

# Arizona's Water Future: *Challenges and Opportunities*



## **85th Arizona Town Hall**

*October 31 – November 3, 2004  
Grand Canyon, Arizona*

### **Sponsors**

**GILA RIVER INDIAN COMMUNITY  
SALT RIVER PROJECT**

### **BACKGROUND REPORT PREPARED BY**

The University of Arizona  
Tucson, Arizona

**EIGHTY-FIFTH ARIZONA TOWN HALL**  
OCTOBER 31 – NOVEMBER 3, 2004

# **Arizona's Water Future:** *Challenges and Opportunities*

*Background Report Prepared By*

**The University of Arizona**  
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AND  
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Cover illustrations, clockwise from upper right: Roosevelt Dam and Lake; Arizona Strip; Arizona Falls on Salt River Project, 56th Street and Indian School Road, Phoenix; and Lake Powell in 2000.



# ARIZONA TOWN HALL

Building consensus — Charting progress

Leaders in all areas of our communities face ever-greater complexity in their business and personal lives. These complexities drive them to focus more intensely and to narrow their viewpoints and beliefs on the challenges and opportunities they confront. Yet, the qualities and capabilities that have propelled these individuals to leadership in their own fields of endeavor are the very qualities essential to understanding and resolving the broader issues and concerns of all Arizonans.

Since 1962, the Arizona Town Hall has been bringing together leaders from across our state to carefully consider and discuss the critical challenges and opportunities facing our state. These leaders come with their varied expertise from a carefully selected cross-section of our state's citizens. The participants at each Town Hall are geographically and occupationally balanced and represent the wide diversity of political, social and economic philosophies found in Arizona.

There have been eighty-four Town Halls to date. The eighty-fifth will be held at Grand Canyon, October 31 – November 3, 2004 and will address “Arizona’s Water Future: Challenges and Opportunities.” This Town Hall will examine Arizona’s future water supply as it relates to our state’s continuing rapid population growth, ongoing drought conditions, potential settlement of Indian water claims, need for water for environmental and recreational uses, and Arizona’s institutional and financial capacity to address future water needs.

To provide all participants in the Town Hall with fundamental background information from which to launch their detailed discussions, the University of Arizona developed the following background report. The research team consists of faculty and professionals from the University and ThinkAz—Arizona Center for Public Policy. Our sincere thanks are extended to University of Arizona President Peter Likins and the entire research team who worked so diligently to bring together this document.

The timeline for the writing of this report was extremely short. Therefore, there was not sufficient opportunity for a detailed review by the Town Hall’s Research Committee of the material presented. Additional editing may take place between now and the time of the final publishing that also will include the recommendations developed at this Town Hall.

*The specifics to be addressed at this Town Hall depend upon identification by you, the participants, of the most significant subject areas you consider necessary to cover.* You should have received a questionnaire included with a memo of details dated October 1. We ask that you use that questionnaire to send us your questions and ideas on what needs to be discussed regarding Arizona’s water future. The concerns that you identify need not be limited to those discussed in this document. *Your replies are key to the success of the Town Hall.* Please take time right now to complete and return the enclosed questionnaire. **Don’t wait until you’ve read this entire report to reply.** At this point, we want your personal ideas on the most important issues to be discussed.

The recommendations that you develop at the Town Hall will be combined with the following background information into a final document and circulated widely throughout the state. That report will make a lasting contribution toward identifying what steps Arizona needs to take to ensure our state’s water future.

Sincerely,

Alan E. Maguire  
Chairman of the Board

September 2004



## ACKNOWLEDGEMENTS

A seven-person research team from The University of Arizona and the Arizona Center for Public Policy prepared this report.

The research team included persons from several disciplines: economics, anthropology, geography, environmental planning, public policy, law and chemistry. Different academic, research and public service units at The University of Arizona were represented on the writing team: Bonnie Colby of the Department of Agricultural and Resource Economics; David de Kok of the Office of Economic Development; Kathy Jacobs of the Department of Soils, Water and Environmental Science, the Water Resources Research Center and SAHRA; Sharon Megdal of the Water Resources Research Center and the Department of Agricultural and Resource Economics and; Gary Woodard of the Center for Sustainability of semi-Arid Hydrology and Riparian Areas in the Department of Hydrology and Water Resources; and Marshall Worden from the Office of the Associate Vice President for Economic Development. In addition, the research team included Rita Maguire of the Arizona Center for Public Policy.

The concept and initial outline for the report were developed in consultation with the Eighty-fifth Arizona Town Hall Research Committee. That original outline was clarified in a series of meetings involving the Research Committee, Kathy Jacobs, Sharon Megdal and Marshall Worden.

An initial but incomplete draft of the report was reviewed and critiqued by the Arizona Town Hall Research Committee during August and early September 2004. The Committee, chaired by Darryl B. Dobras, comprises Shirley Agnos, ex officio, Timothy J. Barnett, Michael J. Brophy, Catherine Connolly, Herb Dishlip, Paul F. Eckstein, Chuck Essigs, Grady Gammage, Jr., Susan N. Goldsmith, Patrick Graham, Herb Guenther, James Holway, Janet Jennings, ex officio, Anna Jolivet, Rodney Lewis, Rita Maguire, Elizabeth McNamee, David Modeer, Paul R. Orme, James L. Parsons, M.D., Warren L. Prostrollo, Jr., Vice Chairman, Fred H. Rosenfeld, Robert B. Strain, John F. Sullivan and D.S. (Sid) Wilson. The Research Committee's thoughtful suggestions for improvement and correction were important and greatly appreciated.

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Several persons at the University of Arizona deserve thanks for their strong efforts in bringing the final report to completion. In the Office of Economic Development, Kathleen Gardner prepared the tables and text for the final manuscript, Linda Francis assisted in coordinating the technical, reproduction and administrative details of the project and Lourdes Gonzalez and her staff handled the mailing and distribution of the report. Kyle Carpenter in the Center for Sustainability of semi-Arid Hydrology and Riparian Areas assisted in preparing the maps found throughout the report. Ken Seasholes of the Arizona Department of Water Resources assisted in the design of the maps and reviewed significant portions of the report. The U.S. Bureau of Reclamation, the Salt River Project and the

Central Arizona Project provided various data, graphics and photographs.

Finally, the kindness and patient direction from Shirley Agnos, President of the Arizona Town Hall, needs to be recognized. She was a strong source of encouragement throughout the preparation of the report and, once again, has made the Arizona Town Hall a valued experience.

Marshall A. Worden  
Office of Economic Development  
The University of Arizona

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*Kathy Jacobs, Sharon Megdal and Marshall A. Worden*

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# Initialisms, Acronyms and Abbreviations

ACC	Arizona Corporation Commission
ADEM	Arizona Division of Emergency Management
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
AF	Acre-Feet
AMA	Active Management Area
ARS	Arizona Revised Statutes
AWBA	Arizona Water Banking Authority
AWS	Assured Water Supply
CAGR	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CLIMAS	Climate Assessment for the Southwest
DES	Department of Economic Security
ED	Endocrine Disruptor
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Act
ET	Evapotranspiration
GMA	Groundwater Management Act
GPCD	Gallons per Capita per Day
GRD	Groundwater Replenishment District
GRIC	Gila River Indian Community
GSF	Groundwater Savings Facility
GUAC	Groundwater Users Advisory Council
HSR	Hydrographic Survey Report
IBWC	International Boundary and Water Commission
ICUA	Intentionally Created Unused Apportionment
IGFR	Irrigation Grandfathered Right
INA	Irrigation Non-Expansion Area
M&I	Municipal and Industrial
MSCP	Multi-Species Conservation Plan
NIWWTP	Nogales International Wastewater Treatment Plant
PDO	Pacific Decadal Oscillation
PIA	Practicably Irrigable Acreage
RNCA	Riparian National Conservation Area
SAHRA	Semi-Arid Hydrology and Riparian Areas
SAWRSA	Southern Arizona Water Rights Settlement Act
SRP	Salt River Project

TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
USF	Underground Storage Facilities
UWS	Underground Water Storage, Savings and Replenishment Act
WMAP	Water Management Assistance Program
WMIDD	Wellton-Mohawk Irrigation and Drainage District

## Chapter 1

# WATER IN ARIZONA: CHALLENGES MET AND REMAINING

KATHY JACOBS AND MARSHALL A. WORDEN

*The situation with respect to groundwater shortage and depletion is critical and growing worse in most sections of Arizona; . . . As a general rule the present supply is inadequate to meet existing demand, resulting in severe overdrafts against the underground reservoirs. (Fourth Arizona Town Hall, 1964)*

*The goals set for the next 50 to 100 years should address the needs of sustainable development and preservation of water supplies for future generations of Arizonans. They should include achieving safe-yield in certain areas and looking beyond domestic, industrial and agricultural uses to the effect water use and allocation have on riparian areas, the environment and our overall quality of life. (Seventy-first Arizona Town Hall, 1997)*

*Arizona water managers, thus far protected from water shortage by legal rights that have guaranteed full delivery of the state's share of the Colorado River despite dire drought conditions, are correct to raise the specter of water shortages in the future. (Robert Glennon and Jennifer Pitt, 2004)*

The Eighty-fifth Arizona Town Hall marks the fifth time in 40 years that it has convened to wrestle in public conversation with the enormous and complex issue of providing, maintaining and ensuring water of sufficient quantity and quality to meet the requirements of the citizens, economy and environment of Arizona. Some topics, such as groundwater depletion and limited water sources in various parts of the state, have remained constant throughout the decades. The completion of the Central Arizona Project (CAP), the creation of the Arizona Department of Water Resources and the promulgation of the Groundwater Management Act are milestones in Arizona's water management history. Now discussions of the terms "safe-yield" and "sustainability" are coming to the forefront as Arizona evaluates the implications of continued growth in the major metropolitan as well as the rural areas of the state. Through the years, Arizonans have become more sensitive and sophisticated in their understanding of environmental re-

relationships involving the human use of water. The public debate now regularly includes concerns about climatic conditions and drought, riparian habitat, endangered species and the hydrologic connection between surface water and groundwater. The policy dialogue has become much more complex during the last four decades. Something of that change is revealed in the partial list of recommendations and conclusions from past Arizona Town Halls recorded in Appendix A. This background report explores the complexity of water management issues facing Arizona at the beginning of the 21st century.

This chapter provides context and institutional background for Chapter 2's discussion of major themes in Arizona's water future. Chapter 3 introduces water-related background material on Arizona's hydrology, population and border with Mexico; while Chapter 4 discusses the implications for water management of climate variability and change. Chapter 5 describes the sources of water available, the institutional aspects of water rights and associated issues. Chapter 6 addresses water management concerns in the five Active Management Areas (AMAs). Chapter 7 introduces the water management issues beyond the boundaries of the AMAs, issues that are significantly different than those faced in the major metropolitan areas. Chapter 8 details the bases and specifics of existing and proposed Indian water settlements, while Chapter 9 outlines environmental issues in the context of changing land use and land cover. Chapter 10 identifies multiple demand management and supply enhancement approaches for addressing water supply issues. The final chapter focuses on key policy and strategic questions for consideration by Town Hall participants.

## **HISTORICAL AND INSTITUTIONAL PERSPECTIVE**

Arizona's history, politics and development patterns are strongly tied to water availability and water management decisions. Arizona's first settlements were all located near surface water streams, and the fate of both ancient and modern residents has been affected by water availability. A thousand years ago, the Hohokam Indians developed an extensive irrigation system in the Gila and Salt River valleys to provide water to their fields. They cultivated thousands of acres and

supported a large population. Most current population centers also are located where water is relatively plentiful, though the ability to store and transport it over long distances has dramatically changed development patterns.

Federal water management policies, such as the Reclamation Act of 1902, have had a significant impact on all aspects of Arizona's water supply and continue to affect water allocations and costs today. The Reclamation Act focused on constructing a water storage and delivery system to encourage irri-

gation of the western United States and "make the desert bloom." This Act resulted in the development of the Salt River Project (SRP), the CAP and the dams and diversions on the Colorado River (Figure 1.1). Surface water supplies from these sources serve approximately 58 percent of the water demand within the state.

Figure 1.1  
**Major Streams and Rivers**



### **Water Supplies and Sources**

Four sources of water are available within Arizona: Colorado River water, other surface water, groundwater and effluent. Each source is managed according to separate rules and definitions that are discussed in Chapter 5. There is considerable complexity to the water rights systems. Colorado River water is available primarily to CAP contractors and users along the Colorado River that have legal rights to a portion of Arizona's allocation. Other significant surface



water sources include the Salt, Verde and Agua Fria Rivers that serve the Phoenix metropolitan areas. Groundwater is abundant in many of the alluvial valleys of the state and serves over 40 percent of the water demand.

An acre-foot is 325,851 gallons, or enough water to cover an acre one foot deep. With an average household use of 150 gallons per person per day and an average household size of 2.5 people, an acre-foot can serve almost 2.5 households for a year.

### **The Colorado River**

The Colorado River is among the most heavily regulated rivers in the world, affected by over 50 court decisions, state statutes, interstate compacts and international treaties that are collectively known as the “Law of the River.” A key component is the Colorado River Compact of 1922, which divided the Colorado River Basin into an Upper and Lower Basin and apportioned 7.5 million acre-feet annually to each basin. The Upper Basin was required to restrict its use so that the flow of the river at Lee’s Ferry would not fall below an aggregate of 75 million acre-feet for any period of ten consecutive years. Although Arizona did not ratify the Compact until 1944, this allocation became the centerpiece of the Law of the River. In addition, the Mexican Treaty of 1944 annually allocated 1.5 million acre-feet of Colorado River water to Mexico, to be increased in times of surplus to 1.7 million acre-feet, but also to be reduced proportionately during years of “extraordinary” drought.

The Colorado River supplies much of the water needs of seven states in the United States, two Mexican states and thirty-four Native American tribes. Ninety percent of the annual streamflow is generated in the Upper Basin. The Bureau of Reclamation estimates the population of the areas served with Colorado River water at 30 million (Bureau of Reclamation, August 2004), with 38 million projected by the year 2020. The associated dams generate an average of 12 billion kilowatt hours of electricity per year.

Meeting water rights obligations in the context of changing societal values and increasing demands is bringing increasing pressure on the Law of the River. Water quality and environmental concerns, particularly the federal Endangered Species Act, also have altered the traditional

roles of federal, state and local agencies. The continuing regional drought, including the extreme conditions of 2002, draws attention to the importance of understanding climate variability and change in the context of long-term water supply and the need for proactive mitigation of drought impacts.

### Groundwater and the Groundwater Management Act

Groundwater is the sole source of water supply for much of rural Arizona and is relatively plentiful in large alluvial basins. The Colorado Plateau to the north and the southeastern part of the state are dependent solely on groundwater. This source is of critical importance throughout the state, providing over 40 percent of the state's total water supply. Although Arizona adopted a number of groundwater management regulations starting in 1945, no meaningful regulation of groundwater use was in place until the 1980 Groundwater Management Act (GMA). The GMA established the Arizona Department of Water Resources and focused groundwater management efforts within four original AMAs: Phoenix, Pinal, Tucson and Prescott. A fifth AMA, the Santa Cruz AMA, was formed by splitting it off from the Tucson AMA in 1994 (Figure 1.2). For each of the AMAs, the GMA established water management goals focused on limiting the overdraft of groundwater. It also established a new water rights system, precluded the development of new irrigated agricultural land and established a well-measuring and reporting system and a mandatory conservation program. A summary of the history of groundwater management in Arizona is

Figure 1.2  
Active Management Areas and  
Irrigation Non-Expansion Areas



found in Appendix B.

### Surface Water

The Gila River and its tributaries is the largest watershed within the state, draining the majority of central Arizona. Important tributaries in southern Arizona are the Santa Cruz and San Pedro Rivers, and in central Arizona, the Salt, Verde and Agua Fria Rivers. However, the majority of



Figure 1.3 Roosevelt Dam with capacity of 3.43 million acre feet.

flows in the central part of the state have been diverted for agricultural and municipal use. Major reservoir storage systems, such as Roosevelt Dam (Figure 1.3), are located on the Salt, Verde, Gila and Agua Fria Rivers. In-state surface water systems (Figures 1.1 and 4.2) supply about 19 percent or 1.4 million acre-feet of Arizona's water. Although the Little Colorado River that flows from the White Mountains to the Grand Canyon is an important watershed, it does not provide significant surface water supplies for human use.

Surface water is governed by the prior appropriation doctrine, which provides the highest priority right to the first person that beneficially uses water in the watershed. The SRP is the largest provider of in-state surface water, serving water from the Salt-Verde watersheds to agricultural and municipal users in the Phoenix metropolitan area.

### Effluent

Effluent, or treated municipal wastewater, is an expanding water resource for all of Arizona and will be of particular importance in rural communities in the future. Water users in the AMAs and in water-short communities throughout the state have made substantial investments in

reclaiming wastewater and expect to more fully utilize the available effluent. Municipal effluent commonly is considered to be a renewable water supply, but it is only truly renewable when its original source is renewable, *i.e.*, CAP or surface water. Essentially, effluent use is the recycling of water. Like CAP water, treated effluent can be used directly or stored underground for future use.

### **ACHIEVEMENTS AND COSTS TO DATE**

Arizona has made significant strides in water management over the last 25 years. Although the water issues facing the state are daunting, they need to be understood in light of what already has been accomplished. Clearly, the most dramatic change was caused by implementation of the GMA itself. It established a long-term water-planning horizon for the state that focused on a long-term water supply. For example, the Assured Water Supply (AWS) program is probably the most far-sighted regulatory program connecting water supply and municipal demand in the country. It requires that a demonstrated 100-year water supply of adequate quality will be available prior to approval of new subdivisions. No other state requires a 100-year renewable water supply prior to development. Appendix C summarizes the Assured Water Supply Program. The GMA charted a course for the municipal sector in AMAs to move away from groundwater and towards renewable water supplies through the AWS Program. The AWS Rules, adopted in 1995, require the use of renewable supplies and are based on the expectation that municipal and industrial demand will continue to grow while the demands of other sectors will diminish over time.

### **The Central Arizona Project**

The CAP is the backbone of the State's renewable water supply system. The CAP is designed to bring 1.5 million acre-feet of Arizona's 2.8 million acre-foot Colorado River allocation into central and southern Arizona. The CAP aqueduct has the capacity to annually deliver a total of 1.8 million acre-feet, and its total cost exceeded \$4 billion. The CAP aqueduct is 336

miles long and includes 15 pumping stations that lift the water from Lake Havasu to its terminus south of Tucson. The CAP service area is limited to Maricopa, Pinal and Pima Counties. It is operated by the Central Arizona Water Conservation District, which has taxing authority and a board elected by the citizens within its three-county service area. Authorized in 1968, the CAP is critical to achieving a sustainable water supply for the central portions of the state (Figure 1.1). The CAP system, along with its storage, flood control and delivery components, is a major investment in water supply sustainability for the state. By providing a renewable supply to replace dependence on mined groundwater, the investment in the CAP already has proven essential to limiting groundwater overdraft and providing water supplies during drought.

Although the three-county CAP service area contains 82 percent of the population of the state, substantial development pressure is facing communities in other counties. In addition to providing water to its subcontractors, the CAP system has been delivering excess Colorado River water to several entities that store water underground for various purposes and has delivered substantial quantities of water to offset shortages in the SRP system. SRP purchased and exchanged nearly 500,000 acre-feet from the CAP between 1996 and 2003.

### **Institutional Innovations**

The conversion from dependence on mined groundwater to use of renewable supplies from the Colorado River has required the development of new institutions as well as major financial investments. For example, soon after the adoption of the GMA it became clear that recharge would be a major component of storing and utilizing renewable water supplies. In 1986, significant legislation was adopted that established the Underground Water Storage and Recovery Program summarized in Appendix D. Since 1986 there have been numerous refinements and additional components. This program has been very successful and, as of 2002, had resulted in the development of 66 storage facilities, primarily in the AMAs, and storage of over three million acre-feet of water in the state.

Another institutional innovation that has been very successful is the Arizona Water Bank-

ing Authority (AWBA), which was established in 1996 to store excess Colorado River water for use during future shortage years and to support other water management objectives as well as interstate water banking. Annual water use is strongly affected by agricultural demand and the availability of other surface water supplies within the state. The AWBA, in combination with incentive pricing programs to encourage the short-term use of CAP water for agriculture and underground storage, has enabled the full use of Arizona's allocation.

### **Indian Water Right Settlements**

Significant progress also has been made in finalizing Indian water rights claims. One of the biggest variables in Arizona's water supply picture has been how much water will be allocated to the Native American tribes in the state and how that water ultimately will be used on and off the reservations. As discussed in Chapter 8, settlements have now been completed with eight tribes and four more settlements are pending. Tribal water rights claims are based on the federal reserved rights doctrine—the “Winters Doctrine” of 1908. The Winters Doctrine indicates that the priority date of the water rights for reservations is the date the reservation was established, and the volume of the right is based on the purpose of the reservation. The large amount of potentially irrigable acreage on the Gila River Indian Community reservation, along with their significant historical dependence on the Gila River, has led to a large water right claim. The total volume of water associated with tribal settlements in the Arizona Water Rights Settlement Act, currently pending before Congress, is roughly half the total CAP allocation. Because tribal lands are not subject to the GMA, tribes will have the opportunity to expand irrigated acreage on reservations. However, other provisions are intended to mirror the limitations of the GMA.

The total amount of CAP water that will be available to Indian communities under the pending Arizona Water Rights Settlement Act is 665,000 acre-feet, just short of one-half the total CAP water available. The tribes may choose to lease some of this water for off-reservation uses within Arizona. There are restrictions within the settlements themselves on how the water can be used off reservation, but leasing is expected to be an outcome of several tribal settlements and



already is the source of water for non-reservation communities such as Anthem in Maricopa County. Indian settlements also have important water management implications outside of reservations because of the multiple agreements with water users who are part of the settlements. In several cases, these agreements constrain the way water can be used in the vicinity of the reservation, and they also have more comprehensive impacts on water availability by limiting new agricultural production and new wells in the affected watershed. For example, the Gila River Indian Community Settlement, now pending before Congress, includes agreements that affect water users in Safford, Duncan, Pima, Fort Thomas, Winkelman and Kearny as well as three mining companies. Indian water settlements are discussed in more detail in Chapter 8.

### SUSTAINABILITY

Discussion of future water needs for Arizona should be in the context of policy objectives that are clearly articulated. Throughout this background report the various authors use the words *sustainable*, *sustainable development* and *sustainability*—terms that have risen in importance in scholarly analysis and policy debates regarding water management and water science. All three of Arizona’s state universities have research centers focused on sustainability issues.

The management goal for three of the five AMAs (Phoenix, Prescott and Tucson) is “safe-yield . . . a water management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an AMA and the annual amount of natural and artificial recharge in an AMA” (A.R.S. 45-562 A). However, there is a distinction between *safe-yield*, which focuses on the amount of water that can be pumped from an aquifer for water supply purposes without causing overdraft, and *sustainable yield* or *sustainable development*, which many hydrologists view as more comprehensive concepts that would maintain surface flows that recharge the groundwater and provide water for environmental uses as well (Appendix E). Since *sustainability* is a concept that is approached differently by various individuals based on personal values and is much-debated, this background report uses the most commonly accepted working definition, that of the Brundtland Commission: “*The abil-*

*ity of current generations to meet their needs without compromising the ability of future generations to meet their needs” (World Commission on Environment and Development, 1987).*

Scale affects the application of the definition of sustainability. For example, Colorado River water that is diverted into Arizona is viewed as a “renewable” supply from the perspective of the state of Arizona, unlike groundwater that is in most cases renewed over such a long period of time that it is viewed as non-renewable. However, diverting water from the Colorado River affects the sustainability of downstream users and environments outside of the state and, therefore, has consequences that may be overlooked when viewing the water use only from the perspective of Arizona’s water users. For example, the Colorado River Delta environment has changed substantially over time as larger quantities of water have been dammed and diverted upstream, and this in turn has affected water flows to Mexico and the marine environment in the Gulf of California.

Temporal issues also are of concern, since the impacts of water management decisions may not become obvious until many years later. For example, there was little evidence of subsidence of the land surface in the Tucson basin until about a decade ago. Since then, subsidence avoidance has become a major policy objective for Tucson Water. Because we are dependent on the use of groundwater models to understand water movement and availability in the subsurface, because impacts of groundwater pumping are commonly not recognized for decades and because the hydrologic system itself changes over time, a long-term view is needed in water supply planning.





## Chapter 2

# MAJOR THEMES IN ARIZONA'S WATER FUTURE

KATHY JACOBS AND MARSHALL A. WORDEN

Seven major themes or overarching concerns regarding Arizona's water future are discussed in succeeding chapters. Information and discussion about each of these topics is found in several places throughout the text; the themes are previewed in this chapter. They include:

- Drought, climate variability and change
- Rural water supply
- Growth, water supply and meeting management goals within the Active Management Areas
- Surface water adjudications
- Riparian protection and endangered species
- Water quality as a water management issue
- Economics as a water management issue

### **Drought, Climate Variability and Change**

Arizona currently is affected by a severe drought that is nearing a decade in length, with the El Nino year of 1998 being an exception. Although some portions of the state have received near-normal rainfall during the past year, experts believe that Arizona may be in the beginning stages of a longer-term drought than has been experienced in the last 40 years. Part of the significance of this drought is its regional nature. It is affecting the entire Colorado River watershed, and consequently both Arizona's in-state and Central Arizona Project (CAP) supplies are affected. Reservoir conditions on the Colorado River and throughout the state have been at or near record low levels in the last two years. In addition to increased wildfires—the Rodeo-Chediski fire in 2002 was the largest in the state's history—the drought has resulted in significant economic impacts on rural areas (particularly in the ranching, recreation and forest products sectors) that generally do not have supplemental water supplies. Water supply conditions have been critical in the summer months in Flagstaff, Prescott, Williams, Mayer, Payson, Pine-Strawberry and other

communities on the Mogollon Rim as well as elsewhere in the state.

Although the extensive investments in water supply infrastructure for the Phoenix and Tucson areas have provided substantial protection from the current drought, there are concerns about the future in the case of continued droughts simultaneously affecting the Salt River-Verde River system and the Colorado River system. Governor Napolitano has established a Task Force to develop a state drought plan that would limit the state's vulnerability to drought in the future. The Arizona Drought Preparedness Plan is expected to be adopted in early fall of 2004. Drought also has raised the stakes in: (1) negotiations with other Colorado River basin states, (2) shortage sharing agreements, (3) long-term supply reliability discussions and (4) relations between the United States and Mexico.

In addition to concerns about the effects of climate variability on water use and supply, there is substantial scientific evidence that longer-term changes in climate conditions are occurring. Scientists have observed that increases in average global temperatures already are affecting water supply availability in the Colorado basin (Christensen *et al.*, 2004). There also are concerns about the implications of higher temperatures because they reduce soil moisture, increase evaporation and transpiration by plants, and change snowpack and runoff volumes and timing. Climate and drought considerations are further discussed in Chapters 3 and 4.

### **Rural Water Supply**

Even in the absence of drought, water supply conditions in some communities of rural Arizona are a serious problem. Growth rates are very high, with projected continued growth in many communities that may not have water supplies or financial resources to sustain that growth. There are inadequate mechanisms to ensure availability of water supplies to support growth in the rural areas of the state. In addition, increasing demands for groundwater are very likely to affect important springs and surface water flows that support riparian areas and recreation.

The portions of the state outside the Active Management Areas (AMAs) encompass 87 percent of the land area and almost a million people. According to Arizona Department of Eco-

conomic Security data, the population in these areas is expected to nearly double in the next 50 years, but these projections probably are low, as discussed in Chapter 3. High population growth rates, in combination with water supplies that often are susceptible to drought, increase the likelihood that there will be water supply shortages in rural communities.

Areas of the state beyond the boundaries of the AMAs have significant challenges in meeting their water supply needs because (1) many of these areas do not have adequate water supply and demand data and (2) they, unlike the major metropolitan areas, generally are dependent on a single water source. Lack of information is a major frustration for jurisdictions, watershed groups and land managers because they cannot make informed decisions without good water supply data. From a data availability and water supply perspective, there are essentially two Arizonas: the major metropolitan areas and irrigation districts served by the Colorado River and the rest of the state, which has limited water supply alternatives and even more limited planning information. These issues are discussed further in Chapters 3 and 7 and Appendix G.

### **Growth, Water Supply and Meeting Management Goals Within the Active Management Areas**

Concerns about whether the AMAs are on track to meet their management goals were among the reasons that Governor Hull established the Governor's Water Management Commission in 2000. An extensive evaluation of the ability of the AMAs to meet their management goals resulted from that Commission's activities. Regarding conditions of the individual AMAs, the Commission (2000) concluded:

*In the Phoenix and Tucson AMAs, water budgets based on current supply availability projections indicate that achieving safe-yield may not be as difficult as maintaining that condition . . . the expected population growth beyond 2025, particularly in the major metropolitan areas, may ultimately exceed the availability of renewable supplies and result in increasing costs for providing renewable water supplies and again put pressure on groundwater availability. This situation may occur earlier in the Prescott AMA, where renewable supplies are not as abundant or as readily available . . .*

*The Santa Cruz AMA goal of preventing long-term declines in local water table levels provides the means to deal with "sub-area" issues and physical water*

*supply conditions, which does not exist in the others AMAs . . . Management of the water levels is an important objective due to the desire to protect the surface water flows and riparian habitat along the river while maximizing available supplies . . .*

*In the past the water management goal of the Pinal AMA was referred to as “planned depletion.” However, this characterization has recently been identified as encompassing only one aspect of the management goal. Preserving water supplies for non-irrigation users is also an important part of the Pinal AMA management goal. Because agriculture can use mined groundwater supplies in the Pinal AMA until they are no longer affordable, and sufficient groundwater appears to be available based on projected needs, the goal of preserving the agricultural economies for as long as feasible is achievable well beyond 2025. With regard to achieving the goal for non-irrigation uses and accommodating projected population increases, strategies must be identified and implemented to lower overall water use, specifically the non-residential component, and/or secure additional renewable supplies.*

The ability to achieve and maintain the long-term management goals within the AMAs is a key water management consideration for Arizona. Substantial progress has been made to date through use of renewable supplies, conservation programs and conversion of rights. Continued efforts will be required, but projections by the Arizona Department of Water Resources (ADWR) show shortfalls in those efforts (Tables 6.1 through 6.5). In many cases ADWR's ability to influence critical water management decisions is both indirect and insufficient. Cooperative efforts with regional entities and technically sophisticated long-term planning are likely to be critical to achieving the AMAs' water management goals.

Decisions related to acquiring sufficient water supplies to meet the rapidly growing water demands in the AMAs will need to be made in the context of ever-increasing competition for water. Competition exists at multiple levels, both within Arizona and between the Colorado River basin states and Mexico, particularly in the context of shortages. Recent discussions related to ensuring reliable long-term water supplies for Assured Water Supply purposes in the context of the Central Arizona Groundwater Replenishment District show that water interests are becoming more aware of the risks of future shortages and are always vigilant about protecting their own water rights. These topics are reviewed in Chapters 3 and 6.

## **Surface Water Adjudications**

A key variable in Arizona's water supply picture is that most of the surface water rights in the state have not been legally quantified and prioritized. Only the water rights that have been established by court decree in separate legal actions have set volumes and priority dates. Because the surface water rights system is based on prior appropriation ("first in time, first in right"), a determination of the amount and priority of each right is required in order to manage the system. Although formal court adjudications of the surface water rights are ongoing for the Gila River and Little Colorado River, there is no indication that these proceedings will be completed in the near future. Tribal claims generally have senior priority to state-based claims and could have a significant impact on Arizona's water supply picture. Chapters 5 and 8 and Appendix P discuss this theme.

## **Riparian Protection and Endangered Species**

Most of the state's free-flowing streams that existed prior to the last century have been affected by dams and diversions as well as by groundwater pumping that depletes the base flow. The remaining free-flowing streams and shallow groundwater tables of the state support riparian habitats that are the locations of Arizona's greatest biodiversity. The riparian corridors are of particular importance to migratory birds. These areas also are major contributors to Arizona's economy because they are destinations for recreation and tourism as well as contributors to the quality of life in Arizona. Finding a balance between the needs of protected species through the Endangered Species Act and the water supply needs of growing communities will be an ongoing debate. A multi-species conservation plan for endangered species along the Colorado River, mitigation requirements related to willow flycatcher habitat at Roosevelt Lake and issues associated with managing the San Pedro River are examples of ways in which habitat conservation efforts will affect water supply availability in the future. These issues are discussed further in Chapters 5 and 9.

## **Water Quality as a Water Management Issue**

Water supply limitations often are created by water quality problems. If a water source is contaminated and a community cannot afford to treat the water prior to use, the water supply is essentially unavailable. Ability to pay for treating water supplies depends on local economic conditions as well as available financing mechanisms. Water quality protection programs in Arizona are based on both federal and state law and primarily are administered by either the Arizona Department of Environmental Quality or the United States Environmental Protection Agency Region IX through the Safe Drinking Water Act.

Groundwater or surface water that contains contaminants at levels that exceed the primary water quality standards must be treated prior to use. Depending on the type and concentration of contaminants, different treatment and/or blending techniques can be used to meet the standards prior to delivery to customers. Although virtually any contaminant can be removed from water, the key water supply issue is the cost of treatment. If the treatment costs exceed the willingness of the public to pay, the water supply is at least temporarily unusable.

The key water quality issues from a regulatory perspective in the state are summarized in Appendix F. Of particular concern are nitrates in groundwater, primarily associated with former agricultural and industrial sources or wastewater discharges, and arsenic, a naturally occurring metal that appears at elevated levels in some parts of the state. The standard for arsenic is changing from 50 to 10 micrograms per liter, with the new standard becoming effective in January 2006 at an estimated cost to Arizona water providers of \$100 million. The impact of this change in standards is particularly significant for 300 small water systems, *i.e.*, those systems serving less than 10,000 people, which tend to be in rural areas. An area of increasing concern is the salinity of water supplies in the AMAs since water imported from the Colorado River is higher in salinity than the groundwater in many parts of the CAP service area. Concerns also are increasing about industrial contamination of groundwater supplies in urban areas and the presence of pharmaceuticals and other substances in discharged effluent.

## **Economics as a Water Management Issue**

Water is commonly viewed as a natural resource that is integral to supporting life, but it also is a commodity and an economic input to multiple products. The cost of water has substantial implications for influencing water management decisions and economic productivity. For example, in the absence of regulation, federal subsidies and financial incentives, many Arizonans who are customers of the CAP probably would be using groundwater today because groundwater often is cheaper than the full cost of CAP water and is in many cases of higher quality. Changes in the cost of water, caused by changes in supply and demand or changes in energy costs, have ripple effects throughout Arizona's economy.

Economists agree that market-based systems can increase the efficiency of water use because such systems result in moving the water rights to the "highest and best use," *i.e.*, to the water use that can pay the highest price. There are equity, social and environmental considerations associated with this perspective and, consequently, there are virtually no cases of a totally unregulated water market in the United States. Without an established water rights system, however, it is difficult to implement even rudimentary market-related concepts such as leasing into water management. Until the tribal claims and the surface water rights of the state are clear, it will be difficult to develop more flexible market-based water management systems to address the changing water needs of Arizona. These issues are primarily discussed further in Chapter 5.

## **DIFFICULT CHOICES AND HARD DECISIONS**

This background report provides a context for discussing future decisions about water supply and water management in Arizona. Difficult choices and hard decisions that have economic, environmental and social consequences must be made. Tradeoffs between water quality and water quantity, growth and economic development and environmental protection, agricultural water use and municipal and industrial uses, cost of living and quality of life, private property rights and protection of public values, are all significant issues that deserve to be addressed in the public arena.



The complexity of water issues in Arizona, however, often makes it difficult for all citizens to participate in these public debates. Basic questions emerge regarding Arizona's institutional capacity to deal with the state's water problems, the potential need for additional regulation of water availability outside the AMAs, the types of new regulation and the responsible parties for their enforcement, the financial resources necessary to pay for the transportation and storage of new supplies for rural communities as well as drought and water supply planning needs.

Achieving a sustainable water future for all of Arizona is a worthy but daunting goal. The significant drought that Arizona has been experiencing has brought the issue of sustainability of our water supplies into sharper focus. Now is an excellent time to consider whether the efforts that have been made to date will be sufficient to carry Arizona into the future, or whether the dramatically expanding population, the lack of sufficient water resources in some rural areas, and the increasing competition for municipal supplies justify additional efforts to ensure that Arizona's economy and quality of life can be sustained into the future.

### Chapter 3

## ARIZONA'S HYDROLOGY, POPULATION AND BORDER WITH MEXICO

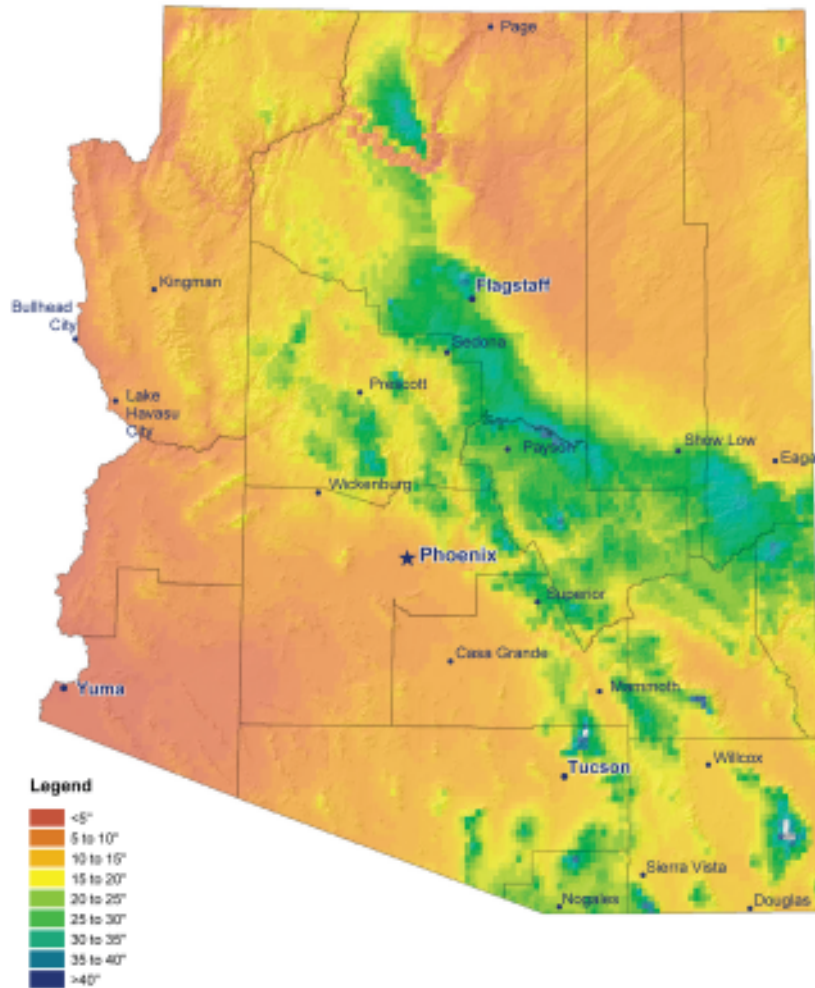
DAVID A. DE KOK

There is no denying Arizona's appeal. Hundreds of hopeful new residents enter Arizona everyday. They are drawn by both Arizona's great natural beauty, as popularized in the pages of *Arizona Highways*, and its vibrant economy. The cumulative effect of this unrelenting migration has made Arizona the exemplar of the Sun Belt phenomenon. From a half million people just prior to the start of World War II, the state's population soared ten-fold in just six decades. The post-war boom shows no sign of slowing down. Although this growth has helped fuel a booming economy, it also has taxed the state's water resources, revealing the possible limits to growth in some parts of the state.

The diversity of Arizona's terrain, climate, flora and fauna is the state's most striking feature. Despite the state's enormously varied physical components, there is one unifying element that serves to define Arizona—its climate; except at its highest elevations Arizona is arid.

There is a strong relationship between elevation and precipitation, particularly in the western and southern two-thirds of the state (Figure 3.1). Southwestern Arizona is a low-lying desert—a place where evaporation far exceeds rainfall and where water is severely limiting to life most of the time. The abruptly rising central highlands receive far more precipitation and experience lower evaporation. The northeastern third of the state gets much less precipitation than the central highlands due to its slightly lower elevation and its position in the rain shadow to the lee of the highlands which intercept eastward traveling winter storms. The eastern two-thirds of Arizona receives its maximum precipitation from summer monsoon storms, whereas the western third of the state gets most of its rain in the winter. Each 1,000-foot increase in elevation generally is accompanied by an increase of three inches in annual precipitation and a decrease of from three to

Figure 3.1  
Precipitation



five degrees Fahrenheit in temperature. In reality, the distribution of precipitation is highly irregular and is affected by both the altitude and arrangement of the state's landforms and their interaction with seasonal weather patterns.

Precipitation by itself does not always translate into an available water resource. Evaporation reduces it, rocks deflect and channel it and porous soils absorb it. This leads to **Arizona's great water paradox**—water is most readily available for human use in some of the state's most arid parts and, conversely, water is more difficult to access in some of the state's wettest regions. The recent drought has highlighted the precariousness of water resources in parts of the central

Figure 3.2  
**Physiographic Regions**

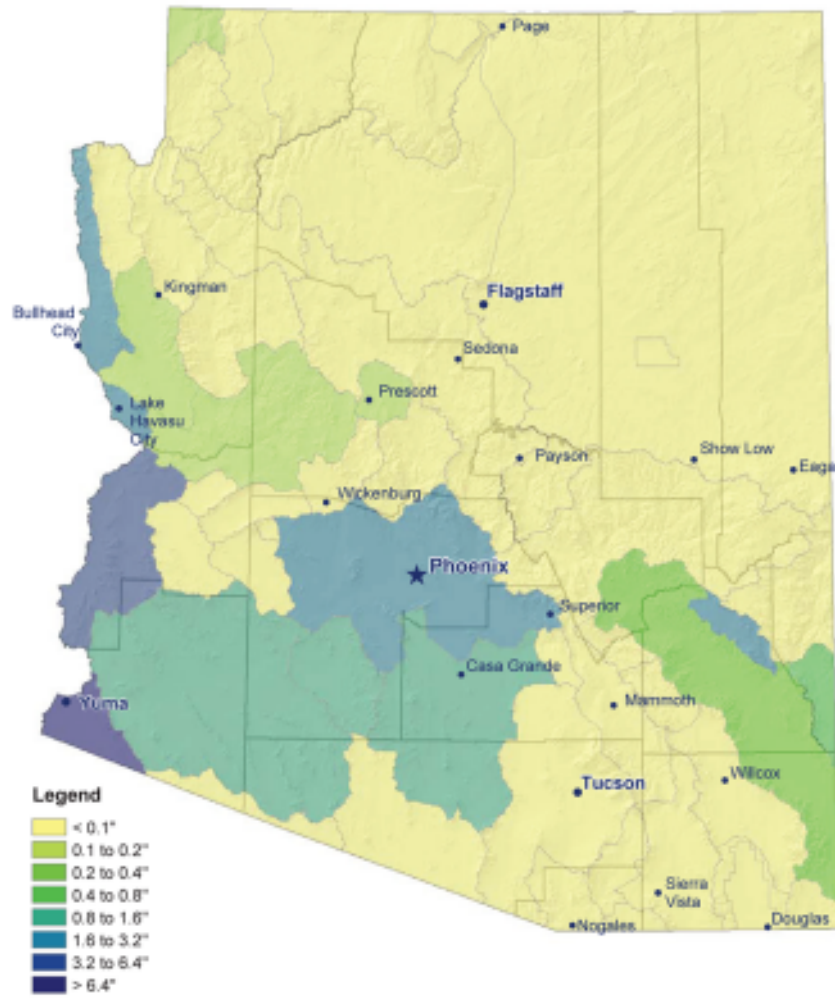


highlands and plateau uplands where water providers in such communities as Payson, Pine, Strawberry, Williams and Flagstaff have had to scramble to secure new water sources as shallow aquifers and reservoirs have run dry.

### **PHYSIOGRAPHY AND HYDROLOGY**

Arizona can be divided into three physiographic regions: (i) the basin and range lowlands, (ii) the central highlands and (iii) the plateau uplands (Figure 3.2). Appendix G contains a detailed description of the principal streams and major drainages, natural recharge patterns, ground-

Figure 3.3  
**Intensity of Surface Water Use**



water resources and regional aquifers found in these physiographical regions.

### **Basin and Range Lowlands**

The basin and range lowlands contain 45 percent of the state's land area and 89 percent of its population. The lowlands include all of Yuma, La Paz, Pima, Pinal, Santa Cruz and Cochise Counties as well as most of Maricopa County and portions of Mohave, Graham and Greenlee Counties. The basin and range lowlands consist of isolated, northwest trending, uplifted fault block mountain ranges jutting from alluvial sediments that form the broad desert basins. The

valley floors range in altitude from about 100 feet at Yuma to 4,600 feet near Sierra Vista. The interspersed mountain ranges vary from 1,000 to 6,000 feet above the valleys and reach elevations as great as 10,700 feet above sea level in the Pinaleno Mountains. Annual precipitation in the region generally averages less than ten inches, but ranges from four inches near Yuma to 30 inches along the peaks of the Santa Catalina and Chiricahua Mountains.

The basin and range lowlands generate very little runoff over most of their area. Streams in the region are characterized by extreme seasonal variation in flow levels. Ephemeral streams (those which flow only in response to precipitation events in their watersheds) in the low mountain ranges and alluvial valleys experience maximum flows in the summer in response to monsoon storms. Streams in the higher mountain ranges have maximum seasonal runoff in late winter and early spring as accumulated snowpacks melt off. Channel losses have a great effect on alluvial valley streams. Low groundwater tables and sandy, usually dry channels encourage the rapid infiltration of surface flows into the streambed. Channel losses in combination with the region's high evaporation rates result in streams that have relatively short stretches of surface flow. Only runoff from major storms is usually carried to the lower reaches of the main stream channels, many of which are controlled with dams. While the basin and range has the preponderance of surface water use in Arizona (Figure 3.3), the source of that water primarily is outside the physiographical region.<sup>1</sup>

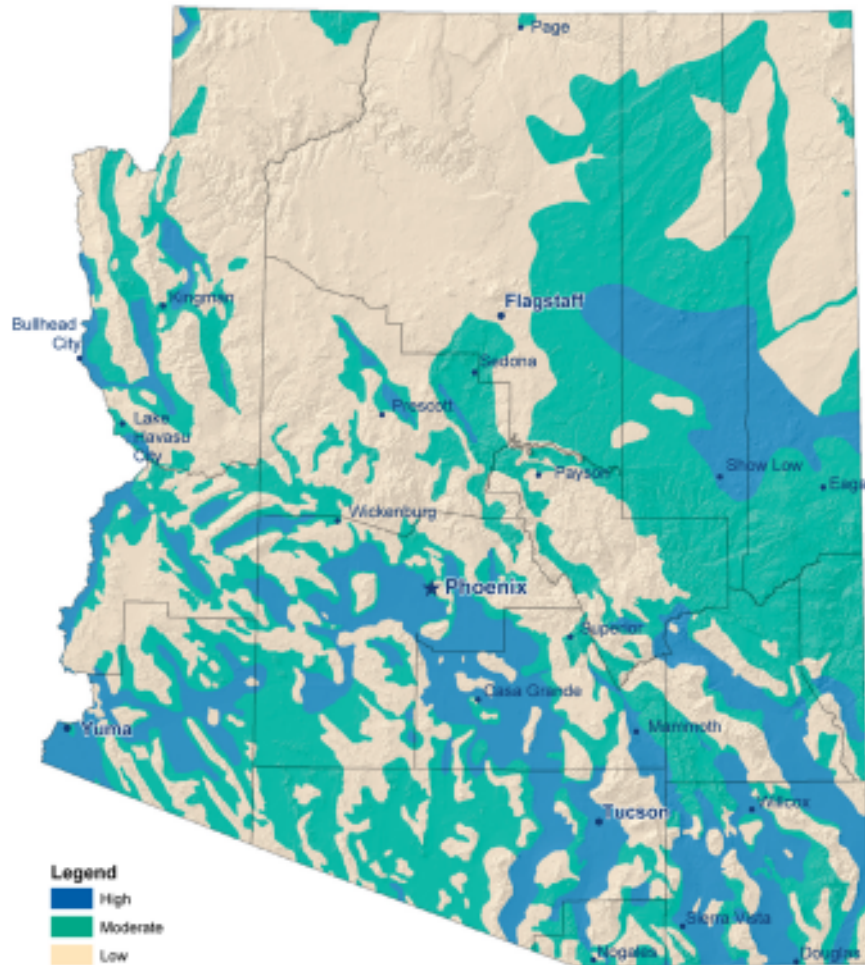
Even as the basin and range lacks indigenous surface water, it is both the locale of the state's most easily mined groundwater and the region with the most highly developed groundwater resources, with over 100,000 registered groundwater wells. Figure 3.4 shows in quite general terms areas of Arizona where groundwater wells are likely to be capable of high flow rates, based

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<sup>1</sup> Figures 3.3 and 3.5 represent intensity as the volume of water used (in acre-inches) in the basin, divided by the area of the basin (in acres). The resulting units are simply inches, which can be thought of as the depth of water that would result if all the water used in the basin were spread uniformly over the entire basin. While such units seem odd at first, they are, of course, used for precipitation. The figures clearly illustrate the spatial variability of usage as well as the fact that groundwater resources are more widely used and available.



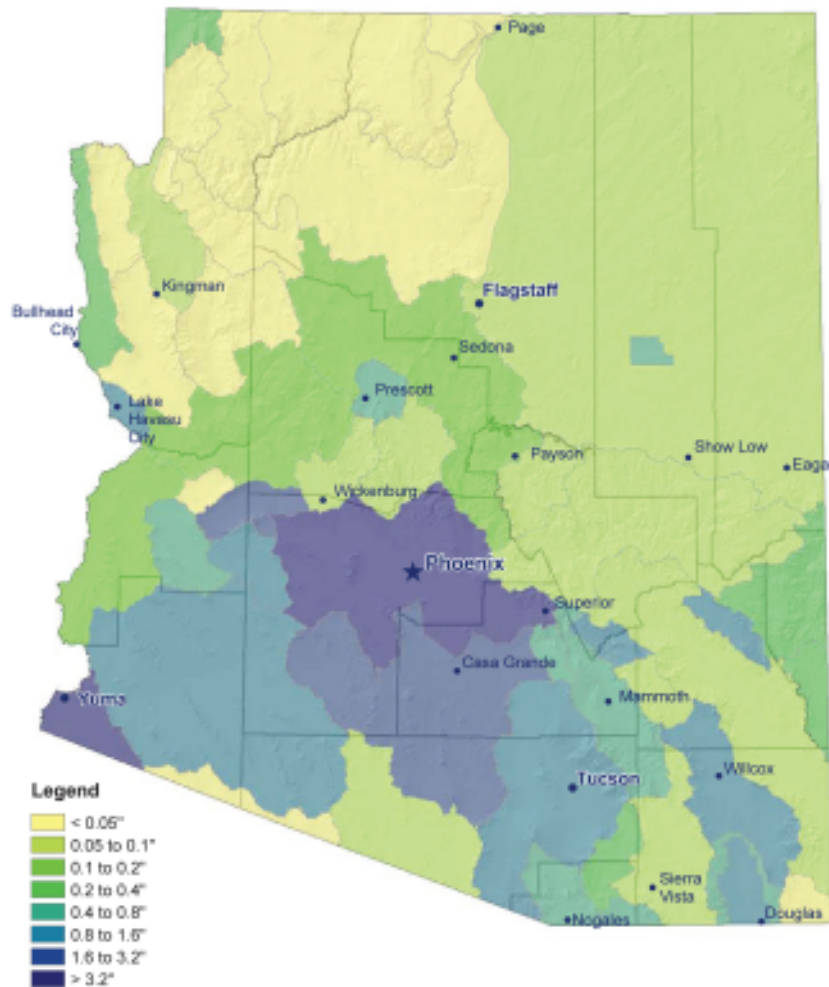
Figure 3.4  
**Aquifer Production**



on aquifer characteristics and well records. The figure illustrates the spatial variability of groundwater, providing a useful contrast between the alluvial aquifers of the basin and range and the less productive hardrock areas of the plateau. The intensity of groundwater use is correspondingly high (Figure 3.5).

Some of the most distinctive features in the basin and range are artificial, notably irrigated agriculture and urban areas. The dams and diversion structures that regulate and direct the Colorado River have transformed the hyper-arid river corridor into a fertile and highly productive agricultural area. There are several large irrigation districts in the Yuma area, along with the

Figure 3.5  
**Intensity of Groundwater Use**



Wellton-Mohawk Irrigation District stretching to the east. Further north, the Colorado River Indian Community has large-scale agricultural operations, as does the Fort Mohave Indian Reservation near Bullhead City.

Likewise, in the central part of the state, the “plumbing” of the Salt River Project (SRP), the growing use of the Central Arizona Project and productive alluvial aquifers have given rise to large-scale irrigated agriculture in Maricopa, Pinal and Pima Counties. Add to that the fields in the Sulphur Springs and San Simon Valleys of southeastern Arizona, and the basin and range region accounts for 89 percent of the approximately 1.3 million agricultural acres in Arizona.



## **Central Highlands**

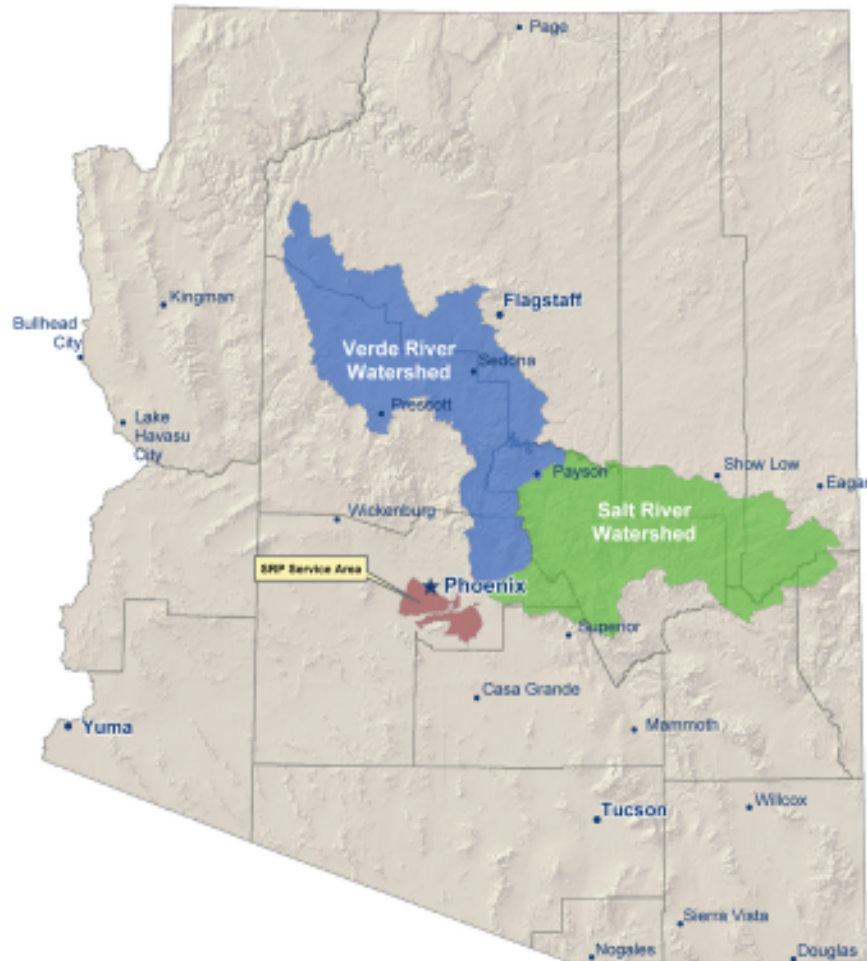
The central highlands contain 15 percent of the state's land area and five percent of its population. The highlands are composed of parts of Mohave, Maricopa, Graham, Greenlee, Navajo and Apache Counties, as well as most of Yavapai County and all of Gila County. The highlands were formed by differential movements along complex fault systems resulting in sharp, rugged mountains of extruded volcanic rock. The basins in the central highlands are generally small, shallow and isolated from one another. Sharp, steep elevational differences characterize this region, with altitudes ranging from 1,400 feet at Fort McDowell to 11,500 feet at Mount Baldy. The region's most salient feature is the 200 mile long Mogollon Rim which forms the boundary between the central highlands and the plateau uplands. This northwesterly trending escarpment ranges in height from 200 feet to over 2,000 feet. Annual precipitation in this region ranges from ten inches near Fort McDowell to 40 inches on top of Mount Baldy.

