and Intermittent Streams, and Areas of Shallow Groundwater. January 2000.

Riparian Protection, Management and Restoration September 2000.

Pima County Riparian Vegetation Mapping Pilot Study . May 2000.

Riparian Vegetation Mapping and Classification December 2000.

Springs in Pima County. May 2000.

Overview of Pima County's Watersheds and Watercourses. April 2000.

Arivaca Water Education Task Force. *Water in Arivaca. May 2000*

Historical Occurrence of Native Fish in Pima County. December 2000.

Aquatic Vertebrate Conservation in Pima County. July 2000

Water Usage along Selected Streams in Pima County. July 2000.

Groundwater Level Changes in the Tanque Verde Valley. January 2001.

Water Conservation in Pima County. March 2001.

Climate Variability In Pima County, Arizona And Its Significance To The Sonoran Desert Conservation Plan. June 2001.

Arivaca Water Education Task Force. *Arivaca Resource Management Zone.* June 2001.

Other Sources

Baird, Kathryn, R. MacNish, and D.P. Guertin. 2000. *An Evaluation of Hydrologic and Riparian Resources in Saguaro National Park, Tucson, Arizona.* Department of Hydrology and Water Resources, University of Arizona. Tucson.

Bouwer, Herman. Oct. 2000. *Groundwater problems caused by irrigation with sewage effluent.* Environmental Health.

Chong-Diaz, Damaris. 1995. *Modeling of stream aquifer interaction in lower Cienega Creek using a finite element technique.* MS Thesis. University of Arizona. Tucson.

Gelt J., J. Henderson. K. Seasholes, B. Tellman, and G. Woodard. 1999. *Water in the Tucson Area: Seeking Sustainability.* Water Resources Research Center. University of Arizona. Tucson

Leshy, John D. and J. Belanger 1988. *Arizona Law Where Ground and Surface Water Meet.* Arizona State Law Journal 20:657-747.

Meko, D., C. Stockton, and W. Boggess. 1995. *The Tree-Ring Record of Severe Sustained Drought.* Water Resources Bulletin. Vol. 21 #5.

Postel, Sandra. 1999. *Pillar of Sand. Can the Irrigation Miracle Last?* Norton & Co. New York.

San Xavier District and Sonoran Institute. 2000. *Guide to Riparian Restoration on the San Xavier District.* Tucson.

Sprigg, William A. et al. 2000. *Preparing for Climate Change: The Potential Consequences of Climate Variability and Change.* Southwest Regional Assessment Group. University of Arizona.

Tellman, B.J., R. Yarde, and M. Wallace. 1996. *Arizona's Changing Rivers: How People Have Affected the Rivers.* Water Resources Research Center. University of Arizona. Tucson

Web sites

Arizona Department of Water Resources
www.water.az.gov

Arizona Water Banking Authority
www.awbr.state.az.us

Central Arizona Project
www.cap-az.com

Metropolitan Domestic Water Improvement District
www.metrowater.com

Sonoran Desert Conservation Plan
www.co.pima.az.us/cmo/sdcp/

Tucson Regional Water Council
www.azstarnet.com/~trwc/

Tucson Water
www.ci.tucson.az.us/water/

Water CASA
www.watercasa.org

Water Resources Research Center
www.ag.arizona.edu/azwater/