The central highlands are the source for about half of the stream flow originating in Arizona. All of the major reservoirs in the state, except for the San Carlos Reservoir on the Gila River and the various Colorado River lakes, receive the bulk of their water supply from streams originating in the central highlands. Most of the areal extent of the Salt and Verde River watersheds fall within the central highlands. Streams in this region generally experience their maximum seasonal flow in March and April due to snowmelt. Runoff from this region, though exhibiting considerable areal variation, is generally much greater than in all but the highest ranges of the basin and range lowlands. The SRP essentially guides the fate of much of the precipitation originating in the central highlands (Figure 3.6).

## **Plateau Uplands**

The plateau uplands are bounded to the south by the Mogollon Rim and to the west by the Grand Wash Cliffs. The plateau region contains 40 percent of the state's land area and five percent of its population. The region consists of most of Coconino, Navajo and Apache Counties as well as a small portion of Mohave County. The plateau region is an uplifted layer cake of

Figure 3.6  
**SRP Service Area and Watershed**



sedimentary rocks consisting mostly of sandstones interspersed with shales and limestones. The relatively flat uplands are topped with eroding mesas and punctuated with volcanic buttes as well as the towering San Francisco Mountains, the remnants of an ancient volcano. Without taking into account the deeply entrenched Grand Canyon, the region ranges in altitude from 4,200 feet near Cameron to 12,600 feet atop Humphreys Peak in the San Francisco Mountains. Annual precipitation ranges from just six inches near Cameron to 35 inches on Humphreys Peak.

Much of the plateau uplands region consists of barren plateaus and mesas that are ringed with the moisture-robbing Kaibab, San Francisco, Mogollon and White Mountains. With the

exception of the moisture intercepted by these surrounding highlands, little runoff originates in this region. The stream flows that do descend from these highlands reach their maximum in the spring as snowmelt occurs. Stream flow from the region's lower central plateaus is usually confined to the summer months and occurs only in response to intense thunderstorms. Outside the localized streambed deposits, groundwater production in the plateau uplands is often poor. The Little Colorado River Basin does contain three large regional aquifers, though availability and quality vary (Figure 3.4 and Appendix G).

### POPULATION GROWTH

Although Arizona is a high-growth state, many residents take this condition for granted and have become blasé about the remarkable transformations that have occurred over the last half-century. A review of the record of Arizona's growth reveals some eye-popping results (Table 3.1). The two most striking aspects shown in this half century of growth are the sheer magnitude of that growth and its great variability across the state. In both the 1950s and 1960s Arizona added about 50,000 residents per year. During the 1970s and 1980s the state added about 95,000 residents per year. The boom decade of the 1990s brought in nearly 150,000 people per year. And despite a mild national recession at the start of this decade, Arizona added nearly a half million people between April 1, 2000 and July 1, 2003.

The great range in the rate of population growth in Arizona's counties highlights the fact that the state's man-made environment is as variable as its physical environment. With the consolidation, mechanization and decline of its copper industry, Greenlee County lost a third of its populace between 1950 and 2000. Gila County's mining economy has suffered even greater decline, but the resulting population losses have been more than offset by the second home and retirement home boom in the Payson-area high country. On the opposite end of the scale, Mohave County's population shot up 17-fold over the last half-century as people flocked to the Colorado River Cities of Bullhead and Lake Havasu. The fact that Maricopa County's enormous population climbed by over 800 percent in the last five decades is testimony to the great appeal of its

TABLE 3.1

	1950		1960		1970		1980		1990		2000		% Change 1950-2000
	No.	% Change	No.	% Change	No.	% Change	No.	% Change	No.	% Change	No.	% Change	
Arizona	749,587	73.7	1,302,161	36.3	1,775,399	36.3	2,718,215	53.1	3,665,228	34.8	5,130,632	40.0	584.5
Apache	27,767	9.6	30,438	6.1	32,304	6.1	52,108	61.3	61,591	18.2	69,423	12.7	150.0
Cochise	31,488	74.8	55,039	74.8	61,918	12.5	85,686	38.4	97,624	13.9	117,755	20.6	274.0
Coconino	23,910	75.1	41,857	75.1	48,326	15.5	75,008	55.2	96,591	28.8	116,320	20.4	386.5
Gila	24,158	6.6	25,745	6.6	29,255	13.6	37,080	26.7	40,216	8.5	51,335	27.6	112.5
Graham	12,985	8.2	14,045	8.2	16,578	18.0	22,862	37.9	26,554	16.1	33,489	26.1	157.9
Greenlee	12,805	-10.1	11,509	-10.1	10,330	-10.2	11,406	10.4	8,008	-29.8	8,547	6.7	-33.3
La Paz	<sup>a</sup>		<sup>a</sup>		<sup>a</sup>		<sup>a</sup>		13,844		19,715	42.4	NA
Maricopa	331,770	100.0	663,510	100.0	971,228	46.4	1,509,052	55.4	2,122,101	40.6	3,072,149	44.8	826.0
Mohave	8,510	-9.1	7,736	-9.1	25,857	234.2	55,865	116.1	93,497	67.4	155,032	65.8	1,721.8
Navajo	29,446	29.0	37,994	29.0	47,559	25.2	67,629	42.2	77,658	14.8	97,470	25.5	231.0
Pima	141,216	88.1	265,660	88.1	351,667	32.4	531,443	51.1	666,880	25.5	843,746	26.5	497.5
Pinal	43,191	45.1	62,673	45.1	68,579	9.4	90,918	32.6	116,379	28.0	179,727	54.4	316.1
Santa Cruz	9,344	15.7	10,808	15.7	13,966	29.2	20,459	46.5	29,676	45.1	38,381	29.3	310.8
Yavapai	24,991	15.7	28,912	15.7	37,005	28.0	68,145	84.2	107,714	58.1	167,517	55.5	570.3
Yuma	28,006	65.1	46,235	65.1	60,827	31.6	90,554	48.9	106,895	18.0	160,026	49.7	471.4

a. La Paz County was part of Yuma County until 1983.

Source: U. S. Department of Commerce, Bureau of the Census: 1950-2000.

vigorous economy. The third fastest growing county in the last half-century was Yavapai, which has drawn people in with its pleasant climate, the small town charm of Prescott and the affordable home prices of Prescott Valley.

Between 2000 and 2003 Arizona's population grew by 499,238 or 9.7 percent according to Arizona Department of Economic Security (DES) estimates. Five counties exceeded that growth rate: Pinal, Yavapai, Coconino, Maricopa and Mohave. Coconino County has some communities that are encountering difficulties providing adequate water supplies during the current drought and the Prescott Active Management Area is finding itself challenged to achieve its safe-yield groundwater mandate even before the eventual construction of the thousands of new homes slated for the Prescott and Chino Valleys. Both Coconino and Yavapai Counties may not be able to sustain their current high growth rates far into the future.

### FORECASTING POPULATION GROWTH

Forecasting is an inherently problematic task and the chances for significant error grow with the length of the forecast. The rate of recent population growth in Arizona has not been steady for either the state or the constituent counties. Migration, which is responsible for more than two-thirds of Arizona's population growth, is highly cyclical, rising and falling in reaction to the economic cycle. Other factors that affect migration rates include demographic trends such as the graying of America, the relative attractiveness of other regions and sharp changes in the rates of international migration. Given this uncertainty, the concept of **accurate** population forecasts for a high-growth state such as Arizona, and especially for individual counties or sub-county areas, is almost an oxymoron.

The Population Statistics Unit of the DES develops Arizona's official population projections. The projections are supposed to be updated on a regular basis as benchmark data from the U.S. Census and other sources becomes available. However, the most recent DES population projections appeared in 1997 and are, at this point, at considerable variance with both current U.S. Census and DES estimates. This matters because many State agencies, including the De-

TABLE 3.2  
ACTUAL 2000 AND PROJECTED POPULATION OF ARIZONA'S COUNTIES

County	2000	2010	2020	2030	2040	2050	Percent Change 2000-2050
<b>Arizona</b>	<b>5,130,632</b>	<b>6,145,125</b>	<b>7,363,625</b>	<b>8,621,050</b>	<b>9,863,625</b>	<b>11,170,975</b>	<b>117.7</b>
Apache	69,423	76,650	85,775	94,700	103,700	113,225	63.1
Cochise	117,755	137,025	150,000	160,050	167,400	174,550	48.2
Coconino	116,320	147,350	169,350	189,875	211,625	235,700	102.6
Gila	51,335	54,600	60,750	66,375	70,175	73,700	43.6
Graham	33,489	43,500	50,675	57,350	63,500	69,250	106.8
Greenlee	8,547	9,600	10,275	10,975	11,625	12,325	44.2
La Paz	19,715	25,100	29,075	31,975	33,900	35,600	80.6
Maricopa	3,072,149	3,709,575	4,516,100	5,390,775	6,296,225	7,264,725	136.5
Mohave	155,032	194,400	236,400	270,775	295,050	316,950	104.4
Navajo	97,470	99,975	111,950	123,450	134,325	147,275	51.1
Pima	843,746	1,031,625	1,206,250	1,372,325	1,522,625	1,671,175	98.1
Pinal	179,727	199,725	231,225	255,700	273,050	288,525	60.5
Santa Cruz	38,381	46,250	55,100	64,450	73,900	84,475	120.1
Yavapai	167,517	198,050	240,850	278,425	305,675	331,450	97.9
Yuma	160,026	171,700	209,850	253,850	300,850	352,050	120.0

Source: U.S. Department of Commerce, Bureau of the Census, 2000; and Arizona Department of Economic Security, Research Administration, Population Statistics Unit, 1997.

partment of Water Resources, rely on the projections for planning purposes. A decadal synopsis of the 1997 DES population projections appears in Table 3.2. It shows Arizona's population doubling in about the next 45 years, with growth especially high in Maricopa, Santa Cruz and Yuma Counties.

Although the projected growth portrayed in Table 3.2 looks impressive, and perhaps formidable from a water planning perspective, it now appears likely that the projections are too low, perhaps by a wide margin. The 1997 DES projection for Arizona's population in the year 2000 was 4,961,953, which was 168,679 people or 3.3 percent, fewer than the U.S. Census counted in that year. The DES had projected that Arizona would add 355,502 people between 2000 and 2003, whereas the state appeared to have added 499,238 people in that time span, a shortfall of 28.8 percent.

As would be expected, there is considerable variation between the 1997 DES projections for 2003 and the estimates for that year among Arizona's counties. The projections seem to have put more people into Graham, Greenlee and La Paz Counties than recent estimates show are there. Projections for Apache, Cochise, Coconino, Pima and Santa Cruz Counties were within one and a half percent of contemporary estimates. However, the projections under-predicted the 2003 populations of several counties by wide margins: 5.1 percent in Mohave County, 5.8 percent in Gila County, 6.4 percent in Maricopa County, 10.9 percent in Yavapai County, 11.1 percent in Navajo County, 13.8 percent in Pinal and 15.5 percent in Yuma County.

Arizona State University's Center for Business Research projects the state's population to be 8,305,000 in 2020, according to its middle growth scenario. Extrapolating from that projection, Arizona's population would reach 13,015,000 in 2050, nearly 2,000,000 more than the DES projection for that year.

### **POPULATION GROWTH AND WATER USE**

It has been estimated that in 1950 the statewide use of water for municipal and manufacturing purposes totaled 125,000 to 150,000 acre-feet, about three percent of all water used. A



more detailed analysis of water use in 1958 estimated that municipal usage accounted for 3.6 percent of all water used, mining accounted for 1.3 percent, manufacturing was 0.6 percent, power generation 0.1 percent and crop agriculture consumed 93.4 percent. By 1970 municipal and manufacturing use claimed a seven percent share of state water use, mining was using 2.7 percent of the water and agriculture accounted for 89 percent of all water used.

Estimates of water use by category reveal that accounting for water usage in Arizona is not always as simple as it sounds. The Arizona Department of Water Resources estimated that municipal and industrial use comprised 20 percent of statewide water use in 1990 and agriculture accounted for the remaining 80 percent. The University of Arizona's Water Resources Research Center estimated that in that same year municipal usage was 16.3 percent of the total, industrial use was 7.2 percent and agriculture used the remaining 76.5 percent of the state's water. The U.S. Geological Survey estimated that water withdrawals for Arizona in 1990 were 10.8 percent for public supply, 1.6 percent for thermoelectric, 2.4 percent for mining and 80.7 percent for irrigation. Clearly, estimates vary by use definition, categorization and estimating organization.<sup>2</sup>

Although accuracy and reliability of the Geological Survey estimates can be questioned, they do have two significant virtues—they are conducted every five years, including the decadal census years, and they are available for a variety of geographic areas, from individual drainage basins to counties. The lack of regular and frequent reportage of water use data by agencies within Arizona serves as a hindrance to understanding the changing dynamics of water use in such a rapidly growing state. The availability of county-level water use data allows comparison and analysis of water use in conjunction with demographic and economic data that is most typically available at the county level but not at the groundwater basin or drainage basin level.

Selected categories of water usage from the last three Geological Survey estimates are presented in Table 3.3. Statewide total water use, which grew between 1990 and 1995, declined slightly by 2000. Patterns of total water use in individual counties varied considerably, reflecting changes in major usage categories over time. Maricopa County, the state's largest water using county, has had a steady decline in total water usage since 1990, despite a 56 percent increase in



TABLE 3.3  
RECENT HISTORY OF ESTIMATED WATER USE IN ARIZONA'S COUNTIES

	Total Water Use (Mgal/d)*			Public Supply (Mgal/d)*			Thermoelectric Use (Mgal/d)*			Mining Use (Mgal/d)*			Irrigation Use (Mgal/d)*		
	1990	1995	2000	1990	1995	2000	1990	1995	2000	1990	1995	2000	1990	1995	2000
<b>Arizona</b>	<b>6,570.66</b>	<b>6,830.07</b>	<b>6,729.15</b>	<b>706.59</b>	<b>807.38</b>	<b>1,082.55</b>	<b>103.23</b>	<b>61.50</b>	<b>100.45</b>	<b>156.85</b>	<b>158.30</b>	<b>93.85</b>	<b>5,301.46</b>	<b>5,671.77</b>	<b>5,403.66</b>
Apache	61.32	39.03	47.63	4.96	4.54	5.00	18.42	14.89	15.96	0.06	0.00	0.01	20.95	16.03	24.18
Cochise	171.18	233.96	233.27	17.56	11.85	10.93	5.84	5.11	5.36	0.22	0.27	0.26	142.19	210.62	214.17
Coconino	40.62	47.32	52.68	13.97	16.55	19.10	18.46	19.80	25.66	0.03	0.00	0.01	4.50	8.18	6.49
Gila	73.10	42.88	14.78	6.60	4.57	5.82	0.00	0.00	0.00	54.45	22.32	2.12	4.09	14.58	5.90
Graham	198.89	176.36	172.21	2.56	3.19	4.79	0.00	0.00	0.00	0.00	0.00	0.17	194.82	172.50	166.74
Greenlee	24.97	43.65	33.34	0.96	0.70	0.59	0.00	0.00	0.00	12.18	23.78	18.92	11.40	18.75	13.67
La Paz	715.48	628.59	879.01	1.60	0.93	3.28	0.00	0.00	0.00	0.55	0.00	0.00	712.63	626.85	874.71
Maricopa	2,494.45	2,392.04	2,151.37	473.49	587.92	738.55	46.21	10.50	36.08	0.08	4.47	8.81	1,952.38	1,764.02	1,356.78
Mohave	145.28	140.32	153.66	21.56	15.11	19.93	0.00	0.00	0.00	2.73	19.75	0.43	102.13	104.00	132.14
Navajo	73.03	63.65	69.96	8.65	5.01	10.30	12.29	9.43	13.12	3.52	4.40	4.35	23.86	23.93	28.58
Pima	228.92	263.76	300.38	94.09	103.16	169.81	1.86	1.17	2.91	32.12	36.50	35.95	69.23	93.53	88.85
Pinal	882.08	1,262.17	1,052.44	16.52	15.29	34.32	0.11	0.31	0.84	14.27	22.04	2.94	713.67	1,205.27	1,009.76
Santa Cruz	9.38	15.37	22.66	2.92	3.49	8.77	0.04	0.00	0.00	0.00	0.37	0.02	5.78	10.71	13.10
Yavapai	192.11	82.39	82.40	16.95	13.50	22.61	0.00	0.00	0.00	36.64	24.40	19.72	115.41	38.75	36.87
Yuma	1,259.85	1,398.58	1,463.36	24.20	21.57	28.75	0.00	0.29	0.52	0.00	0.00	0.14	1,228.42	1,364.05	1,431.72

\* Mgal/d stands for million gallons per day.

Source: U. S. Geological Survey, National Water Use Program, 1985-2000.

public supply use between 1990 and 2000, as the much larger irrigation use category fell by 30 percent over the same time period. This demonstrates the common notion that as cropland is converted to residential neighborhoods water use declines.

Public supply water use, which provides the majority of residential and industrial water use, grew in almost all counties between 1990 and 2000, and quite sharply between 1995 and 2000 in La Paz, Maricopa, Mohave, Navajo, Pima, Santa Cruz, Yavapai and Yuma Counties. Public supply use in Cochise County declined by more than a third between 1990 and 2000. Although thermoelectric water use is only about one and a half percent of total water use for the state as a whole, it constitutes nearly a fifth of all water use in Navajo County, nearly a third of all water use in Apache County and nearly a half of all water use in Coconino County. Mining water use dropped precipitously in Arizona between 1995 and 2000, and especially so in Gila and Pinal Counties as mines were closed in response to low copper prices. Gila County's dramatic drop in mining water use between 1990 and 2000 caused an equally dramatic drop in total water use, as mining's share of all water use fell from 74 percent to 14 percent. Irrigation water use in Arizona declined moderately between 1995 and 2000, led by large drops in Maricopa and Pinal Counties. The trend was not universal however; irrigation water use in both Cochise and Yuma Counties has climbed over the last ten years.

Factors that affect domestic water demand include the ethnic, income and age structure of Arizona's population, household size, housing type and residential lot size, water pricing, conservation programs and climate changes. Water demand forecasts based on population projections alone are likely to result in significant error, not only in terms of total demand, but also in terms of indoor and outdoor demand, peak demand and seasonal demand. Incorporating factors such as socio-demographics, housing stock changes and wealth is more difficult, but can greatly improve water demand projections.

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<sup>2</sup> The long-term decline of agriculture's role in the state's economy is central to understanding total water use in Arizona. Appendix H describes this dramatic transformation during the last six decades.

## SHARING WATER ALONG THE BORDER WITH MEXICO

The complexities of water issues are particularly knotty when it comes to watersheds and water supplies that are shared with Mexico. The international boundary separates two different legal systems with different political and decision-making structures, acutely different levels of development and prosperity, different cultures, social structures and customs, and different perceptions of environmental quality. These many differences come to the fore when actions in one country affect the shared water resources of the other country. Appendix I assesses international issues related to the San Pedro and Santa Cruz Rivers; the remainder of this chapter considers the Colorado River.

### The Colorado River

The Colorado River is the mightiest river in the driest part of North America. It drains a 242,000 square mile watershed that stretches over seven states and comprises nearly one-twelfth of the land area of the continental United States. From its origin high in the Rocky Mountains of Colorado, it flows for 1,450 miles before emptying into the upper end of the Gulf of California. The Colorado, which means red in Spanish, got its name from the color of its sediment-rich water. Historically, its flows were characterized by extreme variability both seasonally and annually, ranging from more than 24 million acre-feet some years to less than 5 million acre-feet in drought years. Melting snows in the Rockies swelled its flow in the spring and the raging waters were at their reddest as the flood waters picked up and moved millions of tons of sediment and deposited them at its delta. By mid-summer the torrent would have abated considerably to become a more placid and shallow stream. Needless to say, the Colorado River no longer is as it was. The construction of Boulder Dam (now called Hoover Dam), which was completed in 1935, tamed the Colorado and evened out its flows. With the subsequent addition of Parker, Davis and Glen Canyon Dams for storage and Imperial, Laguna and Morelos Dams for irrigation diversion, the Colorado River was turned into a water storage and delivery system.

The first large-scale diversions of water from the lower Colorado River occurred in 1901.

The Colorado Development Company dredged a channel of the former Alamo River to create the Alamo Canal that carried water downhill to its fields in the Imperial Valley west of Yuma. Since the canal crossed the international border into Mexico before re-crossing the border at Mexicali, the Mexican government required that half of the water from the canal be used on Mexican soil in exchange for the concession to use the canal. The Colorado Development Company eventually bought large tracts of land around Mexicali that it also developed into irrigated fields. Because the Colorado River was as yet untamed, the intake for the Alamo Canal kept getting washed out or silted up. In early 1905, the river started flowing through a new bypass into the canal and the flow became uncontrollable. Water continued pouring through the Mexicali and Imperial Valleys to a low point 50 miles north of the border, where the ponded water became what is today the Salton Sea.

Irrigated farming in the Mexicali and Imperial Valleys developed rapidly during the first third of the Twentieth Century. During the 1930s, the Mexican government bought out most of the Colorado River Land Company's (the successor to the Colorado Development Company) ownership of the Mexicali fields. As Mexican ownership of the Mexicali fields increased, so did the binational competition to develop agricultural lands and efforts to claim rights for the water to irrigate those lands.

In a 1906 legal ruling regarding the division of water from the upper Rio Grande between the United States and Mexico, Attorney General Judson Harmon declared that in disputes over international rivers, the country of origin retained the right to use as much of the disputed water as it desired. With this ruling in mind, the United States ignored Mexico's pleas to be included in the talks between the seven Colorado River Basin states, which resulted in the Colorado River Compact of 1922 and the Boulder Canyon Project Act of 1928 that together failed to apportion any water to Mexico. This failure led Mexico to accelerate its efforts to develop as much irrigated agriculture as it could on its side of the lower Colorado River valley in an attempt to define a water usage history.

The Boulder Canyon Act also authorized the construction of the All-American Canal,

which carried Colorado River water directly to the Imperial Valley irrigation district without traveling through Mexico. This further solidified the United States control over the waters of the Colorado River. Mexico continued to receive Colorado River water through the Alamo Canal, but it was now the very last water that was in the river.

The Mexican Water Treaty of 1945 allocated 1.5 million acre-feet of Colorado River water to Mexico annually, with the provision that the amount could be increased to 1.7 million acre-feet in wet years and reduced proportionally during years of extreme drought. The Treaty did not explicitly guarantee a specific level of water quality, but instead stipulated that the delivered water be fit for domestic and agricultural use. The Treaty also allowed Mexico to build Morelos Dam to the west of the City of Yuma to improve the flow of water to the Mexicali Valley.

Settlers were irrigating alfalfa fields as early as 1875 along a stretch of the lower Gila River called the Mohawk Valley, about 30 miles east of Yuma. By 1931, using electric pumps to draw up underground water, the acreage under cultivation reached 6,200 acres. However, after the completion of Coolidge Dam in 1935, the Gila River no longer delivered sufficient water to replenish the Mohawk Valleys floodplain aquifers or to cleanse the poorly drained fields of accumulated salts. The Mohawk Valley farmers therefore applied for, and eventually received, the right to be included in the Gila Project, which was designed to bring Colorado River water to irrigate Yuma Mesa. The Wellton-Mohawk Canal, which splits off of the Gila Gravity Main Canal, was completed in 1957.

The delivery of Colorado River water failed to solve the Mohawk Valleys salinity problems. The irrigated acreage increased dramatically, and by 1959 there were 50,000 acres under cultivation. The abrupt increase in irrigation and the area's poor drainage qualities combined to produce a sharp rise in the water table. As the groundwater rose to within four feet of the surface, capillary action caused the water to be wicked up to the surface, depositing its salt load there when the water evaporated. The solution to this problem was the installation of drainage wells and the construction of a 58-mile long drainage channel to carry the tail-water to the Colorado

River. The Wellton-Mohawk Main Outlet Drain was completed in 1960 and immediately created a salinity crisis in the Mexicali Valley.

By 1960, most of the water in the Colorado River at Morelos Dam consisted of return flows, or tail-water, from various irrigation projects along the river. Water being delivered to Mexico had gotten increasingly salty throughout the 1950s, but the delivery of the Wellton-Mohawk drainage water made the situation far worse. The salt concentration of the water deliveries at Morelos Dam reached a high of 2,690 parts per million (ppm) by the fall of 1961. The drainage waters carried in the Wellton-Mohawk Main Outlet Drain neared 6,000 ppm as farmers in the Mohawk Valley tried to flush the salt from their fields and drain their highly saline aquifers.<sup>3</sup>

The water delivered to the Mexicali Valley not only irrigated most of the fields there, but also served as the source of drinking water for the majority of its population. The much more saline water provoked mass demonstrations in front of the United States consulate in Mexicali on December 14, 1961. The United States refused to send Mexico any additional, fresher water to help dilute the brackish return flows that were being delivered to the Mexicali Valley. Protests and complaints continued until 1965 when the United States agreed to Minute 218 of the Mexican Water Treaty to help resolve the salinity crisis. Under the provisions of Minute 218, the United States agreed to construct a 13-mile bypass to carry the saline waters from the Mohawk Valley to a point just below Morelos Dam. The bypass proved effective, with the water delivered to Mexico between 1965 and 1969 averaging 1,050 ppm of salt content.

During the early 1960s, Mexicali farmers increased their use of well water to dilute the salty water from the Colorado River. Mexico was pumping about 600,000 acre-feet of water a year in 1966 from well-fields near Mexicali and San Luis Rio Colorado. In 1972, Mexican president Luis Echeverria planned to double the amount of water pumped at San Luis from 160,000 acre-feet per year to 320,000 acre-feet per year. This threatened to set off a pumping war

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<sup>3</sup> By way of comparison, most tap water in the United States has 300 to 500 ppm of salts, and the World Health Organization set 1,500 ppm as the level of excessive salinity for potable water.





Figure 3.7 Yuma Desalting Plant Process Area. Pressure vessels for the 8-inch reverse osmosis elements.

with the American farmers of Yuma Mesa who shared the same aquifer. Because Mexico desired to renegotiate the Mexican Water Treaty to define its groundwater rights, and because it sought a permanent solution to the salinity problem, president Echeverria refused to sign an extension of Minute 218. This tough stance resulted in the drawing up of Minute 242 of the Mexican Water Treaty in August 1973.

The pact called for the United States to give technical and financial assistance to help rehabilitate farms in the Mexicali Valley. The United States also agreed to build a desalinization plant to help purify the water delivered to Mexico and to construct a drainage channel to carry the Wellton-Mohawk tail-water to the Gulf of California in order that it would not pollute any remaining water that flowed down the Colorado River below Morelos Dam. Minute 242 also guaranteed that water at Morelos Dam would not exceed a salinity magnitude of 115 ppm more than that delivered at Imperial Dam and limited Mexican pumping in the San Luis-Yuma area to 160,000 acre-feet per year.

Congress passed the Colorado River Basin Salinity Control Act in 1974 in order to provide for the physical works necessary to implement Minute 242. The Act authorized the construction of three salt control projects along the river, in addition to the desalinization plant so as



Figure 3.8 Solids Contact Reactor at the Yuma Desalting Plant.

to maintain salinity at or below 1972 levels. The Act also authorized the construction of a large well field along the international border south of Yuma in order to enforce the cap on Mexico's pumpage there. The total cost of the Salinity Control Act has approached a billion dollars so far.

The Yuma Desalting Plant, five miles west of Yuma, is the second largest reverse osmosis desalinization plant in the world (Figures 3.7, 3.8 and 3.9). The plant was originally scheduled to start operating in 1981, but design changes, rising costs and funding problems pushed the final completion to 1992. The plant, which cost \$280 million dollars, operated at one-third capacity for nine months starting in late 1992. A flood along the lower Gila River then washed out one of the delivery channels to the plant. By the time repairs were complete, a series of wet years in the Colorado River



Figure 3.9 Control Block at the Yuma Desalting Plant. Bank of pressure vessels that hold reverse osmosis elements in the process area.



watershed obviated the need to restart the plant, as there was sufficient water to fill all water orders, including Mexico's, as well as fill the rivers reservoirs.

Since the mid-1970s, a concrete lined drainage channel mandated by Minute 242 has carried the brackish Wellton-Mohawk tailwater safely past Yuma and San Luis Rio Colorado and deposited it at the Cienega de Santa Clara about 50 miles south of Yuma. This channel has delivered about 108,000 acre-feet of water a year that has not counted against Mexico's annual allotment of 1.5 million acre-feet. The brackish water has brought back to life about 50,000 acres, or about two percent, of the former 3,800 square mile Colorado River delta.

Because of the current drought affecting the Southwest, the Colorado River reservoirs have been drained of over half of their stored water, and water levels continue to drop rapidly. This has spurred calls for the Yuma Desalting Plant to be brought back on line, in order to stop the loss of the more than 100,000 acre-feet of water that flows into the Cienega de Santa Clara annually. Advocates for restarting the plant argue that during this drought every gallon of water that can be saved from going to waste should be saved. The Bureau of Reclamation estimates that it would take up to four years and \$26.1 million dollars to put the plant back into operation, and nearly \$29 million a year to run it. A large part of the annual operating costs would be for electrical utility payments for the extremely energy-intensive reverse osmosis process. In fact, from when reverse osmosis desalinization plants were first conceived by the Department of the Interior's Office of Saline Water in the 1950's through the late 1960s, when a joint United States-Mexico commission was considering building a plant near San Luis Rio Colorado, the plants were always planned to be nuclear powered, in order to supply their own tremendous energy requirements. However, cost considerations and the realization of the closeness of the San Andreas Fault required a switch to more traditional energy sources. Appendix J discusses the Desalting Plant further, particularly in the context of the Central Arizona Project.

If the Yuma Desalting Plant were run at full capacity, it could desalinate about 75,000 acre-feet of water a year. The treated water, which would have a salinity level of about 300 ppm, would then be delivered to the Colorado River, where it could help fulfill Mexico's annual 1.5

million acre-feet water allocation. The treated water would cost the United States about \$311 per acre-foot. The waste brine left over from the desalination process, at a salinity level of about 17,000 ppm (about half as salty as seawater), along with that portion of the Wellton-Mohawk drainage water that went untreated, would then be delivered to the Cienega de Santa Clara. The 33,000 acre-feet of brine delivered to the Cienega each year would be less than a third of the amount of water that currently flows there. Opponents of restarting the plant argue that this would kill the recently rejuvenated Cienega and that less environmentally destructive method, such as paying farmers to fallow land, should be considered.

In recent decades, environmentalists on both sides of the border have pressed for the restoration of the Colorado River delta's estuary habitat. They argue that a restored estuary would not only support biodiversity and aid endangered species, but also would provide natural wastewater filtration and treatment, nursery areas for fish and other marine organisms and economic opportunities through recreational and other commercial uses. In 1993, the Mexican government established the Alto Golfo de California-Delta del Rio Colorado Biosphere Reserve to safeguard the region. However, to date, the resources devoted to the Reserve have been minimal.

Dr. Edward Glenn, a professor of soil, water and environmental sciences at the University of Arizona, has estimated that sustaining a riparian corridor of native trees and other vegetation along a sixty mile reach of the Colorado River between Morelos Dam and the confluence with the Rio Hardy would require a perennial flow of 50,000 acre-feet of water a year, along with a simulated flood flow of 260,000 acre-feet of water every four years to regenerate trees and cleanse the riverbanks of accumulated salt buildups. This would total 115,000 acre-feet of water on an annualized basis and would be separate from the water needed to maintain the rejuvenated Cienega de Santa Clara.

Thus far, the Mexican government has expressed no interest in such a project and declines to devote any of its annual allocation of 1.5 million acre-feet of Colorado River water to environmental uses. Arturo Herrera Solis, the commissioner of the Mexican section of the International Boundary and Water Commission, has dismissed proposals to let the United States in-

clude the brackish water delivered to the Cienega de Santa Clara in Mexico's annual river allocation. For its part, the United States does not want to use any more water from an already over-allocated river to sustain an ecological project in another country.

However, even if drainage water were to continue to flow into the Cienega de Santa Clara and additional water resources were dedicated to bringing back the main riparian section of the Colorado River delta, the delta would still be a far cry from its character of a century ago. At that time not only was the delta receiving some five trillion gallons of water a year, it was also being invigorated by all the nutrients and sediment collected from its immense watershed. Prior to construction of Glen Canyon Dam, the Colorado River near Phantom Ranch in the Grand Canyon carried an average of 144 million tons of sediment a year. After the construction of the dam the sediment load dropped to approximately 18.7 million tons per year. The balance of the sediment is now trapped in the bottom of Lake Powell. The accumulation of the trapped sediment not only deprives the delta of a necessary replenishing infusion, but also will eventually convert Lake Powell from a reservoir into a terrace. To restore some measure of balance into the Colorado River system would probably require the construction of a type of slurry conduit to transport the sediment from where it is not wanted, Lake Powell, to where it is, the delta.

## Chapter 4

# CLIMATE, DROUGHT AND WATER SUPPLY

KATHY JACOBS

Climate drives Arizona's water supply picture through both the supply and demand sides of the equation. Air temperature has a strong impact on demand, while precipitation is our only truly renewable source of water. Improving our understanding of past conditions and improving our ability to predict likely future climate conditions will improve our adaptive capacity and limit the negative economic impacts currently associated with climate extremes. Temperature and precipitation patterns change on a daily, monthly, seasonal, inter-annual and decadal basis. **Climate conditions, defined as prevailing weather conditions over a long period of time, do not necessarily return to the same average condition, but rather the climate itself changes over time.** The southwestern United States has been unusually hot and dry in recent years, with 2002 being one of the driest years since the weather record began about a century ago. It is unclear whether this is part of a long-term trend or the result of climate variability.

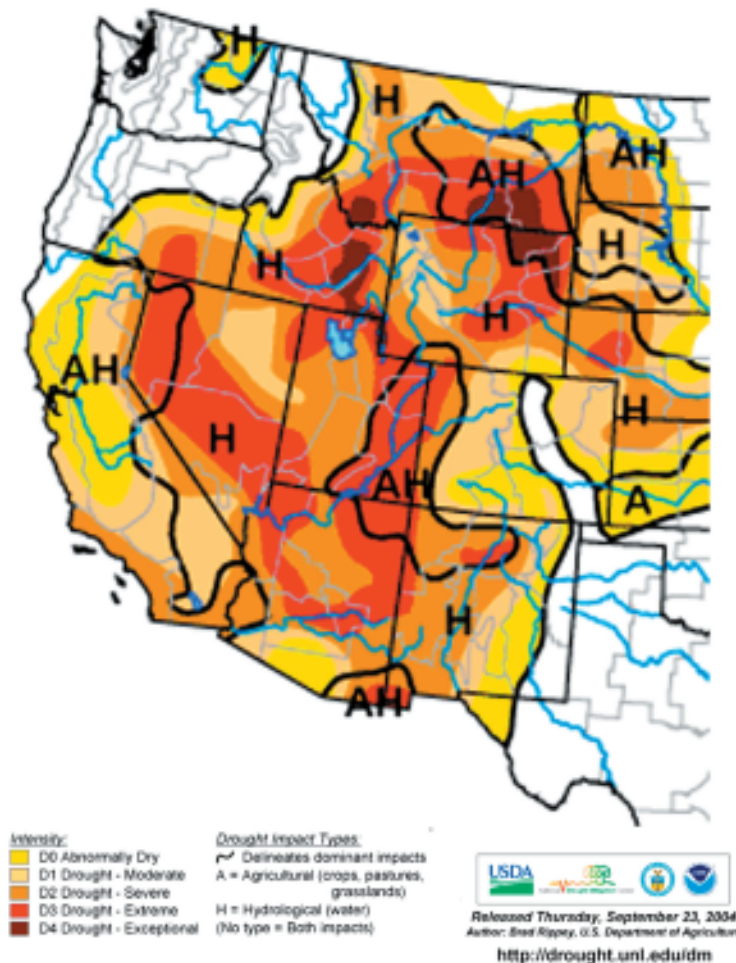
### CURRENT DROUGHT CONDITIONS

The National Weather Service's Arizona Drought Data site has a summary of precipitation records for 83 Arizona stations. All stations in the state have developed a precipitation deficit since 1998, the largest being Flagstaff, which has accumulated a 53.45-inch deficit. This is almost three times the total normal annual rainfall of 22.91 inches. Research by the Climate Assessment for the Southwest (CLIMAS) at the University of Arizona indicates that, across Arizona, 1999 through 2003 was one of the driest five-year periods of winter precipitation in the climate record.<sup>1</sup> The National Drought Monitor produces a weekly map of drought conditions

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<sup>1</sup> For background on this subject, see <http://www.ispe.arizona.edu/climas/research.html>.

Figure 4.1  
**U.S. Drought Monitor**



nationwide.<sup>2</sup> Figure 4.1 illustrates that the entire state was in some degree of drought as of September 23, 2004, ranging from abnormally dry to extreme drought.

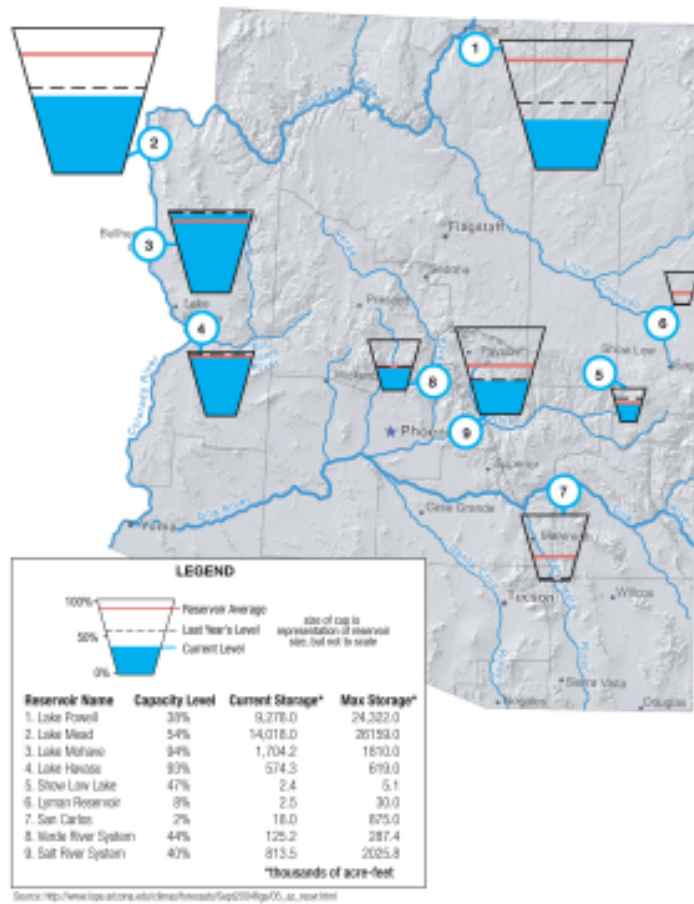
Among the most visible impacts of the drought have been large-scale forest fires at higher elevations throughout the state, bark beetle infestations due to drought-stressed trees across the northern and eastern portions of the state, significant statewide impacts on cattle ranching due to reduction in forage and changes in habitat quality in key environmental areas. In addition,

drought impacts on the water supply system have been substantial, with reservoirs on the Colorado River at below 50 percent of capacity, the lowest level since Lake Powell was first filled, Roosevelt Lake in the Salt River Project system currently at 28 percent (Figure 4.2) and groundwater level declines documented throughout Arizona. Lake Powell is below ten million acre-feet for the first time since May 1970; Lake Mead is at 14 million acre-feet for the first time since June 1964. Most other western states also have experienced critical water supply, wildfire and endangered species issues.

<sup>2</sup> See <http://www.drought.unl.edu/dm/monitor.html>.

Both droughts and floods have very significant implications for water managers, because providing for adequate water supplies during droughts and limiting damage from flooding both require long-term investments in infrastructure and planning. Preparing for the extremes of climate variability is much more challenging than managing water supplies for “normal” conditions. Although Arizona currently is focused on drought, it would be incorrect and shortsighted to assume that flooding will not be a major problem in Arizona at some point in the future. Preparing for sustainability means being prepared for both ends of the water supply spectrum.

Figure 4.2  
Current Reservoir Storage



There are two primary seasons for rainfall in Arizona: the winter season (November through April), which is particularly important to Arizona water supplies, and the summer “monsoon” season (July through September). Winter precipitation is associated with widespread storms, one to several days in duration, which provide rains at lower elevations and snowfall at higher elevations.

### CLIMATE “DRIVERS”

Climate conditions in the southwest United States are linked to sea surface temperatures and global circulation patterns. Understanding these climate drivers improves our ability to project



probable future climate conditions. A key factor affecting winter precipitation is the El Niño-Southern Oscillation (ENSO), which results from changes in equatorial Pacific Ocean sea surface temperatures and associated atmospheric circulation. When ENSO is in its El Niño phase due to warm temperatures in the eastern Pacific, Arizona frequently receives above average winter precipitation. In the La Nina (cool) phase of ENSO, drought conditions generally prevail in the southwest, though there are exceptions in both cases.

Summer precipitation currently is not well understood from the perspective of climate “drivers,” but it is associated with the North American monsoon and typically is of high intensity and short duration. Precipitation provided by the monsoons may be locally very important from a range, forage and soil moisture perspective, but it varies substantially from place to place and is not as important as winter precipitation for filling Arizona’s reservoirs.

Improved climate predictions can have great importance from an economic perspective because drought causes severe hardship for some sectors, and there are many adaptive actions that can be taken to limit impacts (Christensen *et al.*, 2004). Very significant contributions to understanding the history of climate conditions and drought over the past 1,000 years have been made by the Laboratory of Tree Ring Research at the University of Arizona and others studying a variety of proxy records such as ice, sediment and coral reef cores (Figure 4.3). For example, although the amount of water allocated among the Colorado River basin states and Mexico is 16.5 million acre-feet and the measured flow at the time of the Colorado Compact in 1922 was 15.8 million acre-feet, long-term tree ring records show an average flow of only 13.5 million acre-feet. Other evidence indicates that the average long-term flow may be even lower. Thus,

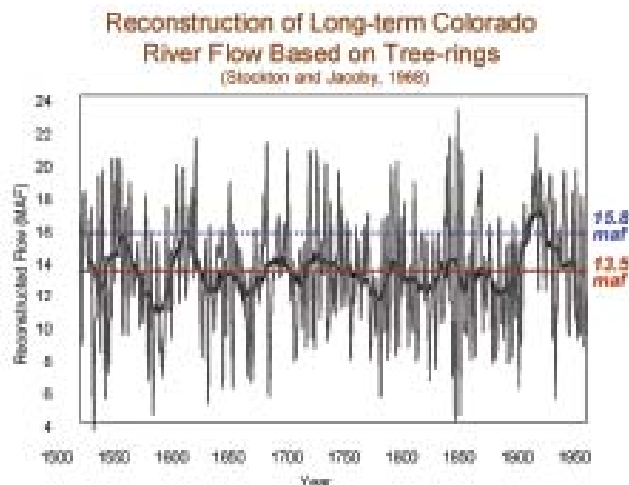


Figure 4.3 Colorado River Flow, 1500-1950.

the Colorado River is over-allocated, potentially leading to additional conflict between the states. The combination of a long-term record of climate conditions, which provides evidence of more severe, sustained droughts in the past than those experienced in this century, and new understanding of multi-decade climate variability patterns both lead to concerns about the reliability of future water supplies to serve Arizona's growing population (Jacobs and Garfin, in press).

An understanding of long-term trends in climate conditions is needed in order to give context to Arizona's water supply planning. For example, when compared to the tree-ring records of the last 1,000 years, it appears that the last quarter of the twentieth century was abnormally wet. Yet, the 30-year period from 1970 to 2000 is the time frame most commonly used to calculate the "average" climate conditions for Arizona. If this time period was anomalously wet, as most experts believe, water supply planning in the coming decades could be very problematic because our assumptions about supply availability will have been overly optimistic. The previous 30-year period of 1940 to 1970 contained the noted drought of the 1950s, which would have provided a very different view of the "average" conditions.

Rapid "step" changes from one climate regime to another, such as the recent transition from a multi-decade wet period to serious drought, may be associated with major ecological change, especially wildfires. High levels of precipitation result in a buildup of forest fuels. Drought following this buildup is likely to result in massive fire damage, such as has recently been experienced in Colorado and Arizona (Swetnam and Betancourt, 1998). Thus, climate factors need to be considered in addition to fire suppression in explaining current forest conditions.

Enhanced ability to predict probable future climate trends may be a significant tool for resource managers in the future. For example, information about the likelihood of a wet winter could allow reservoir managers to release more water to ensure that there is adequate flood flow protection. Conversely, a projection of dry conditions might result in curtailing reservoir releases. For this reason, recent increases in understanding the implications of multi-decade phases in the sea surface temperatures of both the Pacific and Atlantic Ocean basins may become very important. In the Pacific Ocean, a feature called the Pacific Decadal Oscillation (PDO) has been



associated with winter precipitation variations in the western United States (Mantua *et al.*, 1997; McCabe and Dettinger, 1999; and Sheppard *et al.*, 2002). The PDO appears to have a 20 to 30 year cycle that may be related to long-term climatic conditions in Arizona. Sea surface temperatures and western United States drought patterns since 1999 indicate the possibility that the PDO might have shifted to a phase favoring dry conditions in Arizona for the next ~20 years. Multi-decadal temperature changes in the Atlantic Ocean (the Atlantic Multi-decadal Oscillation) also have recently been found to be associated with dry conditions in Arizona (McCabe *et al.*, 2004). If this is true, Arizona may not be well prepared for the implications, due to the high likelihood of impacts on the Central Arizona Project (CAP) system in the relatively short term. Shortage sharing discussions, now ongoing between the seven Colorado River basin states and within Arizona, are of great importance in preparing for this possibility.

### **POLICY IMPLICATIONS OF GLOBAL WARMING FOR WATER SUPPLY PLANNING**

In addition to natural variability in climate, long-term human-induced climate change also is altering the hydrologic cycle in important ways. There is evidence that the Colorado and other western rivers are already being affected by changes in snowpack that are likely to be related to global warming. Increases in temperature affect the rate of evaporation and water use by plants, lowering soil moisture and increasing stress on water supplies. The key challenge for water managers, who traditionally have looked at past climate conditions as an indicator of the future, is anticipating the ways in which climate change may lead to new extremes or possibly even abrupt changes in the climate system.

The earth's surface has warmed over one degree Fahrenheit over the last century, leading to melting glaciers and ice caps, sea level rise, extended growing seasons and changes in the geographical distributions of plant and animal species documented by, among others, the National Research Council and the Intergovernmental Panel on Climate Change (Figure 4.4). Although the average temperature change seems small in comparison to daily temperature fluctuations, the warming is not spread evenly over the globe. It is concentrated most heavily at higher

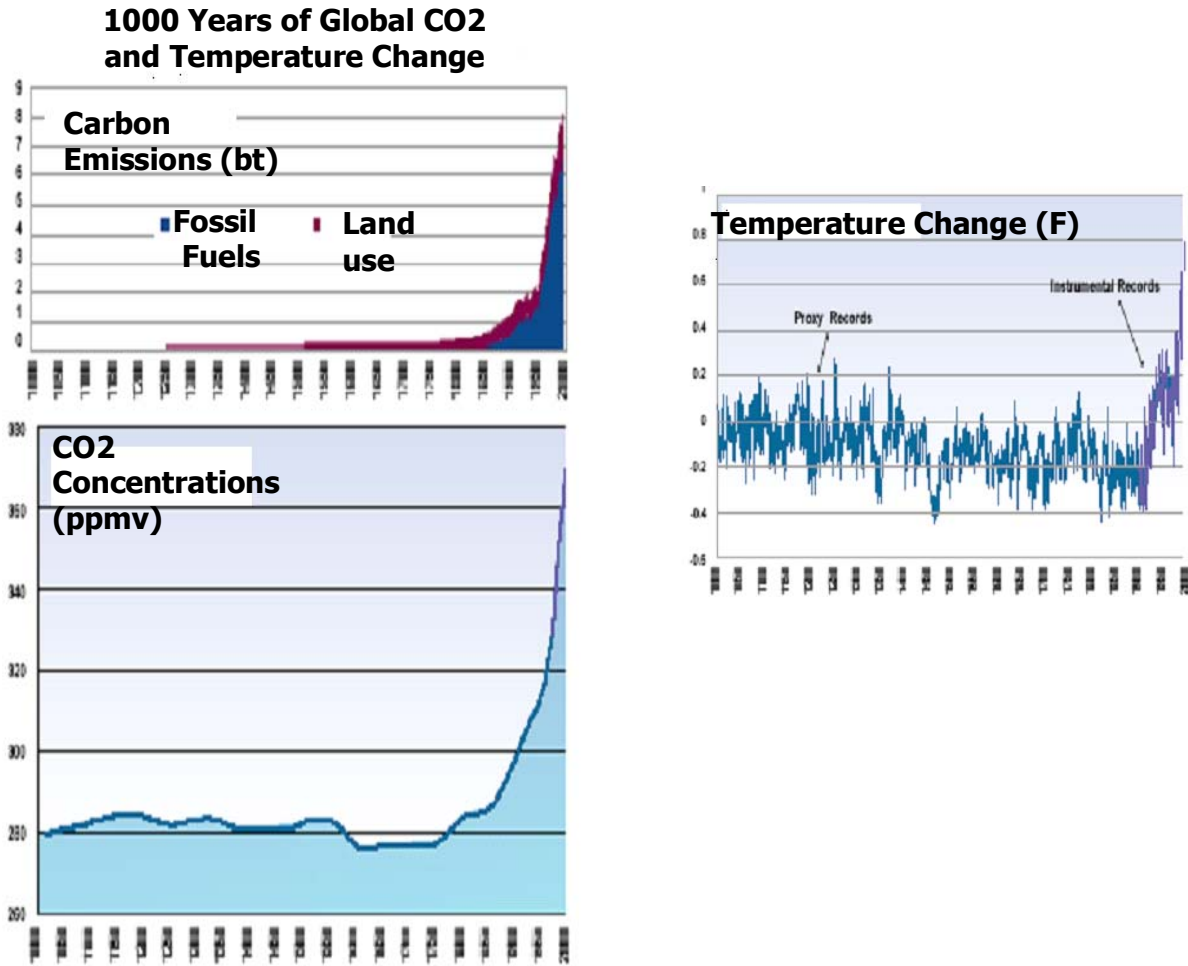


Figure 4.4 Global warming phenomenon.

latitudes, and the impacts are most visible near the poles.

Uncertainties remain about the magnitude and effects of future climate change, but almost all global climate models show that even very conservative assumptions about continued increases in temperature in the two degree Centigrade range over the next 100 years lead to key impacts from a water supply perspective. The most important consequence for the western United States, other than increasing evaporation and plant water use, is a reduction in snowpack and changes in runoff patterns (US Global Change Research Program, 2000). These changes may require new investments in storage and water delivery facilities as well as changes in water demand patterns to ensure sufficient water supply availability in critical areas. The primary policy

implication of climate change is that it is likely to increase competition for water by increasing demand while simultaneously reducing supplies that are dependent on snowpack. Water-dependent habitats, such as riparian corridors in the southwest, have been identified as being among the natural ecosystems most vulnerable to climate change and, therefore, natural resource managers may have additional challenges ahead.

### **DROUGHT PLANNING AND ADAPTATION OPTIONS IN ARIZONA**

Virtually all parts of Arizona currently have a cumulative water supply deficit due to lower than average precipitation over multiple years. However, Arizona's major urban areas, Phoenix and Tucson, were until recently thought to be somewhat insulated from the impacts of drought because of past federal and state investments in water supply sources such as the Salt River Project and the CAP. In addition, Arizona's efforts to manage the groundwater supplies in the Active Management Areas of the state have made substantial contributions to reducing drought impacts in those areas. However, recent drought conditions have raised awareness of the need for a comprehensive state drought plan, including ways to address the possibility of long-term, sustained drought conditions as well as short-term emergencies.

The most urgent need for drought planning is in the growing cities, towns and communities in the rural parts of the state, especially in the Central Highlands, the southeastern parts of the state and the Colorado Plateau where alternative water supplies generally are very limited and the economy, particularly the grazing, recreation and forestry-related sectors, is strongly affected by drought. The environmental impacts of drought generally are more difficult to manage than the societal impacts, and there are limited ways to limit the impacts on wildlife and vegetation.

### **DROUGHT TASK FORCE**

In response to the current drought and in recognition of the need for better planning, Governor Janet Napolitano established the Governor's Drought Task Force by executive order on March 20, 2003, requiring three major products:

- A short-term drought plan for the summer of 2003 that was adopted on July 10, 2003

and amended on June 10, 2004 for use in 2004;

- A long-term drought mitigation and coordination plan to address various specified areas of concern, *i.e.*, the Arizona Drought Preparedness Plan itself; and
- Development and implementation of a statewide water conservation strategy.

The Drought Task Force is composed of various state agencies and elected officials. Workgroups were established to solicit input from the municipal and industrial sectors, irrigated agriculture, environmental and resource management interests, tribal governments and the commerce, recreation and tourism sectors. In addition, public and private sector volunteers who supply much-needed expertise directly supported the planning process. The Task Force also was aided by experts from the National Drought Mitigation Center and supported financially by the United States Department of the Interior, Bureau of Reclamation. Current expectations are that the drought plan will be adopted in October 2004.

Drought is cumulative and does not affect all economic sectors in the same ways. The proposed Arizona Drought Preparedness Plan<sup>3</sup> is designed to respond to the differences in water supply availability and drought vulnerability for each sector and geographic area. The plan contains a separate section called the “Operational Drought Plan,” which addresses the recommended adaptation, mitigation and response activities.

### **APPROACH AND OBJECTIVES OF THE DROUGHT PLAN**

The adopted mission statement for the Governor’s Drought Task Force is to develop a sustainable drought planning process for Arizona that includes:

- Timely and reliable monitoring of drought and water supply conditions in the state and an assessment of potential impacts;
- An assessment of the vulnerability of key sectors, regions, and population groups in the state and potential actions to mitigate those impacts; and

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<sup>3</sup> <http://www.water.az.gov/gdtf/>.

- Assisting stakeholders in preparing for and responding to drought impacts, including development of a statewide water conservation strategy and public awareness program.

The focus on a sustainable drought planning process, one that continues over time regardless of current drought status, has been a key objective from the beginning of this effort. However, sustaining the drought planning process over time will be resource intensive and the source of resources is not yet clear.

The Drought Task Force adopted for the summers of 2003 and 2004 an *emergency Potable Water Plan* that focused on communities that have had drought-related supply problems in the past. Response activities such as trucking of water are coordinated through the Arizona Division of Emergency Management (ADEM). However, the longer-term Operational Drought Plan will include a network of monitoring and response agencies and committees to address most drought planning and response. While there is no funding for implementation of the Drought Plan at this time, it does make recommendations regarding funding and staffing.

The Drought Task Force developed a planning process that encourages the use of the latest scientific information, particularly the use of climate forecasts and monitoring data at the regional scale to enhance the utility of drought-related information for decision-makers. It is hoped that providing longer-term climate projections, even those that are relatively uncertain, can provide valuable information about the possible range and intensity of drought. Such projections allow a broader assessment of potential drought impacts and identification of early steps to reduce vulnerability and enhance adaptive capacity.

Key vulnerabilities have been identified within the rural portions of the state, related primarily to whether the supply source is drought prone and whether alternative water supplies are available. The Arizona Short-Term Potable Water Plan, updated in June of 2004, noted that several providers had been put into an emergency situation by the recent drought, with some requiring trucked water. Others were identified as at risk. Based on information from the ADEM, Arizona Department of Environmental Quality, Arizona Corporation Commission and Arizona

Department of Water Resources (ADWR) Rural Watershed Initiative Program, systems with historic drought related problems have been identified in or near the communities of Sonoita, Nicksville, Pine, Strawberry, Payson, Chloride, Dolan Springs, Bellemont, Mayer, Summerhaven, Ashfork, Black Canyon City, Cottonwood, Eager, Seligman, Tusayan, Kirkland and Williams.

### **ARIZONA DROUGHT PREPAREDNESS PLAN**

The Arizona Drought Preparedness Plan acknowledges that drought affects multiple sectors in the same location differently and establishes trigger mechanisms<sup>4</sup> or thresholds that are related to the vulnerability of each sector and region rather than establishing statewide drought stages. This approach is imperative in a state that is so dependent on imported surface water supplies from the Colorado River, with reservoirs that hold a multi-year water supply and large groundwater reserves. In the portions of the state that do not have these long-term, generally reliable water supplies, sectors such as grazing and recreation are likely to be in serious drought status more commonly than the major urban areas. The Plan is intended to be compatible with existing institutions and water management activities and to focus on local government adaptation and response options. The current draft indicates that communities may be required to develop their own drought plans.

General recommendations in the Plan include:

- Fund a Drought Coordinator and two half-time staff persons to be located at the ADWR, in addition to adequately funding the State Climatologist, who will share responsibilities (1) to improve the state's preparedness through implementation, assessment and improvements to the Drought Preparedness Plan, including database development, monitoring enhancements and meeting coordination, and (2) to ensure that the drought planning process is maintained.
- Facilitate and encourage coordinated water planning between counties, cities and water providers.
- Require all potable water systems to develop a Drought Contingency Plan. This Plan

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<sup>4</sup> Crossing identified threshold conditions results in a change in drought status and may "trigger" particular responses in the affected area.

could be part of an overall Water Plan for each system. Including a drought component and a water conservation component.

- Explore the need for and make recommendations on having potable water systems provide consistent and coordinated water supply information in order to identify the water uses within the system and ensure reductions during times of critical need.
- Initiate immediately the Local Area Impact Assessment Groups to identify a structure and contacts and to facilitate the implementation of the Arizona Drought Preparedness Plan.

Proposed membership in Local Area Impact Assessment Groups consist of the following:

- County Government (Co-Chair)–County Emergency Manager
- County Extension Agent (Co-Chair)
- Rural Watershed Alliance Chair (Co-Chair)
- ADWR (Monitoring Committee Liaison)
- Local Governments
- Potable Water Providers
- Other Local Water suppliers
- Tribal Government
- Local Non-Governmental Organizations
- Arizona Game and Fish
- Irrigation Districts
- Watershed Groups
- Natural Resource Conservation Districts

Tables found in Appendix I of the Operational Drought Plan<sup>5</sup> list sources of drought vulnerability as well as adaptation and mitigation options for municipal and industrial, agricultural, commerce, recreation and tourism, Indian nations and wildlife and watershed health.

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<sup>5</sup> <http://www.water.az.gov/gdtf/>.

## Chapter 5

# WATER RIGHTS, SOURCES AND ISSUES

KATHY JACOBS

Arizonans rely on four sources of water to meet their water demands: Colorado River water, other surface water, effluent and groundwater. Arizona's water supplies are physically constrained by climate conditions, but they also are legally constrained through interstate and international compacts, federal decrees and state law. Although surface water rights in Arizona are based on the relatively common "prior appropriation" or "first in time, first in right" system, the groundwater rights within the Active Management Areas (AMAs) are unique. This chapter discusses the legal definitions of the sources of water, the water rights systems and issues associated with those systems. The issues described include institutional limits on sustainability.

### SOURCES OF WATER

#### Colorado River Water

The Colorado River flows through seven states and Mexico prior to discharging into the Gulf of California. Its flows are managed through a series of dams and diversions. Table 5.1 shows the allocation of the waters of the Colorado River between the four Upper Basin states, three Lower Basin states and Mexico. The Upper Basin is allocated by percentages, while the Lower Basin is allocated by volume. Arizona is allocated 2.8 million acre-feet from the Colorado River. Colorado River water used in Arizona is subject to Congressional acts, interstate and international compacts as well as court decrees, collectively known as the Law of the River. The "water master," the decision-making authority for the Lower Colorado, is the Secretary of the Interior, who manages the river through the U.S. Bureau of Reclamation. The Colorado River provides on average about 39 percent of Arizona's water supplies. The Arizona Department of Water Resources (ADWR) is responsible for making recommendations to the Secretary of the



TABLE 5.1  
**COLORADO RIVER ALLOCATIONS**

	<b>Percent of Basin Allocation</b>	<b>Acre-feet per Year</b>
<b>UPPER BASIN STATES</b>		
Wyoming	13	1,043,000
Utah	21	1,713,500
Colorado	47	3,855,375
New Mexico	10	838,125
Arizona	<1	50,000
<b>LOWER BASIN STATES</b>		
Arizona		2,800,000
California		4,400,000
Nevada		300,000
<b>MEXICO</b>		1,500,000

Interior regarding the allocation of Colorado River water to mainstream water users and to customers of the Central Arizona Project (CAP) as well as reviewing proposed transfers of CAP water.

About half of Arizona's Colorado River allocation is delivered to central Arizona through the CAP. Currently the CAP has 50-year subcontracts with 56 municipal and industrial users, ten Indian communities and ten non-Indian agricultural districts. The conditions under which this water can be used are contained in subcontracts between the Central Arizona Water Conservation District, the Secretary of the Interior and the subcontractor. An important contract provision is the requirement to pay the capital, but not the operations, maintenance or energy, components of the CAP water price, even if the water is not used.

### **Surface Water**

Arizona statutes define surface water as "the waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, flood, waste, or surplus water, and of lakes, ponds and springs on the surface." In addition, the courts have found that if pumping subsurface water appreciably dimin-

ishes the flow of the surface stream, then that water is deemed to be “subflow,” also a form of surface water. Surface water from lakes, rivers and streams other than the Colorado River is governed by the “doctrine of prior appropriation,” which means that the first person to put water to beneficial and reasonable use, *i.e.*, use without waste, acquires a superior right to later appropriators. Prior to June 12, 1919, a person could acquire a surface water right simply by applying the water to a beneficial use and posting a notice of the appropriation at the point of diversion. On June 12, 1919, the Arizona surface water code was enacted. Now known as the Public Water Code, this law provides that a person must apply for and obtain a permit in order to appropriate surface water. The surface water rights system is administered by the ADWR. Over the last century, storage reservoirs and conveyance systems for surface water have been constructed throughout the state. Major reservoir storage systems are located on the Salt, Verde, Gila and Agua Fria Rivers. In-state surface water systems (Figures 1.1 and 4.2) supply about 19 percent or 1.4 million acre-feet of Arizona’s water.

### **Effluent**

Effluent, or treated municipal wastewater can be treated to a quality that can be used for virtually any purpose, including potable water supply. However, it is most commonly used for agricultural irrigation, turf watering, industrial cooling, maintenance of riparian areas and artificial recharge. Effluent is an expanding source of water that has great value in meeting future water supply needs. It currently serves only two percent or 0.14 million acre-feet of the total water demand in the state. Legally, effluent is neither surface water nor groundwater, but is a third class of water until it is discharged to a riverbed where it becomes surface water or percolates into the groundwater table.

### **Groundwater**

Groundwater means water under the surface of the earth regardless of the geologic structure in which it is standing or moving. Groundwater does not include water flowing in under-

ground streams with ascertainable beds and banks (A.R.S. § 45-101.5). Groundwater supplies on average about 40 percent or 2.9 million acre-feet of the state's water use. Since the 1940s, groundwater has been pumped more rapidly in certain parts of the state than it has been replenished, resulting in a condition called "overdraft" or "groundwater mining." The areas of greatest concern are within the AMAs, though significant conflicts over groundwater use and declines in groundwater levels have developed in rural parts of the state as well. Large amounts of water are stored in Arizona's aquifers, but its use is limited by location, depth and quality. Groundwater use also is affected by concerns that over-pumping will result in subsidence of the ground surface, potentially damaging infrastructure and buildings as well as limiting the water storage capacity of the aquifer. The groundwater rights and permits system was established in the 1980 Groundwater Management Act (GMA) and is administered by ADWR.

### **THE ARIZONA GROUNDWATER MANAGEMENT ACT**

The GMA was adopted on June 12, 1980 in response to multiple pressures on the state's groundwater rights system. The pressures included lawsuits that threatened the water supplies of the mining and municipal water use sectors related to the transportation of groundwater in the Tucson area and a threat by the federal government to halt construction of the long-awaited CAP unless groundwater management issues and concerns about the economic implications of severe overdraft conditions in several parts of the state were addressed.

The GMA has three primary goals. The first is to control the severe overdraft occurring in many parts of the state. The second is to provide a means to allocate the state's limited groundwater resources within AMAs to most effectively meet the changing needs of the state. The third goal is to offset Arizona's use of groundwater through renewable water supply development. To accomplish these goals, the GMA set up a comprehensive management framework and established ADWR to administer its provisions.

### **Active Management Areas and Irrigation Non-Expansion Areas**

The GMA created four initial AMAs, the Phoenix, Tucson, Pinal and Prescott AMAs, with a fifth, the Santa Cruz AMA, established from a portion of the Tucson AMA in 1994 (Figure 1.2). Groundwater overdraft in the AMAs was more severe than in other parts of the state and, therefore, the regulations in these areas are more substantial than elsewhere. The vast majority of the state's population lives in the AMAs. Although the management goals of the AMAs differ, they all focus on reducing the overdraft and/or maintaining groundwater levels.

Three Irrigation Non-Expansion Areas (INAs) were established in rural farming areas where the groundwater overdraft was less severe. The Douglas INA and the Joseph City INA were established as the initial INAs. The Harquahala INA was designated in 1982. The management objective in INAs is the prevention of further declines in groundwater supplies through prohibition of irrigation acreage expansion. General provisions that apply to groundwater management on a statewide basis are discussed in the following sections. Chapter 6 provides a more detailed description of the AMAs.

### **Statewide Groundwater Management Activities**

The ADWR's authorities relative to water management are relatively limited outside of the AMAs. Statewide planning efforts include technical studies of local areas and assistance in projecting future water demands. The most recent statewide water assessment available is the Arizona Water Resources Assessment compiled by ADWR in 1994. There has been no update of this comprehensive statewide water supply database since then, although an effort to compile more recent data currently is underway.

The lack of current information on water supply and demand conditions outside the AMAs limits planning and management activities. A Rural Watershed Initiative, started in 1998, has provided technical assistance to 17 watershed groups to develop regional watershed solutions through locally driven partnerships, complete water resource studies and evaluate management options.

Statewide regulatory programs and requirements managed by ADWR include well drilling, construction, licensing, registration and abandonment, groundwater transportation restrictions, adequate water supply requirements and surface water rights administration. ADWR conducts testing for well drilling licenses and issues Notices of Intent to Drill for any well drilling and construction that occurs in the state. ADWR enforces groundwater transportation restrictions and maintains the provisions of the Water Adequacy Program throughout the state. Unlike the Assured Water Supply Program inside of the AMAs, the Adequacy Program allows new subdivisions to be approved even if the water supplies are found to be inadequate. Chapter 7 contains a more detailed description of the Water Adequacy Program.

### **Groundwater Rights in AMAs**

The GMA established a new groundwater permit system designed to limit expanded use of groundwater and protect the water rights of water users who were in place in 1980, when the law was passed. Most groundwater withdrawals within AMAs are limited in volume on an annual basis and are subject to conservation requirements. There is very limited ability to market these rights. There are four basic requirements that must be met prior to pumping or using groundwater in an AMA:

- Establish the legal right to withdraw the water,
- Obtain a well permit and employ a licensed well driller if a new well is required,
- Unless the well is an “exempt” well or subject to limited other exemptions, withdrawals must be measured and annual groundwater withdrawals reported to ADWR, and
- Specific conservation program requirements and water use limitations apply to particular kinds of water use within the AMAs.

*Irrigation Grandfathered Rights.* Within AMAs, anyone who owns land that was legally irrigated with groundwater at anytime from January 1, 1975 to January 1, 1980 and has been issued a Certificate of Irrigation Grandfathered Right (IGFR) by ADWR has the right to use

groundwater for irrigation of that land. Irrigation is defined as growing crops for sale or human or animal consumption on two or more acres. The volume of IGFRs is established by the conservation requirements in the adopted management plan for each AMA through a maximum annual groundwater allotment for each farm or specifically identified best management practices.

*Type 1 Non-Irrigation Grandfathered Rights.* A Type 1 non-irrigation grandfathered right is associated with land permanently retired from farming and converted to a non-irrigation use. This right, like an irrigation grandfathered right may be sold or leased only with the land. Type 1 rights are established based on a maximum of three acre-feet per acre of retired irrigated land and generally are used for industrial purposes such as sand and gravel facilities, golf courses or dairies. They are subject to specific conservation requirements in the industrial chapter of the management plan for each AMA.

*Type 2 Non-Irrigation Grandfathered Rights.* Groundwater withdrawn pursuant to a Type 2 non-irrigation grandfathered right generally can be used for any non-irrigation purpose. The right is based on the maximum amount of water pumped for a non-irrigation use from a non-exempt well, *i.e.*, a well with a pumping capacity of greater than 35 gallons per minute, in any one year between 1975 and 1980. Type 2 rights can be sold or leased separately from the land and most often are used for industrial purposes. They generally are required to follow the conservation requirements associated with the industrial conservation programs in the management plans for each AMA.

*Service Area Rights.* Service area rights allow cities, towns, private water companies and irrigation districts to withdraw and transport groundwater to serve their customers. Most persons within an AMA receive water through a municipal water provider pursuant to a service area right. The volume of a service area right is not quantified, but is subject to either a gallons per capita per day conservation limit or alternative conservation requirements based on best management practices.

*Groundwater Withdrawal Permits.* Groundwater withdrawal permits allow new withdrawals of groundwater for limited nonirrigation uses. Seven types of withdrawal permits cur-

rently are allowed under the GMA. A General Industrial Use Permit, the most commonly used type of permit, allows the withdrawal of groundwater for industrial uses outside the service area of a city, town or private water company. Users of these permits generally are required to participate in the Industrial Conservation Program.

*Exempt Wells.* With minor exceptions, wells with a pump capacity of 35 gallons per minute or less are legally “exempt” from many of the provisions of the GMA. Water can be withdrawn from exempt wells for any purpose. Non-domestic exempt wells drilled after 1983 are limited to 10 acre-feet per year, but domestic wells can withdraw up to 56 acre-feet per year if they are pumped on a full-time basis.

## WATER RIGHTS ISSUES

### Groundwater Rights

There are multiple water rights issues within the AMAs, many of which relate to the grandfathered right and permit system in the GMA. The GMA protects pre-1980 pumpage rights and allows for certain kinds of new groundwater withdrawal permits, potentially jeopardizing the ability of the AMAs to meet their management goals. These rights allow the continued mining or over drafting of groundwater.

Water rights issues recently identified in the context of Governor Jane Hull’s Water Management Commission include the amount of allowable groundwater pumping relative to the safe-yield goals, the impact of exempt, domestic wells on existing water rights and the management goals and specific issues related to municipal, agricultural and industrial groundwater rights. Appendix K contains the Executive Summary of the Governor’s Water Management Commission’s findings and recommendations related to this issue.

### Surface Water Rights and Adjudications

Adjudications are court proceedings in which the nature, extent and priority of water rights are determined. The majority of the surface water rights in the state have not been formally

quantified at this time, although there are several court decrees in the central part of the state that identify right holders and volumes. For example, the Kent Decree established the relative rights of Salt River Valley landowners to the Salt and Verde Rivers and established which lands had normal flow rights based on priority of use prior to delivery of stored water from Roosevelt Dam. Until water rights are adjudicated, there is no clarity about the size of water rights and whether they are senior or junior to other water rights in the same basin. The two general stream adjudications ongoing in the state, the Gila River Adjudication and the Little Colorado River Adjudication, are discussed further in Chapter 8. The exterior boundaries of these two adjudications include more than half of the state, where most of the Indian reservations and federal land is located. The adjudication courts have been working on Indian and federal non-Indian claims first, and then intend to move to state-law-based water claims. There are nearly 26,500 parties in the Gila River Adjudication and over 3,000 parties in the Lower Colorado River Adjudication. Because of the complexity of the legal and hydrologic issues involved, final resolution of the water rights in these basins is elusive. The adjudication proceedings have been ongoing for several decades, and it is likely that there will be no significant resolution in the near future. This lack of certainty limits management options and makes enforcement of the surface water law more difficult.

### **The Distinction Between Groundwater and Surface Water**

Arizona's courts since statehood have handled surface water and groundwater separately, despite the hydrologic connection between the two sources. This results in a number of legal and institutional issues. Surface water allocations are based on the "first in time, first in right" priority system. Groundwater generally is governed by the reasonable use doctrine that the landowner, without waste, can use water beneath the land for any beneficial purpose. There is no priority system for groundwater, other than the grandfathered groundwater rights system within the AMAs that protects water users that were in place prior to the 1980 adoption of the GMA. Rights to groundwater were relegated to the courts for some time before any action was taken by the state



legislature to regulate or control its use.

Because the water rights system does not acknowledge the hydrologic connection between surface water and groundwater, it generally is not possible to limit groundwater pumping in order to protect surface water rights or riparian habitat. However, the courts have found that if pumping subsurface water appreciably diminishes the flow of the surface stream, then the water is deemed to be subflow and subject to the general adjudication. An Arizona Supreme Court case determined in 2000 that a well is subject to adjudication if it is located either in the saturated floodplain alluvium or outside of the younger alluvium and has a cone of depression that extends into the subflow zone. Factors likely to be considered in individual cases include the elevation, gradient, flow direction and chemical makeup of the water. Key problem areas within the state related to the distinction between groundwater and surface water include the San Pedro River and the Verde River basins.

### **RIPARIAN PROTECTION**

The need to quantify and prioritize the surface water rights in the state as well as to distinguish which water sources meet the legal definition of “groundwater” and which are “surface water” is essential to a workable water management system. Resolving this confusion is of particular concern in the areas where water is pumped from wells in the vicinity of surface water streams. Establishing which wells are pumping groundwater and which are pumping subflow is a necessary step for enforcing the surface water law. This determination generally has not been made. Over-pumping of water from wells has had significant impacts on surface flows in the state and has resulted in the elimination of a large percentage of the natural perennial flow of miles of rivers.

Most of the remaining perennial flows in the state are outside of the AMAs (Figure 9.10), and many support areas of high biodiversity, including endangered species, as well as have significant aesthetic and recreational value. Many top tourist destinations within the state are associated with flowing water. Impacts of pumping on surface water flows are of particular concern

along the Salt, Verde and San Pedro Rivers.

There is a type of surface water right called “instream flow rights” that can be established based on the need for particular flow levels to protect habitat or recreational uses. However, few such rights have been established, and they have recent priority dates, so are generally junior to other rightsholders in a watershed. The only state program that provides funding for riparian protection and restoration, the Arizona Water Protection Fund, has received no appropriations for the last few years. The Arizona Water Protection Fund Commission, which was created by the legislature to preserve and enhance flows in rivers and streams and their associated riparian habitats, continues to be staffed by ADWR, although only a few small restoration and riparian land use management projects are still underway. Projects funded previously were instrumental in preserving riparian habitats throughout the state. The lack of mechanisms to protect the remaining riparian areas is an issue given development pressure and changing climate conditions.



## Chapter 6

# WATER MANAGEMENT IN THE ACTIVE MANAGEMENT AREAS

KATHY JACOBS AND SHARON MEGDAL

The 1980 Groundwater Management Act (GMA) mandates water planning and groundwater management activities within the five Active Management Areas (AMAs) shown in Figure 1.2. The boundaries of the AMAs are, for the most part, coterminous with hydrologic basin boundaries. Each of these areas has a statutory water management goal related to limiting over-pumping of groundwater. Management plans must be adopted for each AMA every ten years to further achievement of the goal. These regulatory plans—now the Third Management Plan for each of the AMAs—include mandatory conservation requirements by municipal, agricultural and industrial water use sectors (Appendix L). Irrigated agriculture cannot be expanded beyond acreage irrigated during the late 1970s within the AMAs and the Irrigation Non-expansion Areas (INAs), also depicted in Figure 1.2. An important provision of the GMA is that all large wells must be measured and the annual water use reported to the Arizona Department of Water Resource (ADWR). This information has provided a useful database for water management. In addition, the Assured and Adequate Water Supply Rules mandate that municipal water companies, whether they are privately or publicly owned, limit their use of groundwater for population growth served by those companies.

The AMAs include more than 80 percent of the state's population. The majority of the state's economic activity and more than 50 percent of the total water use occurs in these areas. Therefore, achieving the water management objectives in these areas is a significant component of achieving the water sustainability goal for the state. This chapter describes the five AMAs and discusses their water management efforts and associated issues<sup>1</sup>.

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<sup>1</sup> The Final Report and Recommendations, Briefing Book, and Technical Advisory Committee Issue Papers of the Governor's Water Management Commission (2001) and the Transition Report by the Arizona Department of Water Resources (2002) provide additional detail and foundation for the following sections.

TABLE 6.1  
PHOENIX AMA WATER BUDGET  
(in acre feet)

	1998					2025				
	Municipal	Agricultural	Industrial	Other		Municipal	Agricultural	Industrial	Other	
Groundwater	207,112	403,268	78,937	135,679		132,100 -	94,700 -	133,600		
Groundwater (In-Lieu)		106,999					121,300			
CAP Water	171,081	99,046	2,227	0		452,600	50,500	1,500	139,100	
Surface Water	456,831	350,410	9,102	144,089		820,700	21,500	18,400	185,300	
Effluent	15,459	63,765	73,374	2,325		233,400	60,000	87,500	9,000	
Incidental Recharge	61,055	324,543	8,378	67,067		135,900 -	66,100 -	12,500	124,600 -	
Other Inputs			195,021				256,500 -	263,000		
<b>Overdraft</b>			<b>250,693</b>				<b>146,400 -</b>	<b>278,900</b>		

**Note:** Incidental Recharge is water that reenters the aquifer after use or discharge, Other Inputs include Cuts to the Aquifer, Canal Recharge and Net Natural Recharge (Mountain Front Recharge, Stream Channel Recharge and Groundwater Inflow - Outflows). Budget is from Governor's Water Management Commission Final Report, which assumes non-drought (past 30 years) conditions. Per 2003 legislation, cuts to the aquifer no longer exist for CAGRDR replenishment and replenishment reserve.

## PRESENT CONDITIONS AND GOALS

Tables 6.1 through 6.5 summarize the water budgets for each of the five AMAs for 1998 and 2025 and describe current and anticipated water supply. The tables show the sources of water and the uses of that water by municipal, agricultural, industrial and other sectors. Each table also reports the amount of overdraft associated with the expected pumpage in 2025 and assumes compliance with the conservation goals. These tables as well as the statutorily required Third Management Plans provide an important indication of the progress the AMAs are making toward meeting their respective water management goals.

### Phoenix Active Management Area

The Phoenix AMA management goal is to reach safe-yield by 2025. Safe-yield is achieved if groundwater withdrawals in the AMA do not exceed the long-term natural and artificial recharge. The Phoenix AMA encompasses 5,646 square miles in central Arizona and consists of seven groundwater sub-basins. A diverse mix of water uses characterizes the AMA, with a heavy and increasing emphasis on municipal and industrial use. Multiple sources of water—Central Arizona Project (CAP) water, Salt River and Verde River surface waters, effluent and groundwater—are available and being used to varying degrees. Approximately 2.4 million acre-feet per year of water are used in the Phoenix AMA: 1.4 million acre-feet of renewable water from the CAP, Salt River and Verde River surface waters and effluent, and 900,000 acre-feet of groundwater. Agricultural use accounts for 55 percent of the total, while municipal (water served by municipal water providers) accounts for 37 percent, and industrial use is seven percent. The 1998 water budget for the Phoenix AMA (Table 6.1) shows a 250,000 acre-foot overdraft. This overdraft is expected to be reduced, but not eliminated, by 2025. The wide range of potential overdraft results from uncertainty about the future of agricultural water use in the Phoenix AMA.

The Phoenix AMA staff administers 8,500 groundwater rights and permits in the Phoenix AMA and Harquahala and Joseph City INAs. Approximately 7,300 of these rights are for irrigation use, 650 are Type 1 and Type 2 non-irrigation grandfathered rights, 106 are rights held by





municipal water providers and 36 are rights held by irrigation districts. There also are approximately 210 groundwater withdrawal permits in the Phoenix AMA. As in the other AMAs, administration of these rights comprises annual pumpage report preparation and review, random report audits, failure to file activities, debit and credit balance determinations for agricultural flexibility accounts, conservation requirement reviews, water right conveyances and general assistance to right holders.

Each of the AMAs also dedicates some staff time to technical assistance and long-range planning. Water management planning and assistance projects of particular note in the Phoenix AMA involve working with local water providers, developing future scenarios and using ADWR's hydrologic models to project future conditions. These efforts made a significant contribution to regional water management in the West Valley; a project has recently been initiated with a coalition of East Valley water providers.

### **Tucson Active Management Area**

Like the Prescott and Phoenix AMAs, the Tucson AMA also has safe-yield as its management goal. The AMA encompasses 3,866 square miles in southeast Arizona and two groundwater sub-basins. The AMA's population is approximately 870,000 people. The AMA contains five incorporated cities and towns: Tucson, South Tucson, Oro Valley, Marana and Sahuarita. The average annual water use between 1998 and 2000 in the Tucson AMA was approximately 324,000 acre-feet, of which 90 percent was groundwater, seven percent was CAP water used in lieu of groundwater in agriculture and three percent was effluent. Groundwater use is declining as municipal providers, in particular the City of Tucson, are expanding the use of CAP water through recharge and recovery activities. Municipal water use accounts for approximately 49 percent of total demand, agricultural use, 32 percent, and industrial use, 19 percent. The AMA currently is over-drafting groundwater (Table 6.2).

There are 211 large irrigation rights (generally defined as farms of ten or more acres), 65 Type 1 rights, 349 Type 2 rights, one irrigation district and 147 municipal water providers regu-

lated by the AMA. In addition, the Tucson AMA administers 52 groundwater withdrawal permits and 65 recharge-related permits. Projections for the Tucson AMA show that overdraft will be cut from around 160,000 acre-feet per year in 1998 to around 50,000 acre-feet per year in 2025.

Key assistance activities of the Tucson AMA staff include facilitating the development of regional recharge and recovery strategies and conservation assistance focused on ordinance development, educational presentations and work with the landscape industry to encourage efficient irrigation.

### **Prescott Active Management Area**

The Prescott AMA, like the Phoenix and Tucson AMAs, has a goal to achieve safe-yield by 2025. Located in the northern portion of the state, it encompasses 485 square miles within central Yavapai County. The physical environment of the AMA varies significantly, with major differences in elevation, climate and precipitation. The area has been experiencing rapid growth. Nearly 75,000 people reside within the Prescott AMA. Population in the AMA is projected to increase to 148,000 people by 2025. Nearly 80 percent of the AMA's current population resides within the City of Prescott, the Towns of Prescott Valley and Chino Valley and the communities of Dewey and Humboldt.

The City of Prescott and Prescott Valley Water District, the two large municipal water providers in the AMA, supply the majority of potable water in the AMA. These two providers supplied 11,050 acre-feet of groundwater or 76 percent of the total municipal groundwater demand in 2001. Unlike the AMAs in Central Arizona, water users in the Prescott AMA do not receive deliveries of surface water through major constructed water projects, such as the CAP. One-half of the total water use comes from overdrafted groundwater (Table 6.3). Approximately half the current water demand is agricultural; the other half is municipal. There are no new renewable supplies available, though certain entities in the Prescott AMA have legal authority to transfer groundwater from the Big Chino basin under certain conditions. It is not clear whether

TABLE 6.3  
**PRESCOTT AMA WATER BUDGET**

(in acre feet)

	1998			2025		
	Municipal	Agricultural	Industrial	Municipal	Agricultural	Industrial
Groundwater	11,805	4,489	576	13,574	3,200	300
Surface Water	0	4,472	0	1,500	900	0
Effluent	685		0	6,426	0	0
Incidental Recharge	0	3,822	55	0	1,025	15
Total	12,490	12,783	631	21,500	5,125	315
Other Inputs	1,347			3,041		
Overdraft	<b>11,646</b>			<b>12,993</b>		

**Note:** Incidental Recharge is water that reenters the aquifer after use or discharge, Other Inputs include Cuts to the Aquifer and Net Natural Recharge (Mountain Front Recharge, Stream Channel Recharge and GW Inflow - Outflows). Budget is from Governor's Water Management Commission Final Report, which assumes non-drought (past 30 years) conditions. Per 2003 legislation, cuts to the aquifer no longer exist for CAGRDR replenishment and replenishment

environmental and legal concerns associated with the proposed transfers will be resolved, but the outcome of the water transfer decision will affect whether the Prescott AMA has the potential to meet its management goal. Communities within the AMA also will need to decide whether any imported water will be used solely to serve new growth (which they can legally do) or whether at least some portion of the imported water will be used to offset the overcommitment of groundwater to already approved subdivisions. Key assistance activities for the Prescott AMA staff involve assisting in evaluation of water management importation options.

**Pinal Active Management Area**

The Pinal AMA encompasses approximately 4,000 square miles in south central Arizona and includes five groundwater sub-basins. In contrast to the Phoenix, Tucson and Prescott AMA goals of safe-yield by 2025, the Pinal AMA has the dual goal of maintaining the agricultural economy for as long as feasible while protecting water supplies for future municipal growth (Table 6.4). The unique Pinal AMA management goal is evidence that the GMA recognized the

TABLE 6.4  
**PINAL AMA WATER BUDGET**  
 (in acre feet)

	1998				2025			
	Municipal	Agricultural	Industrial	Other	Municipal	Agricultural	Industrial	Other
Groundwater	18,700	371,351	7,088	44,328	20,833	451,413	11,647	68,852
Groundwater (In- CAP Water	512	266,367	0	87,672	8,587	150,000	50	106,964
Surface Water	534	114,958	0	43,521	588	152,803	0	40,303
Effluent	33	4,530	1,204	5,231	2,928	4,274	1,139	5,231
Incidental Recharge	9,890	199,512	0	39,271	16,453	181,688	0	51,237
Other Inputs	60,989				57,426			
<b>Overdraft</b>	<b>194,154</b>				<b>267,606</b>			

**Note:** Incidental Recharge is water that reenters the aquifer after use or discharge, Other Inputs include Cuts to the Aquifer and Net Natural Recharge (Mountain Front Recharge, Stream Channel Recharge and Groundwater Inflow - Outflows). Budget is from Governor's Water Management Commission Final Report, which assumes non-drought (past 30 years) conditions. Per 2003 legislation, cuts to the aquifer no longer exist for CAGRDR replenishment and replenishment reserve.

need to respond to different water supply and economic conditions in different parts of the state. Farming still is the largest and most vital industry in the AMA, with cotton and wheat the principal crops. Dairy operations as well as the production of hay and other feed products are increasing. Agriculture accounts for 96 percent of the current water demand. Other important industries include tourism, light manufacturing and food processing.

The region has been experiencing considerable residential growth, with the AMA's population now exceeding 120,000 people. The AMA contains four incorporated municipalities, the largest being Casa Grande. There are four large irrigation districts, together encompassing approximately 247,000 acres of irrigable farmland. The Pinal AMA administers 1,413 rights and permits, of which 1,200 are agricultural.

The Pinal AMA's planning efforts are focused on using renewable supplies available to the region (largely through in-lieu recharge deliveries to agricultural districts) and ensuring that a sustainable supply is available for rapidly growing municipal and industrial uses. It is likely that the Pinal AMA's two goals can be met, though there are concerns about storage and recovery of renewable supplies, agricultural supplies during drought and whether the Assured Water Supply (AWS) criteria should be modified to ensure sustainable supplies for municipal growth.

### **Santa Cruz Active Management Area**

The Santa Cruz AMA was established as a separate AMA in 1994. The region had been part of the Tucson AMA prior to that time. The AMA currently is in a safe-yield condition, but has shallow aquifers, limited supplies and significant unused rights. The AMA management goal is to maintain the safe-yield condition and to prevent local water tables from experiencing long-term declines. The Santa Cruz AMA encompasses approximately 716 square miles in the Upper Santa Cruz Valley Basin and includes the City of Nogales. It contains a 45-mile reach of the Santa Cruz River from the international border to the Continental gauging station, located a few miles north of the Santa Cruz and Pima County line.

The Santa Cruz AMA is in the process of clarifying its water management goal and

TABLE 6.5  
**SANTA CRUZ AMA WATER BUDGET**  
*(in acre feet)*

	1998				2025			
	Municipal	Agricultura	Industrial	Other	Municipal	Agricultura	Industrial	Other
Water (All Sources)	7,036	11,274	1,372	22,200	10,776	10,300	2,400	22,200
Incidental Recharge	0	3,950	70	0	0	3,610	120	0
Surface Water & Groundwater Inflow-	48,435							
Effluent Discharges	16,271							
<b>Overdraft</b>	<b>(10,573)</b>							
	24951 - 42,558							
	5,800 - 23,532							
	<b>(612) - 31,811</b>							

**Note:** Incidental Recharge is water that reenters the aquifer after use or discharge. Budget is from Governor's Water Management Commission Final Report, which assumes non-drought (past 30 years) conditions. Per 2003 legislation, cuts to the aquifer no longer exist for CAGR and replenishment and replenishment reserve.

developing AWS rules to better address the AMA's unique hydrology, environmental and geographic characteristics. Although the region currently is assumed to be in safe-yield (Table 6.5), regional growth, both in Arizona and Sonora, Mexico, will increase pressure on local water supplies. The Santa Cruz River and the Nogales Wash both flow north across the border, and effluent from Nogales, Mexico, is treated north of Nogales, Arizona, at the International Wastewater Treatment Plant and discharged into the Santa Cruz River. Water in the border region is truly a shared resource.

All demand sectors rely on water withdrawn from wells. Effluent from the International Wastewater Treatment Plant, surface water, mountain front recharge and incidental recharge contribute to the replenishment of the younger alluvial aquifer. Withdrawals from shallow wells, therefore, are comprised of water originating from several sources. The average annual water use in the Santa Cruz AMA is over 23,000 acre-feet. Municipal water use accounts for approximately 30 percent of total demand, agricultural use, 62 percent, and industrial use, eight percent, though these percentages fluctuate significantly from year to year. The riparian vegetation along the Santa Cruz River and its tributaries use another 22,000 acre-feet per year, an amount approximately equal to the municipal, industrial and agricultural demand in the AMA. There are 82 irrigation-grandfathered rights, nine Type 1 rights, 36 Type 2 rights and 14 municipal water providers, four of which are large providers.

Maintaining a safe-yield condition and managing local water levels in the Santa Cruz AMA is a much more complicated goal than that faced by the other AMAs. Issues such as the inability to distinguish between surface water and groundwater, the lack of adjudication of surface water rights, the uncertainty of continued delivery of effluent from Mexico and the need to amend the well location and well replacement criteria as well as the AWS Rules to address the specific management goal for the Santa Cruz AMA all need to be addressed. The wide range of overdraft shown in Table 6.5 relates to the strong influence of surface water inflows on the water budget. In wet years, safe-yield is not difficult to maintain, but in dry years there are major impacts on groundwater levels.



## MEETING THE ACTIVE MANAGEMENT AREA GOALS

A comprehensive examination of the achievability and appropriateness of the AMA management goals was performed by the 49-member commission appointed by Governor Jane Dee Hull in June of 2000. The Governor's Water Management Commission was charged with reviewing the GMA and recommending changes needed to maintain a reliable and sustainable water supply to meet current and future water needs in the AMAs. Appendix K contains the executive summary of the Commission's recommendations. In December 2001, the Commission concluded that the goals and framework of the GMA were sound and should continue to guide AMA water management decisions and investments. The Commission also endorsed the statutory management goals of the AMAs. However, the Commission concluded that more work was necessary in order to meet the management goals in the time frame established by the GMA.

The Commission recognized that, although groundwater overdraft conditions in the Phoenix, Pinal, Tucson and Prescott AMAs persist, hydrologic conditions vary widely within the AMAs, with some areas experiencing waterlogged conditions, *e.g.*, the Buckeye area in the Phoenix AMA, while others experience significant declines in water tables. Likewise, subsidence and water quality problems as well as concerns about protecting riparian areas vary within and among the AMAs. The Commission acknowledged that renewable water supplies are not universally available and the costs of new major infrastructure can be prohibitively expensive, especially for smaller communities. Regarding conditions of the individual AMAs, the Commission (2000) concluded:

*In the Phoenix and Tucson AMAs, water budgets based on current supply availability projections indicate that achieving safe-yield may not be as difficult as maintaining that condition . . . the expected population growth beyond 2025, particularly in the major metropolitan areas, may ultimately exceed the availability of renewable supplies and result in increasing costs for providing renewable water supplies and again put pressure on groundwater availability. This situation may occur earlier in the Prescott AMA, where renewable supplies are not as abundant or as readily available . . .*

*The Santa Cruz AMA goal of preventing long-term declines in local water table levels provides the means to deal with "sub-area" issues and physical water supply conditions, which does not exist in the others AMAs . . . Management of*

*the water levels is an important objective due to the desire to protect the surface water flows and riparian habitat along the river while maximizing available supplies . . .*

*In the past, the water management goal of the Pinal AMA was referred to as “planned depletion.” However, this characterization has recently been identified as encompassing only one aspect of the management goal. Preserving water supplies for non-irrigation users is also an important part of the Pinal AMA management goal. Because agriculture can use mined groundwater supplies in the Pinal AMA until they are no longer affordable, and sufficient groundwater appears to be available based on projected needs, the goal of preserving the agricultural economies for as long as feasible is achievable well beyond 2025. With regard to achieving the goal for non-irrigation uses and accommodating projected population increases, strategies must be identified and implemented to lower overall water use, specifically the non-residential component, and/or secure additional renewable supplies.*

Although some conditions have changed since the Commission published its findings, these conclusions in general continue to be relevant.

Achieving a sustainable water supply within the AMAs requires continued water management efforts and consideration of local conditions. While groundwater and surface water availability depends to a considerable extent on geography, effluent is a growing resource in all of the AMAs. However, successful residential conservation programs may reduce the growth rate of effluent.

The management plans for each of the AMAs contain detailed information on their water supplies and management programs. Important programs and mechanisms exist to facilitate achievement of the management goals. In addition to the conservation programs (Appendix L) that address the demand side of the equation, there are multiple programs aimed at expanding the use of renewable supplies. They include the AWS program, the Recharge and Recovery Program, the Central Arizona Groundwater Replenishment District (CAGRDR) and the Arizona Water Banking Authority.

### **THE ASSURED WATER SUPPLY PROGRAM**

The GMA mandated the adoption of rules to implement a program of AWS. Prior to

planning any new subdivisions in AMAs, a demonstration of sufficient water supplies to serve the proposed development for 100 years is required. Either the water company providing water to the development must have an AWS designation, or the developer must obtain an AWS Certificate. However, it was not until the 1995 adoption of the AWS Rules that the requirements for this demonstration were codified. Although certain elements of the AWS program differ by AMA, designation or certification of AWS requires that certain criteria be met to the satisfaction of the ADWR. A successful applicant must show that the water to supply the new water use is physically, continuously and legally available for 100 years and that the water supply meets applicable water quality standards. The proposed water use must be consistent with the management goal, *e.g.*, safe-yield, of the AMA. Finally, the applicant must establish financial capability to construct the necessary infrastructure required for the proposed use.

The portfolio of water supplies held by municipal providers that have been designated as having an AWS contains a variety of sources. These include groundwater, surface water, effluent, CAP water, CAGR membership, recharge credits, extinguishment credits from retiring grandfathered rights, groundwater transfers from basins outside of AMAs, water exchanges and Indian leases. Many of these supplies bring new layers of administrative, legal and technical complexity to water management in the state. In the Prescott and Santa Cruz AMAs, implementation of the AWS Rules has been especially challenging because of the unique hydrologic conditions and lack of alternative supplies (Jacobs and Holway, 2004).

The consistency with the management goal provision of the GMA resulted in the AWS Rule requirement to use renewable supplies to meet a substantial portion of new water demand. Renewable supplies can be directly delivered to customers or indirectly through a program of recharge and recovery. This provision is perhaps the most significant incentive for the use of CAP water for water companies in the three AMAs served by the CAP, *i.e.*, Phoenix, Pinal and Tucson. Although the use of renewable water supplies is universally viewed as positive, it would

have been difficult in some cases to justify the costs associated with the quick conversion to renewable supplies without a significant regulatory incentive.



Figure 6.1 Granite Reef Diversion Dam.

It was recognized at the time of development of the AWS Rules that it would not be acceptable to include a requirement for use of renewable water supplies without mechanisms to enable those without long-term subcontracts for CAP water access to new sources of supply. Without new institutional mechanisms, such as recharge and recovery and the CAGR, growth would be limited to those water systems in close proximity to the CAP canal and with CAP subcontracts.

### RECHARGE AND RECOVERY

The Underground Storage, Savings and Replenishment (Recharge) Program was established in 1986, and the statutes have been expanded and refined over time. The program was developed to facilitate storing water underground, protecting the aquifer from harm and establishing ownership and recovery provisions for the stored water. Recharge and recovery can greatly facilitate conjunctive management of available supplies, allowing, for example, the storage of excess treated effluent in the winter to be recovered in the summer and used for turf irrigation. Permits issued by ADWR pursuant to statute govern recharge activities in Arizona. Water stored at Underground Storage Facilities and Groundwater Savings Facilities generates cred-



Figure 6.2 Lower Santa Cruz recharge basins.

its that can be recovered later in time or in other locations.

Underground Storage Facilities often consist of man-made basins built for the purpose of replenishing underground aquifers (Figures 6.1 and 6.2). At Groundwater Savings Facilities, agricultural users substitute CAP water or effluent for use of groundwater. Groundwater that is saved through the use of CAP water and effluent or the water stored underground allows for accrual of storage credits that can be recovered by the entity or assignee that stored the water. When those credits are recovered, they are legally accounted for as the type of water that was stored—not groundwater—and can be used for AWS purposes. Most recharge activity is for storing water for AWS purposes or increasing water delivery reliability by storing today excess CAP water that can be recovered during droughts or system failures in the future.

Once a recharge permit has been issued, ADWR monitors compliance with permit conditions at the recharge facility and tracks the resulting credits. This is done through the evaluation of reports that are submitted by every permit holder on at least an annual basis. Staff examines each report for accuracy and completeness as well as compliance with permit conditions that may include water level and water quality limits as well as other requirements.

The Arizona Department of Environmental Quality (ADEQ) also is involved in the permitting of recharge facilities. Effluent recharge facilities require an Aquifer Protection Permit from ADEQ and facilities recharging Colorado River Water are reviewed by ADEQ to consider their impact on migration of existing contaminant plumes.

Recharge credits are calculated based on water stored and recovered during the year. Credits are tracked internally at ADWR as well as reported to permit holders (Table 6.6). As of the end of 2002, over 3.5 million acre-feet of recharge credits are held by more than 70 different entities.

#### **THE CENTRAL ARIZONA GROUNDWATER REPLENISHMENT DISTRICT**

The CAGRDR was created in conjunction with the development of the AWS Rules. Operated by the Central Arizona Water Conservation District, which also operates the CAP, the CAGRDR is one of the most innovative and complex water institutions that exists anywhere in the

TABLE 6.6  
**STATUS OF RECHARGE PERMITS AS OF JULY 2004**

Type of Recharge Permit	Use of Permit	Major Criteria for Issuing Permit	Total Permits Currently Active	Permits Issued FY 04		
				New Apps	Mod Apps	Total
Underground Storage Facility (USF) Permit	Allows operation of direct recharge facility using natural steam channels, infiltration basins, injection wells, trenches, <i>et cetera</i> .	Storage will not cause unreasonable harm to land and water users. Storage is hydrologically feasible.	55	14	22	36
Groundwater Savings Facility (GSF) Permit	Allows operation of a facility where a renewable supply is substituted by a water user for groundwater that would otherwise have been pumped.	Replacement of groundwater on a gallon for gallon basis. Renewable supply would not be reasonable alternative except through the GSF.	20		16	16
Water Storage Permit	Allows storage of an excess renewable supply, <i>e.g.</i> , CAP water.	Applicant has the legal right to use.	180	28	7	35
Recovery Well Permit	Allows recovery of stored water through pumping a well.	Pumping will not damage surrounding users. Consistency with the management plan and goal.	85	15	17	32



United States. It was authorized to facilitate use of renewable supplies by new developments that had no direct access to CAP water. The CAGRDR is required to replenish in perpetuity all groundwater pumped by its members that exceeds the groundwater use allowed under the AWS Rules. Economic conditions over the past decade have resulted in an unexpectedly high rate of CAGRDR enrollment. Because the number of members of the CAGRDR far exceeds the original expectations, ensuring adequate water supplies to meet its long-term obligations has proven to be challenging. For example, the CAGRDR serves a substantial number of designated water providers as well as individual subdivisions in the three-county CAWCD service area, *i.e.*, Maricopa, Pinal and Pima Counties.

Membership in the CAGRDR is voluntary, but the CAGRDR currently must accept as members those who are (1) within the CAP service area, (2) can meet the other four AWS criteria and (3) agree to pay CAGRDR replenishment assessments. The CAGRDR has three calendar years in which to fulfill its replenishment obligation, which it does by storing water at permitted recharge facilities. Because the water is essentially replacing groundwater, this storage is termed “replenishment.” CAGRDR performs the replenishment at recharge sites it selects within the AMA where the replenishment obligation was generated.

Several CAGRDR-related issues were considered during the deliberations of the Governor’s Water Management Commission (Appendix K). Some of the issues have been or are being addressed statutorily and/or through policy changes. The CAGRDR itself does not currently have a firm, 100-year supply of water for replenishment. The AWS Rules assume that the CAGRDR will fulfill its function, thus granting an AWS based on non-firm supplies, something not allowed for individual municipal providers as part of their AWS portfolios. Recent amendments to its statutes authorized a replenishment reserve and strengthened elements of the operating plan that must be updated and submitted every ten years for ADWR approval. The CAGRDR has been working more actively with members and other stakeholders to project its future obligations and methods for meeting them. Still, the popularity of the CAGRDR as a mechanism for fulfilling the renewable water utilization requirement of the AWS Rules has surprised nearly all involved.

The high rate of enrollment, drought conditions and increased use of river water by others have all required more careful evaluation of the CAGR to ensure that it can meet its future replenishment obligations in an affordable manner.

### **THE ARIZONA WATER BANKING AUTHORITY**

The Arizona Water Banking Authority (AWBA) is another statutorily created innovative mechanism that uses recharge to meet important state goals. The AWBA was established in 1996, shortly after Governor Fife Symington's Central Arizona Project Advisory Committee issued its report regarding use of CAP water. Concerns about California's over-utilization of its 4.4 million acre-foot allocation and Nevada's need for additional water supplies led to concerns that Arizona's allocation of Colorado River water could be at risk. The AWBA was created to meet four primary objectives:

- Store water to ensure reliable municipal water deliveries during future shortages on the Colorado River or CAP system failures;
- Support the management goals of the AMAs;
- Support Indian water rights settlements; and
- Provide for interstate banking of Colorado River water to assist Nevada and California in meeting their water supply requirements while protecting Arizona's entitlement.

Since 1997, the AWBA has stored over two million acre-feet of excess CAP water, more than two-thirds of Arizona's annual allocation of Colorado River water. AWBA operations have enabled Arizona to fully use its Colorado River entitlement and to store water on behalf of the other two Lower Basin states. The AWBA has been hailed as a major innovation in water management, and it has changed the tenor of interstate negotiations substantially by showing that Arizona was serious about using its entire CAP allocation (Jacobs and Holway, 2004). The AWBA does not compete with other water users for supplies; rather it uses water that is not used by other contractors. It stands last in line in priority for water supplies and for storage space in



recharge facilities.

The reason Arizona was not utilizing its full entitlement relates to the cost of CAP water relative to groundwater. Failure to recognize the impact that the high cost of CAP water would have on farmers lead to overly-ambitious projections regarding the demand for CAP water by agriculture. It was expected that, in the early years of the CAP, agricultural entities would use all excess CAP water, *i.e.*, all of the state's CAP allocation not used by municipal, industrial and Indian demand. It was further assumed that agricultural use would phase out as the municipal, industrial and Indian demand increased over time. In fact, the cost of CAP water, coupled with the financial obligations associated with infrastructure construction, made use of full-cost CAP water cost-prohibitive for agricultural users. In response, Arizonans developed the Groundwater Savings or "in-lieu" recharge program and made major changes in the pricing policy for CAP water, including the establishment of an agricultural incentive pricing system. These changes have enabled agriculture to be major users of CAP water and reduced the overall size of the state's repayment obligation to the federal government (because low interest payments are made on the debt for the portion of the CAP used by agriculture). The total number of credits stored in Groundwater Savings facilities is listed in Appendix M.

Municipal and Indian CAP sub-contracts are not yet fully utilized by the sub-contractors themselves but, nevertheless, Arizona has been able to use its full CAP allocation in recent years. This is in part due to the activities of the AWBA to store excess CAP water, CAWCD programs such as incentive pricing to reduce costs for agricultural users and the Groundwater Savings or in-lieu recharge program. The drought also has increased the demand for CAP water, particularly by the Salt River Project, since water supplies in other surface water systems have been significantly curtailed.

### **WATER MANAGEMENT CHALLENGES REMAIN**

The GMA has provided a sound framework for water management in the AMAs, and significant progress has been made, particularly in the use of renewable water supplies. Yet,

unresolved issues and challenges remain. Fundamentally, the ability to achieve and maintain safe-yield is unknown, especially in light of existing groundwater rights and projections for additional growth.

### **Where is the “Next Bucket” of Water Coming From?**

With an expanding population and no identification of the sources of water that will be available for future urban growth, either per capita water use will have to be reduced or water use will need to shift from other sectors to the municipal sector if safe-yield is to be achieved and maintained. The “next bucket” of water to support growth in Arizona has not been identified, although many believe that conservation and technologies like desalination will play a role. Additional renewable supplies exist, but there are legal, political, physical, institutional and economic challenges to putting them to use. A number of the supplies will have to be moved into the AMAs with new or existing infrastructure, including the CAP. Yet the physical capacity of the existing infrastructure to move water is limited.

### **Access to “Wheeling Capacity” for Non-CAP Supplies in the CAP Canal**

The CAP under normal conditions delivers approximately 1.5 million acre-feet of Arizona’s 2.8-million acre-foot Colorado River allocation. However, the system is capable of delivering as much as 1.9 million acre-feet each year on a nearly continuous basis under optimistic assumptions. Discussions have been initiated to set policies and priorities for that additional “wheeling” capacity. Although these discussions have not been finalized, this capacity to move water is a valuable asset that will affect future supply alternatives.

### **Long-Term Supplies for the Central Arizona Groundwater Replenishment District**

The CAGRDR’s Plan of Operation—currently under development—provides an intriguing glimpse into how future supplies may be developed. To meet the estimated 227,000 acre-foot demand of members projected to be enrolled through 2015, the CAGRDR has proposed a supply

acquisition strategy, phased-in over three decades, that includes (1) importation of groundwater, (2) Indian leases, (3) on-river Colorado River supplies and (4) the use of local effluent. It is widely anticipated that other entities will pursue similar supply acquisitions in the coming decades. How that process will proceed is unknown, but it will be strongly influenced by the rate of population growth, competition for supplies and climatic conditions. There are indications, for instance, that some holders of water rights along the mainstem of the Colorado River are willing to enter into market-based transfers. However, the protracted and highly divisive dispute between California's Imperial Irrigation District and San Diego demonstrates how politically volatile such transfers can become.

### **Sub-Area Management or Ability to Manage Local Water Levels to Avoid Negative Impacts**

Safe-yield is an AMA-wide goal based on total inflows and outflows to the basin, a water budget balance that does not prevent over-pumping within localized areas in the AMA if they are offset by groundwater storage elsewhere. These localized groundwater problems can have significant impacts, such as subsidence of the ground or dewatering of surface flows. The Governor's Water Management Commission discussed this topic in detail, but no resolution was proposed.

### **Addressing Unique Management Issues in the AMAs**

Meanwhile, the Prescott AMA seeks to determine how much groundwater it can reliably withdraw from its aquifers and to import new groundwater supplies to support its rapid growth without harming the Verde River and the quality of life that attracts that growth. The relatively "young" Santa Cruz AMA must develop its AWS, recharge and well spacing programs to facilitate conjunctive management, meet its unique goal, and deal with the uncertainties associated with its surface water supply and ensure the flow of effluent from an international treatment plant, given that Mexico has a legal right to that water supply. The Pinal AMA is working to simultaneously meet the needs of agriculture and growing municipal and industrial uses by examining

their AWS Rules and mechanisms to bring in renewable supplies for both municipal and industrial growth and by considering recharge and recovery strategies by amending the AWS rules to focus more fully on ensuring a renewable supply. The Tucson AMA continues to work through issues related to current and future utilization of CAP water, including storage and recovery needs. The Tucson area will need considerably more water stored for reliability than can currently be paid for by the AWBA in order to offset future shortages in municipal deliveries.

Planning for recovery of the millions of acre-feet stored by the AWBA in the Pinal and Phoenix AMAs awaits attention and may prove to be expensive and somewhat controversial. Major Indian water settlements await approval, and severe drought conditions only exacerbate the issues. While much has been accomplished, much work remains for the water managers, policy makers and the public in the AMAs. **Of particular importance is building the necessary institutional capacity and long-range planning and technical assistance capabilities to meet these needs.**

### **Integrating Water Quality Management with Water Quantity**

Water quality problems affect the water supply picture within the AMAs in different ways depending on the concentration of contaminants, the existing treatment capacity and cost and the size of the water provider. The changing regulatory environment and perceptions of risk related to water quality both have a substantial impact on quality-related management decisions. Emerging water quality concerns such as pharmaceuticals and other contaminants in effluent used for recharge also must be addressed and overcome. Likewise, options for responding to the increasing salinity of the water supply will be an ongoing debate.

### **Need for Regional Coordination**

Water interests within the AMAs have made great progress in working together on a regional basis to resolve issues of mutual concern. Regional coordination will continue to be of great importance in the future as competition for supplies increases. This will be of particular

importance in achieving economies of scale for recharge, recovery and transportation infrastructure.

## Chapter 7

# WATER SUPPLY AND MANAGEMENT BEYOND THE ACTIVE MANAGEMENT AREAS

KATHY JACOBS AND SHARON MEGDAL

The Groundwater Management Act (GMA) has provided a sound framework for water management in the Active Management Areas (AMAs). This chapter discusses state, watershed and community-based regulatory and non-regulatory efforts to manage water supplies for municipal and industrial purposes *outside* of AMAs. Water supply availability and other rural water issues also are addressed in this chapter. Beyond the boundaries of the AMAs, there are few regulatory programs addressing groundwater management, very limited opportunities to access imported water supplies and only sporadically reported water use data.

### ACCESS AND AVAILABILITY OF GROUNDWATER, SURFACE WATER AND EFFLUENT

From a water supply perspective, access to imported surface water is the major characteristic that distinguishes the central Arizona AMAs (Phoenix, Pinal and Tucson) from the rest of the state, including the Prescott and Santa Cruz AMAs. Many communities and tribes along the Colorado River in western Arizona have Colorado River water contracts and, consequently, their water supply circumstances differ markedly from other parts of the state. For those without contracts or with allocations smaller than their needs, legal access to Colorado River water remains an issue.

Water providers and communities throughout the state are concerned about access to water supplies sufficient for future growth. Although effluent use is prevalent in major municipalities, that source is relatively rare in the rest of the state. Outside of the AMAs, effluent is now a significant source of supply only for Flagstaff, Payson, Sierra Vista and a few smaller commu-

nities, such as Tusayan.

There are two major water supply distribution systems in the state, the Salt River Project (SRP) and the Central Arizona Project (CAP). The watershed of the SRP system extends significantly beyond the AMAs, but the benefits accrue primarily within the Phoenix AMA. SRP, which began operating in 1903, was the first multi-purpose federal reclamation project and currently delivers more than a million acre-feet of water to its water service area of 240,000 acres and other lands in the Phoenix metropolitan area. On average this supply is about two-thirds surface water and one-third groundwater. The CAP system is interconnected with the SRP system, providing maximum flexibility for conjunctive management. This has proven to be extremely beneficial in the context of the recent drought, but does not result in enhanced water supplies outside the AMAs.

Availability of water supplies has multiple components. Physical access to water is the limiting factor in many places where there is no surface water and where groundwater may be either very limited or difficult and expensive to withdraw. Reliability of supply also is important, since some supplies are subject to seasonal or drought-related shortages. In some cases, physical availability is not a problem, but there are legal impediments to the use of the water such as a senior water right holder with a court decreed right to a particular supply. Financial access is the third major challenge. If water supplies are available and water rights issues are resolved, there still may be inadequate financial resources to build the required distribution and/or storage system.

If major new pipelines or canals are constructed in the future to transfer water supplies within the state, financial constraints may require a federal partner in the project. In some cases, the partnership may develop as a component of Indian water settlements. Among the options that have been evaluated is the piping of Colorado River water from Lake Powell south to Flagstaff and then west to Williams and also east onto the Navajo and Hopi Reservations. Multiple other water transfer, storage and exchange options are under consideration, including some that focus on moving groundwater from one location to another. Water transfers generally entail multiple

legal, economic and political issues that may prove difficult to overcome. Currently transfers of groundwater between basins are prohibited except for specific exemptions.

Communities that have considered the need to import water supplies to address expected increased demand include Williams, Flagstaff, Grand Canyon Village-Tusayan, Pine-Payson-Strawberry, Sierra Vista, the Navajo and Hopi Reservations and municipal users inside the Prescott AMA.

## **WATER MANAGEMENT**

### **Water Adequacy Program**

As a consumer protection measure, a statewide water adequacy program has been in place since 1973. The Water Adequacy Program, described in A.R.S. § 45-108 and in rules adopted by the Arizona Department of Water Resources (ADWR) in 1995 (R12-15-715—R12-15-725), requires subdivision developers to obtain a determination from the ADWR regarding the availability of water supplies prior to marketing lots. Developers are required to disclose any inadequacy of supply to potential buyers, but subdivisions can be and frequently are approved in areas where the water supply is inadequate. Furthermore, the disclosure is required only in the initial public report and, therefore, subsequent buyers generally are unaware of the water supply conditions. In many cases, developers do not even submit hydrologic information to request an adequacy statement and simply request that the department quickly issue them their inadequacy letter so they can proceed with the approval and marketing of the subdivision.

Within the AMAs the Assured Water Supply (AWS) Program does not allow new subdivisions if the water supply is inadequate to serve the proposed use for 100 years. However, the Water Adequacy Program is the only regulatory mechanism addressing water supplies for new subdivisions outside of AMAs. Although the authority of the ADWR does not ensure adequacy of water supplies for new subdivisions outside of AMAs, other jurisdictions have even more limited authority to address the connections among land use, population growth and water supply. This situation is particularly frustrating to county land use jurisdictions, which have more



limited powers than cities and towns to deny approval of, or limit the size and density of, new subdivisions. In spite of the limited authorities available to counties, efforts have been made to coordinate land use plans with water supplies (Appendix N). The Water Adequacy Program is clearly an insufficient tool to coordinate water supply with land use and population growth, yet it currently is the only regulatory tool available.

### **Growing Smarter Water Planning Efforts**

An effort to address growth-related issues and urban sprawl resulted in the passage of the Growing Smarter Act of 1998 and the Growing Smarter Plus Act of 2000. Taken together, the Growing Smarter legislation was intended, on the one hand, to provide a framework for comprehensive land use planning and zoning, including the acquisition of open space and, on the other hand, to give residents of Arizona cities, towns and counties some tools to shape growth in their own communities. The legislation includes the right to vote on general plans and restrictions on how general and comprehensive plans can be amended. Growing Smarter Plus requires a water resources element from: (1) municipalities with a population over 2,500, unless they have a population under 10,000 and have an annual growth rate of less than two percent and (2) counties with populations greater than 125,000. There are four counties and 23 communities outside of AMAs that are required to produce a water resources element under these criteria. The legislative language (Appendix O) requires identification based on existing data for:

- Known legally and physically available supplies,
- Future demand for water, and
- How demand will be served by currently available supplies or a plan to obtain the necessary supplies.

In 2003 ADWR circulated a questionnaire that was sent to all cities, towns, counties, Indian tribes and water providers to identify water issues and concerns outside AMAs. The county version of the 2003 ADWR Rural Water Resources Questionnaire included multiple

questions related to the Growing Smarter legislation and its effectiveness. Findings included observations that:

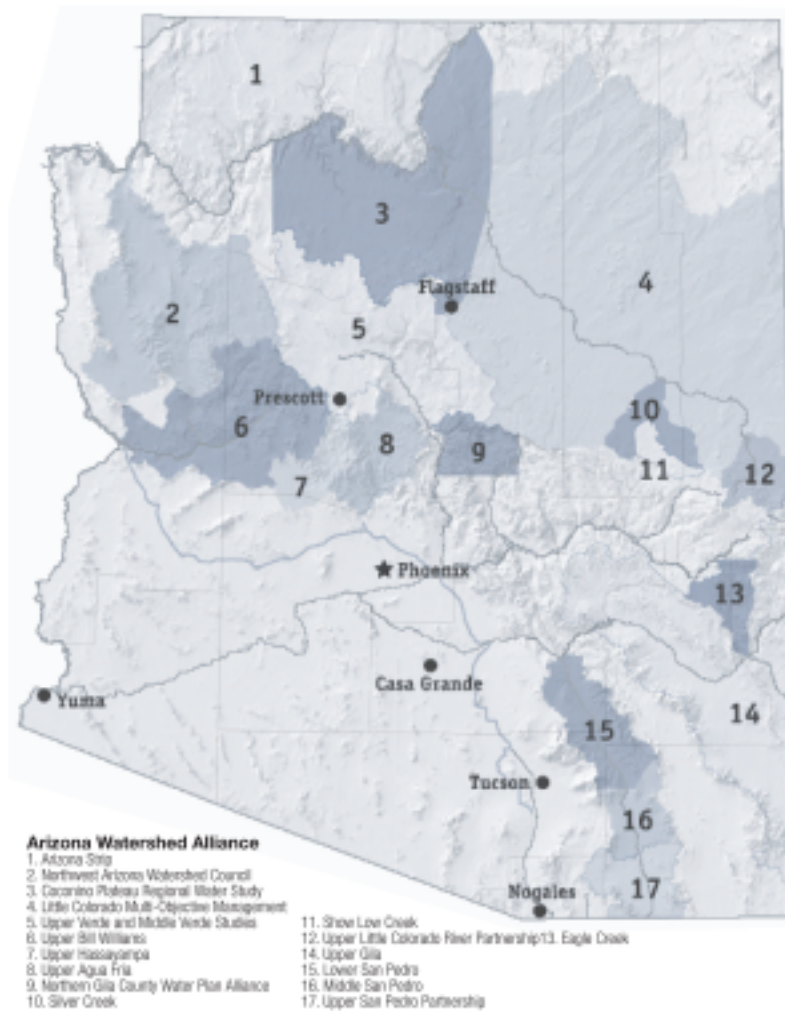
- The Growing Smarter legislation appears to have had a very limited impact on improving the coordination between water management and population growth;
- Although many non-AMA jurisdictions have reported that this was a useful exercise, data are inadequate for meaningful planning, and the lack of enforcement means that the effort will be very uneven at best;
- No new state financial resources have been provided to counties or communities to develop the needed information; and
- Although the legislation appears to give counties some authority in water resource planning, the focus seems to be on looking for water resources to facilitate projected growth and not on considering the impacts of growth on available water resources or developing a “carrying capacity” concept.

Counties have found preparation of the water resources element to be difficult. The requirement is particularly difficult for the many rural municipalities that have no control over the water suppliers within their jurisdictions. This means that the entities that actually run the water systems and decide who to serve are not within the control of the land use planning authority and themselves have no planning requirements. There frequently is little coordination between the water companies and those who must submit the water resources element. The principal benefit of the requirement for a water resources element is that it has made apparent the critical lack of information and coordination in rural areas of Arizona. Within AMAs, the Growing Smarter legislation appears to offer no benefit not already provided by the AWS Program.

### **Watershed Initiative Efforts**

The call for an increasing focus on water issues in the non-AMA portions of the state began to emerge during the mid-1990s. The ADWR encouraged these areas to form regional groups of stakeholders to work towards local solutions to watershed problems. **With technical assistance from the ADWR, 17 watershed groups formed to conduct water resource stud-**

Figure 7.1  
**Arizona Watershed Alliance**



**ies and evaluate management options.** Figure 7.1 illustrates the Arizona Rural Watershed Initiative participants. Several of the watershed groups were started as part of a water quality planning effort by the Arizona Department of Environmental Quality, while others were initiated in response to the Watershed Initiative effort of the ADWR. The groups vary substantially in terms of resources and staff support, ranging from the Upper San Pedro Partnership that receives significant funding from the federal government, has staff support and a well-articulated mission, to other groups that do not meet regularly, have no staff support and an unclear agenda. Of the 17 watershed groups established through the ADWR Rural Watershed Initiative, 15 are actively

working on regional solutions to water problems with the ultimate goal of developing a comprehensive water resource management plan for each. The Coconino Plateau Water Advisory Council, the Upper and Middle Verde Groups, and the Upper San Pedro Partnership are the most active and have the most resources available to them. The groups formed the Arizona Watershed Alliance in 2000 to enhance coordination and raise the visibility of their issues.

The Rural Watershed Initiative was funded by the Legislature in 1999 at \$1.2 million to assist the groups with development of information to support water resources planning in their areas. Although funding has diminished since then, matching funds from other entities have assisted in keeping key projects funded and moving. The main projects funded by the Initiative are U.S. Geological Survey hydrologic studies in the Coconino Plateau, Upper and Middle Verde, Mogollon Highlands and San Pedro areas. None of these studies has been completed to date, although preliminary work products are available.

Key issues for the watershed groups are: (1) most are entirely volunteer groups, with no paid staff, and thus are severely constrained in their ability to accomplish a cohesive planning effort; (2) inadequate hydrologic data; (3) key players, such as the managers of water companies, are in many cases not part of the conversation; and (4) the multiple water management entities involved have little incentive or ability to forge regional cooperative efforts. The absence of key players makes meaningful planning very difficult. If the development of a readily accessible rural water supply database is to occur, significant investments are needed.

The Watershed Initiative is focused on locally initiated efforts to manage water supplies. The key advantage to this approach is empowering local citizens to find solutions that match the specific problems in their own regions. However, given the strong private property rights sentiment in rural Arizona, it is not clear that all of the watersheds can find meaningful solutions that generally are acceptable to the residents. A key issue is the lack of water management and land planning authority.

In addition to the Rural Watershed groups, there are multiple other water-related groups that address issues in the non-AMA portions of the state. They include the Navajo Nation's

Municipal and Non-municipal Task Forces, the Oak Creek Canyon Task Force, the Mohave County Water Authority, the Yavapai County Water Advisory Council, the Northern Arizona Municipal Water Users Association and the Verde Watershed and Natural Resources Association.

### **Regional Water Management**

There is interest in the non-AMA areas in establishing regional water management entities to oversee the planning and management of water resources within watersheds. This issue was raised as a top priority at the Arizona Watershed Alliance meeting in Globe in December of 2002 and has continued since then to be discussed in various forums, including Representative Tom O'Halleran's "Water Group," an ad hoc group of interested parties. **Many rural entities are concerned that state-level regulatory entities will not develop appropriate solutions to local problems, and that local management would be more acceptable.** However, there are very significant legal, financial and representational issues that need to be resolved if effective regional entities with the legal and financial capability to implement water management solutions are to be established. Experience with one such district, the Santa Cruz Valley Water District within the Tucson AMA, demonstrated that such issues could undermine the structure of the local entity, despite good intentions. The Santa Cruz Valley Water District was begun under provisional authority but was unable to resolve taxation and representation issues and dissolved prior to final establishment (Megdal, 2003).

Land use planning entities, particularly counties, are frustrated that they do not currently have authority to consider water adequacy in approving new subdivisions. Although several counties historically have used inadequate water supplies as a rationale for denying a subdivision plat, the practice is not widespread. New subdivisions are allowed under the Water Adequacy Program outside of AMAs even if the water supply is found to be inadequate by ADWR. The only legal requirement is that the inadequacy finding be disclosed in the public report for the initial owners of lots in such subdivisions. There have been numerous discussions of ways to

resolve this issue so that counties can have discretion to deny subdivision plats without being in conflict with state statute. However, clear Arizona legislative authority for counties that choose to use water supply availability, as determined by ADWR, as a condition of platting or zoning could be an effective tool.

### **Conservation Efforts**

Most potable water conservation efforts to date have occurred within AMAs, though there are notable exceptions such as the Town of Payson, the Upper San Pedro Partnership and the City of Flagstaff. Statewide conservation efforts have been very limited. Governor Napolitano's Executive Order of March 2002 establishing the Arizona Drought Task Force contains a requirement to "[d]evelop and implement a statewide conservation education strategy that emphasizes educational advertising for good water habit development" and to form a work group on Conservation Education to "design an educational advertising plan for use in water conservation education throughout the state, but focused on rural areas." The statewide conservation strategy currently is under development, but some educational programs now are promoted widely throughout the state.

Payson, for example, distributes conservation literature, has a rebate program for conservation investments, adopted conservation-oriented ordinances restricting turf and requiring low water-use landscaping and waterless urinals in public restrooms, has conservation-oriented hook-up policies, applies short-term water restrictions in response to drought and reuses its wastewater for recharge and irrigation. Flagstaff uses all of the same methods except for conservation-oriented hook-up policies and significantly has restricted outdoor watering year round in response to drought.

Conservation opportunities exist outside the AMAs, in particular because many delivery systems are not fully metered. However, potable water use on a per capita basis in the rural parts of the state is relatively low in comparison to the larger urban areas. This is in part due to the lack of available surface water for landscape irrigation. In addition, some parts of the state lack ad-

equate water delivery infrastructure. For example, water users on the Navajo Reservation, where up to 50 percent of the rural residents haul their own water, use as little as ten gallons per person per day. Many rural communities are resistant to the idea of conservation regulations since they witness the higher water use rates within the AMAs. However, the differences in temperature and precipitation throughout the state do result in higher demand for landscape water in the lower desert areas, so these factors need to be taken into account when assessing water use efficiency. Demand reduction is an option in some rural areas, but conservation yields are limited in cases where there is already little discretionary water use.

Conservation opportunities in the non-AMA portions of the state include:

- System improvements to reduce leaks and enhance monitoring,
- Expanding the use of meters,
- Price-related conservation signals, such as rate structures that charge more for higher volumes of water use,
- Ordinances limiting high water-use landscaping and encouraging appropriate landscape irrigation design and scheduling,
- Financial or other incentives for replacing high-water use fixtures with conserving appliances, removing high water-use landscaping, incorporating water harvesting (collection of storm water), gray water (water from sinks and washing machines) and effluent for landscape applications in new developments, and
- Conservation-oriented hookup policies and building code provisions.

Results from the Rural Water Resources Study questionnaire indicated that many water providers in rural Arizona would like assistance with establishing or expanding their conservation programs. There is a high degree of interest in conservation as a water management tool, but it has not been a high priority for many providers who may not have the resources or training to pursue it. A statewide conservation office that would assist with conservation technology and information transfer has been proposed on multiple occasions but has not yet been established.

### **Local Drought Planning and Mitigation Efforts**

Significant impacts of drought outside of the AMAs include: ranchers reducing herd size by two-thirds statewide over the past five years; severe wildfires in the mountains; widespread



bark beetle infestations and die-off of up to two million ponderosa and pinyon pines; forest closures limiting recreation opportunities; and health and safety concerns in many municipal supply systems due to inadequate water supplies. The visibility of this issue has resulted in strong interest in developing a state drought plan in order to limit such impacts in the future, with particular focus on rural areas. Drought response efforts to date have focused entirely on reactive mechanisms, such as hauling water, that may not reduce risk in the longer term.

The Governor's Drought Task Force has focused on the need for drought planning within rural communities because the major metropolitan areas have more water-supply options available. Assessment of vulnerabilities and development of mitigation strategies is expected to be an ongoing process in the hope that the impacts of future droughts will be less substantial. However, the lack of alternative supplies in many rural areas leaves them with a high degree of vulnerability.

Legal limitations on the ability to transfer groundwater across basin boundaries also pose some unique challenges in the context of drought. The 1991 Groundwater Transportation Act was intended to protect rural areas from having their water exported to the AMAs to meet AWS requirements. The Act, along with 1993 amendments, prohibits moving groundwater from one basin to another, with certain specified exceptions. Ironically, it is now the rural areas that seek to move groundwater from one basin to another in order to alleviate severe shortages outside the AMAs. Exceptions to this prohibition have been allowed by ADWR permit, pursuant to annually re-adopted emergency legislation each year, over the last few years of severe drought conditions.

One focus of the Operational Drought Plan is on improved monitoring of climate conditions and impacts as well as on enhancing the reliability of municipal supply systems. However, individual well owners in shallow and fractured rock aquifers, where productivity may be very low, often feel drought impacts. High densities of domestic wells exacerbate the drought impacts in some areas. The ADWR is monitoring public contacts related to individual well problems, but this is a more difficult issue to address than water supplies for larger water systems. The Arizona



Drought Preparedness Plan currently is evolving and the specific structure of the adaptation and mitigation efforts is not final.

Other than the Navajo Reservation, which recently adopted a sophisticated drought plan with assistance from the Bureau of Reclamation and the National Drought Mitigation Center, no communities or jurisdictions outside of the AMAs have officially adopted drought plans. Jurisdictions and water providers that have had specific problems meeting water demand in their areas have instituted drought-related conservation requirements and water use restrictions such as those in Flagstaff and Payson. However, these were not in the context of a long-term drought response or mitigation plan.

Curtailment plans exist for roughly 30 private water providers regulated by the Arizona Corporation Commission (ACC). Some of these plans have been put in place in response to emergency conditions experienced within the provider's service area. Others were implemented as part of a revised ACC standard procedure that requires these plans as part of the implementation of a new rate structure. The curtailment plans are not focused specifically on drought, but instead on any problem that can cause a shortage of available supplies. In addition, they are not focused on adaptation or mitigation options that would prevent the shortage in the first place. Instead they focus just on restrictions of customer use during the duration of the problem. However, once they are in place, they provide the water company with authority to restrict water deliveries to their customers in order to avoid more serious consequences.

A recommendation in the draft Drought Preparedness Plan is that all communities adopt a drought plan for their own community. It is not clear at this time whether this recommendation will become a requirement, and whether resources to support such activities will be available.

## **OTHER WATER ISSUES**

### **Water Supply and Growth**

The connection between water supply problems, drought and growth is complex. A traditional perspective is that water supply availability is an incentive for growth, and that lack of supplies is a significant disincentive. Yet, water is being hauled from standpipes (water supply

valves used for filling tanks) and from larger communities as a regular business practice in much of rural northern Arizona even in the absence of drought. The willingness to haul water may mean that the theory that inadequate local water supplies limit growth does not apply. Still, it is impractical and shortsighted to build communities without access to dependable water supplies. **Many communities, especially in northern Arizona and on the Mogollon Rim, already have hit a threshold relative to their ability to serve new customers.** However, the absence of an enforceable water adequacy requirement means that most of these communities continue to grow even though their water supplies do not. There clearly are health and welfare implications, and state and federal agencies already have been involved in “bail-out” activities, *e.g.*, water hauling, that do not increase the likelihood of the development of a long-term solution.

### **Exempt Wells and Lot Splitting**

“Exempt wells” are domestic wells with a maximum capacity of 35 gallons per minute. They are exempt from regulation statewide, except that they must be registered, a Notice of Intention to Drill must be filed with ADWR and they must be drilled by a licensed well driller in accordance with state well construction standards. Exempt wells are common in rural Arizona and are the primary source of drinking water in many areas, particularly where lots are split without going through the subdivision process. A significant increase in the number of exempt wells being drilled has been documented in every county in the state. In most counties, the number of exempt wells drilled quadrupled between 1997 and 1998, and the high rate of well drilling continued through 2002. There are significant restrictions on the use of such wells, including the requirement to have a water right in order to use them and annual measurement and reporting of water use.

In the ADWR Rural Water Resources Study Questionnaire, virtually all counties indicated that lot splitting and exempt wells were a major concern, though only five water companies indicated exempt wells affected water availability for their company. Under current Arizona real estate law, parcels can be split into up to five lots without requiring subdivision review. This

practice is prevalent in rural, unincorporated parts of the state, and in many cases is the primary source of new residential lots.

Since 1977 there have been efforts by the County Planning Directors to address the issues associated with parcel splitting. Because a significant proportion of growth in rural communities is occurring through this unregulated, unmonitored process, often referred to as “wildcat subdividing,” coordination of land use and water supply availability is needed. Other impacts associated with lot splitting include multiple problems associated with road-building, maintenance and access, inadequate sewer, water, solid waste, electric and gas service, health hazards and erosion associated with dirt roads, inadequate addressing and road systems for emergency response, lack of flood and fire protection and inadequate school facilities.

The primary means of providing water to areas with multiple parcel splits is through exempt domestic wells, and the vast majority of lots are served by septic systems rather than sewer facilities. Installing exempt wells too close to septic systems can result in health hazards. In many cases the water supply for multiple domestic wells that are in close proximity to each other is inadequate. Multiple exempt wells in close proximity to each other may dewater the area if the aquifer is not very productive, leading to the need to deepen wells, drill new wells or haul water. Although those who split lots into multiple parcels reduce their own development costs by not going through the subdivision process, there are substantial taxpayer costs associated with bringing such developments up to county codes when improvements eventually are made. These public costs could be reduced if the services were planned for prior to development and easements for access were provided. The Arizona Department of Real Estate, with responsibility for enforcing the subdivision laws, has limited compliance capability. Illegal lot splits generally are investigated after the fact, and there is little recourse at that point.

Legislative efforts to address the lot-splitting issue occurred in 1978, 1994, 1995, 1997 and 2000. The Growing Smarter Plus legislation in 2000 required an affidavit from the seller to the buyer in a lot-split, disclosing information regarding access, roads, utility availability, wells and septic tanks. The buyer is required to record the affidavit. However, the overall issue is

largely unresolved and in some ways counties are now more restricted than previously in their ability to address lot-split issues. A subdivision was defined as four or more lots prior to 1994. Legislation changing the definition to six or more lots actually exacerbated the problem by increasing the number of lots that can be created without going through the subdivision process.

### **Inadequate Data and Resources for Planning**

Virtually all watershed groups and communities outside of the AMAs are hampered by inadequate hydrologic information, although some basins, such as the Upper San Pedro, have been extensively modeled. Most counties and jurisdictions also have indicated that they have inadequate information with which to plan for future water needs. This was a priority issue at the Arizona Rural Water Planning Conference held in Globe in December 2002. **Groundwater supplies are very difficult to estimate in undeveloped areas.** As more wells are drilled, there are increased opportunities to log the aquifer characteristics and measure water levels. Even in basins that have a significant number of wells, however, there may be inadequate drilling logs.

The AMAs have a great advantage over areas of the state outside the AMAs regarding the availability, amount and quality of information. Since 1984, all water pumped from wells over 35 gallons per minute in AMAs has been required to be measured and reported to the state by the well owners. This has resulted in an excellent database. **There is virtually no annual pumpage information outside of AMAs because metering is not required.** This also limits the ability to encourage efficiency in water delivery systems, since losses are generally not calculated. Without measured pumpage data, it is difficult to correlate changes in water levels with inflows and outflows to an aquifer. A basic inflow-outflow calculation for a basin is key to understanding whether additional growth can be sustained in the area.

### **Well Spacing**

Within AMAs, new large (non-exempt, over 35 gallons per minute) wells are evaluated for impacts on other wells in the vicinity before they are permitted. If the impact of the new well

will exceed ten feet of additional drawdown over a five-year period, the application will be denied unless the impacts are mitigated. Outside of AMAs, there are no well spacing requirements. This is yet another way that rural areas are at a disadvantage, because water users are not protected from impacts of new large wells.

### **POTENTIAL CHANGES IN INSTITUTIONS, POLICIES AND REGULATIONS**

Over the past few years, legislative proposals have been discussed that would address some of the issues described above. These include provisions to allow counties to consider a finding of inadequacy of water supply in platting decisions, requirements for a regional evaluation of water supplies in the context of Growing Smarter water elements, limitations on new exempt wells within municipal water service areas, provisions to control lot splitting and requirements that 100 years of water be available for new developments outside of the AMAs. Though the specifics of these proposals continue to evolve, there is considerable controversy. It is not clear that an AWS provision for areas outside the AMAs could require use of renewable supplies as they do within the AMAs, since there is no CAP supply available and other renewable sources are prohibitively expensive in many areas. To date, there has been resistance to the introduction of any form of assured water supply requirement in the non-AMA areas of the state.

Though watershed groups and local jurisdictions have supported the establishment of regional water management entities, questions remain about how such groups would interface with state regulatory authorities, whether effective programs can be implemented on a voluntary basis, who will have authority to implement and enforce any regulatory provisions and how the efforts would be funded. Legislation passed in 2003 did authorize the formation of voluntary, multi-jurisdictional water infrastructure financing authorities to assist smaller jurisdictions in joining together to fund infrastructure projects.

By establishing different management goals and allowing for the development of AMA management plans, the GMA recognized that water management activities need to be tailored to

local conditions. Aside from major differences in physical water supply availability, communities differ in attitudes about the need for new regulations, potential for access to renewable supplies, acceptability of proposals to transfer water and in ability to pay for technical assistance and new infrastructure. These differences make implementation of a rural regulatory framework challenging and may require an incremental approach.

### **DRIVERS IN LOCAL WATER MANAGEMENT EFFORTS**

Despite the challenges associated with the diversity of water sources, geohydrology, environmental considerations and growth rates, progress toward developing and implementing water plans is being made in some non-AMA areas. Why? Progress can be attributed to the existence of “drivers” or external pressures on the system, as illustrated in the following examples.

#### **The Upper San Pedro Partnership**

Key drivers here are the need to maintain water flows for endangered species and to preserve the San Pedro Riparian National Conservation Area, while protecting Fort Huachuca and development in the Sierra Vista area. The futures of the Fort, riparian areas and endangered species all have federal as well as local implications. The combination of these major concerns resulted in the formation of the Upper San Pedro Partnership, historically an organization that was voluntary and consensus based, made up of local jurisdictions, federal and state agencies and environmental interests. They have now been given a federal mandate to produce a plan that would ensure a sustainable water supply, with specific reporting deadlines. Funding for necessary studies has been abundant because of the significant federal interest and the involvement of several members of Arizona’s Congressional delegation. The area has been studied for some time to determine if hydrologic conditions warrant the formation of an AMA. The area also is important to environmental interests due to high biodiversity and bird habitat. Without the high level of concern by various parties, and the financial resources that have been made available, it is unlikely that the Partnership would have been as successful as it has been.

### **The Upper and Middle Verde Watershed Groups**

Key drivers in this region relate to meeting the water needs of a rapidly growing region in a way that does not adversely affect the environment that is largely responsible for the quality of life and economic vitality of the area. Concerns are focused on ensuring continued flows in the Verde River as well as protecting endangered species, while providing for continued growth. Addressing issues in this region is complicated by the fact that part of the watershed falls within the Prescott AMA. There are more than 20 associations and citizen groups interested in addressing these issues, including the Yavapai County Water Advisory Committee that is staffed full-time by the County. Recently a consortium was formed to enhance communication and collaboration. Even though many studies have been done and are underway, more work remains. Recent deliberations regarding the Yavapai Land Exchange, which would exchange federally owned land for private land in disconnected parcels, have engaged Arizona's United States senators in the discussion. Federal legislation has been contemplated, modeled to some extent on the Upper San Pedro Partnership, that would provide financial resources as well as a requirement to develop a plan.

### **The Colorado Plateau**

The Colorado Plateau is an area with diverse populations and geography. The main driver is the need to supply water to meet Indian and non-Indian demands in the face of limited access and/or rights to renewable water supplies. There are concerns about the impact of the Peabody Coal operation on water supplies and important springs across the Hopi and Navajo lands. The City of Flagstaff has successfully used a variety of conservation measures that have reduced per capita water use one percent per year since 1990. Although Flagstaff has made strides in reducing water use, the city and others in the region have yet to agree upon plans for augmenting water supplies. Water rights of the Navajo and Hopi Nations are under consideration by the courts and may ultimately be decided in a settlement agreement with state, federal and local

parties that could result in new imported water supplies, most likely from the Colorado River. However, there are numerous legal obstacles to a solution.

### **SUMMARY**

Water issues outside of the AMAs are challenging, and in some cases ensuring a sustainable water supply may not be possible without importing water from elsewhere. **The impacts of drought are more severe in many areas outside the AMAs because of the limited size of aquifers and the absence of multiple water supply sources, and financial resources are scarce because of the relatively small size of the rural economies.** There are polarized views held by, on the one hand, those whose primary concern is protecting the quality of life that drew them to the area in the first place and, on the other hand, private property rights and development interests. Resolution of the water supply and growth issues will require significant leadership and foresight as well as investments in renewable supplies. Despite these challenges, the likelihood of positive outcomes in the areas listed above seems high because financial resources are available and there is a federal interest in resolution. Also, the magnifying power of drought has helped to reveal the extent of the problem and helped to concentrate the thinking of those involved.





## Chapter 8

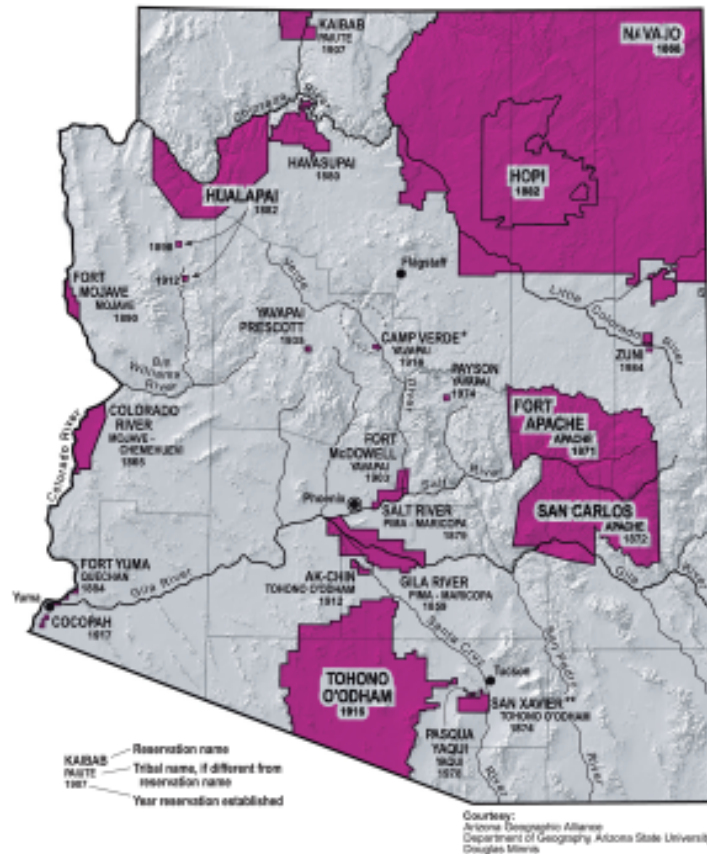
# TRIBAL WATER SETTLEMENTS IN ARIZONA

BONNIE G. COLBY

Indian water settlements will play a crucial role in shaping the future of tribal and non-Indian communities in Arizona. Numerous factors are creating unprecedented pressure to resolve tribal water claims, including the rapid growth of Arizona cities, full appropriation of dependable surface water supplies, declining groundwater levels and environmental opposition to new water development projects. Arizona Indian tribes control large amounts of land and have vast entitlements to water resources. Nineteen Indian reservations account for 20 million acres (28 percent) of the state's land base (Figure 8.1). Some observers have calculated that the water entitlements of Arizona tribes, many of which remain to be quantified, easily surpass the state's surface water supplies, all of which presently are used by other parties.

A complex and sometimes contradictory body of federal and state laws and policies governs the water rights of tribes and non-Indian water users. For decades, litigation was the traditional method to quantify tribal water rights throughout the western United States. In Arizona, the state initiated a specific form of litigation—general stream adjudication—in order to clarify water rights and quantify tribal and federal reserved water rights. Tribal water settlement discussions occur in the context of Arizona's adjudications. The negotiating process in Arizona, while more *ad hoc* and private than in states like Montana, is productive. Parties in Arizona have achieved eight settlements, more than any other state. The leadership of influential members of Congress has helped many of Arizona's settlements. For example, Senator Barry Goldwater and Representative John Rhodes were influential in securing the first tribal water settlement in the United States, the Ak-Chin Settlement.

Figure 8.1  
**Arizona Indian Reservations**



### THE CONTEXT FOR TRIBAL WATER SETTLEMENTS

The Winters Doctrine established the reserved rights doctrine, setting the priority date of water rights for reservations at the date the reservation was established, and the volume of the right based on the purpose of the reservation. In its 1963 decision *Arizona v. California*, the United States Supreme Court reaffirmed the *Winters* doctrine of reserved water rights associated with tribal reservations and established “practically irrigable acreage” (PIA) as a standard for quantifying reserved water rights. This litigation was prompted by Arizona’s need for a determination of its share of water from the Colorado River in order to obtain federal appropriations for the Central Arizona Project (CAP). The United States intervened to assert, among other things, the reserved water rights of the Chemehuevi, Cocopah, Yuma, Colorado River and Fort Mohave Indian reservations on the lower reaches of the mainstem of the Colorado River. These five

reservations have quantified rights to over 900,000 acre-feet per year, with early priority dates making these some of the most reliably and potentially valuable water rights in the southwest *if* freely marketable.

In seeking to use water for the benefit of tribal members, Indian tribes in the arid West face a gauntlet of complex federal environmental laws with the potential to limit much-needed water development on reservations. The construction of community water supply facilities, taken for granted in the rest of the country, is essential to Indian reservations. Water development has only slowly advanced in Indian country, so the rivers and streams that can satisfy tribal water needs frequently also provide the last remaining useful habitat for aquatic species on the brink of extinction. On the Navajo Reservation, for example, approximately 40 percent of the population lacks a potable domestic water supply. While there is a widely perceived value in conserving endangered species and maintaining the habitat on which those species depend, this provides little comfort to tribal members who haul water to their homes. Despite the seniority of tribal reserved rights, Indian tribes encounter difficulties in using their water supplies due to the Endangered Species Act and other applicable federal environmental laws.

These issues are acute in Arizona. Non-Indian communities have understandably sought to maximize the use of water, including transportation of water over great distances or between basins and construction of massive water storage projects. These activities required extensive federal funding and took place with limited attention to environmental consequences. Projects such as the CAP and the San Juan-Chama Project provide water to support large municipal populations and maintain economic growth throughout the regions that they serve.

However, Indian tribes that seek to use water can find themselves at odds with those who oppose the development of new water supplies in the West due to environmental consequences. Existing water supplies commonly are committed to current non-Indian uses that are impractical to dislodge in a negotiations setting.

With the confirmation of the reserved rights doctrine in *Arizona v. California* and the increasing demands for water to meet growing populations and other uses in the area, it became

apparent that the question of tribal water rights could not be deferred forever. Identifying the appropriate judicial forum for hearing cases concerning tribal water rights has been a key issue in Indian water settlement efforts. Under the legal doctrine of sovereign immunity, the federal government and tribes as sovereigns, historically could not be brought into state court to have their water rights determined. This frustrated state attempts to quantify and prioritize all water rights in general stream adjudications of basins where federal reserved water rights exist. In 1952 Congress passed the McCarran Amendment that allowed the federal government to be brought into state general stream adjudications, thereby waiving its sovereign immunity in such matters. Later, the Supreme Court ruled that the McCarran Amendment also applied to state adjudications of Indian reserved water rights, which are held in trust by the United States. The McCarran Amendment and related court rulings do *not* mean that *Winters* rights are quantified according to state law, but only that the extent of the federal reserved water rights can be determined in state court proceedings.

Adjudications are court determinations of water rights volumes and priorities. There are two general stream adjudications ongoing in Arizona: the Gila River Adjudication, covering the southern and central portions of the state and the Little Colorado River Adjudication, covering the northeastern portion of the state. These two cases involve claims to water asserted by individual users as well as municipalities, industrial users, irrigation districts, the State of Arizona and the federal government on behalf of national forests, national parks, wilderness areas and numerous Indian tribes. Both adjudications are over twenty years old. Costs to participants and to federal and state taxpayers have been high and progress has been uneven.

The goal of both adjudications is to assure a comprehensive final determination of two types of water rights: (1) rights subject to the state doctrine of prior appropriation and (2) rights subject to claims based on federal law, including claims for national forests, national parks, wilderness areas and particularly the extent and priority of rights for Indian tribes. Because of the potential magnitude of Indian water rights, uncertainty has existed for some time as to the impact of these rights upon other users. The adjudications are intended to provide a process through

which a certain and lasting determination of Indian rights and the rights of federal land reserves can be achieved, thereby assuring other water users of the relative value and security of their own water uses. Summons were issued in both adjudications and served on potential claimants in each watershed—a million summons in all. The summons required a claimant to file a statement with the Arizona Department of Water Resources (ADWR) if the person claimed a water use in the watershed. More than 24,000 parties in the Gila River Adjudication filed more than 83,500 statements of claimant and over 3,100 parties filed more than 11,300 claims in the Little Colorado River Adjudication.

Legal issues have been the primary cause of delays in the adjudications process. The general adjudication statutes went through substantial legislative changes in 1995. The constitutionality of these amendments was litigated before the Arizona Supreme Court, causing delay in adjudication proceedings until 1999. The Court ruled some provisions of the 1995 legislation unconstitutional, upheld some and required that some provisions applied only prospectively.

The Arizona Supreme Court also has heard arguments on and ruled on several substantial, long-standing legal issues. Two of these decisions are especially relevant to tribal water rights. In 1999, the Arizona Supreme Court held that federal reserved rights extend to groundwater to the extent groundwater is necessary to accomplish the purpose of a reservation. In 2001, the Arizona Supreme Court held that

- The purpose of a federal Indian reservation is to serve as a “permanent home and abiding place” to the people living there,
- The practicably irrigable acreage standard is not the exclusive measure to quantify water rights on Indian lands,
- Quantifying an Indian reserved right is a fact-intensive, reservation-specific inquiry that must address numerous factors, such as a tribe’s land use plans, history, culture, geography, topography, natural resources, economic base, past water use, present and projected future population and any others deemed relevant,
- Proposed uses must be reasonably feasible, and

- The amount of water adjudicated must be tailored to the reservation's minimal need.

Following these rulings, major parties continue to engage in active efforts to resolve Indian and federal reserved rights by negotiated settlement.

In *Arizona v. California*, the United States Supreme Court noted that the quantification of reserved water rights, but not the use of the water, is determined by the purposes for which the reservation was created. Since that time, tribes have used their *Winters* rights for a variety of purposes on their reservations. Negotiated settlements often stipulate specific allowable uses. In the Southern Arizona Water Rights Settlement Act (SAWRSA), for example, the settlement legislation allows the Tohono O'odham Nation's reserved water rights to be used "for any use, including but not limited to agriculture, municipal, industrial, commercial, mining or recreational use." This language is typical of other settlements. While the use of *Winters* rights on the reservation generally has been free of controversy, transferring water use off the reservation has proven contentious.

Tribes have not been authorized to permanently alienate (sell) their reserved water rights, but can, with congressional approval, lease water for use off reservations. Some Indian law scholars disagree on this point, arguing that congressional approval of off-reservation water leases is not required. Nevertheless, Congress has delegated to the Secretary of the Interior the authority to approve leases of Indian land to non-Indians, and some interpret this to include the water needed to fulfill the purpose of the lease. Off-reservation leasing provisions are included in many of Arizona's negotiated settlements. They generate income for tribes, offset the impact of the settlement on local non-Indian water users and, in some instances, help provide consistency with state water management goals. Where off-reservation leasing of tribal water is contemplated in settlement negotiations, the negotiating parties must decide on the extent of protection extended to junior water rights. Protection of non-Indian water users has been addressed in a variety of ways in negotiated settlements. In most Arizona settlements, tribes may lease only their CAP entitlements and only within designated portions of the state.

Tribal water settlements have provided water, under long-term leases, to Arizona cities. Cities in the Phoenix metropolitan area have leased thousands of acre-feet of water from several Arizona tribes, under provisions negotiated as part of overall settlements of tribal water rights. These leases provide a long-term water supply for growing cities and much-needed revenues for tribal governments.

There have been eight negotiated settlements of tribal water rights in Arizona, and several more settlements are in active negotiations (Table 8.1). Appendix P provides more detailed information on the settlements and also on tribal rights confirmed through litigation in *Arizona v. California*. Congressional belt tightening has had an effect on ongoing Indian water rights negotiations. Although over twenty active negotiations have been in process around the West for years, Congress has approved very few settlements since 1994. Arizona was fortunate to get so many settlements through Congress and at least partially funded in the 1970s, 1980s and early 1990s. However, unresolved claims remaining in the Gila River Adjudication and the Little Colorado River Adjudication are overwhelming with respect to the magnitudes of water involved, the complexity of the issues and the expense of settlement provisions proposed by various parties

TABLE 8.1  
**ARIZONA SETTLEMENTS AND PENDING NEGOTIATIONS**  
 (as of March 2004)

<b>Settlement (date authorized by Congress)</b>	<b>Pending Negotiations</b>
Arizona vs. California (1963)	Gila River Indian Community
Ak-Chin (1978)	San Carlos Apache Tribe (Gila River drainage)
Southern Arizona Water Rights Settlement (SAWRSA) (Tohono O'odham) (1982)	Little Colorado (Navajo, Hopi San Juan Paiute)
Salt River Pima-Maricopa Indian Community (1988)	White Mountain Apache
Fort McDowell Indian Community (1990)	
San Carlos Apache Tribe (San River drainage) (1992)	
Yavapai-Prescott Tribe (1994)	
Pueblo of Zuni (Zuni Heaven) (2003)	

The state's comprehensive Groundwater Management Act (GMA) has shaped the character of settlements in Arizona. This legislation, enacted in 1980, is designed to eliminate ground-



water overdraft in selected areas of the state through strict limits on groundwater pumping, mandatory conservation measures and increased reliance on renewable water sources. The state insists that Indian water settlements be consistent with these goals, emphasizing the benefits to tribes and other water users of decreased reliance on diminishing groundwater resources. The constraints imposed by the GMA have resulted in increasingly complex provisions, as evident from comparing earlier and later litigated and negotiated settlements.

Most of the Arizona settlements authorized by Congress in the last twenty years include these key features:

- Provide federal project water to tribes through the CAP;
- Explicitly authorize leasing of tribal CAP water to water users in designated areas within Arizona; and
- Set groundwater pumping limits for the reservation.

### **OVERVIEW OF SELECTED ARIZONA SETTLEMENTS**

The Arizona water adjudications, for all their complexity, delay and expense, have provided impetus for a series of innovative and important Indian water right settlements. One of these, the Salt River Pima-Maricopa Indian Community Settlement (1991), was the first Indian water settlement to be successfully incorporated into a final general stream adjudication decree. Appendix P examines in detail several representative Arizona settlements: Ak-Chin, Salt River Pima-Maricopa, Yavapai- Prescott, Southern Arizona Water Rights Settlement and the Zuni Heaven Settlement. Because of the magnitude of the Gila River Indian Community Settlement and its potential for approval in the short term, it is addressed below.

### **Current Status of the Gila River Adjudication**

In recent years, the principal activity in the Gila River adjudication involves the water rights claims of the Gila River Indian Community (GRIC). Parties in the adjudication entered into settlement negotiations to accomplish a myriad of goals. The GRIC settlement is closely tied

with an agreement between the Central Arizona Water Conservation District (CAWCD) and the Bureau of Reclamation over repayment for CAP costs. In fact, part of the money paid by CAWCD into the Lower Colorado River Development Fund also will be used to implement the settlement of the GRIC's water rights. In exchange for the GRIC accepting a reduced amount of reserved right water, \$200 million from the CAWCD and CAP repayment money will be redirected toward construction costs of a CAP water delivery system onto the Gila River Indian Reservation. Thus, the GRIC would accept a *Winters* allocation of 653,500 acre-feet per year, of which 328,500 acre-feet would be met by CAP water.

Senator Kyl, accompanied by Senator McCain, introduced The Arizona Water Settlements Act in the 107th Congress. A revision of a bill introduced in 2000, the new bill incorporates further negotiations. The new bill has three headings: the Central Arizona Project Settlement, the Gila River Indian Community Water Rights Settlement and the Southern Arizona Water Rights Settlement (SAWRSA). There is no heading for an agreement with the San Carlos Apache Tribe. However, the bill does reference an "Upper Gila" settlement between the Gila River Indian Community and the irrigation districts of the Safford Valley. In addition, the new bill specifically addresses after-acquired trust lands in both the GRIC and the SAWRSA sections. A second major adjustment occurred in the SAWRSA provision of the bill. The new bill states that the pumping right obtained by the Tohono O'odham Nation in the 1982 settlement is not a reserved right to groundwater, but is a right that hinges on the state enforcing well-spacing and pumping protections in the areas surrounding the Nation. The GRIC obtained provisions that limit future increases in groundwater pumping by non-Indian water users located near their reservation. Further, the bill addresses mitigation provisions during sustained drought conditions as well as equitable apportionment of water during drought shortages.

## SUMMARY

Arizona now has a quarter-century of experience in negotiating Indian water right settlements. The experiences recounted in this chapter demonstrate the innovative approaches that

have been employed both to settle past uncertainties and disputes and to plan for the future. Many lessons may be drawn from this rich body of experiences. Settlements take many years and, even when finally approved, the settling parties must give sustained attention to implementation. For agreements to be implemented, they require money for water development or, in some cases, for environmental restoration. Funding is always difficult to secure, especially in an era where state, federal and tribal budgets are stretched thin.

As states, tribes, and federal agencies have gained more experience in negotiating water settlements, problems overlooked in earlier agreements may be avoided. However, only the passage of time can disclose the unique, unanticipated problems of every agreement. Settlements should include procedures for addressing these future problems, and negotiators and their successors must monitor implementation and stay committed to the goals and processes of the agreement.

Most importantly, people make these agreements. Leaders among all the diverse interests have reached out to bring others into the process. Specialists have generated and compiled hydrologic, legal, engineering and economic data. Negotiators have stayed at the table during exhausting, intense negotiations. Elected officials have approved the resulting accords and appropriated money. Even after the excitement of successful legislation fades, people stay committed to the settlement to ensure that water development occurs, watershed improvements are made, unanticipated problems are addressed, needed funds are appropriated and future disagreements are expeditiously and fairly resolved. Fundamentally, Indian water right settlements are about people and creating durable interpersonal relationships in Arizona watersheds.

## Chapter 9

# ENVIRONMENTAL ISSUES AND WATER MANAGEMENT

GARY WOODARD

Arizona's environment and its water resources are inextricably linked. The ways we use water alter the environment, and changes in the environment affect our water resources. Surface water diversions and groundwater pumping have depleted or dried up much of the state's streams and rivers, causing the loss and alteration of extensive areas of aquatic and riparian habitat. Introduction of exotic species has altered grasslands, reduced xeric desert areas and altered species distributions.

A growing number of factors other than water use have contributed to major changes in landscapes and ecosystems over the last 150 years, and the rates of change appear to be accelerating. These land cover changes are affecting our water supplies in ways that we only partially understand.

While these wholesale land cover changes continue, demand for and uses of our state's limited water resources are shifting and increasing. Traditional water uses—agriculture, mining, domestic and industrial—increasingly are competing with new uses, many of them in-stream uses. These include preserving habitat under the Endangered Species Act, supporting water-based recreation and tourism and meeting tribal water claims and the requirements of interstate or international river compacts.

### LAND COVER CHANGES AND WATER SUPPLIES

Land cover, soils and slope largely determine the *partitioning of precipitation* and thereby available water supplies (Figure 9.1). After rain and snow fall to the ground, much of it evaporates, but some runs off to streams and river channels and some infiltrates the soil. Soil moisture can evaporate, be absorbed by plant roots and transpired or infiltrate deep below the surface,

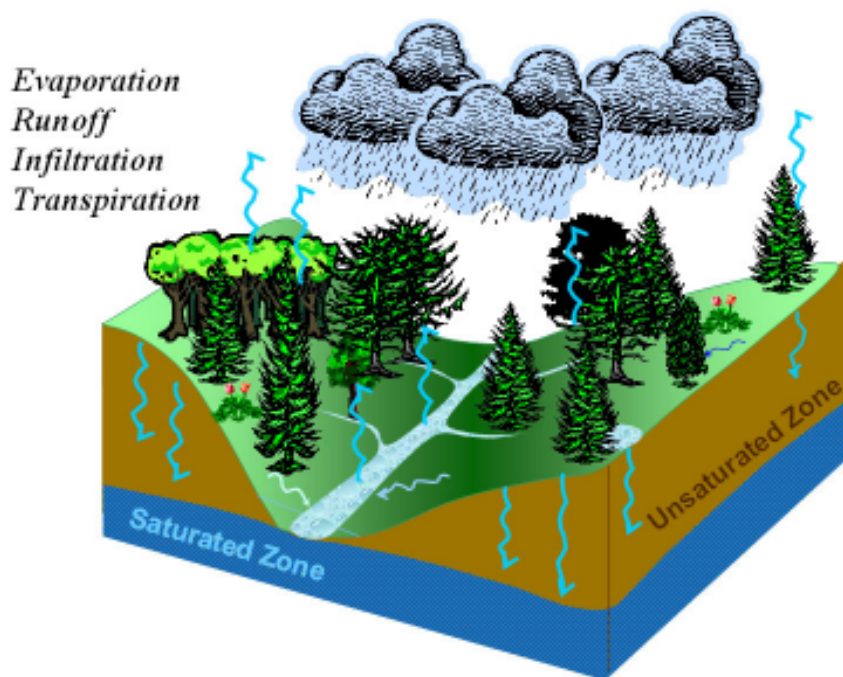


Figure 9.1 Partitioning of Precipitation.

eventually recharging aquifers. Runoff and deep infiltration are the sources of our renewable surface water and groundwater supplies. Evaporation and plant transpiration, collectively known as evapotranspiration or ET, is water lost to the atmosphere.

In most Arizona basins, precipitation and ET are very nearly equal to each other; nearly all precipitation is lost through evapotranspiration. Only a small percentage of precipitation recharges aquifers or runs off to streams and rivers. Because vegetation type and other ground cover characteristics affect ET, they largely determine the rates of runoff and recharge.

Land cover changes therefore affect the partitioning of precipitation, resulting in large increases or decreases in surface water and groundwater supplies. This in turn has major impacts on habitat, flood plains, water quality and nutrients reaching rivers and streams.

Natural and human-built land covers are undergoing rapid and massive change across the state. There are several causes of land cover changes, including:

- Climate fluctuations—drought and flood,
- Clear-cutting of forests in the past and re-growth,
- Wildfire suppression over the last 90 years leading to altered fire regimes,
- Insect infestations,
- Intentional or accidental introduction of exotic species,
- Carbon Dioxide increases in the atmosphere favoring woody species over grasses,
- Climate change increasing temperature, precipitation, evaporation and snow melt,
- Population growth and shifting socio-demographic patterns,

- Suburbs, exurbs, ranchettes and second homes which displace agricultural lands and natural vegetation and reduce infiltration,
- Impacts of farming and grazing, including abandonment of agricultural lands, and
- Damming and diverting surface waters.

Some of these changes, such as one vegetation type crowding out another, occur gradually over many decades or even centuries. Others, such as construction of suburbs or bark beetle infestations, occur in just a few years. High-intensity fire can alter a landscape in weeks or days. Some changes are natural, humans directly or indirectly cause some, and some are caused by a complex and only partially understood combination of anthropogenic and natural events.

### **LAND COVER CHANGES AND HYDROLOGIC IMPACTS**

Examples of land cover change occurring in Arizona are described in the following sections, starting at the upper elevation of the basins and working downward to lower elevations.

#### **Loss of Coniferous Forests**

Over a century ago, Teddy Roosevelt succinctly described the critical importance of forests in water resource management:

*The forests are natural reservoirs. By restraining the streams in flood and replenishing them in drought they make possible the use of waters otherwise wasted. They prevent the soil from washing, and so protect the storage reservoirs from filling up with silt. Forest conservation is therefore an essential condition of water conservation* (President Theodore Roosevelt, State of the Union Address, December 3, 1901).

Arizona's high-elevation coniferous forests, with Ponderosa pine being the most common species, have been described as our water towers. Natural, fire-influenced forests were relatively open, with large trees, meadows and abundant understories of grass and other groundcovers. Historic and more recent events have profoundly altered these forests and their ability to serve as natural reservoirs. Old-growth forests and biodiversity declined initially due to clear-cutting, which produced more runoff, floods and erosion from watersheds. This was followed by a century of fire suppression, in both logged and unlogged areas.



Figure 9.2 Old growth forests had large, well-spaced trees and understories; fire suppression created dense thickets.

But the old-growth forests were adapted to periodic low-intensity fires, which cleared out accumulated fuel loads without killing the larger trees. Over many decades, fire suppression in combination with high precipitation levels from 1975 through 1995 produced dense thickets of stunted trees, shading out understory grasses and forbs, which greatly decreased in abundance and diversity. Montane meadows shrank due to tree encroachment (Figure 9.2). Such forests produce less total streamflow, peak flows and base flows in streams. On the positive side, erosion and sediment loads in streams and rivers were reduced.

Over time, the high density of trees and accumulating deadwood increased fuel loads. Then, in the late 1990s, the current drought began. Many trees have died, or are dying, simply from lack of water. Drought-stressed trees cannot produce enough sap to ward off bark beetles, which have infested vast areas of the state, killing entire stands of trees. The combination of high forest densities, drought and beetles results in extreme fire danger and very large, especially severe forest fires. The last three years have seen an increase in the number, size and severity of stand-replacing fires. Should the current drought continue for two or more years, most of the mature coniferous forests in the state might well be lost.

The impacts of large, severe fires on watersheds are immediate and extreme, and difficult to forecast. In part, they depend on whether any grass or other groundcover can be established before intense summer rains begin. Runoff from previously forested areas that have been se-



verely burned often is increased by a factor of 10 or even 100, resulting in serious flooding and erosion.

Downstream, runoff from burned areas often clogs stream channels with sediment and boulders. Water quality effects include severe short-term turbidity and near-zero dissolved oxygen in streams draining burned areas, which cause fish kills (Figure 9.3). Further downstream, increased nutrients and dissolved organics may promote algae growth in reservoirs. This can deplete oxygen levels, leading to fish kills, and may cause taste and odor problems for municipal water users. Sediments deposited in reservoirs decrease the volume of water that they can store (Figure 9.4).



Figure 9.3 Creek choked by sediment and ash after rain on Chedeski burn area, Arizona, 2002.

Flood plains—areas likely to be inundated by particular storm intensity—are immediately and greatly enlarged by these types of fires, and flash floods can cause property losses and even deaths. Over the ensuing years, as vegetation begins to become re-established, there likely will be more modest increases in runoff and stream base flow due to less water use by vegetation.

### **Pinyon-Juniper Expansion**

Pinyon-Juniper woodlands have increased tremendously over the last several decades and continue to expand across the landscape of Arizona and the West (Figure 9.5). They are spreading both upslope and downslope and becoming denser. Today there are 50 to 60 million





Figure 9.4 Sediments deposited downstream in reservoirs decrease the storage volume.

ment fluxes during heavy precipitation events. Whether overall runoff increased is not clear. Some evidence suggests that periodic recharge events may be increased (Allen, nd; Wilcox *et al.*, 2003).

### Woody Species Invasion of Grassland

Shrubs, such as creosote, have from the early 1880s to today invaded some 150 million acres of grassland in the Southwest, an area roughly the size of Arizona and New Mexico combined (Figure 9.6). Reasons include: overgrazing when

acres of pinyon-juniper in the western United States. There appear to be multiple causes of this land cover change:

*[S]ubstantial changes have taken place in the pinyon-juniper woodlands in the past 150 years ... this period was characterized by: (1) a warming climate following the Little Ice Age, (2) the period of heaviest use by European livestock, and (3) a decrease in wildfire frequency. These factors in combination, enabled [pinyon and juniper] trees to establish in and then dominate new communities, expand to higher and lower elevations, and, more recently dramatically thicken in tree densities and canopies of both existing and new stands (Laycock, 1999).*

The impacts of pinyon-juniper invasion of grasslands on basin hydrology include increased sedi-



Figure 9.5 Spread of juniper near Acoma, New Mexico, 1899 and 1977.

Europeans first reached the area; periodic drought; and increased levels of atmospheric CO<sub>2</sub> that have benefited woody species more than grasses.

At somewhat lower elevations, mesquite rather than creosote is successfully supplanting grasses (Figure 9.7). Such incursions may take decades or occur quite rapidly. In the Upper San Pedro basin between 1973 and 1986, mesquite increased by 415 percent, at the expense of grasslands, which decreased by 15 percent. Runoff is increased with woody species, particularly during heavy precipitation events.

### POPULATION PRESSURES AND DEVELOPMENT

On many desert basin floors, the most noticeable and rapid land cover changes are associated with development. Arizona's burgeoning population, shrinking household size, popularity as a location for second homes and relatively affordable housing, all are fueling a long-term boom in housing construction. Maricopa County continues to be one of the fastest-growing metropolitan areas in the United States, and Pima County is well above average. Some rural Arizona areas are growing even faster, including several communities along the Colorado River and the Mogollon Rim.

Traditionally, most housing developments occurred as urban in-fill or suburbs that displaced irrigated agriculture. Increasingly, development is occurring on raw desert land, often



Figure 9.6 Grasslands being supplanted by creosote in New Mexico.

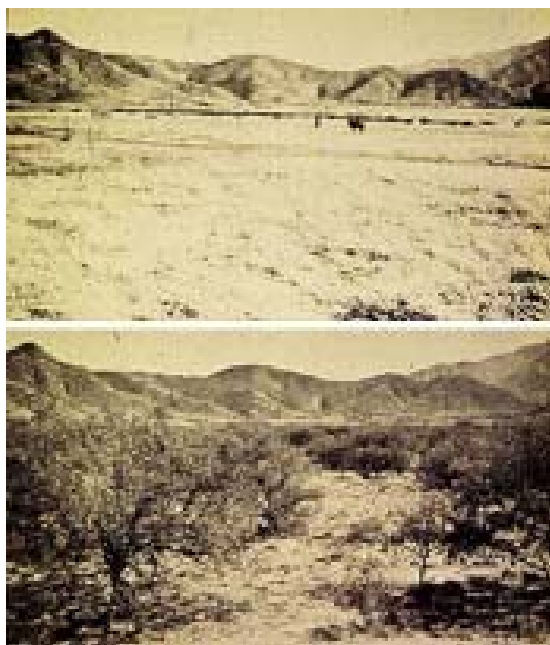


Figure 9.7 Less grass, more mesquite: changes from 1903 to 1941, Santa Rita range, south of Tucson.

well beyond the current urban fringe. Urban development of desert land does not have the benefit of offsetting an existing water use.

### Changing Microclimates in Urban Areas

Urban areas create different microclimates than surrounding areas. Most notable is the “urban heat island” effect, caused by pavement, buildings and masonry walls absorbing heat during the day and radiating heat at night. Phoenix has a pronounced urban heat island effect, especially during the summer. This increases ET rates and the

amount of water needed to maintain landscapes. It also significantly lengthens the growing season, and therefore the irrigation season, for a number of common landscape plants. To date, Tucson does not have a pronounced urban heat island effect.

### Land Use Change and Evaporation Rates

Mesa, Arizona, 1917 - 1985

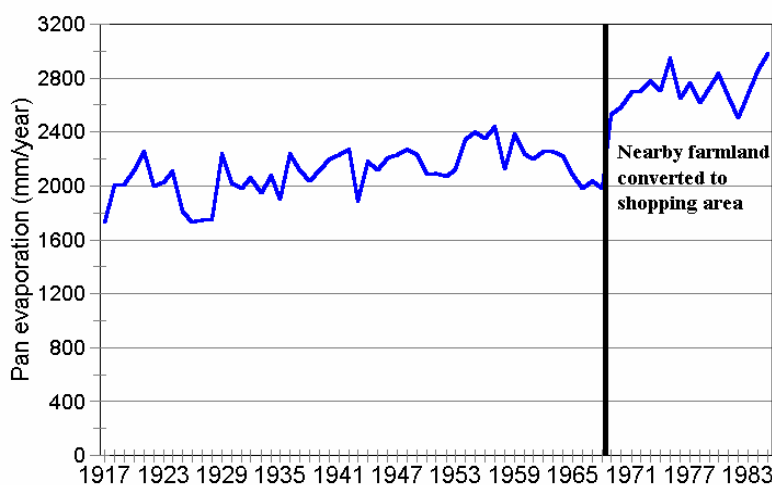


Figure 9.8 Evaporation Rates. Loss of nearby cotton field increased pan evaporation.

Loss of irrigated agricultural lands to development is creating warmer, drier microclimates. A classic example is recorded in pan evaporation data from Mesa, where conversion of a neighboring cotton field to strip mall increased evaporation rates 35 percent (Figure 9.8).

Pavement, rooftops, and other urban “hardscapes” also affect the partitioning of precipitation, increasing the amount and suddenness of runoff to washes and rivers, but decreasing area-wide infiltration. Recent research also suggests that urban areas like Phoenix can affect frequency and location of summer thunderstorms.

### **Impacts on Aquatic and Riparian Habitat**

Dams, surface water diversions and groundwater pumping all have greatly reduced or eliminated the flow of water in many of Arizona’s rivers. Not only does this deprive deeply rooted trees, such as mesquite, of water but under reduced flow regimes, native aquatic and riparian species such as fish, frogs, willows and cottonwoods often are unable to compete with introduced species such as tamarisk (salt cedar). The result is loss or severe degradation of most aquatic and riparian habitat in the state (Figure 9.9).

### **FRESHWATER BIODIVERSITY**

Arizona’s deserts, grasslands, forests and canyons attract visitors from around the world and delight those who live here. This variety of habitats supports one of the most diverse assemblages of plants and animals found anywhere in the United States. Arizona is an arid to semi-arid state with limited surface water. Nonetheless, freshwater systems, including rivers, streams, creeks, cienegas and other wetland types, and their associated riparian habitats, support a disproportionately high number of species relative to their aerial



Figure 9.9 Santa Cruz River as seen from A Mountain, 1940 and 1975.

extent. In addition, riparian corridors provide migratory birds and pollinating insects and bats critical travel corridors.

Satisfying the water demands of a growing population while protecting aquatic ecosystems and ecological services requires a collaborative and informed water management approach that recognizes the value of aquatic and riparian ecosystems, develops the science to understand how water management choices may affect those systems, and works with stakeholders to derive water supply solutions that meet the needs of both human communities and natural ecosystems. Such a water management approach is challenged in Arizona by a lack of legal mandate to consider impacts to aquatic systems and by the legal separation of surface water and groundwater.

As a result, considerable damage has occurred to Arizona's freshwater ecosystems over the past 150 years (Figure 9.10). An estimated 91 percent of natural (unregulated) perennial flow reaches has been lost from Arizona's big rivers—the Salt, Verde, Gila, and Colorado Rivers—due to diversions, reservoir development and groundwater pumping. At least 35 percent of natural perennial flow miles have been lost state-wide (based on Brown, Carmony and Turner, 1981, Map of Perennial Streams). We have only recently begun to understand how natural freshwater ecosystems provide the myriad of services we rely on, including clean water, mitigation of droughts and floods, recharge of groundwater supplies, regeneration of soil and soil fertility, nutrient cycling and extensive recreational opportunities. Many of the top recreational attractions in Arizona are water-based, and hikers, birders, hunters and fishermen are a growing economic force.

The distribution of freshwater biological diversity in Arizona may be illustrated by in part examining the number of native fish species in perennial streams. Arizona's native fish are found nowhere else on earth. They have survived droughts and flash floods for thousands of years. However, human-caused changes are taking a toll. One species, the Santa Cruz pupfish, is extinct and 20 of the 35 remaining native species or subspecies are federally listed as endangered, threatened or candidate for listing under the Endangered Species Act.

Arizona's rivers and streams also maintain Arizona's riparian systems, which support the



highest densities of breeding birds found in North America. Riparian areas, particularly the cottonwood-willow forests, provide migratory corridors for birds, butterflies, bats and many other pollinators that winter in Central and South America and summer throughout the western United States and Canada. Depth to groundwater is a critical factor for many native riparian species.

The most basic need of fish is permanent water. Diverse riparian forests are maintained by the natural hydrologic cycle—floods, periods of base flow and shallow groundwater conditions. The majority of aquatic and riparian habitat in Arizona occurs in streams draining the Mogollon Rim and White Mountains. However, desert streams such as the Verde River, Aravaipa Creek and Eagle Creek exhibit the highest native fish diversity. Important riparian and aquatic diversity also occurs at locations in western and southeastern Arizona with permanent water.

Perennial flow in streams is maintained by discharge of groundwater from adjoining aqui-

Figure 9.10  
**Loss of Natural Flow in Arizona Streams**



fers. Even streams supported by extensive aquifers may eventually be affected by groundwater pumping at locations distant from the streams. Examples include the Verde River and the San Pedro River, where rapid population growth is tapping groundwater aquifers whose discharge maintains high-diversity fish and aquatic habitat.

The National Research Council (2001) has stated that the capability of the nation to successfully meet challenges in water management while sustainably managing its water resources will depend, in large part, on employing new knowledge gained through research. Improved knowledge of groundwater recharge (water in) and discharge (water out) relationships and groundwater-surface water interactions is needed to better understand the consequences of groundwater use.

### **RIPARIAN PRESERVATION**

There has been a growing awareness over the last 35 years that riparian habitats are important for more than biological diversity. They have measurable economic value, their aesthetics are increasingly appreciated and, in general, they enhance quality of life. Our understanding of how riparian areas work—the fluxes of water, carbon and energy, the relationship between surface water and groundwater and native plant communities, and how nutrients cycle through the systems—is incomplete, which makes preservation and/or restoration difficult. Riparian preservation and restoration efforts may include bank protection, fencing to exclude grazing, restoring the natural hydrologic regime, eradicating exotic species and restoring native species.

Experience and research reveal that knowledge of the system is required to avoid failure of preservation and restoration projects. For example, studies by researchers at Arizona State University have estimated the minimum depth to water and flow conditions needed to maintain a healthy cottonwood population. Riverine ecosystems are complex, yet our knowledge of the water needs of these systems, and their attendant services to humans, is increasing.

Restoring base flows can be difficult since Arizona's water laws recognize and reward "development" of water, which means diverting it from a stream to further a traditional economic

or domestic activity. In-stream flow rights were recognized only recently and have junior priority relative to other surface water rights. In addition to legal barriers, the costs of acquiring and converting senior water rights to in-stream rights can be high.

Social scientists have been tackling the issue of how to measure the value of the ecological services provided by riparian habitats with some success. Research a decade ago estimated the significant economic impacts of bird watchers along the Upper San Pedro River on the local economy. Other studies are examining what people are willing to pay to hike and camp in various river corridors. Research at the University of Arizona on the impact of proximity to and quality of riparian habitat on home values reveals a significant price effect.

Proactive water management planning and water supply development can protect and restore remaining aquatic and riparian systems and avoid costly and lengthy solutions that must be applied to highly degraded systems. The Multi-Species Conservation Plan (MSCP), developed over the last nine years for the Lower Colorado River by Arizona, California and Nevada is intended to avoid the potential economic and hydrologic consequences of protecting individual species. Although the proposed plan will cost \$620 million over 50 years, with \$77.5 million coming from Arizona water users, it likely will result in significant cost savings if implemented. Proactive planning to protect natural systems rather than individual species is clearly more effective in the longer term (National Research Council, 2004).

### **KEY REGULATORY AND INCENTIVE PROGRAMS**

Some existing programs, both regulatory and incentive-based, provide tools for addressing issues involving environmental impacts on water resources and *vice versa*. Some of these key programs include:

- New federal programs for forest thinning aimed at reducing fire hazards and, in some cases, increasing available water supply,
- State and federal funds and non-governmental organization resources for eradicating exotic species, such as tamarisk, and re-establishing native species, especially in riparian corridors,



- Federal projects investigating the impact of altered dam releases on downstream flows and habitat, particularly in the Lower Colorado River,
- Arizona Water Protection Fund, which among other things, provides monies to groups seeking to preserve or restore riparian habitat (but legislation may sunset in 2005), and
- Heritage Fund, which allows for acquisition of habitat.

### **WATER QUALITY ISSUES AND ENVIRONMENTAL HEALTH**

Water quality problems are not necessarily environmental problems, but some constituents do significantly affect habitat quality. Heavy metals generally are toxic at very low levels and can bioaccumulate or increase gradually within living tissues. This causes particular problems for long-lived fauna at the top of the food chain.

Mercury is a persistent, bioaccumulating toxin found in surface waters, making it both a public health and an environmental concern. It adversely affects the nervous system of both humans and wildlife. Found in lakes and rivers throughout the United States, eating fish is the single greatest source of exposure. The Arizona Department of Environmental Quality's strategy is to prevent new mercury from entering the environment and reducing contributions to surface water from existing sources.

Nitrate is a common groundwater pollutant, almost always from human sources, including fertilizers, septic tanks, sewage treatment plants and concentrated animal feeding operations. Large portions of some Arizona aquifers have nitrate concentrations that render the water non-potable. Nitrate can cause algal blooms in water and reduce dissolved oxygen that is required to maintain aquatic species.

Salinity is a large and growing water quality problem in Arizona surface water and groundwater. Measured as Total Dissolved Solids (TDS), salinity is composed of salts, minerals and metals. A natural component of all surface and groundwaters, low levels of salinity have negligible or even positive impacts. But undesirably high TDS levels affect virtually all water users. High TDS water harms plants and may limit biodiversity.

Endocrine disruptors (EDs) are compounds that disrupt the endocrine system by mimicking or inhibiting the effects of hormones. Sources include discarded and partially metabolized synthetic hormones and steroids, pesticides and industrial chemicals. EDs are persistent and can bioaccumulate. Since the common functions of the endocrine system are reproduction and metabolism, researchers are concerned that EDs accumulating in the environment may cause increased breast cancer, sterility, other endocrine illness, and changes in wildlife populations. Of particular concern are effluent-dominated waters, including flows in the Salt River through Phoenix. Current research is examining impacts of low-level exposure on native fish. The Environmental Protection Agency has made EDs a top priority and has established the Endocrine Disruptors Research Initiative.

The hydrologic cycle is strongly affected by land use and vegetation cover. To be successful, water sustainability efforts need to incorporate an understanding of the implications of changes in environmental conditions over time.



## Chapter 10

# TOWARD A SUSTAINABLE WATER SUPPLY: TOOLS AND OPPORTUNITIES

KATHY JACOBS AND RITA MAGUIRE

Solutions to water supply problems generally fall into two categories: reducing demand and increasing supply. There are a wide variety of tools available and opportunities to consider within each category. Choosing which options are appropriate for a particular region, community or water provider will depend on the nature of the problem as well as a number of feasibility factors, including available resources and political and social considerations.

When considering a community's water needs, population forecasts, current and projected per capita residential consumption and non-residential sector needs should be taken into account. Moreover, the mix of uses, *i.e.*, industrial, commercial and residential, can dramatically alter the amount and patterns of water use.

Water shortages are caused by demand in excess of supply and can be addressed by enhancing supplies, reducing demand or a combined approach. Whether the problem is seasonal, drought-related or a long-term imbalance between demand and supply, the nature of the shortage affects the selection of solutions.

Short-term water shortages are less costly and easier to address. For example, a temporary water shortage, whether caused by drought, equipment failure, poor water quality or the need to meet peak demands on a seasonal basis, could be addressed through conservation, system improvements, water hauling or the temporary acquisition of a new water supply.

On the other hand, overcoming water shortages that result from population growth is more costly and requires long-term planning and long-term solutions, *i.e.*, new facilities, significant conservation investments and additional water rights). Rapidly growing populations in many areas of Arizona, combined with increasing demand for water for recreation, aesthetic values and

fish and wildlife habitat, have resulted in a growing need for additional water along with more efficient use of existing supplies.

There are numerous options available to reduce the demand for water. Water conservation efforts aimed at reducing residential, industrial and agricultural consumption of water have been implemented in the state's five Active Management Areas (AMAs). Outside of the AMAs, conservation has been mandated by some local jurisdictions. In other jurisdictions, voluntary and/or education programs have been implemented.

## **DEMAND REDUCTION OPTIONS**

### **System Improvements**

- **Leak Detection and Repair:** Repairing leaks in pipelines, canals, water treatment and storage and delivery systems often yields substantial water savings.
- **Minimize Waste:** Engineering improvements to treatment and delivery systems can minimize water loss. For example, reducing the pressure in the system is one means of limiting losses.
- **Metering:** Metering or measuring water use can reduce demand even in the absence of a conservation-oriented billing system. This often results in better monitoring to avoid leaks and raises awareness of water use by consumers

### **Customer and Resident Programs**

- **Educational Programs:** Public education programs that advise residents about the limitations of available supplies, the implications of personal decisions about water use and options for reducing demand are important components of any water conservation program. These programs could include information about low flow plumbing fixtures, proper utilization of xeriscape landscaping principles, water harvesting, gray water use and irrigation system maintenance.
- **Incentive Programs:** Programs that create financial incentives for adopting water conservation measures help increase the likelihood that residents will implement and utilize water saving techniques. Reimbursements for low flow plumbing fixtures or landscape retrofit to lower water use plants are examples of such programs.
- **Assistance Programs:** Direct assistance can be provided to water users to help implement water saving measures such as irrigation scheduling assistance, advice about how to incorporate low water use vegetation into the landscape or audits of water use on residential and commercial properties.

### **Regulatory Controls**

- **Drought Restrictions:** Typical drought restrictions include limiting the hours that water can be used for domestic irrigation, car washing or other outdoor activities. More dramatic restrictions, such as prohibitions on outdoor watering, are generally implemented only in emergency drought conditions.
- **Conservation Ordinances:** Local conservation ordinances can be established to limit the quantity of water used for specific purposes or to ban certain high water use practices. For example, local ordinances have been adopted that restrict the amount of grass permitted in new developments, *e.g.*, golf courses, municipal easements and the common areas of residential communities, the types of landscaping and the use of misting systems.

### **Economic Signals**

- **Incremental Pricing:** A tiered rate structure or a conservation surcharge imposed by the water provider can be used to encourage lower water use.
- **Differential Hook-Up Fees:** The fees charged to hook-up a home to water service can be reduced in exchange for an agreement to incorporate water saving measures into the home's design, *i.e.*, limit turf, low flow fixtures *et cetera*. Meter size also can be used to limit the total water available to particular developments or lots.
- **Drought Penalties and Surcharges:** Pricing mechanisms can be used to reduce water use during drought conditions, focusing on higher water users in a system or those that do not meet required reductions.

## **SUPPLY ENHANCEMENT OPTIONS**

### **Local Supply Enhancements**

- **Surface Water Diversions:** An application to divert surface water can be filed with the Arizona Department of Water Resources (ADWR). However, most surface waters in Arizona are fully appropriated and it is likely that downstream water users will object to new applications.
- **Groundwater Pumping:** ADWR regulates the construction of groundwater wells in Arizona. The Department requires a Notice of Intention to Drill be filed for all wells outside AMAs. Within AMAs, a water right is required in addition to obtaining authority to drill a well. Availability of groundwater varies dramatically based on the geology of the area.

### **Effluent Use**

- **Reclaimed Wastewater System:** Reclaimed water is highly treated wastewater that can be utilized for turf and landscape irrigation, *i.e.*, golf courses, parks and play-

grounds, thereby reducing the amount of potable water needed. It also is suitable for some industrial uses, particularly for cooling towers.

- **On-Site Gray Water Use:** Gray water is wastewater collected separately from sewage flow. Its use is restricted to the property from which it originated. Gray water sources include clothes washers, bathtubs, showers or sinks but not the kitchen sink, dishwasher or toilet. Using gray water can decrease the amount of potable water used for irrigation. There can be water quality issues associated with the use of gray water; guidelines established by the Arizona Department of Environmental Quality (ADEQ) govern its use.
- **Water Purification/Potable Use:** Poor quality water can be purified to increase its utility. Reclaimed water that is treated to potable standards and used directly as potable water can provide a ready supplement to existing supplies. However, direct potable use is uncommon.
- **Recharge and Recovery of Effluent:** Effluent is water treated at a municipal treatment plant prior to being discharged. So long as the effluent meets appropriate water quality standards established by ADEQ, it could be used to recharge aquifers, thereby reducing the risk of subsidence and enhancing groundwater supplies.

### **Import Water**

- **Temporary Transfers:** A temporary water transfer involves paying for the use of water rights on a temporary basis. This type of transaction typically occurs when farmers opt to fallow their land and lease their water rights to a nearby community. Although uncommon in Arizona, temporary water transfers have been used to address short-term water needs in many states. Water markets have emerged in some states to facilitate this process; a governing body typically runs such markets.
- **Outright Purchase:** Because most groundwater rights in Arizona are not easily separated from the land (the ability to do this is affected by whether the land is within an AMA or not), a permanent water transfer generally involves the purchase and retirement of agricultural land for its water rights to be used by non-agricultural interests.
- **Dry Year Options:** This approach can be utilized when a community has an adequate water supply in most years, but is confronted with a water shortage in the driest years. Dry year options generally require a community or other water user to pay a flat sum of money for the option to purchase water when it is needed. When the option is exercised, the community pays an additional charge for the actual water usage, generally by the acre-foot. This tool is being used increasingly in other western states, but there are institutional limitations in Arizona.

### **Water Storage**

- **Distribution System Storage:** Increasing water storage capacity can enhance the ability to meet peak demand.
- **Underground Storage:** The availability of groundwater aquifers that are conducive to artificial recharge depends entirely on the local hydrology. Opportunities to utilize underground storage should be fully explored since artificial recharge is both legally and physically complex.
- **Surface Reservoirs:** Most surface reservoirs in Arizona are man-made and opportunities for new reservoir construction are limited by geographic and environmental conditions and regulatory requirements.

### **Other Water Supply Options**

- **Water Harvesting:** Capturing water on a property for reuse can create a new supply of water while decreasing demand for potable water on the site. Water harvesting is especially useful for landscape irrigation. Water harvesting can be “passive,” meaning that the water delivery occurs through gravity alone, or “active,” including pumps and more complex systems. Some water harvesting systems include storage for future use, while others involve land contouring to direct water to plants or retention areas.
- **Watershed Management:** Decreasing the number of trees and shrubs in a natural watershed may increase the amount of water available for other uses. There are controversial aspects to thinning or removing vegetation for water supply purposes, including debate about the effectiveness and environmental implications of such techniques.

## **SUMMARY**

Once viable water management options have been explored, they should be carefully evaluated to identify the legal, financial, political and social ramifications of each alternative. Relevant criteria for evaluating options include: costs, *i.e.*, capital and operational costs over the short and long-term; the reliability and risks associated with new supplies; potential environmental and social impacts; and identification of relevant institutional or legal constraints.

Voluntary programs such as educational, incentive and assistance programs can often be implemented quickly; however, the results can vary and have only a temporary effect. A recent study (Woodard, Weber and Stewart, 2004) conducted in the metropolitan Tucson area indicated



that over 60 percent of the surveyed households reported at least one type of water reuse activity. Among those that did not reuse water, the top reasons given were “we don’t know how” and “need help” followed by “not worth the cost,” “unsafe,” and “not worth the trouble.”

Before serious consideration of any alternative advances, it is wise to consider how and when affected communities can provide input to the decisions makers. Failure to engage stakeholders early on can result in unnecessary costs, delays or significant political limitations on the ability to solve water problems.

## Chapter 11

# QUESTIONS OF WATER, GROWTH AND POLICY

KATHY JACOBS, SHARON MEGDAL AND MARSHALL A. WORDEN

*In the long run, shortages of water quantity can be met only by increasing efficiency of existing uses, transfers of water between uses, reducing or eliminating existing water uses, the development of alternative sources of water such as desalination, or by storing additional water in wet years for use in dry years.*

*Public and policy-level attention to water supply issues in drought conditions tends to disappear as soon as rain (or snow) relieves the drought. But drought is only a magnifier of the larger problems associated with rapid population growth and environmental demands for water in areas where water supplies are already over-allocated.*

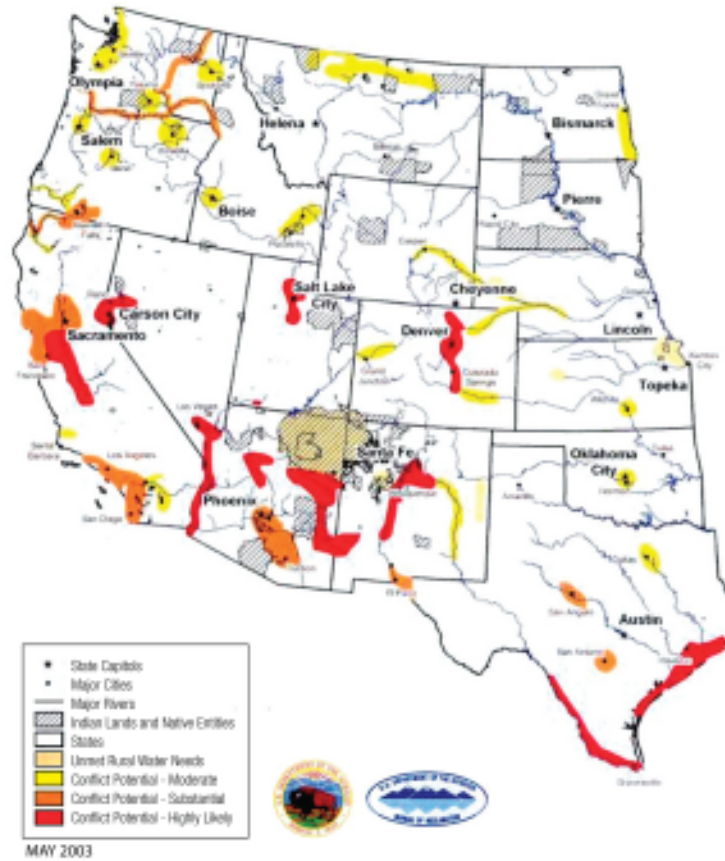
*Simply put, the West has developed to the point that the social, economic and environmental consequences of water supply crises are no longer a local or regional issue. These crises now affect economies and resources of national importance. (Bureau of Reclamation, 2004)*

United States Secretary of the Interior, Gale Norton, recently launched *Water 2025*, a national initiative that draws attention to the American West's challenge of meeting the water demands of people, cities, industry, agriculture and the environment. The Bureau of Reclamation (2004) identified five realities of water management that are shared by Arizona and the other Western states:

- Explosive population growth in arid areas,
- Existing water supplies are inadequate,
- Over-allocated water supplies can cause crises and conflict,
- Aging water facilities limit management options, and
- Crises management is not effective.

Along with the ongoing regional drought, this background report has drawn attention to the considerable complexity of water management issues confronting the citizens, governments

Figure 11.1  
**Potential Water Supply Crises**



and localities of Arizona at the beginning of the 21st Century. The extent to which citizens and elected officials are able to make difficult choices and hard decisions now may well determine if crises can be avoided in the future.

Figure 11.1 illustrates the magnitude of potential water supply crises by 2025 for Arizona as well as the Western United States, as determined by the Bureau of Reclamation. What is immediately clear is the concentration in Arizona of potential supply crises. These include:

- Unmet rural water needs and potential for conflict on the Navajo and Hopi Indian Reservations, and in the areas around Williams, Flagstaff and Prescott in Coconino and Yavapai Counties, and in the White Mountains, the areas around Show Low, Winslow and Holbrook and significant portions of eastern Arizona,
- Conflict potential along the Colorado River south of Lake Mead,

- Conflict potential in the Central Arizona Project corridor between the Phoenix and Tucson metropolitan areas.

In order to avoid these potential supply crises, Arizonans need to debate and seek public policy answers to a long list of questions. Some of these questions include:

What is the potential role and need for additional infrastructure improvements for the transportation and storage of water throughout Arizona?

How might such improvements, if needed, be financed?

What is the role of agricultural water rights in Arizona's economic and water supply future?

Does Arizona have the institutional capacity to deal with the water problems that face the state?

Can and should water pricing be used as a water management tool to a greater degree in Arizona?

What are the effects in Arizona of current water-related regulation on economic development, housing affordability and quality of life?

Is Arizona prepared for the possibility of a multi-decade drought?

Should mandatory state drought response mechanisms, including restrictions on water use or incremental water tax or fee increases, be linked to length or severity of drought conditions so as to better control water use?

How might changes in existing water-related regulations alter, favorably or unfavorably, the state's economic vitality, sustainability, housing affordability and quality of life?

How might environmental interests, concerns and qualities in Arizona best be addressed inside and outside of Active Management Areas?

How can land use and community and regional planning adequately and successfully be linked to water supply planning in Arizona?

Is Arizona doing enough to address the water supply requirements for growing communities?

Should water allocation and regulatory mechanisms be developed for those parts

of Arizona outside the Active Management Areas and, if so, who should implement them?

Can the Active Management Areas meet the water demands of future citizens based on currently available municipal supplies and, if not, where will the next water supply come from?

Does Arizona need additional regulatory mechanisms in the Active Management Areas to ensure achievement of the management goals?

From where are the financial resources and leadership going to come for long-term support of water resources planning and management as well as drought response in Arizona at state and community levels?

As noted by Secretary Norton, "Crisis management is not an effective solution for addressing long-term, systematic water supply problems." Careful consideration of these and other questions will enable Arizonans to approach water supply planning so that potential water crises are avoided.

## Appendix A

# PAST ARIZONA TOWN HALL RECOMMENDATIONS AND CONCLUSIONS

FOURTH ARIZONA TOWN HALL  
*ARIZONA'S WATER SUPPLY*  
April 6-8, 1964

The policy of the state should be to conserve water. All farmers, industries, and municipal and private water entities should continue sound conservation practices, and all organizations and agencies should alert their customers, members and employees to the need for preventing the waste of water.

We strongly urge the resolution of sectional differences and expediting hydrological, legal, engineering and other studies bearing on this issue, both on federal and state levels. Specific studies are particularly needed on such systems as the Bill Williams River, Diamond Creek, The Virgin River, and the Little Colorado River.

No solution should be adopted which could in any manner be interpreted as an acceptance by the United States of any obligation to deliver to Mexico water of any particular quality. No solution should be suggested or implemented which would result in any water in the Colorado River entering Mexico which is not chargeable to Mexico's treaty allocation.

The situation with respect to groundwater shortage and depletion is critical and growing worse in most sections of Arizona; exceptions exist, such as in the Yuma area, which are created by strictly local conditions. As a general rule the present supply is inadequate to meet existing demand, resulting in severe overdrafts against the underground reservoirs.

[W]here a retreat of groundwater in any part of Arizona threatens to make the cost of pumping too high for agricultural use, thereby threatening the existence of any community, every proper resource of the community and state, intellectual and material, should be mustered to analyze and overcome the threat by whatever means may be devised, whether this be the introduction of light industry, the creation and application of new techniques in agriculture, provisions for additional water from other sources, or any feasible combination of such practices.

In view of the fact that existing projects and proposals, including the Central Arizona Project, will leave Arizona still showing a water deficit, and assuming effective community and state conservation practices, both before and after these projects are realized, the ultimate needs for full development will require negotiation of additional water supplies on a regional basis. Research should be continued into the possibility of the processing of saline water as a future solution to the regional water problem.

It is the widely held belief among Arizonans within the Central Arizona Project area that this project must and will serve the people of the entire state through exchanges, direct diversions and whatever other means may be devised. It is the firm purpose of the people of the state to work out such details on a basis of equity for all parts of the geographic, economic, and political entity which is Arizonan.

Proven means of watershed management can improve the yield of water, improve grazing, increase timber production, and maintain the recreational use of land. This multiple use concept of the watershed should be continued and emphasized. Profitable areas for expanded study in management are: vegetation modification on watersheds, control of transportation losses in streambeds and canals, control of seepage in canals and reservoirs, and control measures against evaporation on lakes, reservoirs and elsewhere.

*PAST ARIZONA TOWN HALL RECOMMENDATIONS AND CONCLUSIONS*

The control of uneconomical water-consuming plants, such as salt cedars (phreatophytes), offers a great opportunity to increase water yields. Additional research is necessary to achieve economic methods for elimination of these plants. Full scale action programs toward this end should now be implemented.

In addition to canal and ditch lining, on-farm practices recommended for more attention include: proper timing of irrigation, short-row irrigation, pump-back practices for reuse where feasible, stricter control of tail water from irrigated fields, and better land leveling. We recommend for special attention:

1. Canal, lateral and ditch lining;
2. Use of crop species requiring less water;
3. More and better information on costs and savings to farmers of various conservation methods in farming;
4. More research into the economics of crops yields relative to water requirements.

Although in the experimental stage, sprinkler irrigation offers the opportunity of much more efficient use of water on the farm and substantial water savings in some areas.

[W]e urge each community to establish its conservation practices. To accomplish this, it is suggested that the local governing body create a permanent committee of persons competent to consider water programs and plan accordingly.

Sewage effluent offers a tremendous source of reusable water in Arizona. Since approximately half of the water used in Arizona communities goes out as sewage, this source must receive additional attention.

Water catchment or "harvesting" systems are known to be the most efficient of all systems for gathering rainfall. We strongly recommend a large-scale pilot program in a suitable location to determine the benefits that can be expected from such a program in Arizona.

[W]e recommend the creation by an appropriate state authority of a state-wide committee to make a thorough study and analysis of the efforts in Arizona and in other states and areas, and of any other applicable factors, with the goal of recommending the most efficient organization or centralization of water functions.

**THIRTY-FIRST ARIZONA TOWN HALL  
ARIZONA WATER – THE MANAGEMENT OF SCARCITY  
October 9-12, 1977**

There was general agreement that, for some parts of the state, existing sources of water in Arizona can be further developed to increase accessibility. Methods which can be further developed include:

- a) Drainage control and catchment;
- b) Evaporation suppression;
- c) Seepage control;
- d) Watershed management;
- e) Regional weather modification;
- f) Desalination;
- g) Effluent recycling for non-domestic and some agricultural uses;
- h) Improved agricultural irrigation techniques;
- i) Education promoting water conservation;
- j) Exploration for new water sources.

Proper watershed management, a proven economic technology, should be further utilized; Effluents should be used as efficiently as possible; conservation should be encouraged with water rate structures and

*PAST ARIZONA TOWN HALL RECOMMENDATIONS AND CONCLUSIONS*

allocations that do not promote high use and inefficiency. Desalination also represents a potential source of water for Arizona. A greater investment should be made by the state in research and development of technologies designed to reduce water quantity and quality problems. Especially important will be new methods for using and conserving agricultural water, since the agricultural sector has such a significant impact on total water use in Arizona. Conservation measures should be encouraged primarily through the use of economic incentives and education rather than mandatory controls.

All agree that the present law is not adequate, and that it does not address the problems of groundwater overdrafts.

Theoretically, there should be no difference between the law relating to groundwater and the law relating to surface water. These two types of water are, in fact, inextricably tied together. As a practical matter, however, it is not feasible at the present time to begin treating these types of water identically.

Most participants believe that the State Legislature should have primary responsibility for the formulation of water policy in Arizona and urge that the Legislature act to discharge this responsibility by enacting legislation which will provide an adequate groundwater law.

A great need exists to coordinate the activities of the numerous agencies responsible for the implementation of the state's water policy. The number of such agencies should be sharply reduced, and the functions of the remaining agencies should be clearly delineated. The consolidation of responsibility should result in more effective implementation of the established policy, and should avoid some of the inaction and inefficiency which has led to the present disjointed water policy.

Compensation for the settlement of valid Indian claims arising from federal actions should be made by the federal government without adversely affecting Arizona interests. These issues are of national rather than simply statewide concern.

A majority of the panelists supports a system of water priorities favoring domestic and urban users. Concern was expressed that a reasonable balance of priorities be maintained so that no segment of the state's economy would be seriously damaged. Any future system of water management in Arizona must accommodate the allocations of water to which it is determined our Indian populations are entitled. Many panelists feel that aesthetic and recreational factors should also be given some degree of priority.

Arizona's groundwater should be managed so as to avoid exhaustion of major water basins. While groundwater overdrafts are currently a necessary part of our water system, they should be minimized to the extent possible with a view toward preserving the major groundwater supplies forever.

Future planning and management must deal with the problem of groundwater transfers within basins, as well as trans-basin diversions.

Future planning for surface waters should emphasize watershed management, reduction of transmission loss, evaporation control, flood control, and construct effective storage facilities (both above and below ground) on all lands within the state, both public and private.

Water transfer projects like the CAP are indeed justified, and represent a significant component of the state's long-term water strategy.

Most panelists believe that no direct limitations should be placed on Arizona's population, agriculture or industrial growth by means of water management, although a comprehensive water management plan will undoubtedly affect such growth. Incentives to conserve water should be further encouraged, with consideration given to imposing penalties for misuse of water.

The economic forces of supply and demand should also be given full opportunity to influence the



allocation of water to high-value uses. Market factors alone, however, may not be sufficient to achieve the desired allocations, in which case regulatory constraints such as extraction taxes may be necessary. If implemented, such constraints must recognize existing property rights.

Although our entire water allocation system cannot be revamped, widespread support does exist for vesting some statewide regulatory agency with authority to regulate the use of groundwater.

Regulatory alternatives which might be considered in the future include the following:

- a) Taxation;
- b) Improved definition of “reasonable use”;
- c) Limitations on decorative water uses;
- d) Penalties for water misuse.

Water rights, where they exist, are a form of private property. Consequently, the owner of such rights may legally be entitled to compensation if they are taken from him, and most panelists concluded that such compensation is mandatory.

It is essential for the development of a comprehensive water plan for the state of Arizona that the reserved water rights of the Indians and the Federal Government be finally defined and quantified. The Federal Government should accept financial responsibility for resolving on an equitable basis Indian claims, taking into consideration the legitimate water needs of all the interested parties.

**FORTY-SEVENTH ARIZONA TOWN HALL**  
*MANAGING WATER QUALITY IN A WATER SCARCE STATE*  
**October 27-30, 1985**

[T]he state must accommodate development and growth, on the one hand, with protection of the environment and public health, on the other. To achieve that balance, the issues of water quantity and quality must be viewed as inextricably interrelated. In short, no longer can we afford to consider these two issues in isolation.

Arizona’s success in developing a public philosophy for water quantity – as manifested by its enactment of the Groundwater Management Act – demonstrates this state’s ability to develop a successful philosophy toward water quantity. The time for focusing on water quality is now at hand.

A review of the statutes governing the transfer of water should be undertaken to facilitate matching the quality of available water with its anticipated uses.

Water augmentation should be expanded by all means including storing floodwaters and other surplus waters. Groundwater recharge should be further encouraged with attention to appropriate precaution to minimize degradation of the aquifer. The protection and management of the state’s watersheds remain important. It is also imperative to recognize the importance of effluent as a valuable resource.

In examining sources and activities for possible regulation, Town Hall recommended that sources and activities with a reasonable probability of impairing the state’s water quality should be regulated.

The participants reiterated their recognition that water quality and quantity issues are interrelated and that a comprehensive approach to overall management of the resource must be implemented. All panels recognized that the present system is ineffective and that environmental issues – particularly water quality – do not receive sufficient attention at the state level. Nevertheless, participants could not agree on the single best approach to coordinating an appropriate, statewide response.

*PAST ARIZONA TOWN HALL RECOMMENDATIONS AND CONCLUSIONS*

The Town Hall panels reviewed and recommended specific proposals to enhance the management of water quality and quantity in Arizona. Among the specific proposals suggested are the following: Location and sealing of abandoned wells to prevent pollution; Implementation of a water pricing system that encourages conservation; Improvement of water yield and quality through improved watershed management; Encouragement of water allocation to a use consistent with its quality, to the extent economically feasible (and, conversely, establishment of quality standards based on nature of use); Augmentation of the water supply by constructing catchment dams, recapturing and storing CAP water by recharge and other means devised to capture or conserve water

**SEVENTY-FIRST ARIZONA TOWN HALL**  
***ENSURING ARIZONA'S WATER QUANTITY AND QUALITY INTO THE 21<sup>ST</sup> CENTURY***  
**October 26-29, 1997**

The issues of water quantity, quality and allocations are tied together, but often difficult to reconcile. Despite the overriding concern about water quantity, attention also must be given to quality.

Town Hall believes that Arizona's water supply can support current and predicted populations if water resources are properly managed. How efficiently water is used will determine its availability. While in theory the available supply is substantial, the economic feasibility of securing sufficient useable and deliverable water where needed is in question.

Delivery of Colorado River water, for example, could be reduced or interrupted in times of drought or by system failure. To prepare for future shortages, Arizona should expand the implementation of water banking procedures and groundwater recharge and should develop a long-term strategy for ensuring supply.

Town Hall believes greater emphasis should be placed on developing the technology and systems necessary to make more efficient use of reclaimed water. If the costs and reliability of this and other alternative sources, such as desalination and cloud seeding, could be controlled, our available water supply could be modestly augmented.

Town Hall believes the federal government's role in managing Arizona water resources should be reduced because decisions at the federal level do not adequately address the diversity and complexity of local needs. More local input is needed. Local communities within hydrological boundaries should work as partners with state and federal governments and less as regulated entities.

Current water law and planning tend to address issues from the top down, where it may be appropriate to look at laws more comprehensively, regulating and managing water rights first at the local level, moving from the bottom up.

Town Hall is dissatisfied with the current status of the adjudication of water rights process, with some even calling the process a failure. The costs of the lengthy proceedings have been significant. Until the adjudication of water rights is resolved, there is a cloud over the rights of water users that creates uncertainty and undermines effective planning and management.

The goals set for the next 50 to 100 years should address the needs of sustainable development and preservation of water supplies for future generations of Arizonans. They should include achieving safe-yield in certain areas and looking beyond domestic, industrial and agricultural uses to the effect water use and allocation have on riparian areas, the environment and our overall quality of life.

Many felt groundwater data should be expanded beyond the AMAs to assist planners in determining what level of development can be supported by existing supplies.

*PAST ARIZONA TOWN HALL RECOMMENDATIONS AND CONCLUSIONS*

Water conservation programs should play a significant role in increasing the efficient use of water, even in times of plentiful supply.

Recognizing that effluent is a valuable resource in an arid environment, suggestions offered by Town Hall include using tax and rate-paying structures to encourage and increase efficient use of effluent for open turf, industrial, agricultural and commercial applications, and for building treatment plants and dual distribution systems.

[T]he GMA has not been entirely effective nor entirely fair as applied and has been unable to achieve many of its stated goals. It does not apply to much of rural Arizona. It has a number of exemptions for agriculture, mining and certain urban demands that create challenges in its implementation.

The adequacy program must be strengthened in appropriate areas outside of AMAs to ensure a higher level of consumer protection. City and county planning authorities should be encouraged to consider lack of adequate water resources in approving subdivision plats.

While the safe-yield goal is appropriate for some AMAs, it should not be a statewide goal. Arizona is too diverse for one goal to meet all needs.

Where safe-yield is a goal, but is not being achieved, the groundwater use limitation across user groups should be reexamined. Responsibility for reaching safe-yield should be allocated among all users within the AMA.

Although the state can establish the regulations to be applied to address critical water supply issues in non-AMA areas, preparation and implementation of the individual plans should occur at the local level.

Sub-basin strategies should be considered, particularly in those areas that request them. Current AMA management mechanisms were tailored to address general AMA water balance. They do not necessarily deal with specific areas of localized water level decline, subsidence and water quality decline. We need to monitor subsidence, while recognizing the related development implications.

Through laws such as the Endangered Species Act and federal application for state instream flow rights, federal law currently plays an inappropriately significant role in developing water policy for Arizona. Many federal laws regulate from the top down and do not take local concerns into account. Ideally, the federal role should be minimized.

Current water management in Arizona is too fragmented.

Town Hall strongly recommends that consideration be given to merging some of the ADEQ's water quality programs into ADWR to ensure continuity in water management.

Additional financial resources will be required to perform geological, hydrological and other technical water studies, particularly in rural areas, to provide ADWR or other state agency technical assistance in non-AMA areas, to fund the activities of a consolidated agency, to assist in accelerated completion of the general stream adjudications and American Indian water rights settlements, and to increase public education and participation on water issues.

Current water pricing does not include total costs such as the external cost of replenishment, environmental regulations and American Indian water rights settlements. Most Arizona water users do not pay the true economic cost of water.

## Appendix B

# HISTORY OF GROUNDWATER MANAGEMENT IN ARIZONA

(Adapted from Governor Hull's Water Management Commission Briefing Book)

### TIMELINE

- 1863 Arizona Territory Established**  
President Lincoln declares Arizona a U.S. territory on February 24th, making it separate from the New Mexico Territory.
- 1864 Howell's Code**  
The first Arizona Territorial Legislature adopts Howell's Code, which establishes appropriate rights to surface water.
- 1877 Desert Land Act**  
Passed by Congress on March 3 to encourage and promote the economic development of the arid and semiarid public lands of the Western United States. Through the Act, individuals may apply for a desert-land entry to reclaim, irrigate, and cultivate arid and semiarid public lands.
- 1902 National Reclamation Act**  
This act by President Theodore Roosevelt recognizes that a key component to Western growth and development is constructing a system of irrigation works for the storage, diversion and development of water. This act, which also created the U.S. Reclamation Service (later the Bureau of Reclamation), provides that "... the right to the use of water acquired under the provision of this act shall be appurtenant to the land irrigated and beneficial use shall be the basis, the measure and the limit of the right."
- 1904 Howard v. Perrin**  
The Arizona Territorial Supreme Court ruling in this case (upheld in 1906 by the U.S. Supreme Court) established a definite distinction, in character and ownership, between surface water and groundwater. This decision adopted the idea that percolating water was the property of the overlying landowner and not subject to appropriation as surface water.
- 1908 Winters v. United States**  
Recognizes Indian water rights are established when a reservation is created, regardless of whether or not a tribe has previously used water.
- 1911 Theodore Roosevelt Dam completed**  
This structure was the first multipurpose project built by the Bureau of Reclamation. The dam is located 76 miles northeast of Phoenix at the confluence of the Salt River and Tonto Creek where it is operated and maintained by the Salt River Project.
- 1912 Arizona Statehood**  
Arizona is accepted for statehood by President Taft and becomes the 48<sup>th</sup> state on February 14, 1912.
- 1918 McKenzie v. Moore**  
This decision reinforced the concept of subsurface spring water as non-appropriable groundwater.

- 1919 Public Water Code**  
Legislation is enacted on June 12, 1919 to establish procedures for developing a right to use appropriable water. These procedures go beyond the prior practice of merely putting the water to beneficial use or posting a notice and recording a water right claim.
- 1922 Colorado River Compact**  
The Compact divides the Colorado River Basin into an Upper and Lower River Basin and apportions 7.5 million acre-feet of Colorado River water per year to each basin. Arizona refuses to ratify the Compact (but signs it in 1944) because of concerns over how its tributary waters from the Salt and Gila Rivers will be counted in the apportionment. Article VII, inserted at the insistence of Herbert Hoover, the commission's federal chairman, states "Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian Tribes."
- 1926 Pima Farms Company v. Proctor**  
In deciding this case (appealed from the Pima County Superior Court) the U.S. Supreme Court upheld the distinction between surface water and percolating water. They found that water flowing underground within well-defined channels was not percolating water and was subject to prior appropriation.
- 1928 Boulder Canyon Project Act**  
Authorizes construction of the Hoover Dam on the condition that the Colorado River Compact is ratified. This act provides a mechanism for approval of the Colorado River Compact that does not require Arizona's approval.
- 1931 Maricopa Co. Municipal Water Conservation District v. Southwest Cotton Co.**  
The Arizona Supreme Court reverses the judgment of the Superior Court, identifying subflow as another source of appropriable water. Subflow is considered water seeping through the streambed or from lands under or immediately adjacent to the stream and is itself part of the surface stream.
- 1932 Maricopa Co. Municipal Water Conservation District v. Southwest Cotton Co.**  
This decision includes a test for subflow waters, stating that if the drawing off of subsurface water directly and appreciably diminishes the flow of the subsurface stream, then it is subflow.
- 1938 First Groundwater Study Group**  
Governor Stanfield appoints a group to study groundwater in response to growing concern over increased groundwater pumping. The efforts of this group lead to the legislature appropriating monies to the U.S. Geological Survey to study and report on state groundwater conditions.
- 1944 Arizona approves the Colorado River Compact**  
Arizona approves the Colorado River Compact in hopes of getting approval for a reclamation project to deliver Colorado River water to central and southern Arizona. Arizona then enters into negotiations concerning the Central Arizona Project.
- 1945 Arizona's first Groundwater Code is adopted**  
The Bureau of Reclamation warns that the CAP will not be approved without restrictions on groundwater use. The federal government holds Arizona to its claim that construction of the CAP would reduce groundwater use instead of allowing for more groundwater use by agricultural users. Legislation is passed, but only requires the registration of wells throughout the state.
- 1948 Critical Groundwater Code is adopted**  
The Federal Government again warns that the funding for the CAP will not be approved without a more meaningful Groundwater Code. The 1948 Code limits development of new wells drilled for groundwater-irrigated agriculture in 10 designated critical groundwater areas, but did nothing to apportion use among landowners in those areas and allowed groundwater pumping to continue at historic levels.

**1951 Arizona's second Groundwater Study Commission is formed**

In response to the widely criticized provision in the 1948 Groundwater Code that allowed groundwater pumping to continue at historic levels within critical areas, the second Groundwater Study Commission is formed to draft a new groundwater bill. The legislature failed to pass any of the Commission's recommendations and the Commission was ultimately abolished.

**1952 Congress passes the McCarran Amendment**

This amendment allowed the federal government to be brought into state general stream adjudications, thereby waiving its sovereign immunity and allowing the extent of federal reserved water rights to be determined in state court proceedings.

**Bristor v. Cheatham I**

Controversial decision by the Arizona Supreme Court that stated percolating waters **were** subject to prior appropriation and that appropriation of water for domestic purposes constituted the highest beneficial use. This ruling reverses nearly 50 years of common law that had stated that percolating water was not subject to prior appropriation.

**1953 Bristor v. Cheatham II**

This decision identified the American common law principle of reasonable use pertaining to groundwater. Specifically in this case, the water in question was not put to beneficial use on the land from which it was pumped, but rather used to irrigate non-adjacent property three miles from the well site.

**1955 Southwest Engineering Co. v. Ernst**

The plaintiff seeks legal recourse, claiming that the restrictions applying to the critical groundwater areas designated by the 1948 Groundwater Code are unconstitutional. The decision upheld the general concept that certain areas may be managed differently, and specifically that the additional restrictions placed on agricultural groundwater users within areas designated by the 1948 Code as critical were not in and of itself unconstitutional.

**1963 Arizona v. California**

Following 11 years of costly litigation, the decision in *Arizona v. California* results in major power shifts between the states and the federal government. Colorado River water was apportioned, with California receiving 4.4 million acre-feet, Arizona 2.8 million acre-feet, and Nevada 300,000 acre-feet, with each state also awarded all the water in their tributaries. *Arizona v. California* opened the door for federal participation in Colorado River affairs, which many state delegates had hoped to avoid through the Colorado River Compact. The decision interpreted the Boulder Canyon Act as empowering the Secretary of Interior to act as water master of the Lower Colorado River, to apportion future surpluses and shortages among the states and even among users within the states.

**1968 Colorado River Basin Project Act**

The construction of the Central Arizona Project is authorized through the Colorado River Basin Project Act. The Act contains a provision that safeguards California's 4.4 million acre-feet entitlement, stating that in times of shortage this full amount will be delivered before any water is provided for the CAP. The stated legislative purpose of the Act calls for ". . . furnishing irrigation water and municipal water supplies to the water deficient areas of Arizona and western New Mexico..."

**1969 Jarvis v. State Land Department I**

The decision resulted in an injunction against the City of Tucson, prohibiting them from transporting groundwater from city-owned wellfields in the Avra and Altar Valleys. The 1948 Groundwater Code designated both areas as critical. The court held that the property right to use the water was limited by the reasonable use doctrine on overlying land, not ownership.



**1970 Jarvis v. State Land Department II**

This decision uses surface water statute to modify the injunction placed against the City of Tucson in 1969. The determination of appropriative rights (based on A.R.S. 45-147) gives preference to domestic and municipal uses over agricultural uses. However, Tucson was allowed to pump and transport the “annual historic maximum use” following the purchase and retirement of irrigated farmland.

**1973 Construction of the CAP Canal begins at Lake Havasu City**

**1974 Water Rights Registration Act**

Allowed individuals alleging a water right claim that existed before June 12, 1919 to file a claim with the state.

**1976 Jarvis v. State Land Department III**

The decision of Jarvis v. State Land Department II is modified, allowing the City of Tucson to pump only 50 percent of the “annual historic maximum use.”

**Farmer’s Investment Company v. Bettwy**

This case involved water transportation issues within a critical groundwater area, beginning with a mining company’s transportation of water for use miles from where it was pumped, and eventually including the City of Tucson. In granting an injunction in favor of the plaintiff, the court found that under the reasonable use doctrine, water could not be pumped from one area for use in another area if other wells suffered injury or damage as a result, although the two areas overlie a common source. The injunction was never acted upon, leaving it up to the legislature to establish a system of preference for rights based on economic interests, and opposing the findings of Jarvis v. State Land Department, limited the City of Tucson withdrawals to pre-1972 levels.

**1977 Stockpond Water Rights Registration Act**

Granted statutory recognition of stockponds.

**Amendments to the 1948 Groundwater Code**

As a result of the FICO decision, the 1977 Amendments to the 1948 Code established a permit system for the transportation of groundwater. A 25-member Groundwater Study Commission was also established, charged with developing a new Groundwater Code that would address groundwater transportation and reduce groundwater overdraft occurring in parts of the State.

**Federal Budget Cuts**

President Carter announces that the CAP is among several Federal projects whose funding will be cut but later removes the CAP from this “hit list”.

**1978 Ak Chin Indian Settlement approved by Congress**

**1979 Groundwater Study Commission releases its Draft Report of Tentative Recommendations**

Secretary of the Interior Cecil Andrus warns that funding for the CAP will not be allocated unless the State passes a Groundwater Code.

**1980 Groundwater Management Code is passed and adopted**

The Arizona Department of Water Resources is created to administer Code provisions.

**Southern Arizona Water Rights Settlement Act approved by Congress**

The SAWRSA settlement was intended to resolve the water rights of the Tohono O’odham, but it was never fully implemented. (The final resolution of outstanding issues is currently before Congress in the Arizona Water Rights Settlement Act).

- 1984/ First Management Plans are adopted**
- 1985** The first of the five Management Plans called for by the Groundwater Management Act are adopted by the Arizona Department of Water Resources for the Phoenix, Pinal, Prescott and Tucson Active Management Areas.
- 1986 The Lakes Bill**  
Generally restricts the construction of bodies of water larger than 12,320 square feet, with most kinds of groundwater and CAP water if it is to be used for landscape or scenic purposes.
- 1986 First Recharge Bill authorizing underground storage and recovery programs**
- 1988 Salt River Pima-Maricopa Settlement approved by Congress**
- 1989 Second Management Plans are adopted**  
The Arizona Department of Water Resources for the Phoenix, Pinal, Prescott and Tucson Active Management Areas adopts the second of the five Management Plans called for by the Groundwater Management Act.
- 1990 Fort McDowell Indian Community Settlement approved by Congress**
- Indirect Recharge**  
The Groundwater Code is amended to promote indirect recharge of excess CAP water.
- 1991 Groundwater Transportation Act**  
Severely restricted the ability of a municipal provider to transport groundwater from rural sub-basins to the Phoenix, Pinal, Prescott and Tucson Active Management Areas, except those operating under a previous agreement.
- 1992 San Carlos Apache Tribe (Gila River drainage) Settlement Approved by Congress**
- 1993 Central Arizona Groundwater Replenishment District**  
CAGRDR is established to serve as a groundwater replenishment entity for member lands and member service areas under the Central Arizona Water Conservation District. CAGRDR must replenish excess groundwater use by lands enrolled in the replenishment district, and therefore assist in meeting requirements of the assured water supply program.
- 1994 Underground Water Storage, Savings and Replenishment Act**  
The legislature repeals previous enactments and consolidates all storage programs into a unified program.
- Yavapai-Prescott Tribe Settlement approved by Congress**
- Water Protection Fund**  
Administered by a commission which issues grants from the fund to water users for implementing projects to protect Arizona rivers and streams, including the use of excess CAP water for riparian enhancement.
- 1995 Assured Water Supply Rules**  
The Assured Water Supply Rules call for Certificates and designation of Assured Water Supply to be demonstrated primarily through the use of renewable water supplies.
- 1996 Arizona Water Banking Authority**  
Created as a mechanism for Arizona to fully utilize its CAP allotment. The Water Bank may annually purchase all or part of the state's unused allotment and store it through recharge. The legislation also allowed the Water Bank to store water for other jurisdictions beside the state of Arizona.



**1999 Arizona Supreme Court held that federal reserved rights extend to groundwater**

To the extent groundwater is necessary to accomplish the purpose of a reservation, federal reserved rights may include groundwater.

**Third Management Plans are adopted**

The Arizona Department of Water Resources for the Phoenix, Pinal, Prescott, Santa Cruz and Tucson Active Management Areas adopts the third of the five Management Plans called for by the Groundwater Management Act.

**2000 Governor's Water Management Commission**

Governor Jane Dee Hull announces the formation of the Governor's Water Management Commission.

**2003 Pueblo of Zuni (Zuni Heaven) Settlement approved by Congress**

RELEVANT ARTICLES

1. Connall, Desmond D., Jr. (1982). "A History of the Arizona Groundwater Management Act." *Arizona State Law Journal* 1982: Pp. 313-344.

This Law Review articles gives the political and legal background leading up to the creation of the Arizona Groundwater Management Act, including the 1976 FICO case and the work of the original Arizona Water Commission.

2. Ferris, Kathy. (2000). "A Twenty-Year Retrospective."

This speech was given by Kathy Ferris at the May 2nd, 2000 Conference on the 20<sup>th</sup> Anniversary of the Groundwater Management Act in Tempe, AZ. The speech outlines the politics and work behind the creation of the Arizona Groundwater Management Act.

3. Goldberg, Barbara. (2000). "Major Issues in the 1980 Groundwater Management Act."

This speech was given by Barbara Goldberg at the June 9th, 2000 Technical Advisory Committee meeting. The speech outlines the water management issues facing the original Arizona Water Commission and the rationale behind different components within the Arizona Groundwater Management Act.

## Appendix C

# ASSURED WATER SUPPLY PROGRAM

Source: Governor's Water Management Commission Briefing Notebook, August 2000

### CHAPTER IV

#### OVERVIEW

#### ASSURED WATER SUPPLY FOR NEW SUBDIVISIONS

Arizona's Assured Water Supply Program is designed to sustain the State's economic health by preserving groundwater resources and promoting long-term water supply planning. This is accomplished through regulations that mandate the demonstration of renewable water supplies for new subdivisions. The program is an integral component of Arizona's 1980 Groundwater Code, which was designed to address severe groundwater level decline rates in major urban and agricultural areas.

#### History

In 1973, the Arizona Legislature enacted a statewide water adequacy statute as a consumer protection measure (A.R.S. § 45-108). The law was passed in response to incidences of land fraud involving the sale of subdivision lots that were later found to have insufficient water supplies. This law required developers to obtain a determination from the State regarding the availability of water supplies prior to marketing new subdivision lots. Developers were then required to disclose any "inadequacy" of the supply to potential lot buyers.

The 1980 Groundwater Code contains more rigorous provisions for new subdivisions in the Active Management Areas (AMAs). The 1980 Code prohibits the sale or lease of subdivided land in an AMA without demonstration of an assured water supply. An assured water supply determination is required to gain approval of a subdivision plat by local governments, and to obtain authorization to sell lots by the Department of Real Estate. A subdivision is defined as land divided into six or more parcels where at least one parcel is less than 36 acres. Land divisions resulting in parcels larger than 36 acres are classified as "unsubdivided" lands and do not require an assured water supply determination.

#### 1995 Assured Water Supply Rules

In 1991, the Arizona Department of Water Resources (ADWR) began developing formal administrative rules for meeting the statutory criteria. The effort, which involved considerable public input, culminated in the adoption of the Assured Water Supply (AWS) Rules in February 1995.

The two most common types of documentation for an AWS are a Certificate of Assured Water Supply (Certificate of AWS) and a Designation of Assured Water Supply (Designation of AWS). New subdivisions are required by the 1980 Groundwater Code to have a Certificate of AWS, unless a water provider designated as having an assured water supply serves them. The Certificate of AWS states that the developer has proven that sufficient water supplies exist for the subdivision for 100 years. If the new subdivision or development is within the service area of a Designated Water Provider, then a Certificate of AWS is not required; provided that the developer has obtained a written commitment of service from a water provider designated as having an assured water supply. As an example, if a subdivision is being built in the Tucson AMA within the City of Tucson's service area, the developer only needs to provide written proof to ADWR of the City of Tucson's commitment of service to meet the AWS requirements, since the City of Tucson has already met the AWS criteria and obtained a Designation of AWS.

For municipal private water providers, a Designation of AWS is issued. This Designation of AWS states that the municipality or private water provider has proven sufficient water supplies to service their current, committed and future demand for 100 years. Municipalities and private water providers are not required to apply for a Designa-

## ASSURED WATER SUPPLY PROGRAM

tion of AWS, but there are incentives to do so. A Designated Water Provider can deliver water to new developments within their service area without the new subdivision having to apply for their own Certificate of AWS. The most populous cities within AMAs have obtained a Designation of AWS, and thus a majority of new subdivisions qualify through this process.

### Assured Water Supply Criteria

To obtain an assured water supply determination, the statute requires a demonstration of:

1. Physical, legal and continuous water availability for 100 years;
2. Water quality standards attainment;
3. Financial capability to construct the delivery system and related features;
4. Consistency with the AMA's management plan; and
5. Consistency with the AMA's management goal.

### Meeting the Assured Water Supply Criteria

Developers seeking a Certificate of AWS must demonstrate that sufficient qualifying water supplies are available to meet subdivision demands for at least 100 years. Water providers seeking a Designation of AWS must demonstrate that sufficient qualifying supplies are available to meet current demand, committed demand (i.e. that which is associated with recorded, undeveloped lots) and at least two years of projected growth for a 100 year period.

### Accounting, Reporting and Monitoring

A credit account is maintained by ADWR for each Certificate and Designation of AWS. The account is updated annually based on reports filed by water providers. ADWR will review the AWS status of designated water providers periodically to determine whether the designation remains valid. Additionally, ADWR monitors the allowable groundwater account, which is based on:

1. Basic groundwater allocations: designation applications for existing water providers are allocated the 1994 water usage multiplied by 7.5 in the Phoenix AMA, 15 in the Tucson AMA. In the Pinal AMA, the basic allowance is determined by multiplying the population of the subdivision by 125 gallons per person per day. In the Prescott AMA, the groundwater allowance is their 15 year demand of the development, multiplied by the number of years until 2025, divided by two. For example, if an existing water provider's 1994 water usage was 1000 acre-feet in the Phoenix AMA, then  $1000 \times 7.5 = 7500$  acre-feet would equal their basic groundwater allocation.
2. Incidental Recharge Factor: Designated water providers, under the AWS Rules, annually receive an incidental recharge allocation of 4% of the demand of the previous year and may apply for a higher incidental recharge factor if they can demonstrate a higher incidental recharge in their service area.
3. Extinguishment credits: the extinguishment of grandfathered groundwater rights creates a credit based on a calculation prescribed in the AWS rules (R12-15-803 MP), which varies depending on the AMA, the type of right and the year of extinguishment.

### **A. Assured Water Supply Regulations for Subdivisions**

Two avenues exist for obtaining an AWS determination for a proposed subdivision. The method used will depend upon the access to a Designated Water Provider. If the water provider has acquired a Designation of AWS, then the developer may obtain a written commitment of service from that water provider. If the water provider has not acquired a Designation of AWS, the developer must independently obtain a Certificate of AWS by submitting an application to ADWR.

### Commitment of Service by a Designated Water Provider

Designated water providers may include cities, towns and private water companies that have previously satisfied the AWS criteria for current, committed and projected customers. If a developer intends to take advantage of a provider's designated status, the developer need only obtain a written commitment from the provider to serve the proposed subdivision. The written commitment is presented to the platting entity, and must be noted on the subdivision plat. An application to ADWR is not required.

### Certificate of Assured Water Supply

To acquire a Certificate of AWS for a proposed subdivision, the property owner must file an application with

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ADWR. If the application is found to meet the AWS criteria, public notification is posted in a local newspaper. If no protests are received, a Certificate of AWS is issued. A typical application is processed in about three months. The Certificate of AWS is issued in the name of the property owner, and is valid only for that owner. A Certificate of AWS may be reissued in the name of a new owner if ADWR is notified within 90 days of the transaction.

Certificates of AWS are issued only for subdivision plats. For “master planned” areas that are not yet platted, the developer may obtain a pre-qualification for an AWS determination by applying to ADWR for an Analysis of AWS.

### Assured Water Supply Statutory Requirements

While these basic criteria have been required since 1980, the 1995 AWS Rules strengthen the management goal component significantly and establish standards for many sources of water, including Central Arizona Project water, other surface water and effluent. The 1995 AWS Rules also raise the depth-to-water standard, and simplify the financial capability requirements. The most important provisions of the five program criteria are discussed in the following sections.

#### 1. Physical, Legal and Continuous Availability; R12-15-703

The applicant must describe the sources of water to be served to the subdivision. This involves demonstrating the actual water availability and the existence of a delivery system.

Water must be physically and continuously available to the subdivision to meet its demand for at least 100 years. This is typically demonstrated through a hydrologic study which must be submitted with the application, unless the entity providing water has previously submitted a valid study to ADWR. To show that supplies will be continuously available, adequate delivery, storage, and treatment works must also exist or be financed. Evidence of a legal right to the water supply or supplies is also required.

A legally recognized water provider must be committed to supply service. If a system does not presently serve the area, two options exist: a) a new water company or co-op may be established in accordance with the applicable Arizona Corporation Commission, ADEQ and ADWR requirements; or b) the subdivision may be developed as a “dry lot subdivision” where individual domestic wells will be drilled on each lot by purchasers. If the subdivision is to be served by a private water company, the proposed subdivision must be within the area prescribed in the company’s Certificate of Convenience and Necessity.

#### 2. Water Quality; R12-15-704

The applicant’s proposed source(s) of water must satisfy existing state water quality standards as well as other water quality standards applicable to the proposed use after treatment. ADWR will consider the possible migration of poor quality water that may impact the applicant’s source. Designated providers must continue to satisfy all applicable state water quality requirements in order to maintain their designation.

#### 3. Consistency with Management Goal; R12-15-705

All five AMAs have water management goals related to reduction in groundwater use. The AWS Rules require that municipal users in growing areas limit the use of mined groundwater through the use of alternative supplies and conservation practices. Mined groundwater is groundwater that is used in excess of the goal of the AMA. A certain amount of mined groundwater is allocated to Certificate and Designation of AWS applicants to allow for the “phasing in” of renewable supplies. Renewable supplies must meet any demand over the groundwater allocations. Each AMA, except the Santa Cruz AMA, has its own formula to calculate the amount of mined groundwater that can be used when demonstrating an AWS, which is discussed in Part Three, Chapter IV, Section C. Although the applicant may meet the goal criterion through recharging a renewable supply outside of the service area and pump groundwater, the groundwater must still be physically available.

The following sections are general ideas for maintaining consistency with the management goal. It is important to keep in mind that dry lot subdivisions of 20 lots or less are exempt from the consistency with management goal requirement in all AMAs. For subdivisions that will be receiving groundwater in an AMA, the Certificate of AWS

applicant may demonstrate consistency with the management goal through any or all of the following methods: membership in the Groundwater Replenishment District (GRD), extinguishment credits, use of poor quality water or use of water from a waterlogged area.

4. Consistency with Management Plan; R12-15-706

The applicant will need to estimate the amount of water use per lot and for any additional subdivision features such as golf courses, parks or lakes. A build-out schedule must be supplied for all subdivisions. Demand estimates are evaluated in the context of water conservation guidelines.

If the subdivision is for more than 50 lots, a description of any proposed conservation measures will need to be provided. If the development is designed so that it conforms to water conservation practices, it will be easier for the serving provider to meet its conservation requirements as prescribed in the management plan for the AMA. While ADWR cannot deny a certificate application if the demand will make it more difficult for the provider to comply with its conservation requirements, the provider will be notified of the potential impact of the new subdivision. A certificate application will not be denied if the water provider is out of compliance with its conservation requirements.

5. Financial Capability; R12-15-707

The developer's financial capability to construct the water delivery system is typically considered through the platting entity's process of approving a plat. The developer's capacity to finance any features that are not included in the plat approval process, such as storage and treatment facilities, generally requires the posting of a performance bond.

**B. Assured Water Supply Regulations for Water Providers**

If a water company is designated as having an assured water supply then individual subdivisions to be served by the water company are relieved of having to independently demonstrate an AWS. The same basic criteria, which apply to Certificates of AWS, also apply to water providers seeking a Designation of AWS. Important items that are unique to the Designation of AWS are addressed in the following sections.

Physical, Legal, Continuous Availability; R12-15-703

Demand and supply information must be provided for the entire service area. The water must be physically and continuously available to the water provider in amounts sufficient to meet current demand, committed demand and a minimum of two years of projected demands for at least 100 years. The water provider must have a legal right to all water to be served. If the provider is not a city or town, applicable Arizona Corporation Commission approvals must exist for private water company regulations.

Consistency with Management Goal; R12-15-705

"Consistency with the management goal" can be demonstrated through utilization of a CAP allocation, other surface water, recharge credits, extinguished grandfathered water rights, water exchange agreements or membership in the GRD. If the water provider meets the consistency with the management goal requirement through membership in the GRD, the service area must be enrolled as a member service area. The provider will pay an annual assessment to the GRD based on the amount of mined groundwater pumped for the entire service area.

Consistency with Management Plan; R12-15-706

Existing water providers can show consistency with the management plan if they are in compliance with their conservation requirements. If the provider is out of compliance, the violation must be remedied by entering into a stipulated agreement with ADWR. New water providers must describe the measures that will be implemented to meet ADWR's conservation requirements. If the water provider is out of compliance, the Designation could be lost.

Financial Capabilities; R12-15-707

To demonstrate financial capability for storage and treatment facilities, private water companies can show Arizona Corporation Commission approval of financing as evidence. Cities and towns can present evidence that

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financing is available for a five-year capital improvement plan containing these facilities.

SERVICE AREAS DESIGNATED AS HAVING AN ASSURED WATER SUPPLY

Within Active Management Areas (AMAs)

As of July 1, 2000

Phoenix AMA

City of Avondale  
City of Chandler  
City of El Mirage  
Town of Gilbert  
City of Glendale  
City of Goodyear  
City of Mesa  
City of Peoria  
City of Phoenix  
City of Scottsdale  
City of Surprise  
City of Tempe  
Chaparral City Water Company, Fountain Hills  
Apache Junction Community Facility District

Prescott AMA

City of Prescott

Tucson AMA

Rancho Sahuarita Water Company  
City of Tucson  
Town of Oro Valley  
Metropolitan Domestic Water Improvement District, Oro Valley  
Town of Marana  
Spanish Trail Water Company  
Vail Water Company

Pinal AMA

Town of Florence  
City of Eloy

Santa Cruz AMA

City of Nogales (Expected to be issued by August 31, 2000)

**C. Groundwater Allocation and Management Goal Accounting**

Assured Water Supply applicants are allowed to utilize a certain volume of groundwater to allow for the “phasing in” of renewable supplies. This volume is calculated differently depending on the type of applicant and the AMA. Each AMA’s groundwater allocation and goal were discussed in Part Three, Chapter IV, Section A- Consistency with Management Goal.

The methods for calculating the allocation, how the groundwater allocation may be used, and the accounting mechanism to determine compliance with the consistency with management goal criterion are explained below.

Calculating the Groundwater Allocation

The groundwater allocation is comprised of three components: the basic allocation, the incidental recharge factor and extinguishment credits. Each of the following sections describes how to calculate these parts of the ground-



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water allocation. Groundwater used above the total of the mined groundwater allocation, the incidental recharge allocation and the extinguishment credits must be replenished unless it is exempt.

### **Basic Allocation**

Designation applications for existing water providers can pledge the 1994 demand (water usage) multiplied by 7.5% in the Phoenix AMA and by 15% in the Tucson AMA. For example in the Phoenix AMA, if an existing water provider's 1994 water usage was 1000 af, then 1000 af X 7.5% would equal their basic groundwater allocation. 75 af/yr would be the amount of groundwater that would not have to be replenished. New water companies formed after February 7, 1995 that apply for a Designation of AWS do not receive a basic allocation.

For Certificates of AWS in the Tucson and Phoenix AMAs, the 15-year demand of the development (which may be the build-out demand) is multiplied by the appropriate factor shown in the table below. This amount is the basic 100-year allocation and not an annual amount. For the Pinal AMA, the basic allowance is determined by multiplying the population of the subdivision by 125 gallons per person per day. For certificates in the Prescott AMA, the groundwater allowance is their 15 year demand of the development, multiplied by the number of years until 2025, divided by two. The rules do not establish a groundwater allowance for the Santa Cruz AMA.

### **Calculating the Basic Groundwater Allocation for Certificates**

Location of Proposed Development	Management Period in Effect on Date of Application	Allocation Factor
Tucson	Third (2000-2010)	8
	Fourth (2010-2020)	5
	Fifth (2020-2025)	2
	After 2025	0
Phoenix	Third (2000-2010)	4
	Fourth (2010-2020)	2
	Fifth (2020-2025)	1
	After 2025	0

### **Incidental Recharge Factor**

Holders of designations under the new rules (except those in the Pinal, Prescott and Santa Cruz AMAs) annually receive an incidental recharge allocation based on 4 percent of the demand in the previous year. Designation applicants may also apply for a higher incidental recharge allocation factor if they can demonstrate that incidental recharge is higher than 4 percent in their service area.

### **Extinguishment Credits**

Groundwater credits can be accumulated through the extinguishment of grandfathered groundwater rights. The credit is based on a calculation prescribed in the rules, which varies depending on the AMA in which the right is extinguished, the type of right, and the year that the right is extinguished. Extinguishment credits may be conveyed so long as they have not already been used as the basis of a Certificate of AWS.

### **Use of the Mined Groundwater Allocation**

The mined groundwater allocation can be used at any time during the 100-year period. It may be spread out over a period of years or the use may occur during a specific time period.

Private water companies that applied for a Designation of AWS by August 7, 1995 were given three years before they needed to show consistency with the management goal of the AMA. This means that for 1996, 1997, and 1998 they may use groundwater and not have it subtracted from their groundwater account. Similarly, if deemed providers (cities or towns with CAP allocations) applied for a Designation of AWS by January 1, 1997, they do not have to comply with the goal consistency provision until 2001.

### **Consistency with Management Goal Accounting**

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To determine compliance with the consistency with management goal requirements, ADWR establishes an account for each holder of a Certificate or Designation of AWS which includes the water supply and demand status of the holder. The account is updated annually and includes the volume of the mined groundwater allocation, including any extinguishment credits and the incidental recharge allocation as applicable. As mined groundwater is used, it will be subtracted from the account unless it is exempt.

### Wet Water v. Paper Water

The process of calculating the basic allocation, the incidental recharge factor and extinguishment credits produces an amount of “paper water.” It may be the case that an existing water provider is entitled to an amount of groundwater on paper that does not exist in the aquifer. It is important to remember that physical availability of the water must still be proven, even if the applicant is entitled to a groundwater allocation.



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## Appendix D

# UNDERGROUND WATER STORAGE AND RECOVERY PROGRAM

Source: Governor's Water Management Commission Briefing Notebook, August 2000

### CHAPTER III

#### OVERVIEW

#### CONVERSION TO RENEWABLE SUPPLIES

Current groundwater withdrawal authorities established in the Code, such as IGFRs, Type 1 and Type 2 Non-Irrigation Grandfathered Rights, withdrawal permits, and service area rights, plus groundwater allocations under the Assured Water Supply (AWS) Rules, play a major role in groundwater overdraft. To address this problem, water management efforts focus on ways to encourage water users to convert to renewable supplies. In the AMAs, these efforts include an Augmentation and Recharge Program, the Underground Storage and Recovery Programs, and renewable supply utilization requirements under the AWS Rules. Additional entities that assist in conversions to renewable supplies are the Central Arizona Groundwater Replenishment District (CAGR) and the Arizona Water Banking Authority (AWBA).

#### Augmentation and Recharge Program

The Augmentation and Recharge Program, in combination with conservation program efforts, is intended to support achievement of the management goal for each AMA by encouraging the acquisition, delivery, use and storage of renewable water supplies now and in the future. Increasing the use of renewable supplies, particularly Central Arizona Project water and effluent, to replace groundwater mining is a key component of achieving the management goals for the Phoenix, Pinal and Tucson AMAs. For the Prescott and Santa Cruz AMAs, effluent, limited volumes of surface water and potential imported supplies will be depended upon to offset groundwater pumping.

One of the most important factors that will shape the Augmentation Program is the unique opportunity to bring excess CAP water into the AMAs (only Phoenix, Pinal and Tucson) and store it underground for future use. A substantial supply of CAP water has been physically available to augment the Phoenix, Pinal and Tucson AMA's water supplies, but will not be fully utilized until some point in the future. Therefore, taking advantage of this supply and storing it now while it is currently available is an opportunity that must be encouraged. The Arizona Water Banking Authority (AWBA) provides the means to purchase and store CAP water that is not currently used directly, and that would otherwise remain in the Colorado River. Furthermore, the AWBA statutes specify that some of this water may be used "to fulfill the water management objectives" of the Groundwater Code.

Incentives to facilitate the utilization of renewable supplies have been incorporated into the Management Plans, providing "breaks" in the conservation requirements for the use of effluent and CAP water, under certain circumstances. Financial assistance is provided through the augmentation assistance program for entities implementing augmentation projects or studies that contribute to achieving the AMA management goal or resolving regional water management issues.

#### Underground Storage and Recovery Programs

Several underground storage and recovery programs enacted under legislation during the late 1980s and early 1990s were unified under the 1994 Underground Water Storage, Savings and Replenishment Act (UWS). The UWS program allows individuals and entities to recharge water into aquifers, and later recover that water, once the individual has received either a storage facility permit, water storage permit or a recovery well permit. Recovery of stored water can occur either annually or long-term, which allows for flexibility in meeting fluctuating water demands and drought conditions.

#### Assured Water Supply Rules

Municipal providers serving new municipal uses are required to utilize renewable supplies through acquisition of an Assured Water Supply designation (Designation of AWS) or Certificate of Assured Water Supply (Certificate of AWS). Because all new subdivisions must demonstrate the use of renewable supplies (through direct use or storage and recovery) or join the Central Arizona Groundwater Replenishment District (CAGRDR) so that their groundwater pumping will be replenished, most municipal water use will gradually transition to renewable supplies. This transition is an important strategy in reducing the long-term reliance on groundwater. However, some amount of groundwater will be allowed to be pumped under the AWS Rules, which will further affect groundwater levels and the rates of decline in each AMA.

#### Central Arizona Groundwater Replenishment District

The establishment of a replenishment entity in the AMAs is closely tied to the Assured Water Supply Program (AWS Program). In 1993, the Legislature authorized CAWCD to undertake replenishment activities that allow municipal providers and new subdivisions seeking an assured water supply (either designation or Certificate of AWS) to become members of the CAGRDR. The CAGRDR provides a mechanism for demonstrating consistency with the management goal, required under the AWS Rules, in the Phoenix, Pinal and Tucson AMAs. Members can continue to pump groundwater and the CAGRDR will replenish that groundwater using a renewable supply somewhere in the same AMA.

#### Arizona Water Banking Authority

In 1996, the Arizona Water Banking Authority (AWBA) was created to assist Arizona in utilizing its 2.8 million acre-feet annual apportionment of Colorado River water and to store unused Colorado River water for future needs, including for use in times of drought. Additionally, the AWBA can participate in interstate water banking with California and Nevada by entering into Storage and Interstate Release Agreements that allow Arizona to store unused Colorado River water for California and Nevada.

### **A. Incentive Programs**

Pricing incentives are one of the most effective tools in encouraging the conversion to the use of renewable supplies. In 1992 the Central Arizona Water Conservation District (CAWCD) established an indirect, or in-lieu recharge program that priced a certain portion of CAP water well below the price of agricultural CAP water. The figures denoting deliveries of in-lieu water and agricultural groundwater pumping indicate that this pricing structure had a dramatic effect on water use patterns, and was very effective in reducing groundwater pumping.

Agricultural CAP use was relatively small in the early 1990s. Therefore, the CAWCD, the managing entity of the CAP canal, established an incentive pricing program for non-Indian agricultural CAP water, beginning in 1994 and ending in 2011, to encourage greater direct use of these supplies. This restructuring program was established primarily to deal with the inability of the irrigation districts in the Pinal and Phoenix AMAs to meet their obligations to CAWCD under their CAP subcontracts. In exchange for waiving their entitlement to CAP water under their subcontracts, the irrigation districts would receive excess and surplus CAP water. The program, called "target pricing," created three pools of agricultural supplies to be available to the Phoenix, Pinal and Tucson AMAs. Pools 1 and 2 each contain a total of 200,000 acre-feet, whereas the amount in Pool 3 is not capped. Pool 1 was made available to each district that executed a CAP subcontract prior to October 1, 1993. Pool 2 water was made available to non-Indian irrigation subcontractors who relinquished part or all of their original entitlement between October 7, 1993 and January 1, 1994. Pool 3 water consists of agricultural water remaining after sales of Pools 1 and 2 and is available to agricultural entities otherwise eligible to receive CAP water service at a price equal to pumping energy costs plus a capital charge.

The benefits of target pricing are twofold. First, CAWCD and ADWR require the irrigation districts to use the low cost pool water prior to taking any in-lieu water if the district is a groundwater savings facility (GSF). This benefits water management efforts by ensuring that a portion of the agricultural water demand is met with CAP water and not with groundwater-groundwater that is either pumped today or the future pumping of long-term storage credits. Second, no interest is due on the total federal repayment obligation of the CAP canal for water supplied to

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agricultural lands. Therefore, the more CAP water, including Pool water, used on agricultural lands, the less the overall repayment debt becomes. For 1998, costs of Pools 1, 2 and 3 were set at \$31, \$21 and \$43 per acre-foot, respectively. The price of Pools 1 and 2 increases \$1.00 per acre-foot annually and the price of Pool 3 will be determined annually.

Provisions established under the agricultural, municipal and industrial conservation programs in the second and third management plans provide regulatory incentives for the use of renewable water supplies. These incentives have focused primarily on the use of effluent but are extended to CAP and other renewable supplies.

### RENEWABLE WATER SUPPLY UTILIZATION INCENTIVES PHOENIX ACTIVE MANAGEMENT AREA

#### **Municipal**

Delivery of effluent by a municipal water provider does not count against the gallons per capita per day (GPCD) requirement, unless effluent is recharged in one location and recovered outside the area of impact. This is an incentive for municipal providers to invest in reclaimed water systems (Chapter 5, section 5.8).

CAP water delivered by a municipal provider to a non-residential water user is excluded from the provider's total GPCD requirements for up to ten years if it is shown that the delivery will expedite the development of infrastructure to deliver reclaimed effluent to the user in the future (Chapter 5, section 5.8).

The Alternative Conservation Program removes the non-residential portion of the GPCD requirement for providers who limit their groundwater use to the highest annual use between 1980-1989, utilize renewable supplies for their remaining demand, and implement specific conservation measures for non-residential customers. This program also includes an incentive to extinguish existing grandfathered rights to groundwater (Chapter 5, section 5.7.1.3.1).

The Non-Per-Capita Program removes the GPCD rate as a regulatory tool entirely in exchange for implementation of specified conservation programs. A "best management practices" approach is designed to achieve the same level of efficiency as the GPCD, but the point of compliance is implementation of the programs, not the level of water use. To qualify, water providers must phase out groundwater use, or have a Designation of AWS (Chapter 5, section 5.7.1.2.3).

#### Industrial

#### **Turf**

Effluent use is discounted when calculating compliance with the annual allotment for each facility. For the Third Management Plan, the incentive has been increased to a 40 percent discount (the Second Management Plan discount was a maximum of 20 percent) (Chapter 6, section 6.3.5.3).

If 100 percent of the water used at a facility in a year is from a non-groundwater source, no compliance is required with the annual allotment for that year.

#### **Cooling Towers**

Cooling towers that beneficially reuse 100 percent of their blowdown water are exempt from meeting the blowdown concentration requirements (Chapter 6, section 6-602.B.1). Cooling towers that convert to at least 50 percent effluent are exempt from the blowdown concentration requirements for one full year. If it is shown that they cannot meet the requirements, amended blowdown concentration levels may be applied (new incentive in the Third Management Plan) (Chapter 6, section 6-602.B.3).

#### **Electric Power**

**Electric power generating facilities are given a full year with no blowdown concentration requirements if they convert to at least 50 percent effluent. If it is shown that they cannot meet the requirements, amended blowdown concentration levels may be applied (new incentive in the Third Management Plan) (Chapter 6, section 6-505).**

### **Dairies**

The reuse of dairy wastewater by a grandfathered groundwater right holder is not counted toward compliance with the dairy's maximum annual water allotment (Chapter 6, section 6-703).

### **Agricultural**

Pursuant to A.R.S. § 45-467, effluent use cannot contribute to a farm exceeding its allotment in any year. In determining whether a farm exceeds its maximum annual groundwater allotment for a year, total water use, including groundwater, effluent, and surface water, is counted. Any effluent used that year is subtracted from the amount of groundwater that otherwise would have exceeded the farm's allotment.

Source: Third Management Plan

## **B. Underground Storage & Recovery Programs**

In 1986, the Arizona legislature established the Underground Water Storage and Recovery Program to allow storage of renewable water underground and to recover it at a later time for the storer's use. Between 1986 and 1993, the legislature added several other programs related to underground water storage. In 1994, the Arizona legislature consolidated these various underground water storage programs into a unified program by enacting the Underground Water Storage, Savings, and Replenishment Act (UWS). The UWS program is administered by the Arizona Department of Water Resources (ADWR).

The UWS program has two sets of goals. The first set of goals is to encourage the use of renewable water supplies to satisfy existing needs, to allow for effective and flexible storage of renewable water supplies not currently needed, and to preserve non-renewable groundwater supplies. The second set of goals for the UWS program is to allow for the efficient and cost-effective management of water supplies by allowing the use of underground storage facilities for filtration and distribution of surface water rather than constructing surface water treatment plants and distribution systems. This UWS program goal allows storage of water in one location and recovery in a different location. Therefore, water may be stored near its source and recovered where it is needed. Although the UWS program contains some restrictions to this "transportation," the program may be used to deliver water to where it is needed without the expense of constructing canals and pipelines.

### **Recharge Methods**

There are various methods to recharge water. The UWS program recognizes two general categories of recharge facilities. These are Groundwater Savings Facilities (GSF) and Underground Storage Facilities (USF). At GSFs, also called "in-lieu" recharge projects, an entity with an excess supply of renewable water (such as a municipal water provider) delivers this water to a facility that would otherwise have pumped groundwater (such as a farm). The recipient then uses the renewable water in lieu of pumping groundwater. The supplier of the renewable water then earns credits to "recover" this renewable water at a later date from anywhere within the Active Management Area (AMA) that meet the requirements set forth in the ADWR Management Plans. The potential for increasing the number of GSF projects is limited by the loss of agricultural land in the AMAs. As agricultural land is taken out of production due to urbanization or other factors, the acreage available for this type of project will decrease.

At USF projects water is physically added to an aquifer by a number of different means. The most commonly used methods are identified below (modified from Table 4 of Regional Recharge Committee Technical Report).

- **Off-Channel Constructed Shallow Spreading Basins:** Designed to be operated in a wet-dry cyclic mode to maintain high infiltration rates. The dry cycle is used to control the development of a biological film at the surface that impedes the movement of water. The water depth during the wet cycle is not more than five feet.
- **In-Channel Constructed Facilities:** Facility functions within the active floodplain of a watercourse. May include use of inflatable dams, gated structures, levees and basins, compound channels, etc.
- **Managed In-channel Recharge:** Facility involves no construction (other than monitoring devices). The natural stream channel is used for "passive" recharge.
- **Injection Wells:** Wells used to inject water directly into the water-bearing unit of the aquifer. Generally requires source water that meets drinking water quality standards. Best and most direct method of limiting subsidence since the water is recharged directly to the aquifer.

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- **Induced Recharge:** Use of extraction wells alongside a river channel to draw down groundwater levels, thereby preventing the water table from intercepting the land surface and sustaining favorable infiltration rates. This method is only applicable in areas where the permeability and transmissivity of subsurface soils are favorable.
- **Vadose Zone Recharge Wells:** Wells introduce water into permeable, unsaturated strata above the water table. Wells differ in design and construction from stormwater drywells, which are commonly used to drain urban runoff into the vadose zone to comply with local detention/retention ordinances. (Note: the vadose zone is the layer of unsaturated soils that usually extends from the land surface to the top of the uppermost aquifer.)
- **Deep Basins or Pits:** Recharge pits differ from drywells in size and shape; unlike wells, they are typically much wider than they are deep. Pits are constructed to expose coarse-grained sediments of the vadose zone when fine grained overburden precludes the use of shallow spreading basins.

Recharge Permits In Arizona

The following table summarizes the currently active permits that have been issued in the corresponding locations. Expired permits, abandoned facilities, permits issued in 2000 and applications currently under review are not included.

	<b>Phoenix AMA</b>	<b>Tucson AMA</b>	<b>Pinal AMA</b>	<b>Prescott AMA</b>	<b>Santa Cruz AMA</b>	<b>Outside of an AMA</b>
<b>USF Permits</b>	20	6	1	2	0	2
<b>GSF 11 Permits</b>	5	3	0	0	0	
<b>Water Storage Permits</b>	72	28	11	4	0	2
<b>Recovery Well Permits</b>	36	6	3	3	0	0

Permitted recharge capacity as of December 31, 1999 and the total volume of long-term storage credits earned at USFs and GSFs and held in long-term storage accounts as of December 31, 1998 are summarized below. In addition the table shows the number of entities participating in water storage. This is the number of cities, towns, private water companies and other businesses that have long-term storage accounts in each AMA.

	<b>Permitted USF Capacity as of 12/31/99 (AF/Year)</b>	<b>USF Storage as of 12/31/98 (AF)</b>	<b>Permitted GSF Capacity as of 12/31/99 (AF/Year)</b>	<b>GSF Storage as of 12/31/98 (AF)</b>	<b>Number of Entities Participating in Water Storage</b>
<b>Phoenix AMA</b>	378,730	707,109	446,450	313,296	43
<b>Tucson AMA</b>	51,807	36,688	60,986	75,748	12
<b>Pinal AMA</b>	456	888	285,000	690,163	5
<b>Prescott AMA</b>	7,521	9,659	0	0	3
<b>Santa Cruz AMA</b>	0	0	0	0	0
<b>Outside of an AMA</b>	35,000	0	0	0	2

The holders of long term storage credits, either the entities that stored the water or the purchasers of the resulting credits, may recover (i.e. pump) a volume of groundwater equal to the accrued credits<sup>1</sup>. This pumped water legally retains the character of the stored water. That is, if CAP water is stored at a facility and long term storage credits are

<sup>1</sup> Recharge facilities are required to leave a specified amount of their stored water in the ground. This is referred to as a “cut-to-the-aquifer”. Managed recharge facilities require a 50% cut-to-the-aquifer. All other types of recharge facilities require a 5% cut-to-the-aquifer (no cut-to-the-aquifer is required for stored effluent at these facilities).



earned for that CAP water storage, then a volume of groundwater equal to that volume of credits may be pumped. However, this groundwater is considered to be CAP water for the purposes of the conservation requirements of the Groundwater Code.

The Arizona Water Banking Authority (AWBA) also functions as a storage and recovery program by storing unused Colorado River water to assist Arizona in times of drought, assist water users and providers in meeting conservation requirements, and assist Indian water rights claims settlements.

### **C. Central Arizona Groundwater Replenishment District**

In 1993, the legislature created a groundwater replenishment authority to be operated by the Central Arizona Water Conservation District (CAWCD) throughout its three-county service area. This replenishment authority of CAWCD is commonly referred to as the Central Arizona Groundwater Replenishment District (CAGRD). In 1999, the legislature expanded CAWCD's replenishment authorities and responsibilities by passing HB2262.

The purpose of the CAGRD is to provide a mechanism for landowners and water providers to demonstrate an assured water supply under the new Assured Water Supply Rules (AWS Rules) which became effective in 1995.

#### Relationship to AWS Rules

The benefits provided by the CAGRD cannot be fully understood without a basic understanding of the AWS Rules. The AWS Rules are designed to protect groundwater supplies within each Active Management Area (AMA) and to ensure that people purchasing or leasing subdivided land within an AMA have a water supply of adequate quality and quantity. Thus, in each AMA, new subdivisions must demonstrate to the Arizona Department of Water Resources (ADWR) that a 100-year assured water supply is available to serve the subdivision before sales can begin. An assured water supply (AWS) can be demonstrated in two ways. First, the owner of the subdivision can prove an AWS and receive a Certificate of AWS from ADWR. Or, the owner of a subdivision can receive service from a city, town or private water company which has been designated by ADWR as having an AWS.

There are five basic criteria for proving an AWS. An applicant for an AWS must prove that:

1. a sufficient quantity of water is continuously available to satisfy the water demands of the development for 100 years;
2. the water source meets water quality standards;
3. the proposed use of water is consistent with ADWR's conservation standards;
4. the proposed use is consistent with water management goals; and
5. the applicant is financially capable of installing the necessary water distribution and treatment facilities.

Under the 1993 CAGRD enabling legislation, membership in the CAGRD provides a means by which an AWS applicant can satisfy criterion number 4 above, which requires that the proposed water use be consistent with the water management goals of the particular AMA. The consistency with management goals section of the AWS Rules limits the quantity of mined groundwater that an applicant may use to demonstrate an AWS. The effect of this groundwater pumping limitation is to prevent new development from relying solely on mined groundwater to serve its water demands.

Development, however, is not stymied for those landowners and water providers who have no direct access to CAP water or other renewable supplies. If a water provider or a landowner has access to groundwater and desires to rely exclusively on groundwater to demonstrate a 100 year water supply, it may do so, provided it joins the CAGRD. As a member of the CAGRD, the landowner or provider must pay the CAGRD to replenish any groundwater pumped by the member which exceeds the pumping limitations imposed by the AWS Rules.

#### Replenishment Obligation of the CAGRD

The CAGRD must replenish (or recharge) in each AMA the 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."

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Recharge may be accomplished through the operation of underground storage facilities or groundwater savings facilities. CAWCD may sell its indirect storage and recovery credits to the CAGRDR at fair value.

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 CAGRDR will use for replenishment will likely be excess CAP water.

### Membership

Membership is voluntary. Any city, town, water company, subdivision or homeowner's association located in Pima, Pinal or Maricopa counties may join the CAGRDR.

There are two types of members:

- a. Member Service Areas: The service area of a city, town or private water company, including any additions to or extensions of the service area.
- b. Member Lands: An individual subdivision with a defined legal description.

### Physical Access to Groundwater

Under the provisions of the 1993 CAGRDR enabling legislation, membership in the CAGRDR 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 CAGRDR 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. The new authorities provided to the CAGRDR in 1999 modify this requirement to some extent for Member Service Areas, as described later in this section.

### Replenishment Taxes/Assessments

Costs of the CAGRDR will be covered by a replenishment tax or replenishment assessment levied on CAGRDR members. Water providers serving Member Service Areas will pay a replenishment tax directly to the CAGRDR according to the number of acre-feet of excess groundwater they deliver within their service areas during a year. For Member Lands, a replenishment assessment will be collected by the county assessor from each tax parcel according to the number of acre-feet of excess groundwater delivered to that parcel.

### Amount of the Replenishment Tax/Assessment

The amount of the replenishment tax/assessment will be the CAGRDR's total cost per acre-foot of recharging groundwater, including: the capital costs of constructing recharge facilities, water acquisition costs, operation and maintenance costs and administrative costs. By statute, the replenishment tax/assessment must be calculated separately for each AMA.

### Additional Authorities Provided by the Legislature in 1999

In 1999, the legislature expanded CAWCD's replenishment authorities and responsibilities by passing HB 2262. Under this legislation, CAGRDR's role in helping members prove an AWS is extended beyond the consistency with management goal criterion described above. Now the CAGRDR may assist a Member Service Area in satisfying criterion number 1, (i.e., proof that a sufficient quantity of water is continuously available to satisfy the water demands within the service area for 100 years).

The new legislation allows ADWR to grant a designation of AWS to a water provider whose service area has been enrolled as a Member Service Area of the CAGRDR and has been granted "Water Availability Status" by the CAWCD Board. If the CAGRDR decides to grant "Water Availability Status" to a Member Service Area, it must formally adopt a resolution and prepare and file a detailed "Capability Plan" with ADWR. The plan must include a description of the replenishment facilities, transportation facilities, and water supplies that will be used to provide a physically available supply of water to the Member Service Area. It must be a 100-year plan, which is subject to public review and a public hearing. The plan is to be updated every ten years. The bill also allows the CAGRDR to make direct deliveries, under certain conditions, to Member Service Areas that have been granted Water Availability Status.



#### **D. Arizona Water Banking Authority**

Arizona does not currently use its full 2.8 million acre-foot per year share of Colorado River water established under *Arizona vs. California*, 373 U.S. 546 (1963). Any of Arizona's apportionment not diverted from the main-stream by Arizona is available for use in California or Nevada. The Arizona Water Banking Authority (AWBA) was established in 1996 as a means to increase the utilization of Arizona's Colorado River apportionment and to store unused Colorado River water to meet Arizona's future water supply needs. As Arizona directly uses more of its Colorado River apportionment, the amount of excess CAP water available to the AWBA for storage is expected to decrease.

The objectives of the AWBA include: (1) protecting municipal and industrial (M&I) users of CAP water from shortages or disruptions of the CAP system; (2) assisting in meeting the management objectives of the state's Groundwater Code (Code); (3) assisting in the settlement of Indian water rights claims; (4) exchanging water to assist Arizona's Colorado River communities; and (5) exploring opportunities for interstate water banking with Nevada and California. Although the AWBA has been working closely with the AMAs to identify storage opportunities that would also help support water management objectives of each AMA, some recharge projects ideally located to meet some of these AWBA objectives may not optimally assist the AMAs in meeting their specific water management goals, for example, hydrologically feasible sites located outside of the AMA.

Annual funding for the AWBA comes from four sources: (1) an ad valorem property tax of four cents per \$100 assessed valuation in the three-county CAP service area; (2) a groundwater withdrawal fee of \$2.50 per acre-foot in the Tucson, Phoenix and Pinal AMAs; (3) general fund appropriations; and (4) the proceeds of interstate banking activities. The ad valorem tax collected for the AWBA in Maricopa County is estimated to be \$6.1 million in 1998. The 1997 groundwater withdrawal fee (collected in 1998) should generate \$2.2 million. General fund money projected to be used for storage in the Phoenix AMA in 1998 is \$235,000. Based on the \$8.5 million that is currently available, the total recharge capacity that could be utilized by the AWBA in the Phoenix AMA is estimated at 121,000 to 170,000 acre-feet per year, based on water costs of \$70 to \$50 per acre-foot, respectively, which may be optimistic for the long-term.

In 1998, the AWBA actually stored over 117,000 acre-feet of water.

The AWBA is authorized to enter into Storage and Interstate Agreements with entities in Nevada and California under certain conditions. Under these agreements, the out-of-state entity, known as the Consuming State, requests Arizona, known as the Storing State, to divert and store a set amount of Arizona's unused apportionment of Colorado River water, which is financed by the Consuming State. Arizona must first verify that no in-state Colorado River right holders could utilize the unused apportionment requested by the Consuming State to be stored. Later, when the Consuming State needs additional water supplies beyond its Colorado River apportionment, the Consuming State requests Arizona to develop an Intentionally Created Unused Apportionment (ICUA) that matches the amount originally stored by Arizona for the Consuming State. The ICUA is developed by decreasing Arizona's consumptive use of Colorado River water and allowing the Consuming state to utilize the water remaining on the mainstream. To the extent interstate water is stored within an AMA, the AMA would receive a short-term benefit of additional water supplies imported into the AMA in advance, perhaps by decades, of when those supplies would be needed for direct use by the out-of-state entity.

#### **E. Augmentation Assistance Program**

The Arizona Department of Water Resources' (ADWR) Water Management Assistance Program (WMAP) is intended to provide financial and technical resources and to assist in the development and implementation of conservation programs, augmentation programs, and programs designed to monitor hydrologic conditions and assess water availability in the Active Management Area (AMA). This program is funded through a portion of the groundwater withdrawal fee paid annually by those who withdraw groundwater in the AMA.

Augmentation assistance may take the form of financial assistance to water users, providing them the means to study, design, and construct renewable resource facilities. Assistance may also take the form of planning and technical assistance designed to develop AMA-wide and local area management strategies, as well as monitoring

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activities. Current monitoring activities include providing staff assistance and funds for water availability and subsidence monitoring studies.

ADWR administers this program through the awarding of contracts to water users, universities, consultants and other eligible persons. ADWR also provides legal, financial, and administrative support to the contracts program. Each AMA has a five-member Groundwater Users Advisory Council (GUAC) appointed by the governor to represent various sectors of the regulated water community. A competitive application review process is conducted after which program staff and the GUAC formulate a set of funding recommendations for submittal to the director for final decision.

The goal of the Augmentation Assistance Program is to assist water users or other eligible persons within each AMA in developing augmentation and recharge projects to maximize the use of renewable sources of water such as Central Arizona Project, other surface water and effluent. ADWR will meet this goal by working toward the following program objectives:

- Identify high priority funding areas, in consultation with the GUAC and the waterusing community, and administer priority programs.
- Provide funds for the planning, design and construction of such augmentation and recharge projects.
- Act as a central source for information on augmentation and recharge.
- Increase public awareness of the importance of augmenting the AMA's groundwater supplies.

In an effort to apply available funding and technical assistance to the most important projects, the AMA identifies annual program priorities. With assistance from members of the water-using community and the GUAC, high priority project categories are identified. Any applications for funding in these categories receive preference during the application review and selection process.

Statutory authorization making monitoring and water availability assessments fundable under this program was given in 1996. Projects that may be funded in this new category include water measurement, aquifer and geohydrologic studies, land subsidence monitoring and aquifer compaction studies.

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# THE JOURNEY FROM SAFE YIELD TO SUSTAINABILITY



## ground water

Issue Paper/

## The Journey from Safe Yield to Sustainability

by William M. Alley<sup>1</sup> and Stanley A. Leake<sup>2</sup>

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### Abstract

Safe-yield concepts historically focused attention on the economic and legal aspects of ground water development. Sustainability concerns have brought environmental aspects more to the forefront and have resulted in a more integrated outlook. Water resources sustainability is not a purely scientific concept, but rather a perspective that can frame scientific analysis. The evolving concept of sustainability presents a challenge to hydrologists to translate complex, and sometimes vague, socioeconomic and political questions into technical questions that can be quantified systematically. Hydrologists can contribute to sustainable water resources management by presenting the longer-term implications of ground water development as an integral part of their analyses.

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### Introduction

With increased worldwide attention to the theme of sustainable development and its extension to the sustainability of ground water resources, one might ask how this new concept of sustainability relates to safe yield, and to what extent do the controversies surrounding safe yield carry over to sustainability. Has the term safe yield simply been reinvented as sustainability? To examine these questions, we begin with a brief review of how the two concepts evolved.

### The Concept of Safe Yield

The safe-yield concept derives from water supply engineering studies. Originally, the concept focused on the relation between the size (capacity) of a surface water reservoir and its safe yield, defined as the maximum quantity of water that could be supplied from the reservoir during a critical period. With respect to ground water resources, Lee (1915) first defined safe yield as the quantity of water that can be pumped “regularly and permanently without dangerous depletion of the storage reserve.” Meinzer (1923) later defined safe yield as “the rate at which water can be withdrawn from an aquifer for human use

without depleting the supply to such an extent that withdrawal at this rate is no longer economically feasible.” It is noteworthy that Meinzer’s definition used economic factors as a key determinant and, like Lee, focused on depletion of ground water resources. Over time, the concept expanded to include degradation of water quality (Conkling 1946), the contravention of existing water rights (Banks 1953), and other factors. Todd (1959) succinctly and broadly defined the safe yield of a ground water basin as “the amount of water which can be withdrawn from it annually without producing an undesired result.”

Various authors have recommended abandoning the term safe yield (Thomas 1951; Kazmann 1956) because of its vagueness, its misinterpretation by laypersons as implying a fixed underground water supply, and its dependence on the particular locations of wells, among other reasons. Nonetheless, the term is still used, and is even found in some state codes. The fundamental idea behind safe yield—quantifying the desirable development of a ground water basin—remains relevant today.

Many suggestions for improving the safe-yield concept have focused on considering the yield concept in a socioeconomic sense within the overall framework of optimization theory. The optimum yield is determined by selecting the optimal management scheme from a set of possible alternative schemes. Of course, within such a framework, consideration of present and future costs and benefits may lead to optimal yields that involve mining ground water, perhaps to exhaustion.

A common misperception has been that the development of a ground water system is “safe” if the average annual rate of ground water withdrawal does not exceed the average annual rate of natural recharge. Bredehoeft et al.

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(1982) and Bredehoeft (2002) give examples of how safe development depends instead on how much of the pumpage can be captured from increased recharge and decreased discharge. Sophocleous (1997) and Bredehoeft (1997) have further discussed this in editorials.

### The Concept of Sustainability

The concept of sustainable development, which emerged in the early 1980s, centered on the idea of limiting resource use to levels that could be sustained over the long term. The World Commission on Environment and Development (1987), better known as the Brundtland Commission, defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This report was followed by the United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro, Brazil, in 1992. Several agreements were signed at the conference, the centerpiece of which was a 40-chapter report—*Agenda 21*, an action plan for sustainable development that integrates environmental and developmental concerns. The recent World Summit on Sustainable Development held in Johannesburg, South Africa, highlighted the challenges of achieving the ideals that have been attached to the concept of sustainable development. Water resources sustainability also continues to move into the international spotlight amidst warnings that more than a third of the world's population will not have access to sufficient freshwater by 2025 (Gleick 2001).

Similar to safe yield, ground water sustainability commonly is defined in a broad context, and somewhat ambiguously, as the development and use of ground water resources in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. Application of the concept of sustainability to water resources requires that the effects of many different human activities on water resources, and on the overall environment, be understood and quantified to the extent possible (Sophocleous 1998; Alley et al. 1999; Sophocleous 2000). In this respect, the importance of managing water at the basin scale, or watershed approach, has emerged along similar lines to the concepts of sustainable development.

Sustainability, like safe yield, is a value-laden concept and one that in many respects is in the eye of the beholder. Defining and measuring sustainability is a major challenge (UNESCO 1999; Loucks 2000). The term sustainability embodies conceptual ambiguities that can be difficult to resolve because they rest on philosophical disagreements (Norton and Toman 1995). For example, ecologists might consider sustainability as use of resources that allows perpetual survival of existing ecosystems, while economists view it more as an allocation of resources that leaves future generations no worse off than present generations. Economists further tend to think about a continuum of sustainability ranging from weak to strong sustainability, with variations in between (Stewart 2003). Weak sustainability requires one generation to hand over to the next a nondeclining total capital stock, which assumes that perfect substitution exists between different types of capital, e.g., new

technologies for water treatment or improved water use efficiencies might be developed that somehow substitute for the reduced capital stock of aquifer water. Strong sustainability, on the other hand, assumes that some kinds of natural capital have no substitutes.

In addition to this complexity of values at a given point in time, values relating to the sustainability of ground water resources change with time. For example, in the first comprehensive paper on the effects of withdrawals on aquifer flow components, Theis (1940) indicated no economic loss would be suffered in the capture of ground water that was previously being discharged by nonbeneficial vegetation. In the mid-20th century, native vegetation that consumed ground water was considered, particularly in the American West, to be nonbeneficial. Today, economists recognize a nonmarket value of features such as native vegetation (Brookshire et al. 1986). As values have evolved in the past decades, they are likely to evolve further in the coming decades. These evolutions will continue in various ways in different countries at different stages of development.

Some have argued that humans have advanced at times by a series of unsustainable developments. For example, use of ground water from the Chalk Aquifer of the London Basin in Great Britain during the 19th and early 20th centuries was not sustainable over the long run, but enabled London to develop as a major center of population and manufacturing (Downing 1993). Likewise, Los Angeles, California, relied on ground water in storage even though the supply was being depleted because of the expectation that imported water eventually would take the place of water used from storage. Thus, when talking about sustainability, it may be necessary to stipulate the period over which the use is planned and any assumptions about future sources of water supply (Hiscock et al. 2002).

### From Safe Yield to Sustainability

It should be clear the concept of sustainability in relation to ground water resources is far from new and is closely aligned with that of safe yield. The differences represent more of a transition, or to paraphrase a National Research Council (1999) report on sustainability, a journey, in our understanding of the dynamic nature of ground water and its linkages across the biosphere and to human activities (Alley et al. 2002).

Safe yield is almost always defined in terms of an annual water withdrawal, whereas the temporal patterns of withdrawal are more open-ended in definitions of sustainability. Indeed, in many situations, a long-term approach to water resources sustainability may involve withdrawals from ground water storage during dry periods that are balanced by replenishment during intervening wet periods.

The definition of safe yield was developed initially based on a very simple view of how a ground water basin might be developed to maximize the quantity of water withdrawn. The concept expanded with time to include economic, legal, and water quality considerations. Sustainability, on the other hand, emerged around the complex interdependence of society and the environment, and the view that no single environmental issue can be addressed in isolation. Presumably, sustainable development encourages

integrated water management approaches such as artificial recharge, conjunctive use of surface water and ground water, and use of recycled or reclaimed water, all of which can profoundly affect the magnitude of development that can be sustained.

Although not originally developed with surface water effects in mind, definitions of safe yield in the United States gradually came to consider the effects of pumping on surface water resources, primarily with respect to water rights in streams. Thus, it became accepted that a yield that is safe with respect to ground water storage might not be so safe with respect to natural discharge areas of aquifers. More recently, concerns about the long-term effects of ground water development have been extended to lakes, wetlands, springs, and estuaries, but these issues seem to have been less tied to determinations of safe yield and more generally related to concepts of sustainability. Today, it is widely recognized that pumping can affect not only surface water supply for human consumption, but also the maintenance of streamflow requirements for fish and other aquatic species, the health of riparian and wetland areas, and other environmental needs. The tradeoff between the water used for consumption and the effects of withdrawals on the environment are increasingly the driving force in determining the sustainability of many ground water systems (Alley et al. 1999). Kendy (2003) emphasizes the importance of distinguishing between water consumption and pumping when assessing sustainability.

Water resources cannot be developed without altering the natural environment; thus, one should not define basin yields, either as safe or sustainable, without carefully explaining the assumptions that have been made about the acceptable effects of ground water development on the environment. Even with assumptions about acceptable changes, the concept of a static safe, or sustainable, yield may not be realistic in light of potential changes in hydrology from land-use activities and climate change. For example, urbanization and agricultural development in a basin affect infiltration, runoff, evapotranspiration, and recharge, effectively changing the hydrologic cycle through time.

### The Role of Hydrologists

An important attribute of the concept of water resources sustainability is that it fosters a long-term view toward management of water resources. The response characteristics of ground water systems and their boundaries often lend themselves to such a long-term view. For example, pumping decisions made today may ultimately affect surface water resources (riverflows, lake levels, discharges to wetlands and springs, etc.), but these effects may not be fully realized for many years. Equilibrium to pumping is reached only when withdrawal is balanced by capture and, in many circumstances, long periods are necessary before even an approximate equilibrium condition can be reached. Some ground water systems do not have boundaries with sufficient potential for capture to match existing or proposed levels of ground water withdrawals, and, thus, new equilibrium is not possible.

Water resources sustainability is not a purely scientific concept, but rather should be viewed as a perspective that

can frame scientific analysis. Key to this idea is that the sustainability goal is very much at the heart of current concerns about the long-term effects of ground water development. We briefly illustrate how ground water hydrologists can contribute constructively to sustainability issues, using Paradise Valley in north-central Nevada as an example.

### Case Study: Paradise Valley, Nevada

Natural drainage through the basin-fill aquifer within Paradise Valley runs southward toward the Humboldt River (Figure 1). According to a calibrated predevelopment steady-state model, natural inflow to, and outflow from, the Paradise Valley ground water system was 91 hm<sup>3</sup>/year (Prudic and Herman 1996). Approximately 88% of the inflow (recharge) occurred through leakage from perennial and ephemeral streams, and the rest occurred through leakage along mountain fronts and ground water inflow across the eastern part of the southern boundary from the adjacent Humboldt River Valley. About 96% of the discharge occurred through evapotranspiration; the rest occurred through outflow across the western part of the southern boundary to the Humboldt River Valley and as seepage to streams.

Analyses of the flow system in Paradise Valley (Figure 1) were carried out using a three-layer numerical ground water flow model (Prudic and Herman 1996). The model was calibrated for a period of historical pumping, and additional simulations were carried out to study possible effects of long-term pumping and recovery. One of the analyses was the simulation of 300 years of pumping using the magnitude and distribution of pumping in 1982, followed by 300 years with no pumping. The pumping rate was 44 hm<sup>3</sup>/year, which is almost half the natural inflow to Paradise Valley.

Results of the analysis (Figure 2) show the long-term consequences of ground water withdrawals. Withdrawals of ground water in Paradise Valley have little potential to increase the total rate of surface inflow to the ground water system because almost all of the surface water that flows into the valley already seeps into the ground water system. Pumping, however, can change ground water underflow to and from the adjacent Humboldt River Valley. The source of water withdrawn by wells initially is a decrease of water in storage in the aquifer. With time, storage changes diminish and the sources of water result in a decrease in evapotranspiration in Paradise Valley and an increase in inflow from, and decrease in outflow to, the Humboldt River Valley. After 300 years, the system is approaching a new steady-state condition, with only 4% of the pumped water coming from storage. At that time, 72% of the pumped water is derived from a reduction in evapotranspiration and 21% is derived from an increase in inflow from the Humboldt River Valley.

This analysis of the effects of long-term withdrawals in Paradise Valley illustrates the role that hydrologists can play in providing information related to sustainability (or nonsustainability) of a particular ground water development. Key information in this case includes measures of water level (head) decline, which can help assess consequences of removal of water from storage; information on



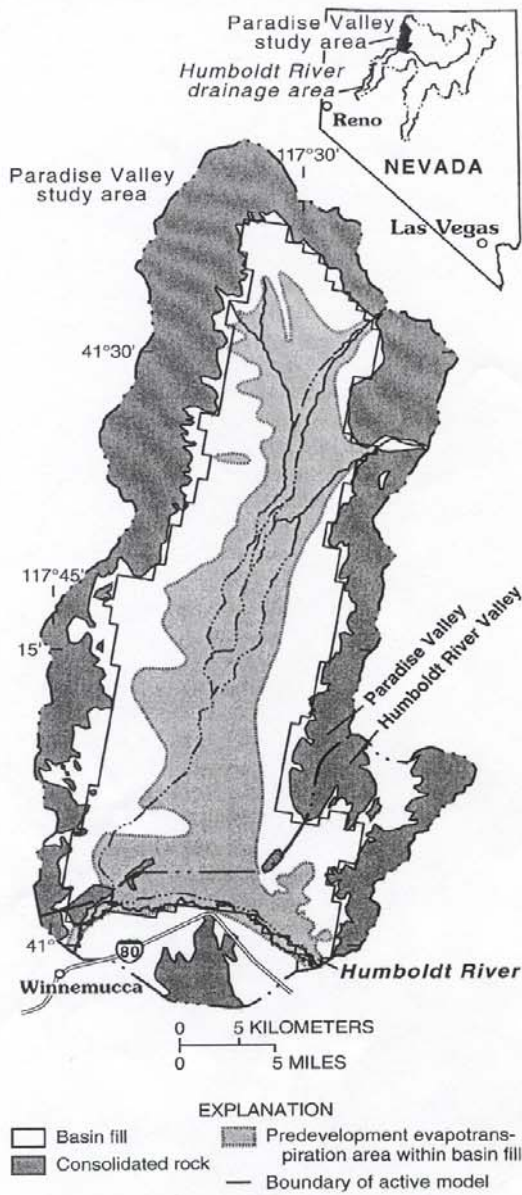


Figure 1. Location of Paradise Valley, Nevada, study area, and select hydrologic and model features. (Modified from Prudic and Herman [1996]).

likely reduction in availability of water for evapotranspiration; and the long-term effects of withdrawals in one area (Paradise Valley) on the flow system in an adjacent area (Humboldt River Valley), which might be managed separately (Figure 2). The possible progression of these changes because of pumping, as well as the dynamics of system recovery if pumping is reduced or ceased, provides a deeper understanding of the consequences of ground water development. A series of such analyses can portray long-term effects caused by alternative scenarios in which the amounts and locations of ground water withdrawals are varied. With this information, society can make better-

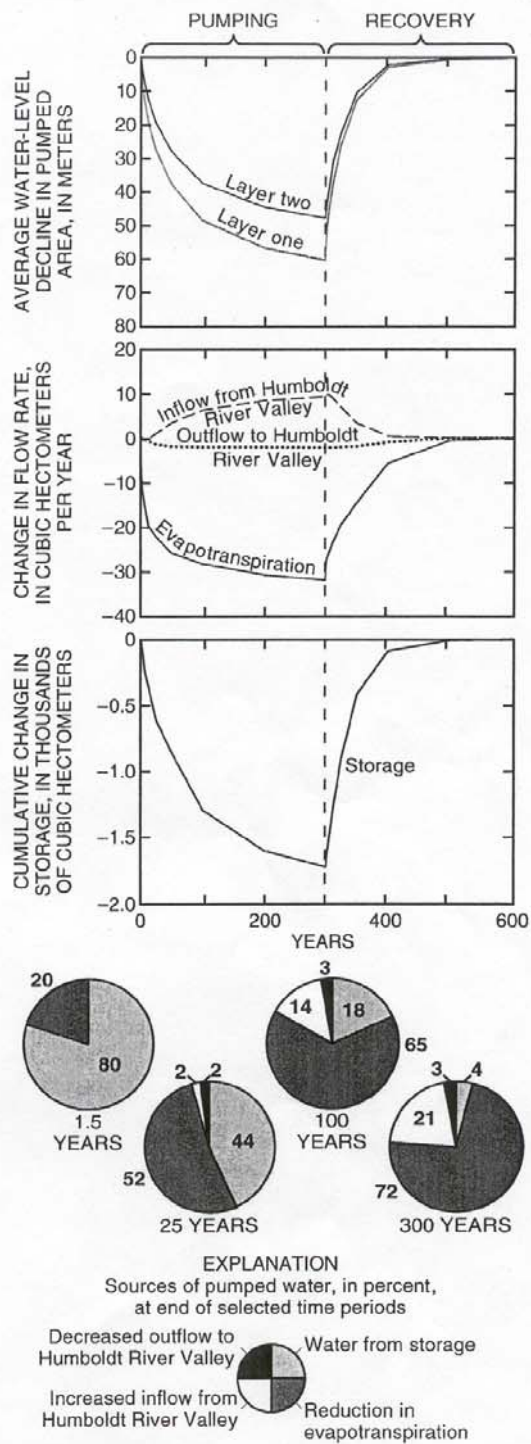


Figure 2. Select results of simulation of ground water withdrawal and recovery for Paradise Valley, Nevada. (Modified from Prudic and Herman [1996]).

informed decisions about how to manage their ground water resources in a long-term context. Such analyses also



ideally lead to the design and implementation of long-term hydrologic networks to monitor projected outcomes of the ground water development and to improve the ability to predict future system responses. A key challenge is to extend the types of long-term forecasts of changing water budgets presented here to forecasts of other associated potential impacts, such as riparian vegetation decreases.

### Summary Remarks

Although many people have expressed concerns about the ambiguity of the term sustainability, the fact remains that prudent development of a ground water basin in today's world is a complicated undertaking. A key challenge for sustained use of ground water resources is to frame the hydrologic implications of various alternative development strategies in such a way that their long-term implications can be properly evaluated. Each hydrologic system and development situation is unique and requires an analysis adjusted to the nature of the water issues faced, including the social, economic, and legal constraints that must be taken into account. The role of hydrologists in addressing issues of sustainability is evolving as technologies, understanding of the long-term effects of ground water consumption, and societal priorities evolve. For example, meeting the challenges of water resources sustainability increasingly involves understanding and predicting long-term ecological and water quality impacts and applying innovative approaches to conjunctive use of ground water and surface water, artificial recharge, and water reuse. Scientists and engineers should continue to play a key role in shaping this transition.

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**Editor's Note:** This is an invited submission. Dr. Alley is an associate editor of the journal. Readers interested in writing an Issue Paper should contact the editor-in-chief at [gweditor@geology.wisc.edu](mailto:gweditor@geology.wisc.edu) prior to submittal.

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## Appendix F

# WATER QUALITY ISSUES

GARY WOODARD

The following sections describe key water quality issues from a regulatory perspective that affect Arizona's future water requirements.

### **Arsenic**

The federal Environmental Protection Agency (EPA) rule lowering the drinking water standard for arsenic from 50 micrograms per liter to 10 micrograms per liter becomes effective on January 23, 2006. This change has an extreme impact in Arizona because arsenic naturally occurs in a large number of groundwater supplies used for drinking water at levels greater than 10 micrograms per liter. Many large systems and an estimated 300 small systems will have to treat, blend or develop alternative sources in order to meet the new standard. Total cost to drinking water systems to comply is estimated at over \$100 million. Concern about management of arsenic-laden treatment residuals also has been expressed. Proper management is necessary to ensure that other environmental problems are not created. The Arizona Department of Environmental Quality (ADEQ) has developed an Arsenic Master Plan to assist drinking water system owners in meeting the new arsenic standard in 2006.

See <http://www.adeq.state.az.us/environ/water/dw/arsenic.html> for additional information.

### **Perchlorate**

Perchlorate, a rocket fuel, munitions and pyrotechnic chemical, is present in Colorado River water from Hoover Dam to the Mexican border at levels of from 4 to 11 micrograms per liter. Perchlorate is an inorganic, soluble salt that is mobile in surface water and groundwater and resistant to degradation. The perchlorate contamination of the Colorado River is due to discharges into Lake Mead that originated from two manufacturing facilities in Henderson, Nevada. Its occurrence in the lower Colorado River is a concern because the river supplies drinking water to millions of people in California and Arizona, including a large population in central Arizona dependent on supplies brought in by the Central Arizona Project (CAP).

No federal drinking water standard has yet been set for perchlorate. The current Arizona Health Based Guidance Level is set at 14 micrograms per liter. California established a Public Health Goal of 6 micrograms per liter as a first step in promulgating a drinking water standard for use there. Standards setting has been highly controversial nationally due to differences of opinion regarding the health impact of perchlorate at low levels. Recent evidence of perchlorate residues in lettuce irrigated by Colorado River water and milk from cows fed on forage irrigated by Colorado River water has heightened concerns.

Governor Janet Napolitano recently formed a task force drawing from four state agencies—the Departments of Environmental Quality, Water Resources, Health Services (ADHS) and Agriculture—to investigate the occurrence levels of perchlorate in Arizona water sources, the risks, if any, it poses to public health, whether Arizona should develop a water quality standard for perchlorate, and to make recommendations for future action, if necessary.

Further information is available at <http://www.adeq.state.az.us/function/about/perch.html>.

## **Lead**

Lead in drinking water at schools has become a concern nationally because of the discovery of lead in some school systems at levels significantly higher than the EPA action level of 0.015 milligrams per liter in tap water samples. The EPA action level was established to protect public health due to release of lead from lead pipes or soldered copper pipes in water system plumbing and distribution systems serving homes, schools and other places of use. High lead levels are of special concern in schools because of the accumulative nature of lead in human bodies and the disproportionate adverse health consequences for children, who tend to absorb more lead than the average adult. ADHS is gathering data from schools and is working with ADEQ to determine if elevated lead levels are a concern in Arizona.

## **Mercury**

Over the past several years, ADEQ has found increasing evidence of mercury contamination in the lakes and streams throughout Arizona. Based on monitoring results, ADEQ has issued fish consumption advisories on at least 12 water bodies in widely varying locations throughout the state including Alamo Lake, Upper and Lower Lake Mary, Lyman Lake and Parker Canyon Lake. These water bodies will now require development of a total maximum daily load (TMDL) and plan of implementation to improve water quality.

Mercury is a toxic, persistent and bioaccumulative pollutant that is both a public health and an environmental concern. Mercury has a direct affect on the nervous system and has long been known to have toxic effects on humans and wildlife. Since eating fish is the single greatest source of mercury exposure for most people, preventing the entry of mercury into the environment is the best way to reduce mercury exposure that causes health effects.

ADEQ has developed a long-term, multi-media, multi-agency strategy that focuses on preventing new mercury from entering the environment and reducing contributions from existing sources. The strategy involves additional data collection and research to determine actual levels and sources of mercury in Arizona. The strategy also addresses reduction of consumer products containing mercury and encouragement of new technologies that can reduce or replace the use of mercury and facilitate proper disposal of existing products at the end of their useful life.

See <http://www.adeq.state.az.us/envirom/water/assessment/ongoing.html#merc> for additional information.

## **Sediment**

Surface waters of Arizona that do not meet associated water quality standards are considered “impaired.” Under the federal Clean Water Act, which is implemented in Arizona by ADEQ, impaired waters must be listed on a Clean Water Act Section 303(d) list. For each impaired water, a TMDL allocation must be completed and an implementation plan developed to restore the waters to standards. In Arizona, suspended sediment, also measured as turbidity, is a major reason for impairment and is responsible for a large percentage of current or proposed listings on the 303(d) list.

## **Nitrate**

Nitrate is one of the most common pollutants in the state’s groundwater and is almost always caused by anthropogenic activities that result in the transport of nitrogen to groundwater. These activities and sources include agriculture, septic tanks, sewage treatment plants and concentrated animal feeding operations. Large portions of aquifers in Arizona contain groundwater with nitrate concentrations high enough to render the water unfit for potable use. ADEQ water quality permitting requirements limit nitrogen discharges from industrial facilities and sewage treatment plants. Agricultural fertilization practices are regulated through water quality general permits. ADEQ is proposing rules that will limit discharges of nitrogen from animal feeding operations



and septic tank concentrations. Proposed regulations would require lined impoundments for wastewater at certain animal feeding operations and allow ADEQ to designate Nitrogen Management Areas to control discharges from concentrations of septic tanks and other nitrogen sources.

### **Salinity**

Salinity, measured by Total Dissolved Solids (TDS), is composed of salts, minerals and metals. A normal component of drinking water, salinity can become undesirable in high concentrations and affect a wide range of water users, including industry, agriculture and municipalities. High TDS levels inhibit agricultural production and also can become a corrosive element, destroying and damaging water delivery systems and water-using appliances. The cost of these combined damages can be extreme. For example, the cost associated with salinity damage for the Colorado River Basin is between approximately \$500 million and \$750 million per year. Additional costs for many water users could include building or upgrading water treatment facilities and desalting plants in order to remove unwanted salts and improve water quality.

In Arizona, high levels of TDS can occur in groundwater, effluent water and CAP water. Groundwater, usually relatively low in TDS, can increase in salinity as pumping continues to decrease ground water levels. Evaporation from open CAP canals and reservoirs, droughts and seasonal flows of the Colorado River and irrigation practices concentrate and contribute to increase CAP salinity levels. Effluent water from wastewater treatment plants is higher in TDS than groundwater and can add TDS to streams and underground aquifers. As more CAP water reaches wastewater treatment plants, effluent TDS levels will increase. Plans to control the rising salinity levels are being studied by the U.S. Bureau of Reclamation, through the Colorado River Basin Salinity Control Program.

Further information is available at <http://www.usbr.gov/dataweb/html/crwq.html>.

### **Endocrine Disrupters**

An endocrine disrupter (ED) is a compound that disrupts the endocrine system by mimicking or inhibiting the effects of hormones. EDs can include a wide array of natural and synthetic hormones, steroids, pesticides and other industrial chemicals. Unfortunately, EDs are persistent and can bioaccumulate in the environment, to later be consumed through contaminated water and food supplies. Since the common functions of the endocrine system are reproduction and metabolism, some researchers are concerned that accumulation of EDs in the environment may be the current cause of increased breast cancer, sterility, many other endocrine illness and changes in wildlife populations.

Current concerns have been directed toward effluent dominated water supplies, especially in arid areas, where riparian habitats rely on effluent outfall. The effects of persistent EDs in effluent dependent riparian areas are currently being researched, including the chronic effects of long-term, low-level exposure of EDs on native fish species. Another concern is that recharge of effluent may accumulate EDs and negatively affect the water quality for future generations.

To study the effects of EDs on people and wildlife, the EPA established the Endocrine Disruptors Research Initiative. In 1996, EDs were one of the EPA's top six research priorities in the Office of Research and Development. The National Research Council and other research groups are studying and monitoring EDs. Much scientific uncertainty remains, as it is difficult to prove that a particular substance or ED is responsible for an endocrine effect.

Further information is available at <http://www.epa.gov/endocrine/> for Arizona-specific information, also see <http://www.ag.arizona.edu/AZWATER/awr/sep00/feature1.htm>.



## APPENDIX G

# MAJOR STREAMS, RECHARGE AND GROUNDWATER RESOURCES

DAVID A. DE KOK

### Basin and Range Lowlands

The major streams of the basin and range lowlands are the Gila River and two of its tributaries, the San Pedro and Santa Cruz Rivers. The Salt, Verde and Agua Fria Rivers flow out of the central highlands and were once important contributors to the Gila River flow, though they are now all diverted for use in the Phoenix area except during flood events. The Salt and Verde Rivers were perennial rivers (those that flow all the time, usually because they are fed by a base flow, or spring, which seeps into the streambed because of a high water table), whereas the Agua Fria was interrupted (its surface flows occurred in some portions of the streambed but not others due to varying underlying geology). Together, they once ensured that the Gila River was perennial all the way to the Colorado River except in years of extreme drought. Downstream from the Granite Reef Diversion Dam, the Salt River is perennial now only because of effluent outflows from sewage treatment plants. The Gila River has perennial effluent flow for a few miles downstream of its junction with the Salt River but is ephemeral (flow in direct response to precipitation events) after that.

Natural recharge to the aquifers in the basin and range region is limited. In the low-lying western portion of the region it is exceedingly limited, occurring mostly in the form of groundwater underflow from neighboring basins and occasionally as streambed infiltration from passing storms. Those basins abutting Lake Mead, Lake Mohave and Lake Havasu have established a hydrologic connection with the lakes, and water tables rise and fall with fluctuations in lake levels. Recharge takes place along the middle reaches of the Gila River from occasional floods that exceed the storage capacity of upstream dams, from underflow of floodwaters captured by the Painted Rock Reservoir, from incidental recharge of urban effluent and irrigation tailwater and from precipitation.

In the Lower Gila and Yuma basins, excessive recharge has created problems. Much like the drain of a bathtub, this area, the state's elevational low point, eventually receives that portion of Arizona's waters that are not lost to evaporation or immediate groundwater recharge. After completion of the canal system that diverts Colorado River water to the fields of the Wellton-Mohawk Irrigation and Drainage District in 1957, water logging (groundwater levels near the surface of the land) threatened crop production in much of the area. In 1961 a network of wells began pumping excess groundwater into drainage canals to lower groundwater levels and relieve water logging. In the adjacent Yuma basin, groundwater levels are controlled by pumping for both irrigation and drainage.

In the eastern portion of the basin and range region, recharge takes place from streambed infiltration of the area's larger rivers (the Gila, San Pedro and Santa Cruz), from mountain-front recharge of precipitation captured by the mountain ranges, from incidental recharge of urban effluent and irrigation tailwater and from direct precipitation. In Cochise County's Sulphur Springs Valley, pumping by large scale irrigated agriculture lowered water tables significantly, eventually resulting in cutbacks in crop production due to high pumping costs and an accompanying leveling off of water table declines. However, unlike those basins adjacent to the Colorado or Gila Rivers or along the path of the Central Arizona Project (CAP) system, there is no recharge of water from outside of the immediate drainage basins. This means that the net recharge into the valley is limited to only that which naturally occurs.

Recharge patterns throughout the basin and range region have been altered considerably by human use. Storage and diversion dams have decreased the natural recharge resulting from flood flows that in the past reached the alluvial valleys. Entrenchment of watercourses such as the San Simon and Santa Cruz Rivers lowered water



tables, reduced local infiltration rates and sped floodwaters downstream at faster rates. Effluent outflows from sewage treatment plants in Nogales, Tucson and Phoenix have brought perennial flows to new reaches of river and have caused incidental recharge to occur in areas removed from the river's former natural recharge sites.

Many of the basins in the basin and range lowlands experienced severe declines of their water tables between the 1940s and the late 1970s. In the Harquahala Plain, the depth to groundwater in one location went from 202 feet in 1955 to 532 in 1985. In the Salt River Valley, the depth to groundwater dropped from 181 feet in 1945 to 373 feet in 1980. In the Avra Valley, the water table depth went from 251 feet in 1955 to 346 feet in 1975, before rising again to 310 feet in 1990. Since the early 1980s many of the lowland basins have achieved a leveling off or even a rebound in their water tables as irrigated agriculture has reduced production and utilized CAP supplies.

### **Central Highlands**

The principal streams of the central highlands are the Salt and Verde Rivers and their tributaries. The highlands account for 30 percent of the total drainage of the two rivers but produce 65 percent of their combined streamflow. The chief runoff producing area of the Verde River is the Mogollon Rim-San Francisco Mountain region. Significant drainages feeding the Verde River are Sycamore, Oak, Beaver, West Clear, Fossil and East Verde Creeks. This drainage area of 1,900 square miles produces an average annual runoff of 300,000 acre-feet. (The entire Verde watershed of 6,600 square miles has an annual average runoff of 468,100 acre-feet). The Salt River's chief runoff producing area consists of the drainage areas of the White and Black Rivers whose headwaters are on, respectively, the north and south slopes of Mount Baldy. Their combined drainage area of 1,860 square miles produces an average annual runoff of 380,000 acre-feet. (The entire Salt River watershed of 6,300 square miles has an annual average runoff of 666,800 acre-feet.) Other significant tributaries of the Salt River are Carrizo, Cibecue, Cherry and Tonto Creeks.

The other major watercourses of the central highlands are the Bill Williams, Hassayampa, Agua Fria and San Carlos Rivers. The two major tributaries of the Bill Williams are the Santa Maria and Big Sandy Rivers. The Santa Maria River drains mountains to the west of Prescott. The Big Sandy's drainage area is to the northwest of the Santa Maria's and includes portions of the basin and range lowlands to the southeast of Kingman. The Hassayampa River has its headwaters in the Bradshaw Mountains and drains the area south of Prescott. The Agua Fria River's 2,700 square mile drainage basin is immediately east of the Hassayampa's. The San Carlos River drains the area east of Globe and empties into the San Carlos Reservoir above Coolidge Dam.

Groundwater resources are much more variable in the central highlands region of Arizona than in the basin and range lowlands. In the eastern central highlands water for the Pinetop-Lakeside-Show Low area is pumped from the Pinetop-Lakeside aquifer. This aquifer has exhibited no significant decline in storage. Well production rates there can exceed 300 gallons per minute. Some wells in the central part of Payson have experienced water-level declines of four to five and one-half feet per year. This aquifer appears to be drought sensitive.

The depth to groundwater in the Verde Valley is generally less than 800 feet and wells produce at rates of 30 to 150 gallons per minute, but yields in some areas may exceed 1,000 gallons per minute. Water levels here have shown no appreciable change. Depths to water in Sedona range from 180 to 1,000 feet. Wells produce an average of about 70 to 80 gallons per minute. Groundwater levels in the area appear to be declining at a rate of less than one foot per year.

The Prescott area straddles two sub-basins, the Little Chino Valley and the Upper Agua Fria basin. The depth to groundwater ranges from 60 feet in the northwestern part of the valley to 580 feet near Granite Dells. Pumping for irrigation water near the Town of Chino Valley dropped water levels as much as 75 feet between 1940 and 1982. A decline in irrigated acreage and a switch to less water consumptive crops has reduced the rate of decline and even allowed water levels to rise in some portions of the valley, however water levels are generally continuing to decline. In the Upper Agua Fria basin depth to groundwater ranges from 25 feet near Humboldt to 530 feet in Prescott Valley. Highly localized water-level declines in the Prescott Valley of over 100 feet have been recorded, however generally the declines, while ongoing, are considerably less than that.

Because of its many small, fragmented and fairly shallow basins, quantities of water stored in the central highlands are small relative to the amounts in storage in the basin and range lowlands. The limited storage capacity of some of the region's aquifers makes them particularly dependent on regular, frequent precipitation in order to remain productive while being pumped at high volume. The climatic sensitivity of some aquifers has already proven troublesome to a few communities in the central uplands and could prove to be an even more difficult problem for these burgeoning towns to address in the future. The limited amounts of irrigated agriculture, chiefly in the Verde and Chino Valleys, have never played as big a role in the region's groundwater development as the farming in the basin and range lowlands. This has saved the central highland's groundwater resources from the tremendous overdrafts that depleted some of the lowland basins, but it also has given the highlands very limited amounts of agricultural land to retire in order to offset the rising water needs of its many fast growing communities. Annual groundwater withdrawals in the central highlands are generally increasing, having reached a high of 92,000 acre-feet in 1989, and probably considerably more than that since estimates were last made in 1990.

### **Plateau Uplands**

The Little Colorado River is the major drainage for the plateau uplands. The river's headwaters drain the northeastern part of the White Mountains. Irrigation diversions near Springerville, Snowflake and St. Johns, along with considerable channel losses, prevent surface flow from reaching the Colorado River in all but the wettest years. Major tributaries of the Little Colorado River are the Puerco River, Silver Creek, Chevelon Creek, Clear Creek and Moenkopi Wash. About 360,000 acre-feet of water are discharged out of the Little Colorado River Basin annually. Most of this is discharged into the Colorado River, including 160,000 acre-feet of highly saline water that issues from springs along the lower 13 miles of the Little Colorado River.

Chinle Creek drains water from the northern third of the Little Colorado River Plateau basin and delivers 18,100 acre-feet of water annually to the San Juan River in Utah. The Paria River, which originates in south-central Utah, is perennial for its entire 25-mile length from the Utah border until it enters the Colorado River near Lees Ferry. It discharges an average of 21,450 acre-feet of water per year. Kanab Creek and the Virgin River are the major streams of the Arizona Strip, that portion of the state to the north and west of the Grand Canyon. The Virgin River has an average annual discharge of 174,6000 acre-feet. Nearly all of the streams on the Coconino Plateau flow only in response to rainfall or snowmelt. Waters from the eastern third of the plateau empty into the Little Colorado River. The central and western third of the plateau is drained by the ephemeral Cataract Creek, which then empties into Havasu Creek. The Colorado River receives an average of 47,000 acre-feet of water annually from Havasu Creek.

Arizona's upland plateau region is far larger than the central highland region, but groundwater resource development is only slightly greater than it is in the highlands. Approximately 112,000 acre-feet of groundwater were withdrawn from the plateau region in 1989. Some portions of the upland plateau have virtually no economically retrievable groundwater. Major population centers are few and widely dispersed. Due to short growing seasons, among other reasons, agriculture has only a limited presence in the region. Groundwater developments on the Navajo and Hopi Reservations are for the most part limited to small wells for domestic and livestock use, although the Black Mesa Coal Mine is a significant industrial user of groundwater from one regional aquifer.

The Arizona Strip is composed of five groundwater basins: the Paria basin, the Kanab basin, the Shivwits Plateau basin, the Virgin River basin and the Grand Wash basin. Because they are virtually empty of people, there has been almost no groundwater development in the Paria, Shivwits Plateau and Grand Wash basins. About 2,000 acre-feet of groundwater were withdrawn from the Kanab Plateau basin in 1985 to support the communities of Colorado City, Moccasin and Fredonia and to irrigate a few hundred acres of crops and pasture. This amount almost certainly has climbed with Colorado City's explosive growth. Alluvium along the washes in the Short Creek-Cane Beds area proved to be the most productive aquifer, with yields of up to 200 gallons per minute. In the Arizona portion of the Virgin River basin 6,000 acre-feet of groundwater were withdrawn for irrigation in 1990.

The Coconino Plateau basin lies in north-central Arizona, south of the Grand Canyon and to the north

and west of Flagstaff. The basin's two major settlements are the City of Williams and the Grand Canyon-Tusayan area. Groundwater development has been negligible because of the great depth to and the limited yields of wells in the basin. However, in the summer of 2003 the City of Williams began drilling a 4,000-foot well, the deepest municipal well in the Southwest, in response to the droughts effects on its surface reservoirs. A 3,000-foot well near Tusayan yields only 80 gallons per minute. In general, springs such as Blue Springs and Havasu Springs that drain into the Little Colorado and Colorado Rivers drain the basin's potential aquifers. The Little Colorado River Plateau basin, at 27,300 square miles, is the state's largest groundwater basin. The basin's groundwater is contained by numerous, small local aquifers as well as three large regional aquifers. Streambed deposits of the Little Colorado River and its tributaries are important sources for domestic water supplies. However, the quality of water from these aquifers varies considerably. The alluvial aquifer along the Puerco River has radiochemical contamination from the 1979 Church Rock uranium mine tailings pond spill. Downstream movement of these radionuclides continues due to discharges from the sewage treatment plant in Gallup, New Mexico.

The three regional aquifers in the Little Colorado River Basin are known as the D-, N- and C- aquifers. The uppermost aquifer, the D-aquifer, extends for 3,125 square miles. Water from this aquifer is used for domestic supplies in the north central parts of the basin where the other two regional aquifers are too deep. Because of its high concentrations of dissolved solids, water from this source is used only where no other water is available. The intermediate-lying N-aquifer covers an area of 6,250 square miles. Water from this aquifer is suitable for most uses. The N-aquifer is a source of water for the Navajo and Hopi Reservations as well as the Black Mesa Coal Mine. The C-aquifer, at 21,655 square miles, is by far the most extensive aquifer and it underlies most of the Little Colorado River Basin. It is for the most part utilized only south of the Little Colorado River, as it is either too deeply buried or has too high a concentration of dissolved solids north of the river. Flagstaff, Heber, Overgaard, Show Low, Snowflake and Concho use the C-aquifer. Although a few cones of depression are developing in areas of heavy pumpage in the D- and C-aquifers, they are still largely in a state of hydraulic equilibrium. Portions of the N-aquifer are showing decline due to heavy pumping for the contentious Black Mesa Coal Mine slurry pipeline, which carries coal to Southern California Edison Company's Mohave Generating Station near Bullhead City. Some opponents of the slurry pipeline expect that the Station will close in 2005 when it must be retrofitted to meet more stringent clean-air standards.

## Appendix H

# AGRICULTURE'S DIMINISHING ROLE IN ARIZONA

DAVID A. DE KOK

Agriculture has long been the primary developer and user of Arizona's water resources. It was agriculture that instigated the construction of the Salt, Gila and Colorado River storage and diversion dams and it was agriculture that first used large numbers of high capacity pumps to irrigate fields that were beyond the reach of canal-distributed river water. Groundwater use shot up from about one and a quarter million acre-feet per year in 1940, to about four and a half million acre-feet a year in 1960, before eventually reaching nearly six million acre-feet per year in the mid-1970s. The tremendous increase in groundwater pumpage after World War II occurred as a direct result of the rapid spread of irrigated fields throughout Arizona's farm belt, which was made possible by widely available turbine pump technology.

Despite the feverish post-war expansion of irrigated agriculture in Arizona, the industry was losing its economic prominence as other economic sectors far outpaced it. Agriculture's share of personal income fell from 12.5 percent in 1940, to 7.3 percent in 1961, to 2.7 percent in 1970, to 1.9 percent in 1980, to 1.0 percent in 1990 and finally to 0.5 percent in 2000. However, agriculture continues to be an important component of the economy in many of the state's more rural areas. Farm income constitutes 9.7 percent of personal income in Yuma County, 6.9 percent of personal income in La Paz County and 5.3 percent of personal income in Pinal County. In booming Maricopa County, where farm income is second only to that of Yuma County, agriculture makes up only a quarter of one percent of all personal income.

Over the last two decades Arizona's agricultural economy has not only been battling the nationwide phenomenon of shrinking agricultural profit margins but also has been losing ground, literally, to urban encroachment, particularly in Maricopa County where crop acreage has fallen by some 50 percent, more than a quarter million acres. The post-war growth and decline of the state's cropped acreage can be tracked in Table H.1. Irrigated agriculture reached its greatest extent in Pima County in 1958 and in Maricopa County in 1960. Farming continued to expand throughout the rest of the state for another decade and a half, reaching a statewide zenith of 1,429,210 harvested acres in 1976. Arizona's harvested acreage dropped rapidly in the late 1970s and early 1980s as high-energy prices and falling water tables and purchase and retirement of farm lands by cities combined to rein in groundwater-irrigated fields.

Although crop agriculture has exhibited a fairly steady statewide decline since the mid-1970s, the pattern has not been consistent across all counties. In Cochise County, where the combination of falling water tables, high energy costs and low commodity hit farmers particularly hard, crop acreage plummeted from 133,150 acres in 1976 to just 32,000 acres by 1990. Crop acreage there has since rebounded modestly to 42,500 acres in 2000. Crop acreage in Yuma County fell from nearly 300,000 acres in 1980 to just over 175,000 acres in 1985. It has been steadily growing since then and reached nearly 225,000 acres by 2000.

Crop acreage in Pinal County has yo-yoed from 284,270 acres in 1980, to 192,405 acres in 1985, to 227,970 acres in 1995 before dropping to 181,175 acres in 2000. Urban encroachment is beginning to claim an increasing share of Pinal County farmlands as fields near Casa Grande, Florence and Eloy are being readied for future subdivisions. There is little reason to think that this pattern of urban encroachment, which began in the vicinity of Phoenix in the 1960s, will not continue to claim farm fields throughout Pinal County and perhaps eventually down the Gila Valley towards Yuma. In a reversal of the old rural fears that city dwellers would buy up water rights and ship water to the cities, urbanization is in many areas migrating to the farm fields. Although this conversion from farm to suburb usually lessens the total water demand appurtenant to that land, it also hardens that demand, as urban water use cannot be allowed to go "fallow" during a drought. This loss of water management elasticity is one of the growing perils of our state's burgeoning population.

AGRICULTURE'S DIMINISHING ROLE IN ARIZONA

Table H.1

ARIZONA CROP ACREAGE: 1940-2000

Year	Pima County		Maricopa County		Other Arizona Counties		Arizona	
	Total	%Change	Total	%Change	Total	%Change	Total	%Change
1940	14,500		370,000		280,500		665,000	
1945	25,000	72.4	400,000	8.1	350,000	24.8	775,000	16.5
1950	24,000	-4.0	435,000	8.8	456,000	30.3	915,000	18.1
1955	55,000	129.2	485,000	11.5	660,000	44.7	1,200,000	31.1
1960	52,105	-5.3	523,863	8.0	687,705	4.2	1,263,673	5.3
1965	49,715	-4.6	481,120	-8.2	629,165	-8.5	1,160,000	-8.2
1970	55,500	11.6	462,710	-10.1	700,820	11.4	1,219,030	5.1
1975	52,880	-4.7	471,740	2.0	852,200	21.6	1,376,820	12.9
1980	36,800	-30.4	474,560	0.6	785,320	-7.8	1,296,680	-5.8
1985	26,690	-27.5	330,680	-30.3	604,947	-23.0	962,317	-25.8
1990	22,550	-15.5	309,345	-6.5	647,890	7.1	979,785	1.8
1995	19,600	-12.9	299,650	-3.1	611,800	-5.6	931,050	-5.0
2000	17,100	-12.8	231,800	-22.6	585,290	-4.3	834,190	-10.4

Source: Derived from Arizona Agricultural Statistics Service.

## Appendix I

# WATERS ALONG THE BORDER WITH MEXICO

DAVID A. DE KOK

### The San Pedro River

The San Pedro River, which has its headwaters near the Sonoran mining city of Cananea, flows northward and, after crossing the international border just south of Palominas, continues another 140 miles northwestward before it joins the Gila River. The river is ephemeral along most of its reach, flowing only in response to local rainfall. The San Pedro has a perennial stretch of about 18 miles between Hereford and a point just south of Fairbank.

The Upper San Pedro Basin, which is bounded to the west by the Huachuca, Mustang, Whetstone and Rincon Mountains and to the east by the Mule, Dragoon, Little Dragoon and Winchester Mountains, has two interconnected aquifers: a regional aquifer composed of alluvial basin-fill and a floodplain aquifer of alluvium from the San Pedro Rivers channel. The total amount of water stored in these two aquifers of the Upper San Pedro Basin is estimated to be 59 million acre-feet. The regional aquifer is the main source of supply for Sierra Vista and Fort Huachuca. Precipitation that occurs along the mountain fronts is the most significant source of recharge of the regional aquifer.

The floodplain aquifer, which spans the San Pedro's floodplain, ranges in depth from 40 to 150 feet and is very permeable, with well yields of 200 to 1,800 gallons per minute. It is this aquifer that is the main source of supply for most of the irrigated fields in the region. The streambed alluvium is primarily recharged from surface-water infiltration; however, it also receives water from the regional aquifer, underflow from Mexico and percolation from irrigation return flows and runoff water. Because of the floodplain aquifers reliance on surface-water flows, water levels fluctuate seasonally, rising slightly in the spring and summer and declining in the fall and winter.

The amount of groundwater recharged into the Upper San Pedro Basin aquifer is thought to total about 30,000 acre-feet per year. Of this total, approximately 75 percent comes from Mexico as underflow and surface flow. Mexico is not bound by treaty to deliver any set amount of water from the San Pedro River to the United States. Agricultural water use in the Mexican portion of the Upper San Pedro amounts to about 14,000 acre-feet annually. Cananea, a city of about 35,000, uses nearly 6,300 acre-feet of water a year. The copper mine at Cananea was pumping 12,500 acre-feet a year in 1999. Although Cananea and Naco have not grown at the same pace as other northern Sonoran towns, there is little likelihood that they will maintain their current size and water demand. The mines at Cananea pump groundwater for use in several mining processes and then discharge the resulting wastewater outside the San Pedro River Basin and into the south-flowing Rio de Sonora River Basin. This unquantified regional outflow obviously lessens the amount of water flowing north into Arizona.

Not all of the water reaching Arizona from Mexico in the San Pedro River Basin is of high quality. In 1977 and 1978 tailing pond spillages at the Cananea copper mine repeatedly contaminated San Pedro River surface water with concentrations of copper, iron, manganese and zinc. There were smaller reoccurrences of these spillages in the 1980s. Since the mid-1980s there also have been repeated instances of spillage from sewage ponds at Naco, Sonora, dumping raw sewage into Greenbush Draw that empties into the San Pedro. Livestock and other farming operations also have led to increased nitrate levels in the San Pedro River.

The population of Sierra Vista, which was 32,983 in 1990, was estimated to have grown to 40,430 in 2003. Pumping from the regional aquifer to supply Sierra Vista and Fort Huachuca has created a cone of depression, or a lowering of the water table, in the location of the main well fields. There were approximately 12,700 acres of irrigated land in the Upper San Pedro in 1990, but these fields were primarily irrigated by wells in the floodplain aquifer. The amount of irrigated land in the Upper San Pedro Basin has since dropped due to the 1988



creation of the San Pedro Riparian National Conservation Area (RNCA). The Act creating the Conservation Area also created an explicit federal reserved right to enough water to fulfill the purposes of the Area. The San Pedro RNCA, which was the first RNCA, was created to protect and enhance the riparian areas and associated resources, and the aquatic, wildlife, archaeological, paleontological, scientific, cultural, recreational, educational, scenic and other resources and values.

The difficulty for Sierra Vista and Fort Huachuca was that the growing cone of depression beneath their well fields was threatening to eventually intersect the floodplain aquifer. This could potentially begin to drain this aquifer, which would likely dewater a portion of the San Pedro River's perennial flow. To counter this threat to the San Pedro RNCA the City of Sierra Vista has constructed the Sierra Vista Wastewater Recharge Project. The intent is to create an underground wall of water between the RNCA floodplain aquifer and the City well field's cone of depression.

An additional concern beyond the overdraft of groundwater (which was just over 10,000 acre-feet in 1990) is the Gila River Indian Community's claims to the San Pedro Sub-basin water. Because the Community draws its water from the Gila River downstream from the Upper San Pedro River Basin, they contend that the Basin's waters are part of the supply for their reservation. This matter should be clarified through the Arizona Water Settlement Act now under consideration in Congress.

Concern about the overdraft of groundwater in the Upper San Pedro River Basin has been growing for decades. In the 1960s, the Central Arizona Project (CAP) was envisioned to bring Colorado River water to the San Pedro via a pipeline from Tucson. Water was to be stored in a reservoir created by a dam to be built on the river at Charleston. The CAP pipeline idea was revived in 1994, when Interior Secretary Bruce Babbitt ordered a study on building a pipeline from the end of the CAP aqueduct in Tucson to Sierra Vista. The idea again surfaced in November 2003 in an editorial in the *Arizona Daily Star*, where Mr. Babbitt championed the idea of delivering 15,000 acre-feet of CAP water to Sierra Vista. The cost of the proposed \$71 million to \$95 million pipeline would be borne, at least in part, by the federal government to assure the continued existence of Fort Huachuca.

At about the same time as the most recent appearance of the CAP pipeline concept, another idea to save the San Pedro's surface flows came to light. This would involve pumping water from the abandoned mines under Tombstone and using it to help the San Pedro River. The total quantity of water available and the effects of mine pumping on the City of Tombstone's water wells are unknown. Additional questions about the efficacy of the mine pumping proposal include the extent that the mine water would have to be treated to bring it up to federal standards, the cost of pumping from the 400 to 500 foot depth of the mines, the effect that dewatering of the mines would have on the structural integrity of the timber support posts in the mines once they were exposed to air, the possibility of subsidence caused by the pumping and the possibility of an existing hydrologic connection between the mine's aquifer and the River, which might make the pumping counterproductive.

Although the Upper San Pedro River Basin has enormous groundwater reserves that could sustain the current overdraft for centuries, continued overpumping poses a very real threat to the river's perennial flow and the tremendous biodiversity, especially bird-life, which relies upon it. To meet this threat the Upper San Pedro Partnership was formed to bring together the region's various stakeholders to suggest ways in which water resources can be managed. The group has set a goal of ending the groundwater overdraft by 2011. Given that nearly 23,000 acre-feet of the surface and groundwater that replenishes the Upper San Pedro comes from Mexico, which has no legal obligation to maintain that continuing supply, and given that some proponents are pushing for Fort Huachuca to double its size with the addition of new operations drawn from the next round of base closures, the Partnership faces a great challenge in achieving its goals. A new organization, the San Pedro Binational Watershed Alliance, which is composed of the Partnership and several municipal, Sonoran and federal entities from Mexico, may ease concerns about the continuing flow of the San Pedro. The Alliance hopes to establish a binational, holistic, ecosystem-based approach to natural resources conservation and environmental planning.

### **The Santa Cruz River**

The Santa Cruz River crosses the international border twice, first flowing into Mexico from Arizona's San Raphael Valley two miles east of Lochiel and then flowing into the United States five and a half miles east of



Nogales. Between the two crossing points the river flows for 32 miles through Mexico. The permeable portion of the basin near the border is only about 300 feet thick at its greatest extent, greatly limiting the aquifer that supplies Ambos Nogales with water.

The basin-fill sediments near Nogales are divided into three aquifers: the younger alluvium, the older alluvium and the Nogales formation. The younger alluvium is the most widely used and productive of the aquifers, with well yields up to a thousand gallons per minute. There is a hydraulic connection between surface flows and this aquifer. Groundwater levels decline and recover in association with river flows or their absence. The surface water flows of the Santa Cruz River are extremely variable, ranging from just a few hundred acre-feet some years to 88,000 acre-feet in 1979. The mean surface flow near the international border since 1935 is 19,110 acre-feet and the median is 14,283 acre-feet. The recent drought has greatly limited the replenishing surface flows, to just 628 acre-feet in 2002 and 936 acre-feet in 2003.

The older alluvium stores a considerable amount of water, but is a poor transmitter of water to wells. Well yields in the older alluvium seldom surpass 30 gallons per minute and, consequently, this aquifer has not been widely tapped. The far deeper Nogales formation has poor water bearing characteristics and has not been widely developed. The few productive wells generally yield less than 30 gallons per minute.

Although the two communities of Ambos Nogales share a common watershed and a wastewater collection and treatment system, their water supply and distribution systems are nearly independent of each other. The shared groundwater basin and the topographical gradient have guided the development of the fresh water and wastewater systems, but the international line separating the communities has repeatedly complicated the building and maintenance of this infrastructure. A shared distribution system existed until 1911, when the City of Nogales, Arizona purchased the system and used public funds to install a well in the Santa Cruz River and expand the Arizona side of the distribution system. Thereafter, Nogales, Sonora was left to eventually develop its own water supply system, which it did in 1940.

Nogales, Arizona also led the way in the development of a sewer system. By the end of World War II virtually all of the City's residents and businesses were served by this system. However, Nogales, Sonora still did not have a sewer system in place and instead relied on cesspools and outhouses. The Mexican health department began developing plans for a sewer system in the early 1940s, but the Nogales Wash topography dictated that a treatment plant and its sewage outfall line would have to be located across the border in the United States. Eventually, the International Boundary and Water Commission (IBWC) persuaded the U.S. Congress to fund a joint treatment plant. The first international wastewater treatment facility for Ambos Nogales was completed in 1951.

Flooding is another problem common to the two communities of Ambos Nogales. Major floods swept Ambos Nogales in 1905, 1909, 1914, 1915, 1926 and 1930. The 1930 flood took five lives, caused much property damage and spurred Arizona's Senator Carl Hayden to get the two federal governments to design and build a joint flood control project. The IBWC built the system in the 1930s and the 1940s. The flood control system currently consists of two covered channels and additional lined open canals.

Nogales, Arizona is entirely dependent upon groundwater for its fresh water needs. The water supply and distribution system is owned and operated by the City of Nogales. Two main well fields, the Potrero Wash and Santa Cruz fields, feed the system and provide an adequate supply of fresh water for the City's current needs; however each field's future productivity is to some extent threatened. A cone of depression has developed around the Potrero Wash well field and water table levels there fell over 20 feet below the level of the surrounding water table between 1982 and 1995. Additionally, a small plume of poor quality water developed in northern Nogales, which curtailed the City's pumpage from one of its major production wells. Plans are under way to clean the contaminated water to potable water quality standards and deliver the treated water to the nearby Palo Duro Golf Course. The threats to the Santa Cruz well field may occur over a longer time period but be more consequential. Nogales, Sonora is undertaking an upgrade of its water system, which is likely to reduce inflows to Nogales, Arizona's well fields.

## WATERS ALONG THE BORDER WITH MEXICO

The water pumped from the Potrero and Santa Cruz well fields is chlorinated on-site and then moved through the delivery system to the City's four main storage reservoirs whose combined capacity is nearly five million gallons. The City supplied 4,290 acre-feet of water to 18,975 people in 1995. The water usage rate was 202 gallons per capita per day (GPCD). This high rate of per capita usage stems from several causes. On a daily basis 30,000 people cross the international border from Nogales, Sonora into the City of Nogales. Additional visitors arrive from the north via Interstate 19. None of these daily visitors are counted as part of the service area population when calculating Nogales GPCD. Additionally, the City's water system suffers from a high volume of unaccounted water losses. It was estimated that in 1990, ten percent of water usage was lost through leakage in the delivery system, and an additional ten percent went unrecorded either through unmetered or under-metered deliveries.

Almost 50 percent of the City's water is delivered to single-family residences, 24 percent of the water goes to commercial users and about 13 percent is used by apartment dwellers. The Nogales Water Department also still supplies some water to Nogales, Sonora customers through four separate water mains, two of which are among the water department's 50 largest customers. Because the level of water consumption by these account owners is larger than would be expected given the nature of their businesses, it is assumed that some of the water is being used for other purposes or by other users.

Aside from the four above-mentioned water lines, the Nogales, Sonora fresh water delivery system is entirely separate from the Nogales, Arizona system. However, because of the shared watershed and topography, the maintenance, operation and plans for the Sonoran water system have a direct effect on the Nogales, Arizona system. The underlying water problem in Nogales, Sonora is the lack of a sound distribution system. The Nogales, Sonora water system gets 15 percent of its water from wells in the Nogales Wash, 45 percent from wells in the Santa Cruz River and 40 percent from wells in the Los Alisos River watershed.

About 36 percent of the Nogales, Sonora population is not connected to the water supply system. These residents must haul their own water or buy it from large water trucks, or *pipas*. The *pipas* are usually filled from wells within Nogales Wash, which are very drought sensitive and frequently run low in the early summer. In the summers of both 2002 and 2003, Nogales, Arizona provided a temporary water line to help keep the *pipas* on their appointed rounds. Connection to the water supply system, however does not guarantee a steady supply of water. In the summertime, even some affluent neighborhoods must put up with water shortages, which means water is rationed and available only a few hours a day. It is estimated that average water usage in Nogales, Sonora only amounts to between 40 and 60 GPCD. The relatively wide range of the estimate is due to the uncertainty about the Nogales, Sonora population. The official population estimate for the year 2000 was 213,784, but many knowledgeable observers think 350,000 might be closer to the reality. Nogales, Sonora currently consumes 18,500 acre-feet of water a year.

In order to deal with this water crisis, Nogales, Sonora has embarked on a \$39 million plan to meet the shortfall and prepare for the continued rapid rate of growth. The plan proposes to increase pumpage along the Santa Cruz River from 6,300 acre-feet per year to 15,200 acre-feet per year. The projected Mexican pumpage would then represent about 75 percent of the long-term annual flow in the Santa Cruz River at the international border. This could have a severe impact on Nogales, Arizona's Santa Cruz well field, both increasing pumping costs from a much-lowered water table and exposing the well field to greater susceptibility to drought. Mexican dewatering of the Upper Santa Cruz River basin could limit the ability of Nogales, Arizona to accommodate future growth. There currently is no international agreement to guarantee that there is water in the Santa Cruz River when it reaches Arizona. However, the Arizona Department of Water Resources and the IBWC are engaged in a hydrologic modeling effort so as to understand the relationship between pumpage and flows in the binational Upper Santa Cruz basin.

As has been discussed, Nogales, Arizona and Nogales, Sonora share a single wastewater treatment plant. The first joint facility went into operation in September 1951, sixteen years after it was authorized. The plant quickly became overwhelmed, with raw sewage being bypassed during 1960.

After considerable negotiation, the Mexican government agreed in 1967 to join with the United States in

constructing a new, larger Nogales International Wastewater Treatment Plant (NIWWTP) nine miles north of the border near Rio Rico at the confluence of the Nogales Wash and the Santa Cruz River. The new plant began operating in 1972. By 1982 the plants daily capacity was once again being regularly exceeded and about 60 percent of its influent was coming from Sonora. After more negotiations an expansion of the plant was begun in 1989. The constant struggle to keep the capacity of the NIWWTP ahead of, or at least not too far behind, the areas population growth has been just one of the difficulties facing the Ambos Nogales wastewater system.

The specter of disease outbreaks has been the driving force behind the communities' improvements to their wastewater systems. In the summer of 1990, monsoon rains broke numerous sewer lines all over Nogales, Sonora. The resulting contamination of Nogales Wash was linked to 42 cases of hepatitis A among residents clustered around the Wash. Cholera has been found in the Wash and a February 1991 test turned up the polio virus. It is estimated that 14 to 21 percent of the Nogales, Sonora population faces health risks due to sewer line breaks.

Despite a large operating budget and expanded capacity, the NIWWTP has repeatedly had difficulty meeting water quality standards. High inflow into the plant has occasionally forced the release of wastewater before treatment has been completed. This has caused the plant to be cited for excessive levels of suspended sediments in its effluent. In addition, the NIWWTP has been cited for excessive levels of phenols, cyanide and mercury. The plant is not designed to remove these chemicals that most likely come from the Mexican maquiladoras. The only way to remove these chemicals from the effluent is to prevent them from entering the sewage system in the first place. The lack of an industrial pretreatment program in Nogales, Sonora is another of the systems inadequacies.

The treated outflow from the NIWWTP flows through the Santa Cruz River channel for about 14 miles before it completely infiltrates into the riverbed near Tubac. Despite the intermittently high pollution levels of the river at its confluence with Nogales Wash, the river manages to cleanse itself as it flows to Tubac and is periodically diluted with fresh rainwater runoff. The effluent discharges from the NIWWTP have stabilized the water table along this section of the Santa Cruz River and have helped to maintain one of the few healthy riparian gallery forests left in Arizona.

Nogales, Sonora has rights to a portion of the NIWWTP effluent equal to its influent contribution, which is now about two-thirds of the total output. The international treaty between the United States and Mexico allows Sonora to retain or reduce the amount of influent at any time and also allows it to transport the treated effluent back to Mexico at any time. Although Nogales, Sonora currently has no means to make use of its share of effluent, it has developed a plan to construct a wastewater treatment plant of its own in Los Alisos, as well as pump stations to convey sewage to the new plant. To address its water supply shortfall, the Mexican government plans to recharge effluent into its own well fields. The current expectation is that Mexico would continue to send the same amount of influent to the NIWWTP as it now does, and that the new Los Alisos Plant would serve the portion of the Nogales, Sonora metropolitan area south of the Nogales Wash Basin boundary. However, if the Los Alisos plant were to treat some of the effluent from the Nogales Wash Basin and recharge into the Los Alisos Basin, it would be lost to the Santa Cruz River system forever, since the Los Alisos Basin is a tributary to the Magdalena River in Mexico.



## Appendix J

# SHOULD YUMA DESALTER OPERATE? VARIED, COMPLEX ISSUES ARE RAISED

SHARON MEGDAL, PH.D.

In May, I visited the Yuma Desalting Plant, which has recently been the focus of much attention. Whether or not the plant is operated has implications for water deliveries to Mexico under U.S. treaty obligations and is important to Central Arizona. It is also important to those concerned about the Cienega de Santa Clara environmental habitat. My visit was very informative.

The U.S. Bureau of Reclamation built the plant to address the high salinity of tail water from the Wellton-Mohawk Irrigation District. About 100,000 acre feet of irrigation water applied to district land but unused by crops was flowing back to the Colorado River. Its very high salt content raised concerns about the water. To meet the requirements of Minute 242 of the 1944 treaty with Mexico, the treatment plant was built to remove the salt from the Wellton-Mohawk tail water. To keep the salty water from flowing into the Colorado River while the plant was under design and construction, Reclamation built a 53-mile bypass canal. This canal diverted the water to the Santa Clara Slough in Mexico.

The bypass canal was built as an interim measure prior to the plant becoming operational. Completed in 1992, the plant operated only for a short period in 1993. It was shut down due to operational issues. Also, excess Colorado River flows met water obligations to Mexico without operating the plant.

Over the years the Santa Clara Slough, now known as the Cienega de Santa Clara, has benefited from this "bypass" water. In recognition of the important habitat of the Cienega and surrounding area, the Mexican government declared the region a Mexican National Biosphere. There is significant interest in keeping the Wellton-Mohawk tail water flowing to the Cienega. But, at the same time, the water was intended to be used to meet the U.S. obligation to deliver 1.5 million acre feet of water to Mexico annually. During wet years, meeting this obligation has not been of concern. In times of drought, however, every drop of water counts, and the water deliveries to the Cienega do not count toward meeting the U.S. obligation. Many Arizona water interests are concerned that the federal obligation to deliver 1.5 million acre feet of water annually to Mexico be satisfied without causing disproportionately adverse effects to Arizona.

What started out as a water quality issue has essentially become a water quantity matter. With drought conditions persisting, storage along the Colorado River is at very low levels. If Wellton-Mohawk water is not treated for delivery to Mexico, that water has to come from elsewhere. Recently, the water has come from storage at Lake Mead. If river supplies, including amounts in storage, are short, Central Arizona Project deliveries are the first to be cut, as the CAP holds the most junior rights to the river. The worst case scenario: The entire 1.5 million-acre-foot CAP entitlement would be cut before others with Colorado River allocations experience cutbacks. This is why the Central Arizona Water Conservation District, the operators of the CAP, have been advocating operation of the Yuma Desalting Plant.

Water issues are complex. And the question of whether or not to run the Yuma Desalting Plant is no exception. There are multiple implications to consider, including environmental and economic. The U.S. Bureau of Reclamation, with responsibility for operating the Yuma Desalting Plant and managing the Colorado River generally, is considering its options. Governor Napolitano, who recently visited the plant, and others in Arizona are likewise evaluating alternatives. Scrutiny of the complicated modeling of the Colorado River scenarios continues. Significant uncertainties are involved. We know there will be shortages. Their frequency and severity over the next 100 years will determine the impacts on the region served by CAP and the Colorado River watershed more generally. If CAP experiences a cutback, users of non-Indian agricultural water will be the first to be cut back

*SHOULD YUMA DESALTER OPERATE? VARIED, COMPLEX ISSUES ARE RAISED*

within the Arizona system.

These users of CAP water have rights to use groundwater, but their ability to do so depends on the condition of their well delivery systems, and there could be significant cost implications associated with the re-substitution of groundwater for surface water. The Arizona Water Banking Authority has been storing water on behalf of CAP municipal water users for several years. So, the impact of any future municipal supply cutbacks will depend on their cumulative size relative to the amount of water stored by the bank. If agriculture returned to groundwater and municipal water users began drawing upon stored water, water tables throughout Central Arizona would obviously be affected

What are the costs and benefits of running the Yuma Desalting Plant to treat the tail water from the Wellton-Mohawk Irrigation District? A lot of effort is going into identifying alternatives, including land fallowing in Arizona. Everything depends upon projections and assumptions. The answer to the question is difficult to provide but must be pursued.

Visiting the plant and the adjacent national water treatment research center helped me realize that the Yuma Desalting Plant is an asset, not the "white elephant" it has been called. It can be operated, if not to treat the irrigation tail water, then to treat water for other purposes, such as delivery of Colorado River water to municipalities in Arizona and/or in Mexico.

Yes, issues related to operating the plant are complex. Their resolution will likely require not only careful analysis but compromise and flexibility.

*Note: Good background papers on the Yuma Desalting Plant are "The Yuma Desalination Plant: Arizona Perspectives," by Tom Carr, Arizona Department of Water Resources (August 2002) and "Dealing with the Colorado River's Salinity: What is the Future of the Yuma Desalting Plant?" by Sue McClurg, Water Education Foundation (Winter 2003-2004).*

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## Appendix K

# GOVERNOR'S WATER MANAGEMENT COMMISSION EXECUTIVE SUMMARY DECEMBER 2001

The December 2001 **Final Report** of the Governor's Water Management Commission (Commission) completes a two and a half-year examination of the Groundwater Code (Code) and water quantity management in Arizona's Active Management Areas (AMA). The Commission concludes that the goals and legal framework of the Code are sound and as such should continue to guide water management decisions and investments in the AMAs. Further, the Commission endorses the statutory management goal of each individual AMA, recognizing as appropriate their differing hydrologic and political characteristics.

The **Final Report** briefly describes the issue identification efforts of the Commission's Technical Advisory Committee (TAC) and the five individual AMA Task Forces that preceded the appointment of the Commission. It also details the Governor's charge to the Commission, the activities of the Commission, and the approximately 50 individual recommendations the Commission is forwarding to the Governor.

Governor Jane Dee Hull appointed the 49-member Commission in June 2000 to review the 21-year-old Groundwater Management Act and recommend changes—if necessary—to ensure that the five Active Management Areas within the State continue to maintain a reliable, sustainable water supply to meet current and future needs. Specifically, the Governor charged the Commission to:

1. "Evaluate progress toward meeting the goals of the 1980 Groundwater Management Act and the management goals of each of the five Active Management Areas to assure that the goals are appropriate and achievable."
2. "Evaluate mechanisms to reduce the use of mined groundwater, increase the utilization of renewable water supplies and most efficiently meet the water needs in the Active Management Areas."
3. "Evaluate whether changes are needed in statutes, rules, or policies to improve the effectiveness of water management in the Active Management Areas at the state and local levels of government."

The Commission held 18 public meetings and two weekend retreats, also open to the public. Additionally, 300 meetings with extensive public involvement were held by Commission subcommittees and work groups and by the TAC and AMA Task Forces. The issues for Commission consideration were presented in a series of seven issue papers developed by the individual AMA Task Forces and the 33-member TAC. The initial issues included: continued groundwater pumping by existing right holders as well as new industrial users and the impact of this pumping on achieving the management goals; how to address sub-area or critical area conditions; proliferation and concentration of small capacity exempt wells; utilization of renewable supplies; concerns about the Central Arizona Groundwater Replenishment District (CAGR); and long-term water supply reliability.

The Commission, after extensive debate, achieved consensus on approximately 50 recommendations for public review. A series of public Open Houses were held in each AMA the first week of October 2001 to solicit public comments. These comments were used to further refine the recommendations and in late October 2001, the Commission adopted their conclusions and the final package of recommendations for the Governor to consider.

The Commission recognizes that although groundwater mining has not been eliminated, water users, in response to the goals and requirements set forth in the Code, have significantly reduced groundwater mining in three of the five AMAs since the 1980s. However, current data indicate the Phoenix, Prescott and Tucson AMAs may not reach their goal of safe-yield by 2025. The actions recommended by the Commission, which include a number of statutory changes, are focused on fine-tuning aspects of the Code and other activities. These actions will assist in further reducing groundwater mining and will maintain the stability and certainty necessary for



investments in water supplies, delivery infrastructure and efficiency improvements which are vital to Arizona's future.

The Commission recommendations will: increase the utilization of renewable supplies to help ensure sustainability; address allowable pumping to reduce groundwater mining; protect ecologically significant habitats; and enhance water resources planning and technical assistance. The major recommendations are summarized below in the seven categories established by the Commission. The full set of recommendations is covered in detail in Section V of the Commission's **Final Report**.

**A. Renewable Supplies** – Utilization of renewable supplies has increased over the past 20 years, facilitated by the construction of surface water treatment plants and the completion of the Central Arizona Project (CAP) allowing the use of Colorado River water either directly or indirectly through artificial recharge and recovery projects. The Commission addressed issues related to the utilization of renewable supplies in all AMAs. These issues included: 1) how to maximize the use of available renewable supplies until currently unused CAP water is fully utilized by municipal, industrial and Indian entities; 2) how to ensure that regulatory programs and institutions promote efficient storage and use of renewable supplies; 3) how to facilitate cooperative efforts to finance infrastructure; 4) how to define the long-term role of the Central Arizona Groundwater Replenishment District (CAGRDR); and 5) how to ensure the long-term adequacy of renewable supplies to achieve a sustainable water supply.

Recommendations include authorizing enabling legislation for a multi-jurisdictional infrastructure financing authority to issue revenue bonds or use other financing alternatives intended for financing multi-jurisdictional water infrastructure projects that benefit a specified geographic area.

The Commission is also recommending changes to the authority and responsibilities of the CAGRDR. The CAGRDR is an entity that currently uses excess CAP water to replenish mined groundwater on behalf of certain subdivisions or water providers in the Phoenix, Pinal and Tucson AMAs for assured water supply purposes. Two of the most significant changes recommended are a requirement for the CAGRDR to establish a replenishment reserve to help secure water supplies for CAGRDR members and an enrollment fee for new subdivisions. This "reserve" would take advantage of currently available CAP supplies to store sufficient water to meet 20 years of demand for CAGRDR members.

The Commission also made a number of general recommendations in the category of Renewable Supplies that do not specify statutory or rules changes, but which are intended to encourage actions outside of the Commission process.

**B. Allowable Groundwater Pumping** - While a number of major water users within the AMAs have become less reliant on groundwater, other existing right holders and even new users continue to rely on groundwater. Issues addressed by the Commission include: 1) the continued pumping of groundwater pursuant to legitimate withdrawal authorities allowed under the Code, described as "holes in the bucket", which are projected to negatively effect the ability to achieve AMA management goals; and 2) the localized impacts that may be created by groundwater withdrawals. Recommendations developed to address these issues include: 1) new well permitting and impact requirements; 2) a "mined groundwater tax" for existing municipal and industrial groundwater users; 3) an obligation for new municipal and industrial groundwater users to utilize renewable supplies or replenish their mined groundwater with renewable supplies; and 4) changes to the exempt well statutes.

The Commission considered and then proposed a recommendation that would limit certain new wells from being drilled within "designated riparian area protection zones" located within the AMAs. These zones are proposed to be legislatively delineated on a map and are based on a 1/2 mile buffer adjacent to specified stream segments or cienegas within an AMA. The limitations apply not only to non-exempt wells, but exempt wells (a well with a pump capacity of 35 gallons per minute or less). Aside from this recommendation being limited to new wells in an AMA, several other exclusions apply including: 1) replacement wells; 2) stock watering wells; and 3) exempt wells used for domestic purposes and proposed to pump less than two acre-feet per year. There are also provisions that allow certain categories of users to get waivers if a demonstration of hardship or non-impact on the

designated riparian area can be made.

The Commission is also recommending changes that would eliminate or reduce groundwater mining by certain municipal and industrial water users within the AMAs. (Designated water providers and members of the CAGRDR are not included in this recommendation, as they are subject to the Assured Water Supply Rules.) First, the recommendation requires certain existing municipal and industrial water users (who currently have no obligation to use renewable supplies) to pay a phased-in "Mined Groundwater Tax." This tax would be used to replace a portion of the mined groundwater or to fund water-planning activities aimed at finding a mechanism to reduce reliance on mined groundwater. Second, certain new municipal and industrial water users would be required to make use of renewable supplies or replenish all of their mined groundwater over a period of time. This would also result in a statutory expansion of the CAGRDR's current authority and allow the CAGRDR to enroll industrial customers as well as municipal customers who predate or are not required to comply with the Assured Water Supply Rules. Finally, the recommendation eliminates issuance of certain new groundwater permits or rights without a full replenishment obligation after 2025 (2040 in Pinal AMA). This last proposal applies in all AMAs; however, provisions for Pinal, Prescott and Santa Cruz recognize the unique conditions within these areas. Additionally, certain users are exempted from this recommendation including agricultural users, metal mining operations and untreated water providers.

The Commission is also recommending changes to the exempt well statutes. These changes only apply within the AMAs. The first proposal would require that new exempt wells be limited to a pump capacity of 20 gallons per minute (a reduction from the current 35 gallons per minute); however, up to 35 gallons per minute could be requested based on a demonstrated need for a higher flow rate. A second set of proposals relates to exempt wells that are within the service area of (or affected by) a water provider or other groundwater withdrawal authority. Within a municipal provider service area, new exempt wells would not be permitted without a denial of service from the provider. Another provision would limit the ability of existing exempt well owners to prevent the drilling of new non-exempt wells (using more than 35 gallons per minute) and would eliminate the ability for a new exempt well owner to protest impacts from a subsequent new non-exempt well.

**C. Environment & Economic** - The Commission recognized that environmental concerns were not addressed in the 1980 Groundwater Code. A number of proposals to protect the environment were presented and discussed. The following recommendations address some of the water needs of environmental habitats within the State. First, the Commission recommends the establishment of zones around specified and legislatively adopted riparian areas for protection from new groundwater withdrawals, within the AMAs. This recommendation is directly linked to the discussion above under the Allowable Groundwater Pumping category.

The Commission is also recommending several statutory changes to increase funding and responsibilities of the Arizona Water Protection Fund.

**D. Conservation** – ADWR establishes "conservation requirements" for agricultural, industrial, and municipal water users within the AMAs. Issues raised included the role and effectiveness of conservation efforts in achieving the goals of each AMA and potential improvements for the current programs.

The recommendation in this category is for the Governor to initiate creation of a nonprofit cooperative association to serve Arizona's need for effective water conservation, education and research throughout the State.

**E. Management Goals** – The Commission concluded that the management goals were appropriate in each of the AMAs; however, the Commission also recognized the unique needs of the Pinal, Prescott, and Santa Cruz AMAs. As such, the Commission recommends local water users and the Department of Water Resources continue to work together to develop new programs to achieve the management goals in these AMAs.

**F. Water Resources Planning** - The Commission recognizes the need for better data and long range planning in the AMAs and throughout Arizona. Specifically the Commission recommends: 1) continued support for funding the current Rural Watershed Initiative; 2) initiation of discussions between stakeholders from throughout Arizona to develop and fund a planning process for addressing the state's future water demands; and 3) preparation of a

periodic report on hydrologic conditions and progress towards meeting the goals of each AMA, and a separate biennial summary report of conditions in the AMAs to the Legislature.

**G. Costs Of Water Management Programs** - The Commission recognizes that some of the 50 recommendations they are forwarding to the Governor will create additional work for the Arizona Department of Water Resources and water users throughout the state. The Commission recommends the Governor and the legislature consider mechanisms to ensure the Department of Water Resources has sufficient resources to carry out programs recommended by the Commission, to maintain current programs and to provide timely and quality technical assistance and water management planning for the State of Arizona.

Arizonans, by working together on water resources, have already achieved enormous gains in our effort to manage this vital resource effectively. The Commission is confident that implementing the package of recommendations we are forwarding to the Governor will maintain and enhance Arizona's water management efforts.

## Appendix L

# AMA MANDATORY CONSERVATION REQUIREMENTS

Mandatory, enforceable conservation requirements are specified in the AMA Management Plans for the agricultural, industrial and municipal water use sectors.

### **Agriculture**

In general, water use for irrigated agriculture is limited through the establishment of maximum annual groundwater allotments for each irrigation-grandfathered right. These allotments are based on acreage and crops grown between 1975 and 1980, multiplied by the water requirements of those crops and assuming maximum conservation efficiency. Alternatively, agricultural water users now have the option to apply for a “best management practices program,” implementing measures designed to reduce overall water use and increase irrigation efficiencies. In addition to these volumetric limitations, there is a prohibition on new irrigated agricultural acreage within the AMAs.

### **Industry**

Industrial water use is defined as a non-irrigation (non-agricultural) use of water not supplied by a city, town or private water company, including animal industry use and expanded animal industry use. Industrial water users include: (1) turf facilities (schools, parks, golf courses, home owner associations and lakes over ten acres in size), (2) sand and gravel facilities, (3) metal mining facilities, (4) large-scale power plants, (5) large-scale cooling facilities, (6) dairy operations and (7) cattle feedlot operations. These industrial rights are generally regulated with annual volumetric groundwater allotments, but the management plans also require the use of specific conservation technologies in particular industries such as metal mining and sand and gravel.

### **Municipal**

The GMA requires municipal water users (cities, towns, private water companies and irrigation districts that supply water for non-irrigation uses) to develop programs that result in reasonable reductions in per capita use. These reductions are based on a gallons per capita per day rate for customers within the service areas of the municipal providers that serve more than 500 people or use more than 100 acre-feet of water per year. The gallon per capita per day rate is converted to an annual volume for each water provider, allowing the water provider to develop its own conservation program and measures that will achieve the targeted reduction set by the State. The measures that have been employed by municipal water providers to meet the state targets include conservation oriented rate structures, landscaping and plumbing ordinances, and education, incentive and water audit programs. Municipal providers that qualify for an AWS also have the option to apply for a “best management practices” type of program.

No other states have comprehensive groundwater conservation programs that are as rigorous as those within the AMAs, though some states do have drought-related measures that are more stringent.



**Appendix M**  
**Storage and Recovery for Phoenix, Pinal and Prescott AMAs through 2002 and Tucson AMA through 2003**  
**(rounded to nearest acre-foot)**

PHOENIX AMA	Annual Capacity			Water Stored			Credits Recovered			Total Credits Remaining in Storage		
	CAP	Effluent	Other	CAP	Effluent	Other	CAP	Effluent	Other	CAP	Effluent	Other
GSF Total	448,000	130,950	100,000 P6	1,511,108	17,748	0	72,600	3,170	0	1,439,771	14,577	0
USF Total	390,682	286,812	S/V 200,000 P6	510,267	162,165	110,574 S/V	14,637	32,682	102,962	501,687	129,252	6,922 P6
USF Total/Outside AMA	20,000	0	0	16,571	0	0	0	0	0	16,571	0	0
USF & GSF Totals	858,682	417,762	SV 300,000 P6	2,037,946	179,913	89,174 S/V	87,236	35,853	81,567 S/V 1,181 offset	1,958,029	143,829	
<b>TUCSON AMA</b>												
GSF Total	82,986			184,603			22,671			161,932		
USF Total (Includes Outside AMA)	151,000	65,196	600	346,859	76,431	277	90,793	65,153	277	256,065	11,278	0
USF & GSF Totals	233,986	65,196	600	531,461	76,431	277	113,464	65,153	277	417,997	11,278	0
<b>PINAL AMA</b>												
GSF Total	286,000	0	0	1,069,919	0	0	6,411	0	0	1,065,406	0	0
USF Total	0	798	0	0.0	1,056	0	0	166	0	0	891	0
USF & GSF Totals	286,000	798	0	1,069,919	1,056	0	6,411	166	0	1,065,406	891	0
<b>PRESCOTT AMA</b>												
USF Total		8,961	6,721		19,486	1,488		2,948	1,594		14,964	-106

Notes: P6 = Plan 6 water; S/V = Salt and Verde Rivers water; GSF = Groundwater Savings Facility; USF = Underground Storage Facility; CAP = water stored and credits remaining in Pinal AMA include 61,099 acre-feet stored by AWBA for Nevada.





## Appendix N

# COUNTY EFFORTS TO COORDINATE LAND USE PLANS WITH WATER SUPPLIES

In spite of the limited authorities available to counties, efforts have been made to coordinate land use plans with water supplies. Some examples include:

- In the Golden Valley area of Mohave County, 22 square miles were down-planned in part to preserve water supplies and to establish lot-splitting limits. Mohave County will approve power plants only if they use “dry cooling” technology when the aquifer is threatened by depletion or subsidence. The County also has added to its water conservation element a goal that seeks water supplies in perpetuity.
- In the Empirita Ranch area of Pima County, because of water availability concerns, the land acquisition agreement included pumping limits on groundwater to protect Cienega Creek and reduced housing densities were included in the Comprehensive Plan.
- Santa Cruz County has a rural planning zone that recommends limits on new development and a rural zoning pattern to sustain limited groundwater resources.
- Yavapai County has included reduced densities in the Comprehensive Plan in response to water supply concerns.

Though most of Pima County is within an AMA and as with other AMAs, issues related to riparian protection are not specifically addressed in state law or the management plans. Pima County has identified a number of regional plan policies that are intended to reduce risk to riparian areas, including (Pima County, 2002):

- limiting pumping near shallow groundwater by using land use controls and the purchase of development and water rights;
- maximizing the use of CAP and effluent and limiting specific water uses;
- limiting rezonings outside of the CAP and effluent water delivery areas and providing incentives to landowners;
- using CAP and effluent for riparian restoration;
- limiting turf water use through a golf course water ordinance;
- minimizing human impact to aquatic and riparian ecosystems by development, roads and trails; and encouraging land use decisions that maintain the function and quality of watercourses.



## Appendix 0

# GROWING SMARTER LEGISLATION REQUIRING A WATER RESOURCES ELEMENT

(excerpted)

### 9-461.05. General plans; authority; scope

D. For cities and towns having a population of more than two thousand five hundred persons but less than ten thousand persons and whose population growth rate exceeded an average of two per cent per year for the ten year period before the most recent United States decennial census and for cities and towns having a population of ten thousand or more persons according to the most recent United States decennial census, the general plan shall include, and for other cities and towns the general plan may include:

5. A water resources element that addresses:

- (a) The known legally and physically available surface water, groundwater and effluent supplies.
- (b) The demand for water that will result from future growth projected in the general plan, added to existing uses.
- (c) An analysis of how the demand for water that will result from future growth projected in the general plan will be served by the water supplies identified in subdivision (a) of this paragraph or a plan to obtain additional necessary water supplies.

F. The water resources element of the general plan does not require:

- 1. New independent hydrogeologic studies.
- 2. The city or town to be a water service provider.

### 11-821. County plans; definitions

C. In addition to the other matters that are required or authorized under this section and article 1 of this chapter, for counties having a population of more than one hundred twenty-five thousand persons according to the most recent United States decennial census, the county plan shall include, and for other counties the county plan may include:

3. Planning for water resources that addresses:

- (a) The known legally and physically available surface water, groundwater and effluent supplies.
- (b) The demand for water that will result from future growth projected in the county plan, added to existing uses.
- (c) An analysis of how the demand for water that will result from future growth projected in the comprehensive plan will be served by the water supplies identified in subdivision (a) of this paragraph or a plan to obtain additional necessary water supplies.

E. The water resources element of the comprehensive plan does not require:

- 1. New independent hydrogeologic studies.
- 2. The county to be a water service provider.



## APPENDIX P

# INDIAN WATER RIGHT SETTLEMENTS

BONNIE G. COLBY

### **Ak-Chin Water Settlement**

The 21,840-acre Ak-Chin Reservation was established in 1912 and is located in the midst of a productive agricultural area in south central Arizona. Prior to completion of the Central Arizona Project (CAP), neighboring irrigators, as well as the Ak-Chin Indian Community, were wholly dependent on groundwater for irrigation and domestic purposes. By the 1960s, the Indian community was irrigating approximately 10,000 acres with groundwater pumped from depths of 40 to 50 feet. Due to the success of the tribal farming enterprise, the Indian community had achieved near economic self-sufficiency. Extensive off-reservation pumping nearby caused sharp declines (approximately 20 feet per year) in groundwater levels beneath the reservation and the Indian community's irrigated acreage declined from 10,000 to less than 5,000 acres.

The Indian community asked the United States in 1976 to file suit against non-Indian pumpers on behalf of the community. In recognition of its trust responsibility to provide the Ak-Chin with a reliable water supply, the federal government entered into negotiations with the community to settle its water claims. The State of Arizona and local non-Indian water users supported this approach.

After two years of negotiations and before a lawsuit was filed, the Department of the Interior reached an agreement with the Indian community. The settlement provided for both an interim water supply to meet the emergency needs of the Indian community and a permanent water supply within 25 years. The settlement envisioned developing a well field on nearby federal land to provide the interim supply. Under the act, the federal government would be liable for the replacement cost of the water if it failed to meet the delivery obligations.

While the federal administration was supportive of the Ak-Chin's claim to water, it was concerned about overall cost and federal liability, in light of the uncertain nature of the water supply. Despite these concerns, the settlement was passed by Congress and signed by President Carter in 1978. Although enjoying the support of the State of Arizona and local water users, this first settlement was opposed by most other western states. Senator Barry Goldwater and Representative John Rhodes were influential in securing the Ak-Chin settlement.

The settlement was amended in 1984 when the anticipated water supplies proved insufficient and too costly. The revised agreement, negotiated with the active involvement of Senator Goldwater and Representatives Morris Udall and John McCain, provided for the federal government to pay damages for failure to make timely delivery of the interim water supply and modified the funding and delivery schedules for the permanent water supply. The federal government provided the community with \$15 million to meet interim water needs, contributed other economic development grants and loan forgiveness worth \$28.7 million and moved the permanent supply deadline up to 1988. In exchange, the Indian community relieved the federal government of its responsibility to provide an interim water supply and agreed to an overall reduction in its permanent water entitlement. Under the revised settlement, the community receives 75,000 acre-feet of water in normal years, as little as 72,000 acre-feet in dry years and up to 85,000 acre-feet in wet years.

The water supply was secured by reallocating 50,000 acre-feet per year of Colorado River water from the Yuma Mesa Division of the Gila Project to the Ak-Chin Indian Community. This water, which is delivered to the community through the CAP canal, was an unused portion of a 300,000 acre-feet allocation available to the Yuma Mesa Division under contracts entered into according to the Boulder Canyon Project Act of 1928. The transferred Colorado River water retains its priority date, a priority superior to that of the CAP, making the entitlement senior

by Arizona standards.

The federal government provided the Yuma Mesa Division with a \$9.4 million grant for improvements and conservation measures and to forgive federal loan obligations worth approximately \$17.8 million in exchange for transferring 50,000 acre-feet of its CAP allocation. The balance of the Community's water entitlement is provided from the Ak-Chin's 58,300 acre-feet CAP allocation. The portion of these supplies not needed to meet the obligations of the settlement is to be re-allocated on an interim basis to the CAP, potentially making additional water available to central and southern Arizona water users. This latter provision makes excess Ak-Chin water available for future Indian water settlements in Arizona. Arizona's agricultural community argues that they were promised any excess water. This proved to be a contentious issue in the San Carlos Apache Tribe settlement, which relies on this source of water to satisfy tribal entitlements.

The federal government bears the entire financial obligation under this settlement and also is responsible for the replacement cost of any water that it fails to deliver to the community. The federal Office of Management and the Budget has strenuously opposed federal liability for damages in more recent Indian water settlements and now also insists on reasonable local contributions.

The original settlement did not provide for off-reservation leasing of any portion of the Indian community's entitlement, due to strong opposition to the principle of off-reservation marketing by the State, western governors, local irrigators and other non-Indian interests. In 1992, fourteen years after the original legislation's enactment, Congress passed a bill, supported by the State of Arizona, the Indian community and local water users, that amends the settlement to allow off-reservation leasing of portions of the water entitlement in select areas of the state.

In an innovative agreement, the Ak-Chin leased part of their water right under a 100-year contract to a large Arizona developer. By increasing their water efficiency through drip irrigation and computer monitoring systems, the community was able to lease 10,000 acre-feet annually to provide the 100-year assured water supply to the Del Webb Corporation for a planned community of 40,000 people north of Phoenix.

In addition, the Arizona Department of Water Resources (ADWR) promulgated a new rule to specifically accommodate transactions like the Ak-Chin-Del Webb deal. Under current Arizona law, a developer needs a 100-year perpetual assured water supply before its development can be approved. Conversely, most tribal settlements restrict tribal water leasing to contracts not exceeding 100 years. Thus, if a developer leases 100 years of water from a tribe to meet its assured supply, the developer must find replacement water for the last years of the 100-year period. Under the new rule, developers and tribes may renew 100-year leases each year to satisfy the state requirement of 100-year assured supplies. The new ADWR rule gives flexibility to providers using Colorado River or CAP water leased from an Arizona Indian community to meet their assured water supply requirements. If the leased water initially satisfies the 100-year assured supply requirement, the department will wait until the fiftieth year to review the developer's assured supply certificate. At that time, the developer must show evidence of active negotiations with the tribe to renew the lease. To ensure security to customers, tribal leased water can account for only 15 percent or less of the provider's total water supply.

The Ak-Chin Water Settlement of 1978 was among the first Indian water right disputes resolved through a legislative settlement. This settlement has several interesting features:

- The original settlement agreement was between the United States and the Ak-Chin Indian Community and did not involve the State of Arizona or local water users directly.
- This is one of only two Indian water settlements passed by Congress in which the federal government bears the entire financial burden.
- Imported surface water supplies were used to satisfy the Community's entitlement.

- The Ak-Chin settlement had to be amended in 1984, six years after its enactment and further amended in 1992, illustrating the difficulty of achieving finality on these complex issues.

The active involvement of key members of Arizona's congressional delegation, who held leadership positions in Congress, greatly assisted in the formulation and passage of this settlement and amendments.

### **Salt River Pima-Maricopa Indian Community Water Settlement**

The Salt River Pima-Maricopa Indian Community Water Settlement addresses water disputes that have existed between the Indian Community and other water users in the Salt River Valley for more than 110 years. This agreement illustrates the increasing complexity of Arizona settlements. Only a few of the significant aspects of the settlement are discussed here.

- These disputes involved the water supplies and water delivery arrangements of two Indian Communities, seven Phoenix area cities and towns and three irrigation districts.
- The settlement relies on intricate arrangements for water transfers and exchanges, leasebacks, contract modifications and ratifications and modified storage rights to satisfy the Community's water entitlement.
- Determining an equitable measure of the local cost share posed a major obstacle in obtaining federal approval for the bill.

Pima and Maricopa Indians irrigated land along the Gila River in central Arizona prior to the arrival of Spanish explorers. During the mid-1800s, immigrants, miners, and the United States army relied on these tribes for much of their food and hay supplies. In order to protect these lands from encroachment by non-Indians, the Gila River Indian Reservation was established in 1859. Beginning in 1868, upstream diversions by non-Indians depleted much of the water supply available to the reservation. During the 1870s, Pima and Maricopa Indians in search of more dependable water supplies began migrating from the Gila River Reservation to cultivate lands along the Salt River. By 1879, the Indians had brought about 3,400 acres under cultivation. In order to protect these Indians from further displacement by non-Indians, some of whom were attempting to homestead on the Indian's improved lands, the Salt River Pima-Maricopa Indian Reservation was created by Executive Order in 1879.

In 1905 a suit was filed in state court to determine the priority and ownership of water rights in the Salt River Valley in preparation for completion of the Salt River Project (SRP), an early Bureau of Reclamation project which serves Phoenix area farms and cities. The federal government filed claims on behalf of the Salt River Pima-Maricopa Indian Community on the basis of its prior appropriation rights under state law. The United States filed no claims for reserved water rights, even though the Supreme Court's landmark *Winters* case had been decided in 1908. The resulting Kent Decree, issued by the court in 1910, awarded the Salt River Indian Community 18,766 acre-feet per year of the natural flow of the Salt and Verde Rivers. The Indian community's repeated appeals to have the United States reopen the Kent Decree were unsuccessful.

The water supply problems of the Indian community were compounded when it was excluded from receiving storage water from the SRP. In 1935, the Secretary of the Interior and the SRP agreed to build Bartlett Dam on the Verde River, in part to provide 20,000 acre-feet annually to the Salt River Reservation. The Bartlett Dam agreement provides a complex accounting system to allocate the storage rights behind the dam. When Bartlett Dam was operated with other SRP reservoirs, this accounting system worked to the disadvantage of the Indian Community, effectively reducing its water storage credits.

For many years the Indian community protested the water entitlement it received under both the Kent Decree and the Bartlett Dam agreement. By the early 1980s the community had initiated a series of lawsuits against the federal government, the SRP and local cities and irrigation districts. Concurrent efforts to negotiate



## *INDIAN WATER RIGHT SETTLEMENTS*

failed to yield an acceptable compromise. In the 1980s, when the Community was joined in the Gila River Adjudication, the United States claimed a total of 202,000 acre-feet annually on behalf of the Community.

Because these lawsuits threatened key water delivery arrangements for irrigators and for the Phoenix metropolitan area, non-Indians had a strong incentive to seek a negotiated settlement, rather than await the uncertain outcome of litigation. Negotiations resumed in 1985, with the added incentive of developing a cost-sharing plan to speed completion of the CAP. The overall cost of the settlement and how it was to be distributed among the federal government, the Indian community and local water users emerged as a critical issue that shaped the character of the final agreement. After more than two years of intensive negotiations, a local settlement was reached in 1988 and ratified by Congress later that same year.

The settlement entitles the Indian Community to a maximum of 122,400 acre-feet annually (4.5 acre-feet per acre water duty applied to the 27,200 irrigable acres on the reservation). The water is to be provided from a combination of sources, including

- firming up existing rights under the Kent Decree and Bartlett Dam agreement,
- a series of exchanges involving CAP and non-CAP Colorado River water,
- Salt and Verde River water, and
- groundwater pumped from beneath the reservation.

In addition, a trust fund was established to enable the Community to rehabilitate, further develop, and maintain its irrigation systems and to put the settlement water to beneficial use.

The settlement relies upon complex transfers, leases and exchanges to provide water for the Indian Community and to protect existing non-Indian water users. For instance, the settlement requires the cities to provide the Indian Community with 20,000 acre-feet annually of Salt and Verde River water available through the SRP. In exchange, the Secretary of the Interior will provide the cities with 22,000 acre-feet per year of pre-CAP priority Colorado River water. The settlement provided that the Colorado River water could be made available from the Wellton-Mohawk Irrigation and Drainage District (WMIDD) near Yuma, even though WMIDD is not a party to the settlement. In exchange, WMIDD received certain benefits from the federal government. Another provision of the act authorizes the Community to lease its entire 13,300 acre-feet per year CAP allocation to local cities for 99 years for \$16 million. This leasing provision is the only exception to the settlement's blanket prohibition on marketing or using the community's entitlement off-reservation. Surrounding non-Indian water users are limited in their groundwater use by the Groundwater Management Act (GMA). The tribe may pump 38,000 acre-feet annually from groundwater wells, but groundwater use restrictions could become more stringent in the future if the East Salt River sub-basin is no longer in "safe yield," as determined by ADWR.

The overall goals of these arrangements were to satisfy the Community's entitlement with native groundwater and surface flows, to minimize the impact of the settlement on existing non-Indian water users and to provide the cities with renewable surface supplies. In addition to protecting existing water supplies, a major goal of local non-Indians in this settlement was to preserve and affirm existing water delivery agreements.

Local cities negotiated lease contracts with the Community for the CAP water. Phoenix contracted back in the late 1980s to begin taking their leased portion of the Community's water in 2001. In exchange, the City of Phoenix provided the Community a one-time lump-sum payment of approximately \$1,200 per acre-foot. One of the important features of the lease is that the water retains its Indian priority and character. This means that when Phoenix orders the water, the city is not obliged to pay the CAP capital repayment cost it would if it were ordering the water as "the city." In addition, in times of shortage, the water retains its Indian priority date.

Congress has made necessary appropriations for settlement implementation. The settlement has been approved by the court presiding over the Gila River general stream adjudication and will be incorporated in the

final decree of that adjudication. Implementation of this settlement is proceeding smoothly.

### **Zuni Heaven Settlement**

The Pueblo of Zuni reservation is located in northwestern New Mexico, near the four-corners region where Arizona, New Mexico, Utah and Colorado join. From time immemorial, the Zuni Tribe has made a pilgrimage to Kothluwala:wa, or "Zuni Heaven." Zuni Heaven is a relatively flat and marshy riparian area of the Little Colorado River, approximately three miles downstream of the Zion Reservoir near Hunt Valley, Arizona. For many centuries selected members of the Zuni Tribe have trekked by foot or horseback over 110 miles to perform religious ceremonies for two days during the summer solstice period every four years. In 1877, the land that comprised Zuni Heaven was lost to the tribe as a result of an executive order. In 1984, Congress passed a law to reacquire lands around the religious site in northeastern Arizona as well as permanent rights of ingress and egress. Recently, the tribe purchased other lands needed for the restoration of the area in fee simple.

Though the Zuni reacquired the land, Zuni Heaven was much altered due to the construction of the Zion Dam in 1920. The dam trapped sediment in the reservoir so outflows scoured the channel of the Little Colorado River to the extent that the river abandoned its historical floodplain and caused rapid destruction of the surrounding wetlands that supported watercress, cottonwoods and willows. Groundwater pumping by nearby non-Indians exacerbated the destruction by draining the artesian springs. Finally, the introduction of non-native plants like tamarisks, along with cattle grazing, further damaged the Zuni religious site.

Under the 1984 congressional act and subsequent 1990 legislation, the Zuni are funded to coordinate with the Bureau of Reclamation, the Environmental Protection Agency and the Arizona Water Protection Fund to develop a program to restore the wetlands. The legislation establishes the Zuni Indian Resource Development Trust Fund and provides an appropriation of \$25 million to aid in the restoration plan. Further, the act declares certain private lands in Arizona to be Zuni Indian Reservation. According to the legislative history, the lands were redesignated as reservation because "extensive damageS to the trust lands within the Zuni Indian Reservation have occurred, including severe land erosion, loss of timber and minerals, spoliation of archaeological sites, and loss of the use of water; . . . these damages have occurred, in part, by reasons of acts and omissions of the United States in breach of its trust responsibility" (Zuni Claims Settlement Act, 1990).

Further, to successfully ensure proper habitat restoration, the Zuni acquired a couple of large ranches upstream from the Heaven. Though few water rights were associated with the purchase of the ranches, the Zuni need this land to facilitate the volume of water delivery necessary to properly irrigate the critical restoration areas. Some parties to the settlement objected to the Zuni putting such fee lands into trust. Eventually, the talks focused on allowing a small corridor of land along the Little Colorado River to go into trust, with the rest remaining in fee unless Congress passed legislation authorizing the trust status.

Water quality was another important issue. Some parties to the negotiations wanted the tribe to waive water quality damages, *i.e.*, waive the right to sue for a certain quality of the tribe's entire decreed right. The tribe was willing to waive claims beyond a level of "natural water quality," or reasonable rises and falls of water quality due to currently practiced circumstances. The tribe was not willing to waive claims to damages that result from the introduction of a hazardous substance into the water supply.

In the later stages of the negotiation, the parties proposed to enable the tribe to purchase water rights surrounding the Zuni Heaven land in order to retire those rights from use. Though the tribe asserts a Practicably Irrigable Acreage-type claim for the fertile area, the dominant focus of the four-year settlement negotiation was for water to restore the religious spot as an "oasis." Non-Indian reliance on groundwater pumping altered the natural hydrologic conditions so that springs no longer irrigate the area. The cornerstone of the negotiated settlement is a voluntary exchange of water rights so the Zuni may use mostly surface water to irrigate the land to its original wetland habitat. The parties agreed to allow the Zuni Tribe, or the United States on its behalf, to purchase up to 3,600 acre-feet of rights from willing upstream sellers in the Norviel Decree Area, with the rights retaining the Norviel Decree priority date. Once these rights are severed and transferred for the benefit of the tribe, state law will no longer apply and the tribe may use the water in any way it deems appropriate on the reservation.

In addition, the parties agreed not to object to Zuni pumping of up to 1,500 acre-feet per year of groundwater on-reservation to supplement the surface water irrigation. The groundwater will be used to ensure constant saturation of the most critical religious habitat, even in drought or shortage years. Further, two large utility companies with operations in the area developed “non-interference” groundwater compacts with the tribe. SRP agreed not to pump groundwater south of a specified area, and Tucson Electric Power agreed not to move their groundwater pumping operation any closer to the Little Colorado River than its current site. Finally, smaller, private parties to the settlement, who are located within an area critical to the restoration habitat, agreed to limit their groundwater pumping to a rate below 500 gallons per minute. These agreements are “Pumping Protection Agreements” that effectively create buffer zones surrounding the reservation that require limited or no use of groundwater by non-Indians in that area.

Some parties in the settlement maintained that the Zuni Heaven deal had to be included in an overall Little Colorado River settlement. Though the Zuni Heaven portion of the Little Colorado River talks is minute compared to the claims, issues and price tags of other interests, the Zuni lands represent a significant piece of leverage with which other Native Americans would like to bargain, due to their close proximity to powerful utility interests. In addition, the federal government has multiple, and sometimes competing, trust obligations in the Little Colorado River negotiation and must make sure a binding and favorable agreement for one tribe does not unduly prejudice another trust beneficiary. While there was some resistance to the Zuni Heaven settlement being introduced as a stand-alone piece of legislation, all local parties eventually signed off on the settlement agreement.

Senator Jon Kyl, accompanied by Senator John McCain, introduced the Zuni Indian Tribe Water Rights Settlement Act of 2002 in July of the 107th Congress. The bill is an agreement with the tribe, the United States, the State of Arizona and major water users in the area of the tribe’s religious lands in northeastern Arizona. The settlement provides the tribe with necessary resources to acquire lands around the religious site from willing sellers to restore the wetland environment that previously existed. In exchange for this settlement, the tribe waives its rights and claims it may have in the pending Little Colorado River Adjudication. The bill was reported from committee to the Senate in October 2002 after changes were made over concern about the water quality waiver provisions and the United States’ liability as sovereign and trustee, right-of-way access across tribal trust land and sovereign immunity and removal issues. The bill passed Congress and was signed into law by President Bush on June 23, 2003.

### **Southern Arizona Water Rights Settlement**

Achieving a legislatively approved settlement is not an end in itself but an important milestone on the way to settlement implementation. No settlement can anticipate all the problems that will arise in the future. Since negotiators had little experience to guide them, some of the earlier pioneering agreements were incomplete or had deficiencies or problems that must be reconsidered. The Southern Arizona Water Rights Settlement Act (SAWRSA) is one example.

The Tohono O’odham Nation located near Tucson historically has used groundwater to irrigate the crops of its agriculture-based culture. In the late 1970s, groundwater depletion began to make farming on the reservation increasingly expensive and difficult. To resolve the tense situation between thirsty Tucson and the tribes, the federal government promised a “firm delivery” of imported surface water and reclaimed municipal effluent in the Southern Arizona Water Rights Settlement. As a condition to receiving their entitlement, the tribe agreed to limit groundwater pumping beneath the San Xavier Reservation to 10,000 acre-feet annually and to the existing pumped quantity below the Schuk Toak Reservation. The tribes have the right to off-reservation marketing of their groundwater entitlement, as long as it is marketed within the Tucson Active Management Area (AMA). In addition, the federal government is liable for damages in the amount of replacement costs if it fails to make its “firm delivery” quantity. The settlement also authorized the federal government to construct and operate delivery systems on and off the reservations to enable the Nation to put their entitlements to beneficial use. Additionally, SAWRSA uses a three-way deal with the City of Tucson so the Secretary of the Interior can use the city’s effluent to satisfy the nation’s entitlement.

Further amendments to SAWRSA are currently included in the proposed Gila River Basin settlement. The proposed SAWRSA amendments have many provisions. The proposed amendments would oblige the Secretary of the Interior to deliver 37,800 acre- feet of agriculturally suitable water annually to the San Xavier and Schuk Toak Districts of the Nation, as well as another 28,200 acre-feet annually of non-Indian agricultural priority water from the main project works of the CAP. As a condition of its water delivery, the proposed amendment requires that the Nation limit the quantity of groundwater withdrawals by non-exempt wells beneath the reservation districts. The Nation must also allocate as the “first right of beneficial consumptive use” a certain amount of its water to groundwater storage, instream flows and riparian and vegetation habitat. The Nation will enact and maintain a comprehensive water code to manage and establish permit requirements for the water resources of the Nation. Significantly, this code must be specifically sensitive to the Nation’s allottees and must include specific permitting and judicial review processes for allottee applications.

The 1982 SAWRSA provided that the City of Tucson would deliver about 22,000 acre-feet per year of effluent to the federal government to assist the United States in meeting its total obligation to the tribe. The Nation has declined to use effluent for its agricultural needs, so the Department of the Interior looked for ways the federal government could recharge the effluent in exchange for state groundwater credits or CAP water delivery. The proposed SAWRSA amendments include a mechanism for the federal government to receive groundwater or CAP credits from the state for recharging Tucson’s effluent so the Nation may use or save such credits. These amendments to SAWRSA will allow the Nation to receive groundwater credits for certain recharge and storage acts and for the retiring of their grandfathered well rights. Like their non-Indian neighbors, the Nation would like to develop these flex credits under the GMA code to have the groundwater for its future use or value. A significant change in the 2000 act allows the Nation to market its waters within the three-county CAP service area, not just the Tucson AMA.

The SAWRSA amendments within the proposed Gila River settlement also are designed to settle litigation by Nation allottees that arose from the 1982 settlement as well as adjust some of the old restrictions on the Nation’s water usage. Tribal allottees contend that they had only token representation in the 1982 negotiations and dispute some of SAWRSA’s terms. The proposed SAWRSA amendments would reallocate benefits between the Nation and the allottees as well as provide additional water to the Nation.

### **Yavapai-Prescott Indian Tribe Settlement**

In 1994, Congress enacted the Yavapai-Prescott Indian Tribe Water Settlement Act. The Act settles the tribe’s water rights claims by: (1) confirming the tribe’s right to pump groundwater within the boundaries of the reservation, (2) providing for the relinquishment of the tribe’s CAP contract, the proceeds to be used for a water service contract with the City of Prescott, and (3) providing that the tribe may divert a portion of the water from Granite Creek currently diverted by the Chino Valley Irrigation District.

The Act also provides authorization to the Tribe and the City of Prescott to market their CAP water to the City of Scottsdale, which has been completed. The Act required a state appropriation of \$2 million that was made in the 1994 session of the Arizona State Legislature and was added to the tribe’s CAP proceeds fund. The Gila River General Stream Adjudication approved this settlement for incorporation into the final decree in that case.

### **Little Colorado River Settlement Talks**

As early as 1986, an attorney for the Hopi Tribe suggested the establishment of a Settlement Committee to explore possibilities for a negotiated settlement. In 1987, Judge Minker, the Superior Court Judge for the adjudication, set forth the general framework of the adjudication, including a schedule for preparation of hydrographic survey reports (HSRs). Among many provisions was the establishment of a Settlement Committee “to meet and explore the settlement potential of this litigation.” The parties involved in the settlement negotiations include four tribes, multiple state and federal agencies, four large electric power utilities and numerous water districts, water users and municipal and county governments.

The ADWR filed the Hydrographic Survey Report for the Silver Creek watershed, part of the Little

Colorado River adjudication, in 1990. At the conclusion of the objection period, more than 3,450 objections had been filed by individuals and three tribes (Navajo Nation, Hopi Tribe and San Juan Southern Paiute) or the United States on the behalf of the tribes in an effort to protect Indian water rights. In 1992, Special Master Thorson commenced proceedings to resolve objections to the Silver Creek HSR. Initially, objections were organized into contested cases involving many issues of broad legal significance concerning state law water rights. The complexity of this litigation soon convinced the parties and the court that a different approach was necessary.

In January 1994, Judge Minker modified previous orders concerning the schedule for HSRs, requesting ADWR to proceed with an Indian Lands HSR. This change in focus was rooted in the excessive numbers of objections filed to the Silver Creek HSR, resulting in numerous pleadings, contentious hearings and undue burdens on all parties, especially small claimants, and on the court. Judge Minker sought to curtail lengthy and costly litigation by focusing attention on claims of reserved rights of Indian lands and federal agencies.

During the first half of 1994, Judge Minker granted stays of the litigation schedule for the ongoing Silver Creek proceedings. This was done to enable the parties to concentrate on prospects for settlement, rather than expend time and resources at litigation. After Judge Minker stayed litigation, the Settlement Committee met frequently and settlement negotiations intensified. This was especially true after Judge Minker appointed Judge Michael C. Nelson, Presiding Judge of the Apache County Superior Court, as settlement judge to oversee and manage the negotiations. In the ensuing time, all parties have praised Judge Nelson's effectiveness and dedication to the settlement process.

The first focus among the parties was to seek protection of existing water uses while providing some means of developing "wet water" for Indian lands. As talks were getting underway, Secretary of the Interior Bruce Babbitt suggested that any settlement should address issues surrounding the Black Mesa Mine. The Hopi Tribe and others, including some environmental groups, have opposed Peabody Western Coal Company's use of underground water from the N-Aquifer to slurry coal from Black Mesa Mine to the Mohave Generating Station in Laughlin, Nevada. Secretary Babbitt urged consideration of a pipeline from Lake Powell to the Black Mesa Mine and to the various Indian communities in the basin.

Under Judge Nelson's guidance, negotiations were split into "North" and "South" issues. On the "North" side, talks involved the proposed Lake Powell pipeline and sharing of water resources available to the Navajo Nation and the Hopi Tribe. The "South" issues are those affecting the vast majority of individual, non-Indian claimants in the watershed. Primary among the issues is grandfathering existing uses, some means of assuring future uses and developing "wet water" for the Navajo Nation.

At the same time, the Pueblo of Zuni and water users in the eastern portion of the watershed engaged in fruitful talks, also with Judge Nelson's help. On a fourth front, state parties and federal agencies have conducted negotiations with respect to the non-Indian federal claims of the National Park Service, Forest Service and Bureau of Land Management. During 2001, parties filed several stipulations as to water right abstracts. The adjudication court has indicated it will approve the stipulations, once minor technical changes are made.

In early 1998, in fact, Judge Minker expressed frustration about continuing to pursue a settlement that perpetually seems to be just beyond reach. Truth about actual settlement possibilities may lie in confidential documents not available for review. The Navajo Nation and Hopi Tribe concur on the need for a pipeline from Lake Powell to the two reservations. Senator Kyl commissioned a \$1 million study through the Bureau of Reclamation to review existing reports concerning the feasibility and cost of the pipeline and other water development projects. The tribes have agreed to forego any challenge to existing surface water and groundwater uses ("grandfathered" uses) in exchange for limiting future surface diversions. The tribes have proposed methods to manage shared aquifers and the waters of five washes and arroyos that traverse both reservations. CAP water may be made available to supply the reservations, but there are significant questions about diversion of that water from Lake Powell.

There is a proposal to divert excess water in the southern portion of the watershed that flows north toward

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the reservations from the Mogollon Rim. Reservoirs would be constructed or enlarged in the "Three Canyon" area. The Endangered Species Act or other environmental laws could affect the new or expanded reservoirs or proposed pipelines.

Water marketing has been an important issue for the Navajo Nation. The ADWR has firmly opposed any possibility of marketing water, especially CAP water, outside of the watershed.

Finally, Judge P. Ballinger, who replaced Judge Minker as the adjudication judge, has requested ADWR to proceed with the Hopi Tribe HSR. In anticipation of returning to litigation, Judge Ballinger has ordered parties to submit disclosures concerning the claimed reserved rights of the Hopi Tribe, Navajo Nation, San Juan Southern Paiute Tribe and the Zuni Pueblo. The Hopi Tribe and the United States also were invited to file new or amended statements of claimant.

To summarize, settlement negotiations remain active on some of the unresolved issues in the Little Colorado River Adjudication. It is not possible to predict whether a comprehensive settlement can be achieved and lengthy litigation averted.







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